Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381-2000

July 2, 2010

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

Watts Bar Nuclear Plant, Unit 2
NRC Docket No. 50-391

Subject: **Watts Bar Nuclear Plant (WBN) Unit 2 - Submittal of Additional Information Requested During May 12, 2010, Request for Additional Information (RAI) Clarification Teleconference Regarding Environmental Review (TAC No. MD8203)**

The purpose of this letter is to provide the U.S. Nuclear Regulatory Commission (NRC) additional information requested during a teleconference May 12, 2010 (Reference 1), in support of the NRC's environmental review of WBN Unit 2. The purpose of the call was to clarify several of the TVA RAI responses provided to the NRC in the February 25, 2010, and April 9, 2010, submittals.

The WBN Unit 2 Final Supplemental Environmental Impact Statement (June 2007) was submitted to the NRC on February 15, 2008 (Reference 2). By letter dated July 2, 2008 (Reference 3), TVA responded to an NRC RAI. January 27, 2009 (Reference 4), TVA provided the Severe Accident Management Alternatives analysis report for WBN Unit 2.

By letter dated December 3, 2009 (Reference 5), the NRC requested additional information subsequent to an environmental site audit in October 2009. By letters dated December 23, 2009 (Reference 6), February 25, 2010 (Reference 7), April 9, 2010 (Reference 8), and May 12, 2010 (Reference 9), TVA provided responses to the December 3, 2009, RAIs.

The enclosure provides the information requested by the NRC. There are no regulatory commitments associated with this submittal. If you have any questions, please contact William Crouch at (423) 365-2004.

Sincerely,

for MB

Masoud Bajestani
Watts Bar Unit 2 Vice President

D030
NRR

References:

1. Teleconference between NRC, PNNL, and TVA on May 12, 2010, "TVA RAI Clarification Call" (ML101370186)

2. TVA letter to NRC dated February 15, 2008, "Watts Bar Nuclear Plant (WBN) - Unit 2 - Final Supplemental Environmental Impact Statement for the Completion and Operation of Unit 2" (ML080510469)

3. TVA letter to NRC dated July 2, 2008, "Watts Bar Nuclear Plant (WBN) - Unit 2 - Final Supplemental Environmental Impact Statement - Request for Additional Information (TAC MD8203)" (ML081850460)

4. TVA letter to NRC dated January 27, 2009, "Watts Bar Nuclear Plant (WBN) Unit 2 - Final Supplemental Environmental Impact Statement - Severe Accident Management Alternatives (TAC MD8203)" (ML090360588)

5. NRC letter to TVA dated December 3, 2009, "Watts Bar Nuclear Plant, Unit 2 - Request for Additional Information Regarding Environmental Review (TAC No. MD8203)" (ML093030148 / ML093290073)

6. TVA letter to NRC dated December 23, 2009, "Watts Bar Nuclear Plant (WBN) Unit 2 – Additional Information Regarding Environmental Review (TAC No. MD8203)" (ML100210350)

7. TVA Letter to NRC dated February 25, 2010, "Watts Bar Nuclear Plant (WBN) Unit 2 - Additional Information Regarding Environmental Review (TAC No. MD8203)" (ML100630115)

8. TVA Letter to NRC dated April 9, 2010, "Watts Bar Nuclear Plant (WBN) Unit 2 - Response to U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information Regarding Environmental Review (TAC No. MD8203)"

9. TVA Letter to NRC dated May 12, 2010, "Watts Bar Nuclear Plant (WBN) Unit 2 - Response to U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information Regarding Environmental Review (TAC No. MD8203)"

Enclosure:

1. Additional Information Requested During May 12, 2010, RAI Teleconference Regarding Environmental Review

Attachments to Enclosure:

1. Tennessee Valley Authority, Office of Natural Resources and Economic Development – Division of Air and Water Resources, "Preoperational Assessment of Water Quality and Biological Resources of Chickamauga Reservoir, Watts Bar Nuclear Plant 1973-1985," December 1986 (paper copy and on enclosed Optical Storage Media [OSM])

2. Figure 1. Tennessee River Downstream from Watts Bar Dam Showing the Locations of the Three Mussel Sampling Stations (paper copy and on enclosed OSM)

3. Tennessee Valley Authority, Resource Group, Water Management, "Aquatic Environmental Conditions in the Vicinity of Watts Bar Nuclear Plant During Two Years of Operation, 1996-1997," Norris, Tennessee, June 1998 (Revised 06/07/2010) (paper copy and on enclosed OSM)

4. Summary of Revised Computation for RAI H-11: WBN_U2_RAI_H-11_Intake_Pumping_Station_Velocity_Rev2.pdf (paper copy and on enclosed OSM)

5. FENCDOSE Run for Fuel Handling Accident: W000221.ASC (located on enclosed OSM)

6. FENCDOSE Runs for Loss of Coolant Accident: R197F21Aout.txt; R197F21Bout.txt; R197F21A.txt; R197F21B.txt; TS9F11AA; TS9F11AB;TS9F11AC; TS9F11AD; TS9F11PA; and TS9F11PC (located on enclosed OSM)

cc (Enclosure):

U. S. Nuclear Regulatory Commission
Region II
Marquis One Tower
245 Peachtree Center Ave., NE Suite 1200
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NRC Resident Inspector Unit 2
Watts Bar Nuclear Plant
1260 Nuclear Plant Road
Spring City, Tennessee 37381

Enclosure

Additional Information Requested During May 12, 2010, RAI Clarification Teleconference Regarding Environmental Review

Tennessee Valley Authority
Watts Bar Nuclear Plant - Unit 2, Docket No. 50-391

Land Use

NRC Request

Clarification requested on total acreage for WBN site - there are inconsistencies with data provided in the February 25, 2010, RAI responses (1055 acres) and the value in the ER (1700 acres).

TVA response

The 1,055 acres is specifically related to Watts Bar Nuclear and just a portion of the Watts Bar reservation. The 1,700 acres encompasses the Watts Bar Dam and Hydro-Electric Plant, the Watts Bar Steam Plant, the TVA Central Maintenance Facility, and the Watts Bar Resort Area.

Aquatic Ecology

NRC Request

We need to be able to access the entire report on Preoperational Assessment – 1986. As we discussed previously on the phone, TVA only provided the document through page 302, and the appendices in Volume II. We are missing from page 302-484-plus from Volume 1.

> *TVA 1986. Preoperational Assessment of Water Quality and Biological Resources of Chickamauga Reservoir, Watts Bar Nuclear Plant 1973-1985. Office of Natural Resources and Economic Development – Division of Air and Water Resources.*

TVA response

TVA is scanning the entire 1986 document and submitting to NRC.

The following document is provided in Attachment 1:

> Tennessee Valley Authority, Office of Natural Resources and Economic Development – Division of Air and Water Resources, "Preoperational Assessment of Water Quality and Biological Resources of Chickamauga Reservoir, Watts Bar Nuclear Plant 1973-1985," December 1986

Enclosure

Additional Information Requested During May 12, 2010, RAI Clarification Teleconference Regarding Environmental Review

NRC Request

Clarification on AE-4 – specifically when we are talking monitoring sites is that the same as "beds." If it is then does the TRM 526-527 site really extend further upstream or is that just a small grouping of mussels at 592.2 R? And are these the ones you relocated across the river? Which ones were relocated to the boulder study area described in AE-7?

TVA Response

There is a 1994 report that has the mussel sampling stations AND the mussel beds in a figure. The mussels from 529.2 (SCCW discharge location) were not considered part of the bed that is downstream of the SCCW discharge. These mussels were moved across the river to the mussel bed by the boat launch. Although the freshwater mussels do tend to congregate in beds, there are a few that are distributed between the beds, and these were the types of mussels that were relocated.

The mussels that were placed in the boulder field as an experiment to see if reducing the flow of water would improve their survival were randomly selected from mussel beds downstream. They are located near the 528 river mile marker and almost directly across from the 528.9 boat ramp, mid-channel. They have not been checked since placement, but they are being checked July 2010 during a mussel survey.

TVA will submit the figure with the sampling locations and mussel bed locations to NRC.

The following document is provided in Attachment 2:

> Figure 1. Tennessee River Downstream from Watts Bar Dam Showing the Locations of the Three Mussel Sampling Stations

NRC Request

Please clarify why did TVA did not provide an update of TVA 1998 Aquatic Environmental Conditions in the Vicinity of Watts Bar nuclear plant, specifically sections on the entrainment sampling that we discussed in a phone call in late January.

TVA response

TVA has revised the 1998 (Aquatic Environmental Conditions in the Vicinity of Watts Bar Nuclear Plant During Two Years of Operation, 1996-1997). The entrainment numbers were recalculated based on the original data and they continue to show low levels of entrainment for the Intake Pumping Station (IPS).

Enclosure

Additional Information Requested During May 12, 2010, RAI Clarification Teleconference Regarding Environmental Review

The following document is provided in Attachment 3:

> Tennessee Valley Authority, Resource Group, Water Management, "Aquatic Environmental Conditions in the Vicinity of Watts Bar Nuclear Plant During Two Years of Operation, 1996-1997," Norris, Tennessee, June 1998 (Revised 06/07/2010)

Hydrology

NRC Request

TVA Response to H-10. Clarification of the Surface Water Chemical Analysis. Was the sample analyzed for trace metals and were they not reported because they were below detection?

TVA response

No trace element analyses were performed other than for copper, iron, and zinc because the analyses were not needed to support the chemical feed program.

NRC Request

TVA Response to H-6. Verification of the withdrawal rate from the French Drain.

TVA Response

The approximately 70 gpm reported by Arcadis is flowing specifically from the French Drain, and the 500 gpm reported by TVA is pumped from the sump and includes the water from the French Drain. The water from the sump is pumped into the yard holding pond.

NRC Request

TVA Response to H-11. Clarification of information regarding through screen velocity for the intake.

TVA Response

TVA responded to RAI H-11 in its February 25, 2010, submittal. As part of this response, TVA provided a computation for the velocity of water through the net open area of the traveling screens. The computation was given in an Excel spreadsheet file entitled H-11_Intake_Pumping_Station_Velocity_Rev1.xlsx. In the spreadsheet, the average velocity found for the flow through the net open area of the traveling screens was 1.2 feet per second (fps).

Enclosure

Additional Information Requested During May 12, 2010, RAI Clarification Teleconference Regarding Environmental Review

Based on inquiries raised in the RAI clarification teleconference on May 12, 2010, TVA has re-examined the computation for RAI H-11. In this process, revisions were made for two aspects of the computation—the withdrawal rate for the IPS and the fraction of the intake representing the net open area through the traveling screens. In the February 25, 2010, submittal, a withdrawal rate 78,200 gpm was assumed for the IPS. This corresponds to a maximum condition commensurate to the flow for an accident situation. In contrast, an IPS flow of about 52,100 gpm is representative of the normal operating conditions of WBN Unit 1 and Unit 2. As such, the computation has been revised using a withdrawal rate 52,100 gpm rather than 78,200 gpm. In the original computation, documentation was weak for the assumed fraction of the intake obstructed by supports and wire for the traveling screens. In the revised computation, new information from detailed vendor drawings was used to provide a more accurate estimate of the open area through the screens. This new information gives the net open area through the traveling screens to be about 50.3 percent of the intake. With these updates, the resulting velocity in the revised computation is approximately 0.8 fps.

Based on the new information presented above, an Excel spreadsheet file entitled WBN_U2_RAI_H-11_Intake_Pumping_Station_Velocity_Rev2.pdf is provided in Attachment 4 to summarize the revised computation for RAI H-11. In the attached Rev 2 spreadsheet, extraneous information given in the Rev 1 spreadsheet has been removed to make the computation more comprehensible.

Design Basis Accidents

NRC Request

Provide information on the status of the accident analysis (it appears some accident scenarios were not analyzed) as well as the assumptions that went into the analysis.

TVA Response

TVA will be providing status of the accidents analysis.

1. *For the design basis radiation analysis, did TVA use TID source terms and ICRP-2 or Alternate source terms and ICRP-30?*

   For the design basis radiation analysis, TVA used TID and ICRP-30. TVA transitioned from ICRP-2 to ICRP-30.

2. *TVA provided the NRC with FENCDOSE files for some of the accidents. The NRC would like to have the FENCDOSE for Loss of Coolant Accident (LOCA) and Fuel Handling Accident (FHA) to compare against.*

   The output files for FHA and LOCA are provided in Attachments 5 and 6.

Enclosure

Additional Information Requested During May 12, 2010, RAI Clarification Teleconference Regarding Environmental Review

3. *The NRC indicated that TVA did not analyze other SRP events such as RCP locked rotor and RCP shaft break.*

   The rod ejection accident was not analyzed for radiation impact. It is noted in FSAR Section 15.4.6.3 that this event is bounded radiologically by the large break LOCA.

   The current Unit 1 thermal hydraulic analysis for the Chapter 15 locked rotor and shaft break events does not predict any fuel experiencing departure from nucleate boiling (failure); as such, a dose analysis has not been performed for Chapter 15. It is anticipated WBN Unit 2 would have similar results when the final core design and thermal hydraulic analysis are completed for Unit 2. Unit 2 uses the same Westinghouse fuel type as Unit 1 and a lower licensed thermal power. At this time WBN Unit 2 does not intend to perform a locked rotor or RCP shaft break offsite dose analysis.

4. *The NRC indicated the latest SRP has a limit of 100 mrem offsite for waste gas decay tank rupture rather than 500 mrem TVA used on WBN Unit 1. The NRC provided this for informational purposes only since they said they obtained acceptable results in either case for the realistic analysis.*

   No action required.

RAD

NRC Request

Clarify information related to the dilution factor for the release from the plant to the river for the liquid effluents.

TVA Response

The dilution factors were calculated by dividing the cooling tower blowdown (20,000 gpm - 44.6 cfs) (see Fig 3-7 of the submittal) by the effluent flow rate (can vary from less than 100 gpm to 290 gpm - 13.4 cfm to 38.8 cfm).

All fishing is assumed to be sport fishing.

There is only one terrain adjustment factor for each sector.

Note: The telecon meeting minutes (Reference 1) indicated 13.4 cfs to 38.8 cfs in the above calculation. It should have indicated 13.4 cfm to 38.8 cfm.

Attachment 1

(Paper Copy and on Enclosed OSM)

Tennessee Valley Authority

Office of Natural Resources and Economic Development

Division of Air and Water Resources

Preoperational Assessment of Water Quality and Biological Resources of Chickamauga Reservoir

Watts Bar Nuclear Plant 1973-1985

December 1986

Attachment 2

(Paper Copy and on Enclosed OSM)

Figure 1

Tennessee River Downstream from Watts Bar Dam Showing the Locations of the Three Mussel Sampling Stations

Attachment 3

(Paper Copy and on Enclosed OSM)

Tennessee Valley Authority

Resource Group

Water Management

Aquatic Environmental Conditions
In the Vicinity of Watts Bar Nuclear Plant
During Two Years of Operation, 1996-1997

Norris, Tennessee

June 1998
(Revised 06/07/2010)

Attachment 4

(Paper Copy and on Enclosed OSM)

Summary of Revised Computation for RAI H-11

WBN_U2_RAI_H-11_Intake_Pumping_Station_Velocity_Rev2.pdf

Attachment 5

(Located on Enclosed OSM)

FENCDOSE Run for Fuel Handling Accident:

W000221.ASC

Attachment 6

(Located on Enclosed OSM)

FENCDOSE Runs for Loss of Coolant Accident:

R197F21Aout.txt
R197F21Bout.txt
R197F21A.txt
R197F21B.txt
TS9F11AA
TS9F11AB
TS9F11AC
TS9F11AD
TS9F11PA
TS9F11PC

Attachment 1

(Paper Copy and on Enclosed OSM)

Tennessee Valley Authority

Office of Natural Resources and Economic Development

Division of Air and Water Resources

Preoperational Assessment of Water Quality and Biological Resources of Chickamauga Reservoir

Watts Bar Nuclear Plant 1973-1985

December 1986

Jenkinson 8543

TENNESSEE VALLEY AUTHORITY

Office of Natural Resources and Economic Development
Division of Air and Water Resources

PREOPERATIONAL ASSESSMENT OF WATER QUALITY AND BIOLOGICAL RESOURCES OF CHICKAMAUGA RESERVOIR, WATTS BAR NUCLEAR PLANT, 1973-1985

December 1986

TENNESSEE VALLEY AUTHORITY

Office of Natural Resources and Economic Development
Division of Air and Water Resources

PREOPERATIONAL ASSESSMENT OF WATER QUALITY AND BIOLOGICAL RESOURCES OF CHICKAMAUGA RESERVOIR, WATTS BAR NUCLEAR PLANT, 1973-1985

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December 1986

TVA/ONRED/WRF-87/1a

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Appendices*	Volume II

*Appendices are available as a separate volume and may be obtained upon request.

EXECUTIVE SUMMARY

As required by the National Pollutant Discharge Elimination System Permit (TN0020168) for operation of Watts Bar Nuclear Plant (WBN), this report is a composite evaluation of nonradiological preoperational aquatic monitoring conducted from 1973 through 1979 and from 1982 through 1985. Baseline biological, physical, and water quality conditions in Chickamauga Reservoir in the vicinity of WBN are described. The following biological components are included: plankton, periphyton, benthic macroinvertebrates, fish eggs and larvae, and juvenile and adult fish. Because Sequoyah Nuclear Plant (SQN) also is located on Chickamauga Reservoir, results of various aspects of preoperational and operational monitoring for SQN are integrated in this report to provide a more comprehensive assessment of reservoir-wide conditions.

Water quality in the vicinity of WBN, while generally satisfactory, was influenced by discharges from Watts Bar Dam, located upstream approximately 2 miles. Typically, hydropower releases (25,000-45,000 cfs) from the dam inhibited stratification and establishment of a thermocline during summer in the upper 30 miles of Chickamauga Reservoir. However, releases from Watts Bar Dam, which reflect water quality in Watts Bar Reservoir and upstream tributary reservoirs, showed periodic deficiencies in dissolved oxygen (<5.0 mg/L) during May through September throughout the preoperational monitoring period. As a result of a prolonged drought, this condition was worse in 1985 than in previous years.

Although numerous spatial and temporal variations in the biotic community were identified during preoperational monitoring, none appeared

to be directly related to fluctuations in dissolved oxygen. Spatial analyses indicated that river flow was the dominant factor influencing abundance and/or occurrence of macroinvertebrates, phytoplankton, and zooplankton in the vicinity of WBN. Periphyton and ichthyoplankton (fish eggs and larvae) also were affected. The ichthyoplankton assemblage in WBN vicinity represented eggs and larvae spawned primarily in Watts Bar Reservoir and exposed to passage through the turbines at Watts Bar Dam. To a lesser extent, flow influenced relative abundance and species composition of juvenile and adult fish in netting and electrofishing samples at two stations in the plant vicinity.

Temporal analyses showed that seasonal and yearly changes in abundance and other variables for all component populations, except freshwater mussels, were common. The freshwater mussel population in the vicinity of WBN is quite old and most of the 30 found species may not have reproduced successfully in the past 40 years. Abundance trends for several communities (macroinvertebrates, plankton, and periphyton) were more cyclic than linear, indicating that preoperational monitoring for WBN covered a wide range of flow and climatic conditions. Also cyclic trends in the harvest of some fish species (e.g., white crappie) were noted in the reservoir-wide creel survey. Largemouth bass harvest, however, showed a significant linear increase. Total fishing pressure on Chickamauga Reservoir has increased dramatically since 1973. Some increasing and some decreasing trends were noted among important fish species in cove rotenone samples since 1970; however, total fish biomass remained relatively stable. The overriding influence on standing stock

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1.0 INTRODUCTION

The Tennessee Valley Authority (TVA), a corporate agency of the United States Government, announced in May 1971 plans to build a two-unit nuclear power plant in Rhea County, Tennessee. In accordance with the National Environmental Policy Act of 1969 (NEPA), TVA prepared a draft Environmental Impact Statement (EIS) which was sent to the Council on Environmental Quality (CEQ), made available to the public, and circulated to other governmental agencies for review and comment on May 14, 1971. Supplements and additions to the draft EIS were sent to the CEQ and made available to the public on April 7, 1972. TVA's Final EIS was sent to the CEQ and made available to the public on November 9, 1972. The Atomic Energy Commission (predecessor of the Nuclear Regulatory Commission) issued Construction Permits Nos. CPPR-91 and CPPR-92 for the Watts Bar Nuclear Plant (WBN) on January 23, 1973. The U.S. Nuclear Regulatory Commission (NRC) issued its Final Environmental Statement in December 1978.

1.1 Purpose and Objective

In accordance with the National Pollutant Discharge Elimination System (NPDES) permit (TN0020168) for operation of WBN by TVA, this report includes results of the nonradiological preoperational aquatic monitoring program for the period February 1973 through December 1985. The purpose of preoperational monitoring is to provide baseline data on the fisheries, limnology, and water quality of Chickamauga reservoir for comparison with conditions following startup and operation of WBN. These

comparisons will be used to identify potential impacts of withdrawal and discharge of water at WBN. Both spatial and temporal variations in biological and water quality conditions in the vicinity of WBN as well as in the far-field zone of the reservoir for selected parameters are evaluated.

Preoperational aquatic monitoring for WBN has been divided into two periods, 1973 to 1979 and 1982 to 1985. Results of the first phase were reported to the U.S. Environmental Protection Agency (EPA) in two documents, fisheries (TVA 1980a) and water quality/aquatic biology (nonfish) (TVA 1980b). Due to various delays in construction and fuel-loading, a second period of monitoring was conducted from March 1982 through December 1985 to update the data base. This report provides a composite analysis of biological and water quality conditions for both periods. Because the Sequoyah Nuclear Plant (SQN) also is located on Chickamauga Reservoir, results of various aspects of the preoperational and operational aquatic monitoring program for SQN are integrated in the WBN preoperational evaluation for a more comprehensive assessment of reservoir-wide conditions.

1.2 Watts Bar Nuclear Plant Description

Watts Bar Nuclear Plant (WBN) is located on the right bank (west) of Chickamauga Reservoir near Tennessee River Mile (TRM) 528. This two-unit nuclear generating plant is designed for an electrical output of about 2,540 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 right bank

of Chickamauga Reservoir (TRM 529). WBF was decommissioned on March 29, 1983, and it was off line all of 1982. Figure 1-1 shows the locations of these TVA facilities.

WBN will be operated in closed cycle cooling mode, using two natural draft cooling towers for heat dissipation. Blowdown from the cooling towers will be discharged through multiport diffusers located in the main channel at TRM 527.8. Makeup water and other water supply requirements will be obtained from an intake channel and pumping station at TRM 528. These intake and discharge structures are indicated 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 ft) mean sea level, and 293 m^2 (3,159 ft^2) at summer pool level of 208 m (682.5 ft). Corresponding average velocities into the intake channel are .03 m/s (.1 ft/s) and .015 m/s (.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 .15 m/s (0.5 ft/s). This pumping flowrate represents about 0.6 percent of the long-term average flow past WBN of 767 m^3/s (27,100 cfs).

Blowdown from the cooling towers will be discharged at a rate of between 1.3 and 2.4 m^3/s (45 and 85 cfs) to maintain concentrations of dissolved solids at approximately twice that of the Tennessee River. Blowdown is discharged directly to the diffuser or into a holding pond which in turn releases water through the diffusers. During periods of no releases from Watts Bar Dam, discharges will be stored in the holding

pond. Releases for normal two-unit operation will be 2.4 m^3/s (85 cfs). Even with additional releases from the blowdown holding pond, releases through the diffuser will in all cases be less than 5.0 m^3/s.

The diffuser 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 diffuser 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 diffuser section beginning where the downstream diffuser section ends. The diffuser 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 45° in the downstream direction. The exit jet velocity will vary depending on operational mode, from 2 to 5 m/s. The expected discharge temperature depends on cooling tower performance and varies from 17°C in January to 35°C in July. The maximum blowdown temperature is 35°C, so the expected monthly average temperature difference between the discharge and the river varies from 10°C during winter and spring to 5°C during summer and fall. The diffuser system will result in a near-field dilution of at least 15. Far-field mixing will depend on releases from Watts Bar Dam. At the long-term average release, maximum diffuser discharge represents 0.6 percent of reservoir flow.

1.3 Chickamauga Reservoir Description

Chickamauga Reservoir is formed by Chickamauga Dam, located 57 river miles downstream of WBN at TRM 471. Water elevation normally varies from 205.7 m (675 ft) msl in winter to 208 m (682.5 ft) in

summer. Reservoir volume is 465 x $10^6 m^3$ (375,000 Ac-ft) at elevation 206 m during winter and 735 x $10^6 m^3$ (600,000 Ac-ft) at elevation 208 m during summer. Figure 1-2 shows Chickamauga Reservoir in profile and approximately cumulative volume from Watts Bar Dam. The Hiwassee River joins the Tennessee River at TRM 500 and Chickamauga Reservoir extends 52 km (32 miles) up the Hiwassee River at surface elevation 208 m. The confluence of the Hiwassee River with the Tennessee River is near the downstream extent of WBN aquatic monitoring stations and provides a convenient reference point. Chickamauga Reservoir can be segmented into three regions as follows: (1) upstream of the Hiwassee River confluence, where Chickamauga Reservoir volume is 160 x $10^6 m^3$ at elevation 208 m (22 percent of total), (2) the Hiwassee segment of the reservoir which has a volume of 50 x $10^6 m^3$ (7 percent of total), (3) and the downstream segment from Hiwassee River confluence to Chickamauga Dam with a volume of 525 x $10^6 m^3$ (71 percent of total). Figure 1-3 shows the upstream segment of Chickamauga Reservoir in profile and the cumulative volume from Watts Bar Dam for this reach. Depths range from 5 m at WBN during winter to 14 m in deep portions of the channel during summer.

Figure 1-4 shows cross sections at several locations in the upstream portion of Chickamauga Reservoir. Areas are 1395 to 2320 m^2 (15,000 to 25,000 ft^2) in winter and 1860 to 3720 m^2 (20,000 to 40,000 ft^2) in summer. When all five hydropower units at Watts Bar Dam are generating at full capacity, releases are 1275 m^3/s (45,000 cfs), so average velocities in the upstream portion of Chickamauga Reservoir are 0.3 to 0.6 m/s (1 to 2 ft/s) in summer and 0.6 to 0.9 m/s (2 to 3 ft/s) in winter.

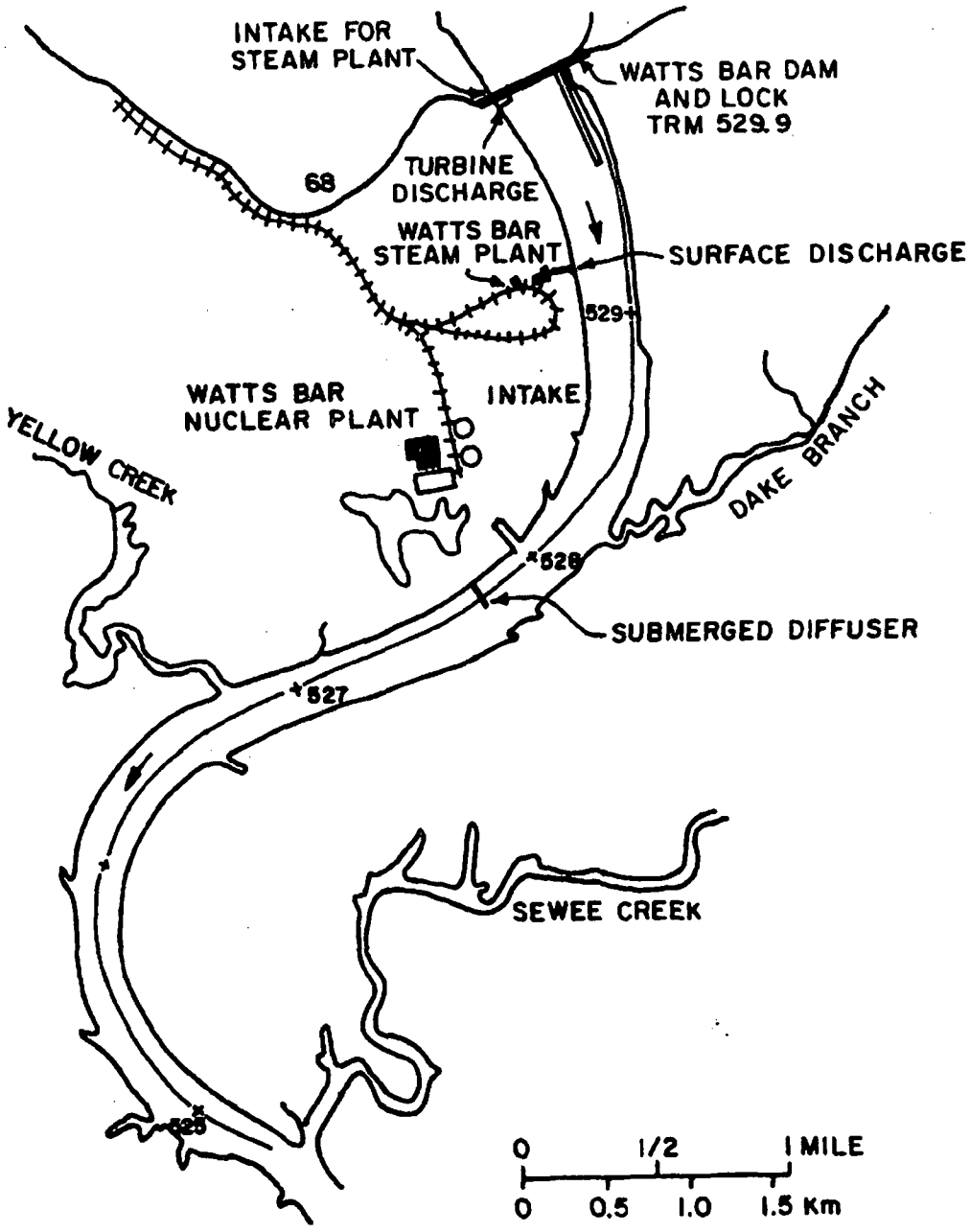


Figure 1-1. Location of Watts Bar Nuclear Plant in Chickamauga Reservoir.

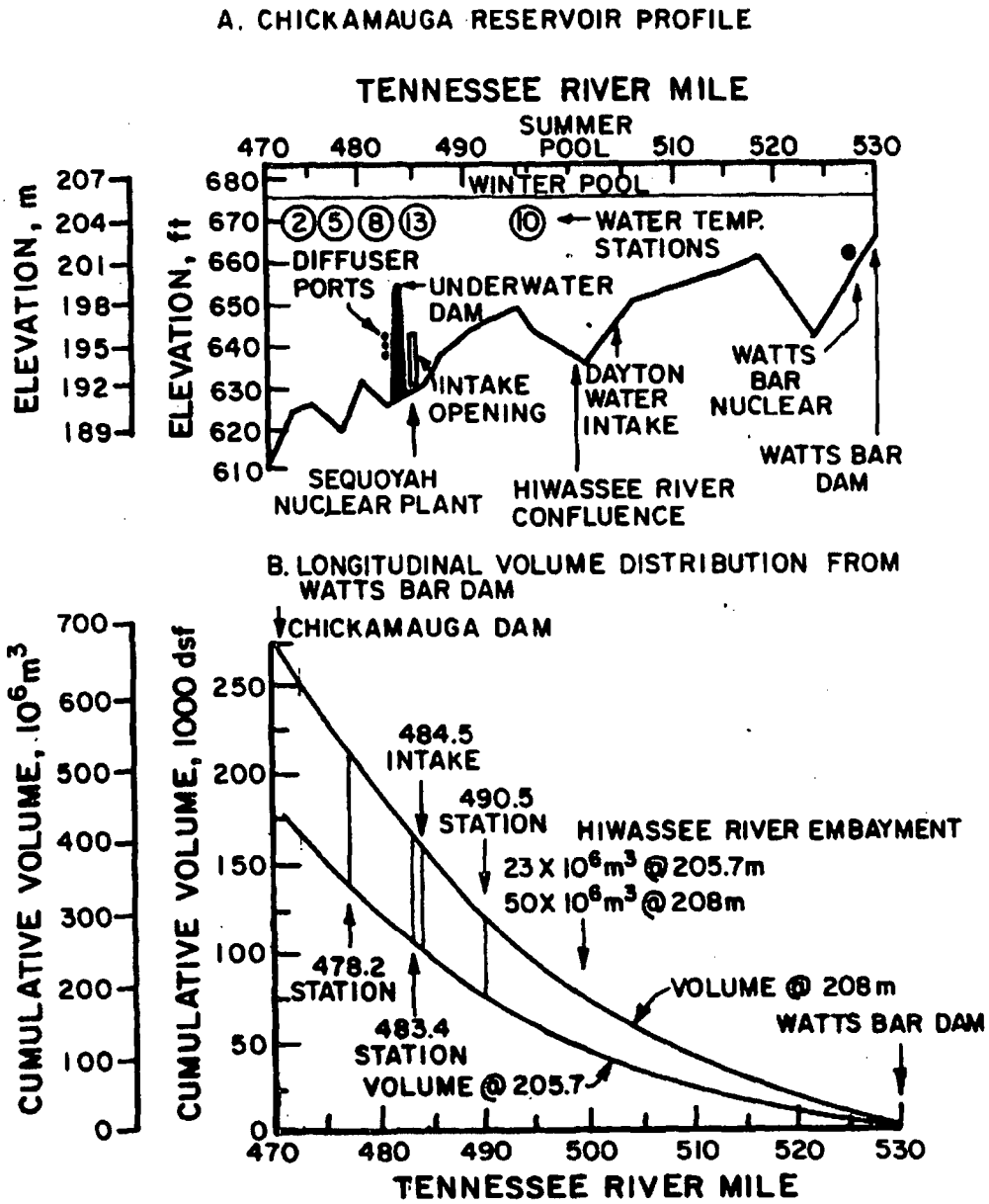


Figure 1-2. Chickamauga Reservoir Profile and Cumulative Volume From Watts Bar Dam.

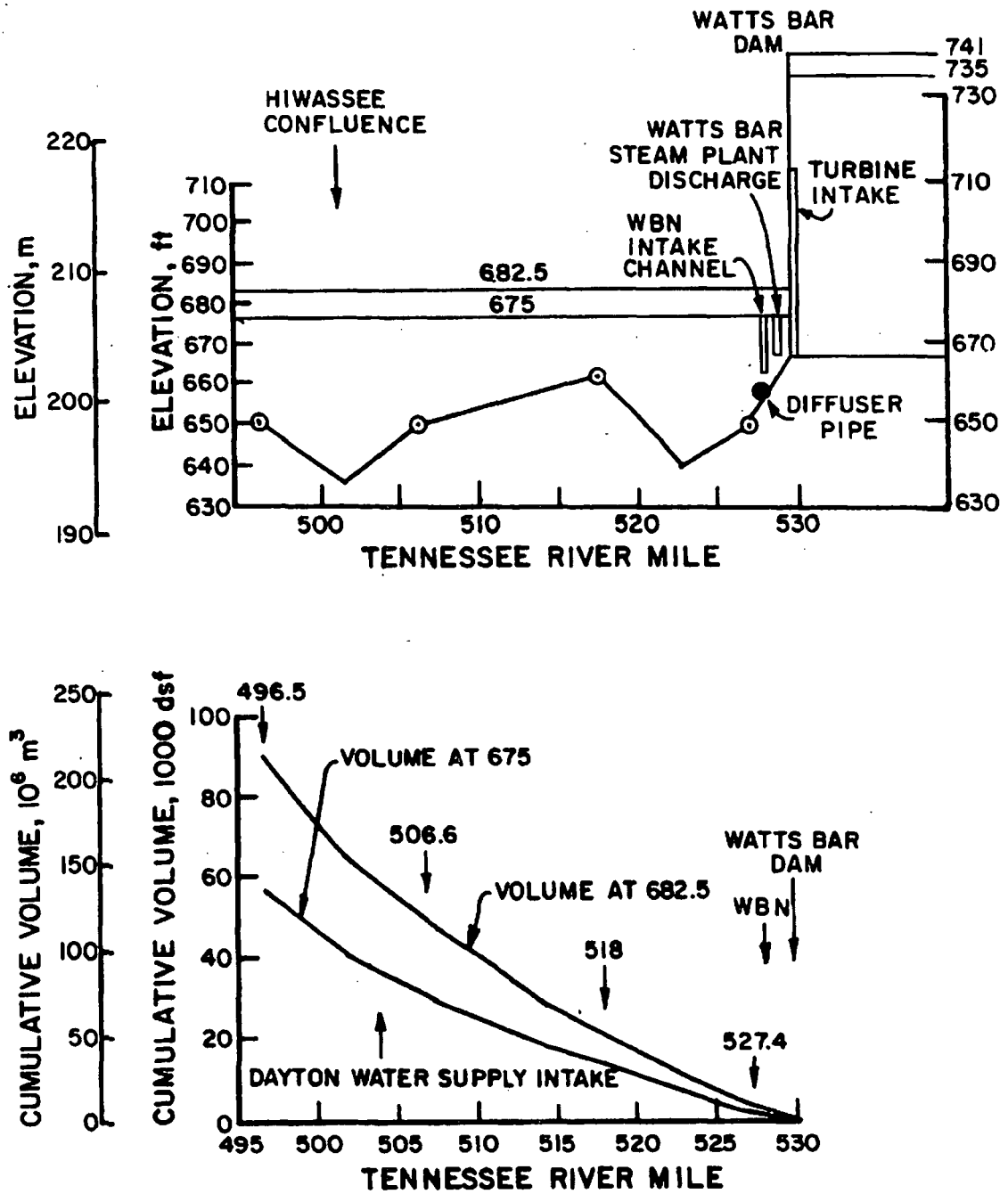


Figure 1-3. Upstream Portion of Chickamauga Reservoir Profile and Cumulative Volume From Watts Bar Dam.

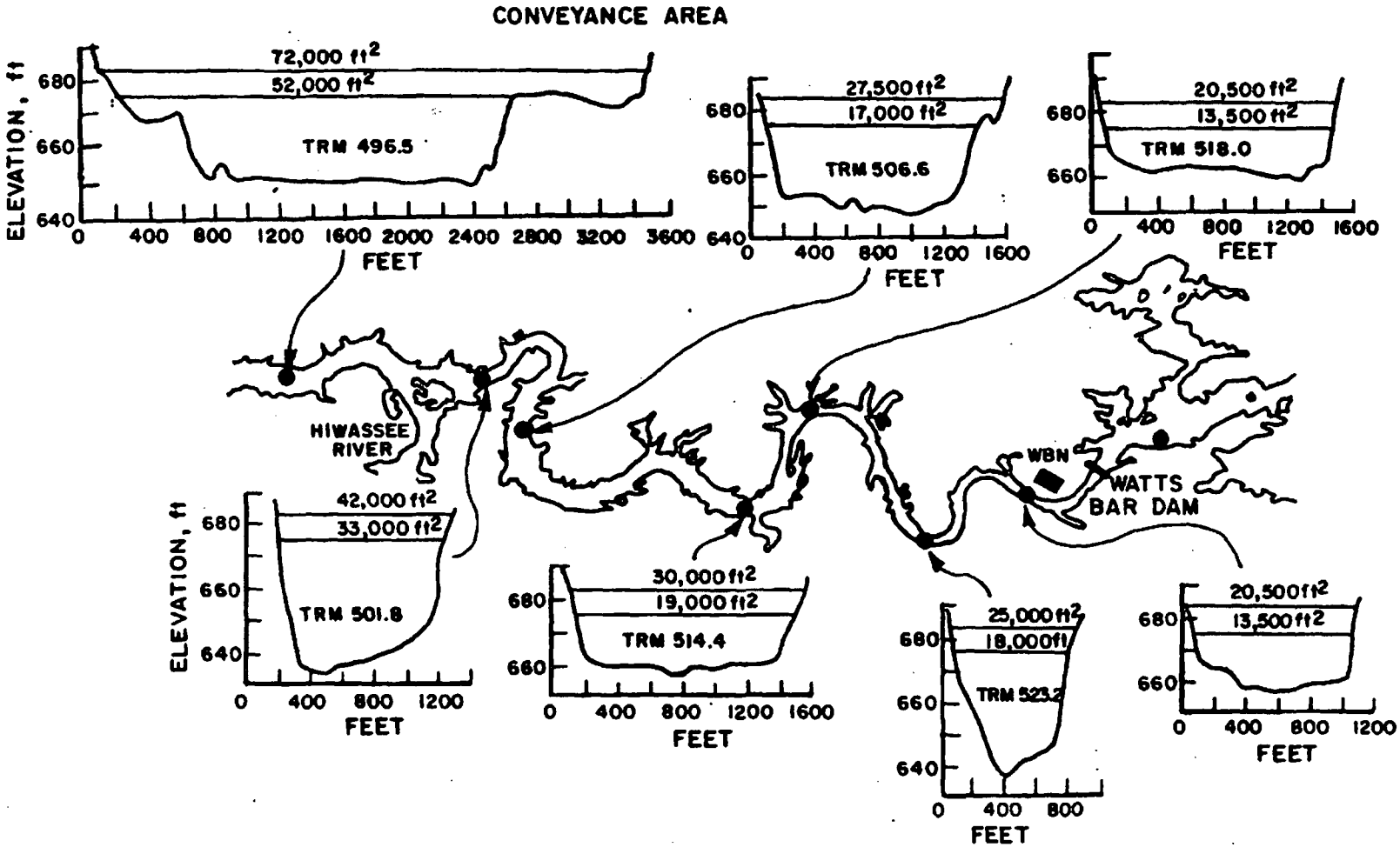


Figure 1-4. Channel Cross Sections in Upstream Portion of Chickamauga Reservoir.

2.0 ENVIRONMENTAL CONDITIONS DURING AQUATIC MONITORING PERIOD

Evaluation of possible effects from WBN operations on aquatic organisms begins with a characterization of major environmental influences on the aquatic environment in the vicinity of WBN. These include reservoir flow and travel time, temperature gradients and mixing, available light and nutrients, and suspended sediment conditions.

2.1 Flow and Travel Time

Travel time from release at Watts Bar Dam governs the time available for biological growth and decay processes as water moves past WBN and through the Chickamauga Reservoir. Although releases from Watts Bar Dam dominate the flows at WBN, two other water sources may be biologically significant. First, there are several small backwater areas and creek embayments throughout the upper 30 miles of the reservoir that may be sources of plankton during high reservoir flow. Peaking power releases produce some change in water surface levels downstream of Watts Bar Dam which leads to exchange with these embayments. Second, local runoff following heavy rainfall can have an effect on water quality.

Watts Bar Hydropower Plant consists of five turbines with a total discharge of approximately 1275 m^3/s (45,000 cfs). The units can operate efficiently at lower flows so that releases vary typically from 710 to 1275 m^3/s (25,000 to 45,000 cfs). The hydropower plant usually operates for 14 to 24 hours a day, supplying power during periods of peak demand. During flood control operations, spillway flows increase the releases above 1275 m^3/s (45,000 cfs).

The long-term average release since closure of Watts Bar Dam (1942) is about 767 m^3/s (27,100 cfs). The flow pattern which changes seasonally and from year-to-year reflects variability in runoff and upstream reservoir operations. Figure 2-1 shows the monthly flows during WBN aquatic monitoring period, 1973-1985. Highest flows normally occur in December through March, but the seasonal pattern is variable. Year-to-year differences are also large, with some years having uniform flow throughout the year (1976, 1984) and other years having more variable patterns (1974, 1975, 1982). During spring, flows are often reduced as upstream tributary reservoirs are filled (1976, 1978, 1981, 1982), but this does not always occur. The WBN aquatic monitoring samples are taken quarterly and the daily flows for particular dates are shown by circles in figure 2-1. These sample date flows are usually representative of seasonal conditions.

Travel time to various downstream locations can be estimated from the releases and the cumulative volume from Watts Bar Dam (shown in figure 1-3). At the long-term average flow of 767 m^3/s (27,100 cfs), water moves in one day past WBN to TRM 515 in summer and to TRM 508 in winter. The cumulative volume from Watts Bar Dam to the monitoring station at TRM 497.0 is approximately $150 \times 10^6 m^3$ during winter and $220 \times 10^6 m^3$ during summer, requiring two days travel in winter and three days in summer at the long-term average flow of 767 m^3/s (27,100 cfs).

Average velocity can be calculated from the Watts Bar Dam release and the cross section area. But as figure 2-2 indicates, velocities are considerably slower in overbank areas and along the

channel bottom and sides. Velocities are 50 percent higher than average in the middle of the main channel. This also means that travel times are shorter in the main channel and longer in the shallow areas. The channel bends in the upstream portion of Chickamauga Reservoir produce additional lateral mixing and circulation. These factors of high flows, small cross sections, and channel bends create conditions of fully-mixed flow upstream of Hiwassee River confluence.

2.2 Temperatures and Mixing

Water temperatures near WBN are moderated by upstream reservoirs, but year-to-year variations in meteorology produce some fluctuations in the seasonal water temperature pattern. Figure 2-3 shows the seasonal temperature pattern with data from 1970-1985. Greatest variability occurs in winter, when temperatures can remain near 10°C or drop to near 2°C, and during summer when temperatures can remain below 25°C or approach 28°C. The effects of meteorological conditions on water temperatures and mixing can be identified from data collected by the temperature monitor #10 located at TRM 497.0. Stratification rarely occurs as fully-mixed conditions normally occur upstream from this point. The Watts Bar Fossil Plant, located at TRM 529, discharged 600 cfs with a temperature rise of approximately 2°C throughout much of the first phase of the WBN preoperational period. The Watts Bar Fossil Plant is no longer operating.

Because flow and temperatures are the dominant characteristics of the habitat in most of the WBN monitoring area, the daily patterns for 1973 through 1985 are shown in figure 2-4 through 2-16 for reference. As

can be seen in figures 2-4 through 2-16, measurements taken at Watts Bar Dam are representative of the monitoring area. Measurements taken at water temperature monitor #13 (TRM 484.7, intake at Sequoyah Nuclear Plant) are shown in figures 2-15 and 2-16. The bottom temperature at station 13 also provides a good indication of temperatures in the vicinity of WBN.

2.3 Available Light

Primary productivity of phytoplankton and aquatic macrophytes depends on available solar energy which in turn depends on solar radiation and light penetration (turbidity). Day-to-day variations in light conditions are great, but these variations may not be reflected in average seasonal condiitons. Interpretation of productivity data should reflect these differences. Light penetration generally increases downstream as suspended solids settle after release from Watts Bar Dam. Depth of one percent surface light penetration varies from 3 to 5 m, unless water turbidity is unusually high or low. Turbidity and light conditions on sample dates are reported in appendix 2-A.

2.4 Seasonal Dissolved Oxygen and Nutrients

Dissolved oxygen concentrations in releases from Watts Bar Dam generally follow the seasonal saturation pattern with some additional DO deficit during low flow periods in spring and summer. Figure 2-3 shows the variability that occurs year-to-year. During some summers, DO concentrations approach 3 mg/L, while during other years, DO concentrations remain above 5 mg/L. Dissolved oxygen conditions are discussed in further detail in section 4.0.

The seasonal patterns for other water quality parameters are not as pronounced as for dissolved oxygen. Available data (1960 to 1985) from TRM 529.9 have been displayed as monthly means in figure 2-17. Turbidity is generally highest in winter and spring (15 to 20 NTU) and lowest in summer and fall (7 to 10 NTU). Alkalinity is generally slightly higher during the summer low flow period. Ammonia (not shown on figure) is generally low, about 0.05 mg/L. Nitrate (NO_3-N) is highest in winter (0.5 mg/L) and drops to between 0.2 and 0.3 mg/L during summer, reflecting algal uptake in Watts Bar and upstream reservoirs. Total phosphorus concentrations are variable, but are generally higher during winter and spring (0.03 mg/L) than summer and fall (0.02 mg/L). These represent the important nutrients for phytoplankton growth and are apparently available in excess of algal requirements.

2.5 Conditions Prior to Quarterly Plankton Sampling

Environmental factors during and prior to each plankton sampling are tabulated in appendix 2-A. Daily average Watts Bar Dam releases, solar radiation, water turbidity, rainfall, and windspeed are the physical factors reported. These are expected to influence all sampling stations. Travel time, temperature, DO, pH, alkalinity, secchi depth (light penetration), and nutrient measurements at each of the seven sampling stations are averaged over depth to describe overall conditions. As described previously, travel time through the upstream portion of Chickamauga Reservoir varies from less than one day to several days during low flow periods.

Water quality data in Chickamauga Reservoir in the early 1970s were mostly sparse and incomplete; these data were collected mainly for long-term reservoir water quality assessment. Available data in the late 1970s and early 1980s were more extensive and detailed enough for an overall analysis of environmental conditions during and prior to WBN aquatic sampling. The influence of these environmental factors on plankton productivity will be discussed in section 5.0. A synopsis of the available data (shown in appendices A-1 to A-35) is summarized in table 2-1. This table identifies differences observed in environmental conditions prior to plankton sampling. Measurements of environmental factors in the same period (i.e., February, May, August, and November) are divided into three categories: low, middle, and high. For each environmental factor, a range of values is assigned to each category with the attributive year(s).

February Conditions--Conditions during the quarterly sampling periods are summarized in table 2-1. River flows during February (1975-1985) are generally between 20,000 and 30,000 cfs with an average travel time through the monitoring area (TRM 496-532) of 1.5 days. February temperatures range from 5 to 10°C and dissolved oxygen concentrations are between 10 and 12 mg/L. Because of well-mixed conditions, little variation in chemical parameters exists among stations or with depth.

May Conditions--River flows during May (1975-1985) are between 20,000 and 30,000 cfs with an average travel time through the monitoring reach (TRM 496-532) of 3.7 days. May temperatures range from 15 to 20°C, dissolved oxygen concentrations are between 7 and 9 mg/L, and the reservoir is well mixed.

August Conditions--River flows during August (1975-1985) are between 30,000 and 35,000 cfs with an average travel time through the monitoring reach (TRM 496-532) of 3.1 days. August temperatures range from 24 to 26°C and dissolved oxygen concentrations are normally between 4 and 5 mg/L.

November Conditions--River flows during November (1975-1985) are between 20,000 and 25,000 cfs with an average travel time through the monitoring reach (TRM 496-532) of 2.3 days. November temperatures range from 15 to 16°C and dissolved oxygen concentrations are between 7 and 8 mg/L.

Table 2-1. Summary of Environmental Factors During and Prior to Plankton Sampling

Environmental Factor	February			May			August			November		
	Low	Middle	High	Low	Middle	High	Low	Middle	High	Low	Middle	High
Flow, 1,000 cfs	<20	20-30	>30	<20	20-30	>30	<30	30-35	>35	<20	20-25	>25
Year	-	*	(74,75,83)	76,82,	*	(83,84)	76,77,85	*	-	(83,85)	*	(76,82)
Turbidity, NTU	<	10-20	>20	<10	10-20	>20	<10	10-20	>20	<10	10-20	>20
Year	(83,84)	*	74,75, 76,77	(82,85)	*	(74,75)	82,83, 84,85	*	(75,76,77)	82,83, 84,85	*	(75,76,77)
Wind Speed, mph	<5	5-10	>10	<5	5-10	>10	<5	5-10	>10	<5	5-10	>10
Year	(83)	*	(73)	(75)	*	(74)	(84)	*	-	(77,82)	*	(74)
Temperature, C	<5	5-8	>8	<17	17-20	>20	<25	25-26	>26	<15	15-16	>16
Year	(77,85)	*	(74,75)	(77)	*	(75)	(76)	*	(77)	(76)	*	(75,85)
DO, mg/L	<11	11-12	>12	<7	7-9	>9	<4	4-5	>5	<7	7-8.5	>8.5
Year	(84)	*	(75,77)	(75)	*	(82,83,84)	(77,85)	*	(76,82)	(77)	*	(76,83)
pH	<7	7-7.5	>7.5	<7	7-7.5	>7.5	<7	7-7.5	>7.5	<7	7-7.5	>7.5
Year	-	*	77,83,85	-	*	73,74, 82,85	-	*	(85)	-	*	(84)
Alkalinity, mg/L	<50	50-60	>60	<50	50-60	>60	<50	50-60	>60	<50	50-60	>60
Year	(84)	*	(77,83)	(76,83)	*	(82)	(76)	*	(82-85)	(75,77)	*	(84,83,84)
Inorganic N, mg/L	<.4	.4-.5	>.5	<.3	.3-.4	>.4	<.3	.3-.35	>.35	<.3	.3-.5	>.5
Year	-	*	(75,76)	-	*	(77,84)	(85)	*	(73,74,76)	(83,84)	*	(77)
Organic N, mg/L	<.1	.1-.2	>.2	<.1	.1-.2	>.2	<.1	.1-.2	>.2	<.1	.1-.3	>.3
Year	-	*	(83,85)	(77,84)	*	(82,85)	-	*	73,82,85	(76,77)	*	(73,74)
Diss. P, mg/L	<.01	.01-.02	>.02	<.01	.01-.02	>.02	<.01	.01-.02	>.02	<.01	.01-.02	>.02
Year	-	*	(83)	-	*	-	(82,84)	*	(76)	(82,84)	*	(83)

Table 2-1 (Continued)

Environmental Factor	February			May			August			November		
	Low	Middle	High	Low	Middle	High	Low	Middle	High	Low	Middle	High
Total P, mg/L	<.03	.03-.04	>.04	<.02	.02-.03	>.03	<.02	.02-.03	>.03	<.03	.03-.04	>.04
Year	-	*	(84)	-	*	(76,77)	-	*	(73,76)	-	*	(84)
Diss. C, mg/L	-	1.5-2.0	>2.0	-	1.5-2	>2.0	-	2-4	-	-	2-4	-
Year	-	(84)	-	-	(84)	(85)	-	(84-85)	-	-	(84,85)	-
Total C, mg/L	<2	2-3	>3	<1	1-2.5	>2.5	<	2-3	>3	<2	2-3	>3
Year	(76,85)	*	-	-	*	-	(74,75,77)	*	(82,83,85)	(76,84)	*	-
Chlorophyll a, ug/L	-	4-5	6-12	1.5-3.5	1.5-5.5	>5.5	2-3	2-5	>5	1-2	3-4	5-6
Year	-	(83,85)	(84)	(82)	(84)	(83,85)	(83)	(84)	(82,85)	(84)	(83)	(82,85)

*All years except those in low and high categories.

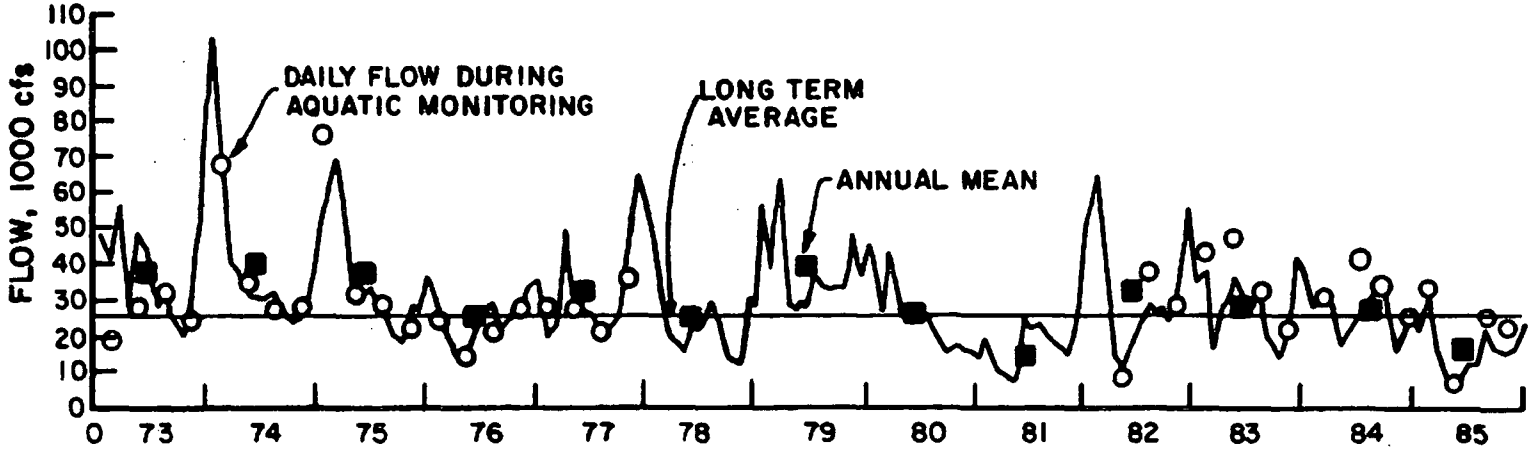


Figure 2-1. Monthly Flows From Watts Bar Dam During Preoperational WBN Aquatic Monitoring.

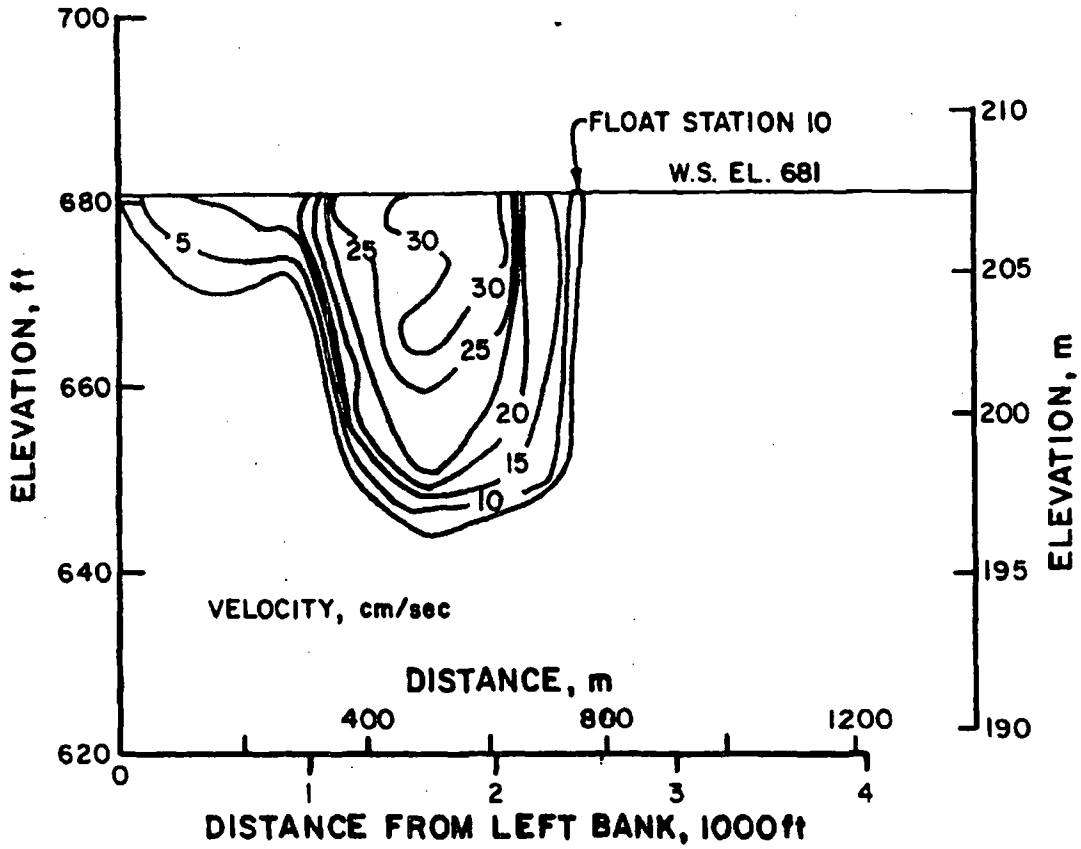


Figure 2-2. Velocity Distribution at TRM 497 During Flow of 1133 m^3/s (40,000 cfs) with a Mean Velocity of 22 cm/s.

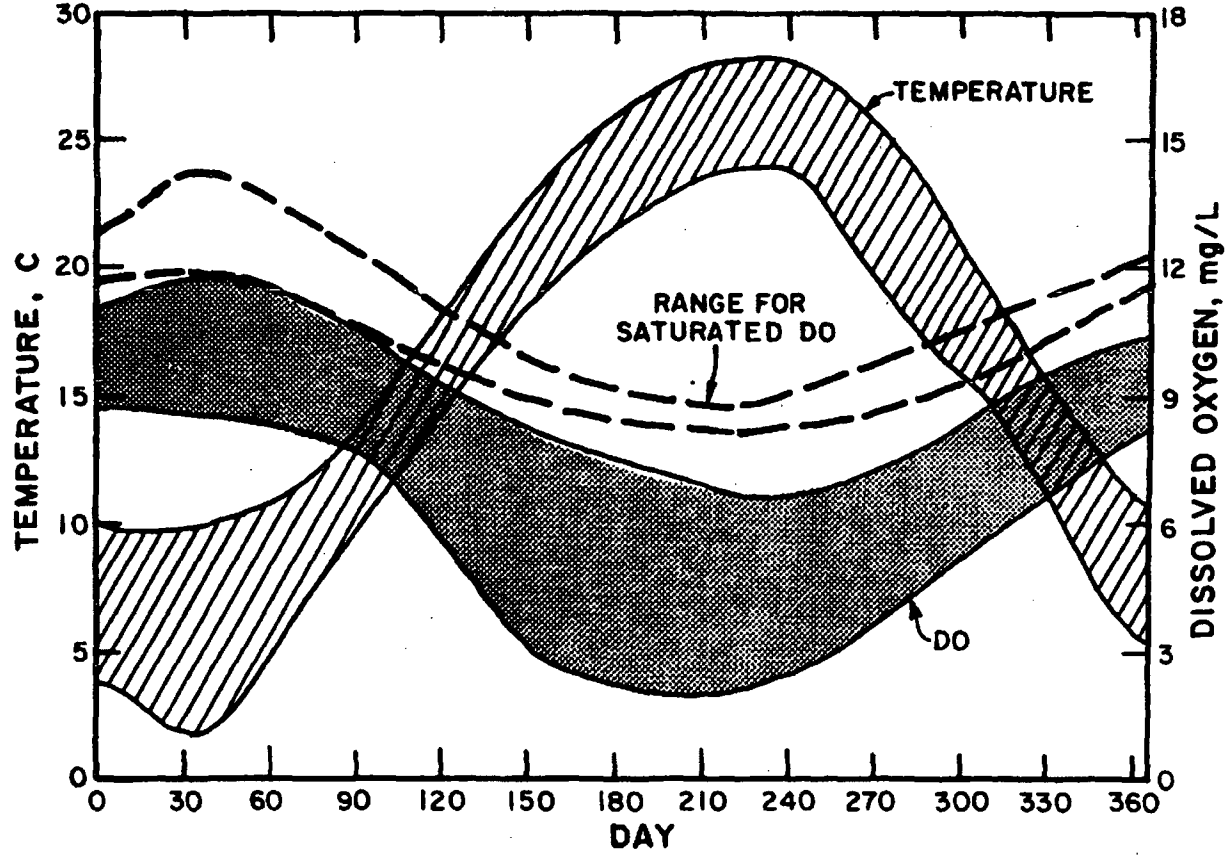


Figure 2-3. Seasonal Temperature and Dissolved Oxygen Concentration Range for Watts Bar Dam Releases, 1970-85.

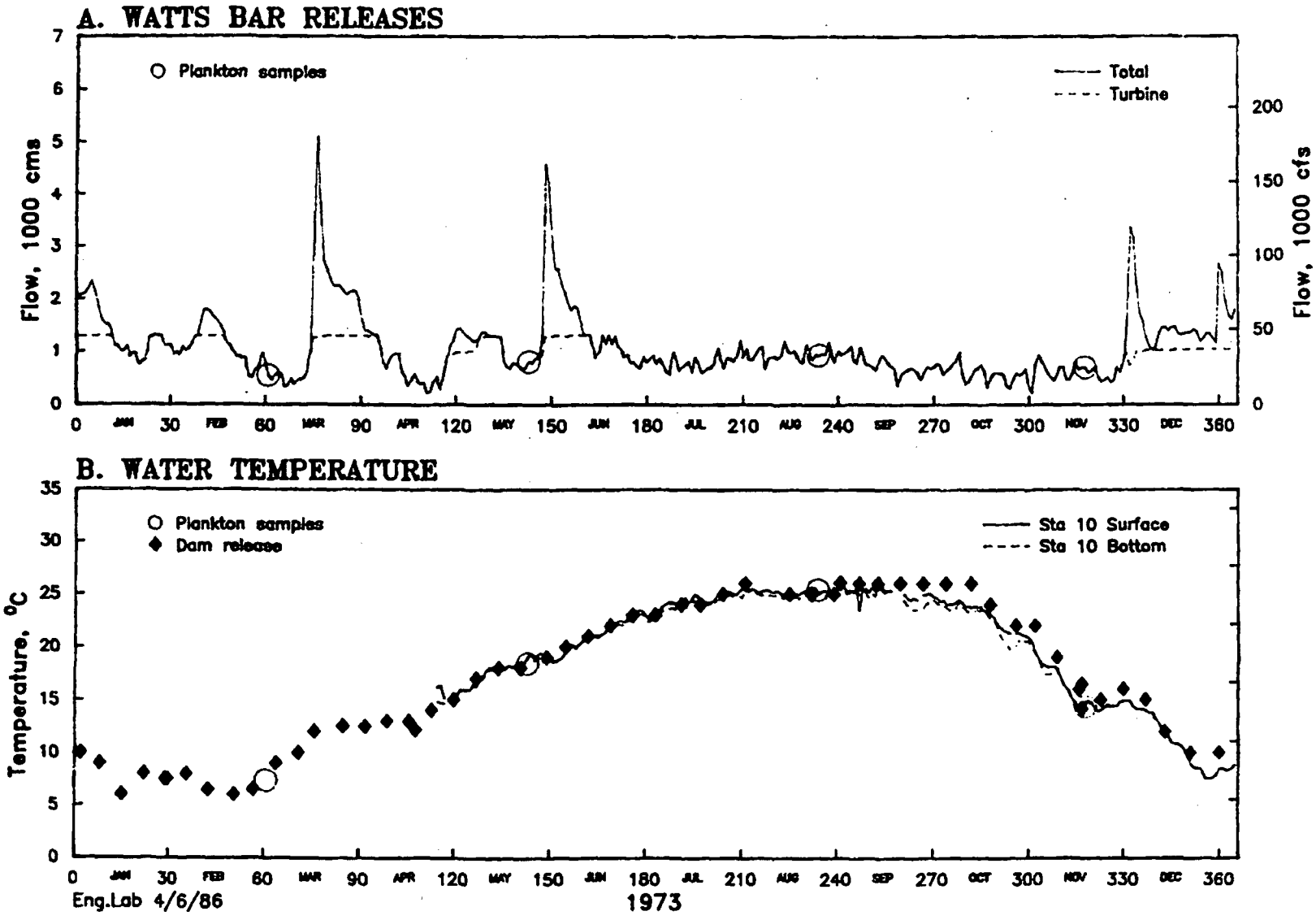


Figure 2.4. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1973.

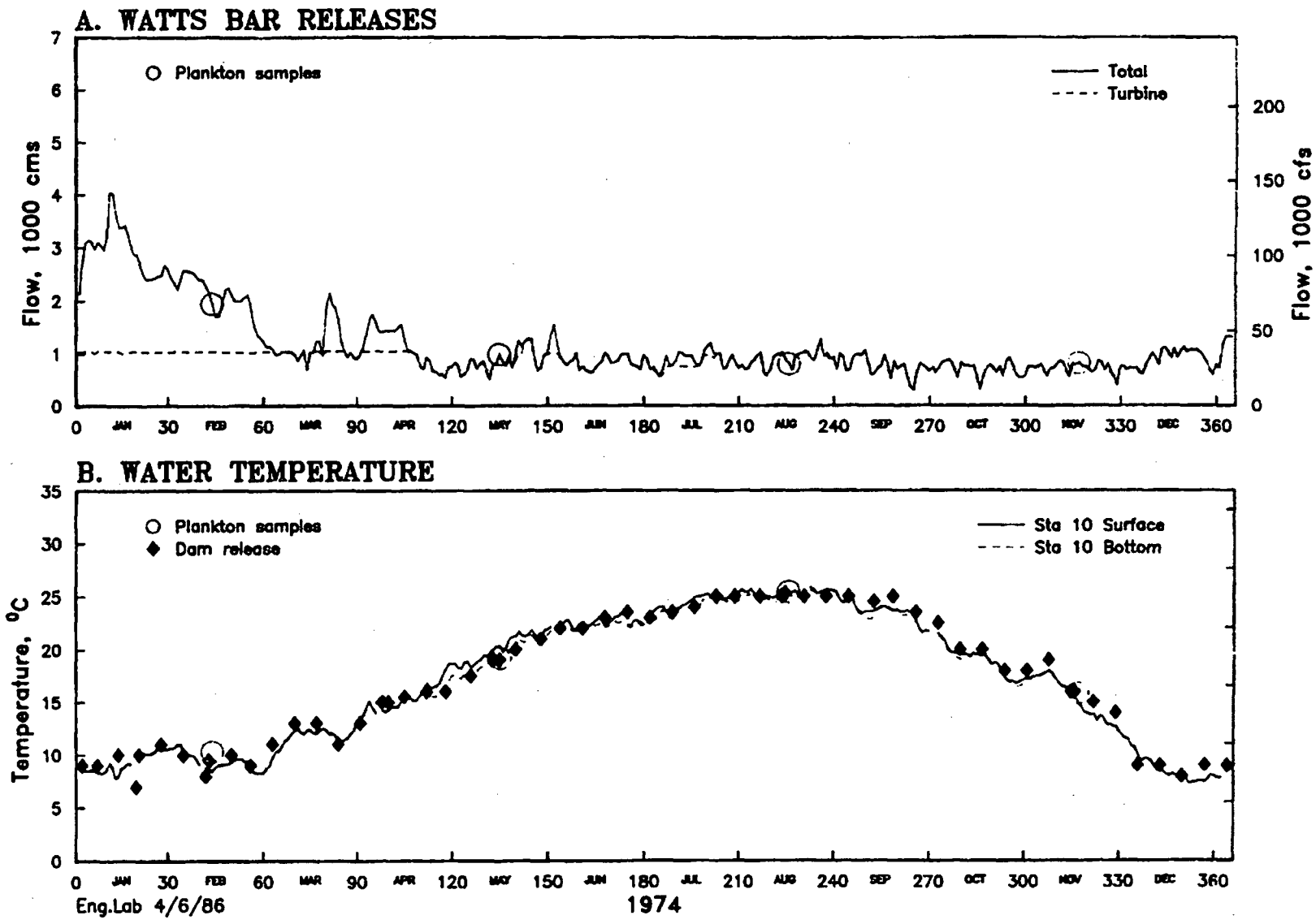


Figure 2.5. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1974.

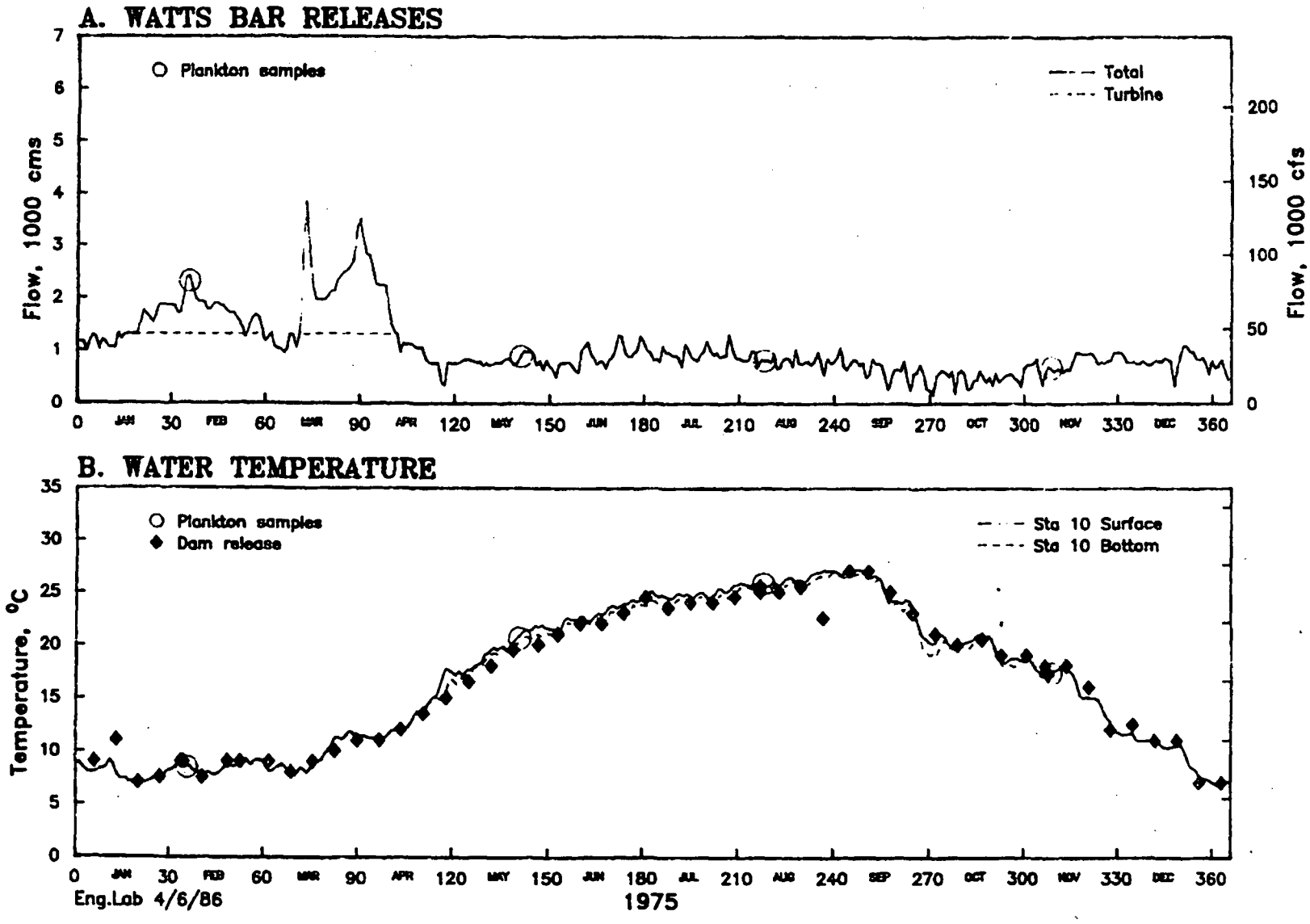


Figure 2.6. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1975.

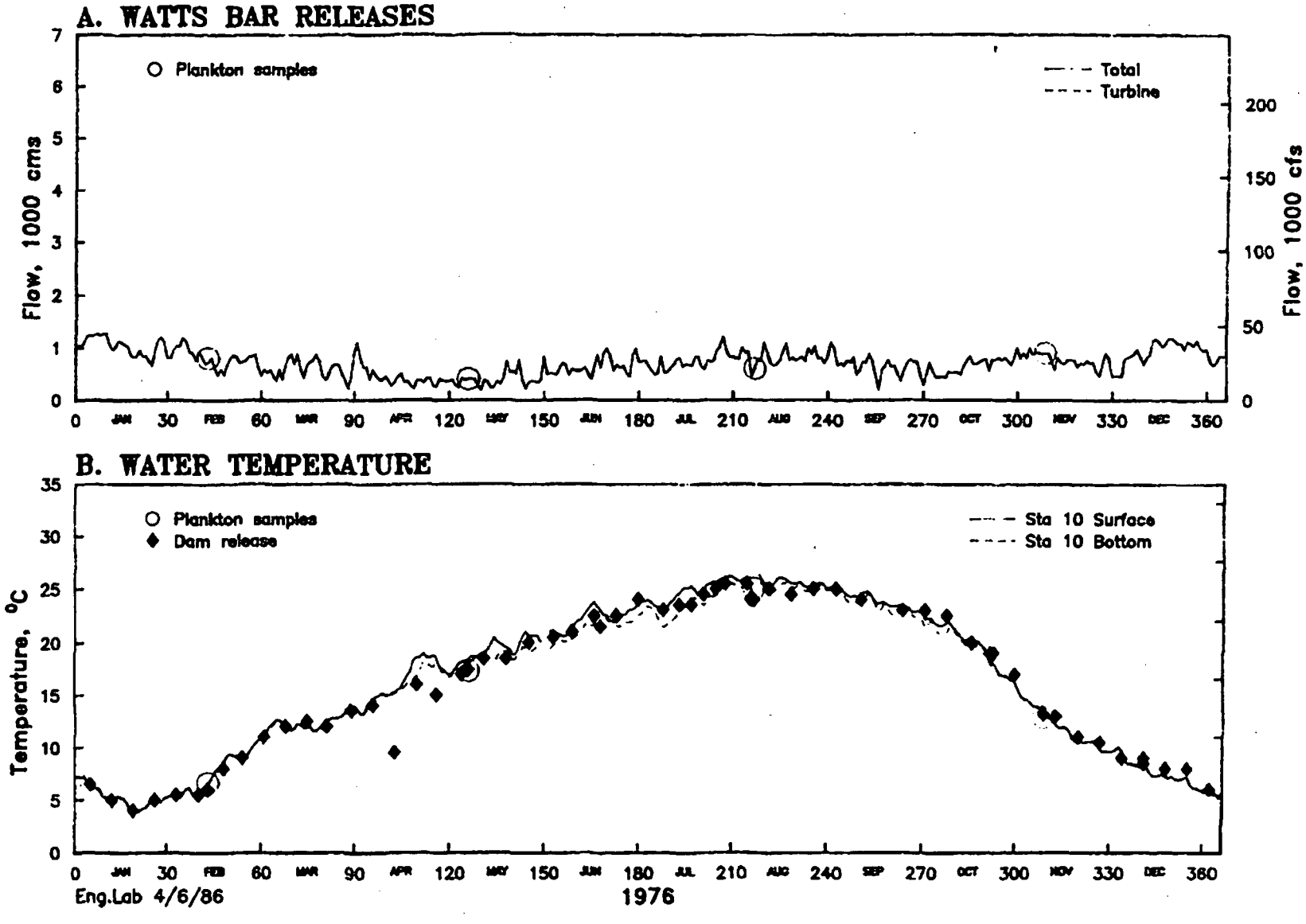


Figure 2.7. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1976.

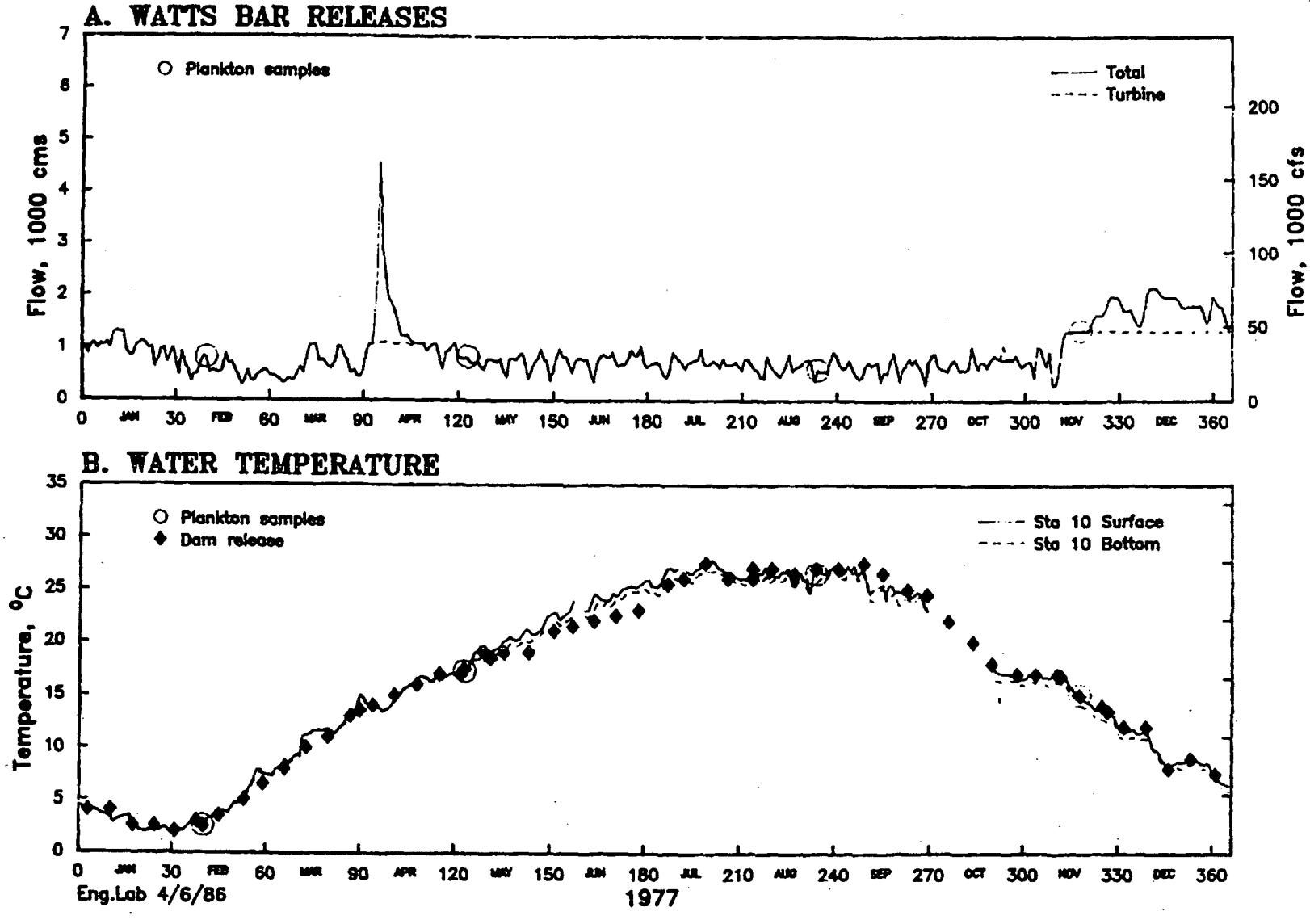


Figure 2.8. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1977.

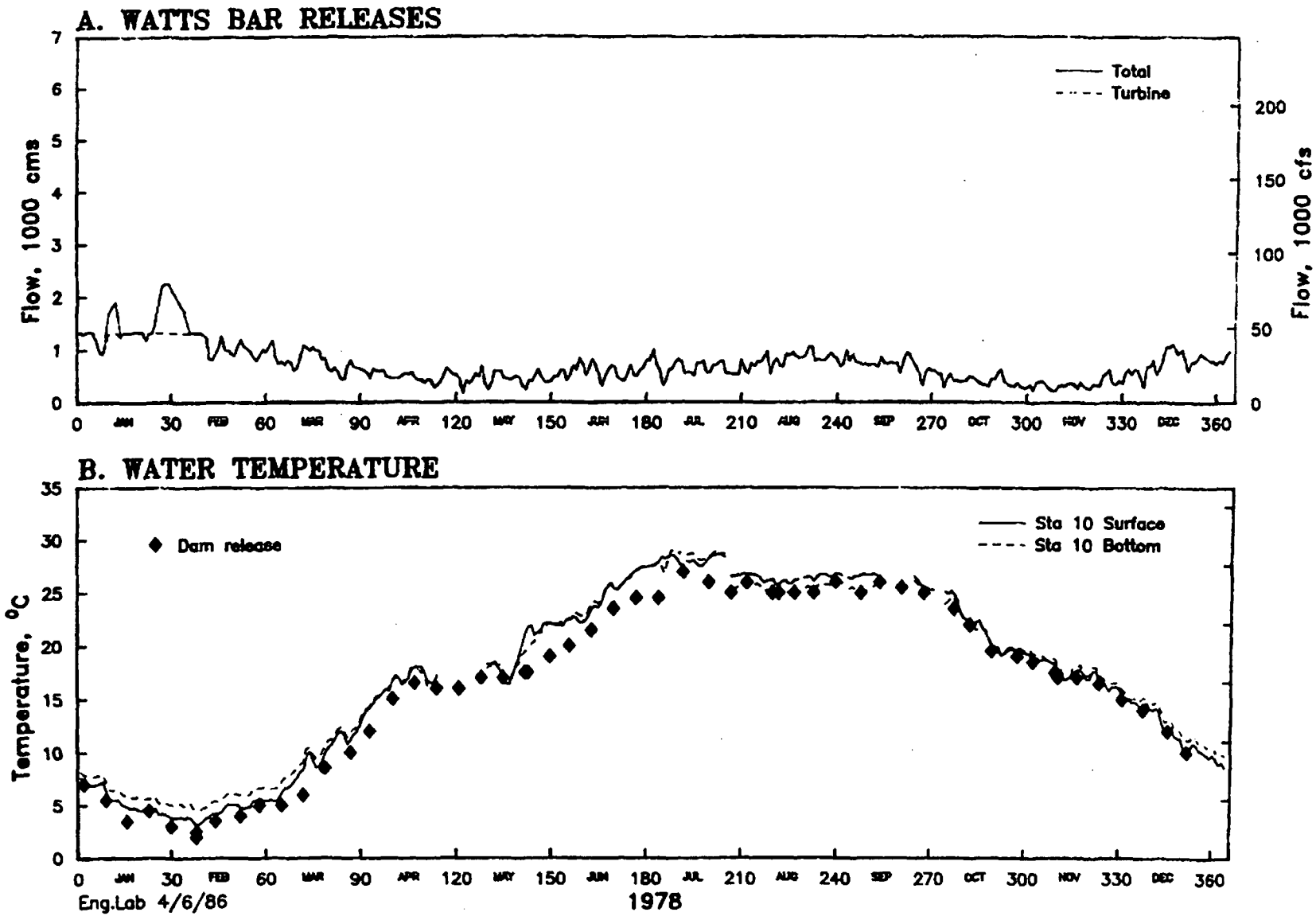


Figure 2.9. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1978.

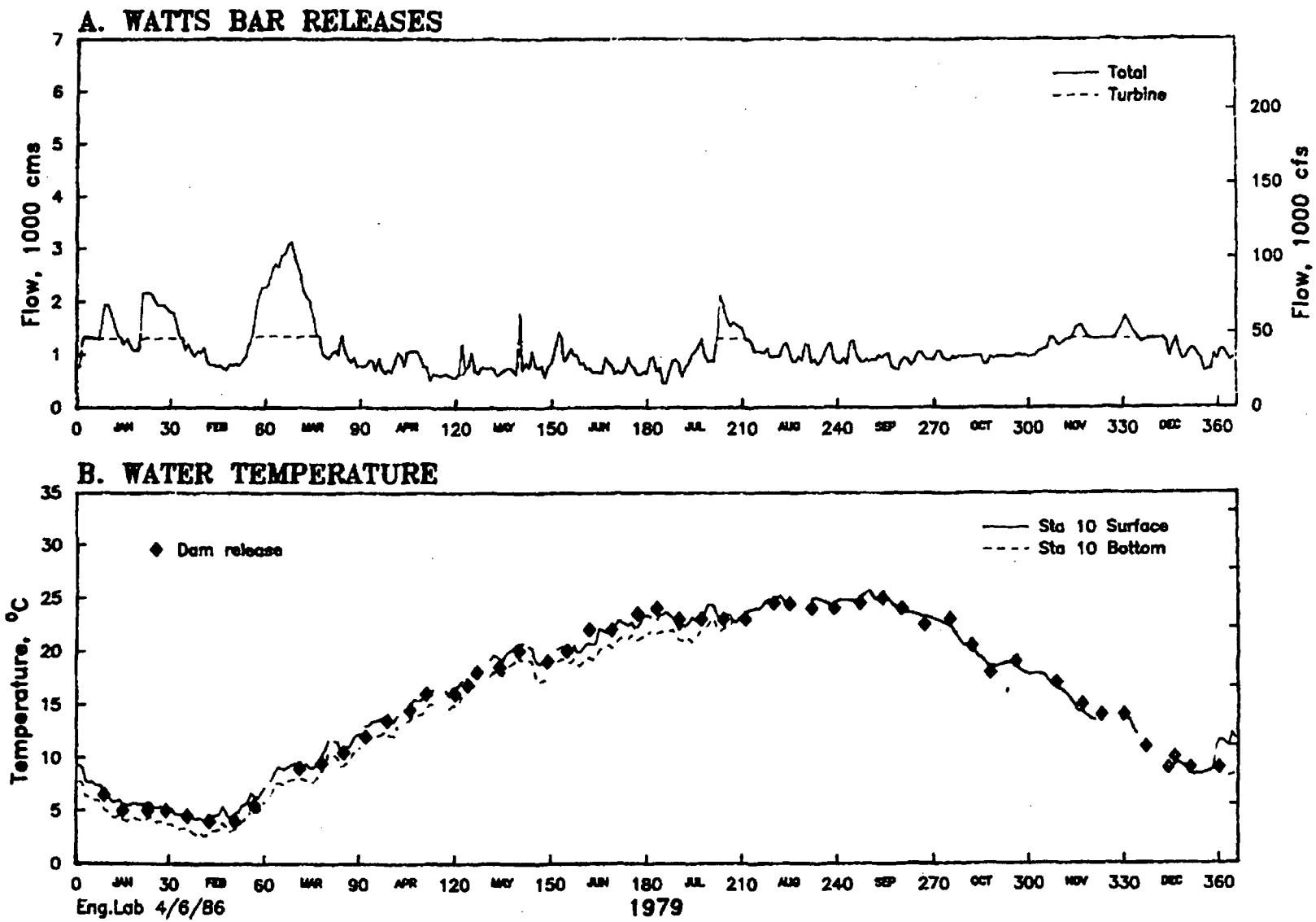


Figure 2.10. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1979.

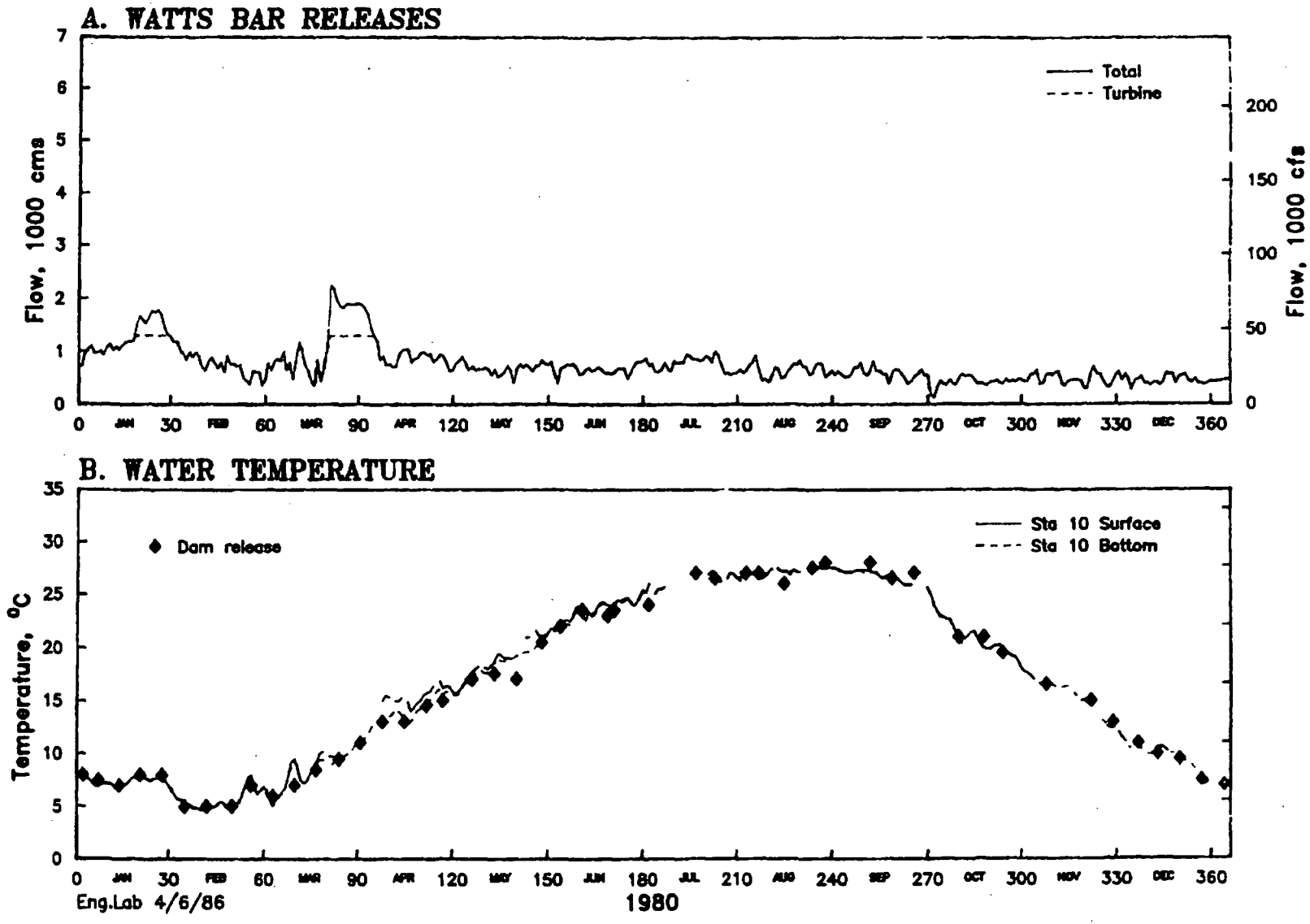


Figure 2.11. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1980.

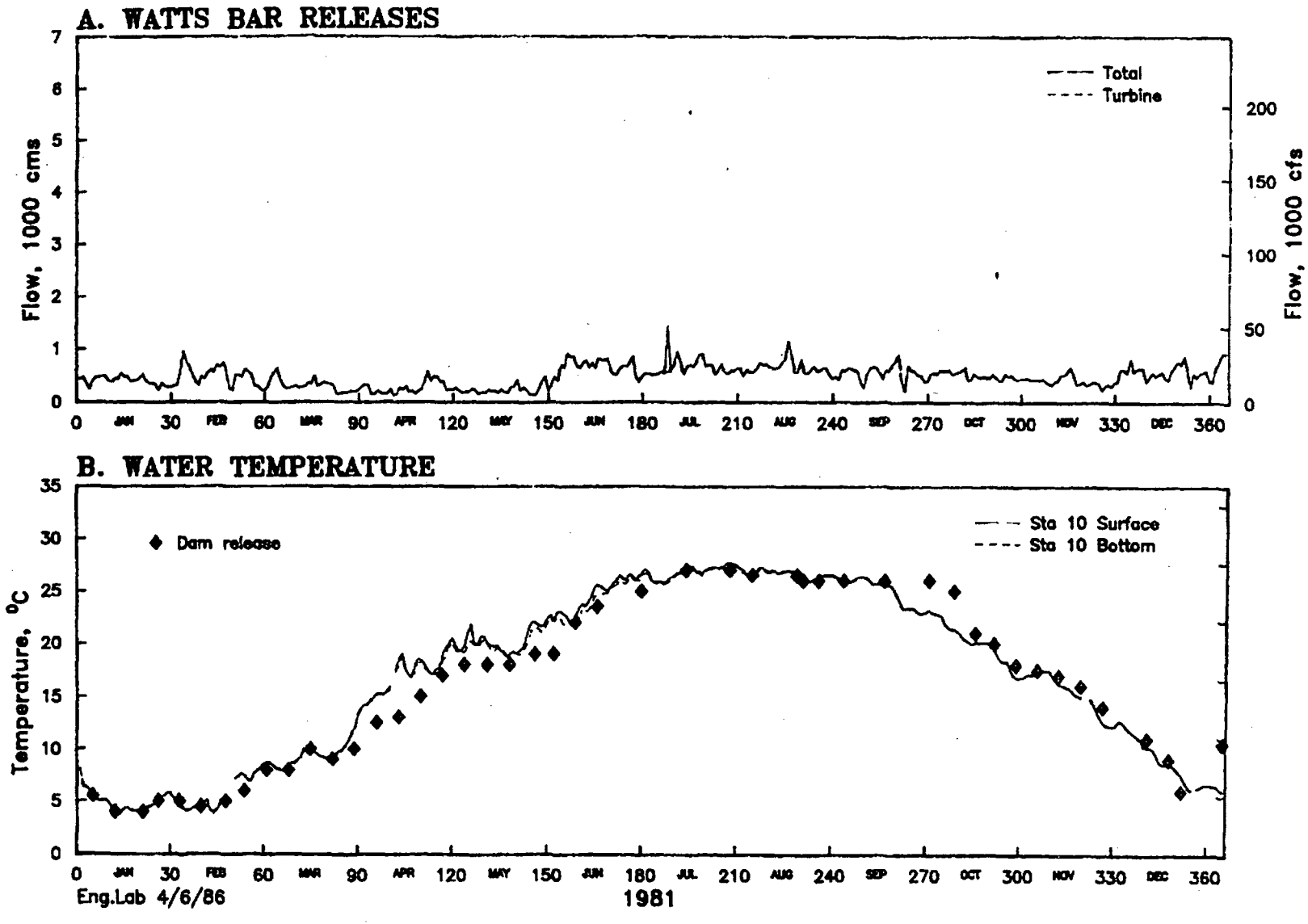


Figure 2.12. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1981.

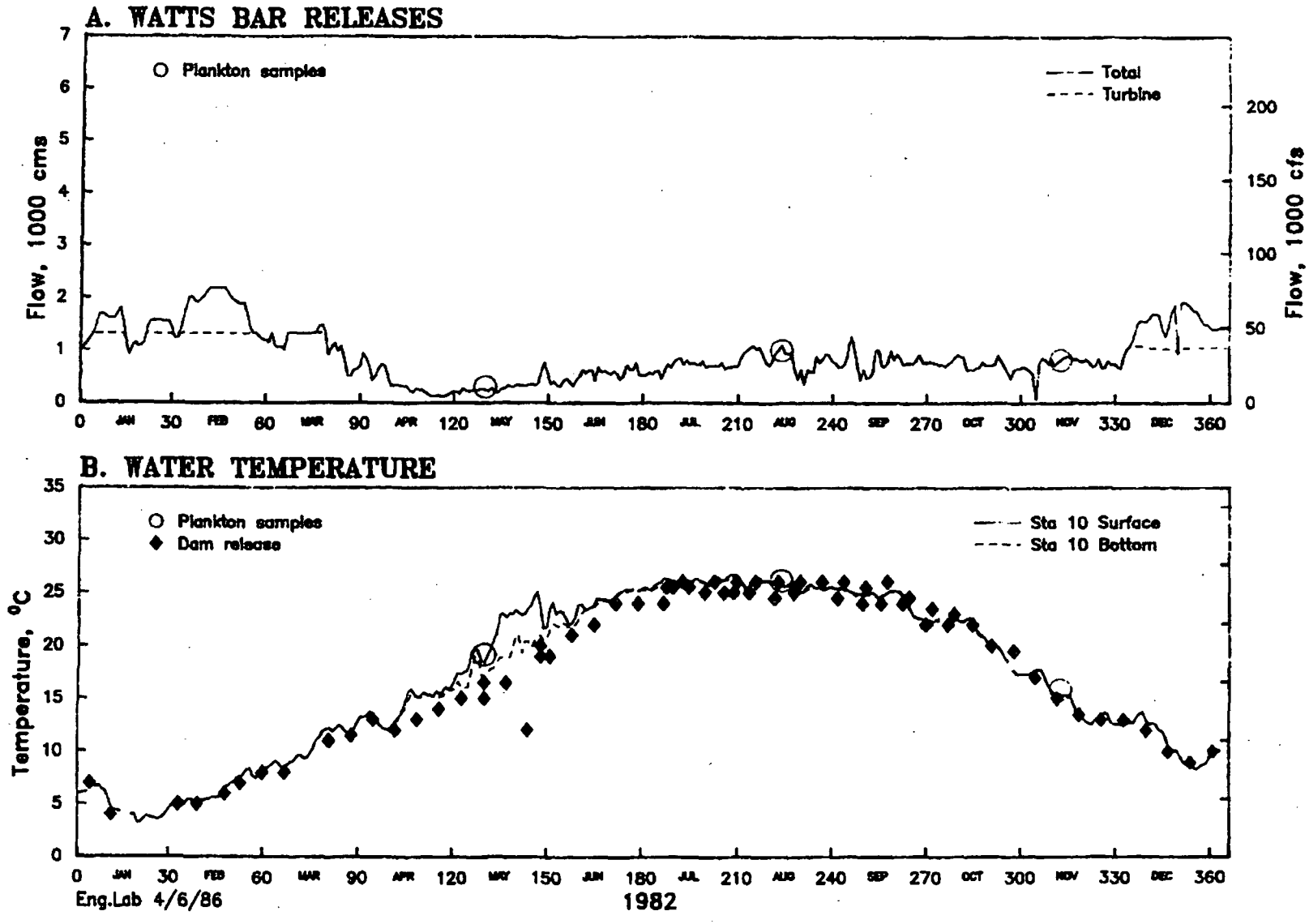


Figure 2.13. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1982.

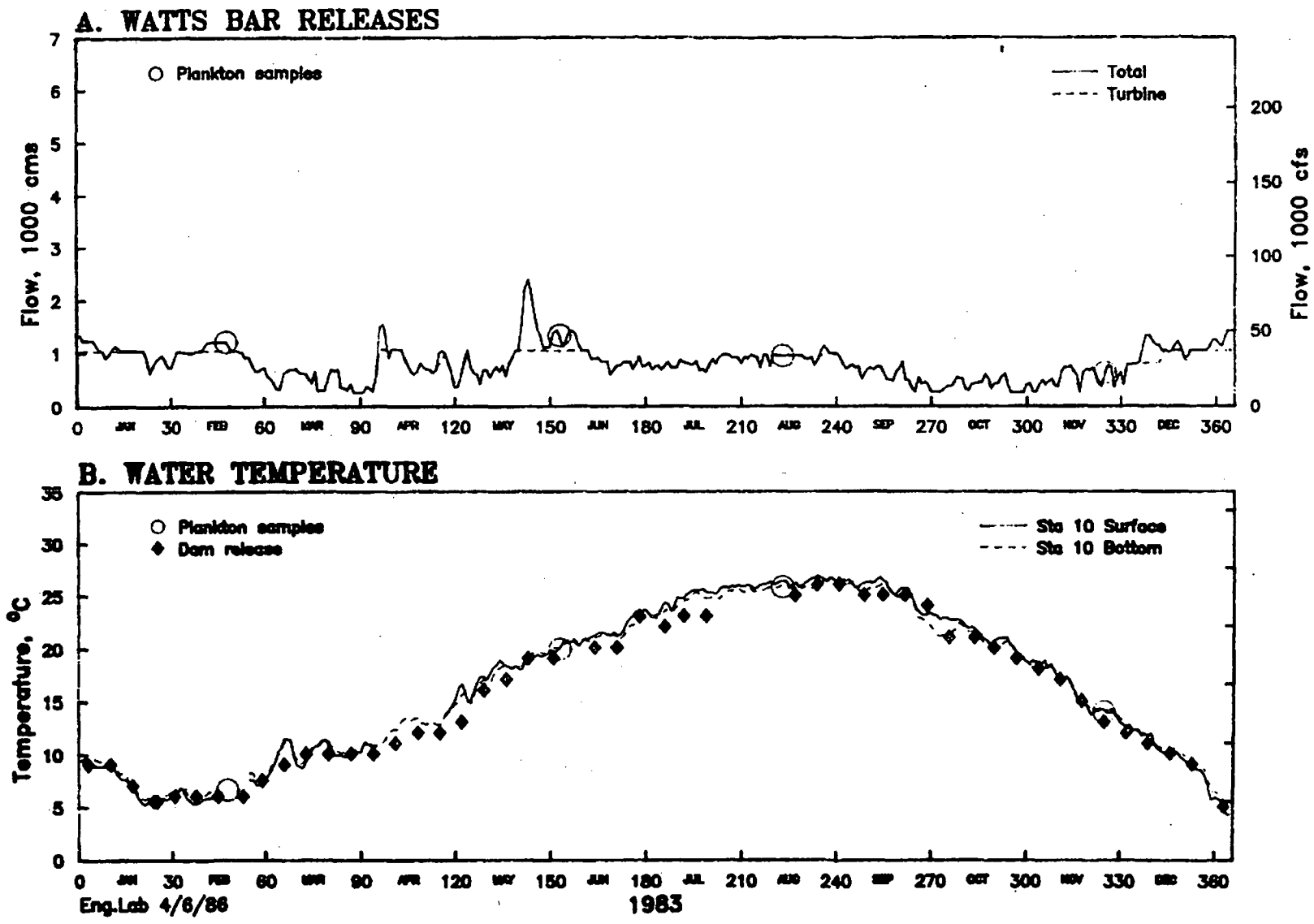


Figure 2.14. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1983.

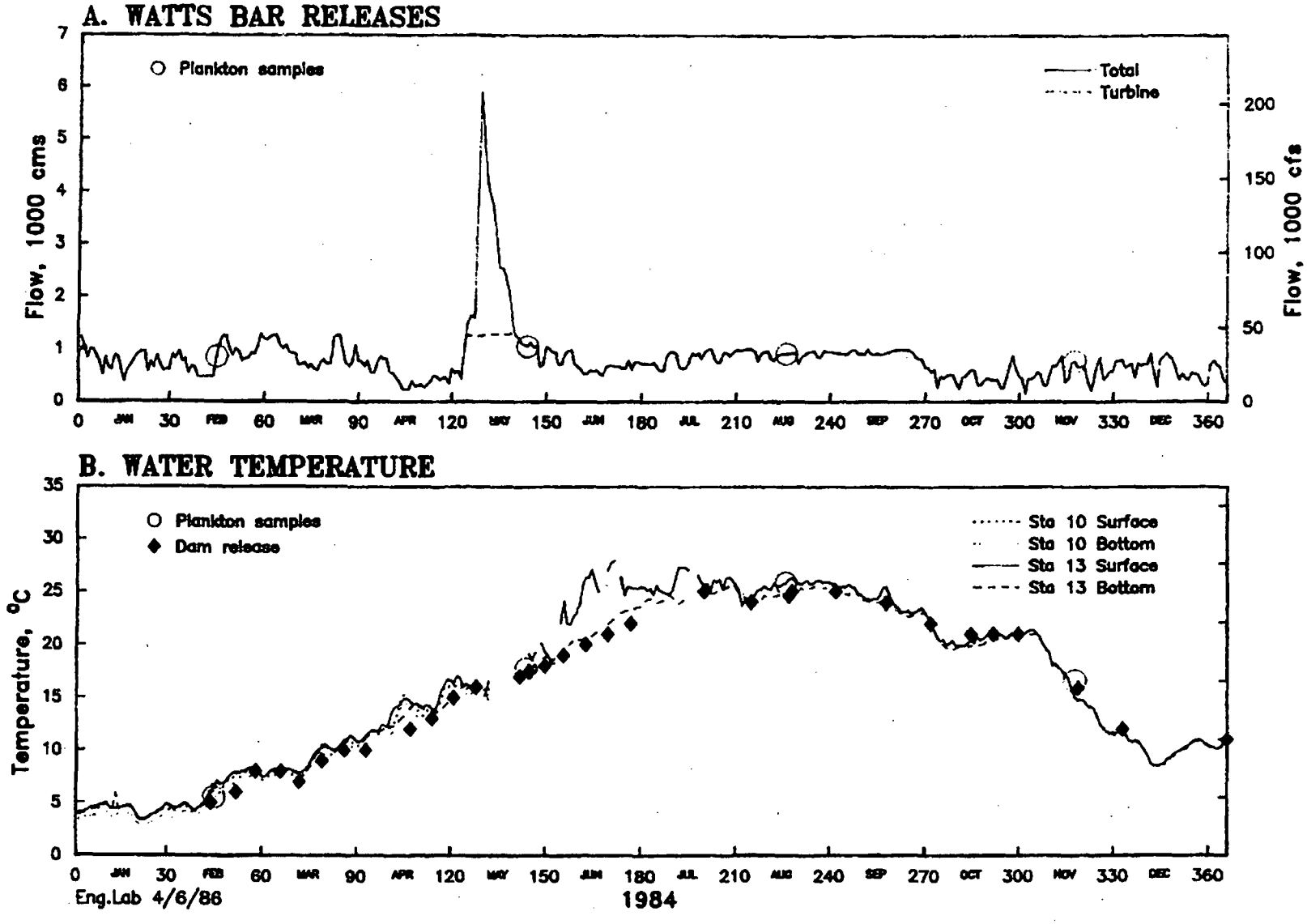


Figure 2.15. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1984.

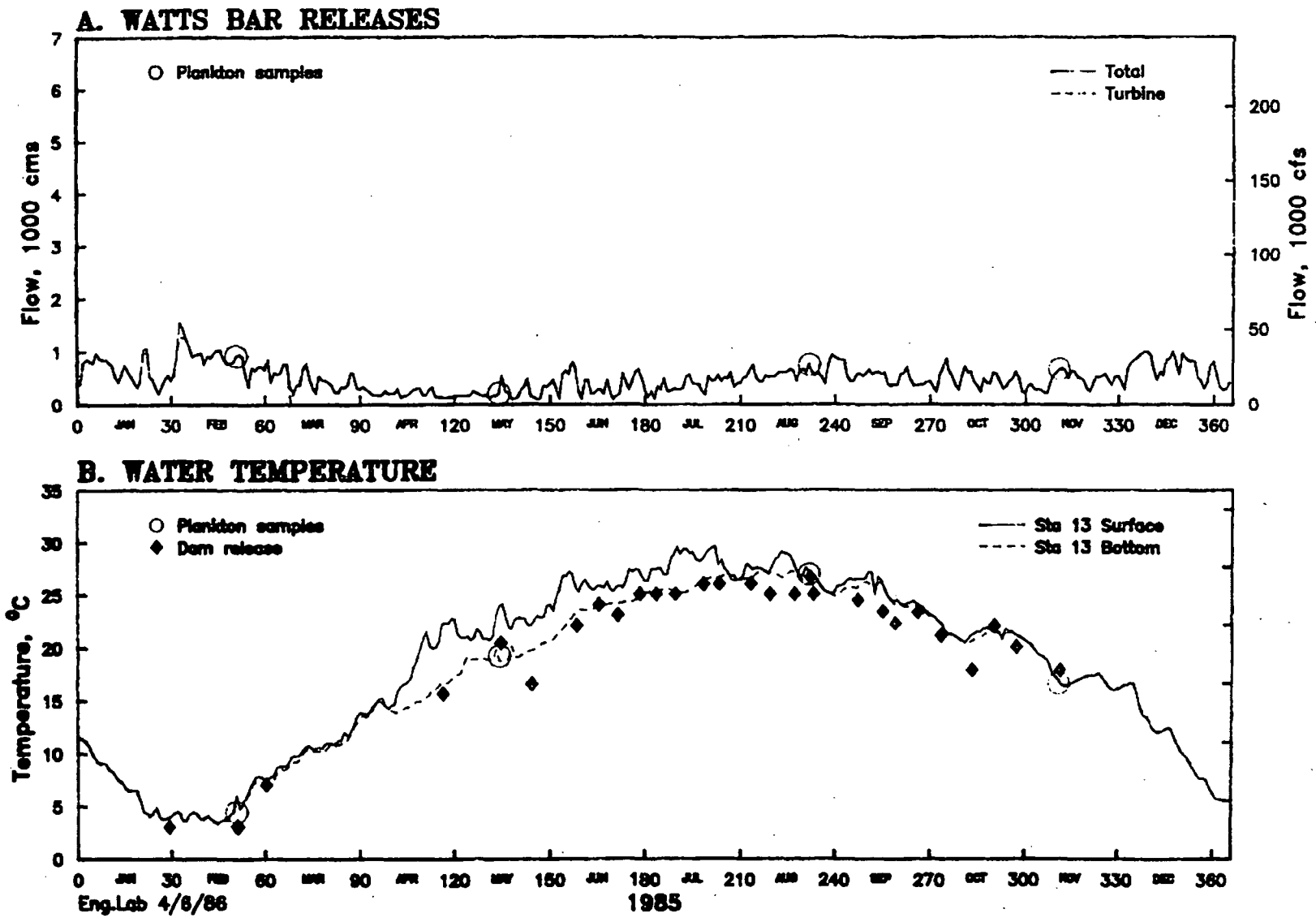


Figure 2.16. Daily Flow and Temperature Patterns for the WBN Aquatic Monitoring Reach, 1985.

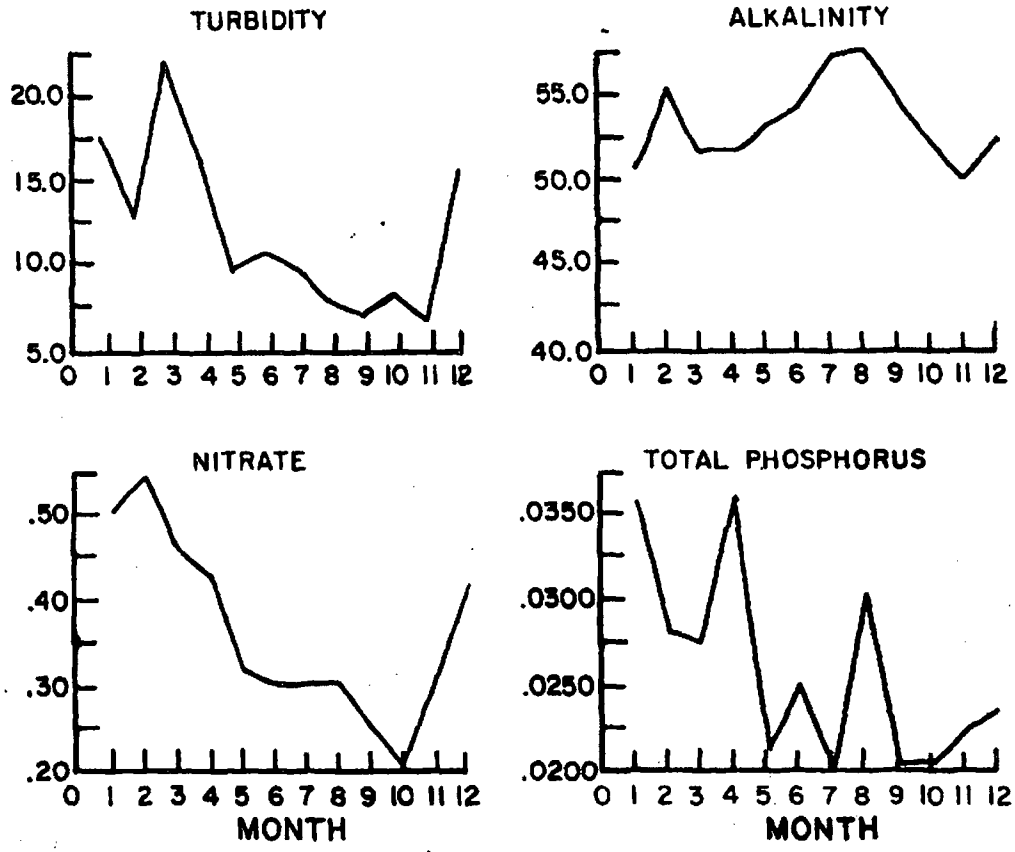


Figure 2-17. Seasonal Water Quality Patterns for Watts Bar Dam Releases.

3.0 OTHER FACTORS POTENTIALLY AFFECTING WATER QUALITY AND BIOLOGICAL CONDITIONS

3.1 Instream Construction

Large-scale monitoring of construction effects was not necessary at WBN, but special monitoring was conducted during dredging operations for the discharge diffuser and removal of the "intake plug." Generally these activities resulted only in short-term, localized perturbations to water quality near the plant. A summary of the monitoring carried out in conjunction with each of these activities follows.

Diffuser Dredging--About 1,200 m^3 of material was removed to install the diffuser line. Originally the expected time required for removal of this small volume of material was three days. Although a much longer period (March 1977-July 1977) was required, the quantity of material removed was the same as the original estimate. The period of diffuser dredging was extended because of a limestone lens in the dredging area and periods of heavy rainfall that raised pool levels.

The presence of the rock, although extending the dredging time, probably resulted in less impact to the aquatic environment. The fractured limestone rock (removed by line drill and shovel) contained smaller quantities of fine particles which could be resuspended in the water column and carried out of the dredge zone. Turbidity was observed <75 m downstream from the dredging operation.

Intake Plug Removal--Removal of the intake plug began August 25, 1977. Riverside dredging resulted in a visible turbidity plume which

extended downstream along the right bank for several hundred meters. A water quality survey was conducted at the peak of dredging activities on October 18, 1977. The survey confirmed that the plume was confined to a narrow portion of the river. Maximum suspended solids concentration and turbidity in this zone did not exceed 29 mg/L and 16 JTU respectively (table 3-1). As expected, these values were higher than those upstream from the dredging operation, but concentrations rapidly receded downstream. Within about 700 m, suspended solids and turbidity levels approached the upstream control levels.

3.2 Facility Discharges

In addition to discharges resulting from assorted water uses at WBN, the principal point-source discharge in this vicinity during the preoperational period was from the Watts Bar Fossil Plant (WBF). As noted in section 2.0, WBF was in operation during the first phase of preoperational monitoirng 1973 to 1979, but operation ceased prior to the second phase, 1982 to 1985. Both WBN and WBF discharges were regulated by NPDES permits. Instream water quality monitoring, conducted as part of the preoperational monitoring program (see section 4.0), provided an additional check of stream conditions relative to these discharges.

3.3 Aquatic Macrophytes

One of the most obvious changes in reservoir condition since the initiation of WBN preoperational monitoring has been the dramatic increase of submersed aquatic macrophytes. Similar increases occurred in other TVA mainstream reservoirs. Although macrophyte colonization has

been limited in the immediate vicinity of WBN, total acreage infested in Chickamauga Reservoir has increased about seven-fold since the mid-1970's. In 1985, 16 percent (5,600 acres) of the total reservoir area was colonized, primarily by exotic species (Eurasian watermilfoil, *Myriophyllum spicatum*; spinyleaf naiad, *Najas minor*; and southern naiad, *Najas quadalupenis*) (Burns et al. 1986). These species have become established in overbank and shallow areas of the reservoir and often create reservoir-use conflicts. Control measures are necessary in areas around recreation and public access sites, lakeshore development, and industrial water intakes. Control activities have entailed an integrated approach using reservoir drawdown and herbicide applications.

Dense aquatic weeds have been implicated in water quality deterioration (temperature and dissolved oxygen) in localized areas, altering fish distribution and standing stocks, and changing flow patterns and silt deposition in reservoirs. Although similar conditions have not occurred in the immediate vicinity of WBN, possible impacts relative to monitoring and evaluation of reservoir-wide conditions are recognized. Various aspects of the impact of aquatic macrophytes have been addressed in the SQN aquatic monitoring program (TVA 1986).

Table 3-1. Water Quality Survey During Dredging from Intake Plug Removal, Watts Bar Nuclear Plant, October 1977.

Location: Tennessee River Mile		Location: % From L. Bank	Depth Meters	Suspended Solids mg/L	Turbidity JTU
528.2	Control Station	95	0.3	7	7.0
			1.5	13	7.3
		50	0.3	9	7.4
			1.5	8	7.8
			5.0	9	6.5
527.95	Dredging Zone	95	0.3	29	16
			1.5	28	16
		80	0.3	7	7.2
			1.5	8	7.2
			5.0	8	7.3
527.8	240 meters below dredging zone	95	0.3	18	9.0
			1.5	25	15
		80	0.3	-	7.1
			1.5	-	7.3
			5.0	-	4.7
527.63	515 meters below dredging zone	95	0.3	17	10
			1.5	21	12
		50	0.3	-	6.4
			1.5	-	5.8
			5.0	-	7.2
527.5	725 meters below dredging zone	95	0.3	15	9.0
			1.5	18	10
		70	0.3	-	6.1
			1.5	-	6.7
			5.0	-	6.8
527.12	1,335 meters below dredging zone	95	0.3	11	8.0
			1.5	13	7.8
		50	0.3	7	6.5
			1.5	9	7.1
			5.0	8	6.0

4.0 INSTREAM WATER QUALITY

The Tennessee River in the vicinity of WBN is presently classified by the State of Tennessee as an "effluent limited" stream, where stream standards are met and there are no significant sources of pollution (Tennessee, 1978). In this classification, stream standards are met through secondary treatment for municipalities and best practicable treatment for industries. The Tennessee River from mile 496.5 (2.9 miles downstream from the mouth of the Hiwassee River in Chickamauga Reservoir) to mile 532.1 (near the Piney River embayment in Watts Bar Reservoir) has been classified as suitable for all water uses--domestic, industrial, fish and aquatic life, recreation, irrigation, livestock watering, wildlife, and navigation (Tennessee, 1983). Water quality criteria and standards for the protection of aquatic life and human health are presented in table 4-1.

The following section summarizes results of the quarterly preoperational instream water quality monitoring program conducted near WBN from August 1973 to November 1977 and May 1982 to February 1986. Data collected during the 1973-77 period have been summarized previously (TVA, 1980b) but are again included as part of this report.

4.1 Materials and Methods

Field--The WBN quarterly preoperational water quality monitoring program is summarized in table 4-2. Horizontal locations at each river mile were selected to coincide with the primary river channel. Where two horizontal locations are given for a particular river mile, both

locations (except for TRM 532.1) are within the main Tennessee River channel. (At TRM 532.1, the two horizontal locations are over original river channels that once were separated by an island. The island is now underwater.) Water quality data were collected quarterly during the August 1973 to November 1977 and May 1982 to February 1986 sampling surveys. Surveys were scheduled as much as possible so that winter collections were made in February, spring collections in May, summer collections in August, and autumn collections in November.

Prior to 1976, in situ full stratum measurements of only temperature and dissolved oxygen (DO) were made at all stations. Full stratum measurements of pH and conductivity in addition to temperature and DO have been made regularly since February 1976.

Since 1976, water quality data (nutrients) were obtained to support assessment of biological data at 7 of the 12 water quality monitoring stations (see figure 5-1). Prior to 1976, only TRM 527.4 was sampled for a comprehensive set of parameters including nutrients. During 1976-77, biological support water quality samples were collected at depths of 1.0, 3.0, and 5.0 m and during 1982-86 at depths of 0.3, 1.0, 3.0, and 5.0 m. These samples were poured from the same subsurface water sample as the replicate phytoplankton samples.

Since August 1973, a more complete set of chemical parameters were determined at TRM 527.4; and starting in February 1984, some of these extra chemical parameters were collected at TRMs 529.5, 528.0, and 518.0.

During the period from August 1973 to February 1986, the stations sampled and parameters measured have changed somewhat. Table 4-2 shows a summary of data collected. Appendix 4-A lists all measured water quality data and provides the most comprehensive list of stations sampled and parameters measured.

Laboratory--Analytical and sample preservation methods currently used for chemical water quality characterizations are shown in appendix 4-B. The referenced laboratory methods are the preferred TVA methods, which are approved by EPA. The Laboratory Branch may occasionally use other EPA-approved laboratory methods. It should be noted that since the initiation of sampling, analytical and preservation techniques have improved and that samples collected earlier in the sampling period may not have been preserved or analyzed by the method listed in appendix 4-B. The methods used, however, were methods approved by EPA at the time of sampling.

Water quality measurements determined in the field were temperature, DO, pH, conductivity, and alkalinity. "Biological support" water quality samples were analyzed for organic nitrogen, ammonia, nitrogen, nitrate plus nitrite nitrogen, total and dissolved phosphorus, and total and dissolved organic carbon. Other chemical and physical measurements included turbidity, 5-day biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nonfiltrable residue (total solids), dissolved residue (total dissolved solids), calcium, magnesium, sodium, potassium, chloride, sulfate, dissolved silica, aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, copper, total and dissolved ferrous iron, lead, lithium, total and dissolved manganese, mercury, nickel, selenium, silver, titanium, and zinc.

Data Analysis--All water quality data were entered into the EPA water quality data STOrage RETrieval (STORET) system and are available from TVA's Data Services Branch. All data reduction and statistical evaluation procedures used standard statistical routines available through the STORET system. Many data inferences and interpretations came from an investigation of simple plots of data over depth or time. Determinations of statistical differences among stations and different sampling periods were made using Duncan's Multiple Range Test in conjunction with an analysis of variance.

4.2 Results and Discussion

The quarterly preoperational data collected from August 1973 to February 1986 are summarized in appendix 4-C. Similar statistics for the same period, but based on the season or quarter, are presented in appendix 4-D. Statistics in appendices 4-C and 4-D combine depth, and thus vertical differences in parameters that may exhibit stratification are not apparent. Therefore, care must be exercised in comparing within and between tables. The raw data used to determine the above described statistics are tabulated in appendix 4-A.

The major factor influencing the water quality of the Tennessee River in the vicinity of WBN (TRM 528) is the flow and quality of releases from Watts Bar Dam. These releases generally inhibit stratification and establishment of a strong thermocline so that the water column is usually well mixed in the main channel. This is especially true for the six river mile stations sampled below Watts Bar Dam (TRMs 529.5 to 496.5). The two stations at TRM 532.1 (above Watts

Bar Dam) both show fairly strong stratification during some months of the year. This stratification is not, however, as strong as that observed in some of TVA's tributary storage reservoirs.

Dissolved Oxygen--While water quality in the vicinity of WBN largely reflects that released from Watts Bar Dam, these releases also obviously reflect the quality of water which flows into Watts Bar Reservoir from upstream dam releases and from the drainage area around Watts Bar, together with the effect of waste discharges, natural reaeration and other factors. With respect to DO, this parameter is affected by the upstream tributary reservoir releases from Cherokee and Douglas. These reservoirs stratify during the summer months (i.e., May through September) and release low DO water which, although reaerated as it travels down to Watts Bar Dam, still has some effect on DO concentrations in the Watts Bar Dam tailwaters. DO concentrations in the Watts Bar Dam tailwaters have been measured on a weekly basis (roughly) since 1960. Therefore, while these data were not specifically part of the WBN preoperational monitoring program, an evaluation of the data collected at the dam from 1973 through 1985 was conducted. These data, having been collected weekly rather than quarterly as were the preoperational data, provide a much more accurate picture of DO concentrations in the vicinity of WBN, especially because the dam is only 2.0 miles upstream from the WBN diffuser (TRM 528).

Table 4-3 summarizes the occurrence of low DO levels (e.g., below the State standard of 5.0 mg/L) at Watts Bar Dam. As shown therein, DO measurements of less than 5.0 mg/L have occurred quite frequently over the past thirteen years as, on the average, the DO was

less than 5.0 in about 37 percent of the measurements made during May through September of 1973-85. Furthermore, DO levels in the Watts Bar tailrace do not appear to be improving in the 1980s because the average percent of DO values less than 5.0 during May through September was about 51 percent during 1980-85, with 1985 being the worst year of all at 81 percent. The year 1985 reflects the effect of the extreme drought which began in June of 1984 and continues in 1986. The lack of rainfall resulted in lower than normal flows during 1985 and the resultant longer detention times caused the water impounded in the reservoir to become more oxygen-deficient than usual.

In summary, DO concentrations below 5.0 mg/L are fairly common during the summer months in the Watts Bar Dam tailrace, and are more frequent during low flow years such as 1985. Discussion of the data collected specifically for the WBN preoperational monitoring program is presented below.

February--February DO profiles showed little or no surface to bottom variation with all stations indicating well mixed conditions. With the exception of two of the river mile stations sampled during 1974, all DO measurements made on the Tennessee River during the preoperational period fall between 9.0 and 14.0 mg/L. The atypical DO observed on February 12, 1974 occurred at TRM 532.1 (37 and 85 percent horizontal locations) and at TRM 496.5 (57 percent horizontal location). DO values over these three profiles ranged from 2.8 to 10.0 mg/L. The reason for these low DO values is unknown as DO concentrations on this day in the dam tailrace and other locations sampled were in the range of 10.0 to 11.0 mg/L. The mean DO concentration at all stations over all years was 11.6 mg/L (306 observations).

May--May DO profiles at the Chickamauga Reservoir stations showed surface to bottom variations from year to year and over the stations downstream from Watts Bar Dam. Most of these DO values fall within the 7.0 to 9.0 mg/L range; however, occasional values less than the 5.0 mg/L standard were observed. These were generally at depths greater than 5 feet. During 1975, an exception, most profiles showed DO values in the 6.0 to 7.8 mg/L range. DO profiles measured at TRM 532.1 (Watts Bar Reservoir) showed 2.0 to 5.0 mg/L variations from surface to the bottom (about 20-m). Surface DO was usually within the 9.0 to 11.0 mg/L range and bottom DO within the 5.5 to 7.5 range. There was seldom any strong oxycline with DO declining at one rate over the entire depth.

August--August DO profiles at all stations below Watts Bar Dam usually showed less than 1.0 mg/L in top to bottom differences and most DO measurements were found to be between 3.0 and 6.0 mg/L. Consistent with the Watts Bar Dam tailrace DO data discussed above, DO concentrations below 5.0 mg/L were common during the August surveys. An average of 46 percent of the August measurements at the 5-foot depth were less than 5.0 mg/L (see table 4-4). The largest variation in top to bottom DO during this study period was found in August at TRM 532.1 in Watts Bar Reservoir. Typically, surface DO was between 8.0 and 12.0 mg/L and bottom DO between 1.0 and 4.0 mg/L with the oxycline in the 3.0 to 7.0-m zone. An exception was 1977 when surface DO at both TRM 532.1 stations was near 5.0 mg/L; the bottom DO was near 1.0 mg/L, lower than other years' observations. Consequently, DO at the Chickamauga Reservoir stations were also lower in 1977.

November--Similar to February, DO profiles in November showed little surface to bottom differences (usually less than 1.0 mg/L) at any station other than at TRM 532.1. Most DO values were between 7.0 and 10.0 mg/L. During 1977, the lowest November, DO values ranged from 6.0 to 7.0 mg/L.

Alkalinity and pH--The State of Tennessee water quality criteria specify that pH shall be within a range of 6.0 to 9.0 for waters used for domestic raw water supply, industrial water supply, recreation, irrigation, livestock watering, and wildlife (Tennessee, 1982). The criterion used for fish and aquatic life is within a range of 6.5 to 8.5 (Tennessee, 1982). Values for pH outside of the less stringent criteria were observed 14 times out of a total of 1,117 pH observations during the preoperational monitoring period. All 14 criteria exceedances occurred during August 1983 at TRM 532.1. In 12 of the 14 instances, the upper pH limit was exceeded in the top five meters. These high pH values were probably related to phytoplankton production in the surface waters. The remaining two exceedances were questionable measurements of 3.0 and 4.6 near the bottom at this same station.

Total alkalinity measurements (4,805) during the preoperational monitoring period ranged from 26 to 81 mg/L as $CaCO_3$ with a mean of 56.2 mg/L, indicating a moderate buffering capacity.

February--Values of pH observed during February ranged from 6.3 to 8.0. Other than one value of 6.3 observed near the bottom at TRM 496.5 (57 percent horizontal location), all values were within the accepted range (6.5 to 8.5) for fish and aquatic life. Most pH profiles, including those at TRM 532.1, showed less than 0.2 pH unit differences

from surface to bottom. Total alkalinity measurements during February surveys ranged from 44 to 64 mg/L as $CaCO_3$ and averaged 54.6 mg/L. The mean alkalinity values for each station (all depths and February's combined) were statistically (0.05 level) indistinguishable from each other with most variation being observed between years.

May--All pH observations, except for some near-surface measurements made in 1982 at TRM 532.1, fell within the 6.5 to 8.5 range. Most pH profiles measured below Watts Bar Dam showed differences from surface to bottom of less than 0.2 pH units. Profiles of pH at TRM 532.1 (Watts Bar Reservoir) showed a consistent surface to bottom variation often more than 1.0 pH unit difference with higher values near the surface (probably associated with phytoplankton productivity). Alkalinity ranged from 26 to 70 mg/L as $CaCO_3$ with a mean of 54.7 mg/L. Surface to bottom variations were relatively small, ranging from 0 to 19 mg/L and averaging 3.4 mg/L. The maximum range occurred at TRM 506.6 in 1977.

August--Except for the aforementioned August 1983 pH profiles measured at TRM 532.1, all values were between 6.2 and 8.5 pH units. Similar to observations in April, profiles downstream from Watts Bar Dam showed little surface to bottom differences with most less than 0.2 pH units. Profiles in Watts Bar Reservoir typically exhibited surface to bottom variations near 1.0 pH unit. Except for 1983, typical profiles had pH values near 8.0 at the surface and 7.0 at 20 m. August alkalinity values ranged from 35 to 81 mg/L as $CaCO_3$ and averaged 58.8 mg/L (90 percent of the observations fell within the range of 47 to 73 mg/L).

November--Values for pH ranged from 6.3 to 9.1 pH units. Excluding these two extreme values, the remaining 299 values ranged from 7.0 to 8.3. Most profiles measured, including those at TRM 532.1 in Watts Bar Reservoir, exhibited surface to bottom variations of 0.2 pH units or less. Profiles of alkalinity at any one river mile within any one year were similar to other profiles. Again, surface to bottom variations were small. Overall, November alkalinities ranged from 39 to 69 mg/L as $CaCO_3$ and averaged 56.8 mg/L.

Turbidity--Seasonal light conditions are governed by ambient solar radiation, water transparency, and vertical mixing. Turbidity was low (less than 10 Jackson turbidity units [JTU]) for all measurements in 1976, but all other years showed one or more winter/spring values greater than 10 JTU and usually above 20 JTU. The maximum turbidity was observed in March of 1973 with a value of 60 JTU.

February--Turbidity in February at the seven Tennessee River stations (except for TRM 529.9) ranged from 4.1 to 20 JTU and averaged 8.3 JTU. This corresponds to a one-percent light penetration depth range of 7.3 to 1.5 m and an average of 3.67 m. The February mean turbidity for any station was not significantly different from any other February station mean.

May--Slightly less than February, May turbidity values ranged from 3.2 to 15 JTU and averaged 7.7 JTU. This corresponds to a one-percent light penetration depth range of 9.4 to 2.0 m and an average of 3.9 m. These values were based primarily on measurements at TRM 529.4.

August--Becoming more transparent, August turbidity ranged from 3.2 to 10 JTU and averaged 7.0 JTU. This corresponds to a one-percent light penetration depth of 9.4 to 3.0 m and an average of 4.3 m. Again the majority of measurements were made at TRM 527.4, but the few measurements at TRM 496.5 did not differ significantly. Two observations at TRM 518.0 averaged 10 JTU, which was statistically (significant at 0.05 level) different from the 6.0 JTU mean at TRM 496.5 and the 6.8 JTU mean at TRM 527.4.

November--November observations of turbidity were the lowest of the four seasons, ranging from 2.2 to 10 JTU and averaging 6.2 JTU. This corresponds to a one-percent light penetration depth of 13.6 to 3 m and an average of 4.8 m. All but one of twenty-five turbidity measurements made in November were at TRM 527.4.

Nutrients--Nutrients analyzed during the preoperational period included organic, ammonia, and nitrate plus nitrite forms of nitrogen, total and dissolved phosphorus, and total organic carbon (TOC).

Over all years and all stations the following values were observed.

	Mean	SD	Minimum	Maximum
Org-N, mg/L	0.174	0.126	0.01	1.65
NH_x-N, mg/L	0.055	0.046	0.01	0.43
NO_x-N, mg/L	0.338	0.256	0.01	3.50
Total P, mg/L	0.026	0.010	0.01	0.08
Dissolved P, mg/L	0.013	0.006	0.01	0.07
TOC, mg/L	2.6	1.2	1	15

Comparing these values to the applicable standards listed in table 4-1, all nitrate (NO_3) values were well below the 10 mg/L

drinking water standard. Also, all ammonia (NH_3) values were below the aquatic life criterion.

February--Observed means and ranges for the various nutrients were as follows.

	Mean	SD	Minimum	Maximum
Org-N, mg/L	0.158	0.106	0.01	1.53
NH_x-N, mg/L	0.041	0.030	0.01	0.12
NO_x-N, mg/L	0.476	0.100	0.38	1.30
Total P, mg/L	0.033	0.013	0.01	0.08
Dissolved P, mg/L	0.017	0.009	0.01	0.07
TOC, mg/L	2.32	0.54	1.4	4.5

Organic nitrogen values in 1983 at all stations were generally greater than those observed in other years with most values greater than 0.2 mg/L. Also, when combining organic nitrogen data over years, a trend was observed by river mile with downstream stations showing slightly lower values than those upstream. The following presents the results of Duncan's Multiple Range Test at the 0.05 level. River miles connected by a horizontal line were found to have mean organic nitrogen values statistically indistinguishable from each other. All three stations located above the WBN discharge point were higher than any of the four downstream stations.

River mile	528.0[a]	532.1[a]	529.5[a]	527.4	496.5	518.0	506.6
Mean Org-N (mg/L)	0.223[a]	0.192[a]	0.186[a]	0.153	0.136	0.129	0.103

a. Upstream from WBN discharge.

Ammonia nitrogen showed an opposite trend, with all three upstream stations averaging less than the averages for the four downstream stations. These differences were, however, statistically indistinguishable at the 0.05 level. The maximum mean was found at TRM 527.4 with 0.480 mg/L and the minimum 0.6 miles upstream at TRM 528.0 with 0.227 mg/L.

Nitrate plus nitrite means at the various stations only showed statistically significant (0.05 level) differences when comparing TRM 527.4 (mean = 0.533 mg/L) to either station TRM 528.0 (0.441 mg/L) or TRM 496.5 (0.426 mg/L). All other combinations of stations were indistinguishable from each other and there were no trends with river mile.

Total phosphorus was slightly higher in 1984 (most values between 0.04 and 0.08 mg/L) than previous values which were in the 0.01 to 0.04 mg/L range. Means at individual stations were statistically indistinguishable from each other although all three stations above WBN had greater mean values than the four downstream stations.

Dissolved phosphorus over time and by station remained quite consistent with all values except one ranging from less than 0.01 to 0.03 mg/L. The maximum value of 0.07 mg/L was found at the surface of TRM 532.1, 37-percent horizontal location in 1984.

TOC values were on an average the lowest in February and were consistent in the seven stations and over the different years sampled.

May--Observed May means and ranges for the various nutrients were as follows:

	Mean	SD	Minimum	Maximum
Org-N, mg/L	0.193	0.137	0.04	1.65
NH_x-N, mg/L	0.070	0.038	0.01	0.28
NO_x-N, mg/L	0.279	0.086	0.02	0.66
Total P, mg/L	0.022	0.008	0.01	0.04
Dissolved P, mg/L	0.011	0.003	0.01	0.02
TOC, mg/L	2.57	0.88	1.1	5.4

Organic nitrogen values observed in 1982 were higher than those in other years. Values observed in 1982 ranged from 0.30 to 1.65 mg/L while those in other years ranged from 0.04 to 0.30 mg/L. There was also little difference by stations except for the mean at TRM 532.1 (0.280 mg/L) and those at TRM 527.4 (0.158 mg/L) and TRM 496.5 (0.145 mg/L). All other station means fell between these extremes and were statistically indistinguishable.

Ammonia nitrogen values in 1982 were also high with five values exceeding 0.13 mg/L, the highest value in other years. Also, the station in Watts Bar Reservoir (TRM 532.1) averaged 0.0329 mg/L and was significantly lower (0.05 level) than any other station in 1982. All six stations were statistically indistinguishable with means ranging from 0.588 mg/L at TRM 496.5 to 0.085 mg/L at TRM 528.0.

Nitrate plus nitrite nitrogen remained relatively constant over all years and all stations with most observations between 0.1 and 0.4 mg/L. Only 2 of 117 May observations were greater than 0.45 mg/L with the maximum of these at 0.66 mg/L.

Total phosphorus showed no significant differences over the seven stations. The range of values was 0.01 to 0.04 mg/L with the laboratory reporting data to the nearest 0.01 mg/L.

Dissolved phosphorus ranged from 0.01 to 0.02 mg/L and showed no significant differences over the seven stations. Again the laboratory only reports data to the nearest 0.01 mg/L with 0.01 mg/L as the lower detection limit.

TOC showed no significant differences over the seven stations or over the various years data were collected.

August--Observed means and ranges for the various nutrients were as follows:

	Mean	SD	Minimum	Maximum
Org-N, mg/L	0.205	0.158	0.05	1.40
NH_x-N, mg/L	0.049	0.049	0.01	0.43
NO_x-N, mg/L	0.306	0.403	0.01	3.50
Total P, mg/L	0.022	0.007	0.01	0.05
Dissolved P, mg/L	0.011	0.003	0.01	0.02
TOC, mg/L	2.87	1.50	1.0	14.0

Organic nitrogen values in 1977 and 1982 were generally higher than those in other years. Excluding these years, organic nitrogen did not exceed 0.32 mg/L (19 of the 1977 and 1982 observations exceeded this value). No significant (0.05 level) differences between stations means were observed during the preoperational period.

Ammonia nitrogen, for the most part, was at or below 0.06 mg/L with only nine observations greater than 0.06 mg/L. Two of these in 1977, were at or near the maximum value of 0.43 mg/L. Comparison among stations showed that TRM 532.1 had a mean of 0.017 mg/L, which was significantly lower than that at TRMs 496.5 or 527.4. All other combinations of mean values were statistically indistinguishable.

The maximum ammonia concentration (0.43 mg/L) during preoperational monitoring was observed in August 1977 at TRM 496.5. However, it occurred at a pH of 7.1 and temperature of 25.5°C, and therefore was well below the aquatic life criterion, which would be 13.5 mg/L (as N) at this pH and temperature. (All elevated NH_3 concentrations occurred at pH and temperature levels such that the aquatic life criterion was easily met.)

Nitrate plus nitrite nitrogen values were all less than 0.05 mg/L except for three at TRM 527.4 made in 1973 and 1983. Also, the station with the lowest mean concentration was TRM 532.1 (mean = 0.099 mg/L) which had a significantly lower mean than the TRM 527.4 mean (mean = 0.476). All other combinations of stations were indistinguishable at the 0.05 level.

Total phosphorus in August was usually 0.03 mg/L or less. Only 3 of 75 measurements were greater than this and these three were less than or equal to 0.05 mg/L. There was not statistically significant (0.05 level) difference over stations with station means ranging from 0.20 to 0.024 mg/L.

All dissolved phosphorus observations in August were reported as 0.02, 0.01, or less than 0.01 mg/L and no statistically significant (0.05 level) differences were observed over stations.

TOC in August generally was less than 4.5 mg/L. Two observations in 1977 exceeded 10 mg/L (14 mg/L at TRM 506.6, 70-percent horizontal location at 3 m and 11 mg/L at TRM 496.5, 57-percent horizontal location at 1 m). Only three other observations exceeded 45 mg/L and these all occurred at the 3 m depth in 1982. No statistically

significant (0.05 level) differences were observed over the stations sampled.

November--Observed November means and ranges for the various nutrients were as follows:

	Mean	SD	Minimum	Maximum
Org-N, mg/L	0.135	0.069	0.03	0.34
NH_x-N, mg/L	0.062	0.055	0.01	0.35
NO_x-N, mg/L	0.298	0.057	0.18	0.44
Total P, mg/L	0.027	0.007	0.01	0.05
Dissolved P, mg/L	0.012	0.005	0.01	0.03
TOC, mg/L	2.67	1.52	1.0	15.0

Organic nitrogen in November varied over a smaller range of values than in any other month and no statistically significant (0.05 level) differences were observed among stations.

Ammonia nitrogen values observed in November were generally less than 0.12 mg/L. Only nine values, all observed in 1977, exceeded this value. No statistically significant (0.05 level) differences were observed among the seven sampled stations.

Nitrate plus nitrite nitrogen values observed in November, similar to organic nitrogen, varied over the smallest range than any other month and no statistically significant (0.05 level) differences were observed among stations.

Total phosphorus observations in November were not too different from those observed at other times. Also, there were no statistically significant (0.05 level) differences among stations.

Dissolved phosphorus observations in November were 0.2 mg/L or less except for three observations (two in 1983 and one in 1976). These three were all 0.3 mg/L and were found over the range of 0.3- to 5-m depths. Station means for November ranged from 0.010 (TRM 496.5) to 0.163 mg/L (TRM 518.0). Stations at TRMs 518.0 and 506.6 were statistically different (0.05 level) from those at TRMs 528.0, 529.5, and 496.5. All other combinations of stations were indistinguishable (at the 0.5 level). Again it should be noted that the minimum detection limit was 0.01 mg/L with data reported to the nearest 0.01 mg/L, so observed statistical differences may be partially due to refinement of the laboratory analysis.

TOC observations in November usually ranged from 1 to 4 mg/L. Four values, all observed in 1982, were at or above 4 mg/L with one of them reaching 15 mg/L, the maximum value observed in any month during the WBN preoperational surveys. No statistically significant (0.05 level) differences were observed among stations.

Other Parameters--Statistics for minerals, metals, and other water quality parameters measured during the preoperational period are provided in appendices 4-B and 4-C. The range and mean values of minerals and metals determinations are summarized in table 4-5.

Table 4-1 shows standards and criteria for some minerals and metals. Standards and criteria for iron and manganese were exceeded several times in both upstream and downstream locations. Forty-two percent of the downstream measurements for iron exceeded the Secondary Drinking Water Standard (300 µg/L) while 67 percent of the upstream

measurements exceeded the same standard. Similarly, 55 percent of the downstream manganese observations exceeded 50 μg/L as did 53 percent of the upstream observations. Three observations at TRM 529.9 or 3 percent of the upstream iron observations exceeded the 1000 μg/L criterion for the protection of aquatic life. One observation at TRM 527.4, or 1 percent of the downstream observations, exceeded this same criterion. These higher concentrations of iron and manganese, which were probably associated with oxidized forms (i.e., particulates), can be easily removed by conventional water treatment processes.

Measured concentrations of copper (Cu) have generally exceeded EPA's 1985 average and maximum criteria for protection of aquatic life at both upstream and downstream locations. Over half of all Cu observations had less than detectable amounts with these lower limits being either 5 or 10 μg/L depending on the analysis. Assuming that all values reported as less than 5 or 10 μg/L are zero, average values for Cu still remain higher than the above mentioned criteria. No Cu measurements exceeded the 1000 μg/L 1977 National Drinking Water Standard.

Table 4-1. Water Quality Criteria and Standards for Parameters Monitored During WBN Preoperational Monitoring

Parameter[a]	Aquatic Life Criteria		Human Health Criteria and Standards
	Average	Maximum	
pH (standard units)	6.0-9.0[b]	6.5-8.5[c]	6.5-8.5[d]
Nitrate (mg/L as N)	-	-	10[e]
Ammonia nitrogen (mg/L as N)	0.07[f,g]	0.48[f,g]	-
Chloride (mg/L)	-	-	250[d]
Sulfate (mg/L)	-	-	250[d]
Dissolved solids (mg/L)	-	-	500[d]
Dissolved oxygen (mg/L)	5.0[h]	-	-
Arsenic	190[f]	360[f]	0.022,[i,j] 50[e]
Barium	NT[k]	NT[k]	1000[e]
Beryllium	5.3[i]	130[i]	68[i,j,l]
Cadmium	0.86[f]	2.6[f]	10[e,i]
Chromium	155[f,m,n]	1300[f,m,n]	50[e,i]
Copper	8.7[f,m]	12.7[f,m]	1000[d,i]
Iron	-	1000[o]	300[d,o]
Lead	2.2[f,m]	53[f,m]	50[e,i]
Manganese	-	1000[p]	50[d,o]
Mercury	0.012[f]	2.4[f]	0.114, 2[i,e]
Nickel	73[i,m]	1400[i,m]	13.4[i]
Selenium	35[i]	260[i]	10[e,i]
Silver	0.12[i]	2.2[i,m]	50[e,i]
Zinc	47[i]	240[i,m]	5000[d,i]

a. Units are µg/L unless otherwise noted.

b. Average not applicable to pH. Range given is State of Tennessee (1983) criteria for domestic raw water supply, industrial water supply, recreation, irrigation, livestock watering, and wildlife.

c. Tennessee (1983) criteria for protection of fish and aquatic life.

d. EPA National Secondary Drinking Water Standards (40 CFR Part 143).

e. EPA National Primary Drinking Water Standards (40 CFR Part 141).

f. EPA 1985 Water Quality Criteria (50 FR 30784; July 29, 1985).

Table 4-1 (Continued)

g. NH_3 as N at pH 9.0, and temperature of 30°C with sensitive coldwater species present; greater concentrations are allowable at lower pH and temperature and when coldwater fish are absent. See reference cited above in footnote "f" for further details.

h. DO criterion is the minimum standard established by State of Tennessee for the protection of fish and aquatic life.

i. EPA 1980 water quality criteria (45 FR 79318; November 28, 1980).

j. Value cited is 10^{-5} risk level, i.e., this level is projected to result in one additional cancer case per 100,000 population. Actual criterion for "maximum protection" is zero. See 45 FR 79318 for further details.

k. Not sufficiently toxic to aquatic life to warrant criteria.

l. criterion as corrected at 46 FR 40919; August 23, 1981.

m. Calculated for 70 mg/L hardness.

n. For Cr^{+3}, the species most commonly occurring in natural waters.

o. EPA (1976) Quality Criteria for Water ("Red Book").

p. McKee and Wolf (1983), Water Quality Criteria, California Water Quality Control Board.

Table 4-2. Summary of Watts Bar Nuclear Plant Nonradiological Water Quality Monitoring Program - Quarterly Sampling in Chickamauga and Watts Bar Reservoirs, 1973-86*

Tennessee River Mile	Horizontal† Location (%)	Sample Collection Depths (m)	Physical-Chemical Measurements	Period of Record
532.1	37	various	*In situ* monitor‡	Aug 73-Nov 77, May 82-Feb 86
	37	0.1, 1.0, 3.0, 5.0	Nutrients§	Feb 76-Nov 77, May 82-Feb 86
	85	various	*In situ* monitor	Aug 73-Nov 77, May 82-Feb 86
529.9	90	various	*In situ* monitor	Aug 73-Nov 77, May 84-Feb 86
	90	0.1 or 1.0	Nutrients	Aug 73-Nov 77, May 84-Feb 86
	90	0.1 or 1.0	Minerals¶	Aug 73-Nov 77, May 82
	90	0.1 or 1.0	Metals#	Aug 73-Nov 77, May 82
529.5	20	various	*In situ* monitor	Feb 76-Nov 77, May 82-Feb 86
	20	0.1, 1.0, 3.0, 5.0	Nutrients	Feb 76-Nov 77, May 82-Feb 86
	20	0.1, 1.0, 3.0, 5.0	Minerals	Feb 84-Feb 86
	20	0.1, 1.0, 3.0, 5.0	Metals	Feb 84-Feb 86
	75	various	*In situ* monitor	Feb 84-Feb 86
	75	0.1 near bottom	Nutrients	Feb 84-Feb 86
	75	0.1 near bottom	Minerals	Feb 84-Feb 86
	75	0.1 near bottom	Metals	Feb 84-Feb 86
528.0	75	various	*In situ* monitor	May 76-May 77, May 82-Feb 86
	75	0.1, 1.0, 3.0, 5.0	Nutrients	May 76-May 77, May 82-Feb 86
	75	0.1 near bottom	Minerals	Feb 84-Feb 86
	75	0.1 near bottom	Metals	Feb 84-Feb 86
527.4	33	various	*In situ* monitor	Aug 73-Nov 77, May 82-Feb 86
	33	0.1 near bottom	Nutrients	Aug 73-Nov 77, May 82-Feb 86
	33	0.1 near bottom	Minerals	Aug 73-Nov 77, May 82-Feb 86
	33	0.1 near bottom	Metals	Aug 73-Nov 77, May 82-Feb 86
	67	various	*In situ* monitor	Aug 73-Nov 77, May 82-Feb 86
	67	0.1 near bottom	Nutrients	Aug 73-Nov 75
	67	0.1, 1.0, 3.0, 5.0	Nutrients	Feb 76-Nov 77, May 82-Feb 86
	67	0.1 near bottom	Minerals	Aug 73-Nov 77, May 82-Feb 86
	67	0.1 near bottom	Metals	Aug 73-Nov 77, May 82-Feb 86
518.0	33	various	*In situ* monitor	Aug 73-Nov 77, May 82-Feb 86
	67	various	*In situ* monitor	Aug 73-Nov 77, May 82-Feb 86
	67	0.1, 1.0, 3.0, 5.0	Nutrients	Feb 76-Nov 77, May 82-Feb 86
	67	0.1 near bottom	Minerals	Feb 84-Feb 86
	67	0.1 near bottom	Metals	Feb 84-Feb 86

Table 4-2 (Continued)

Tennessee River Mile	Horizontal† Location (%)	Sample Collection Depths (m)	Physical-Chemical Measurements	Period of Record
506.6	25	various	*in situ* monitor	Aug 73–Nov 77, May 82–Feb 86
	70	various	*in situ* monitor	Aug 73–Nov 77, May 82–Feb 86
	70	0.1, 1.0, 3.0, 5.0	Nutrients	Feb 76–Nov 77, May 82–Feb 86
496.5	30	various	*in situ* monitor	Aug 73–Nov 75
	57	various	*in situ* monitor	Aug 73–Nov 77, May 82–Feb 86
	57	0.1, 1.0, 3.0, 5.0	Nutrients	Feb 76–Nov 77, May 82–Feb 86

*February, May, August, November.

†Percent distance from left bank looking downstream.

‡Profiles of temperature and dissolved oxygen (DO) prior to 1976 and *in situ* profiles of temperature, DO, conductivity, and pH since.

§Nutrients (alkalinity, organic nitrogen, ammonia nitrogen, nitrite plus nitrate nitrogen, phosphorus, total organic carbon.

¶Minerals (sodium, chloride, sulfate, calcium, magnesium, potassium, silica)

#Metals (iron, manganese, arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, silver, zinc, aluminum, selenium, mercury.

Table 4-3. Analysis of Dissolved Oxygen (DO) at Watts Bar Dam (TRM 529.9) During 1973-1985 (All Units are mg/L)

Year	Number of DO Values in the Range of: 2.0-2.9*	3.0-3.9	4.0-4.9	≤5.0	Number of DO Values Total	May-Sep†	Percent of May-Sep DO Values ≤5.0
73	0	0	5	5	57	23	21.7
74	0	0	0	0	58	24	0
75	0	1	3	4	56	24	16.7
76	0	1	1	2	58	26	7.7
77	1	5	11	17	58	25	68.0
78	0	4	12	16	54	25	64.0
79	0	0	0	0	52	22	0
80	2	5	2	9	48	19	47.4
81	1	4	5	10	47	21	47.6
82	3	10	10	23	67	39	59.0
83	1	0	6	7	49	18	38.9
84	0	0	2	2	35	16	12.5
85	3	7	7	17	31	21	81.0
Total	11	37	64	112	670	303	37.0‡

*No DO values <2.0 mg/L were observed during 1973-85.

†All DO values <5.0 mg/L were observed during May through September.

‡Average percent of May through September DO values ≤5.0 mg/L)

Table 4-4. Analysis of Low DO Concentrations in the Vicinity of Watts Bar Nuclear Plant During 1973-85.

Tennessee River Mile	Number of DO values less than 5.0 mg/L at 5-ft depth	Total number of 5-ft depth values during summer months*	Percent of total that were <5.0 mg/L at 5-ft depth
529.5	4	6	67
528.0	3	6	50
527.4	4	9	44
518.0	5	9	56
506.6	5	9	56
496.5	2	11	18
Total	23	50	46

*"Summer months" = August for most of the quarterly surveys. No DO values less than 5.0 mg/L at 5-ft depth were observed in any months other than August.

Table 4-5. Range and Means of Minerals and Metals Measured on Watts Bar Preoperational Surveys (August 1973-November 1977, May 1982 - February 1986) - All Stations.

	n	x	SD	Minimum	Maximum
Calcium (mg/L)	270	20.8	4.1	8	40
Magnesium (mg/L)	270	4.94	0.90	2.3	8.7
Sodium (mg/L)	271	5.97	3.12	1.6	50
Potassium (mg/L)	271	1.41	0.23	0.90	2.2
Chloride (mg/L)	266	6.58	2.49	3	35
Sulfate (mg/L)	259	13.6	2.90	3	21
Silica (mg/L)	53	5.34	0.92	4.1	7.5
Iron (total)	277	346	344	10	4200
Iron (dissolved)	242	42.9	37.5	10	230
Fluoride (mg/L)	93	0.085	0.018	0.04	0.10
Arsenic	250	2.77	2.15	1.0	11
Barium	247	62.6	39.9	10	200
Beryllium	246	5.36	4.50	1.0	10
Boron	233	87.0	141.8	6	1000
Cadmium	246	0.711	1.108	0.10	13
Chromium	249	3.34	3.12	1.0	39
Cobalt	4	5	0	5	5
Copper	249	24.2	63.3	5	680
Lead	242	7.67	11.4	1.0	130
Manganese (total)	271	62.9	30.1	14	180
Manganese (dissolved)	110	19.6	17.4	10	90
Nickel	249	34.0	100.6	1.0	1200
Silver	247	8.02	3.95	0.20	10
Zinc	249	27.3	106.8	1.0	1600
Aluminum	247	347	351	50	2300
Selenium	250	1.38	0.86	1.0	10
Mercury	250	0.224	0.154	0.2	1.6

*Units are µg/L unless otherwise noted.

5.0 PLANKTON

Discharges from WBN may affect plankton in Chickamauga Reservoir. Preoperational sampling was conducted to describe natural variability associated with phytoplankton and zooplankton communities in the reservoir, and to document biologic trends occurring prior to operation of WBN. These preoperational data serve as the baseline to evaluate effects from operation of WBN.

5.1 Materials and Methods

Field--Phytoplankton monitoring during the preoperational period included estimates of extractable chlorophyll concentration, primary productivity (by C^{14} uptake), and organism density. Zooplankton monitoring evaluated organism density. Phytoplankton and zooplankton samples were collected quarterly at seven WBN stations from February 1973 through November 1977 and from May 1982 through November 1985. From upstream to downstream these stations were: TRM 532.1 (Watts Bar Reservoir forebay); TRM 529.5 (directly downstream of Watts Bar Dam); TRM 528.0 (at the intake to WBN); TRM 527.4 (directly downstream of the WBN submerged diffuser); TRM 518.0; TRM 506.6; and TRM 496.5.

In addition to data from WBN sample sites, some analyses used abundance data from stations associated with Sequoyah Nuclear Plant located at TRM 484.5 on Chickamauga Reservoir. Prior to 1985, three SQN sites (TRM 490.5, TRM 483.4, and TRM 478.2) were regularly sampled. In July 1985 two additional stations were incorporated into the SQN sampling scheme. These were at TRM 484.5 and TRM 472.8 (figure 5-1).

Phytoplankton samples were collected from mid-channel with an eight liter Van Dorn bottle at 0.3, 1, 3, and 5 m depths. Zooplankton samples were collected using a 0.5 m diameter plankton net fitted with #20 mesh (80 μm) nylon bolting cloth as described by Dycus and Wade (1977). During 1982-1985 phytoplankton and zooplankton samples were collected in triplicate, with phytoplankton preserved in M_3 (Meyer, 1971) and zooplankton in 10 percent Formalin. From 1973-1977 replicate phytoplankton samples were not collected and samples were preserved with 10 percent Formalin; however, zooplankton samples were collected in duplicate as described above.

From 1982-1985 triplicate chlorophyll samples were dosed with a magnesium carbonate suspension[1] and then filtered through 0.45 μm glass fiber filters. The filters were placed in darkened vials containing 5.0 ml of 90 percent buffered acetone and transported to the Laboratory Branch (LB) on dry ice. Chlorophyll analysis methods changed during the earlier years of the study, however the above procedures have been standardized and will be used during operational studies at WBN.

During the period 1982-1985, duplicate primary productivity samples from each depth (0.3, 1, 3, and 5 m) were inoculated with 1 ml (approximately 2 μCi) of C^{14}-labeled $NaHCO_3$ and incubated at the depth and station collected. Dark bottles to correct for non-photosynthetic carbon uptake were incubated with the light bottles at 0.3 m and 5 m depths. An attempt was made to incubate the samples for

1. One milliliter of $MgCO_3$ suspension was added to each quart cubitainer at the time of collection. The $MgCO_3$ suspension was prepared by adding 1.0g of $MgCO_3$ to 100 ml deionized water.

three to four hours around solar noon but field conditions often necessitated deviations from this routine. The actual length of incubation and period within the solar day were noted on field sheets so that the appropriate adjustments could be made in the productivity calculations. After incubation the samples were filtered on 0.45 μm pore size membrane filters. The filters were rinsed with 0.1N HCl, placed in scintillation vials, and transported to the Radiation Laboratory for analysis. During the 1973-1977 monitoring period, primary productivity samples from the various stations were all transported to TRM 532.1 (Watts Bar Reservoir forebay) for incubation at the appropriate collection depth. After incubation, the 1973-1977 samples were injected with 1 ml of 10 percent formalin to halt metabolism until the samples could be filtered. After filtration, the 0.45 μm pore size membrane filters were glued to planchets, placed in dessicators in a light-excluding box, and shipped to the Radiation Laboratory for analysis.

A portable pyroheliometer was used to record solar radiation from sunrise to sunset on days of primary productivity studies. On occasions when the pyroheliometer did not function properly, solar radiation data were retrieved from the Watts Bar meteorologic station. From 1982 to 1985 light penetration was measured with a Secchi disc and/or a submarine photometer.

Laboratory--Algal enumeration samples were mixed and a 15 ml aliquot allowed to settle in a settling chamber for a minimum of 12 hours. The algae were enumerated at the generic level using an inverted microscope. From 1973 to 1977, filamentous forms such as

Lyngbya, Oscillatoria, and Melosira were quantified for enumeration by dividing the filament length in microns by a factor of 100 (e.g., 2500 µm reported as 25, 250 µm reported as 3). Oscillatoria comprised over 90 percent of the specimens quantified by this method. Individual cells were counted for all genera for the period 1982-1985.

During 1982-85, chlorophyll sample filters were stored in acetone in a freezer prior to analysis. In 1973 and 1974 the filters were stored in a dessicator at 4° C; after May 1975 the unextracted filters were stored in a freezer.

For the period 1982-1985, chlorophyll extracts were brought to room temperature in the dark, and the filters ground with a glass rod and subjected to ultrasound to disrupt cell walls and ensure complete extraction. Samples were then centrifuged and the optical density of the supernatant was measured at 750, 664, 647, and 630 nm. The extract was then acidified with two drops of 0.1N HCl and the optical density at 750 and 665 nm was determined after one minute. Chlorophylls a, b, and c were calculated using the equations of Jeffrey and Humphrey (1975) and phaeophytin a and the phaeophytin index (PI) were calculated using the equations of Lorenzen (1967). During the 1973-1977 period, chlorophyll filters were extracted in the lab with 90 percent acetone for 24 hours in the dark at 4° C. When glass fiber filters were used in the field, the extract was filtered again through a glass fiber filter before spectrophotometric analysis. When cellulose acetate filters were used, the extract was centrifuged before analysis. From 1973 to 1977, chlorophylls a, b, and c were calculated using the equations of Parsons and Strickland

(1963). For the current analysis, 1973-1977 chlorophyll values were recalculated to make them more comparable to the data collected in 1982-1985. Phaeopigments were not analyzed prior to 1982.

Radioactivity of primary productivity samples was determined by liquid scintillation during 1982-1985 and by a thin-window, low-background, gas-flow proportional counter in 1973-1977. Total alkalinity, pH, and temperature were used to calculate available inorganic carbon using the tables of Bachman (1962) for 1973-1977 and Saunders, et al. (1962) for 1982-1984. Net photosynthetic activity in $mgC/m^3/hr$ was determined by subtracting dark bottle C^{14} activity from light bottle activity. Net photosynthetic activity was averaged for depth intervals, multiplied by the respective depth interval, summed, and proportioned to daily solar radiation to estimate the daily areal productivity, expressed as $mgC/m^2/day$ (Steeman-Neilson, 1952).

Zooplankton samples were diluted or concentrated, depending on the abundance of detritus and organisms. Four 1-ml subsamples were taken from each magnetically stirred sample using a 1-ml Hensen-Stempel pipette, and each subsample was placed in a Sedgewick Rafter cell. Organisms were enumerated at the lowest practical taxonomic level, usually species, on a compound microscope at 35 X or 50 X. After subsample enumeration, the remainder of the sample was scanned under a dissecting microscope at 14 X for additional taxa not encountered in subsampling. Resultant counts were extrapolated to numbers per cubic meter.

Data Analysis--Varability among samples for enumerations (both phytoplankton and zooplankton), chlorophyll a concentrations, and primary

productivity estimates was evaluated by the coefficient of variation. Coefficients greater than 40 percent indicated less than desirable replicability.

Replicate phytoplankton samples for a given depth, station and date were not collected prior to 1982, although replicate zooplankton samples existed for the entire study period. However, because of the intensity of vertical mixing, a judgement was made to use phytoplankton samples collected at the various depths at a single station as replicates for the purpose of statistical analysis. This assumption is consistent with what is known about the hydraulics of the reservoir and allows statistical comparisons among stations by analysis of variance (ANOVA). All numerical phytoplankton data[1] were log transformed before statistical analysis to ensure a normal distribution[2], then subjected to a one-way ANOVA using station as the class variable. A Student-Newman-Keul's test (SNK) was used to rank and find significant differences among station means. A 95 percent confidence level was used for all analyses. By convention, the SNK test was conducted on log transformed means, but arithmetic means have been used in the tables to give a quantitative

1. Total algae (10^6 cells/liter), chlorophyll a (mg/m^3), primary productivity ($mgC/m^2/day$), Chrysophyta present (10^6 cells/liter), Chlorophyta present (10^6 cells/liter), and Cyanophyta present (10^6 cells/liter).

2. Because the chlorophyll data set included values of '0.0', the arbitrary value '1.0' was added to each concentration before log transformation.

indication of the central tendency of the data. Similar procedures were used on zooplankton data, except a $\log_{10}$ transformation was used.

Pielou's percentage similarity index (Pielou, 1975), Sorenson's quotient of similarity (McCain, 1975) and a form of the Shannon diversity index (Patten, 1962) were used to analyze phytoplankton and zooplankton community structures. Pielou's percent similarity (PS) was computed as follows:

$$PS = 200 \sum_{i=1}^{s} \min (P_{ix}, P_{iy})$$

where P_{ix} and P_{iy} are the quantities of genus i at stations x and y as proportions of the quantities of all s genera at the two stations combined.

The index is based on both qualitative and quantitative community characteristics and values of 70 percent or greater were assumed to show similarity.

Sorenson's quotient of similarity (SQS) was calculated as follows:

$$SQS = 2s/(x + y) \times 100$$

where x = number of genera at station X

y = number of genera at station Y

s = number of genera in common between stations X and Y.

This index is based solely on qualitative community characteristics (i.e., genus presence/absence) and values of 70 percent or greater were assumed to show similarity. If comparisons between two stations provided low SQS and PS values, the communities should be considered different. If the SQS value is high but PS is low, the communities are composed of similar genera but differ either in total abundance or relative abundance of genera present. When SQS is low and PS is high, communities may still be considered similar because the low SQS value probably reflects the random occurrence of rare genera which affect SQS values more than PS values. If both SQS and PS values are high, the communities are similar in generic composition, relative abundance of genera, and total algae abundance.

Diversity index values (d bar) were calculated as follows:

$$\text{d bar} = -\Sigma_{1}^{s} (n_i/n) \log_2 (n_i/n)$$

where s = number of genera collected

n_i = number of individuals belonging to the ith genus

n = total number of organisms

d bar = diversity per individual

Transformed ($\log_{10}X+1$) abundance values (total abundance and abundance by season) for seven WBN and three SQN sites (five for July 1985 data) were subjected to first and second order regression analysis. Because of several inconsistencies in the data set phytoplankton numbers

from the 1.0 meter sample only were used in the regressions. Zooplankton samples were collected as continuous tows from near bottom to the surface, consequently the composition of the mixed sample at each station was used for the regressions.

5.2.1 Phytoplankton Results and Discussions

Phytoplankton communities respond rapidly to changing environmental conditions and are capable of demonstrating variation in abundance and/or physiological state within a short period of time, i.e., a week or even days (Wade 1984). However consistent effort over a period of years enables documentation of trends within the phytoplankton community to be used in evaluating effects of WBN on Chickamauga Reservoir. While seasonal patterns (winter, spring, summer, autumn) over years (1973-1977 and 1982-1985) provide inferences about annual periodicity, year to year changes document long-term variations within the river reach. Phytoplankton analyses addressed four community parameters in an inclusive (i.e., long-term) sense. These parameters (community structure, abundance, chlorophyll biomass, and primary productivity) were used to describe long-term temporal (year-to-year) and spatial differences observed in the study area. Seasonal descriptions of the phytoplankton assemblage provided baseline information so that any operational changes in numbers, composition, diversity and phytoplankton similarity indices can be quantified. Although phytoplankton results and discussions will generally address spatial, seasonal, and long-term aspects of the assemblage, specific data presented in appendices allow examination of individual samples which can be compared with physical and chemical parameters discussed in Chapters 2.0 and 4.0, respectively.

Long-term Temporal Trends in WBN Study Reach Phytoplankton

During preoperational monitoring, 124 phytoplankton genera were identified from the Watts Bar forebay and one or more Chickamauga Reservoir channel habitats in the vicinity of WBN (table 5-1). Taxonomically these genera were distributed as follows:

Group	Number Genera
Chlorophyta	63
Chrysophyta	31
Cryptophyta	2
Cyanophyta	20
Euglenophyta	4
Pyrrophyta	4

Twenty-two of the 124 genera accounted for over 88 percent of the total phytoplankton abundance during one or more collection period(s). These genera comprised the numerically important segment of the community and have been designated dominant forms. They are:

	Chlorophyta	
Ankistrodesmus	Coelastrum	Pandorina
Chlamydomonas	Dictyosphaerium	Pediastrum
Chlorella	Kirchneriella	Scenedesmus
	Chrysophyta	
Asterionella	Melosira	Synedra
Cyclotella	Stephanodiscus	
Dinobryon	Fragilaria	
	Cyanophyta	
Anacystis	Lyngbya	Oscillatoria
Dactylococcopsis	Merismopedia	Raphidiopsis

Comparisons of stations using Sorensen's Quotient of Similarity (SQS) showed a generally increasing trend in similarity from 1973-1985 (see appendix 5-A). Pielou's community similarity test showed percentage similarity (PS) to be lower than indicated by SQS comparisons with only 39 percent of possible combinations similar at the 70 percent level or greater (appendix 5-B). These data are summarized by year as follows:

Year	SQS No. Comparisons Similar/Possible	SQS Percent	PS No. Comparisons Similar/Possible	PS Percent
1973	56/84	67	43/84	51
1974	39/84	46	26/84	31
1975	46/84	55	17/84	20
1976	40/84	48	43/84	51
1977	59/84	70	39/84	46
1982	51/63	81	11/63	18
1983	59/84	70	28/84	33
1984	55/84	66	39/84	46
1985	80/84	95	42/84	50
Total	485/735	66	288/735	39

Similarity indices (SQS) were determined for each sample station by season over the time period 1973-1985 (appendix 5-A). These calculations showed dissimilarity among stations to be greatest during the transition seasons (spring and autumn).

Diversity index values for phytoplankton ranged from 0.35 in May, 1975 (TRM 506.6 at 3m depth) to 4.40 in August, 1985 (TRM 496.5 at 5m depth) (appendix 5-C). In one instance (TRM 532.1 at 5 meters) in November 1977, no diversity index was calculated because only one taxon was present in the samples. The greatest number of genera (59) occurred at TRM 532.1 during 1985. Habitat at TRM 532.1, located in the Watts Bar Reservoir forebay area, is lentic and unlike the mixed, lotic environment in the vicinity of WBN. Phytoplankton data from TRM 532.1 were expected to differ from stations near WBN. However, TRM 532.1 was included in the monitoring program as the primary source of plankton in the vicinity of WBN.

Diversity Summary

Year	Range of Genera	Range of Diversity	Low/High Month
1973	5-30	0.53-4.10	Feb/Aug
1974	3-20	0.91-3.17	May/Aug
1975	4-39	0.35-4.23	May/Aug
1976	4-44	0.75-3.87	Feb/Aug
1977	1-51	0.00-4.21	Nov/Aug
1982	12-41	1.03-3.55	Aug/May
1983	10-39	1.84-3.74	Nov/Aug
1984	9-43	0.67-4.01	May/Feb
1985	14-59	1.89-4.40	Nov/Aug

Overall, diversity indices were good with only 29 of 976 values less than 1.0, however only 22 indices were greater than 4.0. These data show the system to be relatively consistent with respect to taxa present.

Phytoplankton community structure showing seasonal succession of the three dominant groups (Chlorophyta, Chrysophyta and Cyanophyta) for 1973 through 1985 is in figure 5-2 through figure 5-5 and table 5-2. The other three groups (Cryptophyta, Euglenophyta, and Pyrrophyta) have been combined and designated as "other" because they generally comprised a small percentage of phytoplankton abundance. These percentage composition data represent average abundance of all seven stations; however individual sample values at each location are in appendix 5-D.

In 1973 and 1974, phytoplankton was dominated by Chrysophyta (table 5-2). The only exception was August 1973 when Chlorophyta (primarily Scenedesmus) dominated. In all cases where chrysophytes were the dominant group, the most prevalent genus was Melosira and only once (August 1973) did

Cyanophyta (30.9 percent) comprise substantially more than 5 percent of the community (table 5-2).

Melosira was usually the dominant chrysophyte genus throughout the entire preoperational period (appendix 5-D) and Chrysophyta tended to dominate the assemblage except for the summer season (table 5-2). In summer, Cyanophyta frequently was dominant. This dominance sometimes persisted into autumn (1977 and 1985; table 5-2). Dominant cyanophytes varied from year to year but were comprised primarily of Dactylococcopsis (1973), Anacystis (1975, 1976, 1977), Raphidiopsis (1982 and 1984) and Oscillatoria (1983 and 1985) (appendix 5-D).

Generally the other phytoplankton groups (Cryptophyta, Euglenophyta and Pyrrophyta) were present in the assemblage but were sparse (appenix 5-D). However during four of the thirty-six quarters of sampling these groups comprised 10 percent or more of the assemblage. These were: winter of 1975 with 10.56 percent, primarily Euglenophyta; spring of 1982 with 46.25 percent, primarily Cryptophyta; autumn of 1982 with 15.75 percent, primarily Cryptophyta and autumn of 1985 with 12.18 percent, primarily Cryptophyta (figure 5-3). Also, during four quarterly samples the group Chlorophyta was dominant. These quarters were: summer of 1973 (38.76 percent); summer (41.6 percent) and autumn (39.4 percent) of 1975; and autumn of 1984 (54.2 percent) (table 5-2).

When percentage composition was determined (seasons combined) by group at each station within each year some changes in the Tennessee River in the vicinity of WBN became apparent (figures 5-6 through 5-8). Beginning in 1973, phytoplankton were dominated by Chrysophyta (figure 5-6) or Chrysophyta and Chlorophyta, however the system gradually shifted to an entirely different

community in later years (figure 5-7). No phytoplankton samples were collected from 1978-1981, and when sampling was resumed in 1982 the assemblage was more eutrophic (figure 5-8). The system (particularly the upstream stations) was totally dominated by cyanophytes with the cryptophyte, Chroomonas, as second in abundance, particularly at TRM 496.5 and TRM 506.6 (appendix 5-D). Cyanophyte dominance moderated in 1983 (table 5-2) but became reestablished in subsequent years (figure 5-8). These figures document a successional change in this reach of the Tennessee River wherein the phytoplankton community changes from a chrysophyte dominated system to a cyanophyte dominated one. There occurs also a gradual shift among stations from over 60 percent cyanophyta (TRM 532.1) to less than 40 percent Cyanophyta (TRM 496.5) (see 1983, table 5-2). This spatial pattern was repeated more (1982) or less (1976) throughout the entire preoperational monitoring period. Cyanophyte dominance in the vicinity of WBN suggests eutrophication; however, because of water travel times this eutrophication is also undoubtedly a reflection of conditions upstream of WBN in Watts Bar Reservoir.

Phytoplankton Abundance--The abundance of phytoplankton communities varies with intensity and duration of available light, quality and quantity of nutrients present in the water column, temperature, current, and the hydrographic configuration of the system. To evaluate differences in phytoplankton abundance, log transformed data were subjected to four-way analysis of variance for population changes at location (river mile), depth, season (quarter), and year. In order to balance the data set only one abundance replicate value was used for each combination of the four test parameters, and 1982 was excluded because winter quarter data were not collected.

Total phytoplankton abundance in the Tennessee River near WBN exhibited significant differences for all main effects except depth (i.e., river mile, season, and year) (table 5-3). A significant interaction also occurred between year and season. This interaction showed, and the abundance data (appendix 5-D) verified, a system with significantly greater numbers present each summer throughout all years than in other seasons. Abundance followed the general trend observed in Sorenson's analyses where highest SQS values were observed in summer followed by the winter season, then spring and autumn in descending order of similarity. The pattern differed in that the SNK Multiple Range Test showed spring and autumn not significantly different from each other.

Year to year differences in total phytoplankton abundance showed 1985 had significantly more phytoplankton ($\alpha = 0.05$) than other years. Abundance in 1974 and 1973 was similar but significantly lower than other years (table 5-3, appendix 5-D). The year to year changes in phytoplankton abundance by sample station, including stations sampled as part of the SQN monitoring effort, are in figures 5-9 through 5-17. These figures show the differences in year by year, seasonal, and river mile ANOVA (table 5-3). Fewest overall numbers of phytoplankton (0.07×10^6 cells liter) were collected at TRM 496.5 during the autumn of 1983 (figure 5-15) and TRM 506.6 during autumn of 1984 (figure 5-16). Greatest numbers (24.93×10^6 cells/liter) were taken in the summer of 1982 at TRM 532.1 (figure 5-14).

Generally summer was the most productive season with the highest community similarity (appendices 5-A and 5-B) and diversity (appendix 5-C). However, presence/absence data (appendix 5-D) and abundance figures

(figures 5-9 through 5-17) show a pattern of between station variability in phytoplankton numbers. Abundance patterns among stations show TRM 532.1 as most productive and TRM's 496.5 and 506.5 as least (table 5-3).

This pattern persisted in other seasons (figure 5-10, spring and 5-13, autumn) with general declines in numbers from upstream to TRM 496.5. However, those stations associated with SQN (TRM's 478.2, 483.4 and 490.5) often showed a pattern of increasing numbers in a downstream direction. This trend is evident at SQN stations "A" (TRM 472.8) through "E" (TRM 490.5) in figures 5-9 through 5-17. These data indicate the effects of discharging deeper strata waters from Watts Bar Reservoir and the importance of reduced flows (increased retention time) to plankton production in Chickamauga Reservoir.

Spatial trends of phytoplankton abundance were further examined using total numbers collected at 1.0 meter depths over years and by seasons within years. These data were regressed against the seven stations in the WBN preoperational data set and stations 1 (TRM 478.2), 2 (TRM 483.4), and 3 (TRM 490.5) of the SQN preoperational and operational data set. Total yearly abundance and abundance by season were examined. Several years, as well as seasons within years, showed significant non-linear regressions of the general quadratic form. Appropriate constants of the equation:

$$y = a + b\,x + c\,x^2$$

where "y" is the logarithm of estimated abundance and "x" is the sample station (e.g., TRM 472.8 . . . TRM 532.1), are presented in appendix 5-E. The $P > F$ values (significance) of regressions are summarized below. Regressions significant at $\alpha = 0.05$ are marked "*."

Year	Total Abundance	Abundance by Season			
		Winter	Spring	Summer	Autumn
1973	0.0682	0.5341	0.0156*	0.0032*	0.0017*
1974	0.0757	0.0357*	0.0311*	0.0277*	0.0072*
1975	0.1069	0.2351	0.0118*	0.0301*	0.2034
1976	0.7534	0.6978	0.4055	0.0773	0.0464*
1977	0.2139	0.0113*	0.6629	0.4933	0.0001*
1982	0.0115*	0.2879†	0.0007*	0.0001*	0.0001*
1983	0.0014*	0.2912	0.0001*	0.0001*	0.0001*
1984	0.0081*	0.0027*	0.0001*	0.0001*	0.0065*
1985	0.4122	0.8599	0.0020*	0.0001*	0.0526

*Significant at $\alpha = 0.05$.
†Three SQN stations only.

Because many F-values were significant, especially in the seasonal regressions, they will be addressed in the seasonal discussions. However, those years where significant departures from the hypothesis of no difference among stations for total numbers occurred, coincided with the operational years for SQN. Operation of SQN could not have influenced phytoplankton abundance in the vicinity of WBN. In the well mixed, relatively fast flowing riverine portion of Chickamauga Reservoir near WBN, residence time in the euphotic zone was inadequate for phytoplankton growth and reproduction. Therefore, if operational impacts to the phytoplankton community occur, they likely will not be apparent in this portion of the reservoir under flow conditions. Downstream from where the reservoir becomes more lacustrine to the forebay of Chickamauga Reservoir slower flows permit phytoplankton abundance to increase.

Chlorophyll Biomass--Because of several changes in field and laboratory procedures, chlorophyll data were not comparable over time. Within

years these data were variable with respect to both seasonal and spatial biomass both among stations and among seasons (appendix 5-F). Although not evaluated quantitatively, the chlorophyll data provided several qualitative insights into overall production of phytoplankton. Chlorophyll a values were generally greatest in the Watts Bar forebay area (TRM 532.1) and least at the most downstream station in Chickamauga (TRM 496.5). During most years chlorophyll biomass was directly correlated with abundance (appendices 5-D and 5-F). Maximum chlorophyll a concentrations recorded each year are summarized as follows.

Year	No. Values $\geq$ 10 mg/m^3	Highest Concentration	Site
1973	None	6.56 mg/m^3	529.5
1974	1	10.76 mg/m^3	532.1
1975	None	7.63 mg/m^3	532.1
1976	4	15.91 mg/m^3	532.1
1977	29	17.34 mg/m^3	532.1
1982	27	23.87 mg/m^3	532.1
1983	13	14.18 mg/m^3	532.1
1984	31	15.46 mg/m^3	532.1
1985	49	21.20 mg/m^3	532.1

The number of chlorophyll a concentrations greater than 10 mg/m^3 has been increasing steadily over the years at TRM 532.1. Similar trends were also documented at other sample sites in the vicinity of WBN (appendix 5-F). These concentrations, in the 10-30 mg/m^3 range suggested by Vincent (1981) as indicative of potential eutrophication, occurred only rarely prior to 1977; however their incidence has increased since that time.

The relationship between chlorophyll a and phaeophytin a (a degradation product of chlorophyll a) expressed as a phaeophytin index (PI)

provides inferences about the physiological status of the assemblage. Phaeophytin indices were determined for samples collected from 1982 to present (appendix 5-F). PI values near 1.7 (the theoretical maximum) imply populations consisting of mainly intact, non-decaying organisms, whereas values near 1.0 (theoretical minimum) indicate little or no active chlorophyll a.

Except for an occasional high PI value, moderate to large relative amounts of phaeophytin a (PI < 1.6) were present at all stations and depths during autumn quarters throughout the period 1983 - 1985 and for all of 1982. Lower PI values, indicative of aging or physiologically stressed algae, would be consistent with high residence time and potential mechanical breakage of phytoplankton. High PI values > 1.6 (in some cases PI values exceeded the theoretical maximum of 1.7) were observed during winter (except for TRM 532.1 in 1985), a period of reduced river elevation and reduced residence time throughout the study reach. These phaeophytin values show the assemblage had responded to physical influences related to season.

Primary Production--Primary production provides a measure of the photosynthetic activity in the water column. Primary production data were summarized into hourly and daily carbon assimilation (appendix 5-G) and expressed as the amount of carbon incorporated by phytoplankton in a square meter area, to a depth of five meters, for an entire day. This technique not only considers the amounts of light available during incubation and for the day, but also integrates depths within the euphotic zone. This zone, defined as the depth to which one percent of surface light penetrates (Jasper, et. al, 1983), roughly correlates with Secchi depth measurements reported in chapter 2 and appendix 2-A of this report.

Unfortunately the entire data set was statistically unbalanced, but could be balanced for analytical purposes over five of nine years (not consecutive) for seven WBN stations for each depth and season. One replicate was used for each of the 560 combinations of the four parameters, and ANOVA of main effects and interactions calculated. The error mean square for the four-way interaction was used to determine F-statistics for secondary interactions. Too few observations (< 7) did not permit any pattern to be observed among secondary interactions, consequently, they were not included in the discussion. Significance of the tests was determined by probabilities of exceeding the F-statistic at the 0.001 level and are summarized in table 5-4. The least significant difference (LSD) test at the 99 percent significance level was used to locate differences among means for each significant F-test. A summary of the treatment means results and 99 percent LSD values is given in table 5-5 with means having the same alpha- betic letter not being significantly different.

The analysis of main effects means is valuable to give an overall view of the system. Each main effect is pooled over the other parameters.

River Mile--Photosynthetic activity varied with respect to river mile, with the most activity occurring in the Watts Bar forebay at TRM 532.1 (table 5-5, comparison I). However, river miles could not be easily sorted out on the basis of photosynthetic activity for the river miles (stations) below the dam because of similarities in activity among some stations. TRM 527.4 and TRM 528.0 were similar but TRM 528.0 could not be distinguished from TRM 529.5 and TRM 518.0, while TRM's 529.5 and 518.0 were similar. Primary production at TRM 496.5 and TRM 506.5 could not be separated

statistically. These results confirm the lacustrine forebay is more photosynthetically active than the area below the dam. The fact that production is somewhat varied among the riverine stations indicates localized differences between the upper and lower river stations (e.g., TRM 527.4 was similar to TRM 528.0 but not to 529.5, while TRM 529.5 was similar to 528.0 and to all the lower stations). Inspection of the area shows Dake Branch enters the Tennessee River slightly below TRM 528.0. River configuration suggests this creek has potential photosynthetic influence on the TRM 527.4 sample site, which may relate to the slightly higher phytoplankton production at TRM 527.4 when compared to TRM 529.5 (table 5-5, comparison I).

Years--As demonstrated in table 5-5, comparison II, photosynthetic activity was not constant for the years examined. The high variability of turbidity, flow, nutrients, and available light among years (appendix 2-A) coupled with large fluctuations of photosynthesis within years (2 $mgC/m^2/day$ to 1652 $mgC/m^2/day$) tended to confuse relationships between years. Based on L.S.D. tests annual primary production showed 1974 < 1983 < 1976 < 1973 < 1977 where years not underlined by a continuous line are significantly different.

Season--Because data were collected at about the same time each quarter, the 140 observations per quarter present credibility in showing seasonal photosynthetic activity. Quantitative results of primary production will be discussed in the respective seasonal sections, however lowest overall activity was observed in November and February with virtually no difference in production between those months. Nearly twice as much photosynthetic activity occurred in May (spring) while productivity nearly tripled in August (table 5-5, comparison III).

Depth--Vertical stratification of photosynthetic activity varies with the penetration of light through the water column (table 5-5, comparison IV). These data showed primary production to be similar at the three and five meter depths (table 5-5, appendix G) and more than 7 times greater at the upper levels (0.3 and 1.0 meters).

Analysis of primary interactions allows for the combination of two factors such that data are stratified in two planes to reveal more complex associations between controlling variables. The word "by" in the interaction term describes arrangement of the variables. For example, river mile by year indicates the data are stratified by year for each river mile, allowing one to examine annual photosynthetic activities for any station. Seasonal analyses (e.g., river mile by month, year by month, and depth by month) of primary interactions are addressed within the respective seasonal discussions.

River Mile By Year--Photosynthetic activity was relatively constant for all years examined for TRM 496.5, the most downstream WBN station and TRM 529.5 just below Watts Bar Dam. This constancy, although at slightly different productivity levels, was also observed for TRM's 506.5, and 518.0. TRM 527.4 and TRM 528.0 showed no consistent pattern through time. Examination of photosynthetic activity for the forebay station (TRM 532.1) shows quite a different pattern. Annual changes become more prominent in the quieter waters above Watts Bar Dam showing highest photosynthetic activity in 1977, lowest in 1983 and gradations in activity among all years.

River Mile By Depth--Analysis of the primary productivity data by depth for each river mile does not indicate how well mixed this portion of the river is vertically. It has been conceded the river was well-mixed. At all

sample stations except TRM 506.5, approximately seven times as much primary production was measured at the surface and one meter depth, which were not statistically different, as occurred at the three and five meter depths, which were also mutually indistinguishable (table 5-5, comparison VII).

Year By Depth--Some year to year variability was present, however photosynthesis was generally similar for all years at five meters and at three meters (comparison IX, table 5-5). At the one meter depth productivity was greatest in 1977 and least in 1973, whereas productivity at the surface (0.3 meters depth) was nearly three times greater in 1973 and 1977 than for the rest of the years at that depth. The euphotic zone, at least the layer of greatest photosynthetic activity, apparently is limited to the surface and one meter depths for this reach of the Tennessee River.

During analysis of phytoplankton abundance data, an ANOVA showed that of the main effects (i.e., river mile (station), year, depth, and month (quarter) only depth was not significant at the 0.001 level or greater (table 5-3). Primary productivity analyses showed vertical differences in phytosynthetic activity at all sites except TRM 506.5 (comparison VIII, table 5-5) and throughout years.

The primary productivity values reported here show that given reduced flow, the phytoplankton grow and reproduce in a manner directly related to available light and nutrients. Dense phytoplankton communities do not persist in the riverine reaches of WBN because high water velocities and associated turbulence prevent algal cells staying in the euphotic zone long enough for growth to occur. However as reservoir cross-sectional area increases, phytoplankters remain in the photic zone longer and can effect growth and

reproduction. This point in the reservoir is usually downstream from TRM 496.5, however, in low flow conditions increased numbers of phytoplankton may be observed further upstream nearer WBN (e.g., winter 1976, 1977, and spring 1985).

Seasonal Descriptions of Phytoplankton within the WBN Study Reach

Biologically the phytoplankton assemblage in the vicinity of WBN showed consistency among stations but considerable variability among seasons (figure 5-2 through 5-5). ANOVA showed the seasonal progression of phytoplankton abundance to be summer > winter > spring > autumn with winter being significantly more abundant than spring (table 5-3). Results presented include short-term temporal and spatial comparisons of seven WBN sample stations beginning at TRM 496.5 (station 4) and progressing upstream to TRM 532.1 (station 10). Stations 1 through 3 were part of the SQN monitoring plan in Chickamauga Reservoir and were used as data sources for examining changes in reservoir-wide phytoplankton abundance.

Winter--Physical conditions varied considerably during winter with flows well below normal in 1977 and 1984, less than normal (1976 and 1985) to normal (1983) and significantly greater than normal in 1974 and 1975. Because of reduced water elevations and generally greater average water velocities in winter, travel times between TRM 532.1 (station 10) and TRM 496.5 (station 4) were shorter than at other times of the year, ranging between 20 hours (1975) and 2.8 days (1976). Other physical and chemical parameters are discussed in chapter 2 and documented in appendix 2-A.

Phytoplankton densities in winter were exceeded only by summer numbers and were usually dominated by the chrysophyte *Melosira* at each station with Chlorophyta (*Chlorella*) and Cyanophyta (primarily

Oscillatoria) being second and third in abundance (appendix 5-D and figure 5-2). In 1983 Oscillatoria was dominant at TRM's 532.1, 528.0 and 506.6 however overall phytoplankton abundance was relatively low (range 0.36×10^6 and 0.66×10^6 cells/liter, and the analyses showed no consistent pattern among the three stations. Generally, winter phytoplankton abundance was low during 1973 (figure 5-9), 1974 (figure 5-10), 1975 (figure 5-11), 1982 (figure 5-14), 1983 (figure 5-15) and 1985 (figure 5-17) with few samples exceeding 1.0×10^6 cells/liter. However, in 1976 (figure 5-12), 1977 (figure 5-13) and 1984 (figure 5-16) numbers were moderate to moderately abundant (range 0.92×10^6 to 9.58×10^6 cells/liter) and were comprised primarily of chrysophytes (see also table 5-2). When winter river velocities were highest (> 68,000 cfs in 1974 and 85,000 cfs in 1975), fewest organisms were collected (range 0.10×10^6 to 0.36×10^6 cells/liter) suggesting washout related to the high flows.

Diversity index values were usually lower during the earlier sample years (1973-1977) ranging between 0.6 and 2.99 while the 1982-1985 period ranged between 2.02 and 3.83. The seven WBN stations showed a high winter diversity index of 3.83 (1984, TRM 532.1) and a low of 0.60 (1973, TRM 496.5). SQS values showed the winter phytoplankton assemblage to be similar at all stations excepting TRM 496.5 (1975) and TRM 532.1 (1975 and 1977, appendix 5-A). Similarity indices (SQS) values were also determined for each station by season over the time period of 1973-1985. In nine instances winter SQS values were high enough to consider sample sites similar among years. These were:

Station	Years When SQS > 70 percent	SQS
532.1	1983-1984	72
	1983-1985	81
528.0	1984-1985	73
518.0	1983-1984	79
506.6	1983-1984	76
	1983-1985	71
	1984-1985	71
496.5	1976-1977	72
	1977-1985	76

High incidence of the years 1983, 1984, and 1985 among stations spanning the study area (TRM 496.5 excepted) indicates relative consistency of taxa collected since sampling was reinitiated in spring 1982. No winter sample was collected in 1982. Continued differences at station 4 (TRM 496.5) may be due in part to recruitment from the Hiwassee River, or from local hydrodynamic changes in Chickamauga Reservoir. Reasons for phytoplankton anomalies at TRM 496.5 are not known, although they have generally persisted throughout the sample years and have been documented. Winter percentage similarity (PS) values between stations within years were generally consistent with SQS indices, but showed TRM 496.5 (1974, 1975, 1976, 1984) and/or TRM 532.1 (1975, 1977) to have less than 70 percent similarity (appendix 5-B).

Regression analyses performed on phytoplankton densities at 1.0 meter depth for combined WBN and SQN stations indicated significant polynomial regressions for 1974, 1977, and 1984; however no pattern of

abundance was established (appendix 5-E). In 1974 the highest predicted abundance was between TRM's 496.5 and 532.1; in 1977 the lowest predicted number was at the same location; whereas, in 1984, the prediction was linear with an increase in numbers from station 1 (TRM 478.2) through station 10 (TRM 532.1) (appendix 5-E, figure 5-16). These patterns suggest that some factor other than sample site is the primary influence on abundance during the winter season.

Primary production was generally low (range 8 (1976) to 433 (1984) mg C/m^2/day) during winter samples and was not statistically distinguishable from autumn based on main ANOVA effects (table 5-5, comparison III). However when we examine interactions among seasons within stations (i.e., station effect is neutralized) winter was different from autumn (table 5-5, comparison VI), and that except for station 5 (TRM 506.5) ANOVA showed consistent year to year differences in winter phytoplankton production at the sample sites (table 5-5, comparison VIII). Lowest production occurred in 1976 (station 4) with median winter quantities of phytosynthetically bound carbon (derived from appendix 5-G) less than 90 mg C/m^2/day.

Spring--Water velocities were near normal (about 26,000 cfs) during 1973, 1974, 1975, and 1977 and above average (≈ 42,000 cfs) in 1983 and 1984 during spring. Flows were generally lower than average in 1976 and very low in the spring of 1982 and 1985 (average flow 7,100 cfs, range 3,100 - 9,300 cfs). Travel times were slower in spring than in winter, ranging between 2.33 days (1983) and 15.2 days (1985) to traverse the river from TRM 532.1 to TRM 496.5 (appendix 2-A). The relatively

long travel times coupled with spring runoff from upstream and from tributary rivers should promote phytoplankton growth in the system.

Phytoplankton densities in spring varied, ranging from 0.13 x 10^6 cells/liter at TRM 506.6 (1976) to 5.89 x 10^6 cells/liter at TRM 532.1 (1983). Although spring phytoplankton densities were generally higher in 1985 (figure 5-17) than when flow was well below normal this trend was not repeated in the low flow conditions of 1982 (figure 5-14). Conversely highest densities as reported above (TRM 532.1) occurred when river velocities were greater than 47,000 cfs (figure 5-15, appendix 2-A).

Year-to-year dominance by Chrysophyta was evident during the first series of preoperational samples (1973-1977) and as was the case during the winter season the dominant taxon was Melosira (appendix 5-D) however the community pattern was changing. Figure 5-3 shows that the middle stations (TRM 518.0 to TRM 529.5) are relatively consistent with respect to composition. TRM's 496.5 and 532.1 show some increase in Cyanophyta (Oscillatoria and Dactylococcopsis were second and third in dominance) and while still relatively few in numbers the minor groups (especially Euglenophyta and Cryptophyta) comprised almost 10 percent of the assemblage particularly in 1982 and 1983 (table 5-2, figures 5-14, and 5-15).

Diversity index values were generally low (range 1.02 to 2.76) during the first years of sampling (1973-1975), improving slightly (1.39 - 3.51) in 1976 and 1977, and showing greater fluctuation but with higher diversities in the 1982-1985 series. Spring densities in the 1980's samples ranged between 0.67 (TRM 527.4, 1984) and 3.95 (TRM 506.6,

1985). Diversity indices tended to correlate directly with the number of taxa collected each year (appendix 5-C) but not with taxa collected at each station. The lowest and highest number of taxa at a single station respectively occurred in 1976 (4) and 1985 (50).

Similarity indices (SQS and PS) showed several patterns of taxonomic complexity. SQS values showed all stations similar (SQS $\geq$ 70 percent) during 1973 and 1985, and the middle stations (TRM's 518.0, 527.4, and 528.0) resembled each other taxonomically during spring samples of other years (appendix 5-A). During 1976, 1977, 1982, and 1984, TRM 496.5 SQS values were less than 70 percent suggesting recruitment of rare taxa from upstream in the Tennessee River and/or from the Hiwassee River. During the entire series of spring samples, SQS and P.S. indices showed the two downstream stations to be similar to each other but quite different from other areas (appendices 5-A and 5-B). These analyses also showed TRM 532.1 (Watts Bar forebay) to be unique with respect to incidence and numbers of rarer phytoplankton forms. SQS indices are usually prepared to test seasonal similarities between stations within a particular year, however the WBN phytoplankton taxa were also analyzed where different years at the same station were seasonally addressed. These analyses showed only four of 252 comparisons with SQS similarities greater than 70 percent between years at a specific station. TRM 529.5 showed 70 percent similarity between 1973 and 1974. TRM 527.4 had SQS of > 70 percent between 1975 and 1976 and between 1976 and 1977. Also at TRM 496.5 the 1977 spring sample was similar to the 1985 sample. The limited number of similarities indicates that while the

system is generally similar within a specific year, taxonomic variability during spring is quite apparent when compared among years.

Regression analyses performed on combined WBN and SQN phytoplankton abundance data showed two spring periods (1976 and 1977) when polynomial regressions were not significant. The several significant regressions (appendix 5-G) and their respective graphic forms can be interpreted as segments of polynomial form with nadirs near TRM 496.5 or TRM 506.6 and highs at or near Chickamauga and Watts Bar forebays. During periods of average flow (1973, 1974, 1975, 1984) we document the "normal" form of the curve, however as flows increase the nadir is pushed downstream and the spring curve approaches linear and directly related to river mile. During periods of continued low flow (1985) phytoplankton production increased at the more downstream stations (i.e., this inflection point of the curve moves upstream), consequently the spring production curve become more linear and inversely related to river mile.

Primary production was quite variable during spring ranging from 0.6 $mgC/m^2/day$ in 1975 to 786 $mgC/m^2/day$ in 1985. Overall, 1975 data were consistently very low (0.6 to 2.1 $mgC/m^2/day$) suggesting few organisms were capable of reproducing during the test series. These values were well below others observed during preoperational monitoring of phytoplankton production, and were not included in the multiple ANOVA of phytoplankton primary production (table 5-5). Interactions among stations within season showed TRM 496.5 and TRM 532.1 had significantly

greater primary production than intermediate sites (table 5-5, comparison VI) and the year 1977 was the most productive during spring (table 5-5, comparison VIII).

Summer--Summer flows are usually greater than other seasons and averaged more than 29,000 cfs in the vicinity of WBN. This flow plus or minus 5,000 cfs was present during all sample years except 1977 (average flow 20,800 cfs) and 1985 (average flow 21,700 cfs). Water travel times were generally greater than spring values ranging between 2.9 days (1982) and 4.1 days (1985) for a water mass to move from TRM 532.1 to TRM 496.5 (appendix 2-A). The relatively consistent flows, travel times and water temperatures (range 24.5C to 28.5C) provided conditions conducive to phytoplankton growth and reproduction.

Summer phytoplankton densities varied with respect total numbers ranging from 0.16×10^6 cells/liter at TRM 506.5 (1974) to 24.93×10^6 cells/liter at TRM 532.1 (1982) (figures 5-10 and 5-14). Only once during the entire study were summer phytoplankton densities surpassed by another season's abundance. This occurred in 1974 when the spring assemblage was more numerous than summer (figure 5-10).

While Chrysophyta generally dominated the winter and spring assemblages, summer phytoplankton were dominated by Cyanophyta (figure 5-4). However, in table 5-2 we see that Cyanophyta did not begin to dominate the system until summer of 1976. Prior to 1976 the Cyanophytes surpassed 40 percent of total abundance twice (TRM 518.0 (45 percent) and TRM 528.0 (49 percent) in 1975), however beginning in 1976 the Cyanophyta comprised from 56 percent (TRM 496.5, 1985) to 91 percent

(TRM 532.1, 1982) of each summer sample. During 1973, Chrysophyta dominated at TRM's 518.0 through TRM 532.1 (Synedra) and TRM 496.5 (Melosira) with Scenedesmus, a chlorophyte, dominant at TRM 506.5. Summer of 1974 was similar to other seasons with Melosira dominating the assemblage at most stations (appendix 5-D). Melosira was dominant only once more among summer samples (TRM 529.5, 1975), as the system shifted toward more eutrophic forms (Cyanophyta) in later years. During the period 1975-1985 summer phytoplankton samples were comprised primarily of Anacystis during earlier years (1975-1977) supplemented by several other Cyanophyta (Merismopedia, Oscillatoria, and Raphidiopsis) at one or more stations during 1982-1985 (appendix 5-D).

Diversity index values were higher during summer than any other season, ranging from 1.03 (TRM 532.1, 1982) to 4.40 (TRM 496.5, 1985) (appendix 5-C). Earlier sampling (1973-1977) showed more consistency of d bar values ranging between 1.73 (1974) and 4.21 (1977), with both values determined at the same location (TRM 527.4). Numbers of taxa reported at each station during summer were greater than any other season, ranging from 17 at TRM 518.0 (1974) to 62 also at TRM 518.0 (1977) (appendix 5-D).

Similarity indices showed the summer assemblage to be relatively consistent taxonomically. SQS values showed all stations to be similar during all years except 1979 (appendix 5-A). The reason for low (< 70 percent) values for this year is unknown. In 1979 only four of 21 comparisons were SQS $\geq$ 70 percent, a trend which was repeated by percentage similarity (PS) analyses (appendix 5-B). Throughout the

summer season PS values showed TRM's 496.5 and 506.5 resembled each other but were different from other stations during 1973, 1975, 1982, 1983, 1984, and 1985. TRM 532.1 was taxonomically unique during several years (1974, 1975, 1982, 1983, and 1985) (appendix 5-B). No distinct pattern of similarity was evident among the other WBN stations. SQS analyses testing seasonal similarities among years at a specific station showed 30 percent of summer comparisons to be similar at $\geq$ 70 percent level. This relatively high incidence of year-to-year similarity, the next highest season was winter with 3.6 percent of comparisons being similar, documents long-term constancy within phytoplankton taxa living in this reach of the Tennessee River.

As was the case for spring, summer phytoplankton abundance regressions were significant for all years except 1976 and 1977 (appendix 5-E). However, because summer travel times were much shorter than those of spring (appendix 2-A), the relationship between river flow and inflection points of the second-order polynomial equations was less apparent (appendix 5-E). In most years (1974 and 1985, excepted) predicted values showed higher abundances in the Watts Bar and Chickamauga forebay areas and lows in the vicinity of TRM 496.5 - TRM 506.6. In 1984 and 1985 with water mass travel times of 3.2 and 4.1 days, respectively, the regressions were almost linear and directly related to river mile.

Summer primary production was more variable than spring, ranging between 14 $mgC/m^2/day$ in 1975 (TRM 506.5) and 78674 $mgC/m^2/day$ in 1985 (TRM 527.4). Overall, 1985 data were consistently

greater (11,789 to 78,694 $mgC/m^2/day$) than generally observed (appendix 5-G). Median daily carbon assimilation rates during summer (all years) was 279 $mgC/m^2/day$. In all cases where analyses of variance tests were performed, main effects analysis showed summer to be significantly more productive than the other seasons. Interactions among seasons within stations (table 5-5, comparison VI), among seasons over years (table 5-5, comparison VIII) and among seasons by depth (table 5-5, comparison X) showed summer to be about three times as productive as the other seasons when station and year effects were neutralized. However neutralization of years and stations showed depth to have no significant proportional effect on seasonal photosynthesis.

Autumn--Water flows in the Tennessee River during November ranged between 20,000 and 25,000 cfs with an average travel time of 2.9 days to traverse the river from TRM 532.1 to TRM 496.5 (chapter 2 and appendix 2-A). Other than surface elevation changes (decrease in elevation to winter pool levels commences around 1 October and continues to the end of December) autumn hydrologic conditions were relatively consistent. Low average flow conditions during or just prior to sampling occurred in 1985 (16,700 cfs), longest travel time was 4.0 days in 1983, and autumn temperatures ranged between 15C and 16C (appendix 2-A).

Phytoplankton densities in autumn were less than at any other season and varied with respect to dominant forms (figures 5-5 and appendix 5-D). Overall the percentage composition by group (years combined) seemed to be balanced with Chrysophyta being the prevalent group (figure 5-5). However, table 5-2 shows that, as was the case in

summer, the community has changed through time with other groups dominating the assemblage. During 1973, 1974, 1975 excepting TRM 506.5 and 1976 excepting TRM 496.5, Chrysophyta (Melosira) continued as the most numerous form at most sites. Anacystis (Cyanophyta) dominated at TRM 496.5 and TRM 506.6 in 1975 and 1976 (table 5-2, and appendix 5-D). In 1977, Anacystis dominated the samples at TRM's 506.5, 518.0, and 527.4. When sampling was resumed in 1982 the numerical distribution of phytoplankton had changed. Along with Melosira and Anacystis were Cryptophyta (Chroomonas at TRM 496.5 in 1982), Oscillatoria (Cyanophyta) at TRM 506.5 (1983) and TRM's 527.4 through 532.1 (1985), as well as Scenedesmus and Cyclotella representing Chlorophyta as dominants throughout the river reach (appendix 5-D). While the assemblage was taxonomically diverse it was numerically sparse with densities ranging between fewer than 0.07×10^6 cells/liter (TRM 496.5, 1983 and TRM 506.5, 1984) and a high of 1.80×10^6 cells/liter at TRM 528.0 in 1977 (see figures 5-15, 5-16, and 5-13, respectively).

Diversity index values were generally lower in autumn than in summer ranging between 1.02 (TRM 506.6, 1974 and 1976) and 3.37 (TRM 496.5, 1982), however, they improved slightly during 1982-1985 (appendix 5-C). Number of taxa at any single station ranged from 9 in 1974 and 1984 to 42 in 1982 (appendix 5-D). Percent similarity (PS) indices showed the downstream stations (TRM's 496.5 and 506.5) to resemble each other during the autumn of 1973, 1974, 1975, 1984, and 1985 but were different from any other station during those years. In 1982, PS showed similarity between adjacent stations but with an upstream

(TRM 532.1) to downstream trend toward differences (appendix 5-B). In 1976 and 1983 no distinct pattern of percent similarity values was discernable. SQS values showed all stations to be similar (SQS $\geq$ 70 percent) during 1982 and 1985, and with only minor exceptions in 1977. No distinct SQS pattern was evident in 1983 and 1984 (appendix 5-A). During 1973, 1974, 1975, and 1976, autumn SQS indices showed TRM's 496.5 and 506.5 to be different from TRM's 518.0 - 532.1, which were generally similar to each other. This same pattern occurred during summer and for TRM 496.5 during winter and spring seasons also (appendix 5-A). Autumn SQS indices of taxonomic similarity over years showed only one of 252 comparisons (1975-1976 at TRM 528.0) had a similarity index $\geq$ 70 percent. This reiterates what was observed during spring and to some extent winter; that while taxonomic homogeneity within years is demonstrated, taxonomic heterogeneity between years also exists and must be considered when evaluating phytoplankton community changes in the vicinity of WBN.

November phytoplankton abundance regressions were significant for all years except 1975 and 1985 (appendix 5-E). However with the possible exception of 1983 (which had the longest travel time (4 + days) of autumn samples) no regressions indicate recovery of autumn phytoplankton numbers to levels observed in Watts Bar forebay. Fitted abundance curves for autumn phytoplankton were more linear (first-order polynomial) than parabolic (second-order polynomial) and were directly related to river mile (appendix 5-E).

Autumn primary production was generally low (median 104 $mgC/m^2/day$, range 2 to 1562 $mgC/m^2/day$) and was not statistically distinguishable from winter based on main ANOVA effects (table 5-5, comparison III). However, when interactions among seasons within stations were examined (i.e. station effect is neutralized) autumn was observed to be more variable than winter (table 5-5, comparison VI) and for several stations (TRM 496.5, TRM 518.0, and TRM 529.5) to have the lowest phytoplankton production.

5.2.2 Phytoplankton Summary and Conclusions

Seasonal preoperational phytoplankton parameters (community structure, abundance, biomass, and productivity) indicate a distribution which varies considerably from year to year, but is primarily controlled by the continuously mixed flow pattern of the Tennessee River in the vicinity of WBN. Although the potential for primary production was demonstrated by carbon-14 assimilation studies at all stations during all seasons, *in situ* growth and reproduction was sparse because turbulent flow in the study reach prevented phytoplankton obtaining enough energy (light) to photosynthesize. Turbulent flow begins to decrease just downstream from the lower most WBN station, consequently production increases as the water mass approaches the forebay area near Chickamauga Dam.

Chlorophyll *a* concentrations during preoperational monitoring were usually lowest in the autumn and highest in summer with considerable year to year variations. Phytoplankton biomass values were generally greatest in Watts Bar forebay (TRM 532.1) with a shallow downward trend to TRM 496.5 and then increased toward Chickamauga Dam (TVA 1984).

The abundance investigations indicated a tendency toward increases in phytoplankton numbers through time in the vicinity of WBN. This increase in numbers along with the change in community dominance (shift from chrysophyte dominated system to a cyanophyte dominated one) needs to be tracked in the future. The shift of the phytoplankton assemblage toward a less preferred community seems to be originating in the Watts Bar forebay area, however it has potential to effect interpretation of WBN operational activities.

Table 5-1. Phytoplankton Genera Collected During Preoperational Monitoring at Watts Bar Nuclear Plant, 1973-1985

Phytoplankton Genera		
CHLOROPHYTA		
Acanthosphaera	Dictyosphaerium	Polyedriopsis
Actinastrum	Echinosphaerella	Protococcus
Ankistrodesmus	Elakatothrix	Pteromonas
Arthrodesmus	Euastrum	Pyramimonas
Botryococcus	Eudorina	Quadrigula
Bracteacoccus	Franceia	Scenedesmus
Carteria	Gloeoactinium	Schroederia
Characium	Gloeocystis	Selenastrum
Chlamydomonas	Gloenkinia	Spermatozoopsis
Chlorella	Gonium	Sphaerocystis
Chlorococcum	Hyalotheca	Spirogyra
Chlorogonium	Kirchneriella	Spondylosium
Chodatella	Micractinium	Staurastrum
Cladophora	Micrasterias	Stigeoclonium
Closteridium	Mougeotia	Tetradesmus
Closteriopsis	Oocystis	Tetraedron
Closterium	Pandorina	Tetraspora
Coelastrum	Pediastrum	Tetastrum
Cosmarium	Planktosphaeria	Treubaria
Crucigenia	Platydorina	Trochiscia
Dactylococcus	Pleodorina	Ulothrix
CHRYSOPHYTA		
Achnanthes	Dichotomococcus	Nitzschia
Asterionella	Dinobryon	Ophiocytium
Attheya	Eunotia	Pinnularia
Caloneis	Fragilaria	Pleurosigma
Chaetoceros	Gomphonema	Rhizosolenia
Cocconeis	Gyrosigma	Rhoicosphenia
Cyclotella	Mallomonas	Stephanodiscus
Cymatopleura	Melosira	Surirella
Cymbella	Meridion	Synedra
Diatoma	Navicula	Synura
		Tabellaria
CRYPTOPHYTA		
Chroomonas	Cryptomonas	

Table 5-1. (Continued)

Phytoplankton Genera		
	CYANOPHYTA	
Anabaena	Calothrix	Gomphosphaeria
Anabaenopsis	Chroococcus	Lyngbya
Anacystis	Coelosphaerium	Merismopedia
Aphanizomenon	Cylindrospermum	Microcystis
Aphanocapsa	Dactylococcopsis	Oscillatoria
Aphanothece	Eucapsis	Phormidium
	Gloeothece	Raphidiopsis
	EUGLENOPHYTA	
Cryptoglena	Phacus	Trachelomonas
Euglena		
	PYRROPHYTA	
Ceratium	Gymnodinium	Peridinium
Glenodinium		

Table 5-2. Percentage Composition of Phytoplankton Groups During Preoperational Monitoring (1973-1985), Watts Bar Nuclear Plant

Date	Phytoplankton Group	Tennessee River Mile						
		496.5	506.5	518.0	527.4	528.0	529.5	532.1
March 1973	Chlorophyta	1	24	18	9	7	12	1
	Chrysophyta	96	78	77	84	90	83	94
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	3	5	5	6	3	5	5
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
May 1973	Chlorophyta	15	13	14	5	10	9	21
	Chrysophyta	80	84	81	93	88	89	76
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	5	3	5	2	2	2	3
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
August 1973	Chlorophyta	47	50	43	38	37	35	37
	Chrysophyta	39	23	29	31	28	28	29
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	14	26	27	29	31	37	32
	Euglenophyta	0	0	0	2	0	0	2
	Pyrrophyta	0	0	0	0	0	0	0
November 1973	Chlorophyta	32	32	30	36	34	30	31
	Chrysophyta	62	59	63	59	61	59	60
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	3	6	6	3	3	7	5
	Euglenophyta	3	3	0	2	2	4	4
	Pyrrophyta	0	0	0	0	0	0	0

Table 5-2. (Continued)

Date	Phytoplankton Group	Tennessee River Mile 496.5	506.5	518.0	527.4	528.0	529.5	532.1
February 1974	Chlorophyta	27	24	19	11	10	20	23
	Chrysophyta	65	66	73	81	81	73	70
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	1	5	2	4	5	5	5
	Euglenophyta	3	2	5	2	3	2	0
	Pyrrophyta	4	3	2	1	2	0	3
May 1974	Chlorophyta	39	19	13	14	15	15	17
	Chrysophyta	55	78	79	83	80	81	82
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	5	3	8	3	4	3	2
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
August 1974	Chlorophyta	38	38	43	43	39	29	34
	Chrysophyta	49	50	56	55	61	70	63
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	11	5	1	1	0	1	1
	Euglenophyta	2	2	0	0	0	0	0
	Pyrrophyta	0	5	0	0	0	0	0
November 1974	Chlorophyta	26	17	21	22	21	16	17
	Chrysophyta	69	80	74	72	76	77	76
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	3	2	5	4	3	5	5
	Euglenophyta	2	0	0	1	0	2	2
	Pyrrophyta	0	0	0	0	0	0	0

Table 5-2. (Continued)

Date	Phytoplankton Group	Tennessee River Mile 496.5	506.5	518.0	527.4	528.0	529.5	532.1
February 1975	Chlorophyta	77	34	48	54	53	58	61
	Chrysophyta	14	46	29	23	24	20	18
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	4	15	9	12	12	7	7
	Euglenophyta	4	4	14	11	11	15	14
	Pyrrophyta	0	1	1	1	0	0	0
May 1975	Chlorophyta	19	11	7	11	11	10	14
	Chrysophyta	72	74	76	77	66	68	79
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	9	16	17	12	23	22	5
	Euglenophyta	0	0	0	0	0	0	2
	Pyrrophyta	0	0	0	0	0	0	0
August 1975	Chlorophyta	39	50	41	39	33	44	44
	Chrysophyta	26	23	13	32	18	29	23
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	34	27	45	27	49	25	32
	Euglenophyta	0	0	0	0	0	2	0
	Pyrrophyta	0	0	0	0	0	0	0
November 1975	Chlorophyta	49	26	37	40	32	44	47
	Chrysophyta	37	22	33	40	40	46	30
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	12	53	29	17	24	6	18
	Euglenophyta	2	0	0	3	3	3	4
	Pyrrophyta	0	0	0	0	1	1	1

Table 5-2. (Continued)

Date	Phytoplankton Group	Tennessee River Mile 496.5	506.5	518.0	527.4	528.0	529.5	532.1
February 1976	Chlorophyta	3	4	4	6	7	4	4
	Chrysophyta	89	89	85	93	89	92	85
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	7	7	11	1	5	4	10
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
May 1976	Chlorophyta	28	30	6	17	24	26	23
	Chrysophyta	37	46	91	73	70	73	75
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	35	22	4	10	6	1	1
	Euglenophyta	0	2	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
August 1976	Chlorophyta	12	20	14	16	15	14	10
	Chrysophyta	5	8	9	10	10	12	8
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	82	72	77	74	75	75	82
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
November 1976	Chlorophyta	24	5	9	8	13	18	21
	Chrysophyta	26	90	80	83	54	75	66
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	50	4	11	8	33	6	13
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0

Table 5-2. (Continued)

Date	Phytoplankton Group	Tennessee River Mile 496.5	506.5	518.0	527.4	528.0	529.5	532.1
February 1977	Chlorophyta	13	31	25	19	19	19	30
	Chrysophyta	82	65	69	74	75	76	59
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	3	4	6	6	5	4	11
	Euglenophyta	2	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
May 1977	Chlorophyta	34	7	5	3	4	5	9
	Chrysophyta	50	86	88	90	86	84	82
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	15	6	6	6	9	10	9
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
August 1977	Chlorophyta	25	21	16	19	19	22	23
	Chrysophyta	8	7	4	6	6	7	7
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	67	72	79	75	74	71	70
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
November 1977	Chlorophyta	44	30	26	17	20	31	29
	Chrysophyta	39	55	45	25	31	3	33
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	14	14	28	57	48	63	31
	Euglenophyta	0	0	0	0	0	3	6
	Pyrrophyta	0	0	0	0	0	0	1

Table 5-2. (Continued)

Date	Phytoplankton Group	Tennessee River Mile 496.5	506.5	518.0	527.4	528.0	529.5	532.1
May 1982	Chlorophyta	11	8	11	9	14	8	15
	Chrysophyta	10	11	14	30	42	43	21
	Cryptophyta	43	70	53	37	28	36	43
	Cyanophyta	36	10	22	23	16	13	21
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
August 1982	Chlorophyta	19	27	20	10	10	10	5
	Chrysophyta	12	13	11	7	7	7	3
	Cryptophyta	1	1	1	0	1	0	0
	Cyanophyta	68	60	68	83	83	82	91
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
November 1982	Chlorophyta	20	21	21	18	19	22	14
	Chrysophyta	52	44	43	42	43	38	42
	Cryptophyta	22	14	14	16	17	12	14
	Cyanophyta	5	21	20	23	19	28	29
	Euglenophyta	1	1	1	1	1	1	1
	Pyrrophyta	0	0	0	0	0	0	0
February 1983	Chlorophyta	9	8	7	9	10	9	12
	Chrysophyta	70	57	66	68	64	71	52
	Cryptophyta	2	3	3	4	2	2	2
	Cyanophyta	18	31	23	18	23	17	32
	Euglenophyta	1	1	1	1	1	1	1
	Pyrrophyta	1	0	0	0	0	0	1

Table 5-2. (Continued)

Date	Phytoplankton Group	Tennessee River Mile 496.5	506.5	518.0	527.4	528.0	529.5	532.1
May 1983	Chlorophyta	6	6	8	6	7	7	8
	Chrysophyta	30	38	50	52	48	47	41
	Cryptophyta	39	5	3	3	4	4	2
	Cyanophyta	23	50	38	38	41	41	48
	Euglenophyta	1	1	0	0	0	0	1
	Pyrrophyta	1	1	0	0	0	0	0
August 1983	Chlorophyta	28	23	16	14	13	15	8
	Chrysophyta	11	9	9	8	7	10	4
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	59	66	74	78	79	74	87
	Euglenophyta	1	1	0	0	0	1	0
	Pyrrophyta	1	1	0	0	0	1	1
November 1983	Chlorophyta	52	37	37	26	31	25	42
	Chrysophyta	23	31	51	38	57	34	40
	Cryptophyta	21	7	8	6	8	7	13
	Cyanophyta	0	22	0	28	0	33	0
	Euglenophyta	4	3	3	1	3	2	4
	Pyrrophyta	0	0	0	1	1	0	0
February 1984	Chlorophyta	16	14	14	14	15	20	20
	Chrysophyta	69	56	62	66	68	72	66
	Cryptophyta	5	3	3	5	6	5	7
	Cyanophyta	9	25	20	13	10	0	3
	Euglenophyta	1	1	1	1	2	3	3
	Pyrrophyta	0	0	0	0	0	0	0

Table 5-2. (Continued)

Date	Phytoplankton Group	Tennessee River Mile 496.5	506.5	518.0	527.4	528.0	529.5	532.1
May 1984	Chlorophyta	22	7	13	6	3	4	7
	Chrysophyta	68	80	83	92	96	94	78
	Cryptophyta	0	0	0	1	0	0	1
	Cyanophyta	10	12	4	0	0	0	13
	Euglenophyta	0	1	0	1	1	1	1
	Pyrrophyta	0	0	0	0	0	0	0
August 1984	Chlorophyta	27	27	15	9	11	13	14
	Chrysophyta	9	6	6	7	6	7	8
	Cryptophyta	1	1	1	0	1	1	1
	Cyanophyta	64	66	77	83	82	78	77
	Euglenophyta	0	0	0	0	0	0	0
	Pyrrophyta	0	0	0	0	0	0	0
November 1984	Chlorophyta	32	43	71	42	40	50	53
	Chrysophyta	42	38	15	44	35	38	39
	Cryptophyta	1	2	0	1	1	1	1
	Cyanophyta	22	14	12	13	22	6	3
	Euglenophyta	3	2	1	1	2	4	3
	Pyrrophyta	0	0	0	0	0	1	0
February 1985	Chlorophyta	19	13	13	10	11	11	15
	Chrysophyta	54	53	56	51	45	47	47
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	25	32	29	38	44	42	37
	Euglenophyta	2	1	2	1	1	0	1
	Pyrrophyta	0	0	0	0	0	0	0

Table 5-2. (Continued)

Date	Phytoplankton Group	Tennessee River Mile 496.5	506.5	518.0	527.4	528.0	529.5	532.1
May 1985	Chlorophyta	27	24	21	14	14	12	7
	Chrysophyta	27	41	44	52	48	53	46
	Cryptophyta	0	2	1	1	1	1	0
	Cyanophyta	44	32	32	32	35	32	45
	Euglenophyta	1	1	1	1	1	1	1
	Pyrrophyta	0	0	0	0	1	1	0
August 1985	Chlorophyta	27	21	22	21	22	17	21
	Chrysophyta	14	11	12	11	12	10	8
	Cryptophyta	2	1	1	1	0	0	0
	Cyanophyta	56	67	64	67	65	72	69
	Euglenophyta	1	1	0	1	1	1	1
	Pyrrophyta	1	0	0	0	0	0	1
November 1985	Chlorophyta	16	21	27	45	42	45	37
	Chrysophyta	14	18	15	24	27	22	27
	Cryptophyta	0	0	0	0	0	0	0
	Cyanophyta	68	59	56	30	30	32	34
	Euglenophyta	2	2	1	1	1	1	1
	Pyrrophyta	1	0	0	0	0	0	0

Table 5-3. Results of Statistical Analysis (Four-Way ANOVA and SNK Multiple Range Test of Data Sets with Significant F-Ratios) on Phytoplankton Preoperational Abundance Data (Log Transformed) Watts Bar Nuclear Plant, 1973-1985

Variance Square	Degree of Freedom	Sum of Squares	F-Value	Probability > F
River Mile (RM)	6	144.06	5.58	0.0001*
Year	7	670.40	22.27	0.0001*
Depth	3	24.76	1.92	0.1243
Quarter	3	959.07	74.33	< 0.0001*
RM x Year	42	180.98	1.00	0.4680
RM x Depth	18	28.04	0.36	0.9935
Rm x Quarter	18	94.30	1.22	0.2361
Year x Depth	21	40.28	0.45	0.9859
Year x Quarter	21	949.19	10.51	0.0001**
Depth x Quarter	9	11.54	0.30	0.9755
RM x Year x Depth	126	144.66	0.27	1.0000
Rm x Depth x Quarter	54	54.10	0.23	1.0000
RM x Year x Quarter	126	448.77	0.83	0.9175
RM x Year x Depth x Quarter	441	651.60	0.34	1.0000

SNK Multiple Range Tests of Significant Four-Way F-Ratios

	SNK							
River Mile df = 3584	Low Mean							High Mean
	5	4	6	9	8	7	10	
Year df = 3584	74	73	76	75	84	77	83	85
Quarter df = 3584	Fall		Spring		Winter		Summer	

*Significant main effect, subjected to SNK.
** Significant interaction (secondary effect) discussed in body of report.

SNK Multiple Range Test: Means ranked lowest to highest using station numbers; means not underscored by the same line are significantly different at $\alpha = 0.05$.

Station 4 = Tennessee River Mile 496.5
" 5 = " " " 506.6
" 6 = " " " 518.0
" 7 = " " " 527.4
" 8 = " " " 528.0
" 9 = " " " 529.5
" 10 = " " " 532.1

Table 5-4. Results of Four-Way Analysis of Variance for Phytoplankton Production in the Vicinity of Watts Bar Nuclear Plant

Variation Source	Degrees of Freedom	SS	F	PR > F
River Mile (R)	6	4240.27	11.93	0.0001
Year (Y)	4	3750.01	15.79	0.0001
Month (M)	3	7843.72	44.05	0.0001
Depth (D)	3	19646.18	110.32	0.0001
R x Y	24	3538.56	2.48	0.0001
R x M	18	2933.76	2.75	0.0001
R x D	18	2848.42	2.67	0.0001
Y x M	12	4898.65	6.88	0.0001
Y x D	12	3808.94	5.35	0.0001
M x D	9	5040.21	9.43	0.0001
R x Y x M	72	6225.01	4.04	0.0001
R x Y x D	72	2342.89	1.52	0.0113
R x M x D	54	2027.13	1.76	0.0026
Y x M x D	36	3296.18	4.28	0.0001
R x Y x M x D	216	4619.61		

Table 5-5. Summary of ANOVA for Primary Productivity for Watts Bar Biological Investigations. Least Significant Differences (LSD) Indicated if F was Significant (PR > F ≥ 0.001)

Comparison	Primary Productivity	99 Percent LSD
I. River Mile (R) (n = 80)		
496.5 (R1)	5.20a*	
506.5 (R2)	4.15a	
518.0 (R3)	6.31ab	
527.4 (R4)	11.17cd	
528.0 (R5)	8.70bc	
529.5 (R6)	7.21ab	
532.1 (R7)	12.08d	
		3.14
II. Year (Y) (n = 112)		
1973 (Y1)	9.95cd	
1974 (Y2)	4.09a	
1976 (Y3)	7.39bc	
1977 (Y4)	11.38d	
1983 (Y5)	6.35ab	
		2.65
III. Month (M) (n = 140)		
February (M1)	4.95a	
May (M2)	8.26b	
August (M3)	13.78c	
November (M4)	4.34a	
		2.37
IV. Depth (D) (n = 140)		
0.3M (D1)	15.56c	
1.0M (D2)	11.54b	
3.0M (D3)	2.91a	
5.0M (D4)	1.31a	
		2.37

Table 5-5. (Continued)

Comparison	Primary Productivity	99 Percent LSD
V. R x Y (n = 16)		
R1Y1	3.98a	
R1Y2	3.29a	
R1Y3	4.71a	
R1Y4	8.11a	
R1Y5	5.89a	
R2Y1	4.17a	
R2Y2	1.40a	
R2Y3	4.92a	
R2Y4	4.60a	
R2Y5	5.68a	
R3Y1	8.47a	
R3Y2	2.92a	
R3Y3	6.56a	
R3Y4	6.14a	
R3Y5	7.46a	
R4Y1	12.60b	
R4Y2	4.48a	
R4Y3	8.74ab	
R4R4	16.52c	
R4Y5	13.52bc	
R5Y1	12.57b	
R5Y2	5.04a	
R5Y3	8.61ab	
R5Y4	11.93ab	
R5Y5	5.38a	
R6Y1	10.18a	
R6Y2	3.98a	
R6Y3	7.49a	
R6Y4	10.66a	
R6Y5	3.73a	
R7Y1	17.66cd	
R7Y2	7.50ab	
R7Y3	10.68bc	
R7Y4	21.73d	
R7Y5	2.82a	
		7.02

Table 5-5. (Continued)

Comparison	Primary Productivity	99 Percent LSD
VI. R x M (n = 20)		
R1M1	2.89ab	
R1M2	7.78b	
R1M3	8.97b	
R1M4	1.15a	
R2M1	4.83a	
R2M2	4.29a	
R2M3	6.06	
R2M4	1.43a	
R3M1	5.31ab	
R3M2	5.77ab	
R3M3	10.76b	
R3M4	3.40a	
R4M1	5.86a	
R4M2	9.76a	
R4M3	24.09b	
R4M4	4.98a	
R5M1	5.48a	
R5M2	7.88a	
R5M3	15.63b	
R5M4	5.84a	
R6M1	4.66a	
R6M2	6.30ab	
R6M3	12.35b	
R6M4	5.53a	
R7M1	5.64a	
R7M2	16.05b	
R7M3	18.58b	
R7M4	8.04a	
		6.28
VII. R x D (n = 20)		
R1D1	11.01b	
R1D2	7.18b	
R1D3	1.70a	
R1D4	0.90a	
R2D1	7.60a	

Table 5-5. (Continued)

Comparison	Primary Productivity	99 Percent LSD
VII. R x D (n = 20) (Continued)		
R2D2	5.43a	
R2D3	2.07a	
R2D4	1.52a	
R3D1	12.22b	
R3D2	9.90b	
R3D3	2.26a	
R3D4	0.86a	
R4D1	22.03b	
R4D2	16.84b	
R4D3	4.15a	
R4D4	1.68a	
R5D1	17.93b	
R5D2	12.21b	
R5D3	3.22a	
R5D4	1.46a	
R6D1	14.63b	
R6D2	10.52b	
R6D3	2.53a	
R6D4	1.16a	
R7D1	23.53b	
R7D2	18.74b	
R7D3	4.47a	
R7D4	1.58a	
		6.28
VIII. Y x M (n = 28)		
Y1M1	7.31a	
Y1M2	6.63a	
Y1M3	21.51b	
Y1M4	4.34a	
Y2M1	1.09a	
Y2M2	2.82ab	
Y2M3	7.35b	
Y2M4	5.09ab	
Y3M1	4.87a	
Y3M2	4.53a	

Table 5-5. (Continued)

Comparison	Primary Productivity	99 Percent LSD
VIII. Y x M (n = 28) (Continued)		
Y3M3	14.10b	
Y3M4	6.05a	
Y4M1	9.76b	
Y4M2	15.30c	
Y4M3	17.20c	
Y4M4	3.27a	
Y5M1	1.74a	
Y5M2	12.02b	
Y5M3	8.73b	
Y5M4	2.93a	
		5.30
IX. Y x D (n = 28)		
Y1D1	21.26a	
Y1D2	15.09b	
Y1D3	2.53c	
Y1D4	0.90c	
Y2D1	8.52a	
Y2D2	5.60ab	
Y2D3	1.58bc	
Y2D4	0.64c	
Y3D1	14.01a	
Y3D2	11.63a	
Y3D3	2.88b	
Y3D4	1.03b	
Y4D1	24.38a	
Y4D2	15.61b	
Y4D3	3.50c	
Y4D4	2.04c	
Y5D1	9.64a	
Y5D2	9.79a	
Y5D3	4.08b	
Y5D4	1.91b	
		5.30

Table 5-5. (Continued)

Comparison	Primary Productivity	99 Percent LSD
X. M x D (n = 35)		
M1D1	9.17b	
M1D2	7.41b	
M1D3	1.91a	
M1D4	1.33a	
M2D1	16.10b	
M2D2	11.76b	
M2D3	3.49a	
M2D4	1.70a	
M3D1	27.76c	
M3D2	26.72b	
M3D3	4.95a	
M3D4	1.68a	
M4D1	9.22b	
M4D2	6.29b	
M4D3	1.31a	
M4D4	0.52a	
		4.74

*Values with the same letter are not significantly different from one another.

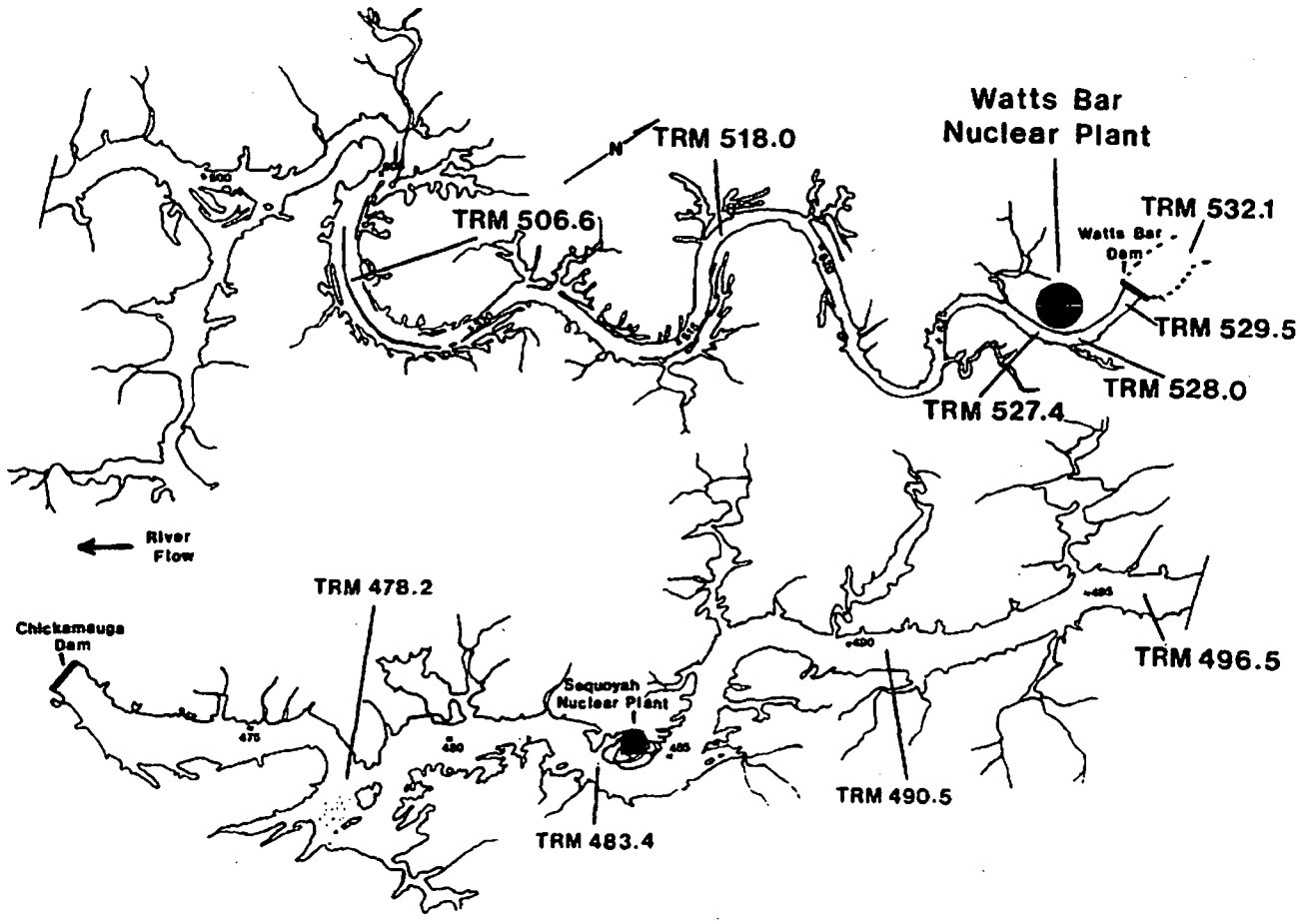


Figure 5-1. Location of Plankton Sample Stations for Watts Bar Nuclear Plant (Larger Sized Print) and Sequoyah Nuclear Plant (Smaller Sized Print) on Chickamauga Reservoir. Two Additional Locations (TRMs 472.8 and 484.5) Were Sampled as Part of Sequoyah Nuclear Plant Monitoring in July 1985.

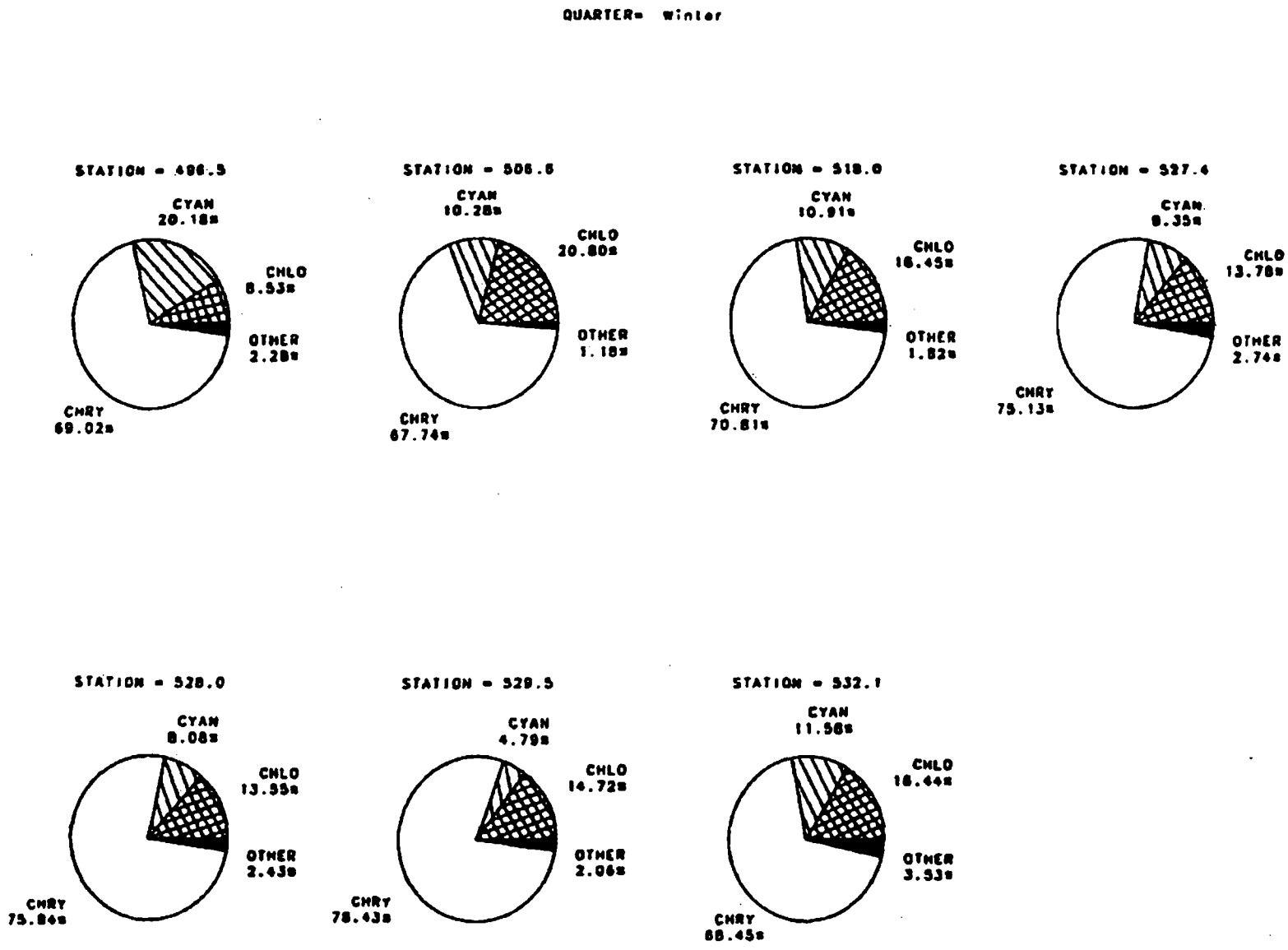


Figure 5-2. Percentage Composition by Major Group (Years Combined) of the Winter Phytoplankton Assemblage in the Vicinity of Watts Bar Nuclear Plant, 1973-1985.

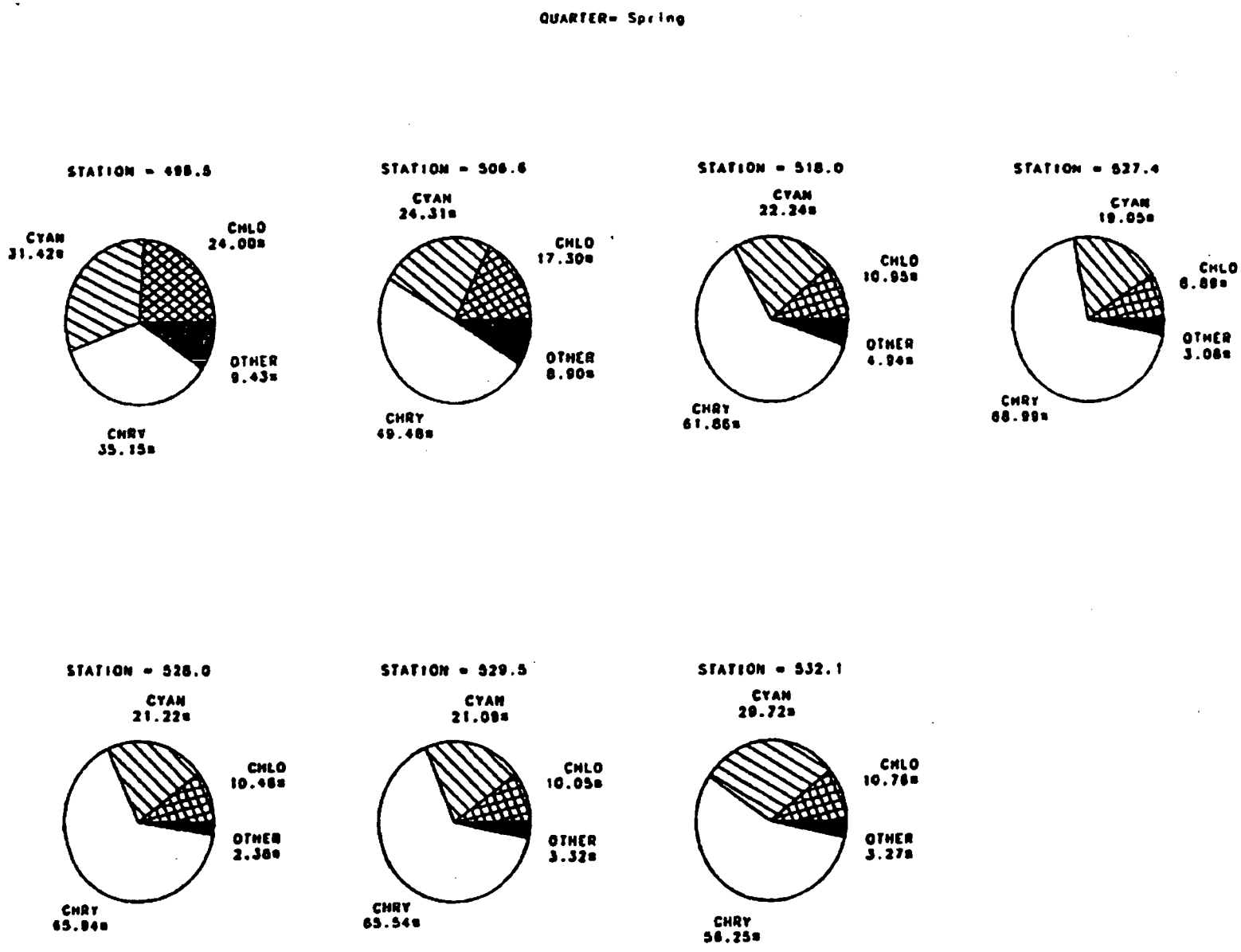


Figure 5-3. Percentage Composition by Major Group (Years Combined) of the Spring Phytoplankton Assemblage in the Vicinity of Watts Bar Nuclear Plant, 1973-1985.

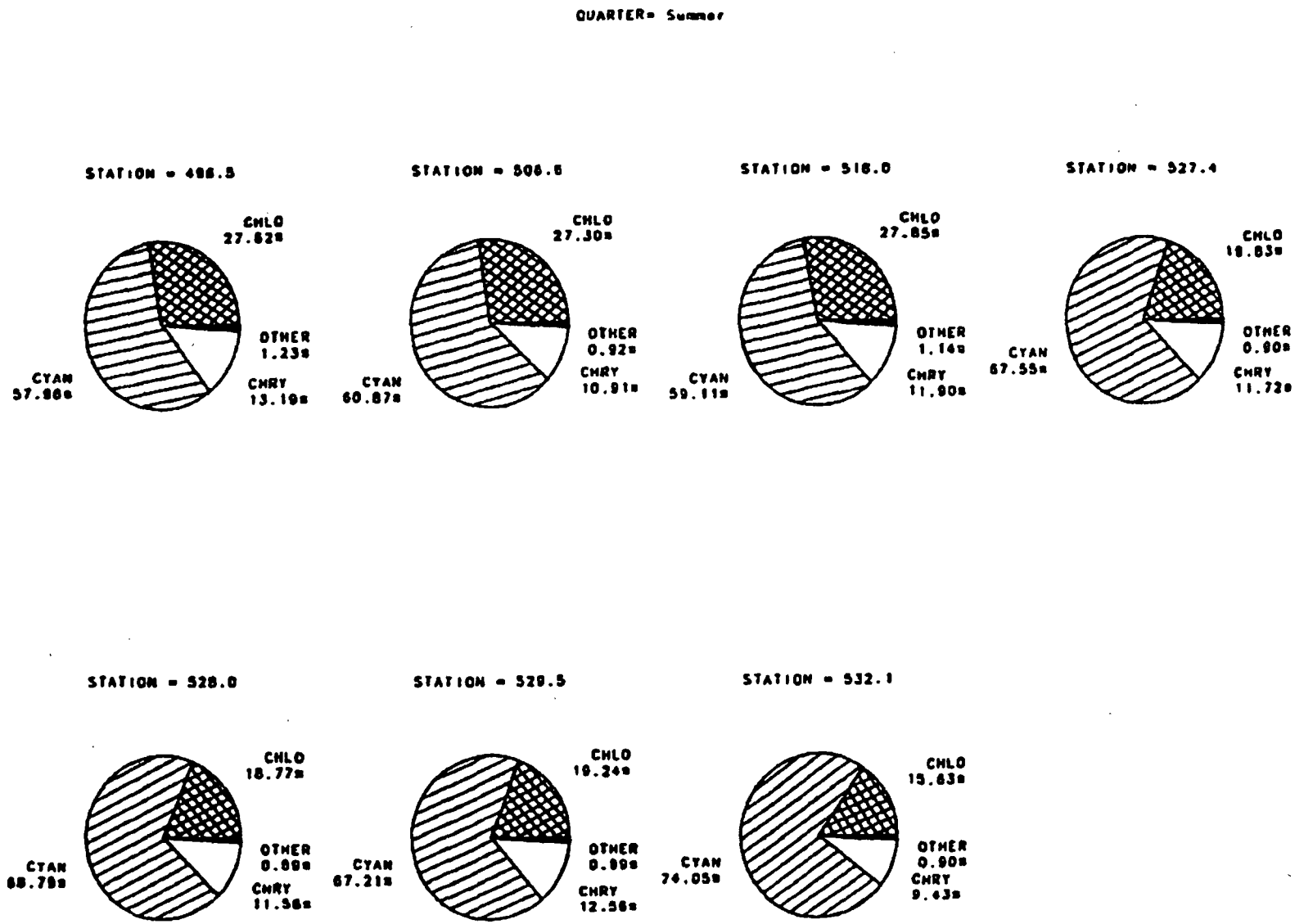


Figure 5-4. Percentage Composition by Major Group (Years Combined) of the Summer Phytoplankton Assemblage in the Vicinity of Watts Bar Nuclear Plant, 1973-1985.

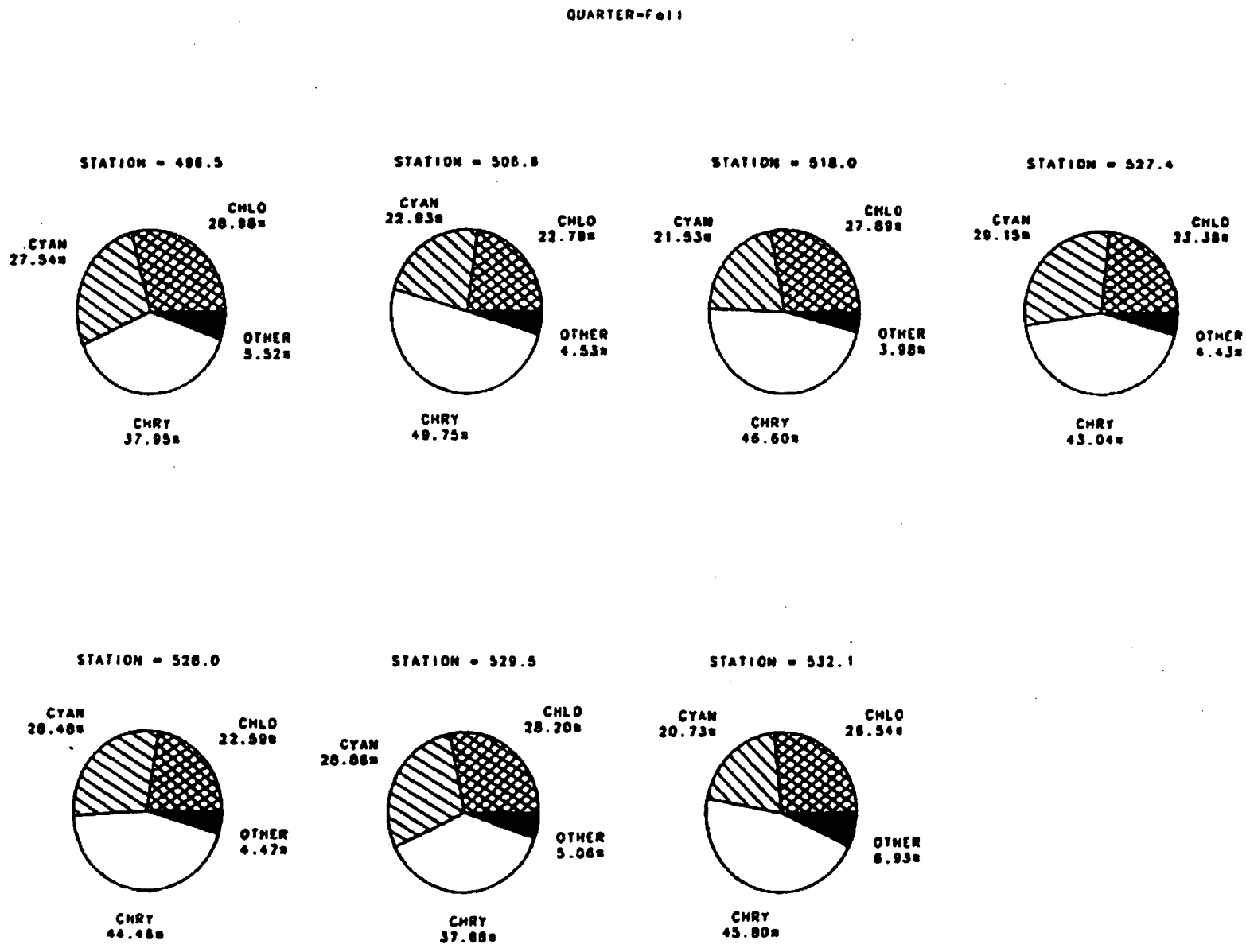


Figure 5-5. Percentage Composition by Major Group (Years Combined) of the Fall Phytoplankton Assemblage in the Vicinity of Watts Bar Nuclear Plant, 1973-1985.

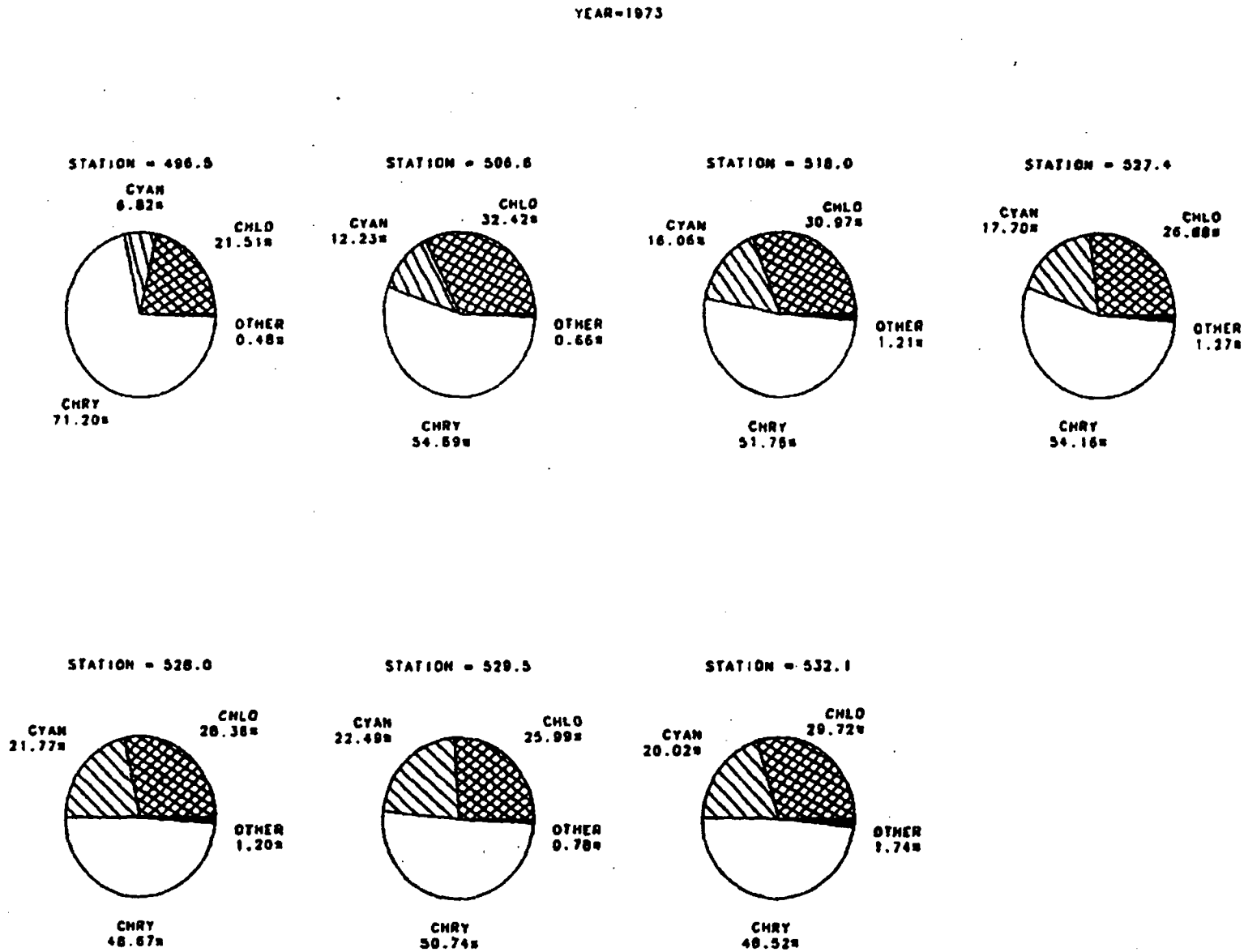


Figure 5-6. Percentage Composition by Major Group (Quarters Combined) of the Phytoplankton Assemblage at Each Station in the Vicinity of Watts Bar Nuclear Plant in 1973.

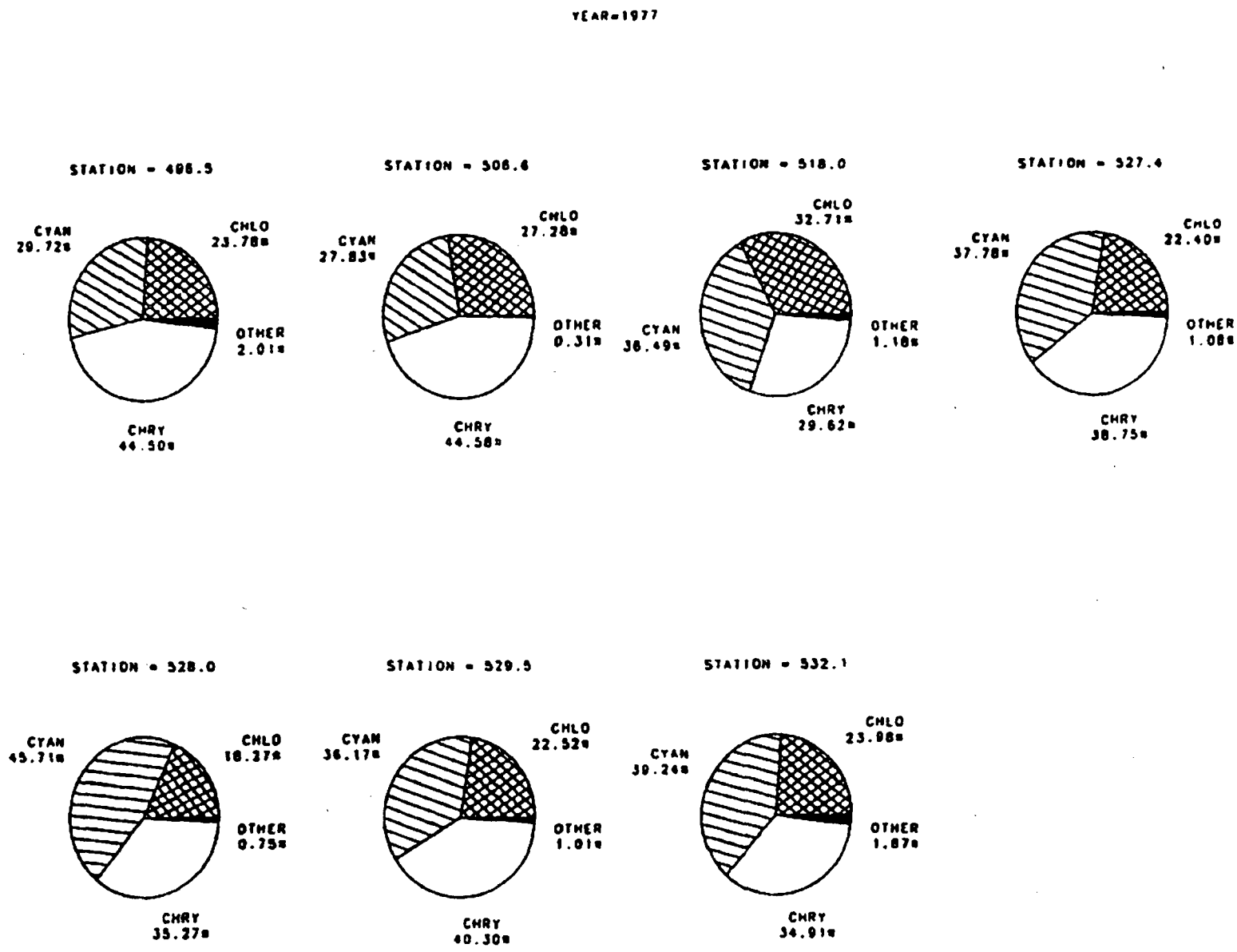


Figure 5-7. Percentage Composition by Major Group (Quarters Combined) of the Phytoplankton Assemblage at Each Station in the Vicinity of Watts Bar Nuclear Plant in 1977.

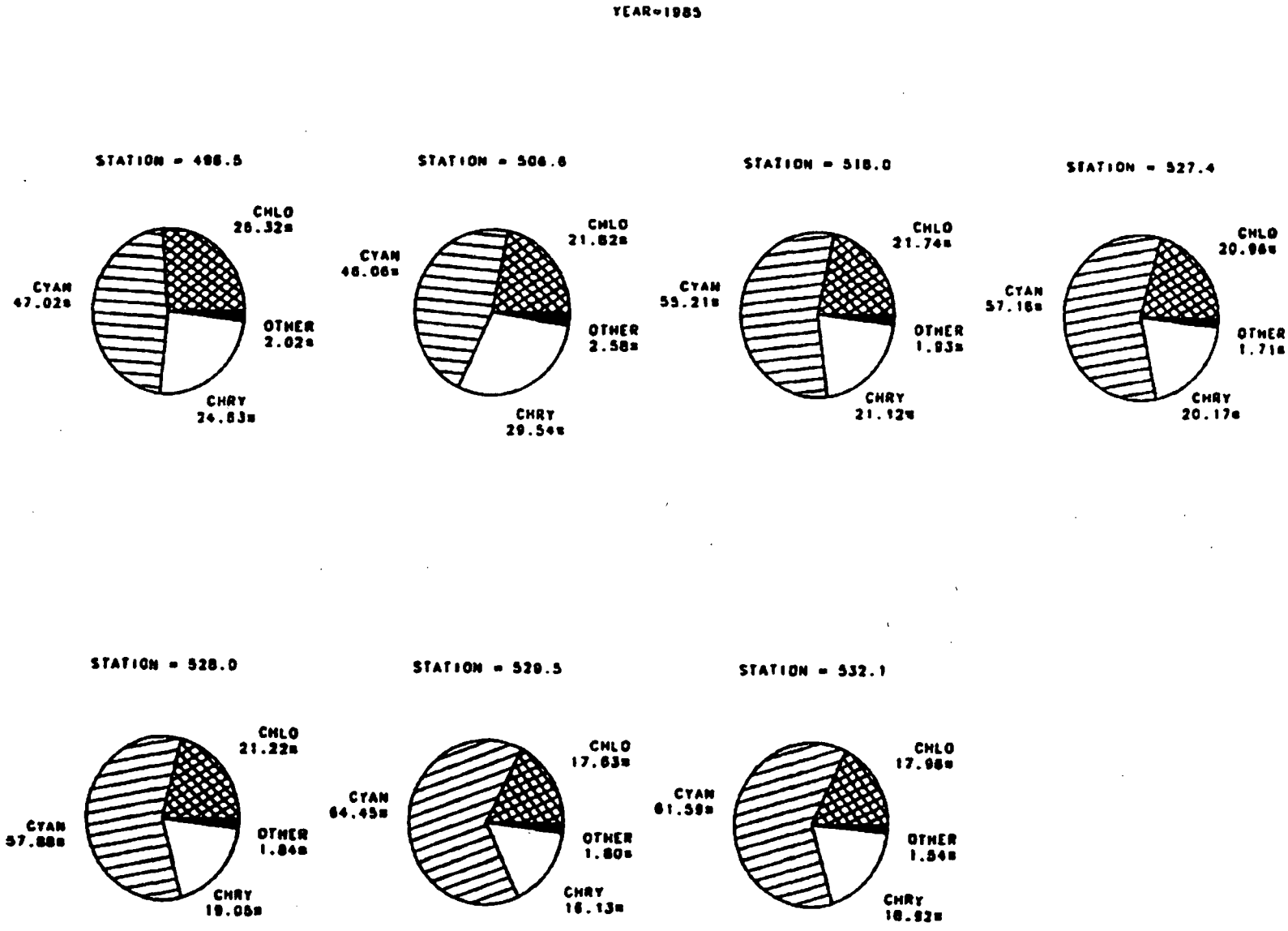


Figure 5-8. Percentage Composition by Major Group (Quarters Combined) of the Phytoplankton Assemblage at Each Station in the Vicinity of Watts Bar Nuclear Plant in 1985.

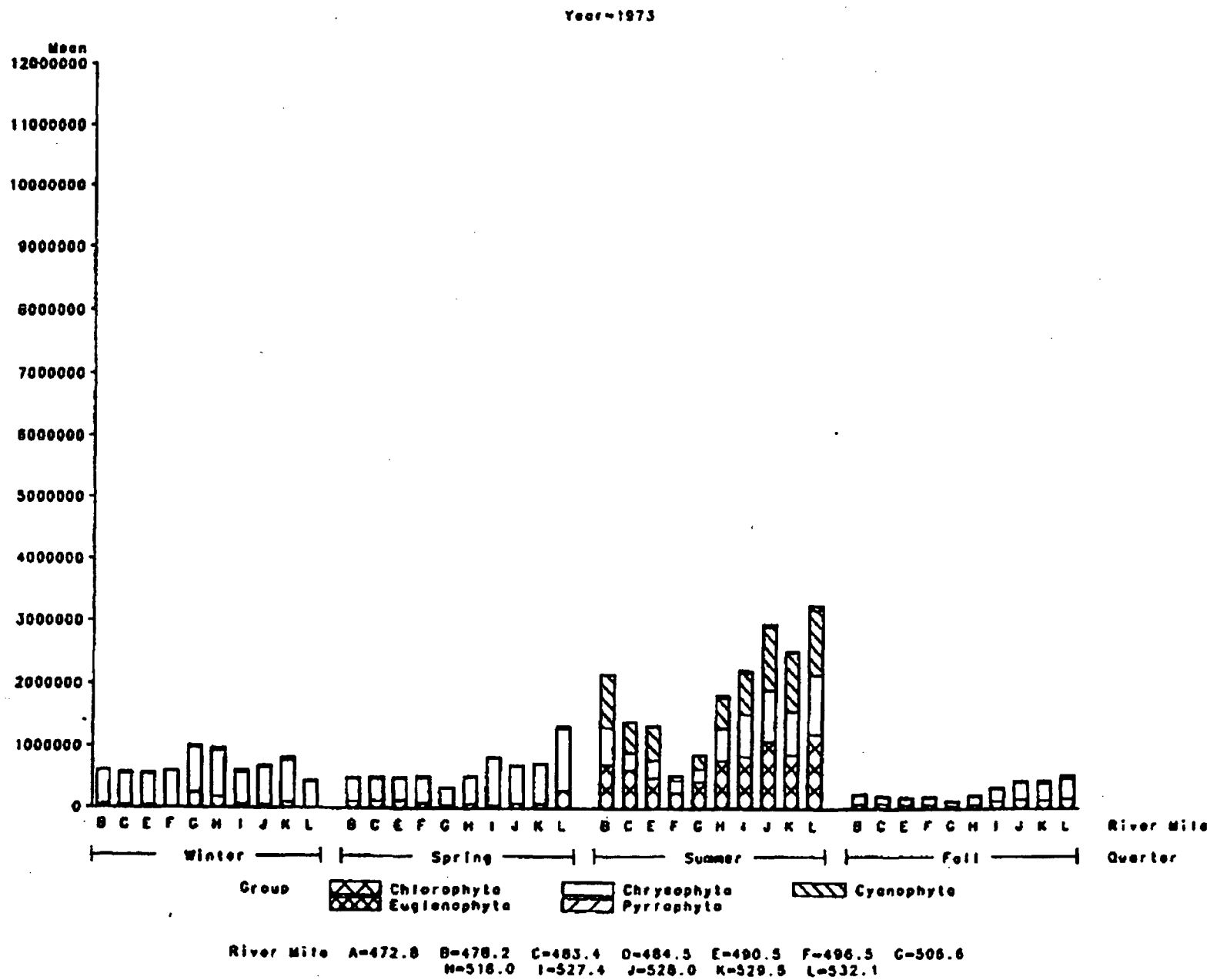


Figure 5-9. Phytoplankton Abundance by Group for Chickamauga Reservoir and Watts Bar Reservoir Forebay Sample Stations, Watts Bar Nuclear Plant, 1973.

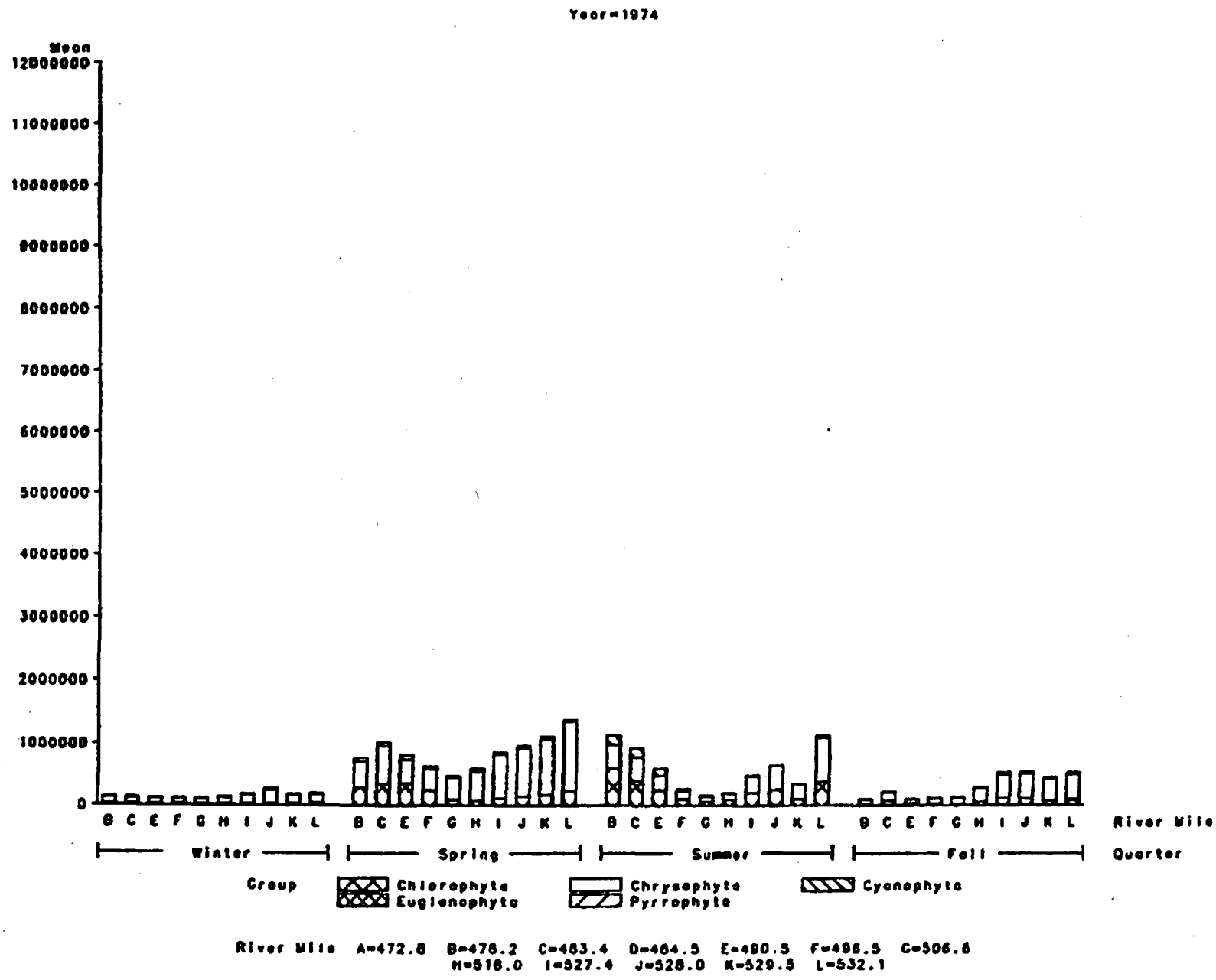


Figure 5-10. Phytoplankton Abundance by Group for Chickamauga Reservoir and Watts Bar Reservoir Forebay Sample Stations, Watts Bar Nuclear Plant, 1974.

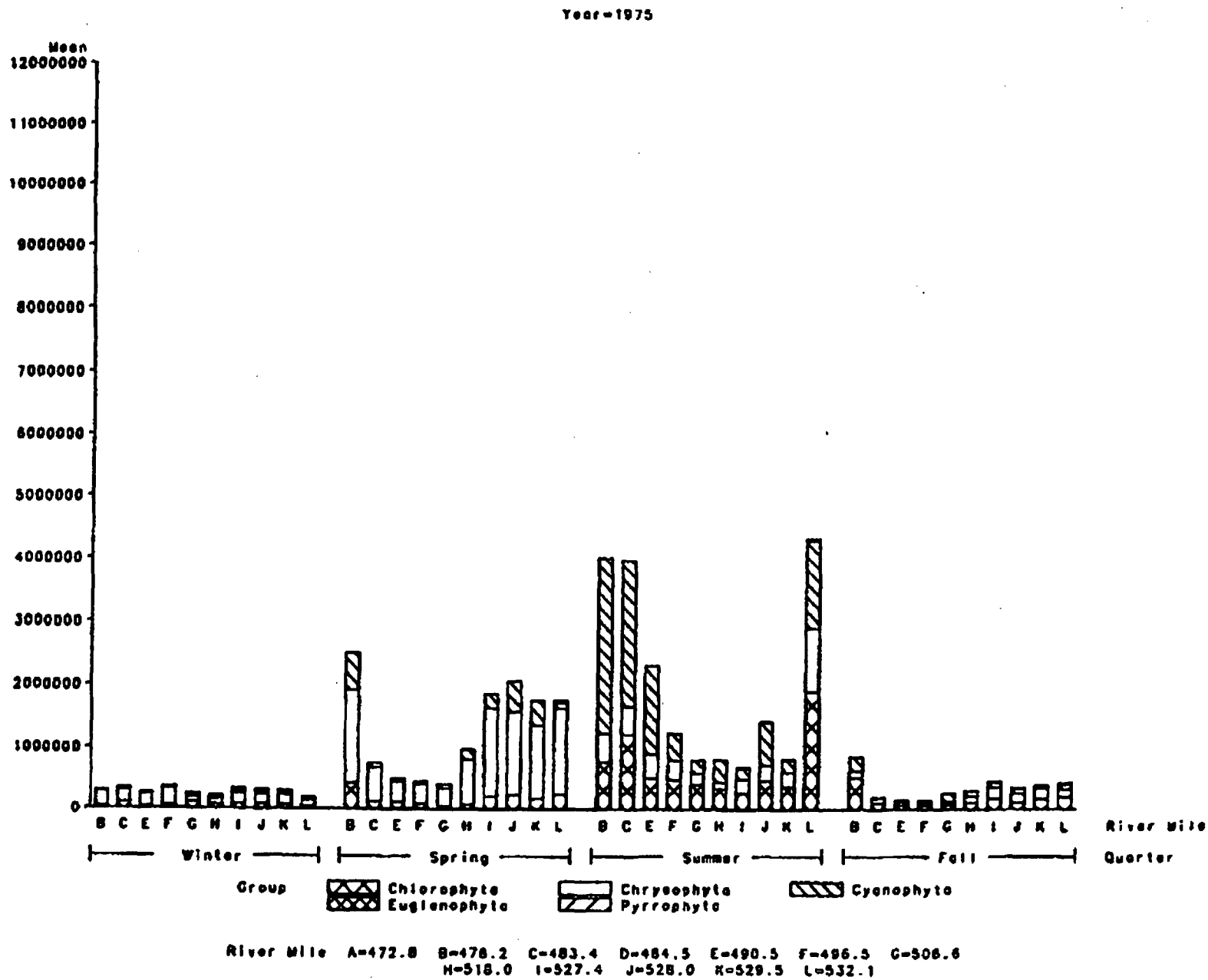


Figure 5-11. Phytoplankton Abundance by Group for Chickamauga Reservoir and Watts Bar Reservoir Forebay Sample Stations, Watts Bar Nuclear Plant, 1975.

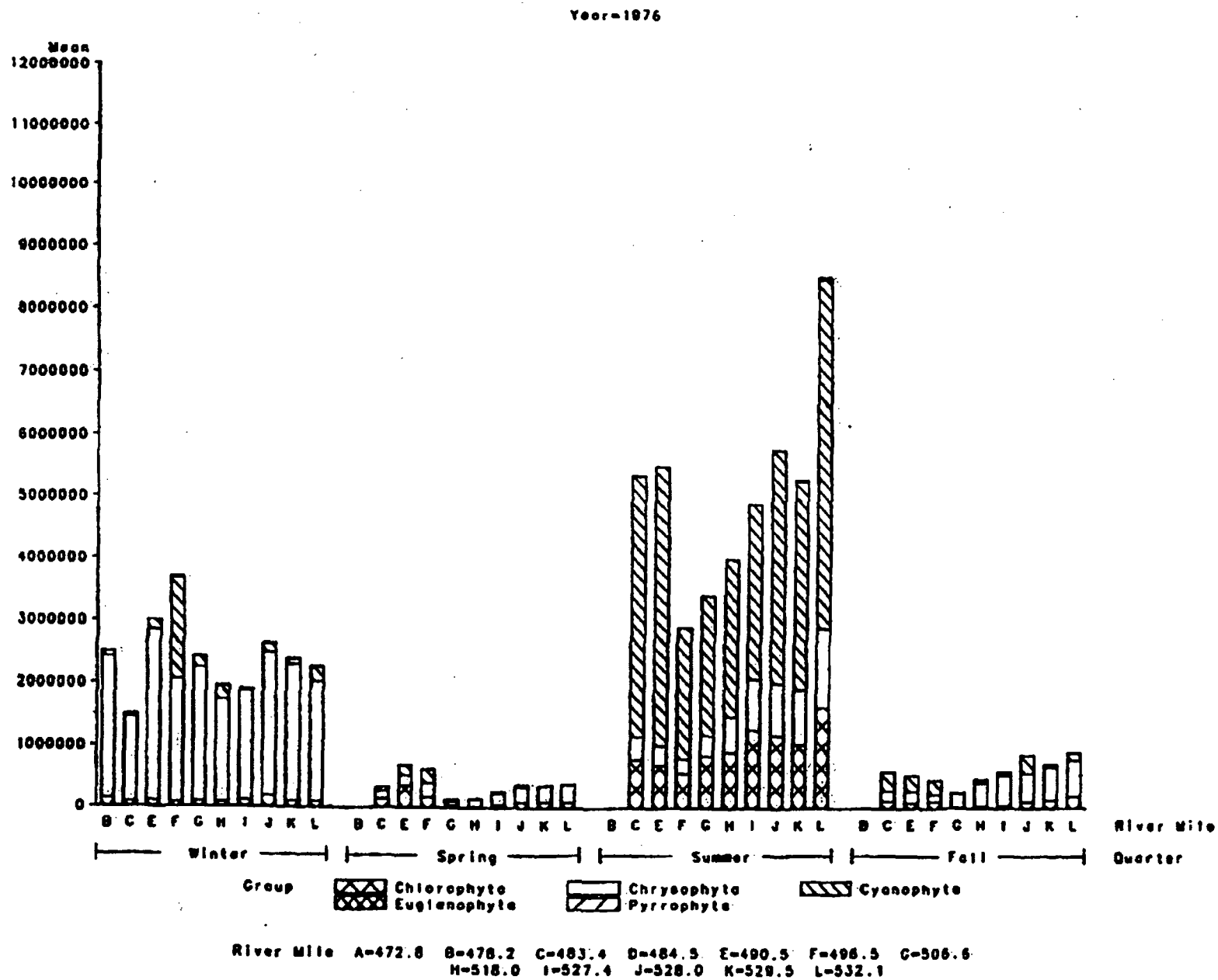


Figure 5-12. Phytoplankton Abundance by Group for Chickamauga Reservoir and Watts Bar Reservoir Forebay Sample Stations, Watts Bar Nuclear Plant, 1976.

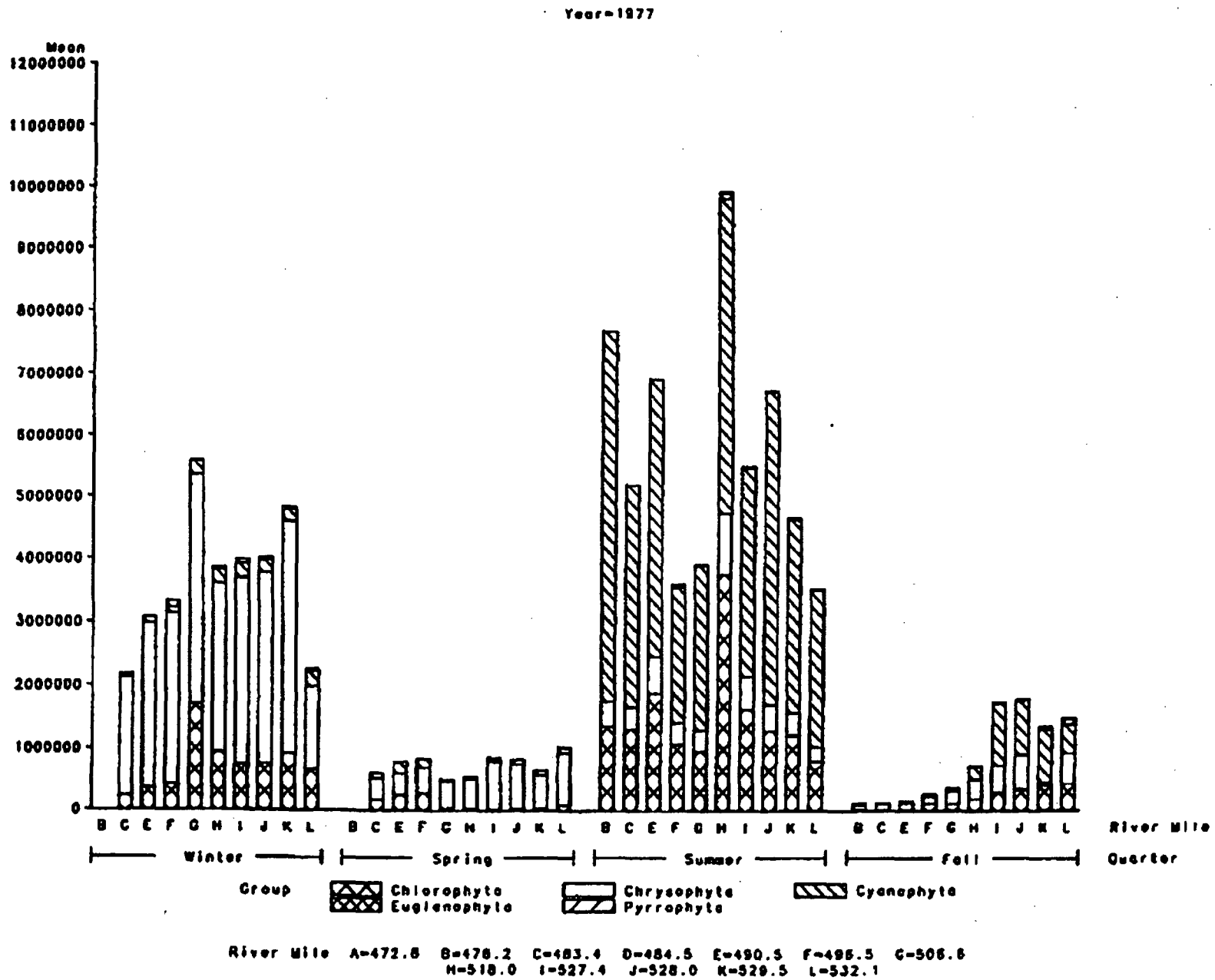


Figure 5-13. Phytoplankton Abundance by Group for Chickamauga Reservoir and Watts Bar Reservoir Forebay Sample Stations, Watts Bar Nuclear Plant, 1977.

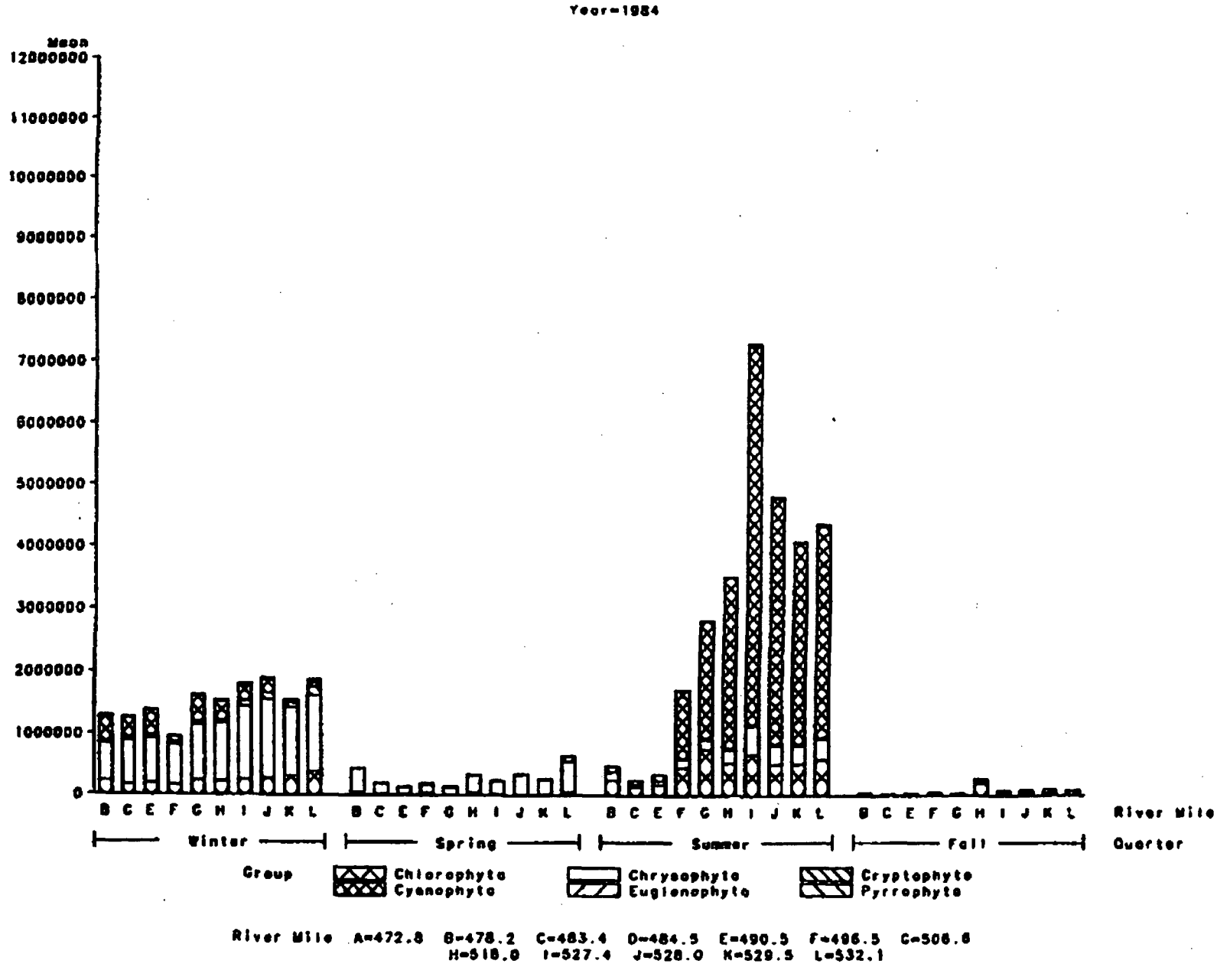


Figure 5-16. Phytoplankton Abundance by Group for Chickamauga Reservoir and Watts Bar Reservoir Forebay Sample Stations, Watts Bar Nuclear Plant, 1984.

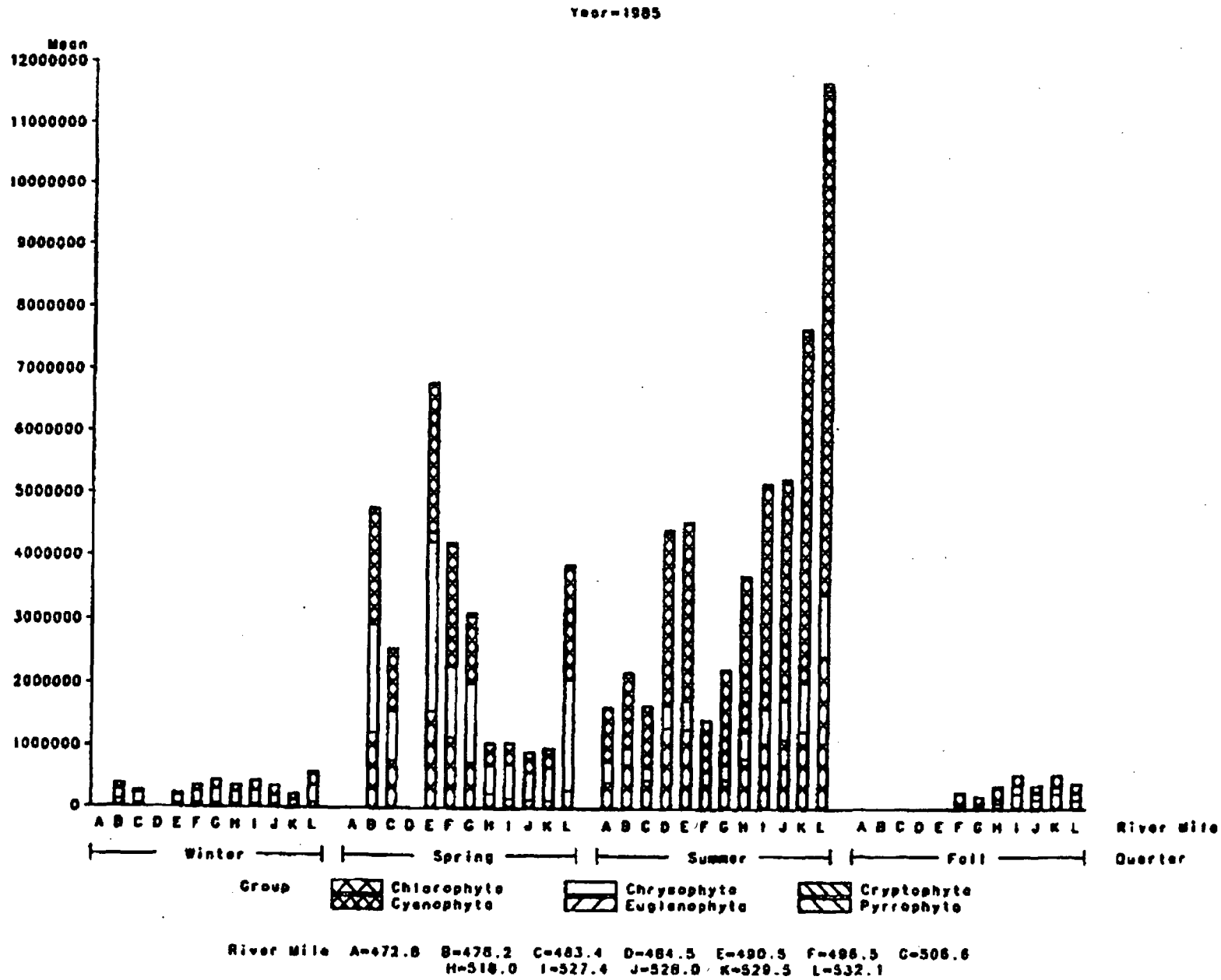


Figure 5-17. Phytoplankton Abundance by Group for Chickamauga Reservoir and Watts Bar Reservoir Forebay Sample Stations, Watts Bar Nuclear Plant, 1985.

5.3.1 Zooplankton Results and Discussion

In excess of 400 zooplankton samples were collected during 32 quarterly surveys for the preoperational monitoring period incorporating a nine-year spread between 1973 and 1985.

The primary purpose for reporting these data is to have baseline results which can be compared to data that will be collected during operation of the Watts Bar Nuclear Plant (WBN). The approach selected here is to present and discuss results for each season using the following two comparisons

(1) Description of Zooplankton Within the WBN Study Reach. This description is provided to assess preoperational baseline conditions, so that any shifts in community structure (numbers and composition) can be identified if they occur after the plant becomes operational. This evaluation was primarily based upon an analysis of total densities, total number of taxa, the diversity index derived from the total number of taxa, dominant and subdominant taxa, Sorenson's Quotient of Similarity (SQS), and the Percentage of Similarity (PS). Results presented include both spatial and temporal comparisons of the seven WBN stations (figure 5-1), which extended from station 4 at TRM 496.5 to station 10 (above the Watts Bar Dam) at TRM 532.1. (Stations 1 through 3 are associated with monitoring at Sequoyah Nuclear Plant, also on Chickamauga Reservoir, and were used in selected data analyses presented in subsequent paragraphs). Preoperational monitoring of WBN stations was carried out over two collection periods, extending from winter 1973 to winter 1978 and from spring 1982 to fall 1985.

(2) Trends in the Chickamauga Reservoir Community. This section examines trends observed in the zooplankton for both the seven WBN stations and the three (five for July 1985 data) Sequoyah Nuclear Plant (SQN) stations to provide an understanding and evaluation throughout the length of Chickamauga Reservoir. Initially, two-way ANOVAs were to be used to examine the spatial and temporal trends each year at the seven WBN stations, but the interaction term was significant in many of the tests, indicating that the involved spatial and temporal factors could not be considered as acting independent of each other. Therefore, it was decided that in lieu of the two-way ANOVAs, temporal comparisons would be based on the subjective evaluation of graphed density data while spatial comparisons would be determined from one-way ANOVAs and Student-Newman-Keuls (SNK) a posteriori tests. Spatial comparisons for the seven WBN stations alone and in conjunction with the three SQN stations were examined using either polynomial regression analysis or linear regression, depending on which provided greatest R^2 value (accountable variability). The three SQN stations were identified as: station 1 TRM 478.2, station 2 TRM 483.4 and station 3 TRM 490.5. The regression analyses were the only tests which included data from all ten stations on Chickamauga Reservoir.

It should be noted that because of the difficulty and expense with sampling the same watermass as it moves downstream, the most expedient compromise was to collect samples for a specific sample period on the same day. Hence, in most cases, collections at stations separated by several miles probably represented different watermasses, which in some cases may have accounted for differences in the zooplankton among sample locations.

Although in theory it would be better to sample the same watermass, monitoring programs such as this one must assume that the zooplankton is a continuum throughout the study reach. This assumption may be generally acceptable when travel time through the study reach is only a few days. However, it would be less valid when water temperatures are high or when there is a travel time of several days between stations. When these latter conditions occur, the data must be evaluated carefully with the above considerations in mind.

Winter

Description of the Zooplankton Within the WBN Study Reach (summarized in table 5-6 and figure 5-18, and detailed in appendices 5-H, 5-I, 5-J, 5-K, and 5-L)--Winter zooplankton densities would be expected to be lower than other times of the year due to the lessening of growth and reproductive rates in the colder water temperatures. As a result, zooplankton from flow-through reservoirs like Watts Bar and Chickamauga Reservoirs would not respond rapidly to environmental changes (such as shifts in food supply, minor temperature fluctuations, etc.), and generally similar densities would be expected among collection locations. This similarity would be even more pronounced under high flow rates, which increases the homogenity of the study reach.

A wide range of physical conditions existed throughout this study (see chapter 2). For the seven WBN stations, water temperatures on the winter sample dates ranged from 2.5° C (1977) to 9.0° C (1975), and flow rates between 19,400 cfs (1973) and 85,400 cfs (1975). Travel times between

the Watts Bar Dam (at station 9) and the lowest WBN station (station 4 at TRM 496.6) varied between 16 hours (1975) to 2.25 days (1973). Travel times in winter generally were shorter than travel times of the other three seasons due to lower water surface elevations in winter. Short retention times coupled with lower water temperatures should have prevented drastic changes in the winter zooplankton composition and density as a watermass moved downstream.

Rotifers numerically dominated the winter zooplankton at the seven WBN stations for all years sampled. Copepods always were the second most numerous group, and cladocerans usually composed a negligible proportion of the zooplankton community. All samples indicated that either Keratella, Polyarthra, Synchaeta or copepod nauplii larvae were dominant or subdominant. Synchaeta was most frequently the dominant zooplankton animal in the winter collections.

Since rotifers consistently dominated the zooplankton, trends observed for total number of taxa, diversity indices, and total densities mirrored patterns in the winter rotifer populations. The lowest number of taxa generally occurred in 1973 and the highest in 1985, with a similar number of taxa collected between these two extremes. Diversity index values were expected to be lowest in the winter because only a few taxa usually dominate the community. The seven WBN stations exhibited these expected results for all years sampled, with a high value of only 2.43, and three values below 1.0 when Synchaeta comprised more than three-fourths of the total community density. The SQS values indicated that similar taxa usually existed at six of the seven WBN stations, with station 4 at TRM 496.5 often

producing dissimilar results (most evident in 1977). The PS values also indicated a difference at station 4. The consistently observed difference between station 4 and the other six WBN stations is believed to be due in part to recruitment and an increase in allochthonous materials originating from the Hiwassee River entering at TRM 500 between station 4 and station 5. These differences were particularly evident during low flow years which allowed community changes to occur even in winter. It is also interesting to note that fewer SQS similarities (SQS value > 70 percent) were obtained for 1983-1985 when preoperational monitoring was reinitiated after a hiatus of five winters than were found from 1973-1977. However, PS values did not show a difference between the two WBN preoperational collection periods. Since SQS is more affected by the presence/absence of "rare" taxa than PS, fewer SQS similarities in 1983-85 than in 1973-77 were probably related to a greater sampling effort (three replicates) in the latter years than in the earlier years (two replicates). In most cases, a greater sampling effort can be expected to result in collecting more "rare" taxa. The lowest total densities in winter occurred in 1974 (range of 3.3 to 6.1 x 10^3 per m^3 at the seven WBN stations) and 1975 (range of 11.1 to 22.4 x 10^3 per m^3 at the seven WBN stations) when river flows were highest (68,800 cfs in 1974 and 85,000 cfs in 1975). No doubt these low densities reflect washout from high flows. In turn, highest total densities (range of 101.4 to 190.20 x 10^3 per m^3 at the seven WBN stations) occurred in 1977 when river flow was only 27,900 cfs. It is interesting to note that the coldest water temperature of 2.5° C also occurred during this sample period,

and that instead of the typical rotifer genus Synchaeta being dominant, another rotifer, Keratella, was dominant. No long-term temporal trends were evident in the winter zooplankton densities.

Trends in the Chickamauga Reservoir Community (summarized in table 5-7)--The one-way ANOVAs examining spatial (upstream/downstream) trends at the seven WBN stations provided only two significant tests copepod densities in 1977 and 1984. In 1977 the highest mean copepod densities at station 10 (the only site above the Watts Bar Dam) were significantly different from the lowest mean copepod densities at stations 4 and 6, while in 1984 the highest mean copepod densities at sites 10 and 8 were significantly different from the lowest mean densities at site 5. These results indicate that in 1977 and 1984 copepod densities were lower at the downstream stations than at the upstream stations. Regression analysis run on the ten combined WBN and SQN stations produced significant polynomial equations in 1977, 1983, and 1984. These regression curves did not produce any consistent trends. Regression analysis on 1976 data was significant but this result is of limited use because data only were collected at one WBN station (station 4) in this year.

Spring

Description of Zooplankton Within the WBN Study Reach (summarized in table 5-8 and figure 5-19 and detailed in appendices 5-H, 5-I, 5-J, 5-K, and 5-L)--In contrast to the anticipated low densities of zooplankton in the winter, spring would be expected to exhibit high numbers of animals. This expectation is due primarily to heavy recruitment of zooplankton, increased

ambient temperatures, and high allochthonous material load continually being introduced into the study area by runoff from rain showers. The slower moving pool-like reservoir waters provide good habitat for growth and reproduction. Zooplankton from the forebay of Watts Bar Reservoir could be introduced into the study reach, collected at the sampled stations, and produce the expected high spring densities. Likewise, slowly moving areas of Chickamauga Reservoir would allow increases to be manifested.

The physical data at the seven Watts Bar stations on the spring sample dates showed water temperatures ranged from 16.5° C (1982) to 21.0° C (1985), and flow rates from only 7,100 cfs (1985) and 8,700 cfs (1982) to 40,100 cfs (1984). Travel times between the Watts Bar Dam (at station 9) and the lowest WBN station (station 4 at TRM 496.6) generally ranged between 2 and 3.5 days, except for 1976 (7 days), 1982 (11 days) and 1985 (13 days). Travel times between station 10 (above the dam) and station 9 (at the dam) were generally sufficiently slow (ranging from 10 hours to 2.2 days, and averaging about 20 hours) to allow time for mature zooplankters to continue the reproductive and growth cycles started in the Watts Bar Reservoir forebay. Travel times between the six WBN stations within Chickamauga Reservoir were the most varied of the four seasons.

Unlike winter, complete numerical dominance by rotifers was not always evident at all seven WBN stations in the spring, and cladocerans no longer represented a negligible portion of the zooplankton community. In 1973, rotifers dominated the upper four Watts Bar stations but were replaced at the lower stations (4, 5, and 6) by cladocerans. Cladocerans also dominated the spring zooplankton for stations 5 through 10 in 1974, all seven stations in 1975, stations 4-9 in 1976, and stations 5 and 6 in 1982.

Rotifers were the most abundant zooplankton group at station 4 in 1974, and stations 4, 7, 8, 9 and 10 in 1982, and (with one exception in 1976) always were the second most numerous group during those years when cladocerans were the dominant zooplankters. The last three collection years of 1983-1985 as well as 1977 yielded a complete dominance of rotifers over the other two groups in a manner similar to the winter collections. Copepods only were dominant at station 10 in 1976. All spring samples indicated that Keratella, Synchaeta, Polyarthra or Conochilus unicornis were the dominant or subdominant rotifers, and that Bosmina longirostris was the most abundant cladoceran species. Nauplii were the common copepod taxon present in the spring zooplankton.

Except for 1983-1985 when rotifers completely dominated the zooplankton, trends observed for the total number of taxa, diversity indices, and total densities reflected patterns occurring in both the rotifers and cladocerans. Number of taxa at a single station ranged from 16 taxa in 1982 to 39 taxa in 1974 and 1985. The highest number of taxa for all years except 1983 occurred at station 4, with the station above Watts Bar Dam producing the highest taxa number in 1983 and either the second or third highest number of taxa for all other years. All diversity indices would be expected to show moderate to high values in the spring reflecting the recruitment and allochthonous materials being introduced into the system from reservoirs (like Watts Bar at station 10) and rivers (like the Hiwassee between stations 4 and 5). The diversity index value for the seven WBN stations ranged from 0.84 to 3.18, with either station 4 or station 10 possessing the highest values for all years except 1975, 1982 and 1983. The

SQS values were consistently highest in spring (except for 1985), fluctuating less than the SQS values for the other three seasons, indicating that similar taxa were generally present at all seven stations. However, the PS values were varied and usually quite low (considerably less than 70 percent), reaching the low values of only 4 percent to 9 percent for the comparisons of station 4 with station 6 through 10 in 1983. Since the SQS values are more affected by the presence/absence of "rare" taxa than the PS values' these SQS and PS values suggest recruitment of both "rare" and common taxa into the study reach from areas such as the Watts Bar forebay or the Hiwassee River (at TRM 500). Station 10 also demonstrated the highest total densities of zooplankton for all years except 1983 and 1985, again suggesting an abundance of animals which could be transported downstream to the other six stations. Likewise, the lowest or second lowest total density values were collected at station 5 (at 506.6 TRM just above the Hiwassee River) for all years except 1983 and 1985, with station 4 (at TRM 496.5, below and receiving drainage from the Hiwassee River) showing an increase in total densities for all years except 1973, 1976, and 1983. Although the Watts Bar Reservoir at station 10 and the Hiwassee River between stations 4 and 5 appear to be the primary sources of recruitment and allochthonous materials, other, smaller tributaries and overbank areas could be involved in this addition of allochthonous materials. Possible locations of introduction of nutrients include the Dake Branch at TRM 528 (by site 8), Yellow Creek at TRM 527 (by site 7), and Sewee Creek at TRM 524.5 (between sites 6 and 7). As with the winter data, no long term temporal trends were

evident in the spring zooplankton densities. However, Rotifera did appear to be more dominant during the latter three years than in previous years.

Trends in Community Densities for the Chickamauga Reservoir (summarized in table 5-9)--The one-way ANOVA and associated SNK tests for the seven WBN stations produced significant tests for all zooplankton groups during all years except cladocerans in 1973, 1982, 1983, 1984 and 1985; copepods in 1983; rotifers in 1975; and total zooplankton in 1982. The general pattern of the SNK tests revealed that station 10 was significantly different from station 5 and usually one or both of stations 4 and 6. All of the significant spring zooplankton tests substantiated the two significant winter SNK tests which separated the downstream WBN stations from the upstream stations. These results strongly suggest a decrease due organisms being removed from the water column or due to dilution as the zooplankton moved downstream from Watts Bar Dam. Regression analysis performed on the combined WBN and SQN stations indicated significant polynominal regression equations for all years except 1974 and 1982. The explained variability (R^2 values expressed as a percent) ranged from 42 percent (1983) to 84 percent (1976). All of the regression curves possessed minima between stations 4 and 5 and maxima at either station 1 (1975, 1976, and 1983) or station 10 (all other years). Station 10 also demonstrated the next highest sub-maximal values in the three years when maxima were evident at station 1. These results indicate the decreases in densities observed in the WBN study reach were followed by increases in lower portions of Chickamauga Reservoir, probably as a result of reduced velocities there.

Summer

Description of the Watts Bar Community (summarized in table 5-10 and figure 5-20 and detailed in appendices 5-H, 5-I, 5-J, 5-K, and 5-L)--Zooplankton densities in the summer and fall seasons would be expected to be between the high spring and low winter results. Relatively consistent flows and travel times would be involved in introducing zooplankton and allochthonous material into the seven station WBN study reach from breeding areas like the pool-like Watts Bar Reservoir forebay and Hiwassee River.

Physical data collected during summer at the seven WBN sites revealed consistency in the ranges of temperature (24.5° C - 28.5° C, with station 10 possessing the highest temperatures for every year except 1974). Flow rates varied between 21,000 and 38,900 cfs. Travel times between the Watts Bar Dam at station 9 and the lowest WBN station (station 4) were 2.5 to 3.6 days, and travel times from the above dam site at station 10 to the dam at station 9 were 9.0 - 17.0 hours.

Rotifers completely dominated the zooplankton at all stations in 1976, 1977, 1982, 1983, and 1984, and selected stations in 1973, 1974, 1975, and 1985. While copepods and cladocerans usually were equally subdominant in all years, cladocerans were the dominant group at stations 4 and 5 in 1973, stations 5 and 6 in 1974, and stations 5, 8, and 9 in 1975, and copepods were dominant at stations 4, 7, 8 and 9 in 1974 and all stations except station 4 in 1985. All three zooplankton groups generally were highest at the upstream station and gradually declined in a downstream direction. Increases in rotifer density also were evident between stations 4 and 5 for all years except 1973, 1976 and 1984, possibly due to recruitment and

the introduction of allochthonous materials from the Hiwassee River just downstream from station 5. Common rotifers during the summer sampling included Keratella, Brachionus angularis, Ploesoma truncata and Conochiloides, with Brachionus budapestinensis and Asplanchna occasionally occurring as subdominant species. The cladoceran Bosmina longirostris was the dominant taxon at stations 4 and 5 for all years except 1976, 1977, and 1982. Copepod nauplii were the subdominant taxon at station 4 for all years except 1973, 1982, and 1983.

As might be anticipated, patterns observed in the total number of taxa, diversity indices, and total densities were primarily due to rotifers. Total number of taxa ranged from 14 (1974) to 39 (1982). Two patterns were evident for the total number--one for 1973-1977 and the other for 1982-1985. In the earlier five summers of monitoring, station 5 (directly upstream of the Hiwassee River) exhibited the lowest number of taxa in all years except 1973, while the highest taxa number was collected downstream of the Hiwassee River at station 4 (1975 through 1977), in Watts Bar Reservoir at station 10 (1974), or at the mouth of the Yellow Creek at station 7 (1973). The latter four years of preoperational monitoring did not show any consistent pattern of stations with highest or lowest number of taxa except station 5 where number of taxa was generally low. Diversity index values ranged from 2.23 (1976 and 1983) to 3.61 (1975), but did not produce as distinct a pattern as was seen for the number of taxa. However, station 4 (directly downstream from the Hiwassee River) did show highest values in 1974 through 1976 and in 1982, and either stations 5 or 6 the lowest values in 1974 and 1982 through 1985. Almost all of the SQS values

for the nine summer sample dates were high (> 70 percent), while usually only the PS comparisons of stations 7 with 8, 7 with 9, and 8 with 9 possessed values approaching 70 percent or greater. The lowest PS values were calculated for the station 4 comparisons with other stations. All of these results indicate community similarity in this part of the study reach due to proximity of stations and short travel times. Long-term temporal trends were not apparent in the summer Watts Bar zooplankton results.

Trends in the Chickamauga Reservoir Community (summarized in table 5-11)--One-way ANOVAs evaluating spatial (upstream/downstream) trends in densities indicated significant tests for all the zooplankton groups during the eight collection years except for rotifers in 1984, copepods in 1977, cladocerans in 1982, 1983 and 1984, and total zooplankton in 1983 and 1984. The general pattern for the SNK tests showed station 10 (above Watts Bar Dam) overlapping in density with stations 9, 8 and sometimes 7, but significantly different from stations 4, 5 and (usually) 6. As with the winter and spring SNK results, this pattern revealed a progressive decrease in zooplankton densities as water flowed from the Watts Bar Reservoir (at station 10) downstream. Regression analysis on the ten stations from the combined WBN and SQN data yielded significant polynomial equations for all years. The explained variability (based on the R^2 values x 100) ranged from 23 percent in 1983 to a highly significant 89 percent in 1973. All significant summer regression curves showed a decline from the above Watts Bar Dam site at station 10 to a minimum at station 4 or 5, and then an increase for the three SQN stations downstream. In 1973, the decline occurred through station 3 at TRM 490.5 (the only SQN station upstream from

the Sequoyah Nuclear Plant), followed by a negligible increase for Sequoyah stations 1 and 2. Only in 1977 did the predicted density at station 1 surpass the density value for station 10. These results indicate that, contrary to results for spring, the zooplankton community did not "recover" in Chickamauga Reservoir to levels observed in Watts Bar Reservoir forebay.

Fall

Description of the Watts Bar Community (summarized in table 5-12 and figure 5-21 and detailed in appendices 5-H, 5-I, 5-J, 5-K, and 5-L)--Zooplankton results for the fall at the seven WBN stations would be expected to resemble overall trends observed in the summer but with lower densities. Consistent flow rates, travel times, and temperatures would be involved in the introduction and maintenance of both zooplankton and nutrients into the study reach.

Physical data during fall for the nine collection years indicated temperatures ranged between 13.2° C and 18.1° C and flow rates between 22,400 and 36,100 cfs. Travel times from station 9 at Watts Bar Dam to the most downstream WBN station 4 at TRM 496.6 varied between 1.8 and 2.5 days for all years except 1983 when the travel time was 3.3 days. Travel times between the above dam station 10 and station 9 were between 13.2 and 18.1 hours.

Rotifers either dominated at all stations or at the upper WBN stations during all years except 1984 when cladocerans were dominant at all stations. Cladocerans were usually the dominant group when rotifers were not dominant. All three zooplankton groups generally showed an overall

decline from upstream to downstream. Most years also demonstrated minor increases between stations 4 and 5, possibly as a result of recruitment and material introduction from the Hiwassee River upstream from station 4. Common fall zooplankton included the rotifers Keratella and Synchaeta and occasionally Polyarthra, the cladoceran Bosmina longirostris, and copepod nauplii, cyclopoid copepodids, and occasionally adult Cyclops vernalis. Taxon dominance always was confined to three species--Bosmina longirostris (station 5 through 8 in 1973, stations 4 and 5 in 1974, stations 4 through 7 in 1982 and all seven stations in 1983 through 1985), Keratella (stations 6 through 10 in 1974, stations 5 through 10 in 1975, all seven stations in 1976, stations 5 through 9 in 1977, and stations 9 and 10 in 1982) or Synchaeta (stations 9 and 10 in 1973, station 6 in 1975, station 10 in 1977 and station 8 in 1982).

As with previous seasons, the fall patterns for total number of taxa, diversity indices, and total densities generally followed that of rotifers. Total number of taxa ranged from 16 (1983) to 35 (1975 and 1983), always peaking at station 4, 9 or 10, and attaining the lowest values at station 5 or 6 in all years except 1977. The increases at station 4 could have been due to the influence of the Hiwassee River upstream of station 4. Diversity index values ranged from 0.68 (1983) to 3.25 (1975), and always demonstrated a peak at station 4 or 10 and a low point at station 5 for all years except 1974 and 1976. The above number of taxa and diversity index results further supported the possibility of the introduction of zooplankton and nutrients from not just the Watts Bar Dam at station 10, but also the Hiwassee River between stations 4 and 5. As with the spring data, most of

the SQS values for the nine fall collection dates approached or exceeded 70 percent, while all of the PS comparisons yielded low values (less than 70 percent) except stations 7 with 8, 7 with 9, and 8 with 9. Again, these results indicate similarity of the zooplankton in this rapidly flowing section of the study area. No long-term temporal trends were noticed for the fall Watts Bar zooplankton results.

Trends in the Chickamauga Reservoir Community (summarized in table 5-13)--Evaluation of the upstream/downstream trends by use of one-way ANOVAs and SNKs revealed significant tests for all comparisons except cladocerans in 1982. Virtually all of the SNK tests separated the upper four WBN stations from lower stations 4, 5 and 6, with either station 9 or 10 having the highest mean value. As was noted for the other three seasons, the ANOVA and SNK tests indicated a progressive decrease in the zooplankton densities as water moved downstream from the Watts Bar Reservoir (station 10). Regression analysis performed on the combined SQN and WBN stations exhibited significant polynomial equations for all eight collection years. Accountable variability (the regression coefficient R^2 expressed as a percent value) ranged from 55 percent (1977 and 1983) to 90 percent (1973). The regression curves also exhibited the highest predicted densities at station 10 followed by a continual decrease downstream until minima were obtained at stations 3 (1977 and 1984) or station 4 (all other years). These results agree with results for summer in showing that the zooplankton community did not "recover" in Chickamauga Reservoir to levels observed in Watts Bar Reservoir forebay.

5.3.2 Zooplankton Summary

Results for this monitoring program show generally similar patterns for all quarters when extreme conditions (e.g., high river flows) did not exist. The zooplankton community typically was composed of the same taxa throughout the study reach, although taxon dominance and densities were usually quite different among sample locations. The typical trend for spring, summer, and autumn (and occasionally winter) was for highest densities to occur at the location in Watts Bar Reservoir forebay, followed by substantial decreases in the swiftly flowing section of Chickamauga Reservoir near WBN and several miles downstream, and then an increase (usually slight) at the last downstream location. This pattern was expected given the differences in habitat within the study reach.

To further examine these upstream to downstream differences, information from the SQN monitoring program, which included sample locations further downstream in Chickamauga Reservoir, was analyzed along with WBN data. This combined data set indicated that in most cases the increase observed at the last WBN location continued further downstream into Chickamauga Reservoir usually to a level comparable to that at the Watts Bar Reservoir forebay location. Addition of SQN information proved useful in understanding zooplankton dynamics in Chickamauga Reservoir.

Table 5-6. Summary of the Winter Zooplankton Community Data for the Seven Watts Bar Stations During the Preoperational Study

Year	Dominant Group	Dominant Taxa	Number of Taxa	Diversity Index (D Bar)	SQS*	PS†
1973	Rotifera 7 sta.‡	Synchaeta 7 sta.	Range 12-17	1.32-1.98 6 sta. 0.34 1 sta.	All but 1 SQS ≥ 70%	8 PS ≥ 70% All sta No. 4§ PS < 70%
1974	Rotifera 7 sta.	Synchaeta 7 sta.	Range 19-26	2.07-2.43 7 sta.	All SQS ≥ 70%	All PS ≥ 70%
1975	Rotifera 7 sta.	Synchaeta 4 sta. Nauplii 2 sta. Both 1 sta.	Range 17-22	1.89-2.28 7 sta.	All but 2 SQS ≥ 70%	16 PS ≥ 70%
1976	Rotifera 1 sta.	Keratella 1 sta.	Only 1 sta. 21	Only 1.52 1 sta.	¶	¶
1977	Rotifera 7 sta.	Keratella 6 sta. Synchaeta 1 sta.	Range 17-22	1.67-1.75 7 sta.	14 SQS ≥ 70% All sta. No. 4 SQS < 70%	All but 1 PS ≥ 70%
1982#	-	-	-	-	-	-
1983	Rotifera 7 sta.	Synchaeta 7 sta.	Range 15-23	1.23-1.33 5 sta. 0.61-0.98 2 sta.	3 SQS ≥ 70%	All PS ≥ 70%
1984	Rotifera 7 sta.	Synchaeta 5 sta. Keratella 2 sta.	Range 20-30	1.73-2.10 7 sta.	9 SQS ≥ 70%	10 PS ≥ 70% All sta. No. 5 PS < 70%
1985**	Rotifera all sta.	Synchaeta 5 sta.	Range 27-34	1.70-2.44 5 sta.	All SQS ≥ 70%	2 PS ≥ 70%

*SQS = Sorenson's Quotient of Similarity; total of 21 comparisons for each survey.
†PS = Percentage Similarity; total of 21 comparisons for each survey.
‡Sta = Stations.
§Station #4 = TRM 496.6; Station #5 = TRM 506.0; Station #6 = TRM 518.0; Station #8 = TRM 528.0; Station #9 = TRM 529.5; and Station #10 = TRM 532.1.
¶Insufficient data to run analysis.
#Samples not collected.
**Stations 7 and 8 were not sampled in 1985.

Table 5-7. Summary of ANOVA, Student-Newman-Keuls Multiple Range Tests and Regression Tests Examining Trends in Zooplankton Densities for the Seven Watts Bar Stations (Stations 4 to 10) and the Entire Chickamauga Reservoir for Winter Quarter of All Years

Year	Data	Range of Densities (No. x $10^3/m^3$)	One-Way ANOVA*	SNK† (Station Mean Ranked High to Low)	Regression Analsysis (Run on Total Zooplankton only)‡ Watts Bar Stations Only: Equations for Regressions (Significant of $\alpha = 0.05$)	R^2	Watts Bar and Sequoyah Stations Combined: Equations for Regressions (Significant at $\alpha = 0.05$)	R^2
1973	Total	14.7 - 55.1	NS§	4 7 8 6 10 9 5	NS	NS	NS	NS
	Clad.	0.1 - 0.7	NS	10 8 7 6 9 5 4				
	Cope.	1.5 - 4.9	NS	10 8 7 5 6 9 4				
	Rot.	12.4 - 53.5	NS	4 7 6 8 10 9 5				
1974	Total	3.3 - 6.1	NS	7 4 5 8 10 9 6	NS	NS	NS	NS
	Clad.	0.2 - 0.4	NS	7 5 8 10 4 6 9				
	Cope.	1.0 - 1.7	NS	7 5 8 4 9 10 6				
	Rot.	2.6 - 3.9	NS	7 4 5 10 8 9 6				
1975	Total	11.1 - 22.4	NS	7 4 10 5 9 6 8	NS	NS	NS	NS
	Clad.	0.5 - 1.6	NS	7 9 10 8 6 5 4				
	Cope.	2.6 - 7.4	NS	7 4 10 9 8 5 6				
	Rot.	5.6 - 13.3	NS	4 7 5 10 6 9 8				
1976	Data for only one WBN Station.		NR¶	NR	NR	NR	$Y = 220.92 - 0.92 (X) + 0.001 (X^2)$#	0.84
1977	Total	101.4 - 190.2	NS	5 10 8 9 7 6 4	NS	NS	$Y = -45.82$ to $0.20 (X) - 0.0002 (X^2)$	0.51
	Clad.	0.5 - 1.2	NS	5 10 8 7 4 6 9				
	Cope.	8.3 - 21.6	Sign.	10 7 9 8 5 6 4				
	Rot.	92.0 - 176.4	NS	5 8 10 9 7 6 4				
1982	No samples collected.		NR	NR	NR	NR	NR	NR

Table 5-7. (Continued)

Year	Data	Range of Densities (No. x $10^3/m^3$)	One-Way ANOVA*	SNK† (Station Mean Ranked High to Low)	Regression Analsysis (Run on Total Zooplankton only)‡ Watts Bar Stations Only: Equations for Regressions (Significant of α = 0.05)	R^2	Watts Bar and Sequoyah Stations Combined: Equations for Regressions (Significant at α = 0.05)	R^2
1983	Total	14.8 - 26.6	NS	4 8 7 5 10 6 9	NS	NS	Y = 31.95 - 0.10 (X) + 0.001 (X^2)	0.2
	Clad.	0.3 - 1.9	NS	4 10 8 9 5 7 6				
	Cope.	0.9 - 2.1	NS	4 5 6 8 7 9 10				
	Rot.	16.8 - 22.7	NS	4 8 7 10 5 6 9				
1984	Total	7.1 - 34.6	NS	10 8 7 6 9 4 5	Y = 181.92 - 0.70 (X) + 0.001 (X^2)	0.36	Y = 44.15 - 0.17 (X) + 0.0002 (X^2)	0.4
	Clad.	0.2 - 0.9	NS	10 9 4 7 6 8 5				
	Cope.	0.9 - 6.8	Sign.	10 8 7 6 9 4 5				
	Rot.	6.0 - 26.9	NS	10 7 8 6 9 4 5				
1985	Total	20.0 - 38.1	NS	5 4 6 10 9	NS	NS	NS	NS
	Clad.	0.4 - 1.7	NS	10 6 9 4 5				
	Cope.	3.4 - 10.9	NS	4 10 5 9 6				
	Rot.	15.0 - 32.6	NS	5 6 4 10 9				

*ANOVA = One-Way Analysis of Variance.
†SNK = Student-Newman-Keuls Multiple Range Test run at α = 0.05 level.
‡Regressions were run on WBN (Watts Bar Nuclear Plant) data alone and WBN plus SQN (Sequoyah Nuclear Plant) data combined because SQN provided data from further downstream in Chickamauga Reservoir.
§NS = Not significant at α 0.05.
¶NR = Test not run.
#Only one WBN station (Station 4) was run with the three SQN stations in 1976.

Table 5-8. Summary of the Spring Zooplankton Community Data for the Seven Watts Bar Stations During this Preoperational Study

Year	Dominant Group	Dominant Taxa	Number of Taxa	Diversity Index (D Bar)	SQS	PS
1973	Cladocera (sta. 4-6) Rotifera (sta. 7-10)	B. longirostris 6 sta. Polyarthra 1 sta.	Range 21-27	1.87-2.38 6 sta. 0.96 1 sta.	All SQS ≥ 70%	6 PS ≥ 70%
1974	Rotifera (sta. 4) Cladocera (sta. 5-10)	Conachilus 1 sta. B. longirostris 6 sta.	Range 18-39	1.10-2.42 7 sta.	All but station 4 SQS ≥ 70%	3 PS ≥ 70%
1975	Cladocera (all sta.)	B. longirostris 7 sta.	Range 24-29	1.23-1.80 6 sta. 2.79 1 sta.	All SQS ≥ 70%	9 PS ≥ 70%
1976	Cladocera (sta. 4-9) Copepoda (sta. 10)	B. longirostris 6 sta. Nauplii 1 sta.	Range 23-33	1.79-2.40 6 sta. 0.89 1 sta.	All SQS ≥ 70%	5 PS ≥ 70%
1977	Rotifera (all sta.)	Synchaeta 4 sta. Asplanchna 3 sta.	Range 24-35	2.90-3.18 6 sta. 2.40 1 sta.	All SQS ≥ 70%	6 PS ≥ 70%
1982	Rotifera (sta. 4,7,8,9, and 10) Cladocera (sta. 5 and 6)	Polyarthra 1 station B. longirostris 6 stations	Range 16-28	1.87-2.81 6 sta. 0.84 1 sta.	All SQS ≥ 70%	7 PS ≥ 70%
1983	Rotifera (all sta.)	Keratella 7 sta.	Range 28-37	2.27-2.74 6 sta. 3.04 1 sta.	All SQS ≥ 70%	3 PS ≥ 70%
1984	Rotifera (all sta.)	Synchaeta 7 sta.	Range 23-34	1.83-2.60 7 sta.	All SQS ≥ 70%	4 PS ≥ 70%
1985*	Rotifera (all sta.)	Kellicottia long. 4 sta. Polyarthra 1 sta. B. budapestinensis 1 sta.	Range 21-39	1.38-2.56 6 sta.	7 of 14 SQS ≥ 70%	2 of 14 PS ≥ 70%

All abbreviations and explanations as in table 5-6.
*Station 8 was not collected in spring 1985.

Table 5-9. Summary of ANOVA, Student-Newman-Keuls Multiple Range Tests and Regression Tests Examining Trends in Zooplankton Densities for the Seven Watts Bar Stations (Stations 4 to 10) and the Entire Chickamauga Reservoir for Spring Quarter of all Years

Year	Data	Range of Densities (No. x $10^3/m^3$)	One-Way ANOVA	SNK-(Station Mean Ranked High to Low)	Watts Bar Stations Only: Equations for Regressions (Significant at $\alpha = 0.05$)	R^2	Watts Bar and Sequoyah Stations Combined: Equations for Regressions (Significant at $\alpha = 0.05$)	R^2
1973	Total	48.5 - 246.5	Sign.	10 8 9 7 6 5 4	$Y = 212.71 - 0.83 (X) + 0.001 (X^2)$	0.76	$Y = 165.63 - 0.64 (X) + 0.001 (X^2)$	0.64
	Clad.	24.7 - 83.0	NS	10 8 9 6 5 7 4				
	Cope.	1.5 - 23.8	Sign.	10 9 8 7 4 6 5				
	Rot.	5.5 - 139.6	Sign.	10 8 9 7 6 4 5				
1974	Total	8.4 - 121.6	Sign.	10 8 9 4 7 5 6	$Y = 688.39 - 2.67 (X) + 0.003 (X^2)$	0.70	NS	NS
	Clad.	3.9 - 57.4	Sign.	10 8 9 7 5 4 6				
	Cope.	0.6 - 17.8	Sign.	10 8 9 7 5 4 6				
	Rot.	3.1 - 46.4	Sign.	10 4 8 7 9 6 5				
1975	Total	42.7 - 138.3	Sign.	10 9 7 4 6 8 5	NS	NS	$Y = 155.56 - 0.59 (X) + 0.001 (X^2)$	0.52
	Clad.	14.7 - 92.1	Sign.	10 7 4 9 6 5 8				
	Cope.	2.0 - 25.8	Sign.	10 9 8 7 6 4 5				
	Rot.	9.3 - 20.5	NS	10 4 7 8 6 9 5				
1976	Total	66.0 - 201.5	Sign.	10 9 7 8 6 5 4	$Y = 204.55 - 0.79 (X) - 0.001 (X^2)$	0.94	$Y = 232.84 - 0.90 (X) + 0.001 (X^2)$	0.84
	Clad.	28.3 - 52.8	Sign.	9 7 8 5 4 10 6				
	Cope.	8.2 - 103.8	Sign.	10 9 8 7 6 4 5				
	Rot.	5.8 - 65.4	Sign.	10 9 7 8 6 4 5				

Table 5-9. (Continued)

Year	Data	Range of Densities (No. x $10^3/m^3$)	One-Way ANOVA	SNK-(Station Mean Ranked High to Low)	Watts Bar Stations Only: Equations for Regressions (Significant at $\alpha = 0.05$)	R^2	Watts Bar and Sequoyah Stations Combined: Equations for Regressions (Significant at $\alpha = 0.05$)	R^2
1977	Total	28.2 - 227.7	Sign.	10 9 7 8 4 6 5	$Y = 415.00 - 1.61 (X) + 0.002 (X^2)$	0.82	$Y = 245.98 - 0.96 (X) + 0.001 (X^2)$	0.63
	Clad.	8.2 - 45.0	Sign.	9 10 7 8 4 6 5				
	Cope.	1.3 - 37.0	Sign.	10 9 7 8 4 6 5				
	Rot.	17.9 - 150.3	Sign.	10 7 9 8 4 6 5				
1982	Total	105.7 - 242.7	NS	10 7 8 6 4 9 5	NS	NS	NS	NS
	Clad.	47.7 - 97.2	NS	6 5 10 4 8 7 9				
	Cope.	11.8 - 51.6	Sign.	10 9 7 8 6 4 5				
	Rot.	5.1 - 140.5	Sign.	7 8 9 10 4 6 5				
1983	Total	6.8 - 306.2	Sign.	9 8 7 6 10 5 4	$Y = 375.69 + 1.44 (X) - 0.001 (X^2)$	0.85	$Y = 471.01 - 1.84 (X) + 0.002 (X^2)$	0.51
	Clad.	0.8 - 27.8	NS	9 6 8 10 5 4 7				
	Cope.	0.5 - 13.8	NS	9 8 10 5 4 7 6				
	Rot.	5.5 - 264.7	Sign.	9 8 7 6 10 5 4				
1984	Total	8.1 - 283.0	Sign.	10 7 8 9 6 4 5	$Y = 420.61 - 1.66 (X) + 0.002 (X^2)$	0.70	$Y = 283.11 - 1.12 (X) + 0.001 (X^2)$	0.71
	Clad.	1.4 - 13.3	NS	7 10 9 8 4 5 6				
	Cope.	0.6 - 8.6	Sign.	10 9 7 8 4 5 6				
	Rot.	6.1 - 264.4	Sign.	10 7 8 9 6 4 5				
1985	Total	121.9 - 579.2	Sign.	9 7 10 4 5 6	$Y = 400.91 - 1.55 (X) + 0.002 (X^2)$	0.58	$Y = 58.94 - 0.22 (X) + 0.0002 (X^2)$	0.42
	Clad.	3.3 - 20.4	NS	10 7 9 4 5 6				
	Cope.	18.6 - 72.4	Sign.	10 9 7 4 6 5				
	Rot.	92.0 - 510.3	Sign.	9 7 4 10 5 6				

All abbreviations and explanations same as in table 5-7.

Table 5-10. Summary of the Summer Zooplankton Community Data for the Seven Watts Bar Stations During this Preoperational Study

Year	Dominant Group	Dominant Taxa	Number of Taxa	Diversity Index (d-bar)	SQS	PS
1973	Cladocera (sta. 4, 5) Rotifera (sta. 6-10)	B. longirostris 2 sta. Brachionus 3 sta. Ploesoma 1 sta. Asplanchna 1 sta.	Range 24-32	2.59-3.36 7 sta.	All SQS ≥ 70%	3 PS ≥ 70%
1974	Cladocera (sta. 5,6) Rotifera (sta. 10) Copepoda (sta. 4,7,8,9)	B. longirostris 3 sta. D. retrocurva 1 sta. Nauplii 3 sta.	Range 14-24	2.63-3.11 7 sta.	18 SQS ≥ 70%	2 PS ≥ 70%
1975	Cladocera (sta. 5,8,9) Rotifera (sta. 4,6,7,10)	B. longirostris 2 sta. Keratella 4 sta. Nauplii 1 sta.	Range 24-34	2.83-3.61 7 sta.	All SQS ≥ 70%	4 PS ≥ 70%
1976	Rotifera (all sta.)	Keratella 7 sta.	Range 24-33	2.23-3.49 7 sta.	All SQS ≥ 70%	4 PS ≥ 70%
1977	Rotifera (all sta.)	B. angularis 2 sta. Nauplii 2 sta. Conochilus 3 sta.	Range 26-33	2.63-3.32 7 sta.	All SQS ≥ 70%	6 PS ≥ 70%
1982	Rotifera (all sta.)	Conochilus 5 sta. Brachionus 1 sta. Ploesoma 1 sta.	Range 30-39	2.90-3.23 7 sta.	All SQS ≥ 70%	7 PS ≥ 70%
1983	Rotifera (all sta.)	B. longirostris 3 sta. Nauplii 1 sta. Ploesoma 2 sta. Polyarthra 1 sta.	Range 18-32	3.05-3.60 6 sta. 2.23 1 sta.	18 SQS ≥ 70%	1 PS ≥ 70% (only sta. 7 with 2)

Table 5-10. (Continued)

Year	Dominant Group	Dominant Taxa	Number of Taxa	Diversity Index (d-bar)	SQS	PS
1984	Rotifera (all sta.)	B. longirostris 2 sta. Ploesoma 3 sta. Brachionus 2 sta.	Range 29-35	3.02-3.58 7 sta.	All SQS ≥ 70%	3 PS ≥ 70%
1985	Copepoda (sta. 5,6, 7,8,9,10) Rotifera (sta. 4)	Nauplii 6 sta. Conochilus 1 sta.	Range 27-39	2.86-3.50 7 sta.	All SQS ≥ 70%	4 PS ≥ 70%

All abbreviations and explanations as in table 5-6.

Table 5-11. Summary of ANOVA, Student-Newman-Keuls Multiple Range Tests and Regression Tests Examining Trends in Zooplankton Densities for the Seven Watts Bar Stations (Stations 4-10) and The Entire Chickamauga Reservoir for Summer Quarter of All Years

Year	Data	Range of Densities (No. 1 x $10^3/m^3$	One-Way ANOVA	SNK-(Station Means Ranged High to Low)	Watts Bar Stations Only: Equations for Regressions (Significant at $\alpha = 0.05$)	R^2	Watts Bar and Sequoyah Stations Combined: Equations for Regressions (Significant at $\alpha = 0.05$)	R^2
1973	Total	17.1 - 290.5	Sign	10 9 8 7 6 5 4	$Y = 147.11 - 0.59 (X) + 0.001 (X^2)$	0.88	$Y = 204.25 - 0.81 (X) + 0.001 (X^2)$	0.89
	Clad.	8.3 - 51.9	Sign	10 9 8 5 7 4 6				
	Cope.	2.4 - 28.4	Sign	9 10 8 7 6 5 4				
	Rot.	6.5 - 211.2	Sign	10 9 8 7 6 5 4				
1974	Total	7.4 - 58.3	Sign	10 8 9 7 6 4 5	$Y = 213.05 - 0.83 (X) + 0.001 (X^2)$	0.89	$Y = 241.73 - 0.94 (X) + 0.001 (X^2)$	0.78
	Clad.	3.5 - 19.3	Sign	10 8 6 9 7 5 4				
	Cope.	3.0 - 18.2	Sign	10 9 8 7 6 4 5				
	Rot.	0.3 - 21.0	Sign	10 4 8 9 7 6 5				
1975	Total	16.7 - 169.0	Sign	10 7 9 8 5 6 4	$Y = 375.56 - 1.47 (X) + 0.001 (X^2)$	0.87	$Y = 273.82 - 1.07 (X) + 0.001 (X^2)$	0.65
	Clad.	5.1 - 46.8	Sign	10 7 8 9 5 6 4				
	Cope.	3.6 - 26.0	Sign	10 9 7 8 6 4 5				
	Rot.	7.0 - 96.2	Sign	10 7 8 9 4 5 6				

Table 5-11. (Continued)

Year	Data	Range of Densities (No. 1 x $10^3/m^3$	One-Way ANOVA	SNK-(Station Means Ranged High to Low)	Watts Bar Stations Only: Equations for Regressions (Significant at α = 0.05)	R^2	Watts Bar and Sequoyah Stations Combined: Equations for Regressions (Significant at α = 0.05)	R^2
1976	Total	33.9 - 316.0	Sign	7 8 10 6 9 5 4	$Y = 102.98 + 0.40 (X) - 0.0004 (X^2)$	0.77	$Y = 226.48 - 0.88 + 0.001 (X^2)$	0.64
	Clad.	6.4 - 34.5	Sign	7 8 9 6 10 5 4				
	Cope.	7.1 - 25.6	Sign	8 7 10 6 9 5 4				
	Rot.	20.4 - 256.0	Sign	7 8 10 6 9 5 4				
1977	Total	25.6 - 170.1	Sign	10 7 8 9 5 6 4	$Y = 246.04 - 0.96 (X) + 0.001 (X^2)$	0.77	$Y = 326.69 - 1.27 (X) + 0.001 (X^2)$	0.81
	Clad.	2.7 - 19.7	Sign	7 9 8 10 5 6 4				
	Cope.	7.1 - 20.0	NS	7 10 8 9 5 6 4				
	Rot.	12.8 - 137.5	Sign	10 7 9 8 4 5 6				
1982	Total	11.7 - 88.6	Sign	7 9 8 10 4 6 5	$Y = 298.90 - 1.16 (X) + 0.001 (X^2)$	0.52	$Y = 258.51 - 1.00 (X) + 0.001 (X^2)$	0.58
	Clad.	3.8 - 8.5	NS	7 9 8 10 4 6 5				
	Cope.	2.1 - 9.9	Sign	9 8 7 10 6 4 5				
	Rot.	5.8 - 71.6	Sign	7 9 8 10 4 6 5				
1983	Total	23.7 - 103.4	NS	8 10 7 9 6 5 4	$Y = 41.55 - 0.16 (X) + 0.0002 (X^2)$	0.40	$Y = 143.39 - 0.55 (X) + 0.001 (X^2)$	0.23
	Clad.	7.7 - 17.2	NS	9 5 7 8 6 10 4				
	Cope.	3.0 - 21.7	Sign	9 8 7 10 6 4 5				
	Rot.	8.9 - 74.8	Sign	10 8 7 6 9 4 5				

Table 5-11. (Continued)

Year	Data	Range of Densities (No. 1 x $10^3/m^3$	One-Way ANOVA	SNK-(Station Means Ranged High to Low)	Watts Bar Stations Only: Equations for Regressions (Significant at $\alpha = 0.05$)	R^2	Watts Bar and Sequoyah Stations Combined: Equations for Regressions (Significant at $\alpha = 0.05$)	R^2
1984	Total	20.2 - 94.0	NS	10 8 7 6 9 5 4	$Y = 29.97 - 0.12 (X) + 0.0001 (X^2)$	0.34	$Y = 134.45 - 0.52 (X) + 0.001 (X^2)$	0.42
	Clad.	2.8 - 10.3	NS	10 5 7 8 4 6 9				
	Cope.	2.0 - 23.3	Sign	10 8 7 9 5 4 6				
	Rot.	11.4 - 72.7	NS	10 8 7 6 9 5 4				
1985	Total	28.6 - 186.0	Sign	9 10 4 8 7 6 5	$Y = 576.36 - 2.23 (X) + 0.002 (X^2)$	0.67	$Y = 144.58 - 0.55 (X) + 0.001 (X^2)$	0.25
	Clad.	11.4 - 60.1	Sign	9 10 8 4 7 6 5				
	Cope.	12.2 - 80.4	Sign	9 10 8 7 4 6 5				
	Rot.	5.0 - 45.5	Sign	4 9 10 8 7 6 5				

All abbreviations and explanations same as in table 5-7.

Table 5-12. Summary of the Fall Zooplankton Community Data for the Seven Watts Bar Stations During this Preoperational Study

Year	Dominant Group	Dominant Taxa	Number of Taxa	Diversity Index (d-bar)	SQS	PS
1973	Cladocera (Sta. 4-8) Copepoda (Sta. 9) Rotifera (Sta. 10)	B. longirostris 5 sta. Keratella 2 sta.	Range 20-28	2.59-3.36 7 sta.	All SQS ≥ 70%	3 PS ≥ 70%
1974	Rotifera (all sta.)	B. longirostris 2 sta. Keratella 5 sta.	Range 18-29	1.68-2.44 7 sta.	16 SQS ≥ 70%	4 PS ≥ 70%
1975	Rotifera (all sta.)	Synchaeta 1 sta. Keratella 6 sta.	Range 24-34	2.17-2.47 6 sta. 3.25 1 sta.	20 SQS ≥ 70% (only sta. 4 with 7 < 70%)	4 PS ≥ 70%
1976	Rotifera (all sta.)	Keratella 7 sta.	Range 22-32	1.85-2.14 7 sta.	15 SQS ≥ 70% (most sta. 4 SQS < 70%)	7 PS ≥ 70%
1977	Rotifera (all sta.)	Keratella 6 sta. Synchaeta 1 sta.	Range 23-31	1.56-2.72 7 sta.	All SQS ≥ 70%	3 PS ≥ 70%
1982	Cladocera (Sta. 4-6) Rotifera (Sta. 7-10)	B. longirostris 4 sta. Synchaeta 1 sta. Keratella 2 sta.	Range 18-28	2.28-2.58 5 sta. 0.87-1.18 2 sta.	12 SQS ≥ 70% (most sta. 4 SQS < 70%)	6 PS ≥ 70%
1983	Cladocera (Sta. 4-6) Rotifera (Sta. 7-10)	B. longirostris 7 sta.	Range 16-35	2.20-2.62 4 sta. 0.68-1.71 3 sta.	15 SQS ≥ 70% (most sta. 5 SQS < 70%)	1 PS ≥ 70% (only sta. 4 with 5)
1984	Cladocera (all sta.)	B. longirostris 7 sta.	Range 19-25	1.42-1.74 2 sta. 0.77-1.21 5 sta.	14 SQS ≥ 70%† (most sta. 4 SQS <70%)	5 PS ≥ 70%
1985	Copepoda (sta. 5) Rotifera (all other sta.)	Keratella 7 sta.	Range 21-32	1.66-2.68 7 sta.	17 SQS ≥ 70%† (most sta. 4 SQS <70%)	2 PS ≥ 70% (only sta. 4 with 5 and sta. 9 with 10)

All abbreviations and explanations as in table 5-6.

Table 5-13. Summary of ANOVA, Student-Newman-Keuls Multiple Range Tests and Regression Tests Examining Trends in Zooplankton Densities for the Seven Watts Bar Stations (Stations 4 to 10) and the Entire Chickamauga Reservoir for Fall Quarter of All Years

Year	Data	Range of Densities (No. x $10^3/m^3$)	One-Way ANOVA	SNK-(Station Means Ranged High to Low)	Watts Bar Stations Only: Equations for Regression (Significant at $\alpha = 0.05$)	R^2	Watts Bar and Sequoyah Stations Combined: Equations for Regression (Significant at $\alpha = 0.05$)	R^2
1973	Total	1.9 - 35.9	Sign.	10 9 8 7 6 4 5	$Y = 477.12 - 1.87 (X) + 0.002 (X^2)$	0.94	$Y = 263.26 - 1.04 (X) + 0.001 (X^2)$	0.90
	Clad.	2.9 - 23.6	Sign.	10 8 9 7 6 5 4				
	Cope.	0.3 - 8.0	Sign.	10 9 8 7 6 4 5				
	Rot.	0.6 - 19.1	Sign.	10 9 8 7 6 4 5				
1974	Total	7.8 - 98.7	Sign.	10 9 8 7 6 4 5	$Y = 441.04 - 1.73 (X) + 0.002 (X^2)$	0.94	$Y = 179.56 - 0.71 (X) + 0.001 (X^2)$	0.89
	Clad.	2.9 - 23.6	Sign.	10 9 8 7 5 6 4				
	Cope.	0.4 - 18.7	Sign.	10 9 8 4 7 5 6				
	Rot.	3.9 - 56.4	Sign.	10 9 8 7 6 4 5				
1975	Total	5.9 - 118.0	Sign.	10 9 8 7 4 6 5	$Y = 619.85 - 2.43 (X) = 0.002 (S^2)$	0.98	$Y = 275.59 - 1.08 (X) = 0.001 (X^2)$	0.67
	Clad.	1.1 - 15.7	Sign.	10 9 8 7 6 4 5				
	Cope.	2.0 - 29.6	Sign.	9 10 8 7 4 6 5				
	Rot.	2.8 - 77.3	Sign.	10 9 8 7 4 6 5				
1976	Total	6.3 - 74.1	Sign.	10 9 8 7 6 5 4	$Y = 120.84 - 0.48 (X) + 0.001 (X^2)$	0.93	$Y = 201.22 - 0.79 (X) + 0.001 (X^2)$	0.89
	Clad.	1.6 - 5.7	Sign.	10 7 9 8 6 5 4				
	Cope.	0.4 - 16.0	Sign.	10 9 8 7 6 4 5				
	Rot.	4.0 - 52.4	Sign.	10 9 7 8 6 5 4				

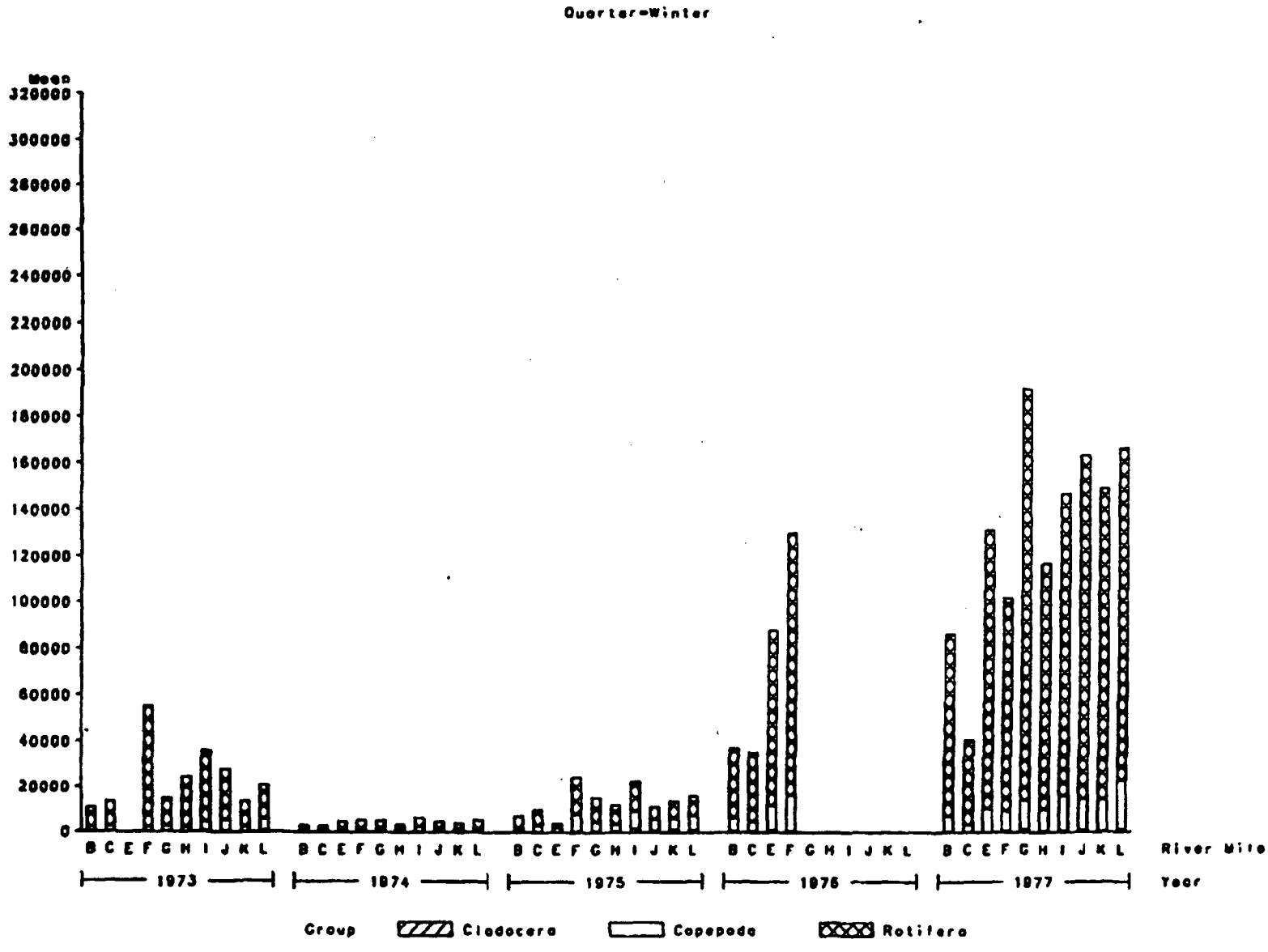
Table 5-13. (Continued)

Year	Data	Range of Densities (No. x $10^3/m^3$)	One-Way ANOVA	SNK-(Station Means Ranged High to Low)	Watts Bar Stations Only: Equations for Regression (Significant at $\alpha = 0.05$)	R^2	Watts Bar and Sequoyah Stations Combined: Equations for Regression (Significant at $\alpha = 0.05$)	R^2
1977	Total	4.1 - 284.3	Sign.	9 10 8 7 6 5 4	$Y = 186.92 - 0.75 (X) = 0.001 (X^2)$	0.80	$Y = 176.29 - 0.70 (X) = 0.001 (X^2)$	0.55
	Clad	0.4 - 7.3		9 7 8 10 4 6 5				
	Cope.	0.7 - 30.6	Sign.	4 10 8 7 6 5 4				
	Rot.	3.0 - 246.4	Sign.	9 10 8 7 6 5 4				
1982	Total	2.8 - 27.1	Sign.	9 10 8 7 6 4 5	$Y = 403.51 - 1.58 (X) + 0.002 (X^2)$	0.76	$Y = 266.95 - 1.05 (X) + 0.001 (X^2)$	0.74
	Clad.	1.9 - 5.7	N.S.	9 7 8 10 4 6 5				
	Cope.	0.3 - 6.9	Sign.	4 10 8 7 6 4 5				
	Rot.	0.2 - 15.1	Sign.	10 9 8 7 6 4 5				
1983	Total	5.2 - 86.3	Sign.	9 8 7 10 6 4 5	$Y = 283.76 - 1.11 (X) + 0.001 (X^2)$	0.52	$Y = 132.57 - 0.52 (X) + 0.001 (X^2)$	0.55
	Clad.	4.4 - 32.9	Sign.	9 8 7 4 6 10 5				
	Cope.	0.4 - 17.1	Sign.	9 10 8 7 6 4 5				
	Rot.	0.4 - 36.3	Sign.	9 8 7 10 6 4 5				
1984	Total	2.1 - 36.3	Sign.	10 8 7 9 6 5 4	$Y = 91.04 - 0.37 (X) + 0.0004 (X^2)$	0.79	$Y = 182.17 - 0.73 (X) + 0.001 (X^2)$	0.80
	Clad.	1.3 - 17.9	Sign.	8 10 7 9 6 5 4				
	Cope.	0.5 - 14.2	Sign.	10 8 9 7 6 5 4				
	Rot.	0.3 - 4.7	Sign.	8 10 7 9 4 5 6				

Table 5-13. (Continued)

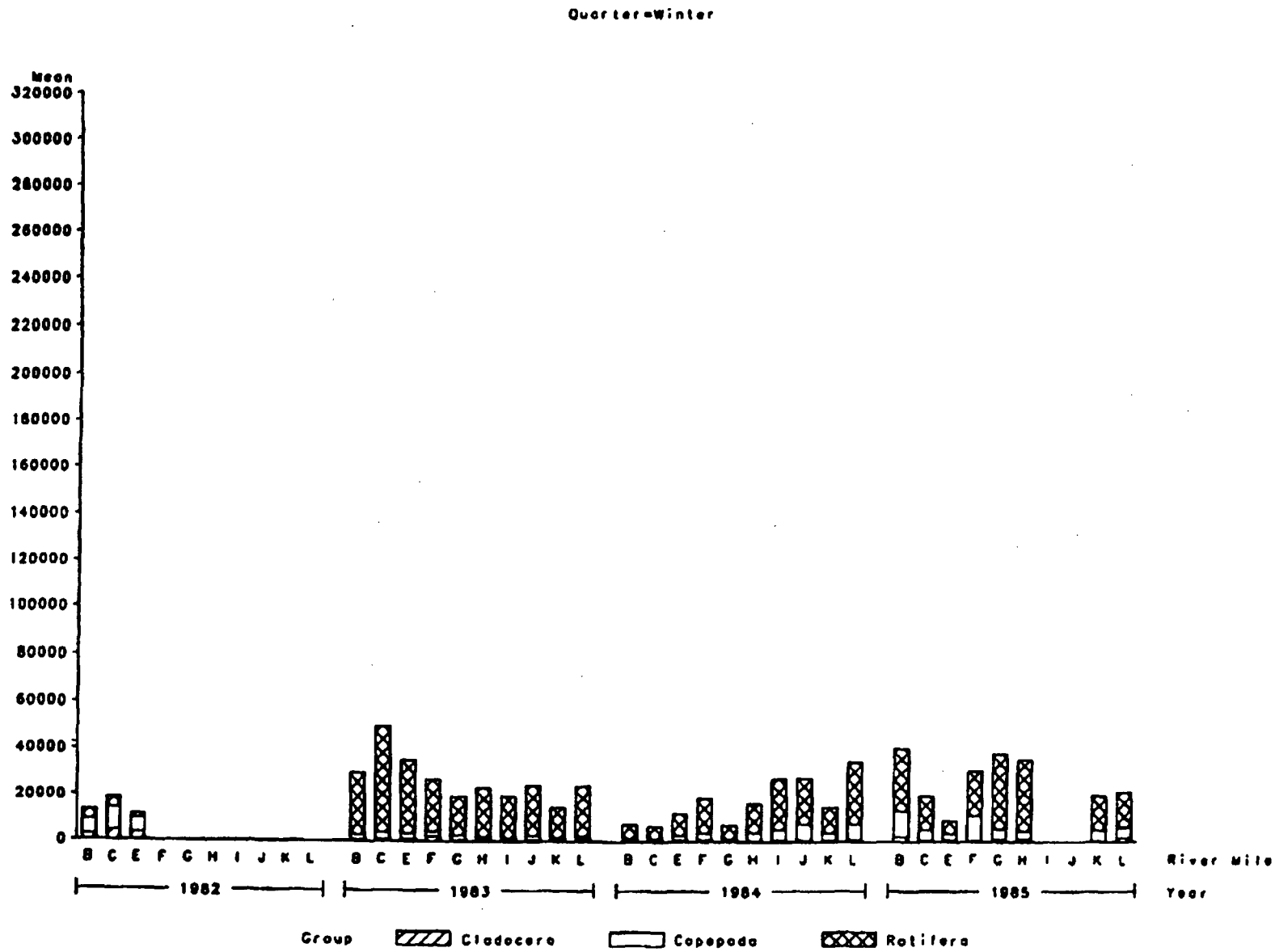
Year	Data	Range of Densities (No. x $10^3/m^3$)	One-Way ANOVA	SNK-(Station Means Ranged High to Low)	Watts Bar Stations Only: Equations for Regression (Significant at $\alpha = 0.05$)	R^2	Watts Bar and Sequoyah Stations Combined: Equations for Regression (Significant at $\alpha = 0.05$)	R^2
1985	Total	7.3 - 173.2	Sign.	10 9 7 8 6 4 5	$Y = 503.32 - 1.98 (X) + 0.002 (X^2)$	0.93	*	
	Clad.	0.8 - 17.8	Sign.	10 9 8 7 4 5 6				
	Cope.	2.4 - 62.9	Sign.	10 9 7 8 5 6 4				
	Rot.	2.5 - 92.5	Sign.	10 9 7 8 6 4 5				

*SQN stations not sampled in Fall 1985.
All abbreviations and explanations as in table 5-7.



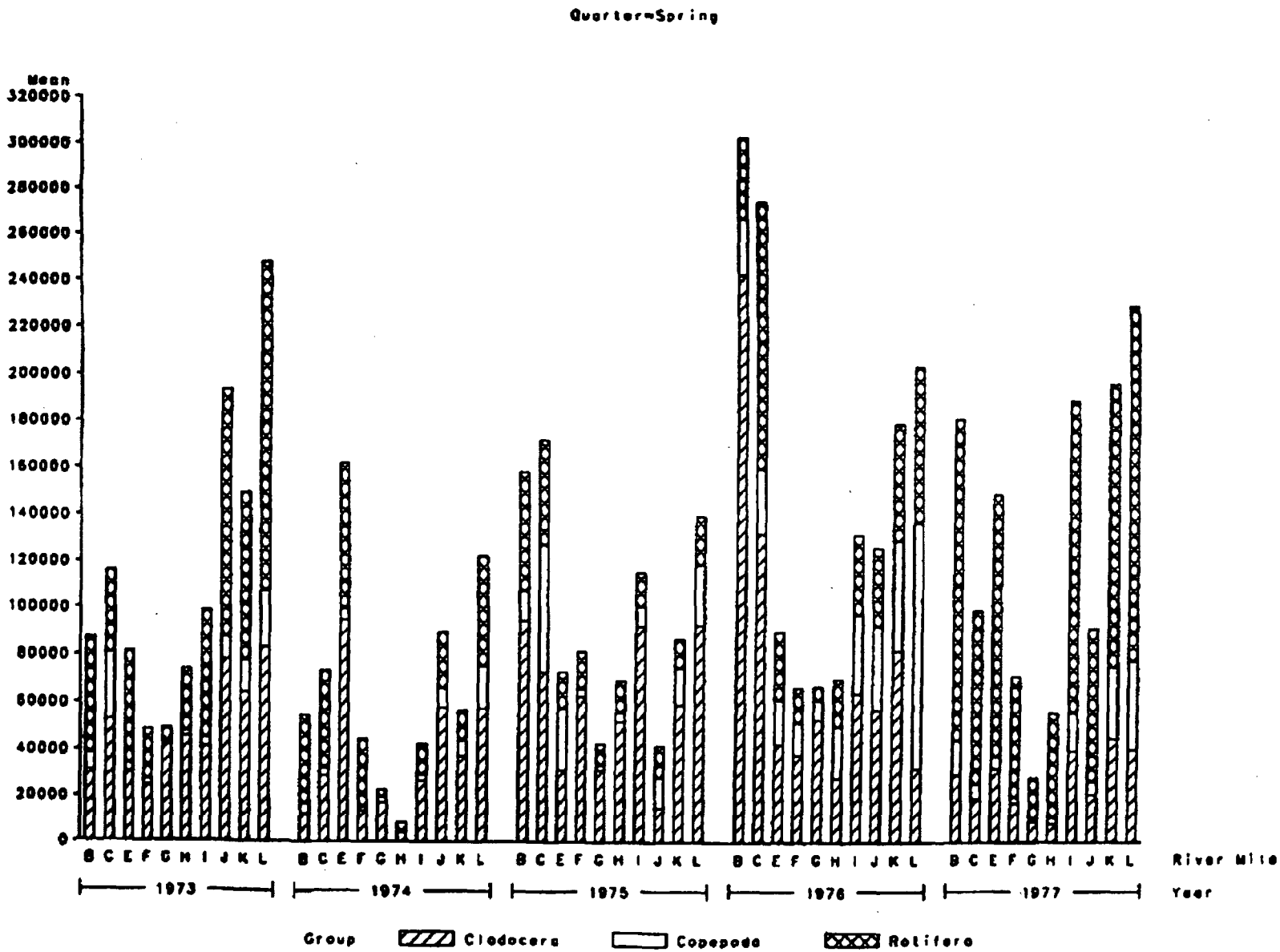
River Mile A=472.8 B=478.2 C=483.4 D=484.5 E=490.5 F=496.5 G=506.6 H=518.0 I=527.4 J=528.0 K=529.5 L=532.1

Figure 5-18. Zooplankton Abundance (No./m^3) for Winter Sample Periods during Preoperational Monitoring at Watts Bar Nuclear Plant. Proportion of Total Comprised by Each Group Shown for Each Location.



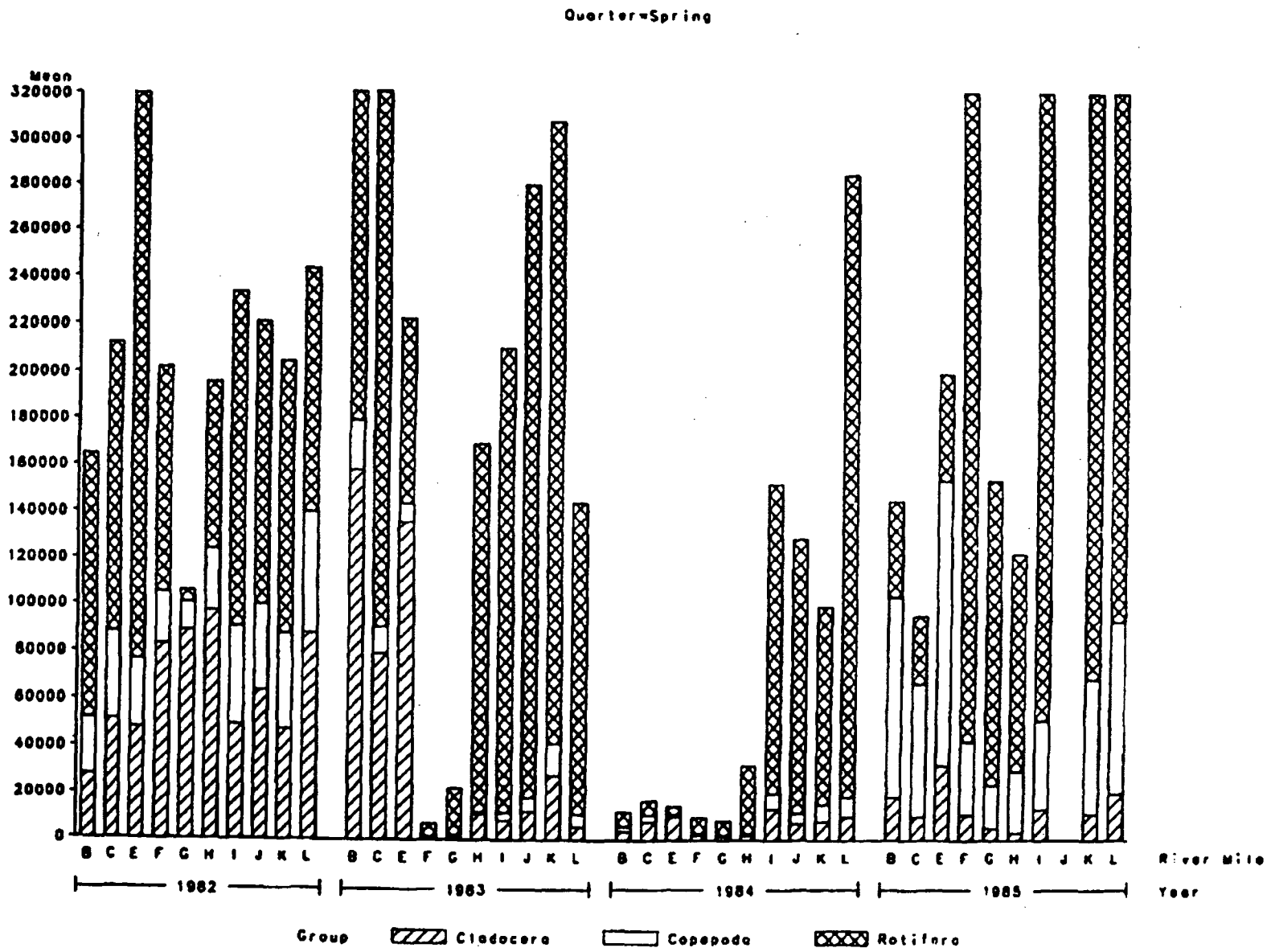
River Mile A=472.8 B=478.2 C=483.4 D=484.5 E=490.5 F=496.5 G=506.6 H=518.0 I=527.4 J=528.0 K=529.5 L=532.1

Figure 5-18. (Continued)



River Mile A=472.8 B=478.2 C=483.4 D=484.5 E=490.5 F=496.5 G=506.6 H=518.0 I=527.4 J=528.0 K=528.5 L=532.1

Figure 5-19. Zooplankton Abundance (No./m^3) for Spring Sample Periods during Preoperational Monitoring at Watts Bar Nuclear Plant. Proportion of Total Comprised by Each Group Shown for Each Location.



River Mile A=472.8 B=478.2 C=483.4 D=484.5 E=490.5 F=496.5 G=506.6 H=518.0 I=527.4 J=528.0 K=529.5 L=532.1

Figure 5-19. (Continued)

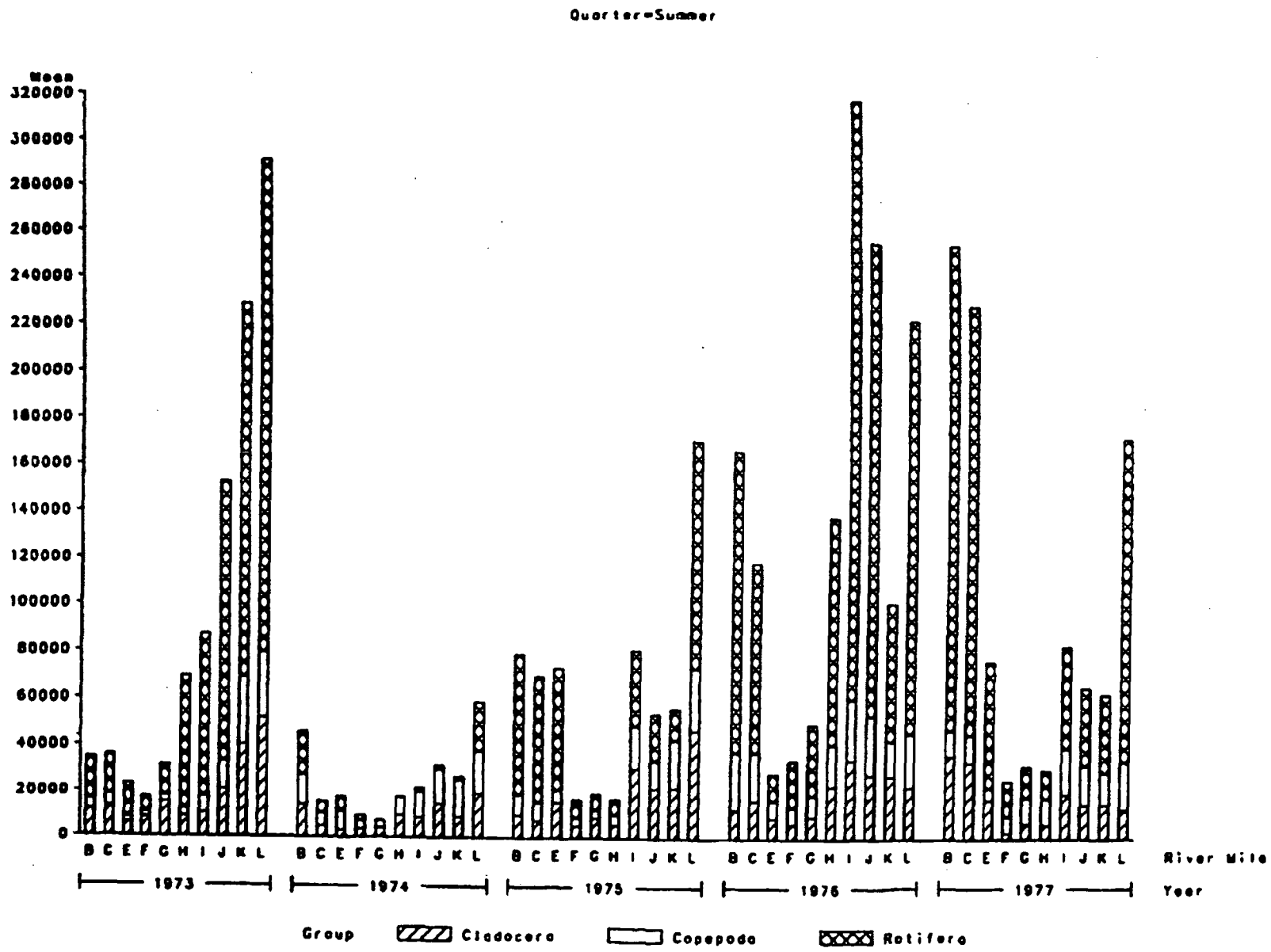
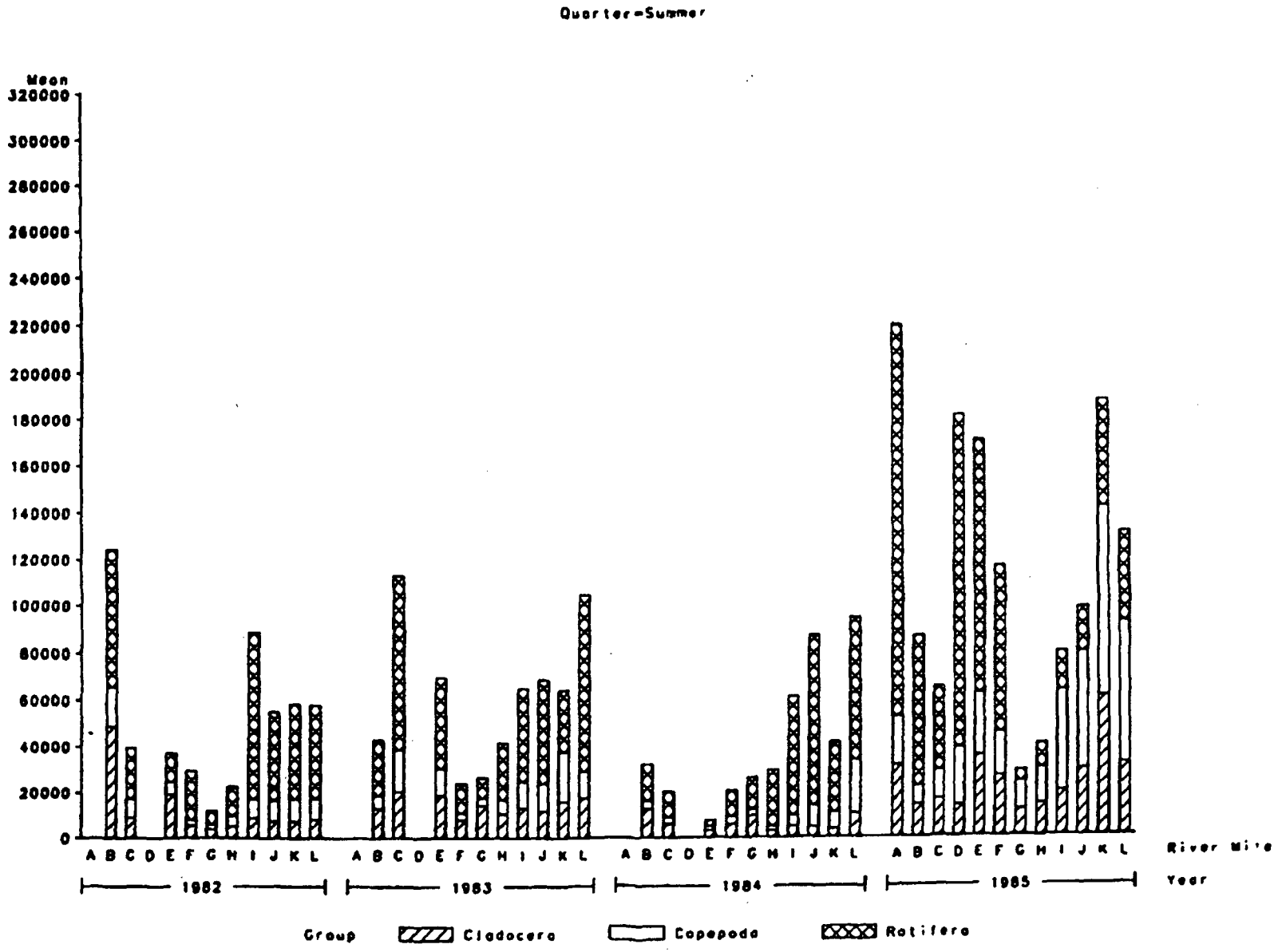


Figure 5-20. Zooplankton Abundance (No./m^3) for Summer Sample Periods during Preoperational Monitoring at Watts Bar Nuclear Plant. Proportion of Total Comprised by Each Group Shown for Each Location.



River Mile A=472.8 B=478.2 C=483.4 D=484.5 E=490.5 F=498.5 G=506.6 H=518.0 I=527.4 J=528.0 K=529.5 L=532.1

Figure 5-20. (Continued)

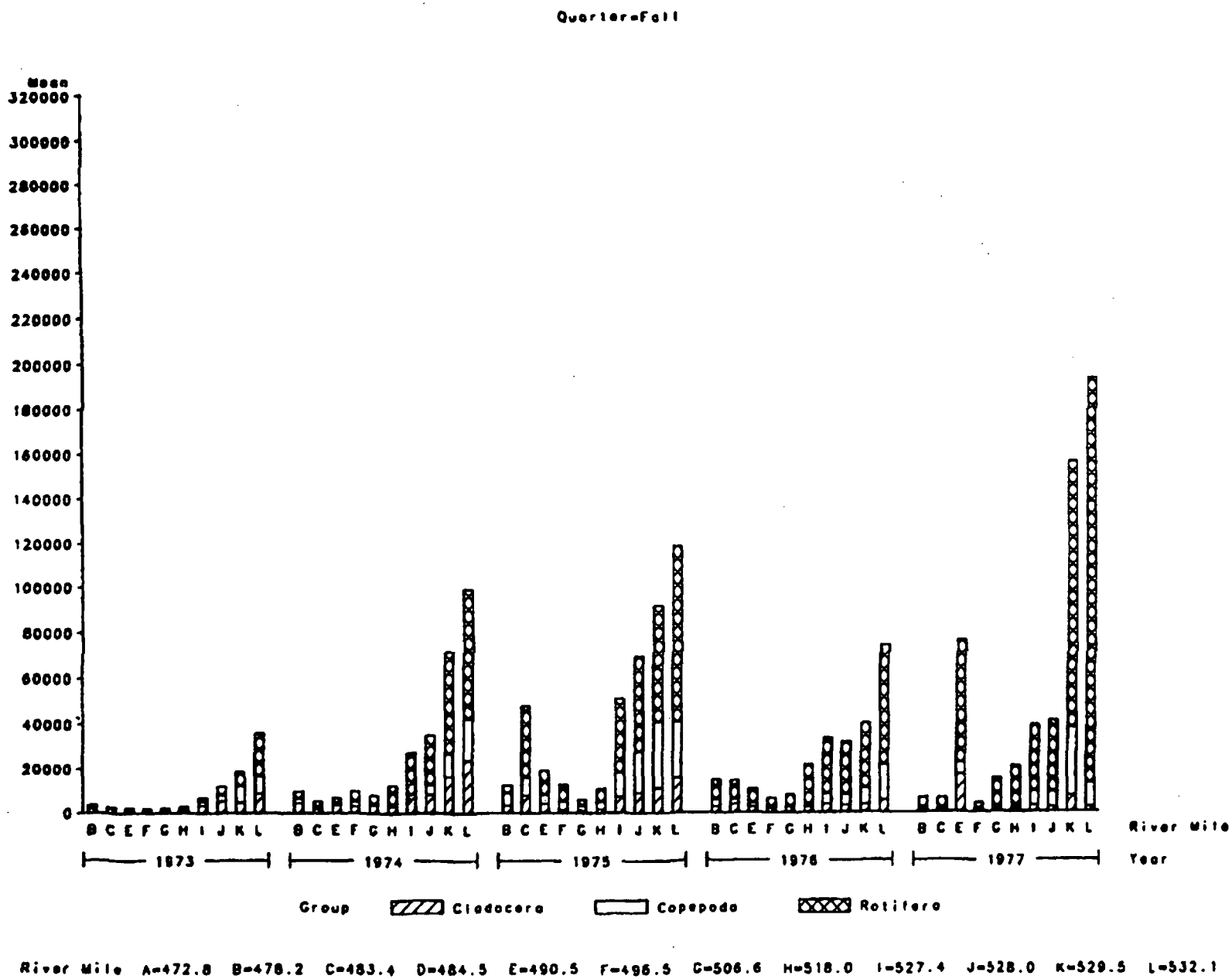
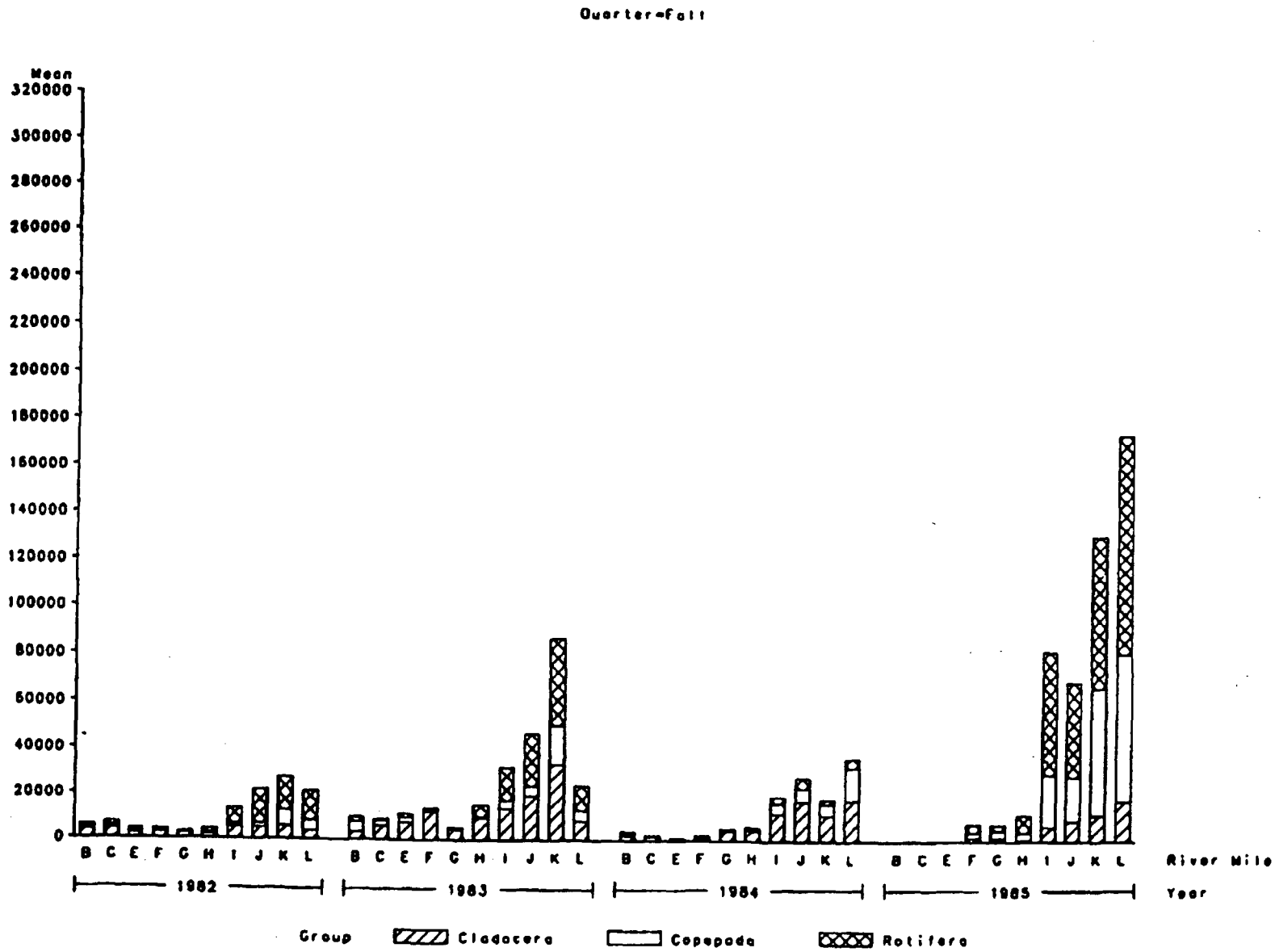


Figure 5-21. Zooplankton Abundance (No./m^3) for Fall Sample Periods during Preoperational Monitoring at Watts Bar Nuclear Plant. Proportion of Total Comprised by Each Group Shown for Each Location.



River Mile A=472.8 B=478.2 C=483.4 D=484.5 E=490.5 F=496.5 G=506.6 H=518.0 I=527.4 J=528.0 K=528.5 L=532.1

Figure 5-21. (Continued)

6.0 PERIPHYTON

Periphyton is most commonly defined as the community of bacteria, fungi, algae, and animals, as well as organic and inorganic detritus attached to submerged substrate, with the substrate being inorganic, organic, alive or dead (Weitzel 1979). It includes additionally, free living microorganisms which swim or become entangled among the attached forms. However, for this study only the algal portion of that community was considered.

Plankton, transported by flow and currents, often does not respond entirely to pertubations in the environment for a considerable distance downstream. Periphyton, on the other hand, being attached can show immediate responses to these perturbations at the source and thus can be a useful indicator of water quality.

Periphyton taxa are somewhat selective to substrate type. To avoid introducing the variable of differing substrata, artificial substrates were used to provide uniform substrate type, orientation, and size.

6.1 Materials and Methods

Field--Preoperational monitoring of the periphyton community in the vicinity of Watts Bar Nuclear Plant (WBN) was conducted from 1973 to 1977, discontinued, then resumed in 1982 continuing through 1985. Stations sampled in May/June and August/September from 1973 through 1976 were TRMs 506.6, 518.0, 527.4, 528.0, and 529.5. An additional station was added in 1977 at TRM 496.5 and the schedule was extended to include a

sampling in December 1977. When the preoperational monitoring resumed in 1982, sampling was on a quarterly basis at all six river miles sampled previously.

Artificial substrates for periphyton colonization, five plexiglass plates (1.5 dm^2 exposed area), were placed in a metal or PVC support rack and suspended 0.5 m from the water surface. Two racks were placed at each sampling location throughout the 1973-1985 study period. The plates were collected after being incubated for approximately one month. Upon collection, each plate was placed in an individual plastic bag and labelled. From 1973 to 1977, one plate from each rack was designated for algal enumeration (ID) and the remaining plates were designated for autotrophic index (AI) analysis. Beginning in 1982, three of ten slides incubated were selected at random for ID; the remaining slides were used for AI analyses. After labelling, all plates were placed on ice, returned to the laboratory, and stored frozen.

Enumeration--Plates designated for algal enumeration were thawed for up to one hour before periphyton was scraped from the plates. If the periphytic growth was moderate to heavy, a small area (usually 25 cm^2) was scraped. If the growth was light to moderate, the entire plate was scraped into a beaker containing a small amount of 10 percent formalin.

The scraped materials were diluted and a subsample withdrawn. Volumes of the diluted sample and the subsample were dependent upon the abundance of organisms and the quantity of detritus. The subsample was placed in a sedimentation chamber, similar to an Uthermohl cylinder, and allowed to settle for at least 12 hours. Classification and enumeration were conducted at the generic level with an inverted microscope at a

magnification of approximately 320X. References and publications used in identification varied for individual algal groups. Sometimes several references were utilized to identify genera within an algal group, but usually a single reference comprised the major taxonomic authority. Major (x) and infrequently (✓) used references were as follows:

	Algal Group					
Reference	Chloro	Chryso	Cyano	Crypto	Eugleno	Pyrrho
Cocke (1967)			x			
Desikachary (1959)			✓			
Drouet (1973)			x			
Drouet & Daily (1973)			x			
Forest (1954)	✓	✓	✓		x	✓
Hustedt (1930)		x				
Patrick & Reimer (1966)		x				
Prescott (1964)	x			x	x	x
Tiffany & Britton (1971)	✓	✓			✓	✓
Whitford & Schumacher (1969)	✓					

Autotrophic Index--Slides selected for autotrophic indices were thawed and large invertebrates (chironomids, caddisflies, etc.) were removed. All periphytic growth was scraped from the slide and placed in a solvent to extract the phytopigments. The scraped material was placed in solvent, homogenized, and steeped for at least 12 hours. In 1973 through 1975, the solvent used for extraction was 95 percent ethanol and the instrument used to determine phytopigment densities was a Klett-Summerson colorimeter. After 1975, the phytopigments were extracted using 90 percent alkalized acetone and a Beckman Model 25 spectrophotometer was used to determine pigment concentrations.

After extraction the sample was filtered onto a preweighed filter pad. Chlorophyll concentrations were determined using the filtrate as described below. Biomass estimate was calculated using data from the residue manipulations. The filter with residue was placed in a preweighed crucible and dried at 105°C for at least 12 hours; weighed, then incinerated in a muffle furnace at 600°C for 1 hour; cooled in a dessicator; and reweighed. This ash-free dry weight provided an estimate of total organic matter or biomass.

To estimate phytopigment concentrations, the filtrate was analyzed photometrically with a Klett-Summerson colorimeter in 1973 to 1975. With the ash-free dry weight, the autotrophic index was calculated as shown:

$$AI = \frac{\text{(Klett-Summerson reading)(0.002)}}{\text{Ash-free dry weight/slide}}$$

Because of the unreliability of the phytopigment readings obtained from the Klett-Summerson colorimeter and the inability to compare the data to later years, the 1973 autotrophic indices are not included in this report. The 1974 and 1975 phytopigment samples were destroyed in a laboratory accident.

After 1975, the filtrate was analyzed spectrophotometrically. From 1976 to 1977, the optical densities were read at 750, 663, 645, and 630 nm. Each sample was then acidified with two drops of 0.1 N HCl, allowed to steep for one minute, then reread at 750 and 663 nm. Chlorophyll a, b, and c concentrations were originally calculated using the 1966 UNESCO equations for chlorophylls and the Lorenzen (1967) equations for phaeophytin a. However, for this report all values have been recalculated using the Jeffrey-Humphrey (1975) equations.

In 1982 through 1985, optical densities of each sample were read at 750, 664, 647, and 630 nm. Again the samples were acidified with two drops of 0.1 N HCl, allowed to steep for one minute, then reread at 750 and 664 nm. Phytopigment concentrations were calculated using the Jeffrey-Humphrey (1975) equations, and phaeophytin a concentration was calculated again using the Lorenzen (1967) equations.

For all samples from 1976 to 1985, the phaeophytin index values were determined (Weber 1973) as shown:

$$PI = \text{Chl } a_b / \text{Chl } a_a$$

where Chl a_a = corrected optical density for chlorophyll a after acidification;

Chl a_b = corrected optical density for chlorophyll a before acidification.

The autotrophic index (AI) value for the sample was calculated according to Weber (1973) as shown:

$$AI = \frac{\text{Ash free dry weight/m}^2 \text{ (mg/m}^2)}{\text{Chlorophyll } a \text{ concentration/m}^2 \text{ (mg/m}^2)}$$

Data Analyses--Periphyton enumeration and autotrophic index data for each sampling date were tested for station differences using a one-way Analysis of Variance after the data were transformed ($\log_{10} + 1$). If there were significant differences among stations, a Student, Newman, Keuls (SNK) Multiple Range Test (Sokal and Rohlf, 1969) was applied to the data. However, this was done only for those sampling dates which had replicate samples for every station.

To examine trends in the enumeration data, the data were transformed ($\log_{10} + 1$) and pooled by years and by stations. Two-way analyses of variance were done on these pooled data sets with station and

time (both year and month) as the variables. Means were further compared using an SNK multiple range test. When cyanophytes were not found at all stations for which substrates were recovered, the station which had no cyanophytes in any replicate substrate was dropped from the analyses. This was done to avoid distorting the ANOVA with "no variance" data.

Similarity of periphytic communities among stations was determined using a two-step approach. Sorenson's Quotient of Similarity, SQS (McCain, 1975), was calculated to determine similarities based solely on presence/absence of genera (qualitative characteristics of community composition). A percentage similarity (PS) index (Pielou, 1975) was calculated, but was based on both qualitative and quantitative characteristics of community structure. In both cases, values of 70 percent or greater were assumed to show similarity.

SQS was calculated as follows:

$$SQS = [2s/(x + y)](100)$$

where, x = number of taxa at station x

y = number of taxa at station y

s = number of taxa in common between stations x and y

Percentage similarity index was calculated as follows:

$$PS = 200\Sigma_{i=1}^{s} \min P_{iX}, P_{iY})$$

where, P_{iX} and P_{iY} are the quantities of genus i at stations X and Y as proportions of the quantities of all s genera at the two stations combined.

If comparisons between two locations provided low SQS and PS values, the communities were considered different. If SQS was high but PS low, communities were composed of similar genera but differed either in

absolute cell density or in relative abundance of genera present. When SQS was low and PS high, communities were still considered similar because the low SQS probably was related to random occurrence of rare genera which affects SQS much more than PS. If both coefficients were high, communities were similar in generic composition, relative abundance of genera present, and absolute cell number.

Correlation coefficients (Snedecor and Cochran, 1967) were calculated on untransformed data to test for possible relationships between total abundance and selected chemical and physical parameters.

6.2 Results and Discussion

High flow conditions, floating debris, or vandalism caused loss of substrates or entire samplers. Listed in table 6-1 are the sampling dates and locations when entire samplers for a particular analyses were lost.

Community Structure--During the 1974 through 1985 preoperational monitoring period, a total of 61 periphyton taxa was found in the vicinity of WBN. The temporal, spatial, and abundance information on the 23 chlorophyte, 26 chrysophyte, 8 cyanophyte, 3 euglenophyte, and 2 pyrrhophyte taxa found are presented in Appendix 6-A. The mean abundance, standard deviation, and coefficient of variation by periphyton group is given in Appendix 6-B. Of these 61 genera, 20 were found only once during the preoperational monitoring study through 1985. These 20 genera are listed in table 6-2. Most of these genera are planktonic forms which probably became entrapped in the filamentous algal periphyton, a common phenomenon.

Nine genera were dominant during the study period. These genera and the percentage of the 101 sample sets in which they were dominant are shown below.

Division	Genus	Percentage
Chlorophyta	Stigeoclonium	33
Chrysophyta	Achnanthes	36
	Cocconeis	1
	Cymbella	4
	Diatoma	8
	Gomphonema	7
	Melosira	5
	Navicula	5
Cyanophyta	Lyngbya	1

The total number of taxa by location is presented in table 6-3. For the first and last quarters of the sampling year, February and December, number of genera was low at all stations except TRM 496.5. For the February quarter at TRM 496.5, the number of genera increased. Correlation coefficients, for the number of genera present as a function of time, indicate these trends (table 6-4). The number of taxa for the remaining two quarters was not consistent, with the number increasing at some stations (TRM 496.5 May/June and TRM 527.4 August/September) and decreasing at others (e.g., TRM 506.6 May/June).

The minimum number of taxa found at any location was seven, and occurred twice at TRM 496.5 (November 1983 and December 1985) and once at TRM 506.6 (December 1985). The maximum number of taxa was 21 at TRM 528.0 in June 1977. The May/June quarters usually contained the maximum number of genera encountered for all stations except TRM 496.5 (August 1982) and TRM 529.5 (August 1982 and December 1982).

When community structure for each quarter was compared using only SQS (table 6-5), frequency of similarity was high among stations, ranging from 81 percent in 1976 and 1982 to 100 percent in 1975 and 1984. When both number of taxa and abundance were considered, PS (table 6-5), the frequency of similarity was lower, ranging from only 15 percent in 1982 to 70 percent in 1974 and 1975. The PS values decreased from 1974 to 1982, then began to rise with 1985 having the second highest PS values. The three upstream stations, TRMs 529.5, 528.0, and 527.4, usually had higher PS values than the lower three stations. This may be caused by the close proximity of these stations to each other and to Watts Bar Dam as well as the riverine habitat at these stations. This pattern was similar for the SQS values but was not as consistent.

SQS values varied from a low of 60 percent in November 1983 (TRM 496.5 vs 527.4 and TRM 496.5 vs 528.0) to a high of 100 percent in February 1983 (TRM 496.5 vs 528.0) and in December 1985 (TRM 528.0 vs 529.5). The PS values ranged from an astounding low of 1 percent in February 1983 (TRM 496.5 vs 527.4 and TRM 496.5 vs 528.0) to a peak level of 93 percent in several quarters, May 1976 (TRM 528.0 vs 529.5), June 1982 (TRM 527.4 vs 529.5), May 1985 (TRM 496.5 vs 529.5 and TRM 518.0 vs 528.0). It is noteworthy that a peak SQS value occurred for the same station comparison at which the lowest PS value occurred. The reason for this was that exactly the same genera occurred at both stations but the cellular abundance was 17,809 percent higher at the downstream station.

Overall, these high SQS values coupled with lower PS values show that the communities are made up of similar genera but differ in the abundance of these genera among stations.

Percentage compositions of the periphyton communities for the 1974 through 1985 sampling periods are given in table 6-6. Chrysophytes were dominant in most quarters and at most river miles. The frequency of chrysophyte domination ranged from 67 percent in 1985 to 100 percent in 1974. Occasionally a typical seasonal pattern occurred with chrysophytes dominant in cooler months and chlorophytes in warmer months. When chlorophytes comprised the dominant group, it was usually at TRM 506.6 and/or TRM 518.0. This occurred in June 1975, August 1976, September 1977, May 1983, July 1984, May 1985, and December 1985. Chlorophytes were the dominant group or codominant with chrysophytes at all stations in May 1985. The frequency of chlorophyte dominance at all sampling stations ranged from 0 percent in 1974 and 1982 to 29 percent in 1985.

Cyanophytes were dominant only once, June 1982 at TRM 518.0, when the group comprised 48.4 percent of the total community. Prior to 1982, cyanophytes were never more than 2.9 percent of the community and were usually less than 1 percent. In 1982, this group made up a much larger portion of the community when it occurred, ranging from 9.1 percent to 48.4 percent. After 1982, the cyanophytes decreased in percentage composition, but consistently occurred in the warmer months.

The dominant genera by quarter and location are presented in table 6-7. These dominant genera individually accounted for 21.6 percent to 84.8 percent of the total community. Chrysophyte taxa were usually dominant, with Achnanthes being dominant in 36 percent of the samples from 1974 to 1985 and accounting for 29.8 percent to 84.8 percent of the total abundance. Prior to 1982, Gomphonema and Melosira were dominant in 14 percent of the samples. Also, Diatoma was dominant in 12 percent of the 1982 to 1985 samples.

When a chlorophyte genus was dominant, 33 percent of the samples from 1974 to 1985, the genus was always the rheophilic filamentous alga, Stigeoclonium. This alga accounted for 24.4 percent to 77.8 percent of the community when it was dominant.

Only once was the periphyton community dominated by a cyanophyte genus. Lyngbya, a filamentous bluegreen alga, comprised 33.8 percent of the total community abundance at TRM 529.5 in December 1982. Dominance of a bluegreen genus during December was unusual. Usually, the cyanophytes do not become abundant until water temperatures increase.

Abundance--As expected with a cyclic community like periphyton, cell abundance varied by quarter, with the May/June quarters usually being the highest (1974-1984). However, in 1985, the highest total abundance for that year occurred in September. Minimum total abundance ranged from 3656 cells/cm^2 (August 1982, TRM 506.6) to 212,387 cells/cm^2 (June 1975, TRM 518.0). Peak abundance varied a great deal ranging from 72,322 cells/cm^2 (May 1974, TRM 529.5) to 3,820,187 cells/cm^2 (June 1982, TRM 506.6).

Cell abundance at TRM 506.6 was lowest in 39 percent of the quarters surveyed. The community at TRM 527.4 was lowest in cellular density for 25 percent of the quarters. However, the highest total abundance in 22 percent of the quarters occurred at TRM 506.6. Also, two other stations, TRM 496.5 and 518.0, each accounted for the highest abundance in 22 percent of the quarters.

By year, total cell abundance was lowest in 1974 with an average of 47,200 cells/cm^2. When monitoring was resumed in 1982, the periphyton total abundance peaked with a average density of 655,900

cells/cm². Thereafter, abundance decreased through 1985 when the second lowest average of the 1974 to 1985 study period occurred (172,500 cells/cm²). This same pattern was exhibited by chrysophyte abundance with a peak abundance in 1982, averaging 416,240 cells/cm², and the lowest abundance in 1974, averaging 4,563 cells/cm².

Chlorophyte cell abundance followed the same pattern as total and chrysophyte abundance. Mean abundance was 1,152 cells/cm² in 1974 and 166,830 cells/cm² in 1982. Chlorophyte densities declined in 1983 (99,880 cells/cm²), reached a secondary peak abundance in 1984 (116,890 cells/cm²), then declined in 1985 to the second lowest (average chlorophyte) density of 62,440 cells/cm².

Cyanophyte yearly average abundance followed the same trend as chrysophyte yearly average abundance, lowest in 1974 (337 cells/cm²) and highest in 1982 (113,680 cells/cm²).

Table 6-8 contains the one-way analysis of variance and SNK test results by quarter and station from 1974 to 1985. With a few exceptions, there were no differences in total, chlorophyte, chrysophyte or cyanophyte abundance among quarters from 1974 to 1977. In May 1976 cell abundance (total, chlorophyte, and chrysophyte) at TRM 527.4 was considerably less than the other stations. In September 1977 there were significant differences among stations. Chrysophyte and total abundance at TRMs 506.6, 527.4, and 528.0 was significantly lower than TRMs 496.5 and 518.0. Total cell abundance was significantly lower at TRM 506.6, and chlorophyte abundance was lower at TRM 496.5.

From 1982 to 1985, significant differences among stations were common. There were no consistent trends among stations except that the

total abundance at TRM 506.6 was significantly lower than other stations for 5 out of 15 quarters. This was also true to some extent for total abundance at TRM 529.5 (4 out of 15 quarters). Because chrysophytes were usually the most abundant group, similarities or differences in the total abundance among stations were usually the same as those for chrysophytes.

Table 6-9 presents the results of two-way analysis of variance and SNK tests on cell abundance pooled by quarter. As in the one-way ANOVAs, the station or year similarities (or differences) in total abundance followed patterns for chrysophytes. Significant differences in abundance by year for each quarter were common. Also, abundance by station was usually significantly different and yielded no consistent trends of similarity, ranking, or difference.

When the data were pooled by year and subjected to two-way ANOVAs and SNK tests, total abundance by year was significantly different (table 6-10). Cyanophyte abundance for 1974 through 1977 was not significantly different. Cyanophyte abundance for 1985 was significantly different than that in 1974 through 1977 and in 1982 through 1984. Abundance in 1985 was higher than 1974-1977 but less than 1982-1984. This reflects a trend found in other TVA reservoirs for bluegreen algae, i.e., an increase in blue-green algal abundance since the late 1970s, peaking in 1982 through 1983, and followed by a dramatic decline in 1984 and 1985.

Total periphyton and chlorophyte abundance at the station immediately below the plant discharge, TRM 527.4, was significantly lower than other stations (table 6-10) abundance. Chrysophyte abundance at this station was also lower than other stations, except for TRM 529.5.

Total abundance data compared with physical and chemical data revealed few relationships (table 6-11). However, a relatively strong inverse ralationship between river flow and total abundance was noted. This might be expected since higher flows can decrease the ability of some periphyton to adhere to a substrate and may increase abrasion of existing colonizing forms.

Autotrophic Indices--Chlorophyll a, the primary photosynthetic pigment for green plants, is useful as an index of the productivity of the periphyton community. The ratio of ash-free dry weight to chlorophyll, i.e., autotrophic index (AI), has been used to indicate periphyton community structure (Weitzel 1971). Additionally, it has been used to indicate changes in the ratio of the primary producing portion (autotrophic) to the consuming portion (heterotrophic) of the community in relation to environmental perturbations. Theoretically, an organic influx to the system will shift the community from a producing (autotrophic) phase to a consumptive (heterotrophic) phase, causing an increase in the AI. Normal AI values range from 50 to 200 with larger values generally assumed to indicate declining or poor water quality (Standard Methods, 1985). However, a problem with this index is the presence of nonviable organic material. Large amounts, which may be normal for the community in a particular location, will increase the amount of ash-free dry weight, thereby, greatly increasing the AI value (Grzenda and Brehener 1960).

Chlorophyll a degrades into several by-products, the major one being phaeophytin a. Because phaeophytin a abosorbs in the same spectral region as chlorophyll a, the concentration of chlorophyll a can be overestimated, if not corrected. Additionally, the ratio of chlorophyll a

to phaeophytin a can be useful in assessing the health of the community. These corrected values were calculated and are presented with the other autotrophic index data.

The ash-free organic weight (AFOW) and phytopigment values for individual samples are in Appendix 6-C. Mean values for each sampling location by sampling dates for AFOW, corrected chlorophyll a, AI's and phaeophytin indices are in Appendix 6-D.

Results of the one-way ANOVAs and SNK multiple range tests for mean corrected chlorophyll a concentrations and ash-free organic weight data are presented in table 6-8. During 1976 through 1985, there were no significant differences in both corrected chlorophyll a concentrations and AFOW in 4 quarters (20 percent) out of the 20 quarters for which data available. Most of the data similarity occurred in 1983 (a low river flow year) when 3 of the 4 quarters had no significant differences among stations. All stations were significantly different from each other in 2 quarters (10 percent). In the remainder of cases, there were station differences but there were no consistent trend among stations.

Mean corrected chlorophyll a concentrations were lowest in 1977, ranging from 1.5 to 68.3 mg/m^2, and highest in 1983, varying from 0.2 to 147.8 mg/m^2 (table 6-12 and figure 6-1). The minimum value for each year usually occurred at one of the two stations upstream of WBN, while the maximum value usually occurred at TRM 518.0 (3 out of 6 years) or TRM 527.4 (2 out of 6 years). However, when the minimum/maximum station means for each quarter are reviewed, the trend is different. The stations above WBN were lowest in 33 percent of the quarters. One station, TRM 506.6, had the minimum station mean in 50 percent of the quarters studied. This

station, together with TRM 496.5, accounted for 66 percent of the minimum station mean corrected chlorophyll a concentrations, 1976 through 1985. The phytopigment concentrations did not follow the same trend as abundance for the periphyton communities.

From 1976 through 1982, the year of peak abundance, the AFOW data followed the same trends as corrected chlorophyll a concentrations with lowest yearly mean values in 1977. Thereafter, there was an inverse relationship between the two parameters. AFOW values ranged from 686 to 5,974 mg/m^2 in 1977, the year with lowest mean values. In 1985 the mean AFOW values were highest, ranging from 186 to 494,173 mg/m^2. The yearly minimum mean values occurred at TRM 528.0 for three of the six years while the yearly maximum mean values occurred at TRM 518.0 in five of the six years studied.

When the station mean AFOW values by quarter (Appendix 6-D) are examined, the station at TRM 506.6 had the minimum value in 45 percent (9 out of 20) of the quarters studied. This station together with TRM 496.5 had the minimum station mean values in 70 percent (14 out of 20) of the quarters. The periphyton communities at TRM 518.0 had the maximum AFOW values in 10 of the 20 quarters studied (50 percent). The maximum and minumum trend found for AFOW values were the same as that for corrected chlorophyll a.

During this study there was a continual increase in the autotrophic indices from 1976, when mean AI values were lowest (ranging from 124 to 590), to the peak year, 1985 (25 to 8,088). This continual rise in AI values over the years has been documented in Guntersville Reservoir, another TVA reservoir (TVA, 1985). The yearly minimum values

occurred at TRM 527.4 in three of the six years studied. There was no consistent trend for the yearly maximum values.

The minimum/maximum station means for AI values by quarter did not exhibit trends as strong as the AFOW or chlorophyll a data. Periphyton AI values were lowest at TRMs 496.5 and 527.4 each in 6 of the 20 quarters studied (30 percent). The AI values at TRM 529.5 were highest in 6 of the 20 quarters studied; and together with TRM 528.0, the other station above WBN, were highest in 10 of the 20 quarters.

The phaeophytin index (PI) values, a ratio of chlorophyll a to phaeophytin a, were lowest in 1976, with station means ranging from 1.13 to 1.47. PI values for the study period peaked in 1977, ranging from 1.42 to 1.66. There were several station means in 1977 which were above 1.70, although out of theoretical range, still indicate healthy periphyton communities. After 1977, PI values decreased somewhat but remained fairly constant throughout the rest of the study. Generally, higher AI and PI values indicate a shift to more heterotrophic growth.

6.3 Summary and Conclusions

Artificial substrates were used to monitor the periphyton community in the vicinity of WBN from 1973 to 1977, then resumed from 1982 through 1985. A total of 61 periphyton taxa was identified which included 23 chlorophyte genera, 26 chrysophyte genera, 8 cyanophyte genera, 3 euglenophyte genera, and 2 pyrrhophyte genera. Of these 61 genera, 20 were found only once during the study. Most of these 20 genera were planktonic forms which probably became entrapped in the periphyton

community. Of the remaining 41 genera, nine were dominant in the periphyton community on one or more occasions. Two rheophilic genera, Stigeoclonium, a chlorophyte, and Achnanthes, a diatom, were dominant in 69 percent of the samples. These two genera typically are dominant in other TVA reservoirs. A cyanophyte genus, Lyngbya, was dominant only once in the entire study, June 1982. The number of genera found at any location ranged from a minimum of 7 to a maximum of 21. The December quarter usually had the fewest taxa and the May/June quarter usually had the highest number of taxa.

Throughout the study period, genera comprising the community structure were usually similar at all stations. The frequency of similarity (Sorenson's Quotient) ranged from 81 percent of the station comparisons in 1976 and 1982 to 100 percent in 1975 and 1984. However, this high degree of similarity decreased when both taxa and abundance were considered. The three stations closest to WBN and Watts Bar Dam, TRMs 529.5, 528.0, and 527.4, usually were more similar in community structure than the lower stations, TRMs 496.5, 506, and 518. Overall, communities among stations were composed of similar genera but differed in abundance.

As expected, total cell abundance varied by quarter, with the May/June quarters usually the highest. By year, total abundance was lowest in 1974 with an average of 47,200 cells/cm^2. Abundance increased in 1975 to an average of 299,000 cells/cm^2. Thereafter, it decreased through 1977. When monitoring was resumed in 1982, periphyton total cell abundance peaked with an average density of 655,900 cells/cm^2. This same pattern of abundance was exhibited by separate taxa, particularly chrysophytes, chlorophytes, and cyanophytes.

With few exceptions, there were no differences in total cell abundance among stations from 1974 to 1977. However, from 1982 through 1985, total abundance at TRM 506.6 and TRM 529.5 tended to be lower than other stations but no consistent trends were established. Abundance data did not correlate strongly with physical or chemical data except that a relatively strong inverse relationship to river flow was noted.

Corrected chlorophyll a concentrations were lowest in 1977, and highest in 1983. Ash free dry weight (AFOW) followed the same trend through 1982, then an inverse relation between the two parameters occurred. Both chlorophyll a and AFOW varied widely by quarter and station. Autotrophic index (AI) values, derived from these parameters, continually increased from 1976 through 1985 (124 to 590 and 25 to 8,088, respectively). Phaeophyton index (PI) values were lowest in 1976, station means ranging from 1.13 to 1.47, and highest in 1977, range of means 1.42 to 1.66. After 1977, PI values decreased slightly and remained fairly constant through 1985.

Generally, preoperational monitoring results indicated that the periphyton community in the vicinity of WBN is typical of mainstream reservoirs on the Tennessee River; however, the relatively high AI and PI values indicate a shift to more heterotrophic growth.

Table 6-1. Sampling Dates and Locations Where Entire Periphyton Samplers Were Lost, Watts Bar Nuclear Plant, Chickamauga Reservoir.

	TENNESSEE RIVER MILE					
DATE	496.5	506.6	518.0	527.4	528.0	529.5
August 1975		ID, AI*	ID, AI	ID, AI	ID, AI	ID, AI
August 1976					ID, AI	
June 1977	ID, AI	ID, AI				ID, AI
September 1977						ID, AI
December 1977	AI				ID, AI	ID, AI
June 1982	ID, AI					
December 1982		ID, AI	ID, AI	ID, AI	ID, AI	
February 1983		ID, AI				ID, AI
May 1983	ID, AI			ID, AI	ID, AI	ID, AI
September 1983	ID, AI		ID, AI	ID, AI	ID, AI	
November 1983		ID, AI				
February 1984	ID, AI					
July 1984				ID, AI	ID, AI	ID, AI
September 1984						ID, AI
December 1984			ID, AI			
March 1985			ID, AI	ID, AI		
September 1985						ID, AI

*ID = Slides for algal identification and enumeration.
AI = Slides for autotrophic index analysis.

Table 6-2. List of Periphyton Genera Which Occurred Only Once During Preoperational Monitoring, Watts Bar Nuclear Plant, Chickamauga Reservoir, 1974-1985.

Division	Genus	Date	Location (Tennessee River Mile)
Chlorophyta	Closterium	MAY 76	506.6
	Draparnaldia	MAY 74	506.6, 518.0, 527.4, 529.5
	Kirchneriella	JUN 77	528.0
	Micractinium	AUG 82	518.0
	Protoderma	AUG 82	496.5
	Schroederia	MAY 85	527.4
	Spirogyra	SEP 77	518.0
	Tetraspora	MAY 74	518.0
Chrysophyta	Cymatopleura	FEB 84	518.0
	Mallomonas	MAR 85	529.5
	Meridion	FEB 83	496.5, 518.0, 527.4, 528.0
	Rhizosolenia	SEP 84	506.6
	Rhoicosphenia	JUN 77	518.0, 527.4
Cyanophyta	Anacystis	JUN 77	518.0, 528.0
	Chroococcus	DEC 77	506.6
	Oscillatoria (spiral)	JUN 82	518.0
	Phormidium	MAY 74	506.6, 518.0, 527.4, 528.0 529.5
Euglenophyta	Trachelomonas	AUG 76	518.0
Pyrrhophyta	Glenodinium	DEC 77	518.0, 527.4
	Gymnodinium	MAY 76	529.5

Table 6-3. Number of Periphyton Taxa at Each Station and Number of Periphyton Taxa in Common Between Stations During Preoperational Monitoring from 1974 to 1985, Watts Bar Nuclear Plant, Chickamauga Reservoir.

Date	Station (TRM)	Number of Taxa at Station	Number of Taxa Common Between Stations					
			TRM 496.5	TRM 506.6	TRM 518.0	TRM 527.4	TRM 528.0	TRM 529.5
May 1974	506.6	17			12	15	10	12
	518.0	14				12	10	11
	527.4	19					10	13
	528.0	10						10
	529.5	14						
August 1974	506.6	13			8	9	11	9
	518.0	8				7	8	8
	527.4	12					10	10
	528.0	14						13
	529.5	14						
June 1975	506.6	17			12	12	13	13
	518.0	14				12	11	13
	527.4	15					12	13
	528.0	15						13
	529.5	16						
May 1976	506.6	20			15	10	13	14
	518.0	20				14	15	14
	527.4	15					12	12
	528.0	19						13
	529.5	16						
August 1976	506.6	17			13	14		11
	518.0	17				12		10
	527.4	15						11
	529.5	13						
June 1977	518.0	16				14	14	
	527.4	19					16	
	528.0	21						
September 1977	496.5	12		9	11	9	8	
	506.6	10			9	8	7	
	518.0	15				10	9	
	527.4	10					7	
	528.0	10						

Table 6-3 (Continued)

Date	Station (TRM)	Number of Taxa at Station	Number of Taxa Common Between Stations					
			TRM 496.5	TRM 506.6	TRM 518.0	TRM 527.4	TRM 528.0	TRM 529.5
December 1977	496.5	12		10	9	9		
	506.6	15			12	11		
	518.0	17				13		
	527.4	15						
June 1982	506.6	20			17	18	16	14
	518.0	19				18	16	14
	527.4	19					17	14
	528.0	18						13
	529.5	15						
August 1982	496.5	20		10	16	14	15	17
	506.6	11			10	9	9	10
	518.0	18				14	15	16
	527.4	15					14	15
	528.0	15						15
	529.5	20						
December 1982	496.5	13						12
	529.5	20						
February 1983	496.5	12			12	11	12	
	518.0	15				14	12	
	527.4	15					11	
	528.0	12						
May 1983	506.6	9			8			
	518.0	13						
September 1983	506.6	13					11	
	529.5	15						
November 1983	496.5	7			7	6	6	6
	518.0	14				12	12	11
	527.4	13					11	10
	528.0	13						11
	529.5	11						

Table 6-3 (Continued)

Date	Station (TRM)	Number of Taxa at Station	Number of Taxa Common Between Stations					
			TRM 496.5	TRM 506.6	TRM 518.0	TRM 527.4	TRM 528.0	TRM 529.5
February 1984	506.6	10			10	10	10	9
	518.0	14				12	11	10
	527.4	14					11	11
	528.0	12						10
	529.5	11						
July 1984	496.5	8		8	8			
	506.6	13			10			
	518.0	10						
September 1984	496.5	11		11	11	11	11	
	506.6	13			12	12	12	
	518.0	13				12	12	
	527.4	16					13	
	528.0	14						
December 1984	496.5	11		11		10	11	11
	506.6	12				11	12	11
	527.4	11					11	10
	528.0	14						13
	529.5	13						
March 1985	496.5	13		8			8	7
	506.6	9					9	7
	528.0	10						8
	529.5	9						
May 1985	496.5	13		9	11	13	11	13
	506.6	10			10	10	9	9
	518.0	13				13	12	11
	527.4	19				14	14	14
	528.0	14						12
	529.5	14						
September 1985	496.5	13		12	13	13	12	
	506.6	12			12	12	11	
	518.0	16				15	13	
	527.4	16					13	
	528.0	13						

Table 6-3 (Continued)

Date	Station (TRM)	Number of Taxa at Station	Number of Taxa Common Between Stations					
			TRM 496.5	TRM 506.6	TRM 518.0	TRM 527.4	TRM 528.0	TRM 529.5
December 1985	496.5	7		5	6	5	5	5
	506.6	7			6	6	6	6
	518.0	10				9	8	8
	527.4	9					8	8
	528.0	8						8
	529.5	8						

Table 6-4. Correlation Coefficients by Quarter and River Mile, Comparing Number of Genera Found Over Time, Watts Bar Nuclear Plant Preoperational Monitoring, Chickamauga Reservoir, 1974-1985.

	TENNESSEE RIVER MILE					
QUARTER	496.5	506.6	518.0	527.4	528.0	529.5
FEB	+1.0	-1.0	-1.0	-1.0	-0.9	-1.0
MAY/JUN	+1.0	-0.9	-0.3	+0.5	+0.1	-0.4
AUG/SEPT	0.0	-0.3	+0.4	+0.7	+0.3	+0.6
NOV/DEC	-0.6	-0.9	-0.9	-0.9	-0.8	-0.8

Table 6-5. Similarity of Periphyton Community Composition/Structure During Preoperational Monitoring from 1974 to 1985. Based on Sorensen's Quotient of Similarity and Percentage Similarity, Watts Bar Nuclear Plant, Chickamauga Reservoir.

Date	Station Comparison	Sorensen's Quotient of Similarity (%)	Percentage Similarity (%)
May 1974	TRM 506.6 - 518.0	77	85
	TRM 506.6 - 527.4	83	79
	TRM 506.6 - 528.0	74	77
	TRM 506.6 - 529.5	77	82
	TRM 518.0 - 527.4	73	72
	TRM 518.0 - 528.0	83	73
	TRM 518.0 - 529.5	79	80
	TRM 527.4 - 528.0	69	81
	TRM 527.4 - 529.5	79	72
	TRM 528.0 - 529.5	83	80
August 1974	TRM 506.6 - 518.0	76	68
	TRM 506.6 - 527.4	72	64
	TRM 506.6 - 528.0	81	58
	TRM 506.6 - 529.5	89	60
	TRM 518.0 - 527.4	70	74
	TRM 518.0 - 528.0	73	63
	TRM 518.0 - 529.5	73	64
	TRM 527.4 - 528.0	77	72
	TRM 527.4 - 529.5	77	70
	TRM 528.0 - 529.5	93	84
June 1975	TRM 506.6 - 518.0	77	57
	TRM 506.6 - 527.4	81	82
	TRM 506.6 - 528.0	81	72
	TRM 506.6 - 529.5	79	80
	TRM 518.0 - 527.4	83	57
	TRM 518.0 - 528.0	76	57
	TRM 518.0 - 529.5	87	70
	TRM 527.4 - 528.0	87	88
	TRM 527.4 - 529.5	84	87
	TRM 528.0 - 529.5	84	83
May 1976	TRM 506.6 - 518.0	75	86
	TRM 506.6 - 527.4	63	29
	TRM 506.6 - 528.0	62	85
	TRM 506.6 - 529.5	78	82
	TRM 518.0 - 527.4	80	32
	TRM 518.0 - 528.0	77	83
	TRM 518.0 - 529.5	78	78
	TRM 527.4 - 528.0	71	27
	TRM 527.4 - 529.5	77	26
	TRM 528.0 - 529.5	74	93

Table 6-5 (Continued)

Date	Station Comparison	Sorensen's Quotient of Similarity (%)	Percentage Similarity (%)
August 1976	TRM 506.6 - 518.0	76	32
	TRM 506.6 - 527.4	88	42
	TRM 506.6 - 529.5	73	43
	TRM 518.0 - 527.4	75	49
	TRM 518.0 - 529.5	67	61
	TRM 527.4 - 529.5	79	68
June 1977	TRM 518.0 - 527.4	80	78
	TRM 518.0 - 528.0	76	68
	TRM 527.4 - 528.0	80	86
September 1977	TRM 496.5 - 506.6	82	29
	TRM 496.5 - 518.0	81	84
	TRM 496.5 - 527.4	82	35
	TRM 496.5 - 528.0	73	42
	TRM 506.6 - 518.0	72	31
	TRM 506.6 - 527.4	80	52
	TRM 506.6 - 528.0	70	70
	TRM 518.0 - 527.4	80	27
	TRM 518.0 - 528.0	72	42
	TRM 527.4 - 528.0	70	68
December 1977	TRM 496.5 - 506.6	74	34
	TRM 496.5 - 518.0	62	72
	TRM 496.5 - 527.4	67	66
	TRM 506.6 - 518.0	75	33
	TRM 506.6 - 527.4	73	35
	TRM 518.0 - 527.4	88	81
June 1982	TRM 506.6 - 518.0	87	30
	TRM 506.6 - 527.4	92	11
	TRM 506.6 - 528.0	84	30
	TRM 506.6 - 529.5	80	12
	TRM 518.0 - 527.4	95	28
	TRM 518.0 - 528.0	87	49
	TRM 518.0 - 529.5	82	30
	TRM 527.4 - 528.0	92	48
	TRM 527.4 - 529.5	82	93
	TRM 528.0 - 529.5	79	49

Table 6-5 (Continued)

Date	Station Comparison	Sorensen's Quotient of Similarity (%)	Percentage Similarity (%)
August 1982	TRM 496.5 - 506.6	65	3
	TRM 496.5 - 518.0	84	61
	TRM 496.5 - 527.4	80	64
	TRM 496.5 - 528.0	86	73
	TRM 496.5 - 529.5	85	39
	TRM 506.6 - 518.0	69	3
	TRM 506.6 - 527.4	69	4
	TRM 506.6 - 528.0	69	3
	TRM 506.6 - 529.5	65	10
	TRM 518.0 - 527.4	85	70
	TRM 518.0 - 528.0	91	66
	TRM 518.0 - 529.5	84	43
	TRM 527.4 - 528.0	93	78
	TRM 527.4 - 529.5	86	56
	TRM 528.0 - 529.5	86	45
December 1982	TRM 496.5 - 529.5	73	4
February 1983	TRM 496.5 - 518.0	89	27
	TRM 496.5 - 527.4	81	1
	TRM 496.5 - 528.0	100	1
	TRM 518.0 - 527.4	93	4
	TRM 518.0 - 528.0	89	7
	TRM 527.4 - 528.0	81	66
May 1983	TRM 506.6 - 518.0	73	64
September 1983	TRM 506.6 - 529.5	79	17
November 1983	TRM 496.5 - 518.0	67	56
	TRM 496.5 - 527.4	60	60
	TRM 496.5 - 528.0	60	67
	TRM 496.5 - 529.5	67	69
	TRM 518.0 - 527.4	89	85
	TRM 518.0 - 528.0	89	76
	TRM 518.0 - 529.5	88	75
	TRM 527.4 - 528.0	85	83
	TRM 527.4 - 529.5	83	82
	TRM 528.0 - 529.5	92	87

Table 6-5 (Continued)

Date	Station Comparison	Sorensen's Quotient of Similarity (%)	Percentage Similarity (%)
February 1984	TRM 506.6 - 518.0	83	56
	TRM 506.6 - 527.4	83	65
	TRM 506.6 - 528.0	91	52
	TRM 506.6 - 529.5	86	27
	TRM 518.0 - 527.4	86	80
	TRM 518.0 - 528.0	85	70
	TRM 518.0 - 529.5	80	33
	TRM 527.4 - 528.0	85	65
	TRM 527.4 - 529.5	88	30
	TRM 528.0 - 529.5	87	22
July 1984	TRM 496.5 - 506.6	76	92
	TRM 496.5 - 518.0	89	88
	TRM 506.6 - 518.0	87	90
September 1984	TRM 496.5 - 506.6	92	76
	TRM 496.5 - 518.0	92	70
	TRM 496.5 - 527.4	82	69
	TRM 496.5 - 528.0	88	67
	TRM 506.6 - 518.0	92	51
	TRM 506.6 - 527.4	83	52
	TRM 506.6 - 528.0	89	52
	TRM 518.0 - 527.4	83	84
	TRM 518.0 - 528.0	89	85
	TRM 527.4 - 528.0	87	91
December 1984	TRM 496.5 - 506.6	96	61
	TRM 496.5 - 527.4	91	62
	TRM 496.5 - 528.0	88	59
	TRM 496.5 - 529.5	92	65
	TRM 506.6 - 527.4	96	81
	TRM 506.6 - 528.0	92	53
	TRM 506.6 - 529.5	88	51
	TRM 527.4 - 528.0	88	56
	TRM 527.4 - 529.5	83	61
	TRM 528.0 - 529.5	96	84
March 1985	TRM 496.5 - 506.6	73	80
	TRM 496.5 - 528.0	70	70
	TRM 496.5 - 529.5	64	41
	TRM 506.6 - 528.0	95	81
	TRM 506.6 - 529.5	78	38
	TRM 528.0 - 529.5	84	39

Table 6-5 (Continued)

Date	Station Comparison	Sorensen's Quotient of Similarity (%)	Percentage Similarity (%)
May 1985	TRM 496.5 - 506.6	78	67
	TRM 496.5 - 518.0	85	65
	TRM 496.5 - 527.4	81	80
	TRM 496.5 - 528.0	82	66
	TRM 496.5 - 529.5	96	93
	TRM 506.6 - 518.0	87	66
	TRM 506.6 - 527.4	69	56
	TRM 506.6 - 528.0	75	70
	TRM 506.6 - 529.5	75	61
	TRM 518.0 - 527.4	81	75
	TRM 518.0 - 528.0	89	93
	TRM 518.0 - 529.5	82	65
	TRM 527.4 - 528.0	85	80
	TRM 527.4 - 529.5	85	81
	TRM 528.0 - 529.5	86	68
September 1985	TRM 496.5 - 506.6	96	41
	TRM 496.5 - 518.0	90	68
	TRM 496.5 - 527.4	90	60
	TRM 496.5 - 528.0	92	62
	TRM 506.6 - 518.0	86	33
	TRM 506.6 - 527.4	86	33
	TRM 506.6 - 528.0	88	27
	TRM 518.0 - 527.4	94	89
	TRM 518.0 - 528.0	90	87
	TRM 527.4 - 528.0	90	84
December 1985	TRM 496.5 - 506.6	71	82
	TRM 496.5 - 518.0	71	67
	TRM 496.5 - 527.4	63	87
	TRM 496.5 - 528.0	67	84
	TRM 496.5 - 529.5	67	77
	TRM 506.6 - 518.0	71	69
	TRM 506.6 - 527.4	75	83
	TRM 506.6 - 528.0	80	76
	TRM 506.6 - 529.5	80	77
	TRM 518.0 - 527.4	95	68
	TRM 518.0 - 528.0	89	65
	TRM 518.0 - 529.5	89	83
	TRM 527.4 - 528.0	94	92
	TRM 527.4 - 529.5	94	77
	TRM 528.0 - 529.5	100	75

Table 6-6. Percentage Composition of Periphyton Groups During Preoperational Monitoring (1974-1985), Watts Bar Nuclear Plant, Chickamauga Reservoir.

Date	Group	TRM 496.5	TRM 506.6	TRM 518.0	TRM 527.4	TRM 528.0	TRM 529.5
May 74	Chlorophyta	0.00	2.36	0.92	3.11	2.41	1.96
	Chrysophyta	0.00	95.12	97.76	96.26	96.91	97.68
	Cyanophyta	0.00	2.52	1.32	0.63	0.69	0.36
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Aug 74	Chlorophyta	0.00	1.86	1.78	2.54	3.11	4.78
	Chrysophyta	0.00	98.14	98.22	97.46	96.89	95.22
	Cyanophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Jun 75	Chlorophyta	0.00	49.19	4.55	44.42	36.83	39.56
	Chrysophyta	0.00	47.91	95.28	55.34	62.50	60.27
	Cyanophyta	0.00	2.90	0.18	0.24	0.67	0.18
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
May 76	Chlorophyta	0.00	45.66	31.69	21.90	36.76	34.98
	Chrysophyta	0.00	53.86	68.01	77.90	63.01	64.73
	Cyanophyta	0.00	0.46	0.30	0.20	0.23	0.29
	Euglenophyta	0.00	0.02	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Aug 76	Chlorophyta	0.00	5.94	78.06	29.65	0.00	45.58
	Chrysophyta	0.00	91.38	20.46	68.84	0.00	54.42
	Cyanophyta	0.00	2.69	1.47	1.51	0.00	0.00
	Euglenophyta	0.00	0.00	0.01	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Jun 77	Chlorophyta	0.00	0.00	41.30	25.01	12.84	0.00
	Chrysophyta	0.00	0.00	58.59	74.88	86.84	0.00
	Cyanophyta	0.00	0.00	0.11	0.12	0.32	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-6 (Continued)

Date	Group	TRM 496.5	TRM 506.6	TRM 518.0	TRM 527.4	TRM 528.0	TRM 529.5
Sep 77	Chlorophyta	7.33	50.74	11.69	24.36	44.57	0.00
	Chrysophyta	92.56	49.11	88.14	75.64	54.91	0.00
	Cyanophyta	0.11	0.15	0.17	0.00	0.52	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Dec 77	Chlorophyta	0.04	31.38	3.78	4.85	0.00	0.00
	Chrysophyta	99.86	68.41	96.13	94.48	0.00	0.00
	Cyanophyta	0.10	0.21	0.08	0.67	0.00	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.01	0.00	0.00	0.00
Jun 82	Chlorophyta	0.00	24.88	30.39	14.25	26.44	15.92
	Chrysophyta	0.00	62.62	21.21	65.85	53.11	65.83
	Cyanophyta	0.00	12.50	48.39	19.90	20.45	18.25
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Aug 82	Chlorophyta	17.56	3.47	6.44	8.59	18.13	7.81
	Chrysophyta	46.55	96.53	70.68	77.85	65.60	83.08
	Cyanophyta	35.89	0.00	22.88	13.56	16.27	9.11
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Dec 82	Chlorophyta	34.64	0.00	0.00	0.00	0.00	4.06
	Chrysophyta	65.36	0.00	0.00	0.00	0.00	49.52
	Cyanophyta	0.00	0.00	0.00	0.00	0.00	46.41
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Feb 83	Chlorophyta	0.00	0.00	0.00	0.15	0.00	0.00
	Chrysophyta	100.00	0.00	100.00	99.85	100.00	0.00
	Cyanophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
May 83	Chlorophyta	0.00	46.71	24.94	0.00	0.00	0.00
	Chrysophyta	0.00	44.38	57.12	0.00	0.00	0.00
	Cyanophyta	0.00	8.92	17.93	0.00	0.00	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-6 (Continued)

Date	Group	TRM 496.5	TRM 506.6	TRM 518.0	TRM 527.4	TRM 528.0	TRM 529.5
Sep 83	Chlorophyta	0.00	45.28	0.00	0.00	0.00	7.98
	Chrysophyta	0.00	54.68	0.00	0.00	0.00	67.43
	Cyanophyta	0.00	0.00	0.00	0.00	0.00	24.58
	Euglenophyta	0.00	0.03	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Nov 83	Chlorophyta	32.35	0.00	10.13	9.64	11.32	11.56
	Chrysophyta	67.65	0.00	89.87	90.36	83.58	88.44
	Cyanophyta	0.00	0.00	0.00	0.00	5.10	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Feb 84	Chlorophyta	0.00	0.00	0.12	0.03	0.00	0.11
	Chrysophyta	0.00	100.00	99.27	99.97	100.00	99.89
	Cyanophyta	0.00	0.00	0.62	0.00	0.00	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Jul 84	Chlorophyta	46.81	47.24	49.91	0.00	0.00	0.00
	Chrysophyta	46.93	41.89	38.77	0.00	0.00	0.00
	Cyanophyta	6.26	10.87	11.32	0.00	0.00	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrophyta	0.00	0.00	0.00	0.00	0.00	0.00
Sep 84	Chlorophyta	35.54	31.75	28.86	23.39	18.88	0.00
	Chrysophyta	54.25	50.55	55.06	56.35	54.94	0.00
	Cyanophyta	10.21	17.70	16.08	20.26	26.18	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Dec 84	Chlorophyta	22.86	17.92	0.00	32.67	48.83	42.94
	Chrysophyta	77.14	82.08	0.00	67.33	38.07	43.50
	Cyanophyta	0.00	0.00	0.00	0.00	13.10	13.56
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Mar 85	Chlorophyta	3.88	0.00	0.00	0.00	0.00	0.00
	Chrysophyta	89.91	100.00	0.00	0.00	100.00	100.00
	Cyanophyta	6.01	0.00	0.00	0.00	0.00	0.00
	Euglenophyta	0.20	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-6 (Continued)

Date	Group	TRM 496.5	TRM 506.6	TRM 518.0	TRM 527.4	TRM 528.0	TRM 529.5
May 85	Chlorophyta	49.99	57.49	43.48	42.20	40.20	51.21
	Chrysophyta	50.01	42.51	35.92	36.14	38.63	48.79
	Cyanophyta	0.00	0.00	20.60	21.66	21.17	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Sep 85	Chlorophyta	39.21	12.46	21.35	14.89	22.42	0.00
	Chrysophyta	44.68	87.54	61.35	69.03	64.89	0.00
	Cyanophyta	16.11	0.00	17.30	16.08	12.69	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00
Dec 85	Chlorophyta	41.74	53.51	35.46	45.81	40.04	45.04
	Chrysophyta	58.26	46.39	64.54	54.19	59.96	54.60
	Cyanophyta	0.00	0.10	0.00	0.00	0.00	0.00
	Euglenophyta	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrrhophyta	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-7. Dominant Periphyton Genera and Percentage of Total Abundance Made Up By That Genera Collected in the Vicinity of Watts Bar Nuclear Plant During Preoperational Monitoring, Chickamauga Reservoir, 1974-1985.

	TRM 496.5		TRM 506.6		TRM 518.0		TRM 527.4		TRM 528.0		TRM 529.5	
Quarter	Dominant Genus	% of Total Abundance	Dominant Genus	% of Total Abundance	Dominant Genus	% of Total Abundance	Dominant Genus	% of Total Abundance	Dominant Genus	% of Total Abundance	Dominant Genus	% of Total Abundance
MAY 74	—		Melosira	25.6	Melosira	34.5	Melosira	33.5	Cymbella	41.3	Cymbella	38.2
AUG 74	—		Navicula	39.5	Melosira	27.5	Navicula	33.2	Melosira	22.6	Gomphonema	22.0
JUN 75	—		Stigeoclonium	48.3	Gomphonema	60.4	Stigeoclonium	44.2	Stigeoclonium	36.8	Stigeoclonium	39.5
MAY 76	—		Stigeoclonium	43.2	Cymbella	32.7	Cymbella	39.2	Stigeoclonium	36.6	Stigeoclonium	34.7
AUG 76	—		Navicula	27.5	Stigeoclonium	77.8	Achnanthes	44.0	—		Stigeoclonium	45.0
JUN 77	—		—		Achnanthes	47.9	Achnanthes	62.5	Achnanthes	67.2	—	
SEP 77	Achnanthes	84.8	Stigeoclonium	50.7	Achnanthes	69.5	Achnanthes	64.6	Stigeoclonium	44.1	—	
DEC 77	Gomphonema	39.5	Stigeoclonium	28.2	Gomphonema	57.3	Gomphonema	41.6	—		—	
JUN 82	—		Achnanthes	58.2	Stigeoclonium	25.9	Achnanthes	40.8	Achnanthes	44.7	Achnanthes	39.5
AUG 82	Achnanthes	29.8	Cocconeis	72.3	Achnanthes	60.3	Achnanthes	58.8	Achnanthes	41.9	Achnanthes	58.1
DEC 82	Achnanthes	49.2	—		—		—		—		Lyngbya	33.8
FEB 83	Navicula	38.9	—		Navicula	22.9	Gomphonema	21.6	Diatoma	33.8	—	
JUN 83	—		Stigeoclonium	46.7	Achnanthes	35.3	—		—		—	
SEP 83	—		Stigeoclonium	42.6	—		—		—		Achnanthes	39.5
NOV 83	Achnanthes	35.8	—		Achnanthes	61.5	Achnanthes	49.0	Achnanthes	42.2	Achnanthes	45.5
FEB 84	—		Gomphonema	35.8	Diatoma	42.1	Diatoma	31.3	Diatoma	50.8	Synedra	27.8
JUL 84	Stigeoclonium	46.8	Stigeoclonium	45.1	Stigeoclonium	49.8	—		—		—	
SEP 84	Achnanthes	39.4	Achnanthes	42.1	Achnanthes	37.2	Achnanthes	33.2	Achnanthes	33.9	—	
DEC 84	Achnanthes	37.9	Achnanthes	32.7	—		Achnanthes	34.5	Stigeoclonium	46.8	Stigeoclonium	41.4
MAR 85	Diatoma	25.0	Diatoma	31.0	—		—		Diatoma	48.2	Diatoma	62.2
MAY 85	Stigeoclonium	28.5	Stigeoclonium	57.5	Stigeoclonium	40.0	Stigeoclonium	24.4	Stigeoclonium	37.7	Stigeoclonium	28.6
SEP 85	Stigeoclonium	38.4	Achnanthes	34.2	Achnanthes	34.4	Achnanthes	44.7	Achnanthes	37.4	—	
DEC 85	Stigeoclonium	41.7	Stigeoclonium	53.5	Stigeoclonium	34.8	Stigeoclonium	44.9	Stigeoclonium	39.1	Stigeoclonium	44.8

Table 6-8. Results of One-Way Analysis of Variance and Student-Newman-Keuls Multiple Range Test on Periphyton Abundance, Chlorophyll a, and Ash-Free Dry Weight Data, Watts Bar Nuclear Plant Preoperational Monitoring, Chickamauga Reservoir, 1974-1985.

Date	Test Parameter	F-Ratio	Student-Newman-Keuls Multiple Range Test Results (Low Mean → High Mean)
May 1974	Total Periphyton	2.37 (NS)**	4† 5 2 3 6
	Chlorophyta	0.76 (NS)	3 5 6 4 2
	Chrysophyta	2.38 (NS)	4 5 2 3 6
	Cyanophyta*	6.73 (NS)	4 6 5 3 2
	Chlorophyll a††		
	Ash-free dry weight††		
Aug 1974	Total Periphyton	5.02 (NS)	2 3 4 6 5
	Chlorophyta	2.55 (NS)	2 3 4 5 6
	Chrysophyta	4.92 (NS)	2 3 4 6 5
	Cyanophyta††		
	Chlorophyll a††		
	Ash-free dry weight††		
Jun 1985	Total Periphyton*	0.70 (NS)	3 5 6 4 2
	Chlorophyta*	3.59 (NS)	3 6 5 4 2
	Chrysophyta*	0.14 (NS)	2 4 5 6 3
	Cyanophyta*	0.06 (NS)	3 6 4 2 5
	Chlorophyll a††		
	Ash-free dry weight††		
May 1976	Total Periphyton	285.76	4 3 2 5 6
	Chlorophyta	90.29	4 3 5 6 2
	Chrysophyta	113.05	4 2 3 5 6
	Cyanophyta	2.44 (NS)	4 5 3 6 2
	Chlorophyll a	3.62	4 6 2 3 5
	Ash-free dry weight	2.57	4 2 6 3 5
Aug 1976	Total Periphyton	8.78 (NS)	2 6 4 3
	Chlorophyta	20.42 (NS)	2 4 6 3
	Chrysophyta	40.75 (NS)	3 2 6 4
	Cyanophyta	0.01 (NS)	1 3 2
	Chlorophyll a	1.07 (NS)	3 2 6 4
	Ash-free dry weight	110.15	2 6 4 3

Table 6-8 (Continued)

Date	Test Parameter	F-Ratio	Student-Newman-Keuls Multiple Range Test Results (Low Mean → High Mean)
Jun 1977	Total Periphyton*	1.09 (NS)	5 4 3
	Chlorophyta*	184.97 (NS)	5 4 3
	Chrysophyta*	0.13 (NS)	4 5 3
	Cyanophyta*	1.31 (NS)	4 3 5
	Chlorophyll a*	17.25	5 4 3
	Ash-free dry weight*	20.48	5 4 3
Sep 1977	Total Periphyton*	13.73	4 2 5 1 3
	Chlorophyta*	3.90 (NS)	4 1 2 3 5
	Chrysophyta*	23.13	2 4 5 1 3
	Cyanophyta*	1.33	2 1 5 3
	Chlorophyll a*	32.52	2 4 5 1 3
	Ash-free dry weight*	36.12	2 5 4 1 3
Dec 1977	Total Periphyton*	34.78	2 4 3 1
	Chlorophyta*	40.51	1 3 4 2
	Chrysophyta*	10.98 (NS)	2 4 3 1
	Cyanophyta*	1.45 (NS)	3 2 1 4
	Chlorophyll a*	50.47	2 1 4 3
	Ash-free dry weight*	20.92	2 1 4 3
Jun 1982	Total Periphyton	462.77	4 6 5 3 2
	Chlorophyta	964.63	4 6 5 3 2
	Chrysophyta	926.24	4 6 3 5 2
	Cyanophyta	36.63	4 6 5 3 2
	Chlorophyll a*	11.76	6 2 4 5 3
	Ash-free dry weight*	10.72	5 2 6 4 3
Aug 1982	Total Periphyton	113.59	2 6 4 3 5 1
	Chlorophyta	100 80	2 6 4 3 5 1
	Chrysophyta	80.13	2 6 4 1 5 3
	Cyanophyta	291.94	2 6 4 5 3 1
	Chlorophyll a*	12.44	2 6 1 4 5 3
	Ash-free dry weight*	44.93	2 1 6 4 3 5
Dec 1982	Total Periphyton	1978.08	6 1
	Chlorophyta	269.65	6 1
	Chrysophyta	2359.40	6 1
	Cyanophyta††		
	Chlorophyll a	12.27	1 6
	Ash-free dry weight	136.17	1 6

Table 6-8 (Continued)

Date	Test Parameter	F-Ratio		Student-Newman-Keuls Multiple Range Test Results (Low Mean → High Mean)				
Feb 1983	Total Periphyton	1385.32		4	5	3	1	
	Chlorophyta	1.00	(NS)	5	3	1	4	
	Chrysophyta	1363.35		4	5	3	1	
	Cyanophyta††							
	Chlorophyll a*	106.72		5	4	3	1	
	Ash-free dry weight*	130.39		5	4	3	1	
Jun 1983	Total Periphyton	18.15		2	3			
	Chlorophyta	120.83		3	2			
	Chrysophyta	105.95		2	3			
	Cyanophyta	32.66	(NS)	2	3			
	Chlorophyll a*	2.30	(NS)	2	3			
	Ash-free dry weight*	4.68		2	3			
Sep 1983	Total Periphyton	10.70		2	6			
	Chlorophyta	0.16	(NS)	6	2			
	Chrysophyta	109.69		2	6			
	Cyanophyta	2064.41		2	6			
	Chlorophyll a	6.51		2	6			
	Ash-free dry weight	0.57		6	2			
Nov 1983	Total Periphyton	8.31		1	6	4	3	5
	Chlorophyta	15.43		4	6	3	5	1
	Chrysophyta	23.29		1	6	5	4	3
	Cyanophyta	3206.52		6	1	4	3	5
	Chlorophyll a*	5.23	(NS)	1	5	6	4	3
	Ash-free dry weight*	5.37	(NS)	1	5	4	6	3
Feb 1984	Total Periphyton	416.71		6	3	4	2	5
	Chlorophyta	0.51	(NS)	5	2	6	4	3
	Chrysophyta	427.58		6	3	4	2	5
	Cyanophyta††							
	Chlorophyll a*	12.65		6	5	4	3	2
	Ash-free dry weight*	5.58		6	5	4	3	2
Jul 1984	Total Periphyton	2.42	(NS)	3	1	2		
	Chlorophyta	1.11	(NS)	3	1	2		
	Chrysophyta	1.78	(NS)	3	2	1		
	Cyanophyta	9.05		1	3	2		
	Chlorophyll a	5.26		2	1	3		
	Ash-free dry weight	8.26		2	1	3		

Table 6-8 (Continued)

Date	Test Parameter	F-Ratio	Student-Newman-Keuls Multiple Range Test Results (Low Mean → High Mean)					
Sep 1984	Total Periphyton	119.95	4	5	3	1	2	
	Chlorophyta	40.93	5	4	3	1	2	
	Chrysophyta	25.68	4	5	3	1	2	
	Cyanophyta	3.79	3	1	4	5	2	
	Chlorophyll a	5.61	5	1	4	2	3	
	Ash-free dry weight	2.50	1	2	5	4	3	
Dec 1984	Total Periphyton	83.47	2	4	5	6	1	
	Chlorophyta	63.74	2	4	1	6	5	
	Chrysophyta	86.49	4	5	2	6	1	
	Cyanophyta	3463.83	2	1	4	5	6	
	Chlorophyll a	6.17	1	2	5	6	4	
	Ash-free dry weight	10.66	1	2	4	6	5	
Mar 1985	Total Periphyton	277.83	6	1	5	2		
	Chlorophyta††							
	Chrysophyta	223.76	6	1	5	2		
	Cyanophyta††							
	Chlorophyll a	20.64	6	2	5	1		
	Ash-free dry weight	5.75	6	5	2	1		
May 1985	Total Periphyton	22.22	2	6	1	5	3	4
	Chlorophyta	2.69 (NS)	2	5	6	4	3	1
	Chrysophyta	20.45	2	3	4	5	6	1
	Cyanophyta	0.24	3	5	4			
	Chlorophyll a*	3.54 (NS)	5	4	1	6	2	3
	Ash-free dry weight*	25.90	2	6	1	4	5	3
Sep 1985	Total Periphyton	235.57	2	1	3	4	5	
	Chlorophyta	10.05	2	4	3	5	1	
	Chrysophyta	218.07	2	1	3	4	5	
	Cyanophyta	3.07 (NS)	1	5	4	3		
	Chlorophyll a*	22.37	2	3	1	5	4	
	Ash-free dry weight*	6.24	4	5	1	3	2	

Table 6-8 (Continued)

Date	Test Parameter	F-Ratio	Student-Newman-Keuls Multiple Range Test Results (Low Mean → High Mean)					
Dec 1985	Total Periphyton	11.77	5	4	6	2	1	3
	Chlorophyta	8.51	5	4	1	3	6	2
	Chrysophyta	34.06	2	4	5	6	1	3
	Cyanophyta††							
	Chlorophyll a*	9.09	1	2	5	4	3	6
	Ash-free dry weight*	3.46	1	2	5	3	4	6

†1 = TRM 496.5
2 = TRM 506.6
3 = TRM 518.0
4 = TRM 527.4
5 = TRM 528.0
6 = TRM 529.5
*Cells sizes not equal
**Not significant at α=0.05.
††Test could not be done because of lack of adequate sample size or absence of data.

Table 6-9. Results of Two-Way Analysis of Variance and Student-Newman-Keuls Multiple Range Test on Pooled Periphyton Abundance Data By Quarter, Watts Bar Nuclear Plant, Preoperational Monitoring, Chickamauga Reservoir, 1974-1985.

Group	Quarter	Parameter	F-Ratio	Rank (α = 0.05) Lowest							Highest
Station Effect Removed	FEB/MAR	Total Number	1549.30	85	83	84					
		Chlorophyta	5.02	83	84	85					
		Chrysophyta	1589.60	85	83	84					
		Cyanophyta	2.98 (NS)*	84	85						
	MAY/JUN	Total Number	464.84	74	85	76	75	77	82	84	83
		Chlorophyta	62.47	74	77	75	76	85	82	84	83
		Chrysophyta	206.52	74	85	75	76	77	84	82	83
		Cyanophyta	72.60	74	76	77	75	85	84	82	83
	AUG/SEP	Total Number	181.75	74	83	77	82	76	85	84	
		Chlorophyta	92.01	74	83	82	77	85	76	84	
		Chrysophyta	134.04	83	74	77	82	76	85	84	
		Cyanophyta	92.91	77	76	83	82	85	84		
	NOV/DEC	Total Number	620.42	83	77	85	84	82			
		Chlorophyta	365.52	77	83	82	85	84			
		Chrysophyta	293.13	85	83	77	84	82			
		Cyanophyta	26.20	85	77	83	82	84			

Table 6-9 (Continued)

Group	Quarter	Parameter	F-Ratio	Rank (α = 0.05) Lowest					Highest
Year Effect Removed	FEB/MAR	Total Number	977.58	6†	4	5	2	3	1
		Chlorophyta	0.03 (NS)	4	6	3	1		
		Chrysophyta	951.13	6	4	5	2	1	3
		Cyanophyta	2.98 (NS)	3	1				
	MAY/JUN	Total Number	69.21	4	6	5	1	3	2
		Chlorophyta	3.73	4	6	3	5	2	1
		Chrysophyta	32.91	4	6	5	1	3	2
		Cyanophyta	5.77	4	6	5	3	2	1
	AUG/SEP	Total Number	96.42	2	6	4	5	3	1
		Chlorophyta	25.85	2	6	4	3	5	1
		Chrysophyta	74.01	2	6	4	3	5	1
		Cyanophyta	6.27	2	6	3	5	4	1
	NOV/DEC	Total Number	166.45	2	4	3	6	5	1
		Chlorophyta	32.74	3	6	4	2	5	1
		Chrysophyta	172.90	6	2	4	5	3	1
		Cyanophyta	0.44	2	3	1	4	5	6

*NS = Not significant
†1 = TRM 496.5
2 = TRM 506.6
3 = TRM 518.0
4 = TRM 527.4
5 = TRM 528.0
6 = TRM 529.5

Table 6-10. Results of Two-Way Analysis of Variance and Student-Newman-Keuls Multiple Range Test on Pooled Periphyton Abundance Data, Watts Bar Nuclear Plant, Preoperational Monitoring, Chickamauga Reservoir, 1974-1985.

Group	Parameter	F-Ratio	Mean Rank (α = 0.05) Lowest							Highest
Station Effect Removed	Total Number	427.73	74	77	85	83	76	75	84	82
	Chlorophyta	270.94	74	77	83	85	76	75	82	84
	Chrysophyta	253.57	74	85	77	76	83	75	84	82
	Cyanophyta	56.46	77	74	76	75	85	83	84	82
Year Effect Removed	Total Number	268.80	4*	6	5	2	3	1		
	Chlorophyta	55.75	4	6	5	3	1	2		
	Chrysophyta	202.15	6	4	5	2	3	1		
	Cyanophyta	3.93	4	2	6	5	3	1		

*1 = TRM 496.5
2 = TRM 506.0
3 = TRM 518.0
4 = TRM 527.4
5 = TRM 528.0
6 = TRM 529.5

Table 6-11. Correlation Coefficients for Periphyton Total Abundance Data Correlated With Selected Water Chemistry Data and River Flow, Preoperational Monitoring, Watts Bar Nuclear Plant, Chickamauga Reservoir, 1974-1985.

		Nitrogen		Organic Carbon	
River Flow	Alkalinity	Inorganic	Organic	Dissolved	Total
-0.39	+0.08	+0.13	+0.11	+0.13	+0.13

Table 6-12. Minimum and Maximum Station Mean Values by Year for Periphyton Corrected Chlorophyll a, Ash-Free Organic Weight, and Corrected Autotrophic Index, Watts Bar Nuclear Plant, Preoperational Monitoring, Chickamauga Reservoir, 1976-1985.

	Corrected Chlorophyll a (mg/m^2)				Ash-Free Organic Weight (mg/m^2)				Corrected Autotrophic Index			
Year	Minimum	Station*	Maximum	Station	Minimum	Station	Maximum	Station	Minimum	Station	Maximum	Station
1976	33.2	6	64.8	4	5,278	2	20,588	3	124	3	590	3
1977	1.4	5	68.3	3	686	5	5,974	3	70	4	521	5
1982	3.2	2	112.8	3	204	2	20,254	3	83	1	623	6
1983	0.2	5	147.8	3	181	5	13,326	3	74	6	1,194	3
1984	2.2	6	107.9	4	502	6	33,149	3	60	4	3,169	5
1985	0.7	6	112.3	6	186	5	494,173	4	25	4	8,088	2

*1 = TRM 496.5
2 = TRM 506.6
3 = TRM 518.0
4 = TRM 527.4
5 = TRM 528.0
6 = TRM 529.5

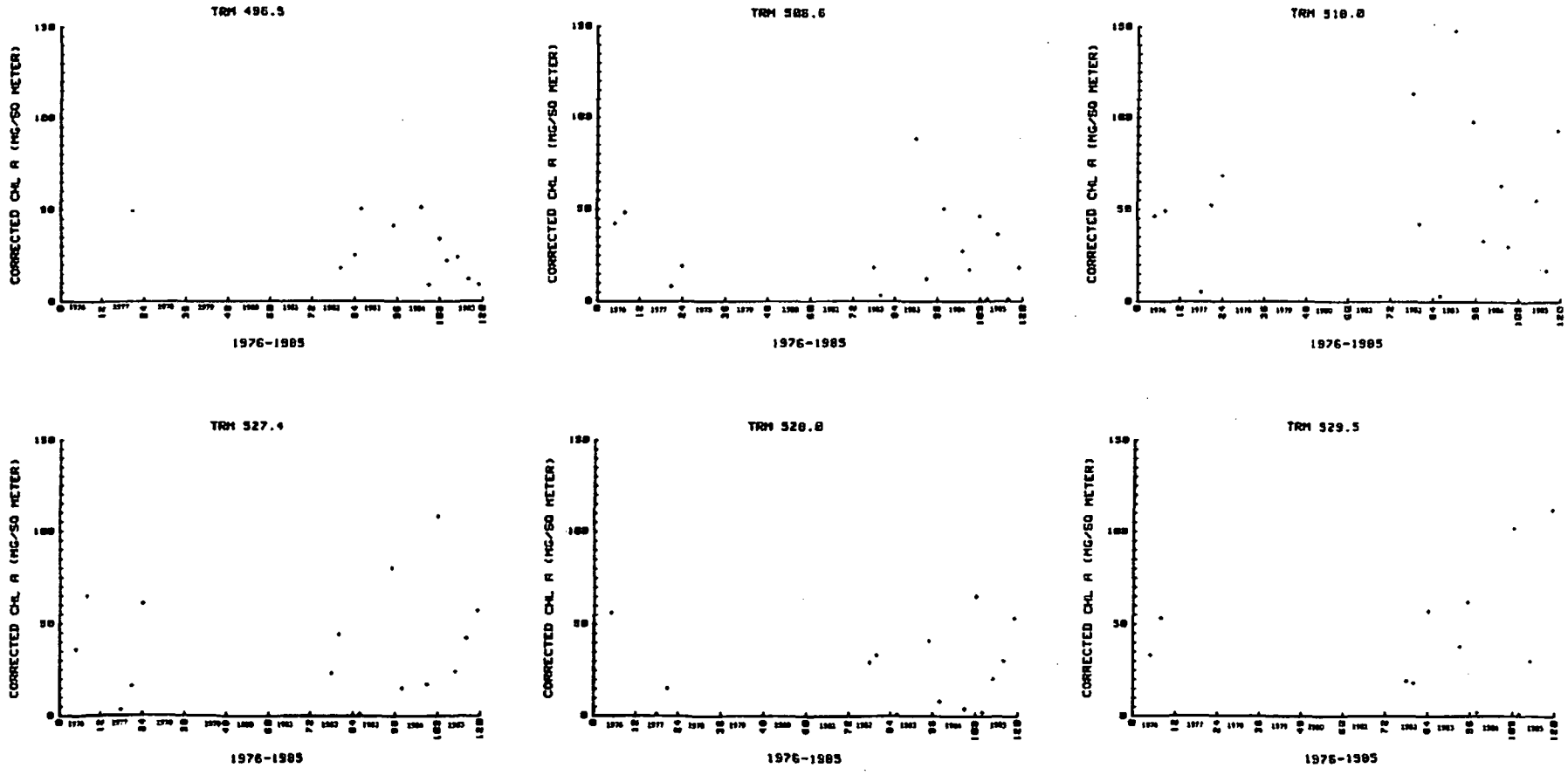


Figure 6-1. Corrected Chlorophyll a Concentrations For Periphyton By Location Surveyed During Preoperational Monitoring, Watts Bar Nuclear Plant, Chickamauga Reservoir, 1976-1985.

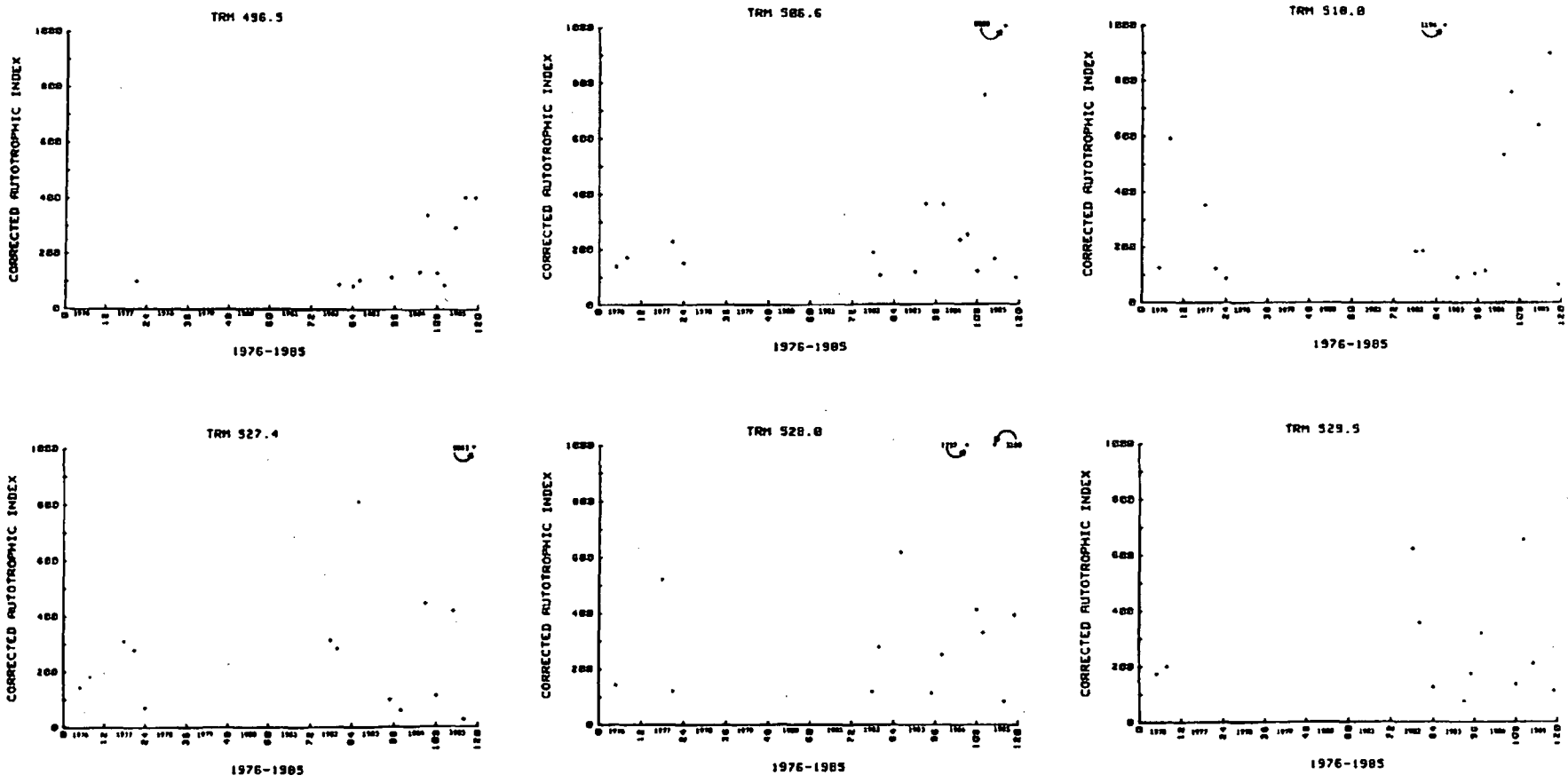


Figure 6-2. Corrected Autotrophic Indices For Periphyton By Location Surveyed During Preoperational Monitoring, Watts Bar Nuclear Plant, Chickamauga Reservoir, 1976-1985.

7.0 BENTHIC MACROINVERTEBRATES

7.1 Community Studies

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 environmental and are neither subject to rapid migrations nor severe translocation by water mass displacement (except under spate 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 usually complex life cycle of a year or more; hence, their presence or absence and abundance patterns help describe environmental conditions over a period of time.

Evaluation of power plant effects depends upon a good preoperational assessment of "natural" abundance and distribution patterns because 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, spates, proximity of suitable habitats, temperature, and dissolved substances (Hynes, 1970). The most obvious factors in the study reach encompassed in the WBN environmental assessment are current speed and substrate composition, which are closely related. Traveling downstream from WBN, there is an obvious lessening of

current velocity which is accompanied by a transition from hard rock and sand to softer, more silty substrates. These factors are expected to greatly affect spatial distributions of macroinvertebrate populations. Additionally, seasonal spates which occur normally during early spring are expected to add considerable temporal variability to the data. Effects of other factors are expected to be more subtle.

7.1.1 Materials and Methods

Field--Several sampling techniques involving two methodologies, artificial substrates and Hess sampler, were utilized to collect benthic macroinvertebrates from upstream (TRMs 496.5-529.5) Chickamauga Reservoir. Artificial substrates have been utilized throughout the entire study (quarterly, spring 1973 through autumn 1985). Use of a Hess sampler and accompanying sediment core sampler was initiated in summer 1983 in the immediate vicinity of WBN (TRMs 521.0-528.8). Hess and core samplers were utilized again during the autumn of 1983 and continued for the same two seasons throughout the study.

Artificial substrates--Sampling stations (figure 7-1) were located at TRMs 496.5, 506.6, 518.0, 527.4, 528.0, and 529.9 from spring 1973 through autumn 1976. Thereafter the upper station was moved downstream to TRM 529.5 because 529.9 was too near Watts Bar Dam and not consistently exposed to river currents. No samples were collected during the winter quarter of 1974. River miles 528.0 (just upstream from the WBN intake) and 529.5 were control stations with 496.5, 506.6, 518.0, and 527.4 (just below WBN diffuser) being the experimental stations.

Field collections of macroinvertebrates were made quarterly from May 1973 to December 1977 and from May 1982 through December 1985 using artificial substrates. Sample collection dates from January-March are referred to as winter quarter, April-June as spring, July-September as summer, and October-December as autumn. Artificial substrates consisted or wire barbeque baskets (volume = 7675 cm^3) filled with river stones of uniform size. Three substrates were placed at each station and a line and float was attached so the substrates could be located easily. During 1973, 1974, and the winter quarter of 1975, substrates were left in the river (colonized) for 90 days. Because of poor recovery percentages due primarily to vandalism, the colonization period was changed to 30 days during the 1975-1977 and the 1982-1985 sampling periods.

During these periods substrates were retrieved primarily by simply pulling them to the surface. Beginning in the winter quarter of 1983, an additional set of three substrates was placed at each station and retrieved by divers placing each substrate in a fine-mesh bag before bringing it to the surface. These samples were used to determine if a significant loss of organisms occurred when substrates were retrieved by pulling them to the surface. Beginning in the summer of 1983, an additional set of three substrates was placed at each station and left for 90 days to provide a basis for comparison of 30-day and 90-day macroinvertebrate collections.

Because of continued loss of samplers due to vandalism, beginning in August of 1983, substrates were anchored to the bottom of the river by attaching them to a piece of steel rail. This allowed their retrieval from the water only by divers even though the marker locating their position was visible.

After retrieving substrates, they were rinsed with water over a standard No. 30 mesh (595 μm) wash screen. Rocks were removed and individually brushed over the screen. All material retained by the wash screen was placed in a container, labeled, and preserved with 10 percent formalin (1973-1977) or 70 percent ethyl alcohol (1982-1985) for laboratory processing.

Hess samplers--Additional macroinvertebrate collections were made using a Hess sampler (area = .0856 m^2) during summer and autumn quarters of 1983-1985 to supplement routinely collected artificial substrate samples. Five stations, TRMs 521.0, 526.3, 527.4, 528.0, and 528.8 were sampled during the summer quarter, 1983 (figure 7-1). After preliminary evaluation of sediment data and a qualitative evaluation of macroinvertebrate data, the sampling location at TRM 526.3 was moved horizontally to an area where the very fine sand component of the substrate would be less and the station at 528.8 was moved downstream to river mile 528.5 to possibly reduce the effect of current and increase the similarity between control stations.

Divers collected 10 samples at each station by pushing the Hess sampler into the river bed and working the substrate to a depth of approximately 15 cm using a hand rake. Dislodged organisms and detritus were carried by the current into a catch cup. All large rocks, mussels, clams, etc., were placed in mesh bags. Collected material was taken to the surface and processed using the same procedures as described for artificial substrates.

Sediment--Sediment samples were collected adjacent to three randomly selected Hess samplers at each station. Samples were collected by

divers pushing a core sampler (81.07 cm^2) into the sediment to a depth of approximately 15 cm. After affixing a lid to the sampler, it was gently removed from the substrate and a plate (attached with elastic tubing to the sampler) was placed over the end of the core before it was taken to the surface. Samples were then taken to the laboratory for analysis.

Laboratory--Macroinvertebrate samples were rewashed over a standard No. 30 mesh screen and placed in white enamel trays. Organisms were picked from the remaining detritus and sediments, placed in vials, labeled, and preserved with a solution of 70 percent ethyl alcohol and 5 percent glycerine. Macroinvertebrates were classified to the lowest taxonomic classification practicable and enumerated. Sediment samples were processed through a series of sieves to determine amounts of silt and clay (<0.063 mm), fine sand (0.063-0.25 mm), medium sand (0.25-0.5 mm), coarse sand (0.5-2.0 mm), granule and pebble (2.0-31.0 mm), and larger pebble (31.0-63.0 mm) present in each.

Data Analysis--Loss of prescribed samples and implementation of sampling schemes augmented to enhance sample recovery over the period of monitoring presented special difficulties in the area of data analysis, especially the comparability among stations and years because of unbalanced sample replicability. Also, potential difference in sampling efficiency among the various collection techniques (i.e., substrates colonized 90 days, substrates colonized 30 days, unbagged substrates, bagged substrates, and Hess collections) caused difficulty in an unified approach to assessing temporal and spatial distributions of benthic macroinvertebrates.

To minimize these problems, data were presented to facilitate comparability among sampling techniques. Average seasonal (combined years) total macroinvertebrate abundance and standard errors of the mean were calculated for each sampling technique and sampling location. These data also were plotted to allow visualization of abundance and variability for each technique. In addition, abundance of predominant taxa (defined as $\geq$20 percent of the total at any location for artificial substrate data and $\geq$5 percent of the total for Hess data) were determined and illustrated for each sampling technique.

Artificial substrates--Because of the low recovery rate of artificial substrates and the changing of colonization periods from 90 to 30 days, artificial substrate data were not subjected to analytical procedures such as Sorensen's Quotient of Similarity, diversity, or percentage similarity. Means, standard deviation, minimum and maximum values were calculated for each collection period for total numbers of organisms and the different taxa collected. Because TRM 529.9 was not considered comparable to TRM 529.5, samples collected at 529.9 during 1975 and 1976 (30-day colonization) were not used in any of the calculations or considered as part of the results.

Principle component analysis (SAS, 1982) was performed on seasonal and combined seasons data sets (30-day colonization) to evaluate similarity among stations. Mean densities for each taxon were calculated for each quarter over the entire sampling period and for all quarters combined. These data were then transformed ($\log_{10}$) prior to analysis.

Although Morrison (1967) and Cooley and Lohnes (1971) give good presentations of these statistical features of principle component

analysis (PCA), a brief discussion in general terms of its applications to the analysis of these data will be given.

Principle component analysis summarizes the data contained in location-by-taxa data matrix in terms of components that are ordered in terms of the magnitude of their variances. The first principle component having the greatest variance, the second, the next greatest, and so forth. Each component has an associated eigenvalue giving the amount of variance accounted for by each component, and it is customary to extract only enough components to remove the majority of the variance. Sokal and Sneath (1973) suggest that enough components be extracted until 75 percent of the variance is accounted for. Often as few as three components will account for most of the variance. In addition, each component has an eigenvector of component coefficients often called scores giving the weighing of each taxon in each linear component.

In this report principle component analysis was used (in addition to the plots of dominant taxa) primarily to evaluate the similarity among sampling locations rather than to identify specific ecological factors. This similarity, derived from the original river mile-by-taxa matrix and expressed in terms of the first three components, was displayed in a single three-dimensional plot for each season and combined seasons. River miles with similar benthic community structures will form a cluster on the plots.

Total numbers of macroinvertebrates collected using bagged and unbagged methods of retrieval (30-day exposure) were tested for significant differences using Wilcoxon's Signed-Rank and t-test (Sokal and Rohlf, 1969). Total macroinvertebrate data from the 30-day unbagged substrates were plotted by year for each sampling location.

Hess samples--In addition to simple statistics, several other types of analyses were used to evaluate data collected with the Hess sampler. Sorensen's Quotient of Similarity (SQS) (McCain, 1975) and Percentage Similarity (PS) (Pielou, 1975) were used to evaluate similarity among stations based on qualitative and qualitative/quantitative community structure, respectively. A criterion of 70 percent 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 analysis of variance (ANOVA) and Duncan's New Multiple Range Test (Steel and Torrie, 1960) were used to aid in evaluating station differences (number of taxa present and abundance/m^2) in each quarter. Abundance data were transformed ($\log_{10}$) prior to the analysis.

Sediment--Amounts of various sediment sizes were calculated and used to characterize substrates at each sampling station. Cluster analysis, in addition to plotting, was used to find groupings of stations with similar substrates. The algorithm employed was the unweighted pair-group using arithmetic averages (UPGMA) using the Euclidean distance to examine the stations for natural groupings. An excellent review of the method is given in Sneath and Sokal (1973).

7.1.2 Results and Discussion

Sample Collection--Collection of artificial substrates was hampered by vandalism, spates (which removed substrates from their marked location), and hazardous river flows (which prevented collections by divers). Even after changing from 90-day to 30-day colonization periods

to increase collection efficiency, no great improvement was noted until summer 1983 when artificial substrates were first anchored to the bottom by steel rails. A summary of sample recovery during the entire monitoring period is provided in table 7-1 for the three artificial substrate collection techniques and for Hess samples also. Collection efficiencies before and after the anchoring of substrates to the bottom were as follows.

Spring 1973-Spring 1983		Summer 1983-Autumn 1985	
No. Substrates Placed		No. Substrates Placed	
30-day unbagged	282	30-day unbagged	180
30-day bagged	36	30-day bagged	180
90-day unbagged	105	90-day unbagged	162
No. Substrates Recovered (%)		No. Substrates Recovered (%)	
30-day unbagged	161(57)	30-day unbagged	155(86)
30-day bagged	10(28)	30-day bagged	156(87)
90-day unbagged	47(45)	90-day unbagged	131(81)

Considering all three collection techniques together, only 52 percent of the substrates placed from spring 1973 through spring 1983 were recovered. Recovery rate increased to 85 percent during the last part of the study. Recovery rate during 1983-1985 would have been even greater except for an almost complete washout of substrates by unusually high flows in spring 1984.

Observations during sample collection revealed benthic substrates consisting of varying amounts of rock and sand in the immediate vicinity of WBN and the upstream part of the study reach (TRMs 518.0-529.5). These substrates were therefore similar to the rock-filled artificial substrates utilized in this study. However, natural substrates at the two downstream stations (TRMs 496.5 and 506.6) were composed of silt, as was reported by divers who usually found the artificial, rock-filled baskets approximately

one-half buried into the substrate after each month's (or three months') colonization period.

During the summer quarter of 1983, divers had difficulty locating artificial substrates at TRM 518.0, resulting in a 14-day delay in retrieval (bagged and unbagged samples) and a 44-day colonization period. All other substrates collected were according to prescribed 30- or 90-day colonization periods.

Comparison of Collection Techniques--Average total macroinvertebrate abundance for each collection technique (table 7-2) is illustrated in figures 7-2 through 7-4 for each season and sampling location along with respective standard errors of the mean. These data indicated no statistical advantage of any particular substrate collection technique (30-day unbagged, 30-day bagged, and 90-day unbagged) because of the large amount of variability within each respective data set over the collection period. A comparison of 95 percent confidence intervals (not shown) would approximately double the degree of overlap among techniques as shown by the standard errors of the mean in figures 7-2 through 7-4. Respective means for the 30-day unbagged, 30-day bagged, and 90-day unbagged data (combined winter, spring, summer, and autumn data for all stations) were 33.9, 74.4, and 68.5 organisms per substrate. Ranges of respective 95 percent confidence intervals were 19.1-48.7, 32.4-116.4, and 27.5-109.5.

Although the entire data set could not be separated (on a statistical basis) into separate populations based upon the three artificial substrate collection techniques, some differences were observed. First, comparison of 30-day bagged and unbagged data showed that the technique of enclosing substrates within a bag before retrieval consistently (45 out of

56 comparisons of paired means) collected more macroinvertebrates. This difference was supported by the non-robust Wilcoxon Signed-Rank test which yielded a standard normal deviate equal to -4.73 and resulted in a $P < .001$, leading one to conclude that the bagged retrieval was superior to the unbagged. This difference is obvious in figures 7-2 through 7-4, comparing closed (bagged) and open (unbagged) circles.

Second, substrates exposed upstream from TRM 506.6 for a period of 90 days in autumn collected many more organisms than substrates exposed for 30 days (figure 7-4). Many of these organisms were rheophyllic insect larvae dominated by trichopterans (caddisflies), especially Cyrnellus fraternus. Cyrnellus abundance in Watts Bar tailwater proliferated from August through October and emergence was likely completed by November (Brigham et al., 1982). Because 90-day substrates were primarily collected in October and 30-day substrates were not collected until November or December, the difference illustrated in figure 7-4 between the 90- and 30-day collection techniques is strongly biased by time of placement.

Third, different collection techniques yielded different results in terms of abundance and distribution of predominant organisms (tables 7-3 through 7-6, figures 7-5 through 7-8). During the winter quarter (figure 7-5) 30-day bagged substrates surpassed other techniques in collection of the amphipod Hyalella azteca and chironomids, while 90-day substrates contained more flatworms (Planariidae and Dugesia tigrina). Two trichopterans, Cheumatopsyche and Cyrnellus fraternus, were predominant on 90-day substrates but not on 30-day substrates. During spring (figure 7-6) 90-day substrates were colonized primarily by chironomids (midge larvae) and Planariidae while the 30-day unbagged substrates were colonized by not only

chironomids and Planariidae but also the hydra Hydra americana, the benthic cladoceran Sida crystallina, and the caddisfly Cyrnellus fraternus. The 30-day bagged samples contained the amphipod, Crangonyx, especially at TRMs 527.4 and 528.0. This organism was never abundant on unbagged substrates. The midge Parachironomus was the predominant organism at TRM 529.5 on 30-day substrates (bagged and unbagged). The most prevalent organism during the summer quarter (figure 7-7) was Cyrnellus fraternus in the 30- and 90-day substrates (bagged and unbagged). Stenacron, a predominant organism on all artificial substrate types in winter, was only abundant on 90-day substrates in summer. During autumn 90-day substrates contained large numbers of three caddisflies, Cheumatopsyche, Cyrnellus fraternus, and Hydropsyche. One of these, Hydropsyche, was not predominant on 30-day substrates.

Abundance data from Hess samples could not be compared to artificial substrate data because Hess data were reported as abundance per unit area (m^2) whereas artificial substrate data cannot be converted and reported on a unit area basis. However, a qualitative comparison was made. The most abundant organism in Hess samples during both summer and autumn quarters (figures 7-7 and 7-8) was Corbicula manilensis, a clam which was relatively rare in other collection techniques. Predominant organisms in Hess samples also included aquatic worms (Oligochaeta) and the amphipod Crangonyx (autumn only). Hess data were similar to the 30-day substrate data (summer and autumn) reporting large numbers of Cyrnellus fraternus. Comparison of coefficient of variation data for all collection techniques (table 7-7) indicates that data derived from the Hess sampler methodology contained much less variability than data representing artificial substrate collections. Additionally, Hess collections included not only Corbicula

manilensis as the dominant organism, but also other bivalve mollusks such as Amblema plicata, Anodonta imbecillis, Cyclonaias tuberculata, Elliptio crassidens, Obliquaria reflexa, Pleurobema cordatum, and Quadrula pustalosa which were not represented in the artificial substrate data.

Spatial Comparisons--Because of differences among collection techniques and because different techniques were utilized separately and/or together during various parts of the study, a spatial description of macroinvertebrate occurrence considered all techniques with proper regard for sampling effort (30-day unbagged--27 quarters, 30-day bagged--12 quarters, 90-day unbagged--16 quarters, Hess sampler--6 quarters). One hundred and eight macroinvertebrate taxa were identified during preoperational monitoring (table 7-8). Of these taxa, 51 were found exclusively downstream of WBN and 3 were found exclusively upstream (table 7-9). All 3 taxa encountered only upstream of WBN (Coenagrionidae, Neurocordulia yamaskanensis, and Rheotanytarsus) were rare being represented infrequently by only a few individuals. Occurrence of the taxon Coenagrionidae only upstream represents identification to family of a very immature individual likely representing Argia, Enallagma, or Ischnura, all of which were also encountered downstream of WBN. Also, Neurocordulia yamaskanensis and Neurocordulia sp. likely are the same, thus being represented both up and downstream of WBN. None of the 51 taxa listed on table 7-9 as occurring only downstream of WBN were dominant organisms. Occurrence of the mussel taxa Amblema, Anodonta imbecillis, Cyclonaias tuberculata, Fusconaia ebena, Obliquaria reflexa, Plagiola lineolata, Pleurobema cordatum, Pleurobema cordatum pyramidatum, Proptera alata, and Quadrula exclusively downstream of WBN reflects important mussel habitat below WBN. Two species of mussels,

Elliptio crassidens and Quadrula pustulosa, which were reported downstream of WBN also occurred upstream, indicating limited mussel habitat existed upstream of WBN. Exclusive occurrence of more taxa downstream of WBN was expected because of greater sampling effort downstream (658 versus 302 samples) and greater downstream habitat diversity. Substrates downstream of WBN included deep silt which was not encountered upstream of WBN.

Seasonal spatial distributions of predominant taxa are provided in figures 7-5 through 7-8. These figures depict spatial results for every collection technique and are discussed below by season. Each seasonal discussion also incorporates results from Principal Component Analysis (PCA) of 30-day unbagged substrate data. Apart from providing supportive information to observations derived from artificial substrate data, Hess data are discussed separately as they represent abundance per unit area (m^2) and are not strictly comparative to artificial substrate data. Hess data also do not represent the entire area sampled by artificial substrates and were collected only during the summer and autumn seasons. Average abundance of organisms collected each sampling period by 30-day unbagged, 30-day bagged, 90-day unbagged, and Hess sampler is provided in respective appendices A through D.

Winter--All three artificial substrate collection techniques indicated a greater macroinvertebrate abundance at TRMs 496.5 and 505.5 than at other sampling locations (see figures 7-2 and 7-5). Predominant taxa at these two downstream locations included Oligochaeta, Planariidae, Hyalella azteca, and Chironomidae. Hyalella azteca was very abundant at TRM 506.6. Predominant taxa at locations upstream of TRM 506.6 (those with rock substrates) included two caddisflies, Cheumatopsyche and Cyrnellus fraternus, the mayfly Stenacron, and the midge Parachironomus.

Many of the predominant winter taxa also were important in the PCA grouping of stations (based on 30-day unbagged substrates) illustrated on three axes in figure 7-9. These taxa (table 7-10) included Hyalella azteca, Oligochaeta, Planariidae, Cheumatopsyche, Stenacron, and Chironomidae. Other taxa important in the PCA analysis included Coelotanypus and Hexagenia. PCA results were similar to those based upon dominant taxa in that the downstream two stations (TRMs 496.5 and 506.6) were separated from all other locations by the first principal component (PRIN 1 representing flow) because of the predominance of the silt tolerant Oligochaeta, Hexagenia, and Coelotanypus and also Hyalella azteca. Both downstream stations were also dissimilar to each other (PRIN 2) because of a greater abundance of Planariidae at TRM 496.5 than at TRM 506.6 and also the absence of Cheumatopsyche at TRM 496.5 which occurred at all other locations. TRM 528.0 was different from all other stations (PRIN 3) because of the simultaneous abundance of Chironomidae, Cheumatopsyche, and Stenacron at that station. Average abundance by sampling location of taxa important to PCA is provided in table 7-10.

Spring--Spatial distribution of macroinvertebrates in the spring was unlike winter (figure 7-2) in that there was a marked increase in abundance from TRM 496.5 to TRM 529.5, especially for Parachironomus, Planariidae, and the amphipod Crangonyx, except that Crangonyx was not abundant at TRM 529.5, immediately downstream of Watts Bar Dam (figure 7-6). The conspicuous absence of Crangonyx at TRM 529.5 may suggest its inability to maintain itself in very swift flows. Its absence in unbagged data may also suggest a tendency to be washed from the rock-filled baskets which were pulled freely to the surface during recovery. Predominant taxa (30-day

substrates) also included Oligochaeta, Sida crystallina, Cyrnellus fraternus, and Hydra americana (figure 7-6). Hydra americana occurred in the downstream part of the study reach (TRMs 496.5-518.0) while the netspinning caddisfly Cyrnellus fraternus increased in the upstream area (TRMs 528.0-529.5) where strong currents are prevalent. Cyrnellus fraternus utilizes nets to enhance capture of current-borne foods from a fixed retreat and is epilithic (living on rock substrates) and thus well suited for colonizing substrates in the upstream study reach (Lawrence, 1978). Sida crystallina, a benthic cladoceran, was prevalent in the mid-study reach (TRMs 506.6-528.0).

Predominant macroinvertebrate taxa also were important in the grouping of stations based upon PCA (figure 7-10), in addition to two other taxa: Oecetis (Trichoptera) and Chironomus (table 7-10). PCA results agreed with the spatial comparison based upon dominant (30-day unbagged) taxa in that greater abundance of Parachironomus and Planariidae at TRMs 527.4, 528.0, and 529.5 than downstream and more Hydra americana at TRMs 496.5 and 518.0 than upstream separated the study reach into two distinct areas based upon the first principal component (figure 7-10). Chironomus and Crangonyx were identified as important taxa partly responsible for separating stations based upon the second principal component (figure 7-10), although they were not abundant organisms in 30-day unbagged substrates. (Crangonyx, represented by only a few individuals at TRMs 527.4 and 528.0 in 30-day unbagged data [table 7-10] was the most abundant organism at the same two stations in 30-day bagged data [figure 7-3].) Chironomus, Crangonyx, and Sida crystallina were simultaneously abundant only at TRM 527.4 and absent at TRM 496.5 while Oligochaeta was most abundant at TRM 496.5 and

relatively scarce at TRM 527.4, resulting in the separation of stations based upon the second principal component. Greatest abundance of Sida crystallina at TRM 518.0 and Crangonyx at TRMs 527.4 and 528.0 was largely responsible for separation of these two stations based upon the third principal component.

Summer--Macroinvertebrate abundance increased from downstream to upstream in all three artificial substrate collection techniques (figure 7-3). Predominant taxa were Cyrnellus fraternus, Oligochaeta, Chironomidae, Dugesia tigrina, Cheumatopsyche, Dicrotendipes, and Stenacron (figure 7-7). Cyrnellus fraternus, the netspinning caddisfly, occurred in great abundance in the upstream study area (TRMs 527.4, 528.0, and 529.5). The habitat most favorable to Cyrnellus fraternus and least favorable to Oligochaeta apparently occurred upstream of TRM 527.4 (figure 7-7, Hess sampler). Cheumatopsyche, Chironomidae, and Dicrotendipes were most abundant upstream at TRM 529.5.

Results from PCA (PRIN 1) separated the two downstream stations from the upper study reach (TRMs 518.0-529.5) based mainly upon upstream abundance of Chironomidae and the three caddisfly taxa Cyrnellus fraternus, Cheumatopsyche, and Hydropsyche (figure 7-11, table 7-10). TRM 529.5 was most different from downstream stations, having the greatest abundance of three of the four important taxa (Cyrnellus fraternus was more abundant at TRM 527.4, table 7-10). This type distribution of taxa agrees with habitat conditions (substrate and flow) in the area of preoperational monitoring and with ecology of the trichopteran taxa. Dissimilarity between TRM 527.4 and 528.0 (figure 7-11) based upon PRIN 2 resulted from relative abundance of Cyrnellus fraternus and scarcity of Dicrotendipes, Parachironomus, and

Dugesia tigrina at TRM 527.4 compared with TRM 528.0. Separation of stations based upon PRIN 3 resulted from a comparatively large abundance of all three important taxa at TRM 518.0 and two of three important taxa at TRM 496.5 (figure 7-11, table 7-10).

Autumn--Colonization period and/or time of substrate placement apparently were factors during the autumn as Hess (natural substrate) and 90-day substrate samples, representing long-term colonization (early autumn), both contained similar numbers of organisms and appreciatively greater numbers than short-term 30-day bagged and unbagged samplers (late autumn) upstream of TRM 506.6 (figures 7-4 and 7-8). Spatial distribution of rheophilic caddisflies, like summer, were concentrated in the upstream study reach (TRMs 518.0-529.5). These taxa included Cheumatopsyche, Cyrnellus fraternus, and Hydropsyche. Strong currents apparently are important to those trichopteran taxa as greatest abundance occurred nearest the Watts Bar Dam (all collection techniques). Greatest average abundance of Stenacron measured during the study (48.9 per substrate) occurred in autumn at TRM 527.4. Maximum abundance of Crangonyx (79.6 per m^2) occurred in autumn in the upstream study area (TRM 528.0). Abundance of Cyrnellus fraternus (90-day substrates and Hess data) at TRMs 527.4, 528.0, and 528.5 was greater than populations in summer with maximum densities occurring at TRM 528.0 (426 per m^2), TRM 528.5 (416 per m^2), and TRM 529.5 (170 per 90-day substrate). Like summer, increase during autumn of Cyrnellus fraternus at upstream locations coincided with a decrease of Oligochaeta. The most abundant organism in the upstream study area (Hess data) was the clam Corbicula manilensis.

Although 30-day unbagged substrates yielded relatively few organisms (compared to 90-day unbagged substrates and Hess samples), the first principal component (figure 7-12, PRIN 1) still separated stations in an upstream/downstream fashion. This grouping was based upon occurrence of Coelotanypus and the silt tolerant Hexagenia and Oligochaeta in the downstream study area (TRMs 496.5 and 506.6) and their relative scarcity upstream and also upon increased numbers of Stenacron upstream (table 7-10). TRM 529.5 was very different from other upstream stations (PRIN 3) because of a greater abundance of Cheumatopsyche and few Stenacron at that station compared to TRMs 528.0 and 527.4. However, Cheumatopsyche occurred in large numbers during early autumn as far downstream as TRM 518.0. Stenacron abundance was mainly responsible for the distinction among stations based upon PRIN 2.

Combined Seasons--A Principal Component Analysis was performed on 30-day uncovered substrate data to evaluate overall location similarities based upon macroinvertebrate abundance and community composition for combined seasons. Many of the taxa important to the seasonal results were also included in the overall comparison: Cyrnellus fraternus, Oligochaeta, Sida crystallina, Hydra americana, Stenacron, Cheumatopsyche, Parachironomus, Hydropsyche, and Planariidae (table 7-10). The first three principal components as illustrated by the spatial grouping of stations (figure 7-13) accounted for 87 percent of the variability. The first component (PRIN 1) which accounted for over 60 percent of the variability separated stations in an upstream/downstream fashion because of the relative absence of rheophyllic taxa (Hydropsyche, Cheumatopsyche, Parachironomus) and abundance of silt-tolerant Oligochaeta at TRMs 496.5 and 506.6.

Stations TRM 518.0 and TRM 529.5 were polarized (very different) (PRIN 2) based upon relatively large numbers of Hydra americana and Sida crystallina at TRM 518.0 and their absence at the upstream station. Sampling locations at TRMs 527.4 and 528.0 were different from other stations (PRIN 3) because of a greater abundance of Stenacron than at TRMs 529.5, 496.5, and 506.6 and more Cyrnellus fraternus than TRMs 496.5-518.0 (table 7-10).

Conclusions based upon a single collection technique should be made with caution because of large amounts of missing data throughout the study period and because of some rare taxa utilized in the PCA results. For example, Sida crystallina was a predominant organism during spring at river miles 506.6, 518.0, and 527.4 (table 7-3); however, this organism only occurred in large numbers during 1976 and 1977. Missing samples at any river mile during those years (table 7-1) would strongly affect any results based upon mean numbers. However, it is clear that changes in habitat occurred from the immediate vicinity of WBN downstream to TRM 496.5, such that various descriptions of station differences were based upon occurrence of rheophillic, epilithic taxa near the plant site and taxa adapted to slower current and soft substrates in the downstream study reach. The most obvious points in the reservoir where these changes occurred were in the vicinity of TRM 527.4 and downstream of TRM 518.0.

Hess Data--Summer and fall Hess and sediment core samples were collected in 1983 to better characterize macroinvertebrate communities near WBN (TRMs 521.0-528.8). Three of the fifty-nine taxa collected, Corbicula manilensis, Cyrnellus fraternus, and Oligochaeta, comprised approximately 85 percent of the total community in summer and autumn. The clam Corbicula

manilensis was most abundant summer and autumn throughout the study area. The caddisfly Cyrnellus fraternus was abundant especially upstream of TRM 526.3 and was subdominant in autumn. Four predominant taxa (comprising $\geq$5 percent of the total abundance at any location) in summer and 4 in autumn (table 7-6) comprised 89 percent of the total abundance.

An average of 11 and 12 taxa per station were collected respectively in summer and autumn 1983. Average taxa per station in 1984 and 1985 ranged from 15 to 18 and were significantly greater (α = 0.001) than those collected in 1983. Greatest number of taxa collected at a single station was 24 during summer 1985 at TRM 521.0.

During summer, 21 of 30 station comparisons expressed as SQS (table 7-11) were less than the 70 percent criterion selected to indicate similarity, meaning that communities at these stations were composed of different taxa. Similarities measured in 9 comparisons were inconsistent from year to year. However, comparisons based upon organism abundance and taxonomic occurrence were mostly similar (20 of 30 comparisons having PS values greater than 70 percent). Total dominance by Corbicula manilensis at all stations accounted for much of this similarity. TRM 528.0 (immediately upstream of WBN) and TRM 521.0 (downstream) were similar every year (1983, PS = 84 percent; 1984; PS = 81 percent; 1985, PS = 70 percent). TRM 528.5 (upstream, not sampled in 1983) and TRM 527.4 (immediately downstream) were similar in 1984 (PS = 95 percent) and 1985 (PS = 82 percent). TRM 528.5 also was similar to TRM 521.0 in 1984 (PS =73 percent) and 1985 (PS = 71 percent). Similarities among other stations were inconsistent during the monitoring period.

Both SQS and PS comparisons of TRM 526.3 with upstream stations in summer 1985 were consistently very low (table 7-11). Several silt-tolerant taxa such as Hexagenia, Chironomus, Branchiura sowerbyi, Chironomidae, and Tubificidae were abundant at TRM 526.3 (appendix D), accounting for the low index values. Sediment data (appendix E) indicate an atypically large amount of silt at the TRM 526.3 sampling location in summer 1985.

Autumn SQS data were similar to summer in that most (20 of 30) comparisons based upon taxonomic structure were not similar. The 10 comparisons which indicated similar taxa among stations were again inconsistent (i.e., two stations were similar one year but not all years). Percent similarity data identified similar communities at 18 of 30 comparisons, again demonstrating the strong influence of Corbicula manilensis abundance upon the comparison. Several stations had autumnal PS values greater than 70 percent during every year: TRMs 528.5 and 528.0, TRMs 528.5 and 527.4, TRMs 527.4 and 521.0, and TRMs 526.3 and 521.0. The range of SQS and PS values for both summer and autumn are listed below.

Comparison	Summer		Autumn	
	SQS	PS	SQS	PS
(TRM)	(%)	(%)	(%)	(%)
528.5-528.0	60-74	69-90	59-74	75-90
528.5-527.4	69-72	82-95	61-93	73-81
528.5-526.3	45-65	51-95	58-73	61-76
528.5-521.0	56-67	71-73	57-76	60-75
528.0-527.4	65-85	66-81	57-65	62-85
528.0-526.3	43-60	48-82	55-71	51-80
528.0-521.0	52-67	70-84	45-73	52-79
527.4-526.3	55-69	47-94	58-73	78-95
527.4-521.0	59-77	63-74	55-75	67-93
526.3-521.0	67-74	57-95	52-73	74-93

Comparison of stations based upon analysis of variance for total macroinvertebrate abundance (table 7-12) showed all 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 percent reduction in the dominant organism, Corbicula manilensis, occurred. Stations differences were observed in summer 1984 when total abundance was again tied closely to abundance of Corbicula manilensis. In summer 1985, abundance of macroinvertebrates at TRM 526.3 greatly surpassed abundance at other stations (table 7-13, figure 7-14), primarily because of greater Corbicula manilensis abundance and exceptionally large numbers of the silt tolerant midge, Chironomus (540 per m^2). Sediment core samples collected concurrently with macroinvertebrate sampling contained an average of 18.5 grams (dry weight) silt/clay, representing a non-target substrate type. Macroinvertebrate samples at TRM 526.3 also contained other silt-preferring organisms such as Branchiura sowerbyi, Tubificidae, Hexagenia, and Chironomidae which were not present or abundant at other stations (appendix 7-D).

During autumn, no significant differences were identified among stations in 1983 and 1985. In 1984, total abundance in autumn was greater upstream of TRM 526.3, resulting from a large increase in the caddisfly, Cyrnellus fraternus, and the amphipod, Crangonyx. In autumn 1984, Cyrnellus fraternus was the dominant organism at TRMs 528.0 and 528.5. Lack of significant station differences during autumn 1983 and 1985 was due to greater downstream abundance of Corbicula manilensis than upstream which canceled the effect of more Cyrnellus fraternus upstream.

Community diversity index was low (<2.50) at all stations and frequently below 1.00, especially downstream of TRM 528.0 (table 7-14). Low diversities generally reflected complete dominance by Corbicula

manilensis at most stations. Greatest diversity (index = 2.20) occurred at TRM 527.4 during autumn 1985 when only about 53 percent of the total abundance was composed of Corbicula manilensis and 31 percent of the remaining 47 percent was almost evenly divided between two other taxa, Cyrnellus fraternus and Dugesia tigrina (Planariidae) (appendix D).

Sediment results (appendix E, figures 7-15 through 7-17) indicated sampling stations were most similar with regard to the 2-31 mm particle-size category representing granule and pebble-size rocks. This was also the dominant sediment type with regard to weight. Station substrates were less uniform with regard to other particle-size categories, especially fine sand. Benthic substrates at TRM 526.3 contained much greater amounts of fine sand than at other stations. Lotic condition downstream of Watts Bar Dam restricts deposition of silt and clay (<.063 mm category); however, surprisingly large amounts of silt and clay were measured at TRM 528.5 in summer 1984 and especially at TRM 526.3 in summer 1985 where up to 36 grams of silt/clay were collected. Substrates also varied greatly with regard to the 31-63 mm sized pebbles. These rocks were present at most stations in 1983, but completely missing at many stations during 1984-85.

Clustering of stations based upon overall sediment composition (figures 7-18 and 7-19) showed the upstream stations (TRMs 528.8 or 528.5 and 528.0) and the station immediately downstream of WBN (TRM 527.4) were more similar than other stations during summer. However, TRM 528.0, immediately upstream of the diffuser, was much different during autumn. TRM 526.3 was different from all other stations every sampling period except autumn 1985 when much smaller quantities of fine sand were

collected than in other surveys. Presence of more fine sand and silt/clay at TRM 526.3 than at other stations resulted in increased abundance of Oligochaeta, Chironomus (figures 7-7 and 7-8), and other silt tolerant organisms over other stations.

Temporal Comparisons--Thirty-day unbagged substrate data comprise the only continuous data base (winter 1975-winter 1984) from which temporal comparisons can be made. However, missing substrates during this period limited the definition of any long-term trends. These data (table 7-15, figure 7-20) indicated the following for each season.

During winter macroinvertebrate abundance at the two most downstream stations (TRMs 496.5 and 506.6) was much greater than other stations, especially since 1983. The increase involved primarily Chironomidae, Coelotanypus, Hexagenia, Hyalella azteca, Oligochaeta, and Planariidae (appendix 7-A). Abundance at other stations increased during 1984 and 1985, equaling population levels measured in 1975.

In spring macroinvertebrate abundance was greatest at TRM 518.0 during 1976 and 1977 (involving primarily Hydra americana and Sida crystallina), but was reduced during 1975, 1982, 1983, and 1985 (substrates were not collected in 1984 because of extreme flooding). Abundance was also high in 1977 at TRM 506.6 (Sida crystallina) and TRM 527.4 (Chironomus, Corbicula manilensis, and Sida crystallina). Maximum abundance during the spring season occurred in 1982 at TRM 529.5 (Chironomidae, Glytotendipes, Parachironomus). Spring substrates were not recovered from TRM 529.5 during other years except in 1985, when abundance was also greater than at other stations. Maximum abundance at TRM 528.0 also occurred during 1985 (Planariidae, Cyrnellus fraternus, Crangonyx, and Amnicola).

Macroinvertebrate abundance was exceptionally high in summer during 1984 and to some extent in 1983 at stations primarily affected by strong currents (upstream of TRM 506.6) (figure 7-20). Organisms responsible for this increase were Stenacron, Dugesia tigrina, Chironomidae, Cheumatopsyche, Hydropsyche, and especially Cyrnellus fraternus. The only factor unusual about 1984 was a large spate (figure 2-15) which occurred and persisted through much of May. A much smaller spate also occurred in May 1983. Increased macroinvertebrate abundance of the above taxa likely was associated with the unusual early summer flows, although the mechanisms for this effect were not studied. Little is known about the ecological effects of such natural disturbances in streams (McAuliffe, 1983). Likely mechanisms include (1) increased macroinvertebrate drift and subsequent recolonization, (2) disruption of established competitive structures, (3) greater food availability, and (4) creation of larger microhabitats (niches) through removal of finer substrate types. A similar high flow event occurred in June 1973; high abundance of Cyrnellus fraternus and Cheumatopsyche was observed on 90-day substrates collected in November of that year.

In autumn maximum abundance at TRM 518.0 occurred in 1975 (Oligochaeta). Maximum abundance occurred in 1983 at TRM 506.6 (Planariidae). Abundance at the four upstream stations declined in 1985, a low flow year (figure 2-16).

As described above, yearly abundance patterns depended upon sporadic occurrence of various dominant taxa. Major occurrences of these taxa are summarized below.

Taxa	Year	Season
Cyrnellus fraternus	1975	Summer
	1976	Autumn
	1982	Summer
	1983	Summer
	1984	Summer
	1985	Summer
Sida crystallina	1976	Summer
	1977	Spring
Hydra americana	1976	Summer
Oligochaeta	1977	Autumn
	1984	Summer
Hyalella azteca	1982	Spring
	1983	Winter
	1984	Winter
Planariidae	1983	Autumn
	1984	Winter
	1985	Spring
Stenacron	1983	Summer
		Autumn
	1984	Summer

As indicated Sida crystallina and Hydra americana were prominent during the early preoperational period (1975-1977) while Hyalella azteca, Planariidae, and Stenacron were prominent in more recent years (1982-1985). Cyrnellus fraternus was prominent during summer or autumn throughout the study.

7.1.3 Summary and Conclusions

Benthic macroinvertebrates in the vicinity of WBN (TRMs 496.5-529.5) were sampled quarterly from spring 1973 through autumn 1977 and spring 1982 through autumn 1985, utilizing a variety of collection techniques involving two methodologies, rock-filled artificial substrates and a Hess sampler. The use of various collection techniques was

necessary to (1) enhance sample recovery of artificial substrates which were missing following 90-day colonization periods, (2) provide additional quantitative information regarding substrate and macroinvertebrates in the more immediate vicinity of WBN (TRMs 521.0-528.8), and (3) evaluate comparability of data resulting from the different sample types.

It was found that changing from 90-day to 30-day colonization periods did not appreciably enhance artificial substrate recovery. However, anchoring of substrates to the river bottom, beginning in August 1983, such that recovery could be made only by divers, greatly improved collection efficiency (from 52 percent to 85 percent) and increased the comparability among stations.

Different collection techniques demonstrated different sampling efficiencies depending upon location and season. Most notable was that (1) bagged artificial substrates regularly collected significantly more macroinvertebrates than unbagged, and (2) collection techniques representing long-term colonization (90-day substrates and Hess sampler) collected a greater variety and many more macroinvertebrates during autumn than those utilizing a shorter (30-day) colonization time. However, it appeared that time of placement for short-term exposure in late autumn selected against collecting abundant organisms. Also, various collection techniques yielded different results in terms of abundance and distribution of predominant organisms. Hess sampling was the only methodology to identify the clam Corbicula manilensis as the dominant organism upstream of TRM 521.0 and to collect several species of mussels.

Though conclusions based independently upon each collection technique conflict (because of differences in collecting ability), utilization of the complete data base provided definitive information regarding spatial occurrence and abundance of macroinvertebrates near WBN. Changes in current velocity and substrate greatly affected macroinvertebrate distribution. A large number of taxa (51) occurred only downstream of WBN where greater habitat diversity occurs due to a lessening of current velocity and a change from predominately rock substrates to soft silt and clay, especially at the two downstream most stations (TRMs 496.5 and 506.6). None of these 51 taxa represented predominant organisms and many were only rarely collected or likely represented very immature forms of taxa found upstream. The large number of taxa exclusively downstream of WBN occurred because of greater downstream habitat diversity and sampling effort (658 downstream samples and 302 upstream).

In addition to population differences up- and downstream of the WBN diffuser, the entire study reach was separated into three areas based upon occurrence and abundance of specific taxa. The area upstream of TRM 526.3 (beginning at TRM 527.4) was especially suited for caddisfly taxa (Cyrnellus fraternus, Cheumatopsyche, Hydropsyche) and certain midges Dicrotendipes, Parachironomus). The mid-study area (TRMs 518.0, 527.4, and 528.0) contained greatest abundance of the benthic cladoceran Sida crystallina, the amphipod Crangonyx, and the mayfly Stenacron, and also many Cheumatopsyche (caddisflies). The downstream study area (TRMs 496.5 and 506.6) was especially colonized by aquatic worms (Oligochaeta), the amphipod Hyalella azteca, midges (Coelotanypus and Chironomus), the

mayfly Hexagenia, and Hydra americana. The clam Corbicula manilensis occurred as the predominant taxon at TRM 521.0 and upstream (Hess data). This taxon likely was dominant or present in large numbers downstream of TRM 521.0 but was not documented as such because of the inability of artificial substrates to accurately represent its abundance.

Temporal changes were obvious over the study period. Sida crystallina and Hydra americana were prominent early in the study (1975-1977) while Hyalella azteca, Planariidae, and Stenacron were prominent in more recent years (1982-1984). This change likely reflects flow conditions during sampling, rather than a change in the ecology in this portion of Chickamauga Reservoir. Cyrnellus fraternus was prominent during summer and autumn throughout much of the entire study.

Occurrence of spates during early summer of several years greatly influenced (increased) abundance of several rheophyllic taxa during subsequent late summer (30-day data) or early autumn (90-day data) seasons. Operational evaluation of WBN influence upon macroinvertebrates should not be made apart from considering the important factor of flow which controls both occurrence and abundance of numerically important taxa.

The overall study indicates a diverse, abundant macroinvertebrate fauna in the study area upstream and downstream of WBN. Because of their abundance and occurrence in more recent years, Cyrnellus fraternus, Hyalella azteca, Planariidae, Stenacron, and Corbicula manilensis appear best suited as target organisms for operational studies at WBN.

7.2 Freshwater Mussels

The freshwater mussel (Bivalvia: Unionacea) component of the macrobenthic community is considered separately for several reasons. These animals are unique among benthic invertebrates in terms of attained size (up to 180 mm in length), age (40 years is not uncommon in several species), and complexity of their life cycle (including obligate parasitism, typically on specific fish species). Because of their large size, sedentary nature, and tendency to occur clumped in areas of suitable habitat ("mussel beds"), these animals cannot be accurately sampled using typical benthic sampling techniques. Appropriately sampled and examined, however, these animals can provide substantial information on present and past quality of an aquatic habitat--often including variations around some point of aquatic disturbance.

Historic and archaeologic records indicate that the Tennessee River once contained an extremely diverse and abundant freshwater mussel fauna. In a classic study of this fauna, Ortmann (1918) discussed 88 species and recognized forms which had been found in the Tennessee River system upstream from Chattanooga. Approximately half of these species occur throughout much of the Ohio and Mississippi River systems. The remaining species are more or less restricted to upstream portions of the Tennessee and Cumberland River systems and have been recognized as the "Cumberlandian" faunal group (Ortmann, 1924). Many taxonomic and nomenclature changes have occurred with regard to freshwater mussels; however, current species concepts still indicate that approximately 90 species once were present in the Tennessee River (Parmalee, Klippel, and

Bogan, 1982), including 36 Cumberlandian species. In the following paragraphs, species names from all surveys are presented using only their updated synonyms. While these names may not appeal to all current workers in this area of specialization they are sufficient to identify the biological entities being discussed in this baseline ecological study.

The reach of the Tennessee River included in this study generally is restricted to Tennessee River Miles (TRM) 479 through TRM 529. This reach of large river meanders southwest from near Spring City (Rhea County) toward Chattanooga (Hamilton County, Tennessee). The dams in the reach have substantially altered the river. Chickamauga Dam (TRM 471.0), closed in 1940, impounds 58.9 miles of the river to the base of Watts Bar Dam. Watts Bar Dam (TRM 529.9), which impounds 72.4 miles of the Tennessee River, was closed in 1942. An eleven foot deep (minimum) navigation channel has been maintained in these reservoirs since 1945.

7.2.1 Survey Methods

Preimpoundment Fauna

The preimpoundment freshwater mussel fauna of the Tennessee River was not studied in sufficient detail before the dams were built to satisfy modern statistical interests. However, early distribution records in conjunction with recent work on aboriginal shell middens, provide a preimpoundment species list accompanied by some relative abundance estimates. Aboriginal shell midden material has been studied by Parmalee, Klippel and Bogan (1982) and more recent material (1850-1918) was evaluated by Ortmann (1918). Table 7-16 indicates that 45 identifiable species were found in the shell middens and 58 species (current interpretations) were

included on the 1850-1918 list. These lists suggest that 64 species of freshwater mussels probably occurred near the WBN site before the Tennessee River was affected by substantial human impact, primarily impoundment. Twenty-two of these species are members of the Cumberlandian faunal component (Ortmann, 1924). Quantitative data from the shell midden study (Parmalee, et al., 1982) indicate that the five most abundant species were Dromus dromas (35.25 percent), Elliptio dilatatus (11.36 percent), Actinonaias ligamentina (7.49 percent), Elliptio crassidens (6.11 percent) and Pleurobema plenum (5.58 percent). Together, these five species made up about 66 percent of the community.

Postimpoundment Fauna

Surveys of freshwater mussel stocks near WBN after Chickamauga and Watts Bar reservoirs were filled, fall into two groups: three localized studies or spot checks conducted between 1956 and 1972, and three intensive assessments conducted between 1975 and 1985. Each of these surveys had its own purpose, area of coverage, sampling techniques and intensity of effort.

A U.S. Fish and Wildlife Service study conducted in 1956-1957 (Scruggs, 1960) was primarily concerned with a single commercial mussel species (Pleurobema cordatum). Scruggs examined brail boat catches and performed some scuba searches "near TRM 515" in addition to his primary surveys further downstream (on Wheeler Reservoir). The quantitative data from this study included in table 7-16 are derived from a table of commercial crowfoot bar catch records (Scruggs, 1960:11). The high percentage of P. cordatum in this data set either reflects a substantial sampling bias by the mussel fishermen or the actual composition of beds

that "were discovered in 1956 and had been fished for only 5 months" (Scruggs, 1960:7).

In 1964, Isom conducted an extensive dredge survey of the upper river channel in Chickamauga Reservoir (TRM 471-529) as part of an assessment of mussel resources in the Tennessee River (Isom, 1969). The 300 three-square-foot samples taken in this river reach produced the species list and relative abundance estimates included in table 7-16.

Bates (1975) used brailing, ponar sampling, and hand collecting techniques in a study of mussel resources on overbank areas and in the immediate tailwaters of Tennessee River dams. Near WBN, this survey included the area just downstream from Watts Bar Dam (TRM 529.9) and TRM 481-511. Because quantitative information is not included in this report for the hand collecting technique and so few other specimens were found (21), only indications of live occurrences are recorded in table 7-16.

These three surveys include records for 22 mussel species, eleven of which were only reported by Scruggs. Bates alone reported the occurrence of Anodonta grandis (in his report as A. corpulenta). None of the species found in these surveys are members of the Cumberlandian faunal group. Quantitative data from two of these surveys (Scruggs, 1960; Isom, 1969) suggest that Pleurobema cordatum was the most abundant species (74 and 31 percent respectively), followed by Elliptio crassidens (13 and 19 percent), Quadrula pustulosa (2 and 11 percent) and Cyclonaias tuberculata (2 and 13 percent). Quadrula metanevra made up 2.9 percent in the 1956-1957 survey but was not found in the quantitative work in 1965.

The three most recent and most intensive assessments in the vicinity of the WBN were conducted by TVA during siting surveys or as part

of the WBN preoperational monitoring program. Previously accumulated information and the results of preliminary sampling (conducted in 1971 and 1972) led to a series of five qualitative and/or quantitative collections in July 1975 through August 1977 between TRM 520.5 and 528.5. Brailing and random scuba dives were used to document species occurrence while density was assessed by taking square meter quadrat samples. Composite results of these collections are included in table 7-16.

In 1978, TVA conducted an extensive survey of mollusc resources downstream from all nine Tennessee River mainstream dams (Gooch, Pardue and Wade, 1979). This survey consisted of several hundred timed scuba dives at specific locations. In the WBN reach, 55 dives were made between TRM 514.2 and 528.9. Data from these dives are summarized in table 7-16 and the numbers of species identified at each site are indicated on figure 7-21. Upper Tennessee River data from this survey also have been presented by Pardue (1981).

These surveys confirmed the continued existence of the species and community structure indicated by the less intensive surveys from the 1950's, 1960's and early 1970's. The 1978 survey also provided valuable information on the present distribution of species in the vicinity of WBN. These data formed the basis for mussel sections in the NRC Environmental Statement on WBN (NRC, 1978) and in the initial WBN Preoperational Monitoring Report (TVA, 1980b).

1983-1985 Preoperational Assessment

In 1983, detailed sampling of freshwater mussel concentrations was initiated at TRM 520-521L (along the Left descending bank), 526-527R and

528-529L (figure 7-22). The most upstream of these beds (TRM 528-529L) is located on the opposite side of the river and upstream from the WBN construction site and 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 all WBN 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 approximately 10 to 20 feet deep.

Linearly-arranged sampling stations were established on each of these three beds (figure 7-22). Each sampling station was located as precisely as possible using river mile markers, navigation buoys and bankside landmarks. Each station was sampled once in summer and once in autumn (1983-1985) by scuba divers. All freshwater mussels (thus excluding the Asiatic Clam, Corbicula sp.) encountered in eleven minutes of bottom time were picked up. All mussel specimens were brought to the dive boat where they were sorted by species and counted. On each sampling visit, up to 50 specimens of each species from each bed were measured in three dimensions (length, height and thickness). All specimens were returned to the station from which they were collected.

7.2.2 Results and Discussion

Species Composition and Abundance--Composite results from the 1983-1985 assessment are included in table 7-16. In general, the list of species and relative abundance values are similar to the data from 1975-1977 and 1978. Five species were encountered in 1983-1985 that had not been found in other recent assessments (Anodonta imbecillis, Fusconaia

maculata, Lasmigona complanata, Pleurobema plenum and Ptychobranchus fasciolaris). Of the composite total of 28 species found during these three surveys, only Pleurobema oviforme and Dromus dromus are members of the Cumberlandian fauna. Elliptio crassidens was consistently most abundant (42-64 percent), followed by Pleurobema cordatum (12-15 percent), Quadrula pustulosa (6-17 percent), Cyclonaias tuberculata (5-10 percent), and Plagiola lineolata (2-5 percent), typically in that order. The only deviations from this relative abundance order were the transposition of P. cordatum and Q. pustulosa in the 1975-77 data set and the replacement of Plagiola lineolata by Potamilus alatus in the 1983-85 data set. Considered together, these five species account for 89 to 93 percent of the mussel community.

Survey results from 1956 through 1985 suggest that the extant fauna consists of approximately 30 species, five of which account for roughly 90 percent of the individuals present. Differences in the lists of most abundant species found during this 30-year period suggests that the composition of this mussel community still has not stabilized in this river reach.

The data from various surveys presented in table 7-16 indicate that approximately 35 freshwater mussel species have disappeared from the WBN reach of the Tennessee River since the beginning of the twentieth century. Results from surveys conducted between 1956 and 1972 suggest that most of these species were gone by the mid-1950's. Data do not exist to establish the cause for this loss in mussel diversity; however, it is logical to assume that the extensive modifications of riverine habitat, which occurred when Chickamauga and Watts Bar reservoirs were formed (1940 and 1942), resulted in adverse impacts to the mussel fauna.

Some type of abundance information was collected during each survey from 1956 to 1985. Unfortunately, variations in sampling techniques and areas of coverage make comparison of the data difficult.

Catch-per-effort values from several surveys are presented in table 7-17. The most random technique (Isom, 1969) recorded the second lowest density (0.22 specimens per m^2) and the fewest species (7). Lowest density estimates (0.07 mussels per m^2) came from the 1957 crowfoot bar brailing survey (Scruggs, 1960) which was conducted in conjunction with a scuba-assisted quadrat survey. Species records were comparable between these two techniques (16 and 17 species) but the high density estimate from the quadrat survey (19.97 mussels per m^2) indicated the relative inefficiency of brailing. The 1975-1977 survey also employed scuba-assisted quadrat sampling and included records for 15 species. This density estimate (11.29 mussels per m^2) suggested a 43 percent decline in total mussel abundance between 1957 and 1977. Further comparison of the data from these two surveys (1957 and 1977) indicated that Pleurobema cordatum suffered a 97 percent decline, Quadrula metanevra declined 88 percent, while Elliptio crassidens increased 360 percent.

Data from surveys conducted in 1978 and 1983-1985 were reported in association with the number of minutes of dive time. The more random survey conducted in 1978 included 21 species and averaged 2.32 specimens per minute of dive time. In 1983-1985, 28 species were found and a mean of 4.78 mussels per minute of diving were recorded. Site selection differences are probably responsible for both the larger number of species and the greater density reported for the 1983-1985 survey.

Population Age Structure

During his 1957 study of P. cordatum in Chickamauga Reservoir, Scruggs (1960) measured the length of many specimens and counted external growth rests to estimate their age. He concluded that this population was dominated by the year classes of 1934 through 1936 and that over 95 percent were older than 12 years. No specimens less than 6 years old were found.

Although age data have not been taken on mussels from the vicinity of WBN since 1957, length data were collected during surveys in 1975-1977 and 1983-1985. In the most recent survey, age data were not taken because most specimens had been eroded so extensively that counts of growth rests could not be made. Mean length data from these surveys are compared to the 1957 data in table 7-18. For P. cordatum, mean length increased in both recent surveys, reaching 95.6 mm in 1983-1985 (table 7-19). This is 8.6 mm longer than the length Scruggs calculated for specimens in their 25th year of life--the oldest specimens in his analysis. Also, the 1983-1985 data indicated that sizes of P. cordatum are normally distributed around the mean, with no specimens shorter than the 60 mm and that the mean age is now well over 25 years. The sizes of most other species also appear to be normally distributed. No specimen smaller than the 30 mm was collected for any species. Scruggs (1960) concluded that impoundment had virtually eliminated successful recruitment of P. cordatum. Length data from the 1983-1985 survey support this conclusion and extend it to cover most other extant species as well.

Comparison of Monitoring Beds

Results from the three mussel beds sampled in detail during 1983-1985 were subjected to further analyses to identify similarities or

differences among the specific beds because operational monitoring will be focused at these locations.

Similarities in community composition among the beds was evaluated by two different types of indices: Sorenson's Quotient of Similarity (SQS)--based solely on species presence or absence (McCain, 1975), and Percentage Similarity (PS)--incorporating information on species abundance (Pielou, 1975). Both indices yield values ranging from zero (no similarity) to 100 (identical communities), and a rule of thumb suggests 70 as a minimum score for recognizing similar communities. Since sampling effort was a constant for these data (all data had been collected during pairs of eleven-minute timed dives), SQS provided a numeric index of similarities in species composition while PS summarized relationships in terms of relative abundance. Formulas for these indices and calculated values for the three mussel beds are presented in table 7-20.

Results for summer and fall sampling in 1983-1985 are presented in appendix 7-1. SQS values for all three stations indicate the species composition is quite similar; however, the beds at TRM 520-521L and TRM 528-529L are more similar to each other than either is to the bed at TRM 526-527R. PS values retain the high similarity between the beds at TRM 520-521L and TRM 528-529L but highlight the low similarity in community composition between either of these beds and the bed at TRM 526-527R.

Analysis of variance (ANOVA) of relative abundance within each bed (examined separately) revealed some statistically significant differences among locations within the bed and among years. Differences by location (table 7-21) indicate that the distribution of a few species is not uniform on each bed. More than likely, these differences reflect either minor habitat variations along the length of each bed or random variations in the

data collected. These differences do not appear to be substantial enough to affect comparisons among the full beds. Significant year-to-year differences within each bed were determined (table 7-21). Four of these suggested population declines during the three-year sampling period; the other two indicated population increases during this time. The apparent declines might have occurred through natural mortality or as a result of displacement related to sampling. Length data (table 7-19) argue against substantial recruitment to any of these populations. Given the apparent contradictions of these within-station differences, it appeared that random sampling variations accounted for these differences.

Results of ANOVA of abundance by species among the three beds indicated statistical differences for 11 of the 28 species (table 7-22). Duncan's Multiple Range Test indicated that the bed at TRM 526-527R yielded significantly higher counts for six species and a significantly lower count for one species. The bed at TRM 520-521L yielded two significantly higher counts and the bed at TRM 528-529L yielded one significantly higher count. Data on Ligumia recta indicated significant differences among the beds, with most specimens at TRM 528-529L and fewest at TRM 526-527R.

ANOVA of total abundance by species on all three beds by the year, 1983-1985 (table 7-23) resulted in significant differences for four species. One species, Pleurobema rubrum, was represented by only three specimens. The other three species (Anodonta grandis, Pleurobema cordatum and Quadrula metanevra), however, each were represented by more than 40 specimens and the statistical relationships likely reflect real population trends. These three species were most abundant in 1983 and two of them (P. cordatum and Q. metanevra) were least abundant in 1985. Two other well-represented species (Cyclonaias tuberculata and Plagiola lineolata)

yielded similar declining trends between 1983 and 1985, but these trends were not statistically significant. Two other species (Lampsilis ovata and Potamilus alatus) yielded increasing trends, also without statistical differences. Data for the other 20 species indicated no apparent change in the number of individuals by year.

Mussel size (length) comparisons among the three beds for eight species represented by more than five measured specimens per bed are presented in table 7-24. Results of ANOVA tests of these data indicate that mean lengths of all eight species vary among the beds. Duncan's Multiple Range Test indicated that the bed at TRM 520-521L yielded significantly different (shorter) mean lengths for seven species, and the bed at TRM 526-527R had significantly different (longer) mean lengths for Pleurobema cordatum and Potamilus alatus. Length data for Quadrula metanevra indicate differences among the beds, with a longer mean length at TRM 526-527R and a shorter mean at 520-521L. All size data from the 1983-1985 sampling visits are presented in appendix 7-2.

ANOVA of mean length by year (1983-1985) indicate that the mean lengths of four species varied significantly (table 7-25). However, for most species some growth was indicated from 1983 to 1985.

Collectively, numerical indices and statistical analyses lead to the following comparisons of the three mussel beds. The species presence/absence similarity index (SQS) indicates these mussel aggregations exhibit a high degree of uniformity that might be expected from their proximity to each other. On the other hand, the abundance-weighted similarity index (PS), abundance of individual species, and much of the length analysis indicate substantial differences.

Working from downstream to upstream, the bed at TRM 520-521L seems to support the most species, including two species (Dromus dromas and Ptychobranchus fasciolaris) found only at this station and all but three species found on either of the other beds (Anodonta grandis, Lasmigona complanata, and Plethobasus cyphyus). This bed is quite similar to the one at TRM 528-529L according to both measures of similarity and, generally, in the abundance of most individual species. With regard to mean lengths, specimens of all eight abundant species at TRM 520-521L are consistently shorter than those on the other two beds (table 7-24).

The bed at TRM 526-527R shares the presence of 18 species with one or both of the other beds; however, abundance of the various species is substantially different (table 7-22). Six species (Amblema plicata, Anodonta grandis, Leptodea fragilis, Obliquaria reflexa, Potamilus alatus and Tritogonia verrucosa) are much more abundant on this bed than on either of the others. Two species (Pleurobema cordatum and Potamilus alatus) are consistently larger here.

The most upstream bed, TRM 528-529L, supports one species (Lasmigona complanata) not yet found on the other beds and lacks one species (Anodonta imbecillis) occurring at the other two (table 7-22). Lampsilis orbiculata is more abundant here than on the other beds but, generally, species abundance is similar to TRM 520-521L. Shell length for the abundant species is similar to TRM 526-527R and longer than TRM 520-521L except, as previously noted, for Pleurobema cordatum and Potamilus alatus which are longer at TRM 526-527R.

The abundance and length differences observed among mussel populations on these three beds probably are expressions of habitat

differences among the three sites. Observations made by divers suggest the bed at TRM 526-527R includes more boulders and silt. This may explain why silt-dwelling species (i.e., Anodonta grandis, Leptodea fragilis and Potamilus alatus) are substantially more abundant here. No observations or hypotheses have been advanced to explain the short shell lengths at TRM 520-521L or other differences between the beds.

7.2.3 Summary and Conclusions

The extant freshwater mussel fauna in the WBN reach of the Tennessee River consists of approximately 30 species, far fewer than the 64 species which existed prior to impoundment. Data from five surveys conducted bewteen 1956 and 1985 indicate that relative abundance of the species has not remained constant; however, the same five species have consistently accounted for approximately 90 percent of the community. In typical order of abundance, these species are: Elliptio crassidens, Pleurobema cordatum, Quadrula pustulosa, Cyclonaias tublerculata and Plagiola lineolata. In recent years many of the remaining species have been represented by less than one percent of the specimens examined.

Total relative abundance of this mussel community declined from 20.0 to 11.3 animals per m^2 between 1957 and 1977; however, this apparent decline may have resulted from differences in the sampling programs that were used. More recent quantitative data have been collected on the basis of mussels observed per minute of dive time, which has not been correlated with areal abundance information.

Age data have not been collected in recent surveys because most shells are extensively eroded. Shell length data from the 1957, 1975-1977

and 1983-1985 surveys indicate that mean lengths are increasing for many species. Incremental separation of the 1983-1985 length data indicates that no specimens shorter than 30 mm were found, suggesting that very little recruitment has occurred. Data on the age/length relationship for Pleurobema cordatum suggests that this population is quite old and may not have reproduced successfully in the past 40 years--since before the adjacent dams were closed. Length distributions for most of the other species indicates that they also may not have reproduced successfully since the dams were closed.

The three mussel beds studied in detail during 1983-1985, and proposed to be used for operational monitoring of WBN, are similar to each other in terms of species composition but other parameters differ. Statistical differences among these beds include the greater abundance of several species in the bed at TRM 526-527R and the smaller size of specimens in the bed at TRM 520-521L.

During the next several years, relative abundance on each bed should not change significantly, even though some rare species could disappear from the communities. Actual abundance can be expected to decline slowly as older specimens die but growth (shell length) for many species should continue gradually. All of these changes should occur slowly, without abrupt changes. Substantial deviations from these expected trends would indicate critical changes in the river habitat or water quality.

Table 7-1. Summary of Macroinvertebrate Samples Collected During Preoperational Monitoring at Watts Bar Nuclear Plant, Spring 1973 through Autumn 1985.

Season	Sample Type	Year	Tennessee River Mile*								
			496.5	506.6	518.0	521.0	526.3	527.4	528.0	528.5	529.5
Winter	30-day unbagged substrates	1975	2	2	1	-†	-	1	1	-	-
		1976	0	0	0	-	-	0	0	-	-
		1977	0	3	3	-	-	1	2	-	2
		1983	3	0	3	-	-	1	3	-	1
		1984	3	3	3	-	-	3	3	-	3
		1985	3	3	3	-	-	3	3	-	3
	30-day bagged substrates	1983	3	0	3	-	-	2	0	-	2
		1984	3	3	3	-	-	3	3	-	3
		1985	3	3	3	-	-	3	3	-	3
	90-unbagged substrates	1975	3	3	1	-	-	3	2	-	-
		1984	3	3	3	-	-	3	3	-	3
		1985	3	3	3	-	-	0	2	-	1
Spring	30-day unbagged substrates	1975	2	0	3	-	-	2	1	-	-
		1976	3	3	3	-	-	3	3	-	-
		1977	0	1	3	-	-	3	0	-	0
		1982	0	3	3	-	-	0	3	-	2
		1983	0	2	3	-	-	0	0	-	0
		1984	0	0	0	-	-	0	0	-	0
		1985	3	3	3	-	-	3	3	-	3
	30-day bagged substrates	1983	0	0	0	-	-	0	0	-	0
		1984	0	0	0	-	-	0	0	-	0
		1985	3	3	3	-	-	3	3	-	3
	90-day unbagged substrates	1973	1	0	2	-	-	1	1	-	-
		1974	1	1	1	-	-	1	0	-	-
		1984	0	0	3	-	-	3	3	-	0
		1985	3	3	3	-	-	3	3	-	3

Table 7-1 (continued)

Season	Sample Type	Year	Tennessee River Mile*								
			496.5	506.6	518.0	521.0	526.3	527.4	528.0	528.5	529.5
Summer	30-day unbagged substrates	1975	0	3	3	-	-	3	3	-	-
		1976	3	1	3	-	-	1	2	-	-
		1977	3	3	3	-	-	3	3	-	0
		1982	3	2	3	-	-	3	2	-	3
		1983	3	3	3	-	-	3	0	-	3
		1984	3	3	3	-	-	3	3	-	2
		1985	3	3	3	-	-	3	3	-	0
	30-day bagged substrates	1983	3	3	3	-	-	3	0	-	3
		1984	3	3	3	-	-	3	3	-	3
		1985	3	3	3	-	-	3	3	-	0
	90-day unbagged substrates	1973	0	1	0	-	-	0	0	-	-
		1974	0	3	3	-	-	3	3	-	-
		1984	3	3	3	-	-	3	3	-	0
		1985	3	3	3	-	-	3	3	-	3
	Hess Sampler	1983	-	-	-	10	10	10	10	10‡	-
		1984	-	-	-	10	10	10	10	10	-
		1985	-	-	-	10	10	10	10	10	-
Autumn	30-day unbagged substrates	1975	3	0	3	-	-	3	0	-	-
		1976	0	3	3	-	-	2	0	-	0
		1977	2	3	3	-	-	1	1	-	0
		1982	2	0	0	-	-	0	1	-	3
		1983	3	3	3	-	-	3	3	-	3
		1984	3	3	3	-	-	3	3	-	3
		1985	3	3	3	-	-	3	3	-	3
	30-day bagged substrates	1983	3	3	3	-	-	3	3	-	3
		1984	3	3	3	-	-	3	3	-	3
		1985	3	3	3	-	-	3	3	-	3

Table 7-1 (continued)

Season	Sample Type	Year	Tennessee River Mile*								
			496.5	506.6	518.0	521.0	526.3	527.4	528.0	528.5	529.5
	90-day unbagged substrates	1973	1	1	1	-	-	2	1	-	-
		1974	3	0	1	-	-	0	3	-	-
		1983	3	3	3	-	-	3	0	-	3
		1984	3	3	2	-	-	1	3	-	3
		1985	0	3	3	-	-	2	3	-	0
	Hess Sampler	1983	-	-	-	10	10	10	10	10	-
		1984	-	-	-	10	10	10	10	10	-
		1985	-	-	-	10	10	10	10	10	-

Summary

30-day unbagged substrates		30-day bagged substrates	
Samples required in workplan	465	Samples required in workplan	216
Samples collected	316	Samples collected	166
Percent recovery	68.0	Percent recovery	76.9
90-day unbagged substrates		Hess Sampler	
Samples required	267	Samples required in workplan	300
Samples collected	178	Samples collected	300
Percent recovery	66.7	Percent recovery	100

*Samples were initially collected from TRM 529.9 (spring 1973 through summer 1976); however, because of the poor recovery rate (only 10 substrates) and dissimilarity of the habitat from other stations, this station is not included as part of the preoperational program. TRM 529.5 replaced TRM 529.9 beginning autumn 1976.

†No samples required by workplan.

‡Collected at TRM 528.8.

Table 7-2. Average Abundance of Total Macroinvertebrates Collected by Various Sampling Techniques near Watts Bar Nuclear Plant, Spring 1973 through Autumn 1985.

		Sampling Technique							
		30-Day Unbagged		90-Day Unbagged		30-Day Bagged		Hess Sampler	
Season	Location (TRM)	($\bar{x}$)	($S\bar{x}$)	($\bar{x}$)	($S\bar{x}$)	($\bar{x}$)	($S\bar{x}$)	($\bar{x}$)	($S\bar{x}$)
Winter	496.5	26.8	6.3	42.3	7.4	56.7	12.5	-*	-
	506.6	25.0	8.4	5.4	5.4	51.2	25.1	-	-
	518.0	3.2	0.6	8.0	1.0	4.9	1.3	-	-
	527.4	5.3	2.2	9.8	3.0	7.0	2.8	-	-
	528.0	7.1	2.0	7.3	2.4	18.2	5.3	-	-
	529.5	3.7	1.4	9.5	1.2	6.1	2.0	-	-
Spring	496.5	16.4	3.9	21.8	7.4	29.0	5.9	-	-
	506.6	21.3	5.5	11.8	4.1	22.3	4.9	-	-
	518.0	35.6	7.7	10.0	2.8	33.7	4.3	-	-
	527.4	42.7	6.3	31.8	6.3	76.3	25.5	-	-
	528.0	30.4	5.3	24.0	6.4	114.3	8.7	-	-
	529.5	61.8	19.2	41.3	8.6	50.7	10.5	-	-
Summer	496.5	35.3	10.2	22.8	5.4	46.3	12.5	-	-
	506.6	21.4	4.7	47.0	13.2	32.4	9.6	-	-
	518.0	66.0	21.9	56.6	14.2	190.6	68.2	-	-
	521.0	-	-	-	-	-	-	853.6	42.5
	526.3	-	-	-	-	-	-	1283.2	105.5
	527.4	114.2	39.6	131.8	41.3	296.1	88.7	791.6	67.1
	528.0	79.4	23.4	154.0	57.8	362.3	113.9	770.4	48.0
	528.5†	-	-	-	-	-	-	1008.4	73.5
	529.5	138.1	49.6	76.0	5.6	260.5	79.0	-	-
Autumn	496.5	19.7	1.7	14.5	2.0	43.8	9.2	-	-
	506.6	16.7	3.2	28.0	7.0	24.6	4.9	-	-
	518.0	7.6	2.6	115.8	39.1	13.4	4.2	-	-
	521.0	-	-	-	-	-	-	883.2	37.2
	526.3	-	-	-	-	-	-	965.6	51.2
	527.4	11.6	3.0	189.4	30.5	19.6	2.6	1064.0	64.7
	528.0	15.6	3.9	135.7	38.5	14.1	3.2	1212.0	91.9
	528.5	-	-	-	-	-	-	1148.4	86.3
	529.5	7.8	2.6	448.7	56.6	11.6	2.6	-	-

*No sample collected.
†Includes data from TRM 528.8, collected summer 1983.

Table 7-3. Average Abundance of Predominant* Macroinvertebrates Collected from Artificial Substrates Following One-Month Colonization Periods near Watts Bar Nuclear Plant, Winter 1975 through Autumn 1985 (Unbagged Collection).

		Tennessee River Mile					
Season	Organism	496.5	506.6	518.0	527.4	528.0	529.5
Winter	Chironomidae	3.5	1.4	0.2	1.2	1.7	1.2
	Hyalella azteca	3.1	7.0	0.2	0.0	0.0	0.0
	Planariidae	3.7	0.2	0.6	1.7	0.8	1.3
	Stenacron	0.2	0.0	0.2	0.3	2.6	0.0
	Total	26.8	25.0	3.2	5.3	7.1	3.7
Spring	*Cyrnellus fraternus*	0.1	0.4	1.8	1.8	8.7	1.3
	Hydra americana	5.3	1.1	8.7	0.5	0.0	0.0
	Oligochaeta	3.4	1.5	0.0	0.1	0.0	1.5
	Parachironomus	1.3	0.9	3.6	8.5	3.1	31.3
	Planariidae	1.6	0.2	0.8	4.4	6.2	12.0
	Sida crystallina	0.0	4.0	10.6	7.6	1.4	0.0
	Total	16.4	21.3	35.6	42.7	30.4	61.8
Summer	*Cyrnellus fraternus*	14.3	8.1	15.7	83.8	37.8	68.6
	Oligochaeta	7.1	1.7	2.9	0.7	0.0	0.3
	Total	35.3	21.4	66.0	114.2	79.4	138.1
Autumn	*Cheumatopsyche*	0.1	0.1	0.6	0.7	0.8	3.6
	Oligochaeta	5.7	2.7	3.2	0.3	0.2	0.1
	Planariidae	5.3	2.9	0.2	0.9	4.0	0.7
	Stenacron	0.5	0.2	1.0	4.3	5.0	0.3
	Total	19.7	16.7	7.6	11.6	15.6	7.8

*Taxa comprising ≥20 percent of the total at any location.

Table 7-4. Average Abundance of Predominant* Macroinvertebrates Collected from Artificial Substrates Following One-Month Colonization Periods near Watts Bar Nuclear Plant, Winter 1983 through Autumn 1985 (Bagged Collection).

		Tennessee River Mile					
Season	Organism	496.5	506.6	518.0	527.4	528.0	529.5
Winter	Chironomidae	13.2	2.7	0.9	2.4	5.2	4.1
	Hyalella azteca	10.4	31.0	0.9	0.1	0.0	0.0
	Planariidae	6.4	0.7	0.3	1.4	3.2	0.6
	Stenacron	0.1	0.5	0.7	1.1	7.0	0.3
	Total	56.7	51.2	4.9	7.0	18.2	6.1
Spring	*Crangonyx*	0.0	0.0	7.3	48.0	54.0	0.0
	Hexagenia	7.0	1.0	0.0	0.0	0.0	0.0
	Hyaella azteca	0.0	7.0	0.3	0.0	0.0	0.0
	Oligochaeta	6.0	2.7	0.0	0.0	1.0	0.0
	Parachironomus	0.0	0.3	0.0	1.3	0.7	31.0
	Planariidae	5.0	0.3	6.0	6.3	8.0	6.7
	Total	29.0	22.3	33.7	76.3	114.3	50.7
Summer	*Cheumatopsyche*	0.1	0.2	10.2	10.2	30.5	64.5
	Chironomidae	0.6	0.3	23.8	15.8	44.7	46.8
	Cyrnellus fraternus	19.2	10.8	29.1	197.8	162.5	85.2
	Dugesia tigrina	1.3	4.4	54.4	17.3	37.8	18.2
	Total	46.3	32.4	190.6	296.1	362.3	260.5
Autumn	*Cheumatopsyche*	0.1	0.0	0.8	2.0	2.7	5.6
	Dugesia tigrina	2.9	0.0	3.9	1.4	1.9	1.1
	Oligochaeta	8.8	3.1	0.0	0.0	0.1	0.0
	Planariidae	17.0	1.7	0.3	2.0	2.1	0.6
	Stenacron	0.9	0.8	2.9	5.4	3.0	0.2
	Total	43.8	24.6	13.4	19.6	14.1	11.6

*Taxa comprising ≥20 percent of the total at any location.

Table 7-5. Average Abundance of Predominant* Macroinvertebrates Collected from Artificial Substrates Following Three-Month Colonization Periods near Watts Bar Nuclear Plant, Spring 1973 through Autumn 1985 (Unbagged Collection).

		Tennessee River Mile					
Season	Organism	496.5	506.6	518.0	527.4	528.0	529.5
Winter	*Cheumatopsyche*	0.0	1.4	1.4	1.3	1.4	4.3
	Chironomidae	1.2	1.4	1.7	0.2	0.3	1.5
	Cyrnellus fraternus	0.2	0.9	0.1	2.2	0.1	1.0
	Dugesia tigrina	8.6	0.1	0.6	0.0	0.0	0.8
	Parachironomus	0.4	1.7	0.0	3.3	2.7	0.0
	Planariidae	13.0	1.8	0.6	0.0	0.1	0.3
	Stenacron	0.2	0.2	1.6	1.5	1.1	0.0
	Total	42.3	19.8	8.0	9.8	7.3	9.5
Spring	Chironomidae	1.2	0.0	2.7	8.8	7.6	0.7
	Coelotanypus	0.2	2.5	0.1	0.0	0.0	0.0
	Oligochaeta	5.6	3.0	0.0	0.4	0.0	0.0
	Planariidae	0.4	0.0	2.3	16.9	13.7	35.7
	Total	21.8	11.8	10.0	31.8	24.0	41.3
Summer	*Cyrnellus fraternus*	5.2	13.3	11.4	64.8	69.3	5.7
	Dicrotendipes	0.2	0.0	7.1	10.9	8.0	38.3
	Oligochaeta	5.7	2.3	0.0	0.2	0.0	0.0
	Stenacron	2.3	7.4	12.6	6.0	22.2	0.7
	Total	22.8	47.0	56.6	131.8	154.0	76.0
Autumn	*Cheumatopsyche*	0.2	5.9	42.7	42.9	5.1	115.2
	Cyrnellus fraternus	2.4	6.5	31.1	83.1	68.3	170.3
	Hydropsyche	0.0	0.0	0.3	0.3	0.6	118.7
	Oligochaeta	3.0	1.7	0.0	0.0	0.0	0.0
	Stenacron	0.5	5.5	24.7	48.9	39.0	4.7
	Total	14.5	28.0	115.8	189.4	135.7	448.7

*Taxa comprising ≥20 percent of the total at any location.

Table 7-6. Average Abundance of Predominant* Macroinvertebrates (No./m²) Collected near Watts Bar Nuclear Plant, Summer and Autumn 1983 through 1985 (Hess Sampler Collection).

Season	Organism	Tennessee River Mile 521.0	526.3	527.4	528.0	528.5†
Summer	*Chironomus*	5.2	180.0	5.6	0.0	1.2
	Corbicula manilensis	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
Autumn	*Corbicula manilensis*	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

*Taxa comprising ≥5 percent of the total at any location.
†Includes data from TRM 528.8, collected summer 1985.
‡Includes *Branchiura sowerbyi* and Tubificidae

Table 7-7. Sampling Variability (Coefficient of Variation) for Total Macroinvertebrates Collected by Various Sampling Techniques near Watts Bar Nuclear Plant, Spring 1973 through Autumn 1985.

		Tennessee River Mile								
Season	Sample Type	496.5	506.6	518.0	521.0	526.3	527.4	528.0	528.5	529.5
Winter	30-day unbagged	78	100	71	-*	-	124	96	-	111
	90-day unbagged	52	81	35	-	-	76	86	-	25
	30-day bagged	66	120	78	-	-	114	72	-	92
Spring	30-day unbagged	67	90	92	-	-	49	55	-	62
	90-day unbagged	76	70	84	-	-	56	70	-	36
	30-day bagged	35	38	22	-	-	58	13	-	36
Summer	30-day unbagged	123	93	152	-	-	151	118	-	102
	90-day unbagged	58	89	76	-	-	94	113	-	13
	30-day bagged	81	89	107	-	-	90	77	-	74
	Hess Sampler	-	-	-	28	45	46	34	40†	-
Autumn	30-day unbagged	34	74	147	-	-	100	82	-	116
	90-day unbagged	51	79	107	-	-	96	90	-	31
	30-day bagged	63	60	94	-	-	40	67	-	68
	Hess Sampler	-	-	-	23	29	33	42	41	-

*Sample not required by workplan.
†Includes data from TRM 528.8, collected summer 1983.

Table 7-8. Benthic Macroinvertebrate Taxa Collected During Preoperational Monitoring at Watts Bar Nuclear Plant, Spring 1973 through Autumn 1985.

Taxon	Sample Type			
	30-day (unbagged)	30-day (bagged)	90-day (unbagged)	Hess
Ablabesmyia	X	X	X	X
Agraylea		X		
Amblema plicata				X
Amnicola	X	X	X	X
Amphinemura	X			
Anculosa	X			
Anodonta imbecillis				X
Argia	X	X	X	
Asellus		X	X	X
Bivalvia		X	X	
Bryozoa	X		X	
Caenis	X	X	X	X
Cambarus	X	X	X	
Campeloma	X	X	X	X
Ceraclea	X	X		X
Ceratopogonidae	X			
Chaoborus	X	X	X	X
Cheumatopsyche	X	X	X	X
Chironomidae	X	X	X	X
Chironomus	X	X	X	X
Chironomus tentan	X			
Clinotanypus	X	X	X	
Coelotanypus	X	X	X	X
Coenagrionidae				X
Conchapelopia				X
Corbicula manilensis	X	X	X	X
Crangonyx	X	X	X	X
Cricotopus	X			
Cryptochironomus	X	X	X	X
Cura foremanii	X	X	X	
Cyclonaias tuberculata				X
Cyrnellus fraternus	X	X	X	X
Decapoda	X	X	X	
Dicrotendipes	X	X	X	X
Didymops			X	
Diptera		X		
Dromogomphus		X	X	X
Dugesia tigrina	X	X	X	X
Elliptio crassidens				X
Elmidae		X		
Enallagma	X	X	X	X
Epitheca	X		X	
Epiococladius	X	X		
Erpobdellidae	X		X	X

Table 7-8 (Continued)

Taxon	Sample Type			
	30-day (unbagged)	30-day (bagged)	90-day (unbagged)	Hess
Eurylophella		X		
Ferrissia	X	X	X	
Fusconaia ebena				X
Gammarus	X	X	X	X
Glossiphoniidae	X		X	X
Glyptotendipes	X	X	X	X
Gnathobdellida	X			
Gomphidae		X		
Gomphus	X	X	X	X
Gyraulus	X	X	X	X
Hexagenia	X	X	X	X
Hirudinea	X	X	X	X
Hyalella azteca	X	X	X	
Hydra americana	X	X	X	
Hydrachnidae				X
Hydropsyche	X	X	X	X
Hydroptila	X	X	X	
Ischnura	X	X	X	X
Leptoceridae	X			
Leptodea	X			
Libellulidae	X	X		
Lirceus	X	X	X	X
Macronychus				X
Naididae	X	X	X	X
Nemata	X	X	X	
Nemoura	X			
Neureclipsis	X	X		
Neurocordulia	X	X	X	
Neurocordulia yamaskanensis			X	
Obliquaria reflexa				X
Odonata			X	
Oecetis	X	X	X	
Oligochaeta*	X	X	X	X
Orconectes	X	X	X	X
Orthocladius	X			
Orthotrichia		X		
Parachironomus	X	X	X	X
Parasitengona	X			
Paratendipes	X	X		
Pectinatella magnifica			X	
Physa	X	X	X	X
Plagiola lineolata				X
Planariidae	X	X	X	X
Pleurobema cordatum				X
Pleurobema cordatum pyramidatum				X
Pleurocera	X	X	X	X
Polycentropus	X		X	

Table 7-8 (Continued)

Taxon	Sample Type			
	30-day (unbagged)	30-day (bagged)	90-day (unbagged)	Hess
Polypedilum	X			
Procladius	X	X	X	X
Proptera alata			X	
Pseudochironomus	X	X		
Quadrula pustalosa				X
Rheotanytarsus	X			
Sialis	X	X	X	X
Sida crystallina	X			
Sphaerium	X	X	X	X
Stenacron	X	X	X	X
Stenochironomus			X	
Taeniopteryx	X			
Tanypus	X		X	
Triaenocles	X			
Trichoptera			X	
Tricorythodes			X	X
Viviparus		X		
Xenochironomus	X		X	

*Includes Branchiura sowerbyi, Limnodrillus, and Tubificidae

Table 7-9. Macroinvertebrate Taxa Collected Exclusively Upstream or Downstream of Watts Bar Nuclear Power Plant, During Preoperational Monitoring, Spring 1973 through Autumn 1985 (All Collection Techniques)

Taxon	Downstream	Upstream*
Agraylea sp.	X	
Amblema sp.	X	
Amphinemura sp.	X	
Anculosa sp.	X	
Anodonta imbecillis	X	
Branchiura sp.	X	
Chironomus (*chironomus*) *tentans*	X	
Clinotanypus sp.	X	
Coenagrionidae		X
Conchapelopia sp.	X	
Cryptochironomus sp.	X	
Cura sp.	X	
Cyclonaias tuberculata	X	
Didymops sp.	X	
Diptera	X	
Dromogomphus sp.	X	
Dugesia sp.	X	
Elmidae	X	
Epitheca sp.	X	
Eurylophella	X	
Fusconaia ebena	X	
Gnathobdellida	X	
Gomphidae	X	
Gomphus sp.	X	
Hydrachnidae	X	
Ischnura sp.	X	
Leptoceridae	X	
Leptodea sp.	X	
Limnodrilus sp.	X	
Macronychus sp.	X	
Nemata	X	
Nemoura sp.	X	
Neurocordulia sp.	X	
Neurocordulia yamaskanensis		X
Obliquaria reflexa	X	
Odonata	X	
Orthotrichia sp.	X	
Parasitengona	X	
Paratendipes sp.	X	
Pectinatella magnifica	X	
Plagiola lineolata	X	
Pleurobema cordatum	X	
Pleurobema cordatum pyramidatum	X	
Polycentropus sp.	X	
Proptera alata	X	
Quadrula sp.	X	

Table 7-9 (Continued)

Taxon	Downstream	Upstream*
Rheotanytarsus sp.		X
Sialis sp.	X	
Stenochironomus sp.	X	
Stictochironomus sp.	X	
Taeniopteryx sp.	X	
Triaenodes sp.	X	
Trichoptera	X	
Viviparus sp.	X	

*Upstream: River Miles 529.5, 528.8, 528.5 and 528.0
Downstream: River Miles 527.4, 526.3, 521.0, 518.0, 506.6 and 496.5

Table 7-10. Results of Principal Component Analysis Including Average Abundance of Important* Organisms Collected from Artificial Benthic Substrates After 30 Days Exposure in the Vicinity of Watts Bar Nuclear Plant, 1975-77 and 1982-85.

Season	Principal Component	Cumulative R^2	Eigenvector	Organism	Tennessee River Mile 496.5	506.6	518.0	527.4	528.0	529.5
Winter				n =	11	9	13	9	12	9
	1	.73	+.49	Oligochaeta	4.5	4.1	0.0	0.2	0.0	0.1
			+.52	*Hyalella azteca*	3.1	7.0	0.2	0.0	0.0	0.0
			+.32	*Hexagenia*	3.1	1.0	0.0	0.0	0.0	0.0
			+.42	*Coelotanypus*	2.4	3.6	0.0	0.0	0.0	0.0
	2	.88	+.58	Planariidae	3.7	0.2	0.6	1.7	0.6	1.3
			-.33	*Cheumatopsyche*	0.0	1.2	0.1	0.4	1.1	0.1
	3	.96	+.77	*Stenacron*	0.2	0.0	0.2	0.3	2.6	0.0
			+.40	Chironomidae	3.5	1.4	0.2	1.2	1.7	1.2
			+.41	*Cheumatopsyche*	0.0	1.2	0.1	0.4	1.1	0.1
Spring				n =	8	12	18	11	10	4
	1	.39	+.48	Planariidae	1.6	0.2	0.8	4.4	6.2	12.0
			-.40	*Hydra americana*	5.3	1.1	8.7	0.5	0.0	0.0
			+.49	*Parachironomus*	1.3	0.9	3.6	8.5	3.1	31.3
	2	.67	-.35	Oligochaeta	3.4	1.5	0.0	0.1	0.0	1.5
			+.36	*Chironomus*	0.0	0.3	0.2	4.8	0.5	0.0
			+.39	*Crangonyx*	0.0	0.0	0.2	4.3	2.2	0.0
			+.56	*Sida crystallina*	0.0	4.0	10.6	7.6	1.4	0.0
	3	.80	+.48	Chironomidae	0.3	1.6	3.4	1.2	1.5	9.0
			-.31	*Crangonyx*	0.0	0.0	0.2	4.3	2.2	0.0
			+.38	*Oecetis*	0.1	0.1	0.0	0.0	0.0	0.0
			+.38	Parachironomus	1.3	0.9	3.6	8.5	3.1	31.3
			+.33	*Sida crystallina*	0.0	4.0	10.6	7.6	1.4	0.0

Table 7-10 (Continued)

Season	Principal Component	Cumulative R^2	Eigenvector	Organism	Tennessee River Mile 496.5	506.6	518.0	527.4	528.0	529.5
Summer				n =	18	18	21	19	16	8
	1	.68	+.42	Chironomidae	0.1	0.1	6.0	4.9	5.5	9.0
			+.30	Cyrnellus fraternus	14.3	8.1	15.7	83.8	37.8	68.6
			+.50	Cheumatopsyche	0.1	0.1	6.7	4.7	1.6	26.8
			+.51	Hydropsyche	0.0	0.1	8.0	7.4	4.9	16.9
	2	.81	+.46	Dicrotendipes	0.8	2.1	1.5	0.1	3.6	1.9
			-.43	Cyrnellus fraternus	14.3	8.1	15.7	83.8	37.8	68.6
			+.38	Parachironomus	0.3	0.1	2.0	0.3	4.1	2.3
			+.55	Dugesia tigrina	0.7	2.9	10.9	1.9	9.7	7.6
	3	.89	+.48	Planariidae	4.2	0.2	1.4	0.0	0.8	0.0
			+.58	Oligochaeta	7.1	1.7	2.9	0.7	0.2	0.3
			+.36	Cheumatopsyche	0.1	0.1	6.7	4.7	1.6	26.8
Fall				n =	16	15	18	15	11	12
	1	.52	+.55	Oligochaeta	5.7	2.7	3.2	0.3	0.2	0.1
			+.35	Hexagenia	1.4	1.5	0.0	0.0	0.0	0.0
			-.37	Stenacron	0.5	0.2	1.0	4.3	5.0	0.3
			+.34	Coelotanypus	1.1	1.8	0.0	0.0	0.1	0.0
	2	.74	+.61	Hydra	0.0	0.0	0.1	0.2	0.3	0.3
			+.59	Stenacron	0.5	0.2	1.0	4.3	5.0	0.3
	3	.88	+.30	Planariidae	5.3	2.9	0.2	0.9	4.0	0.7
			-.37	Stenacron	0.5	0.2	1.0	4.3	5.0	0.3
			-.44	Chironomus	0.4	0.1	0.9	1.1	0.0	0.0
			+.37	Cheumatopsyche	0.1	0.1	0.6	0.7	0.8	3.6
			-.46	Oligochaeta	5.7	2.7	3.2	0.3	0.2	0.1

Table 7-10 (Continued)

Season	Principal Component	Cumulative R^2	Eigenvector	Organism	Tennessee River Mile 496.5	506.6	518.0	527.4	528.0	529.5
Combined				n =	53	54	70	54	49	33
	1	.61	-.37	Oligochaeta	5.6	2.3	1.7	0.4	0.1	0.3
			+.40	Cyrnellus fraternus	5.0	2.9	5.3	30.2	14.4	17.0
			+.39	Cheumatopsyche	0.1	0.3	2.5	2.4	1.0	7.8
			+.31	Parachironomus	0.3	0.2	1.5	1.8	2.0	4.3
			+.38	Hydropsyche	0.0	0.2	2.4	2.6	1.8	4.1
	2	.76	+.38	Hydra americana	0.8	0.3	2.3	0.2	0.1	0.1
			-.36	Planarildae	4.0	0.9	0.8	1.4	2.6	2.1
			+.36	Stenacron	0.9	1.1	3.4	3.7	3.8	0.7
			+.61	Sida cryustallina	0.0	0.9	2.7	1.6	0.3	0.0
	3	.87	+.38	Stenacron	0.9	1.1	3.4	3.7	3.8	0.7
			+.46	Cyrnellus fraternus	5.0	2.9	5.3	30.2	14.4	17.0
			-.45	Cheumatopsyche	0.1	0.3	2.5	2.4	1.0	7.8

*Eigenvector $\geq$ 0.300

Table 7-11. Similarity of Benthic Macroinvertebrate Community Composition During Preoperational Monitoring (1983-1985) Based on Sorensen's Quotient of Similarity, Watts Bar Nuclear Plant, Chickamauga Reservoir, Hess Samples.

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 526.3-521.0	13	7	70.00	95.22
	Autumn	528.5	11	TRM 528.5-528.0	14	6	60.00	89.99
		528.0	9	TRM 528.5-527.4	16	7	60.87	80.79
		527.4	12	TRM 528.5-526.3	17	7	58.33	76.05
		526.3	13	TRM 528.5-521.0	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 526.3-521.0	17	6	52.17	93.39
1984	Summer	528.5	17	TRM 528.5-528.0	22	13	74.29	68.74
		528.0	18	TRM 528.5-527.4	21	11	68.75	95.36
		527.4	15	TRM 528.5-526.3	25	12	64.86	94.70
		526.3	20	TRM 528.5-521.0	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
	Autumn	528.5	17	TRM 528.5-528.0	24	14	73.68	86.90
		528.0	20	TRM 528.5-527.4	24	11	62.86	72.50
		527.4	17	TRM 528.5-526.3	22	10	62.50	61.03
		526.3	14	TRM 528.5-521.0	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 7-11 (Continued)

Year	Quarter	Station	NT*	Station Comparison	CS†	NC‡	Sorensen's Quotient of Similarity (%)	Percentage Similarity
1985	Summer	528.5	12	TRM 528.5-528.0	21	9	60.00	89.72
		528.0	18	TRM 528.5-527.4	16	9	72.00	81.69
		527.4	13	TRM 528.5-526.3	24	7	45.16	50.72
		526.3	19	TRM 528.5-521.0	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 526.3-521.0	27	16	74.42	57.06
	Autumn	528.5	14	TRM 528.5-528.0	19	8	59.26	75.23
		528.0	13	TRM 528.5-527.4	15	13	92.86	72.65
		527.4	14	TRM 528.5-526.3	19	11	73.33	63.76
		526.3	16	TRM 528.5-521.0	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 526.3-521.0	22	12	70.59	78.96

*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 7-12. Results of One-Way Analysis of Variance and Duncan's New Multiple Range Test on Total Benthic Macroinvertebrate Standing Crop (number/m²) for Preoperational Monitoring, Watts Bar Nuclear Plant, Chickamauga Reservoir, Hess Samples.

				Tennessee River Mile				
Year	Quarter	F-Ratio	P>F	Low $\bar{x}$				High $\bar{x}$
1983	Summer	7.07	0.0002	527.4	521.0	526.3	528.0	528.8
	Autumn	1.31	0.2818	N.S.D.*				
1984	Summer	5.45	0.0011	528.0	521.0	528.5	526.3	527.4
	Autumn	11.21	0.0001	521.0	526.3	527.4	528.5	528.0
1985	Summer	27.15	0.0001	527.4	528.5	528.0	521.0	526.3
	Autumn	0.75	0.5663	N.S.D.				

*No significant difference.

Table 7-13. Total Abundance of Macroinvertebrates (No./m²) Collected Near Watts Bar Nuclear Plant, Summer and Autumn, 1983 Through 1985 (Hess Sampler Collection).

		Tennessee River Mile				
Season	Year	521.0	526.3	527.4	528.0	528.5
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
Autumn	1983	881	826	834	866	752
	1984	901	1,130	1,392	1,754	1,654
	1985	868	941	966	1,015	1,039

*Collected at TRM 528.8.

Table 7-14. Benthic Macroinvertebrate Diversity Index ($\bar{d}$) Values During Preoperational Monitoring (1983), Watts Bar Nuclear Plant, Hess Samples.

		Tennessee River Mile									
		521.0		526.3		527.4		528.0		528.5	
Year	Quarter	No. taxa	$\bar{d}$	No. taxa	$\bar{d}$	No. taxa	$\bar{d}$	No. taxa	$\bar{d}$	No. taxa	$\bar{d}$
1983	Summer	12	0.77	8	0.60	14	1.76	12	1.30	14	1.21*
	Autumn	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
	Autumn	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
	Autumn	18	2.02	16	1.87	14	2.20	13	2.05	14	2.16

*Data collected from TRM 528.8 in summer 1983.

Table 7-15. Total Abundance of Macroinvertebrates Collected from Artificial Substrates Following One-Month Colonization Periods Near Watts Bar Nuclear Plant, 1975 Through 1985 (Unbagged Collection).

		Tennessee River Mile					
Season	Year	496.5	506.6	518.0	527.4	528.0	529.5
Winter	1975	10	11	5	4	15	*
	1976	†	†	†	†	†	*
	1977	†	0	2	0	0	1
	1982	*	*	*	*	*	*
	1983	12	†	1	1	1	0
	1984	57	47	4	3	12	3
	1985	22	21	5	11	11	8
Spring	1975	7	†	20	33	14	*
	1976	14	5	88	27	4	*
	1977	†	70	51	64	†	†
	1982	†	29	16	†	37	90
	1983	†	24	21	†	†	†
	1984	†	†	†	†	†	†
	1985	25	12	18	45	46	52
Summer	1975	†	9	9	30	7	*
	1976	15	21	40	19	6	*
	1977	18	19	30	6	40	†
	1982	10	12	10	54	40	49
	1983	6	7	42	147	†	81
	1984	47	63	293	470	233	358
	1985	116	15	37	10	76	†
Autumn	1975	18	†	30	6	†	*
	1976	†	6	4	1	†	†
	1977	14	15	1	5	3	†
	1982	12	†	†	†	13	2
	1983	24	33	3	26	21	16
	1984	24	17	5	20	27	12
	1985	23	12	2	4	4	1

*No sample required by workplan.
†Substrates not recovered.

Table 7-16. Relative Abundance or Presence of Freshwater Mussel Species Found in the Vicinity of Watts Bar Nuclear Plant (Generally Tennessee River Miles 470-529) During Various Surveys

Species	AD 1-1600	1850-1918	1956-1957	1965	1972-1974	1975-1977	1978	1983-~~1989~~ 1993	
Actinonaias ligamentina	7.49‡	X	0.1			0.17		0.23	0.26
Actinonaias pectorosa C		X	—					—	—
Alasmidonta marginata		X	—					—	—
Amblema plicata	0.33	X	X		X	2.04	0.93	1.56	1.80
Anodonta grandis				X	X		0.21	0.60	0.87
Anodonta imbecillis								0.02	0.04
Anodonta suborbiculata				X	X			—	0.01
Cumberlandia monodonta		X						—	—
Cyclonaias tuberculata	3.19	X	2.0¶	12.71§		10.22§	6.84§	5.31§	5.95
Cyprogenia stegaria	0.20	X					0.06	0.06	0.04
Dromus dromas CE	35.25*	X					0.06	0.01	0.01
Elliptio crassidens	6.11§	X	12.9†	18.78†	X	42.08*	63.04*	63.62*	62.71
Elliptio dilatatus	11.36†	X	1.1	6.08		0.34	0.21	0.13	0.13
Epioblasma arcaeformis C	1.37	X						—	—
Epioblasma capsaeformis C	0.27	X						—	—
Epioblasma flexuosa	0.09								
Epioblasma florentina C	0.05								
Epioblasma heysiana C	0.37	X							
Epioblasma interrupta C	0.03	X							
Epioblasma lenior C		X							
Epioblasma lewisi		X							
Epioblasma obliquata	T								
Epioblasma propinqua	2.70	X							
Epioblasma propinqua/torulosa	0.11								
Epioblasma stewardsoni C	0.44	X							
Epioblasma torulosa	2.36	X							
Epioblasma triquetra	0.02	X							
Epioblasma turgidula CE	0.06								
Epioblasma/Villosa	0.12								
Fusconaia barnesiana C	0.06	X							
Fusconaia cuneolus CE		X							
Fusconaia ebena			0.1						

Table 7-16 (Continued)

Species	AD 1-1600	1850-1918	1956-1957	1965	1972-1974	1975-1977	1978	1983-1985	
Fusconaia edgariana CE		X						—	—
Fusconaia ~~maculata~~ subrotunda	4.97	X						0.02	0.01
Hemistena lata		X						—	—
Lampsilis fasciola	0.01	X						—	—
Lampsilis orbiculata E		X				0.08	0.57	0.33	0.42
Lampsilis ovata	0.20	X	X				0.09	0.23	0.19
Lasmigona complanata				X				0.01	0.01
Lasmigona costata	T	X						—	0.01
Lemiox rimosus CE	0.09	X						—	—
Leptodea fragilis		X					0.03	0.20	0.33
Leptodea leptodon		X						—	—
Lexingtonia dolabelloides C	0.63	X						—	—
Ligumia recta	0.03	X	X			0.51	0.42	0.43	0.48
Medionidus conradicus C		X						—	—
Megalonaias gigantea							0.15	0.11	0.23
Obliquaria reflexa		X	1.0	6.08	X	1.02	0.87	0.54	0.59
Obovaria olivaria			0.2					—	—
Obovaria retusa	1.64	X						—	—
Obovaria subrotunda	0.64	X						—	—
Plagiola lineolata		X	0.2			4.77¶	2.41¶	1.74	1.78
Plethobasus cicatricosus E	0.73							—	—
Plethobasus cyphyus	0.10	X	1.0	X	X	0.17		0.02	0.02
Plethobasus ~~striatus~~ E cooperianus	0.88	X	X					—	—
Pleurobema clava	0.70							—	—
Pleurobema cordatum	4.88	X	74.6*	31.49*	X	14.99‡	12.50†	15.27†	14.34
Pleurobema oviforme C		X					0.09	0.04	0.06
Pleurobema plenum E	5.58¶	X						0.06	0.04
Pleurobema rubrum	2.20	X					0.03	0.04	0.03
Pleurobema spp.	2.26							—	—
Potamilus alatus	0.01	X	X	6.08		2.39	1.27	2.12¶	2.61
Ptychobranchus fasciolaris	0.91	X	0.1					0.01	0.01
Ptychobranchus subtentum C	0.06	X						—	—
Quadrula cylindrica	0.12	X						—	—

Table 7-16 (Continued)

Species	AD 1-1600	1850-1918	1956-1957	1965	1972-1974	1975-1977	1978	1983-1985	
								—	—
Quadrula intermedia CE	0.23	X							
Quadrula metanevra	0.68	X	2.9‡			2.39	1.81	1.00	0.86
Quadrula pustulosa	0.34	X	2.2§	18.78‡	X	17.55†	8.10‡	5.70‡	5.42
Quadrula spp.	0.02							—	—
cf. Strophitus undulatus	T	X						—	—
Toxolasma lividus lividus C		X						—	—
Tritogonia verrucosa			0.1			0.68	0.30	0.60	0.77
Truncilla donaciformis			0.1					—	—
Truncilla truncata		X	X					—	—
Villosa fabalis		X						—	—
Villosa nebulosa C		X						—	—
Villosa vanuxemi C	0.06	X						—	—
								—	—
Total Specimens	27,875	-	-	-	-	587	3,320	7,891+	3455
Species Listed	45	58	~~20~~ 22	10	~~76~~	15	21	~~28~~	30
Combined Species	64			23			28		

Substantial variations exist in the methods employed, areas of coverage and amount of collection effort expended in these collections. Numbers in the table indicate the percentage composition of each species encountered in surveys which included quantitative results.

Symbols:

C-Cumberlandian Species
E-Endangered Species
T-Trace (less than 0.01 percent)
X-Present but not counted

*, †, ‡, §, ¶, indicate the first through fifth most abundant species (respectively) in each quantitive survey.

Table 7-17. Absolute Abundance of Freshwater Mussel Species Found During Various Post-impoundment Surveys of the Tennessee River Near the Watts Bar Nuclear Plant Site

	1957 (Scruggs, 1960)		1965 (Isom, 1969)	1975-1977	1978	1983-1985
Survey Area	TRM 515 8,358 m^2	16.7 m^2	TRM 472-529 99.1 m^2	TRM 520-528 52 m^2	TRM 514-529 1430 team minutes	TRM 520, 526 & 528 1584 team minutes
Technique	Brail	Scuba	Peterson Dredge	Scuba	Scuba	Scuba
No. samples	16	10 x 2 yds^2	359 x 1/3 yds^2	52 x m^2	55 sites	6 x 12 stations
Actinonaias ligamentina		0.0001	0.12		0.0192	0.0114
Ambiema plicata	0.0010	0.06		0.1346	0.0217	0.0777
Anodonta grandis					0.0049	0.0297
Anodonta imbecillis						0.0013
Cyclonaias tuberculata	0.0030	0.90	0.0275	1.1538	0.1587	0.2645
Cyprogenia stegaria					0.0014	0.0032
Dromus dromas					0.0014	0.0006
Elliptio crassidens	0.0084	1.32	0.0407	4.7500	1.4636	3.1692
Elliptio dilatatus	0.0008	0.18	0.0132	0.0192	0.0049	0.0063
Fusconaia maculata						0.0013
Lampsilis orbiculata				0.0769	0.0133	0.0164
Lampsilis ovata	0.0001	0.12			0.0021	0.0114
Lasmigona complanata						0.0006
Leptodea fragilis					0.0007	0.0095
Ligumia recta	0.0001	0.06		0.0577	0.0098	0.0215
Megalonaias gigantea					0.0035	0.0057
Obliquaria reflexa	0.0010	0.42	0.0132	0.1154	0.0203	0.0271
Obovaria olivaria	0.0006	0.06				
Plagiola lineolata	0.0004	0.24		0.5385	0.0559	0.0865

Table 7-17 (Continued)

	1957 (Scruggs, 1960)		1965 (Isom, 1969)	1975-1977	1978	1983-1985
Plethobasus crphyus	0.0008	0.06		0.0192		0.0013
Plethobasus striatus	0.0001	0.06				
Pleurobema cordatum	0.0465	12.80	0.0682	1.6923	0.2902	0.7607
Pleurobema oviforme					0.0021	0.0019
Pleurobema plenum						0.0032
Pleurobema rubrum					0.0007	0.0019
Potamilus alatus		0.06	0.0132	0.2692	0.0294	0.1054
Quadrula metanevra	0.0011	2.27		0.2692	0.0420	0.0492
Quadrula pustulosa	0.0029	1.20	0.0407	1.9808	0.1881	0.2841
Tritogonia verrucosa	0.0001	0.06		0.0769	0.0070	0.0297
Total specimens	562	333		587	3320	7891
Species found	16	17	7	15	21	28
Total per m^2	0.0670	19.97	0.2165	11.2885		
Total per team minute					2.3217	4.9817

Table 7-18. Mean Shell Lengths (mm) of Various Freshwater Mussel Species Obtained During Three Surveys from the Tennessee River Near the Watts Bar Nuclear Plant Site

	1957 (Scruggs, 1960)		1975-1977		1983-1985	
	No.	Mean	No.	Mean	No.	Mean
Actinonaias ligamentina					18	105.06
Amblema plicata			4	88.75	125	99.36
Anodonta grandis					47	122.67
Anodonta imbecillis					2	53.60
Cyclonaias tuberculata			37	71.70	413	77.87
Cyprogenia stegaria					5	55.02
Dromus dromas					1	60.10
Elliptio crassidens			212	96.59	912	109.25
Elliptio dilatatus			2	105.5	10	100.51
Fusconaia maculata					2	61.39
Lampsilis orbiculata			2	97.50	26	97.41
Lampsilis ovata					18	126.99
Lasmigona complanata					1	180.20
Leptodea fragilis					15	100.39
Ligumia recta					34	159.66
Megalonaias gigantea					9	174.44
Obliquaria reflexa			4	44.25	43	54.28
Plagiola lineolata			19	73.42	137	85.00
Plethobasus cyphyus			1	72.00	2	91.80
Pleurobema cordatum	574	81.71	55	85.22	774	95.62
Pleurobema oviforme					3	70.83
Pleurobema plenum					5	65.40
Pleurobema rubrum					3	87.97
Potamilus alatus			6	128.00	167	139.48
Ptychobranchus fasciolaris					1	94.40
Quardrula metanevra			10	71.10	78	77.47
Quadrula pustulosa			70	50.94	450	56.64
Tritogonia verrucosa			1	117.00	47	116.04
Measured specimens	574		423		3348	
Species included	1		13		28	

Table 7-19. Freshwater Mussel Frequency of Occurrence by Shell Lengths from the 1983-1985 Surveys of Tennessee River Miles 520-521L, 526-527R and 528-529L.

	Mean	Shell Lengths in 10 Millimeter Intervals																	
		30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	Totals
Actinonaias ligamentina	105.06							5	8	5									18
Amblema plicata	99.36					8	16	43	32	21	2	3							125
Anodonta grandis	122.67						1		8	9	15	10	3	1					47
Anodonta imbecillis	53.60			2															2
Cyclonaias tuberculata	77.87			2	52	194	140	25											413
Cyprogenia stegaria	55.02			4	1														5
Dromus dromas	60.10				1														1
Elliptio crassidens	109.25						7	117	356	333	90	9							912
Elliptio dilatatus	100.51							4	5	1									10
Fusconaia maculata	61.39			1	1														2
Lampsilis orbiculata	97.41					2	4	8	10	2									26
Lampsilis ovata	126.99								1	3	6	6	2						18
Lasmigona complanata	180.20																1		1
Leptodea fragilis	100.39			1			4	1	3	6									15
Ligumia recta	159.66												8	8	10	6	2		34
Megalonaias gigantea	174.44														2	4	2	1	9
Obliquaria reflexa	54.28	1	10	24	8														43
Plagiola lineolata	85.00			4	15	18	40	52	8										137
Plethobasus cyphyus	91.80						1	1											2
Pleurobema cordatum	95.62				2	29	159	352	192	32	2	2	1	1	2				774
Pleurobema oviforme	70.83				1	2													3
Pleurobema plenum	65.40			2	2		1												5
Pleurobema rubrum	87.97						1	2											3
Potamilus alatus	139.48		1					4	6	12	18	37	35	26	22	4	2		167
Ptuchobranchus fasciolaris	94.40							1											1
Quadrula metanevra	77.47		1	1	10	36	25	5											78
Quadrula pustulosa	56.64		50	256	138	5	1												450
Tritogonia verrucosa	116.04					1	1	8	8	7	13	6	3						47

Table 7-20. Sorenson's Quotient of Similarity (SQS) and Percentage Similarity (PS) Comparisons of Three Mussel Beds Near the Watts Bar Nuclear Plant Site.

Comparison	SQS*	PS†
TRM 520-521 To TRM 526-527	80.00	60.27
TRM 520-521 To TRM 528-529	89.80	87.75
TRM 526-527 to TRM 528-529	81.82	57.00

$$* \; SQS = \frac{200S}{X+Y}$$

Where S = species in common at X and Y
X = species present at X
Y = species present at Y

$$\dagger PS = 200 \sum_{i=1}^{s} \min. (P_{ix}, P_{iy})$$

Where S = total number of species present at X and Y
P_{ix} and P_{iy} = numbers of species "i" at X and Y, respectively, each divided by the total number of all "s" species present at both locations.

Table 7-21. Results of Significant ($\alpha<0.05$) Analysis of Variance (ANOVA) Tests of Station-by-Station and Year-by-Year Comparisons of the Number of Mussels Found on Each of Three Beds in the Tennessee River Near the Watts Bar Nuclear Plant Site.

Mussel Bed and Species	P>F	Station Differences Duncan's Relationships*				P>F	Year Differences Duncan's Relationships†		
TRM 520-521L									
Cyclonaias tuberculata	0.0012	.6	.8	.3	.0				
Plagiola lineolata	0.0007	.8	.6	.3	.0	0.0008	83	84	85
Quadrula pustulosa	0.0047	.8	.6	.0	.3	0.0453	83	84	85
TRM 526-527R									
Anodonta grandis	0.0387	.0	.8	.5	.3	0.0111	83	84	85
Cyclonaias tuberculata	0.0031	.3	.5	.8	.0	0.0010	83	85	84
Leptodea fragilis	0.0118	.8	.3	.5	.0				
Megalonaias gigantea	0.0205	.3	.5	.0	.8				
Pleurobema cordatum	0.0109	.3	.0	.5	.8				
Tritogonia verrucosa	0.0177	.0	.5	.8	.3				
TRM 528-529L									
Amblema plicata						0.0137	85	84	83
Cyclonaias tuberculata	0.0022	.8	.5	.9	.2				
Elliptio crassidens	0.0001	.8	.9	.5	.2	0.0054	85	84	83
Lampsilis orbiculata	0.0439	.8	.9	.5	.2				
Pleurobema cordatum	0.0180	.8	.9	.5	.2				

*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.

†83, 84 and 85 refer to calendar years (1983, etc.), in each case arranged in descending order for the abundance of the species being evaluated.

Station or year identifiers sharing a common underline are not significantly different from each other.

Table 7-22. Bed-by-bed Results and Statistical Comparisons of the Numbers of Mussels Found During 1983-1985 in the Tennessee River Near the Watts Bar Nuclear Plant Site.

	TRM 520-521L	TRM 526-527R	TRM 528-529L	ANOVA P>F	Duncan's Relationships#		
Actinonaias ligamentina	7	1	10	0.0927			
Amblema plicata	16	75¶	32	0.0001	26	28	20
Anodonta grandis		36	11	0.0001	26	28	20
Anodonta imbecillis	1	1		0.6093			
Cyclonaias tuberculata	262#	50	107§	0.0001	20	28	26
Cyrogenia stegaria	3		2	0.2554			
Dromus dromas	1			0.3746			
Elliptio crassidens	1903*	799*	2318*	0.0001	28	20	26
Elliptio dilatatus	6	2	2	0.1452			
Fusconaia maculata	1		1	0.6093			
Lampsilis orbiculata	5	4	17	0.0076	28	20	26
Lampsilis ovata	5	3	10	0.2652			
Lasmigona complanata			1	0.3746			
Leptodea fragilis	2	10	3	0.0329	26	28	20
Ligumia recta	13	3	18	0.0285	28	20	26
Megalonaias gigantea	2	5	2	0.4004			
Obliquaria reflexa	3	35	5	0.0001	26	28	20
Plagiola lineolata	58¶	38	41¶	0.2486			
Plethobasus cyphyus		2		0.3746			
Pleurobema cordatum	452†	272†	481†	0.0679			
Pleurobema oviforme	1		2	0.5524			
Pleurobema plenum	4		1	0.1660			
Pleurobema rubrum	1		2	0.2848			
Potamilus alatus	40	99§	28	0.0017	26	20	28
Ptychabranchus fasciolaris	1			0.3746			
Quardrula metanevra	43	11	24	0.0023	20	28	26
Quadrula pustulosa	133§	135#	182#	0.2418			
Tritogonia verrucosa	2	40	5	0.0001	26	28	20
Total specimens	2965	1621	3305				
Species found	25	20	24				

*, †, #, §, ¶ indicate the first through fifth most abundant species (respectively) on each bed.

- 20, 26, and 28 refer to Tennessee River Mile locations of the mussel "beds" (TRM 520, etc.), in each case arranged in descending order for the mean lengths of the species being considered. Length identifiers sharing a common underline are not significantly different from each other ($\alpha = 0.05$).

Table 7-23. Year By Year Results and Statistical Comparisons of the Numbers of Mussels Found in 1983, 1984 and 1985 on Three Tennessee River Beds Near the Watts Bar Nuclear Plant Site.

	1983	1984	1985	P>F	Duncan's Relationships*		
Actinonaias ligamentina	5	2	11	0.0780			
Amblema plicata	51	30	42	0.2455			
Anodonta grandis	28	9	10	0.0079	83	85	84
Anodonta imbecillis		2		0.1438			
Cyclonaias tuberculata	158	135	126	0.7068†			
Cyrogenia stegaria	3	1	1	0.4329			
Dromus dromas	1			0.3736			
Elliptio crassidens	1590	1763	1667	0.8592			
Elliptio dilatatus	6	2	2	0.1535			
Fusconaia maculata	2			0.1438			
Lampsilis orbiculata	10	8	8	0.8787			
Lampsilis ovata	4	5	9	0.4730†			
Lasmigona complanata			1	0.3736			
Leptodea fragilis	4	6	5	0.8161			
Ligumia recta	9	14	11	0.6651			
Megalonaias gigantea	3	1	5	0.3029			
Obliquaria reflexa	20	11	12	0.3779			
Plagiola lineolata	53	49	35	0.3601†			
Plethobasus cyphyus	2			0.3736			
Pleurobema cordatum	539	376	290	0.0348	83	84	85
Pleurobema oviforme		2	1	0.5519			
Pleurobema plenum	2	2	1	0.8619			
Pleurobema rubrum			3	0.0427	85	83	84
Potamilus alatus	43	47	77	0.1675†			
Ptychabranchus fasciolaris		1		0.3736			
Quadrula metanevra	38	24	16	0.0435	83	84	85
Quadrula pustulosa	174	138	138	0.4550			
Tritogonia verrucosa	18	10	19	0.5128			
Total specimens	2763	2638	2490				

*83, 84 and 85 refer to calendar years (1983, etc.), in each case arranged in descending order for the abundance of the species being evaluated. Year identifiers sharing a common underline are not significantly different from each other ($\alpha = 0.05$).

†These species show steady increases or decreases during the three year period without yielding statistical differences.

Table 7-24. Bed-by-Bed Results and Statistical Comparisons of the Lengths of Abundant Mussel Species Found During 1983-1985 in the Tennessee River Near the Watts Bar Nuclear Plant Site.

	TRM 520-521L		TRM 526-527R		TRM 528-529L		ANOVA	Duncan's Relationships*		
	No.	Mean	No.	Mean	No.	Mean	P>F			
Amblema plicata	16	91.13	77	99.09	32	104.13	0.0014	28	26	20
Cyclonaias tuberculata	256	75.22	50	82.16	107	82.22	0.0001	28	26	20
Elliptio crassidens	305	103.51	309	111.97	303	112.26	0.0001	28	26	20
Plagiola lineolata	58	79.08	38	90.23	41	88.54	0.0001	26	28	20
Pleurobema cordatum	291	90.84	176	99.92	310	97.63	0.0001	26	28	20
Potamilus alatus	40	126.23	99	145.41	28	137.45	0.0001	26	28	20
Quadrula metanevra	43	74.52	11	84.42	24	79.58	0.0008	26	28	20
Quadrula pustulosa	133	52.88	135	58.61	182	57.93	0.0001	26	28	20

*20, 26, and 28 refer to Tennessee River Mile locations of the mussel "beds" (TRM 520, etc.), in each case arranged in descending order for the mean lengths of the species being considered. Length identifiers sharing a common underline are not significantly different from each other ($\alpha = 0.05$).

Table 7-25. Year-by-Year Results and Statistical Comparisons of the Lengths (mm) of Abundant Mussel Species Found on Three Beds in the Tennessee River Near the Watts Bar Nuclear Plant Site.

	1983		1984		1985		ANOVA	Duncan's Relationships*		
	No.	Mean	No.	Mean	No.	Mean	P>F			
Amblema plicata	53	96.86	30	98.18	42	103.37	0.1553†			
Anodonta grandis	28	121.88	9	124.58	10	123.14	0.7845			
Cyclonaias tuberculata	158	78.95	131	76.09	124	78.39	0.2556			
Elliptio crassidens	304	107.96	302	109.58	306	110.22	0.0006	85	84	83
Lampsilis orbiculata	10	94.39	8	96.66	8	101.94	0.3120†			
Ligumia recta	9	155.30	14	157.96	11	165.39	0.0975†			
Obliquaria reflexa	20	53.78	11	53.63	12	55.72	0.2847			
Plagiola lineolata	53	85.05	49	82.92	35	87.83	0.4197			
Pleurobema cordatum	295	95.39	234	95.08	245	96.42	0.2099			
Potamilus alatus	43	135.39	47	142.73	77	139.79	0.0468	84	85	83
Quadrula metanevra	38	76.46	24	78.68	16	78.07	0.2085			
Quadrula pustulosa	174	55.49	138	56.75	138	57.98	0.0025	85	84	83
Tritogonia verrucosa	18	110.06	10	110.44	19	124.66	0.0039	85	84	83

*83, 84 and 85 refer to calendar years (1983, etc.), in each case arranged in descending order for the mean length of the species being evaluated. Year identifiers sharing a common underline are not significantly different from each other ($\alpha = 0.05$).

†Mean lengths for these species show steady increases over the three-year period without statistical differences.

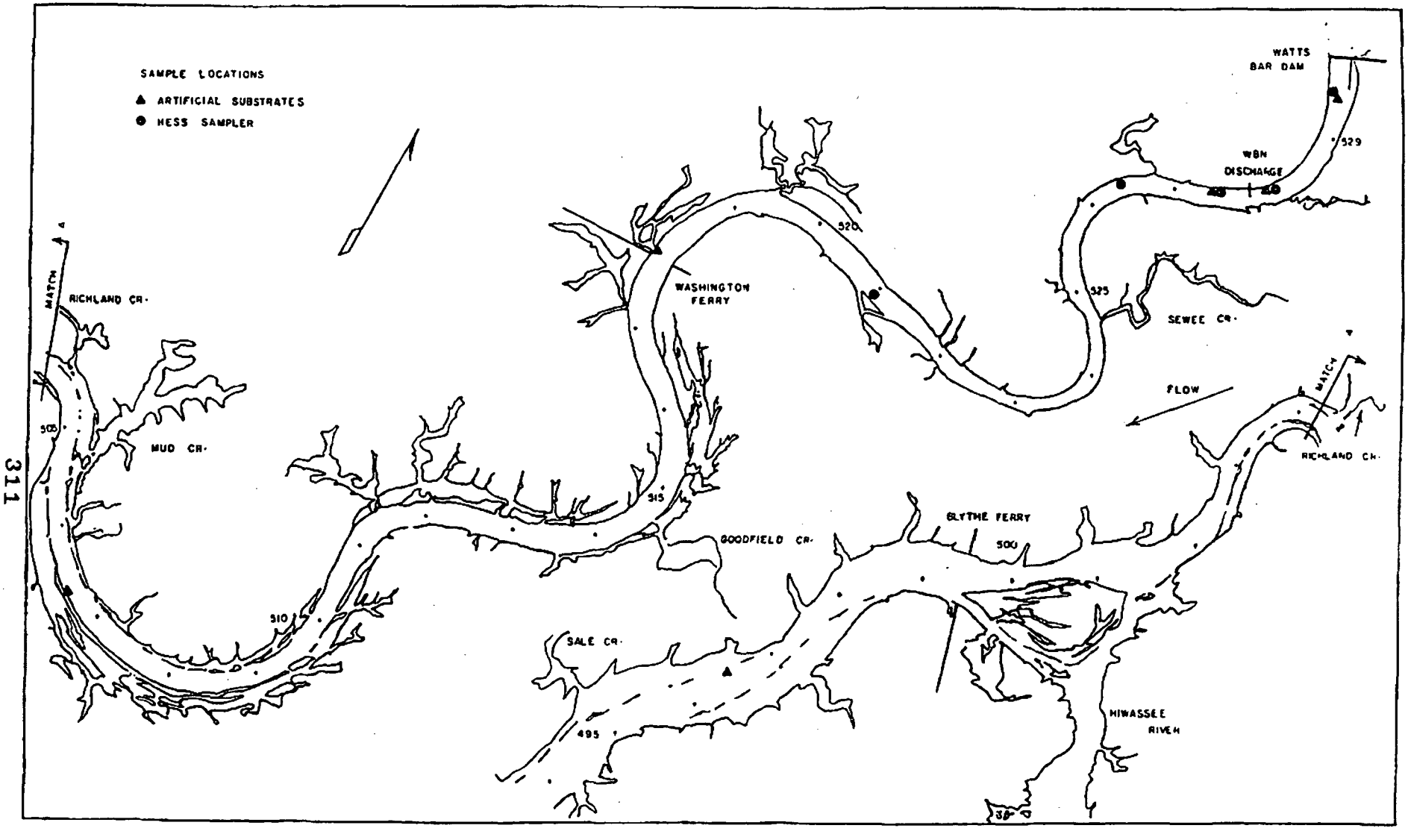


Figure 7-1. Sampling Locations for Benthic Macroinvertebrates Near Watts Bar Nuclear Plant, Spring 1973 through Autumn 1985.

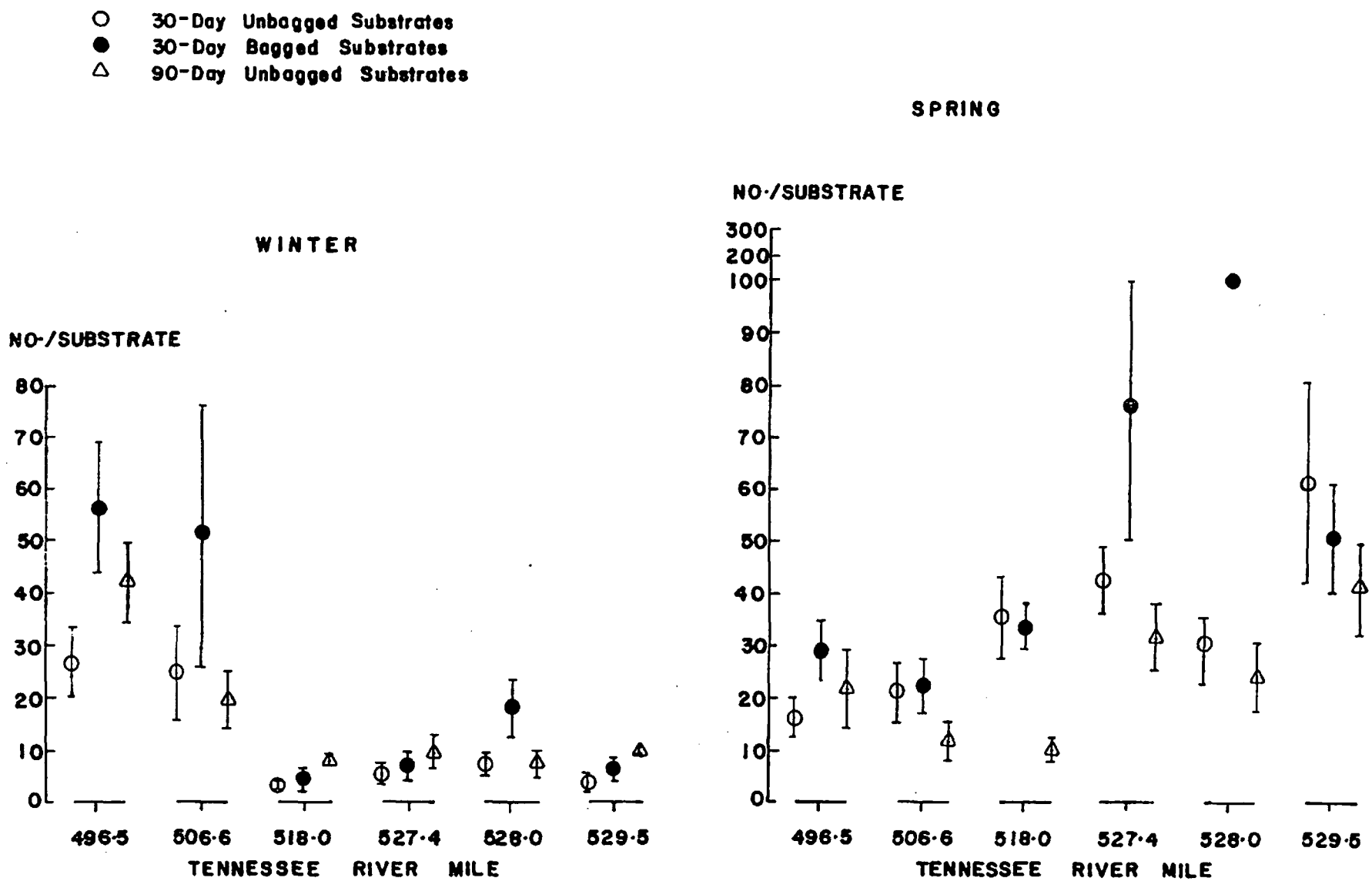


Figure 7-2. Average Total Macroinvertebrate Abundance by Collection Technique for Each Station Sampled During Preoperational Monitoring at Watts Bar Nuclear Plant, Winter and Spring, 1973 through 1985.

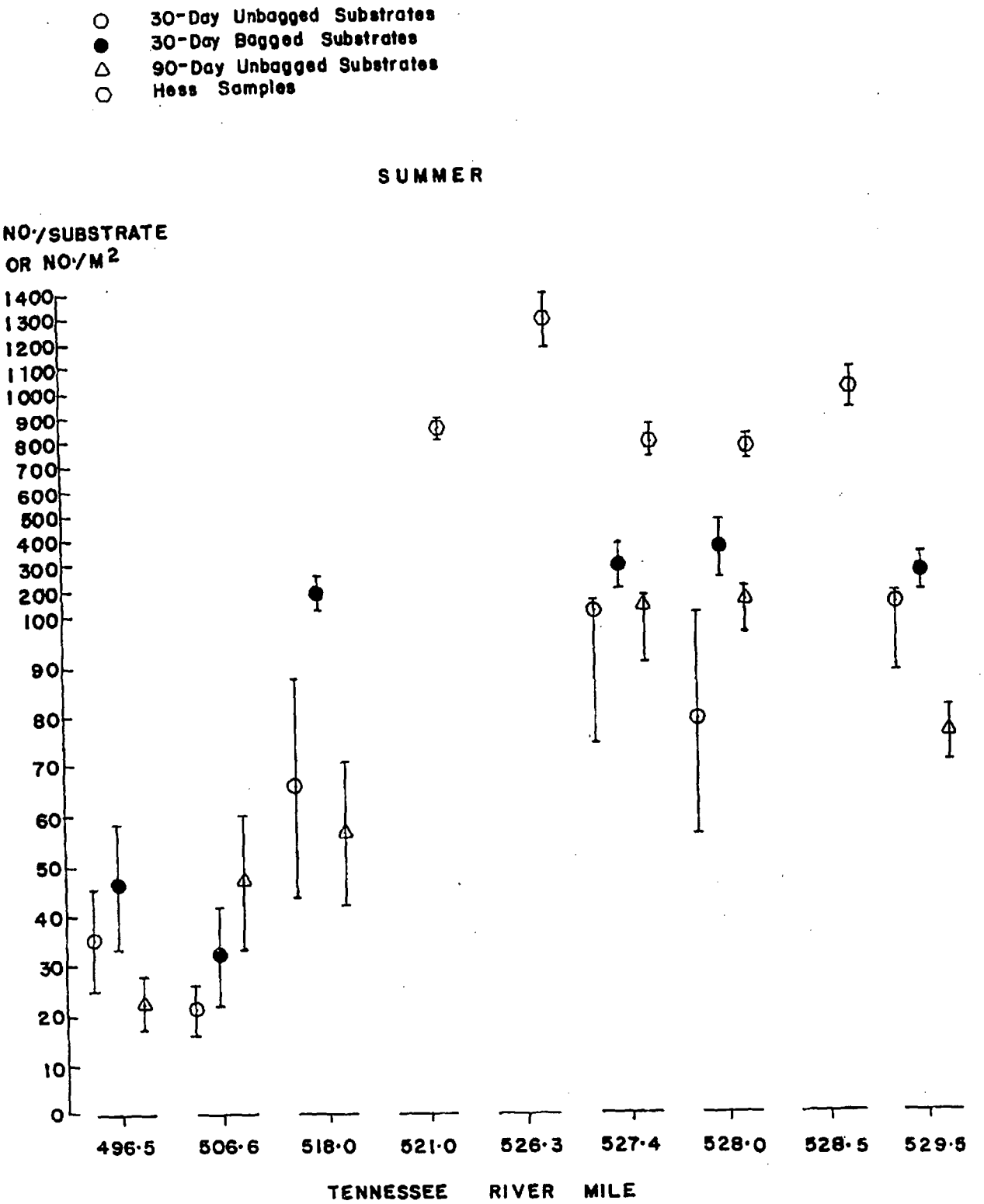


Figure 7-3. Average Total Macroinvertebrate Abundance by Collection Technique for Each Station Sampled During Preoperational Monitoring at Watts Bar Nuclear Plant, Summer, 1973 through 1985.

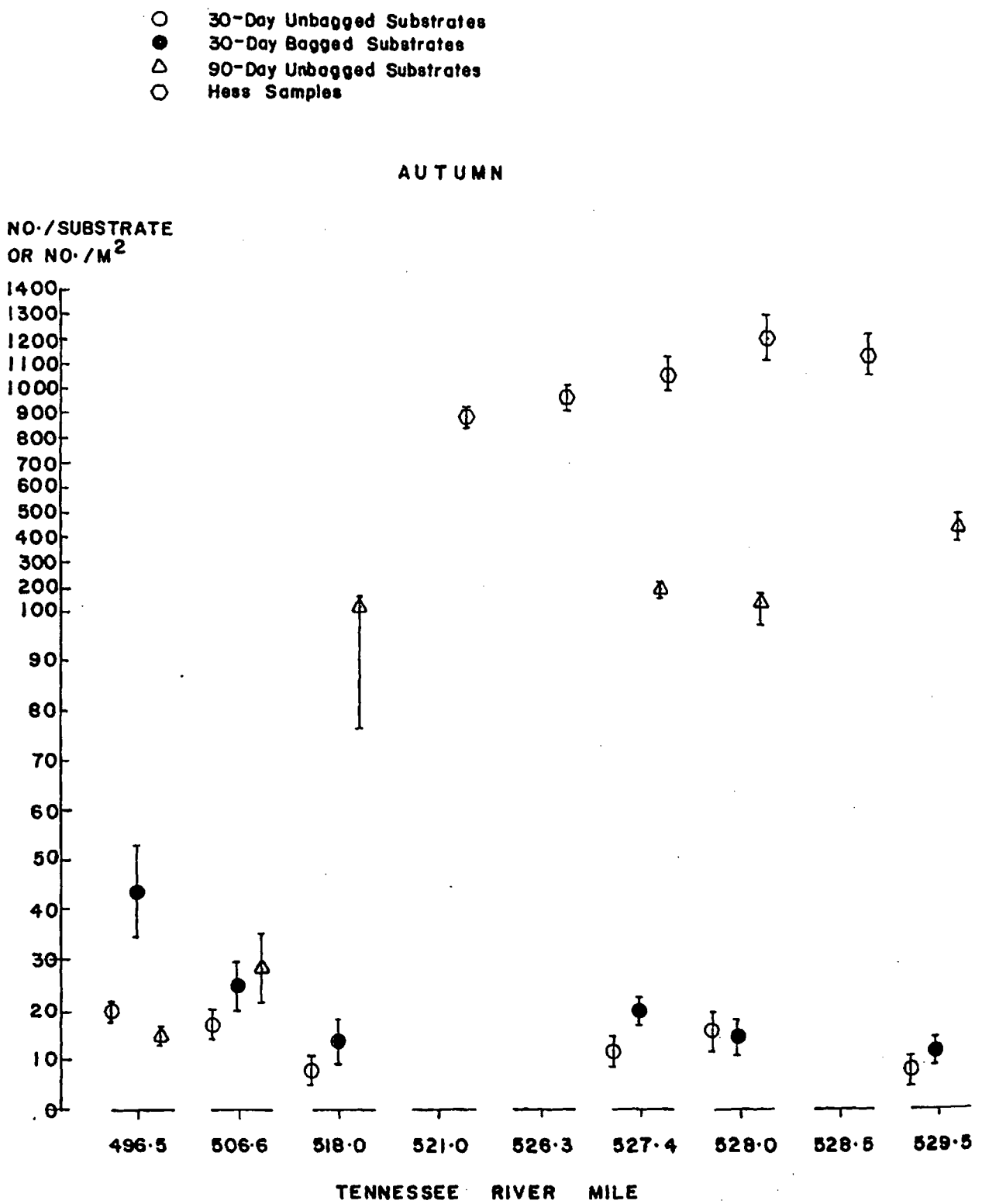


Figure 7-4. Average Total Macroinvertebrate Abundance by Collection Technique for Each Station Sampled During Preoperational Monitoring at Watts Bar Nuclear Plant, Autumn 1973 through 1985.

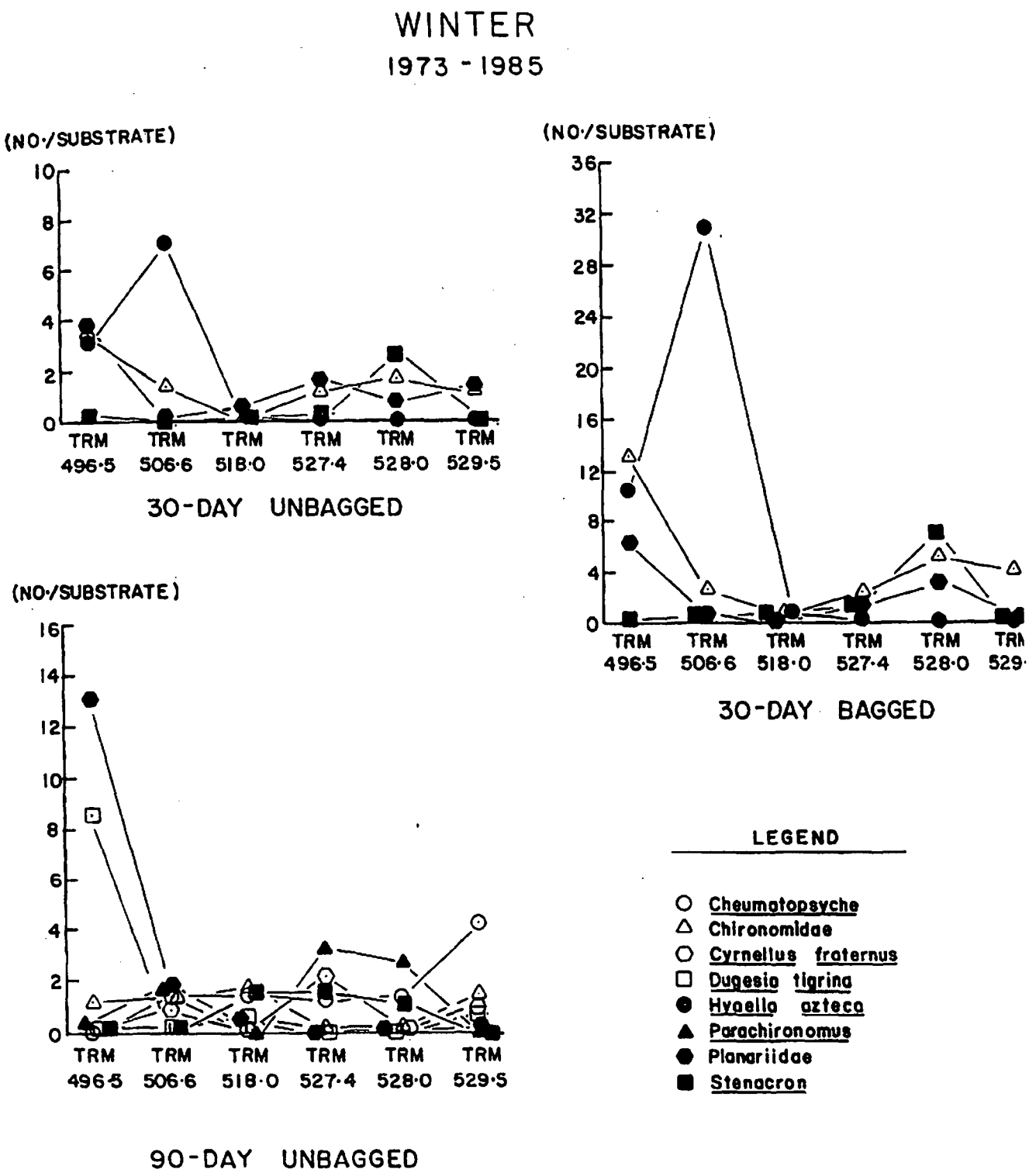


Figure 7-5. Distribution of Predominant Winter Macroinvertebrate Taxa (Mean Values) in the Vicinity of Watts Bar Nuclear Plant as Determined by Various Collection Techniques, 1973 Through 1985.

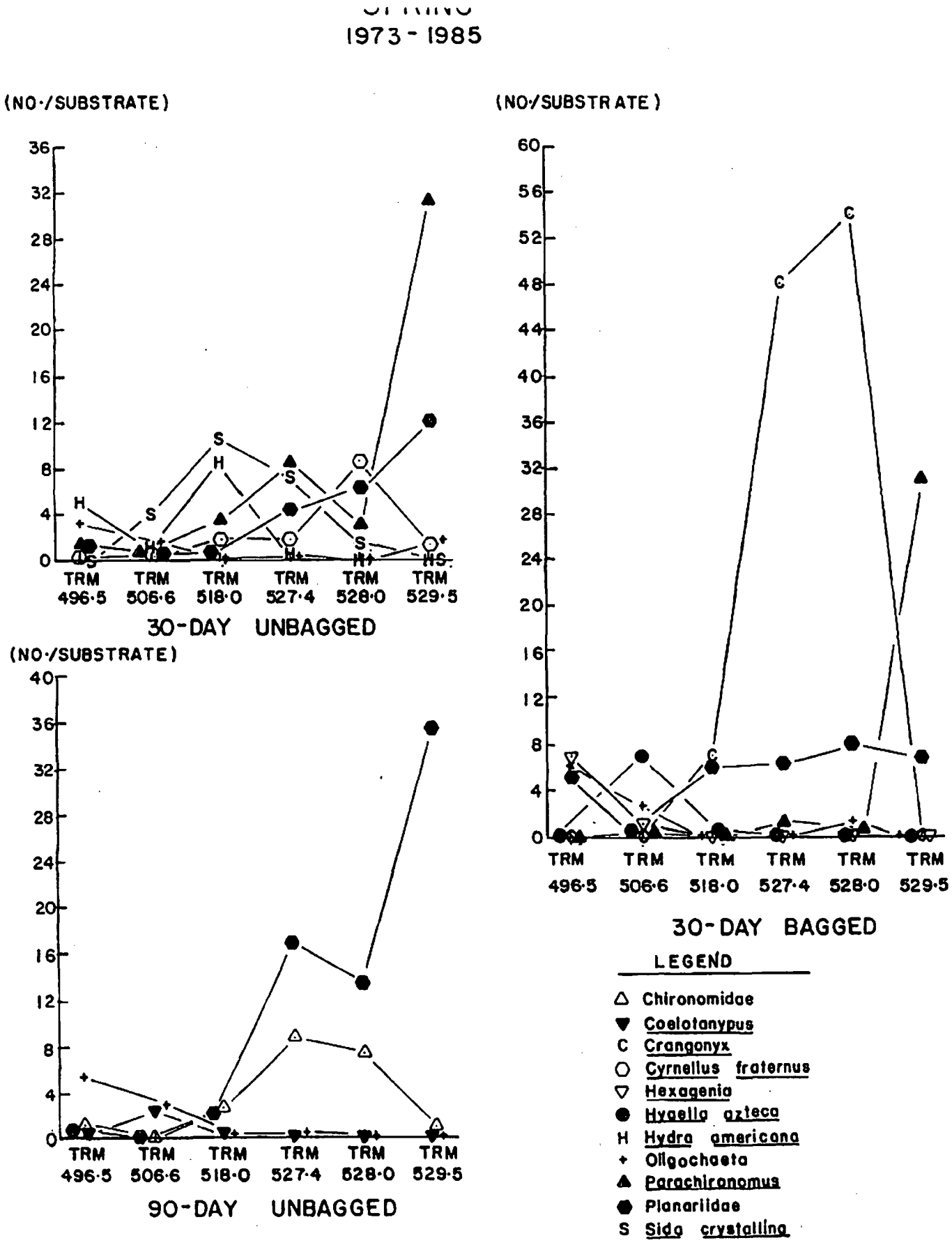


Figure 7-6. Distribution of Predominant Spring Macroinvertebrate Taxa in the Vicinity of Watts Bar Nuclear Plant as Determined by Various Collection Techniques, 1973 through 1985.

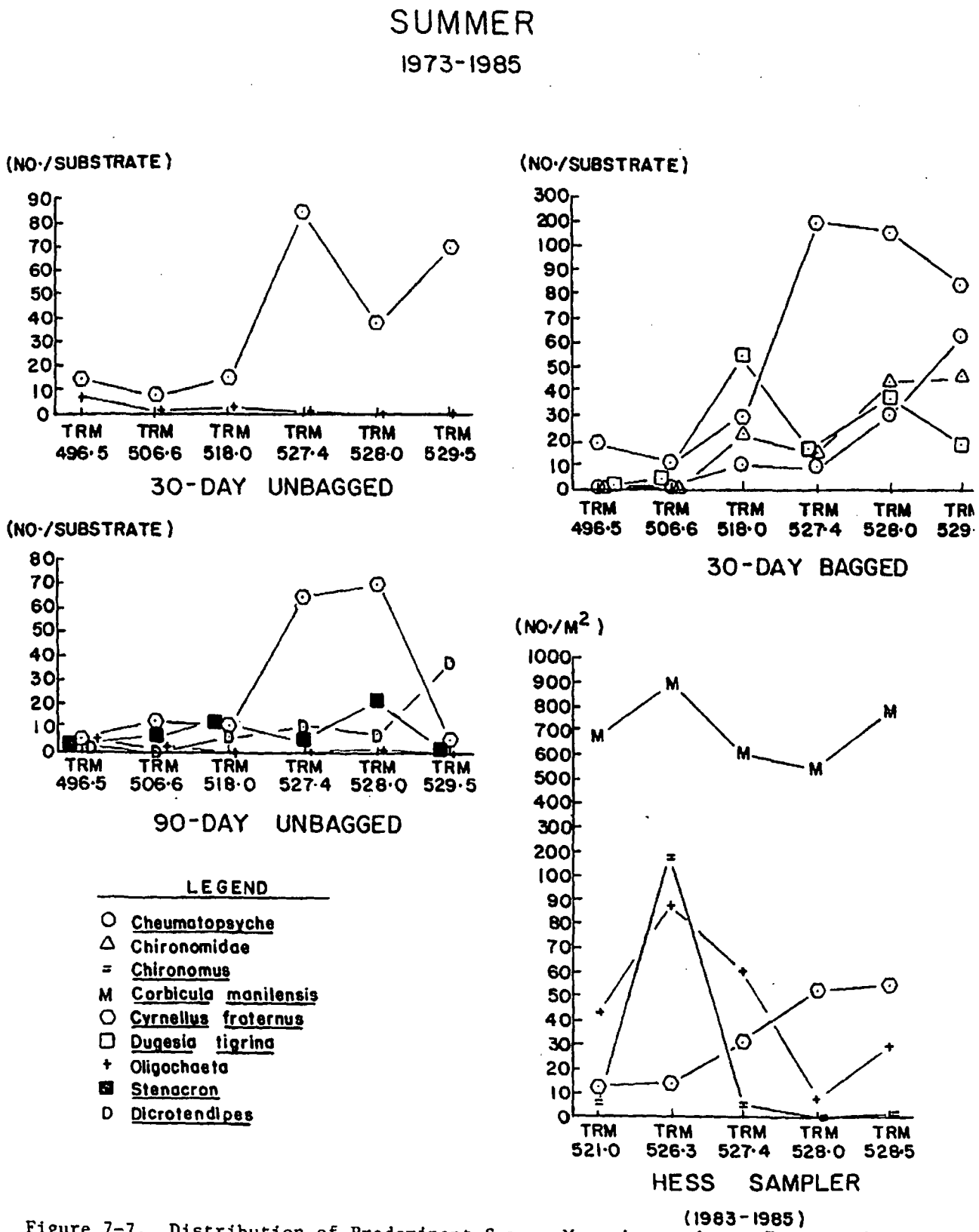


Figure 7-7. Distribution of Predominant Summer Macroinvertebrate Taxa in the Vicinity of Watts Bar Nuclear Plant as Determined by Various Collection Techniques, 1973 through 1985.

AUTUMN
1973-1985

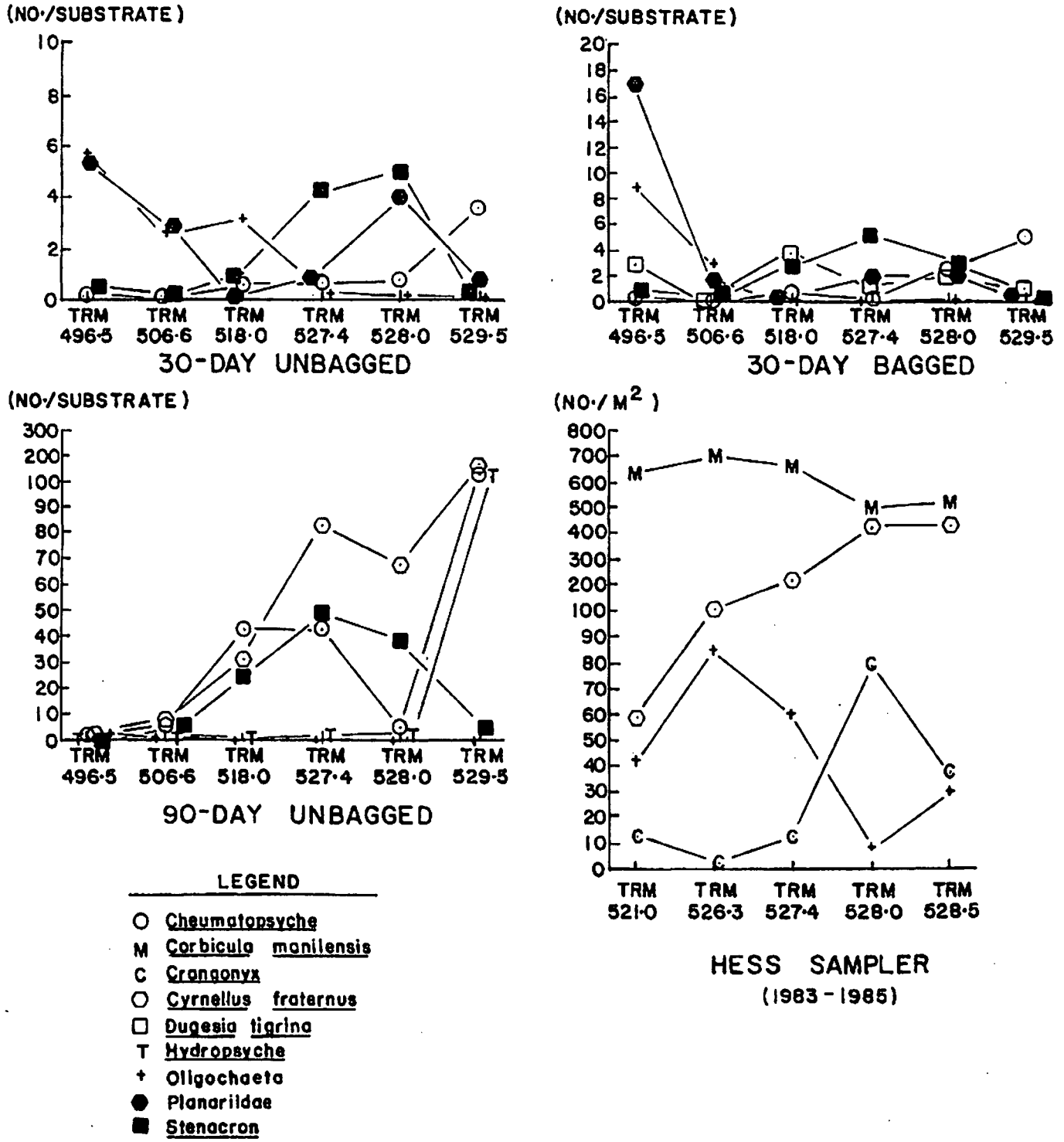


Figure 7-8. Distribution of Predominant Autumn Macroinvertebrate Taxa in the Vicinity of Watts Bar Nuclear Plant as Determined by Various Collection Techniques, 1973 through 1985.

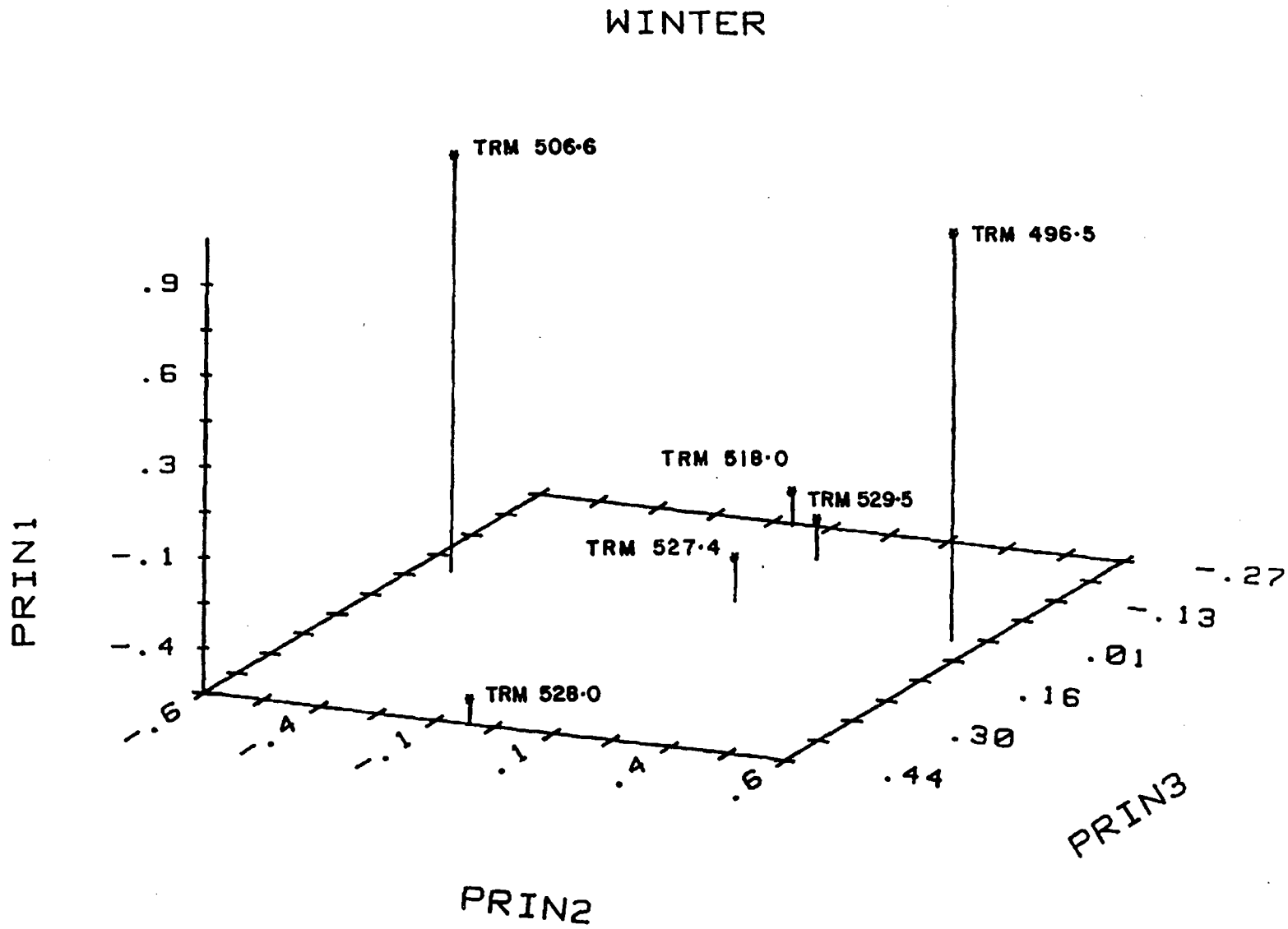


Figure 7-9. Ordination of Sampling Locations Based Upon Principal Component Analysis of Macroinvertebrate Communities Near Watts Bar Nuclear Plant, Winter 1973 through 1985 (Unbagged 30-Day Substrates).

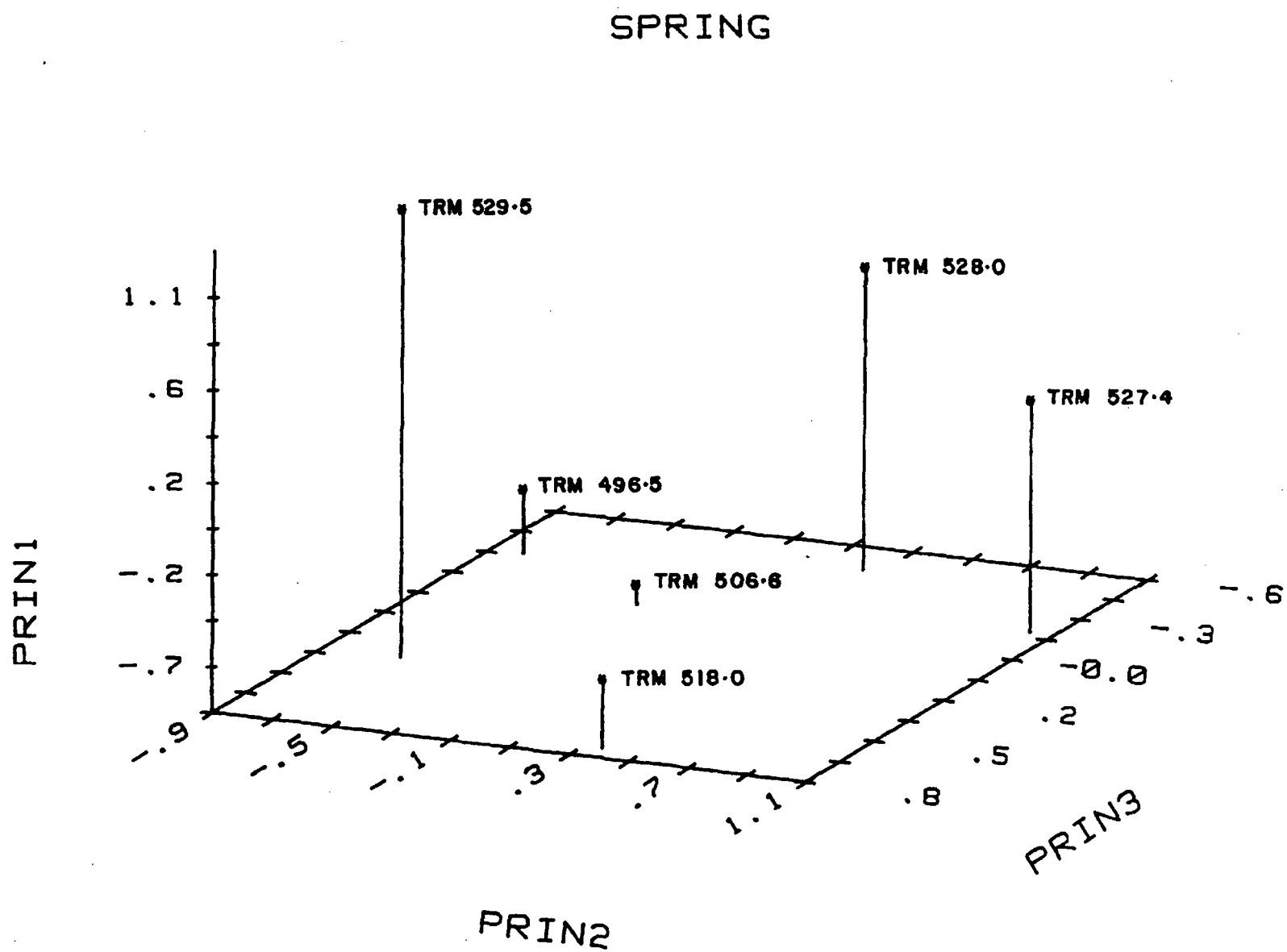


Figure 7-10. Ordination of Sampling Locations Based Upon Principal Component Analysis of Macroinvertebrate Communities Near Watts Bar Nuclear Plant, Spring 1975 through 1985 (Unbagged 30-Day Substrates).

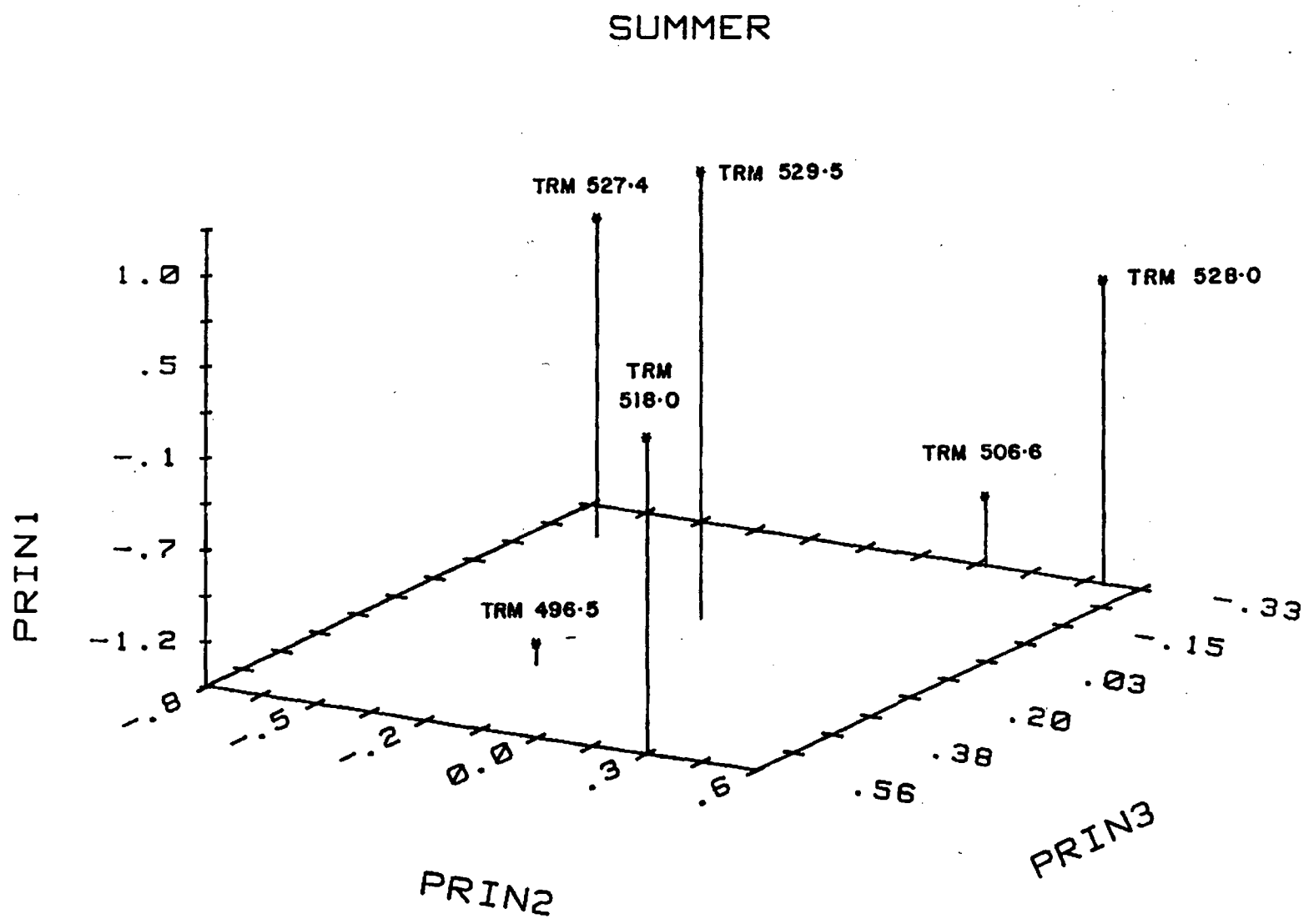


Figure 7-11. Ordination of Sampling Locations Based Upon Principal Component Analysis of Macroinvertebrate Communities Near Watts Bar Nuclear Plant, Summer 1975 through 1985 (Unbagged 30-Day Substrates).

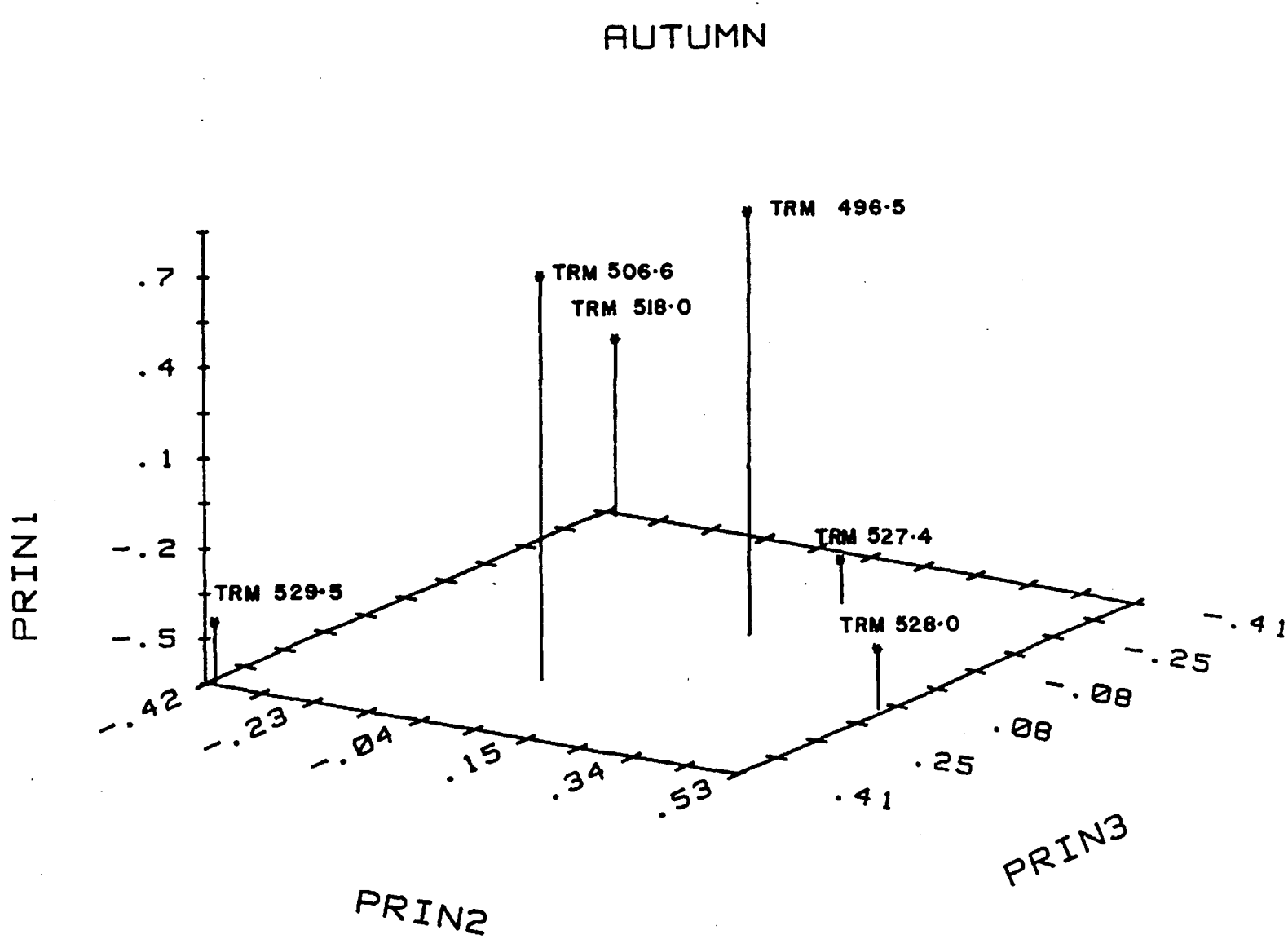


Figure 7-12. Ordination of Sampling Locations Based Upon Principal Component Analysis of Macroinvertebrate Communities Near Watts Bar Nuclear Plant, Autumn 1975 through 1985 (Unbagged 30-Day Substrates).

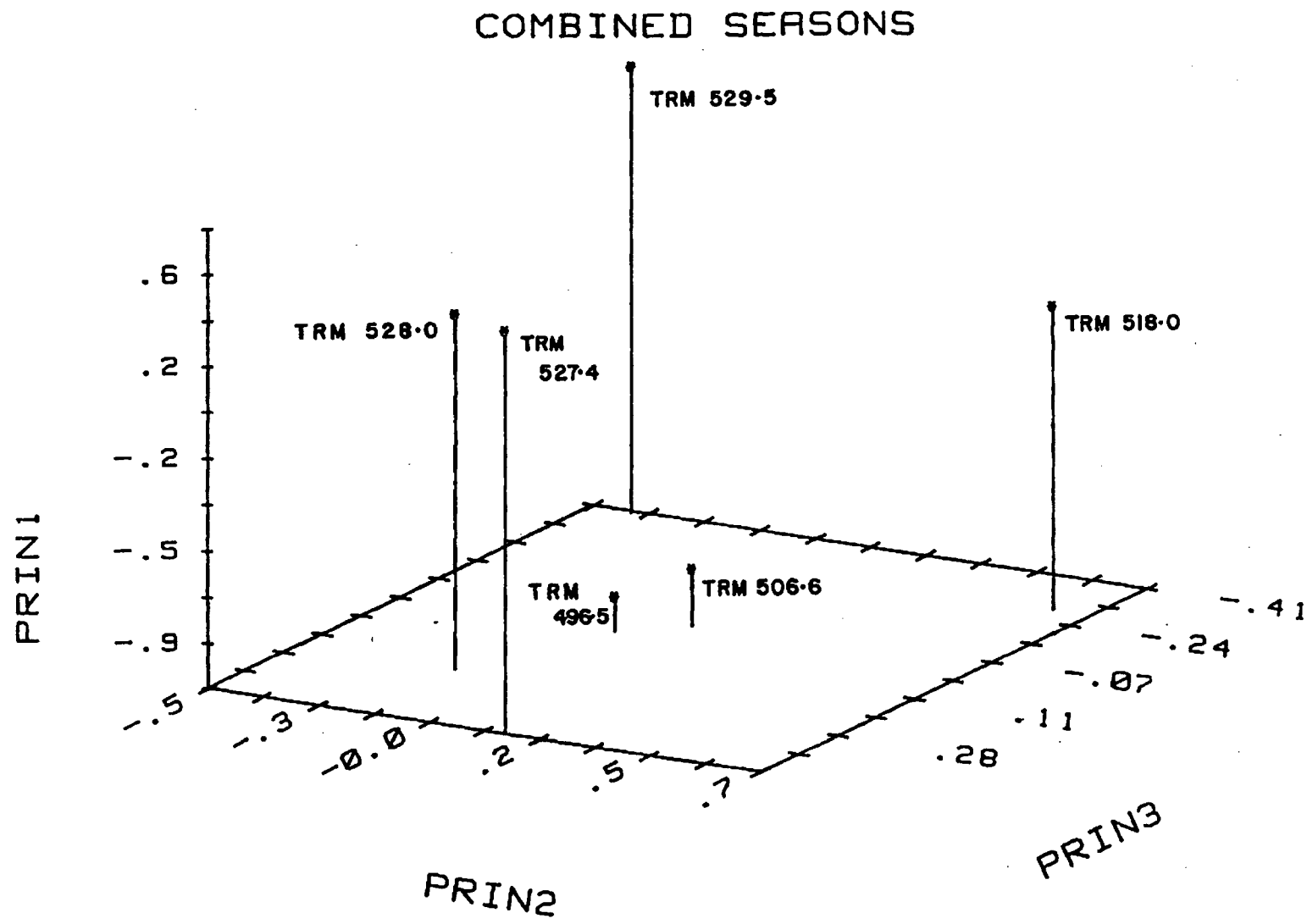


Figure 7-13. Ordination of Sampling Locations Based Upon Principal Component Analysis of Macroinvertebrate Communities Near Watts Bar Nuclear Plant, Combined Seasons, 1975 through 1985 (Unbagged 30-Day Substrates).

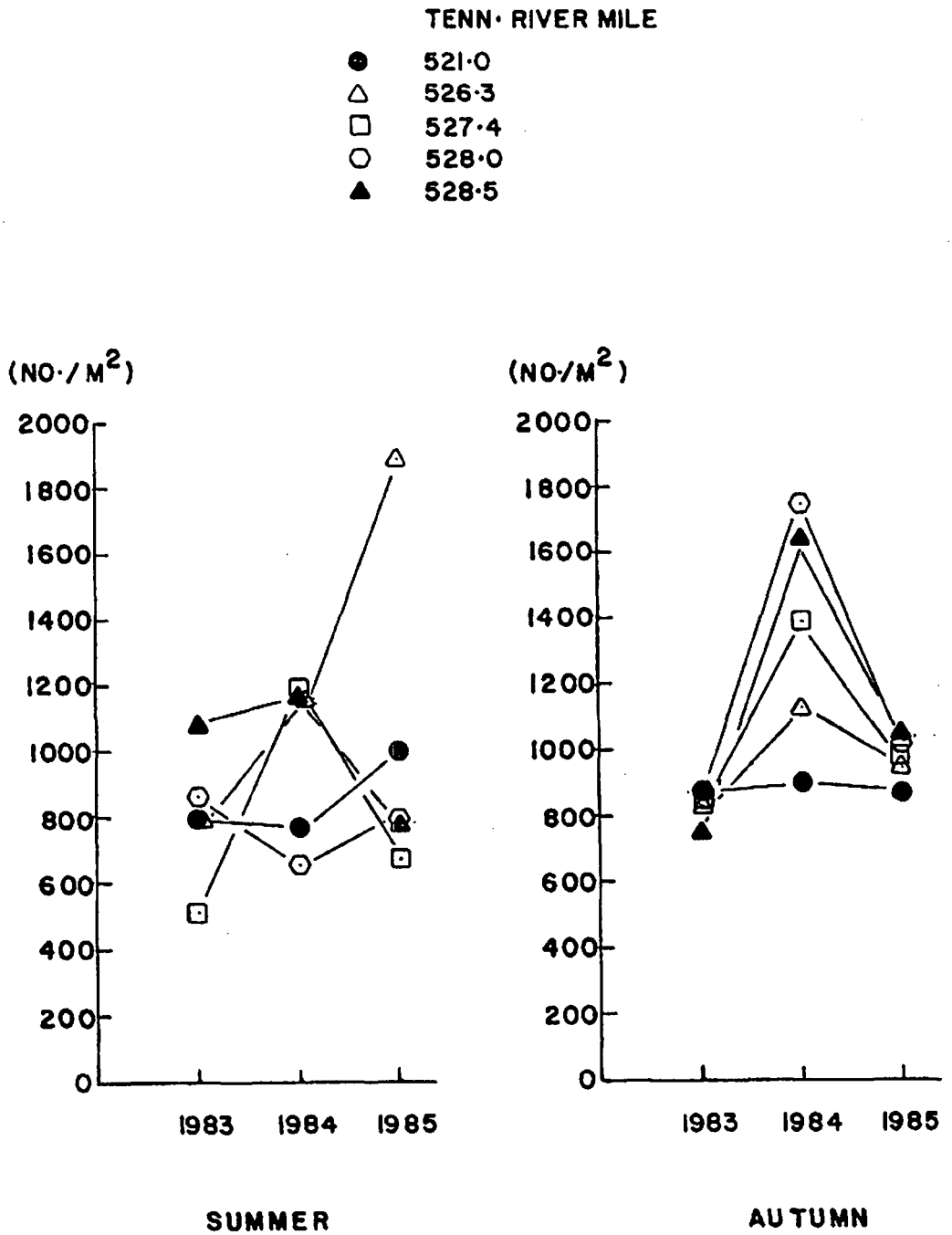


Figure 7-14. Seasonal Total Macroinvertebrate Abundance at Hess Sampling Locations Near Watts Bar Nuclear Plant, 1983 through 1985.

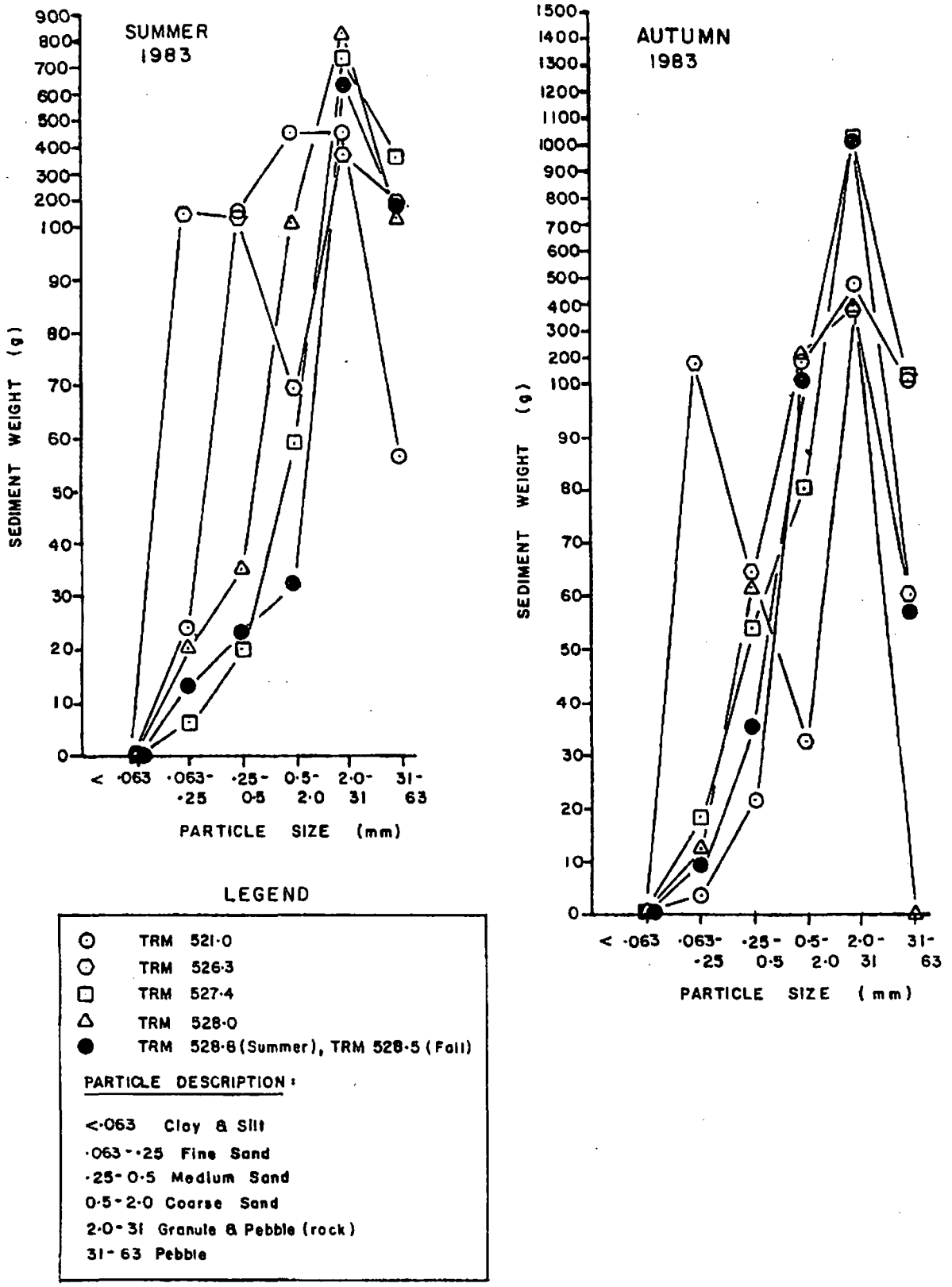


Figure 7-15. Benthic Sediment Composition by Weight at Hess Sampling Locations, Watts Bar Nuclear Plant, Summer and Autumn, 1983.

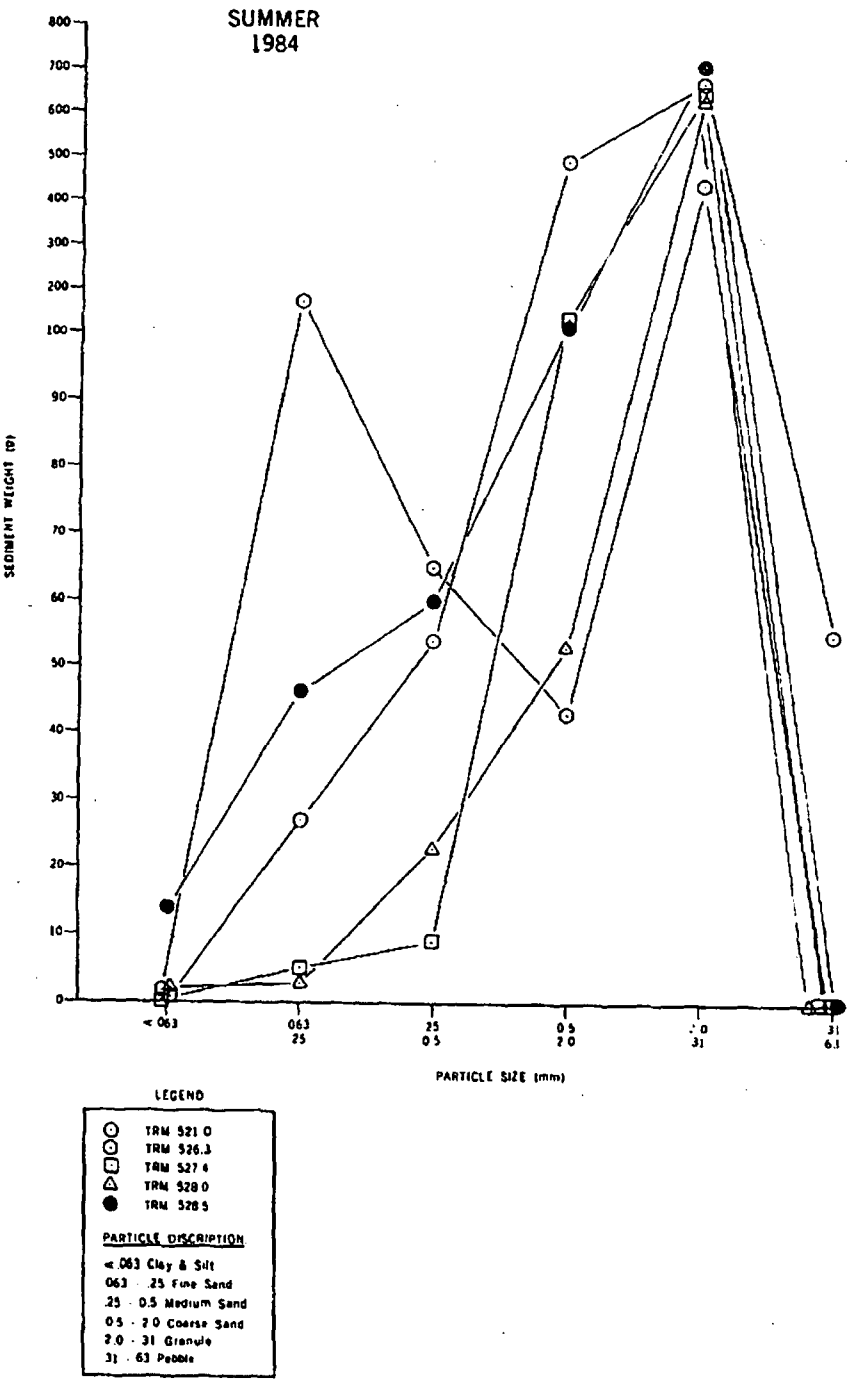


Figure 7-16. Benthic Sediment Composition by Weight at Hess Sampling Locations, Watts Bar Nuclear Plant, Summer, 1984.

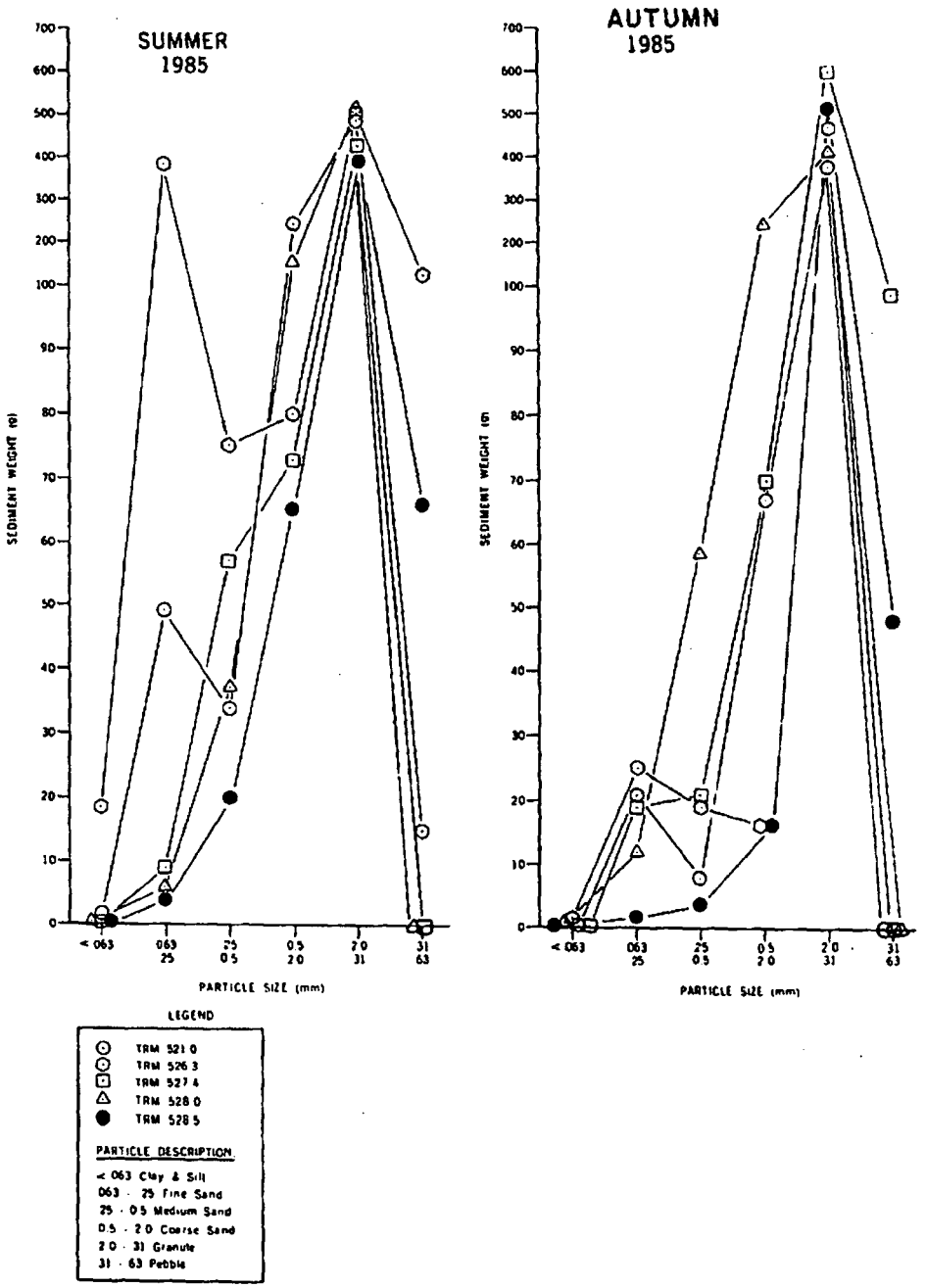


Figure 7-17. Benthic Sediment Composition by Weight at Hess Sampling Locations, Watts Bar Nuclear Plant, Summer and Autumn, 1985.

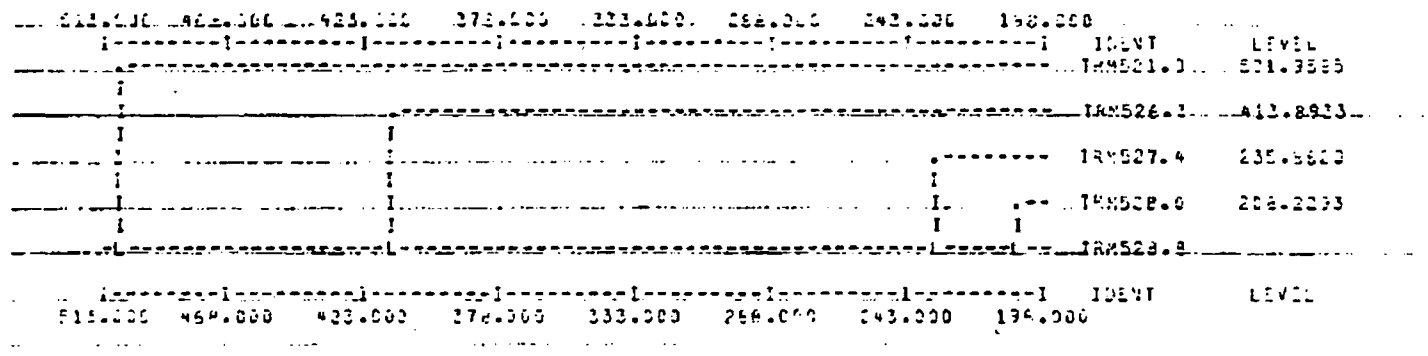
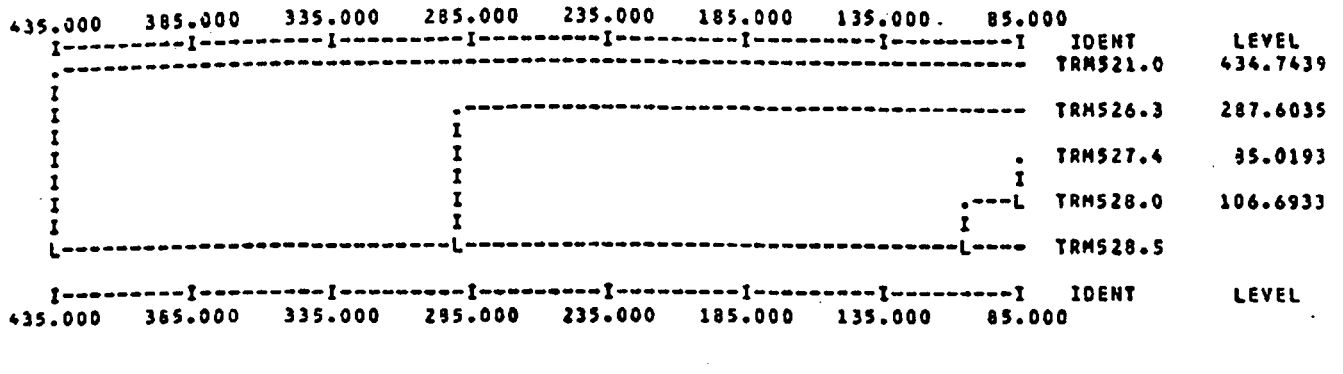
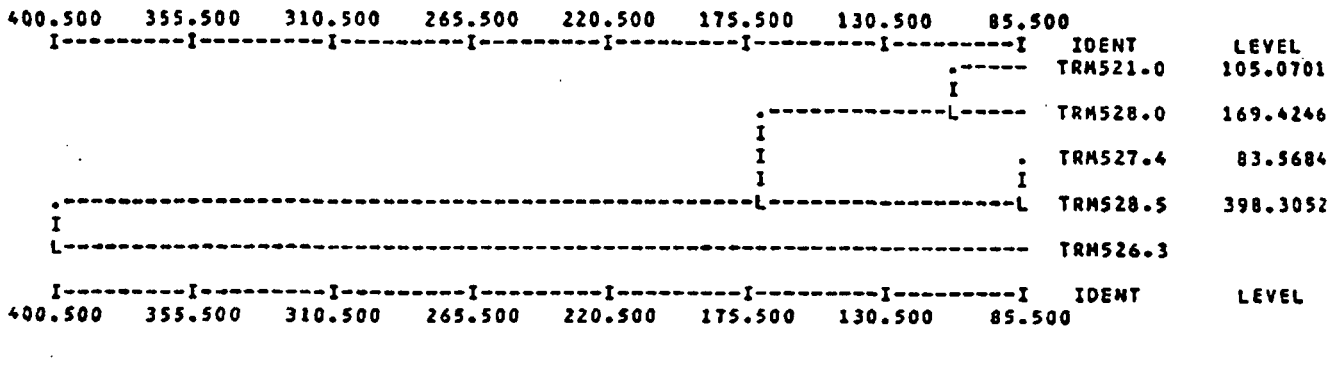
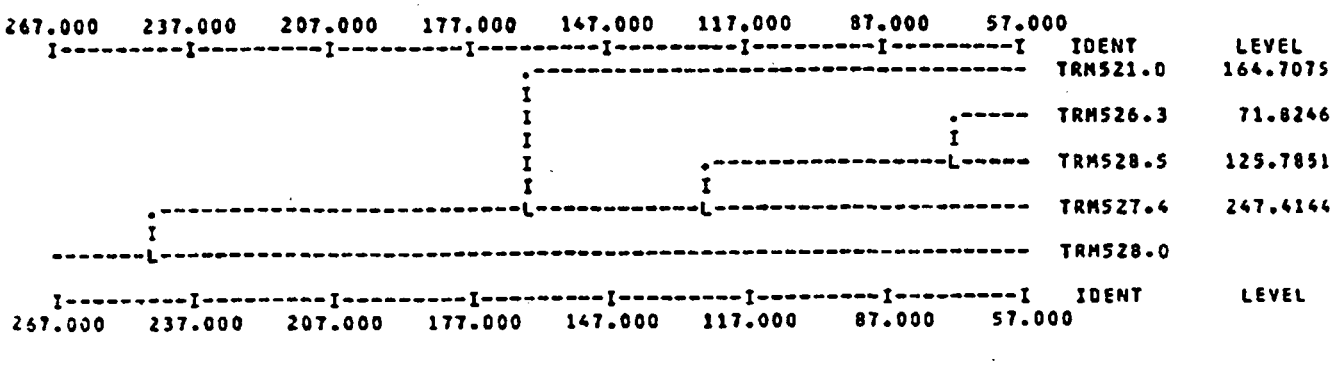


Figure 7-18. Phenogram of Hess Sampling Locations Based Upon Sediment Composition, Watts Bar Nuclear Plant, Summer and Autumn, 1983.



(A)





(B)

Figure 7-19. Phenogram of Hess Sampling Locations, Based Upon Sediment Composition, Watts Bar Nuclear Plant, (A) Summer 1984 and (B) Summer and Autumn 1985.

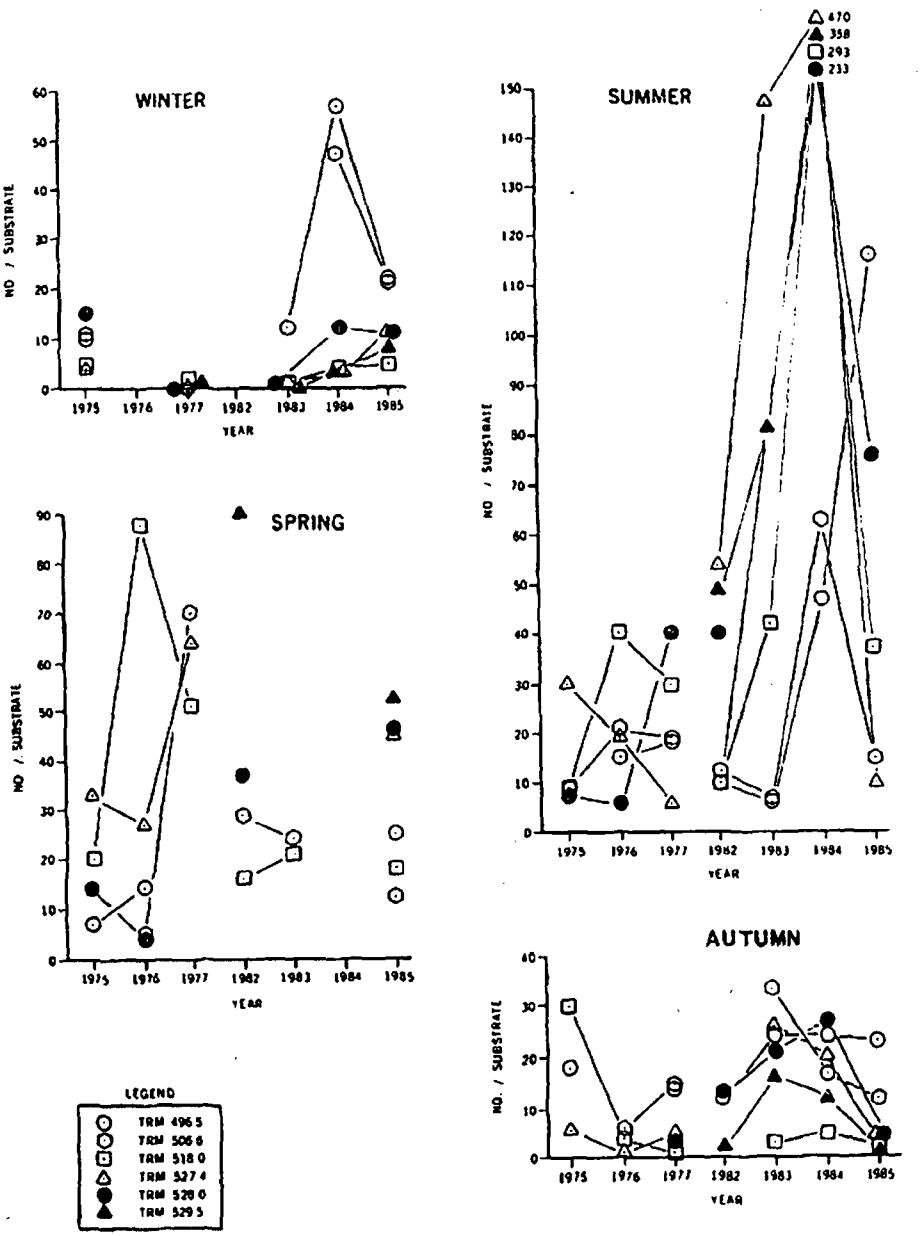


Figure 7-20. Temporal Distribution of Total Macroinvertebrates at Sampling Locations Near Watts Bar Nuclear Plant, 1975 through 1985 (Unbagged 30-Day Substrates).

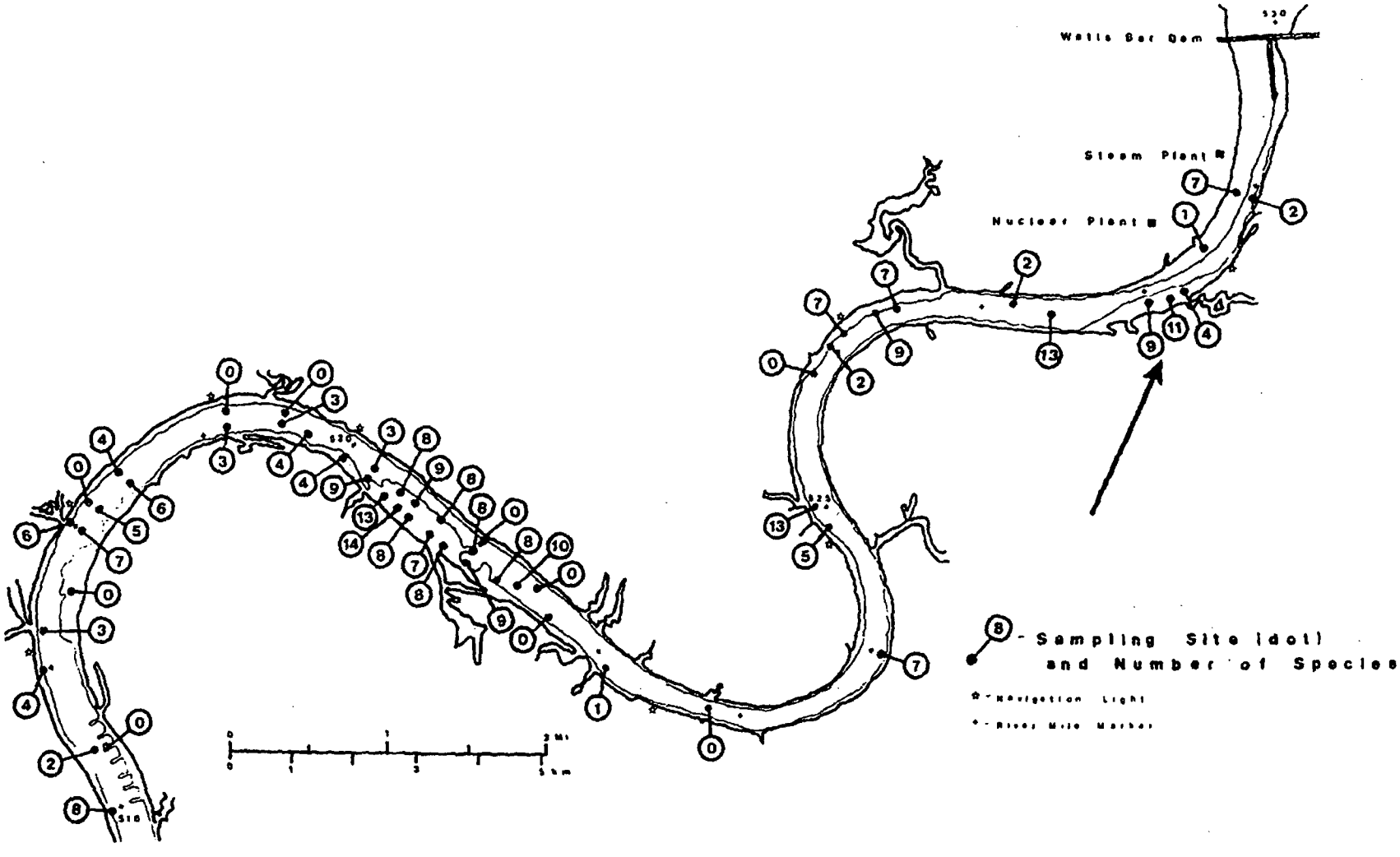


Figure 7-21. Tennessee River Downstream from Watts Bar Dam Showing the Locations of the 55 Sampling Stations and the Numbers of Freshwater Mussel Species Found During the 1978 Dive Survey.

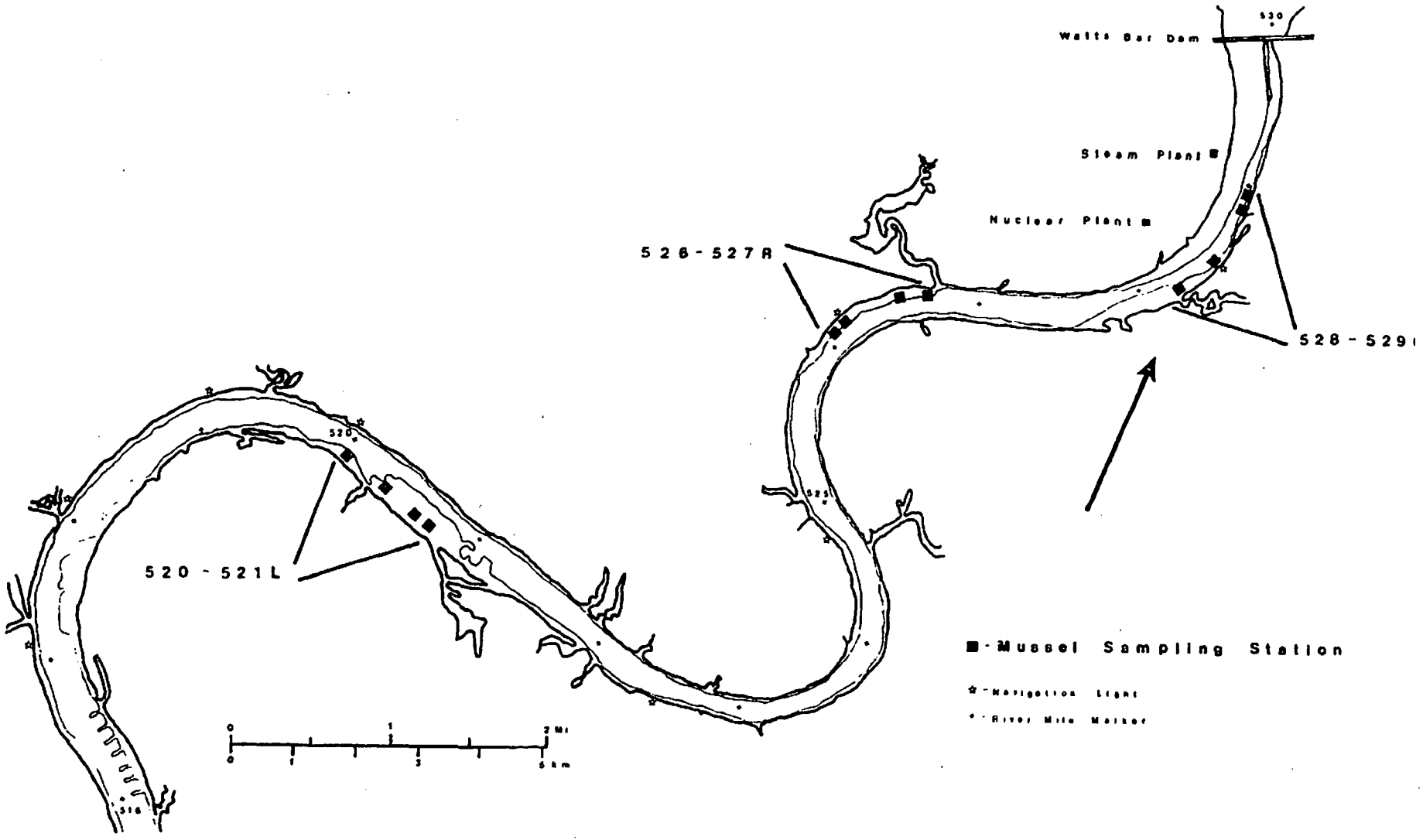


Figure 7-22. Tennessee River Downstream from Watts Bar Dam Showing the Locations of the Three Mussel Beds and the Twelve Sampling Stations Examined in 1983, 1984, and 1985.

8.0 FISH

Preoperational fisheries monitoring studies for WBN were designed to provide baseline data on the fish community in the vicinity of the plant and on the fish community of Chickamauga Reservoir as a whole. Monitoring in the plant vicinity was conducted from 1977 through 1979 and in 1982 through 1985. Sampling design and methods were essentially the same for both periods. Reservoir-wide fisheries data, particularly creel survey and cove rotenone, were collected concurrently as part of the SQN monitoring program which began in 1970 and continued through 1985. Since both WBN and SQN are located on Chickamauga Reservoir, other components of fisheries monitoring conducted at either plant should be applicable in assessing potential combined effects.

Because the fish community is characterized by high mobility and extreme differences in size and habitat selection of individual species, multiple techniques are required to provide baseline data on this community. An overview of the sampling methods used for WBN preoperational monitoring follows. Generally, sampling methods/gear were selected to evaluate the following parameters: species composition, relative abundance, spatial and temporal distributions, and angling success.

Fine-meshed plankton nets were required to capture fish eggs and larvae in the vicinity of WBN. The primary purpose of this sampling procedure was to provide estimates of relative abundance to evaluate potential entrainment losses. Also, time of spawning and spawning location for some fish species could be determined.

Due to frequent periods of high water velocity and variation in water depth in the vicinity of WBN, three types of gear were used to sample juvenile and adult fish: gill nets, hoop nets, and electrofishing. Both gill nets and hoop nets are passive sampling gear and usually selective as to size and species of fish captured; therefore, these data are best used to estimate relative abundance for a limited number of species and to evaluate movement and spatial distribution. Electrofishing, an active sampling method, is less selective as to size and species of fish captured, but generally ineffective at depths greater than 3 m. Electrofishing was used primarily to provide supplementary data on relative abundance and species composition.

Cove rotenone sampling, an active sampling method, was conducted on a reservoir-wide basis to quantitatively monitor fish standing stocks relative to potential long-term or cumulative impacts from operation of WBN and SQN. Although cove rotenone sampling does not necessarily provide true fish standing stock estimates for the entire reservoir, cove rotenone data represents the best available quantitative estimates of relative abundance from year to year for several species.

Creel surveys, conducted reservoir-wide and in the plant vicinity, were designed to provide information on fishing pressure, total harvest and fishing success. Creel surveys generally are oriented to evaluation of long-term effects and provide an indirect measure of abundance for selected species.

8.1 Materials and Methods

8.1.1 Fish Eggs and Larvae

Preoperational monitoring to determine spatio-temporal concentrations of ichthyoplankton in the vicinity of Watts Bar Nuclear Plant (WBN) was conducted from 1976 through 1979 and from 1982 through 1985. Studies were designed to provide baseline data on the occurrence, abundance, and distribution of fish eggs and larvae in the tailwaters of Watts Bar Dam. These data will be compared to subsequent investigations to determine and assess any effects of plant operation.

Field--Ichthyoplankton samples during all eight years were taken along a transect perpendicular to river flow just upstream of the plant intake channel at Tennessee River Mile 528.0. Samples were taken with a beam net 0.5 m square, 1.8 m long, with 505 micron "nitex" mesh netting towed upstream at 1.0 m/s boat speed for 10 minutes, resulting in approximately 150 m^3 of water filtered per sample. A large-vaned General Oceanics® flowmeter was suspended in the net mouth to measure volume filtered.

In 1976 and 1977, five stations were sampled across the transect (figure 8-1). These stations were each sampled with a single, oblique full-stratum tow except in 1976, when three full-stratum samples were taken at the mid-channel station on each sampling excursion. A tow was made by first lowering the net to the river bottom, then, with the boat in motion, raising it obliquely at one minute intervals through the water column. Beginning in 1978 single, oblique, full-stratum samples were collected at four stations across the transect (figure 8-1). Also in 1978, to determine if any larval taxa were drifting only near bottom, an

additional sample was added at the mid-channel station which was a horizontal (epibenthic) tow sampling only the stratum from 0.5-1.0 m from the bottom.

In 1984, sampling for fish eggs and larvae was initiated in the WBN cooling water intake channel in order to describe temporal abundance and potential use of this area as spawning and nursery habitat. Sample procedures consisted of four, full-stratum tows of four minutes each, beginning in front of the intake pump wall and ending at the mouth of the intake channel. Sampling was conducted during day and night on the same date the river transect was sampled. Approximately 40-50 m^3 of water were filtered during each four-minute tow in the intake. No intake samples were collected during sample periods one, two, four, or five in 1984. All samples were immediately fixed in 10 percent formalin and subsequently transported to the Fisheries Laboratory in Norris, Tennessee, for processing.

To assess temporal abundance of larval fish in 1976, samples were taken biweekly on a diel schedule--dawn, midday, dusk, and night. Preliminary analysis of the 1976 data indicated that two sample times (day and night) during a diel period would provide adequate data to describe temporal distribution. Thus, for the remaining seven years of this study, samples were taken two times (day and night) during each sample period.

To ensure that biweekly sampling in 1976 had not missed peak abundance periods for migratory species (e.g., sauger, white bass), sampling in 1977 was conducted on a weekly schedule from March through

June. After June, biweekly sampling was resumed. Biweekly sampling was then employed for the remainder of the study.

Laboratory--Ichthyoplankters were removed from the samples, identified to the lowest possible taxon, counted and measured (larvae only) 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 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 a 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 specimen identified to species level represents a 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 six 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 Analyses--Densities of fish eggs and larvae are expressed as numbers per 1000 m^3 for diel comparisons between stations and among years. Temporal occurrence and relative abundance of eggs and larvae by taxon are presented and discussed for the entire preoperational monitoring period. 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.

8.1.2 Juvenile and Adult Fish

Experimental Gill Nets and Hoop Nets--Two sampling stations, A (TRM 527.4-528.4) and B (TRM 524.2-TRM 524.9), were established for netting studies (figure 8-2). Flow conditions in both these areas are riverine and subject to strong currents resulting from Watts Bar Dam hydroelectric turbine discharges and occasional floodgate spillway releases, during late winter and early spring months. The stations are similar with respect to shoreline, substrate, and aquatic vegetation characteristics. Also, they are both located in a bend of the river with a major tributary entering from the outside bend. General differences between the two stations include: (1) riprapped shoreline areas, especially near the plant site, at station A and upstream of the station

boundary, (2) net sites at station A are exposed to stronger currents from Watts Bar Dam located a short distance upstream, (3) aquatic vegetation, primarily eurasian watermilfoil (Myriophyllum spicatum L.) and spinyleaf naiad (Najas minor All.), is more prevalent at station B, and (4) there is a greater abundance of riparian vegetation and underwater structures (i.e., trees and stumps) at station B (figure 8-2; appendix 8-A).

Sinking experimental gill nets, 38.1 m long x 2.4 m deep, consisted of five 7.6-m panels ranging in size from 1.27 cm to 6.35 cm bar mesh. Nets were set in pairs with a total of four nets at each of the two stations. Each net pair was set approximately 100 m apart within a station, with the mesh size succession between the two nets reversed. Nets were tended daily, and the mesh succession of each net was reversed before being reset. Typically, eight net-nights of sampling effort were expended at each station prior to August 1977. Increased effort from August 1977 to January 1978 resulted from fishing nets for four consecutive nights bimonthly rather than two consecutive nights monthly as done for the remainder of the study (appendix 8-B).

Hoop nets constructed of 5 cm mesh, were 4.75 m in length, with seven hoops, two throats, and a mouth diameter of 1.19 m and were fished at the same sites as experimental gill nets. These nets were also tended daily and fished bimonthly from winter 1977 through fall 1979 after which sampling was conducted on a monthly basis (appendix 8-C).

Since the study was initiated in February 1977, changes were made to alleviate sampling problems and improve the quality of the data collected. These changes included: (1) relocating net site A(2) approximately 15 m upstream when dredging for the plant intake system was

initiated, establishment of net sites A(5) and A(6) immediately below the intake channel in summer 1978, and (3) establishment of two additional net sites, A(7) and A(8), immediately downstream of the discharge diffuser pipe in April of 1984. Preoperational sampling at WBN was suspended with the completion of the fall, 1979 sampling period. Sampling was resumed in the spring quarter of 1982. Gill net samples were not taken during January 1979 due to floodgate discharges (appendices 8-B and 8-C). As a result of these changes, a total of 12 net sites (eight at station A and four at station B) were established with sampling conducted for each gear type on two consecutive days each month.

Data Analyses--The basic unit used in these analyses was catch-per-unit effort (c/f) expressed as number of each fish species caught per net-night (the catch from all mesh sizes in experimental nets was combined). The analyses were designed to detect significant spatial and temporal differences in c/f of important fish species combined and individually. Important species were those occurring at both stations and comprising at least one percent of total number of fish captured. All statistical analyses were performed on log transformed data, $\log_{10}(c/f + 1)$; however, antilogs of transformed data were used in the text and tables and actual quarterly catch data were used to prepare graphs to facilitate comparisons.

A Multivariate Analyses of Variance (MANOVA) was employed to test effects of station, year, quarter, net pairs within station, and interactions among these main effects on combined important species for each sampling method. The MANOVA was then rerun with non-significant

terms (alpha = .05) included in the error term. utilizing only those effects and interactions which proved significant at the 5 percent level during the first test. This procedure identified relative influence of main effects and interactions on the whole fish assemblage. Net pair, nested within station, effects were included in the MANOVA for the purpose of identifying significant differences between: (1) net pairs within station A (e.g., upstream and downstream of the WBN diffusers); and (2) left and right banks within each station, respectively. Pillai's Trace, an approximation of the F-test, was used to test for significant differences.

A univariate Analysis of Variance (ANOVA) was then employed for each gear type in testing influence of those main effects and interactions found to be significant in the MANOVA on c/f of each important species. This procedure identified individual species contributing to assemblage responses observed with the MANOVA. Both tabular and graphic formats were used to examine main effects and interactions for each important species. Bonferroni's adjustment (Miller 1981) was used in order to keep Type I (alpha) errors at the .05 level. This adjustment maintains the experiment wise error rate by dividing the commonly used levels (i.e., .05 and .01) by the number of important species present for each gear type. Because both sampling methods resulted in twelve important species being identified, this adjustment equates a comparison wise (alpha = .004) to an experiment-wise error rate of .05 and a comparison wise (alpha = .0008) to an experiment-wise error rate of .01 for each of the main effects and associated interactions.

Electrofishing--Preoperational electrofishing at WBN was initiated in March 1977 and continued through November 1979. In March 1982, sampling was resumed and continued through December 1985. The electrofishing unit consisted of a 230-volt, 3.5 kilowatt direct current generator delivering a continuous current of approximately four amperes to the water by means of boom-mounted electrodes. During one day each month, five, three-minute (1977-1979), or 100 meter (1982-1985) samples were taken along both left and right shorelines within the same two stations as described for netting (figure 8-2). All sample runs were made with the boat moving upstream. Stunned fish were netted, identified, enumerated and recorded. When large schools of forage fish (usually shad or minnows) were shocked and netting all individuals proved impossible, numbers were estimated. A description of each electrofishing site (shoreline substrate, vegetation, and depth) is given in appendix 8-D). Electrofishing sample dates and number of samples collected at each station during the entire monitoring period 1977-1985 are listed in appendix 8-E.

Data Analyses--Data from all electrofishing samples were characterized by total numbers of each species, number of samples in which each species was collected, and percentage of overall catch by species. Only species termed "important" (those occurring in 50 percent or more of the months sampled and comprising at least one percent of the total catch) were analyzed for spatial and temporal differences and trends.

The standard unit for comparison in these analyses was catch-per-electrofishing-run (c/f). All statistical analyses were performed on $\log_{10}$ (c/f + 1) transformed data; however, in the text and

tables (except where noted) untransformed c/f data were used to facilitate comparison. Monthly catch data were grouped and analyzed by quarters in the same manner as gill netting data. Statistical tests, except MANOVA, used in analyzing electrofishing data were the same as those described for gill net and hoop net analyses.

Reservoir-Wide Creel Survey--This reservoir-wide survey procedure was formulated by Tennessee Wildlife Resources Agency (TWRA) and TVA following closely a design prepared for TWRA by Dr. D. W. Hayne of the Institute of Statistics at Raleigh, North Carolina. Collection of field data and data processing were performed by TVA and TWRA.

This survey was of the roving clerk uneven-probability type with day, work area, and time of day randomly selected. Workdays were drawn, with replacement, until enough days had been selected to fill out the prescribed five-day, weekly workload for the clerk; a record was kept of the number of times each weekday was drawn. After workdays, work area and time for each day were chosen. The reservoir was divided into areas just large enough to be covered by boat in one work period. Each day was divided into two periods, from sunrise until noon and from noon until sunset. After time of day had been selected, time for instantaneous counts was chosen. At this preselected time, the clerk counted the number of persons fishing in the work area. During the rest of the workday, the clerk collected creel information: number of each species caught, weights of individual fish, hours fished, and related data from each fishing party interviewed. Fishing success was established from the interviews, and estimates of fishing pressure were made from the counts of fishermen; total catch was estimated as the product of success and pressure.

A separate estimate of the weekly fishing pressure in fisherman hours (P) was made for each work period using of the following formula:

$$P = \frac{a \times c}{b \times d \times e}$$

where:

a = work area count;

b = probability of drawing this work area;

c = number of hours in work period;

d = probability of drawing this work day;

e = probability of drawing this work time (a.m. or p.m.).

Probabilities for workdays, areas, and times were assigned using information on fishing pressure provided by TVA personnel with previous knowledge of fisherman activity. Each day's estimate of weekly pressure was weighted by the number of times that particular day was drawn in setting up the original sampling schedule and used to calculate a mean (P) for the week.

Estimated weekly harvest (number) of each species was the average catch per hour of that species from the clerk's total interviews for the week multiplied by mean pressure (P). The weekly harvest of a particular species multiplied by its average weight in the creel provided the weekly weight of each species caught. Total number and weight of all fish caught each week were summations of estimates for individual species. Total number of fishing trips was derived from the average length of completed fishing trips in hours divided into the total estimated fisherman hours. Annual data summaries represent data collections in a creel year, beginning July 1 each year and ending June 30 of the following year.

WBN Vicinity Creel--During the period April 1982 through December 1985, TVA personnel collected angler harvest data one day per week in the river reach between Watts Bar Dam (TRM 529.9) and Yellow Creek (TRM 526.8). Selection of the survey day was non-random in order to avoid double sampling on the days the reservoir-wide creel covered the same area. Data collected provided estimates of catch rate (numbers and biomass), average weight of each species, and percent composition of species harvested. Because of the limited sampling schedule, total fishing pressure in the area was not estimated.

Cove Rotenone--Rotenone sampling procedures by TVA were standardized after 1960 to include use of block nets and standard survey techniques. Prior to this, techniques varied from year to year and from one reservoir to another. Sampling in Chickamauga Reservoir from 1947 through 1959 included: (1) use of varying techniques for determining area and volume of the sample site, (2) some samples conducted without the use of block nets, and (3) undescribed subsampling techniques.

Cove rotenone sampling since 1970 was designed to eliminate certain biases through establishment of criteria for sample sites and standardization of field techniques. Criteria for an acceptable rotenone site were: (1) surface area at least 0.4 ha; (2) depth not more than 7.5 m where block net is set; (3) location not adjacent to or within the same cove as housing developments, boat docks, or other recreation areas; (4) absence of streams or other sensitive habitats; and (5) easy access by boat. Some changes in cove sites were made after 1970; however, since 1980 when SQN operational monitoring began, the same five coves have been sampled each year in Chickamauga Reservoir. These coves were located at

TRM 476.2, 478.0, 495.0, 508.0, and 524.6 (figure 8-3). Descriptions of sample sites (1947-1985) are in table 8-1.

Standardized field techniques for rotenone sampling include: (1) sampling when water temperature is $\geq$ 20° C; (2) accurate surveying of surface area within one day prior to conducting sample; (3) block net set on the afternoon prior to sampling; (4) scuba-diver check of block net to ensure isolation of sample area; (5) determination of physical and chemical properties of the sample area; (6) application of rotenone to attain a 1.0 mg/L concentration of toxicant; (7) pick up of all visible fish on two consecutive days; and (8) specified sorting, counting, weighing, subsampling, and data recording procedures.

Physical properties measured were surface area, maximum depth, and mean depth (obtained through a systematic series of depth soundings). Mean depth and surface area were used to determine the volume of the cove and, thereby, the amount of toxicant necessary to achieve a concentration of 1.0 mg/L.

Rotenone was applied with a pump using a weighted, perforated hose to distribute the toxicant evenly at all depths. Initially a curtain of rotenone was applied adjacent to the block net to prevent small fish from escaping. Following this, rotenone was distributed by operating the boat in a zigzag pattern throughout the cove. Finally, shallow shoreline areas were surface sprayed with rotenone to ensure complete coverage of the area. All visible fish were picked up the day of application and sorted by species. Each species was then sorted into groups by 25 mm length increments. Small fish (e.g., Notropis sp.) were preserved in a 10 percent formalin solution and returned to the

laboratory for identification. Each size group was counted and the aggregate weight recorded. Occasionally, some length groups were so numerous that it was not practical to count each fish. In these cases a subsample of that length group was counted and weighed. Remainder of the size class was then weighed collectively and numbers estimated by the relationship:

$$\frac{\text{Numbers in subsample}}{\text{Weight of subsample}} = \frac{\text{Numbers in remainder}}{\text{Weight of remainder}}$$

Since 1982 a modified subsampling procedure has been used to process large numbers of young centrarchids (Lepomis sp.). Small centrarchids (< 76 mm total length) were separated from the remaining cove sample, and a 1 kg subsample was processed. Fish in the subsample were sorted to species, separated into 25-mm length groups, then counted and weighed. The remainder of the sample was weighed collectively. Numbers of each species and size groups were then determined by using a relationship similar to that described above. Fish collected the second day were processed in the same way, except that numbers only were recorded for each size class of each species. Weights of second-day fish were calculated from length-weight relationships derived from first-day fish.

Data Analyses--Standing stocks of each species were calculated by size class. Fish were grouped into game, commercial, and forage species and classified as young, intermediate, and adults, based on total length (table 8-2). Standing stocks of young, intermediate, and adult size classes of important species were analyzed using a linear regression

model to determine statistically significant trends over the period 1970 through 1985. Important species were determined by the following criteria: (1) Occurred in at least 50 percent of samples since 1970, and (2) Comprised one percent of either the total number or total biomass collected.

In addition to species meeting the above criteria, certain species of special interest were included for analysis because of their importance as sport or commercial species.

8.2 Results and Discussion

8.2.1 Eggs and Larvae

Table 8-3 lists dates, number of samples, and mean temperatures (average of all depths) for each sample period during preoperational studies. Table 8-4 and 8-5 lists scientific and common names for each taxon discussed in this section.

Tailwater Populations - Eggs--During the eight-year study period, only 2,881 fish eggs were collected in WBN ichthyoplankton samples. This total consisted of 67 percent unidentified eggs and 33 percent freshwater drum eggs. One *Hiodon* sp. (probably mooneye) egg was collected in 1978. Numbers of unidentified eggs were highest in 1978 and 1983, constituting 82 and 87 percent of total egg collections, respectively, for those years and 97 percent of unidentified eggs collected for the entire period. Egg collections were low the remaining four years and were predominantly freshwater drum eggs (table 8-6).

Low numbers of drum eggs occurred in samples at WBN from early May to early September with peak abundances occurring from late May

through early July. 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, freshwater drum spawning in the Watts Bar tailwater upstream from the sample transect. 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).

A later examination of unidentified eggs collected in 1978 and 1983 resulted in identification as Morone spp. eggs. Identification for most of these eggs must remain tentative due to the morphological similarity to crappie and shad eggs. However, support for this identification is based on the presence of late embryonic development in a few eggs, the simultaneous presence of newly hatched Morone larvae in samples at WBN and the appearance of 3 mm Morone larvae downstream at the Smith Bend and Calico sites (TRM 525 and 522 respectively) the following week (TVA, 1980b). Although Vincent (1968) reports white bass (Morone chrysops) eggs to be adhesive (as are yellow bass eggs unpublished TVA data), it is likely the eggs in question were spawned below Watts Bar Dam and subsequently dislodged by turbine discharge.

Tailwater Populations - Fish Larvae--Total numbers and percent composition of fish eggs and larvae collected by year are presented in table 8-6. Yearly composition of larval fish samples collected near WBN was variable, ranging from 13 (1979) to 23 (1977) taxa. Only eight taxa, unspecifiable clupeids, unspecifiable cyprinids, Ictalurus punctatus,

Morone spp., Morone (not saxatilis), Lepomis spp., Pomoxis spp., and Aplodinotus grunniens were collected all eight years. Dorosoma cepedianum, Cyprinus carpio, and unspecified darter (Percidae) larvae were present five of the eight years. Clupeids dominated all samples (table 8-6) with Lepomis spp. and Aplodinotus grunniens the only other taxa to exceed one percent of the total catch every year. With the exception of unspecifiable clupeids, most taxa were collected in low numbers.

Seasonal density of total larvae was highest (2,697/1,000 m^3) in 1977 and lowest (293/1,000 m^3) in 1979 (table 8-7). Seasonal peak densities of fish larvae near WBN varied through time. Water temperature at seasonal peaks was also variable ranging from 17.2 C to 23.9. Seasonal peak densities typically reflected periods of greatest larval shad abundance. An exception to this was 1982 when centrarchids (Lepomis spp. and Pomoxis spp.) accounted for more than 36 percent of total catch (table 8-6) at the seasonal peak on June 7 (table 8-7).

Migratory Taxa--Larvae of migratory taxa (species known to have distinct spawning migrations) reported to spawn in tailwaters were not numerous in the samples. Spotted sucker larvae (three specimens) occurred only in 1976 and 1977 (table 8-6). Only seven specimens of Stizostedion spp. were collected and none were present in samples the last five years of study. Sauger (Stizostedion canadense) hatch at 5-7 mm TL (Priegel, 1969) and walleye (S. vitreum) at 6.0-6.8 mm TL (Priegel, 1970). The specimens of Stizostedion spp. from the immediate vicinity of WBN were too large (10-18 mm TL) to have hatched below Watts Bar Dam, apparently, occurring in the WBN area as a result of dam passage.

Temperate basses (Morone spp.), another migratory taxon, accounted for more than one percent of total larval catch during five of the last six years of this study. Morone larvae occurred in samples from late March to mid July. Seasonal day/night densities indicate typically higher nighttime catches, although the differences were often minimal (table 8-8). During 1976-1979, Morone larvae were reported to have occurred near WBN only as a result of dam passage (TVA 1980a). Subsequent observations of data from 1984 and 1985 indicated that occurrence of Morone larvae near WBN was the result of both dam passage and tailwater spawning. For example, in 1984, 283 Morone (not saxatilis) larvae collected at WBN were 3-6 mm in length and probably spawned below Watts Bar Dam, while 108 Morone sp. larvae ranged from 7-13 mm suggesting that most were spawned above the dam and collected at WBN after dam passage.

Perca flavescens--Yellow perch is a relatively new species in the Tennessee River system, having been introduced into Chatuge Reservoir on the Hiwassee River in 1953 (Timmons, 1975). The gradual spread in distribution of this species in the system makes documentation of spawning success noteworthy. Yellow perch larvae first occurred in WBN larval fish samples in 1978 and were subsequently collected in April and early May in 1982 through 1985 (table 8-6). Perca flavescens is not typically a tailwater spawner but adults of this species are common in Watts Bar Reservoir. The presence of yellow perch larvae in ichthyoplankton samples at the WBN site is, therefore, probably the result of dam passage.

Clupeidae--Unspecified clupeids first appeared in samples in early April and were captured in greatest numbers in May and June.

Yearly seasonal catch for clupeids varied with greatest numbers observed in 1977 (table 8-6). Horizontal distribution of unspecified clupeids was relatively uniform in 1976 and 1977 (table 8-9). In the four remaining years, the channel stations showed uniform distribution, but for shoreline stations, seasonal densities were highest three of the four years on the right shoreline. Day and night collections of clupeids were similar during the years of greatest densities but during those years when numbers were low (1978, 1979, and 1982), seasonal densities estimated from night collections were approximately twice those for daytime samples (table 8-8).

Gizzard shad post larvae were relatively abundant in samples collected in 1977, 1978, and 1982 (table 8-6). They were present in samples from June through August, with greatest densities occurring in June and July. Mean seasonal densities of gizzard shad were dramatically higher in night samples (table 8-8). Net avoidance in daytime samples is a plausible explanation for this difference.

Threadfin shad post larvae were collected in greatest numbers in 1976 (table 8-6), but then virtually disappeared for three years. This is probably a reflection of cold weather mortality of adult threadfin shad during the severe winter of 1976-1977.

It is unlikely that the Watts Bar Dam tailwater is an important spawning area for clupeids (Dorosoma spp.). Eggs of gizzard and threadfin shad are demersal and adhesive, and larvae of both species hatch at approximately 3.5 mm total length (Shelton, 1972). Shelton also reported growth of both species to be 1 mm or more the first day at 23°C. Typically, water transport time from Watts Bar Dam to the plant site

(TVA 1986)

would not exceed five to six hours (personal communication with Christopher Ungate, TVA Water Systems Development Branch). Most of the smaller clupeids (4-5 mm) were collected during peak density periods in May when water temperatures were less than 23°C (table 8-3). Developmental rates should, therefore, be comparable to or slower than those described by Shelton. With the short transport time, high densities of 4 mm clupeids would be expected at the plant site if the tailwater were an important spawning area. Table 8-10 shows relatively low densities for this size class near WBN, suggesting the origin of most clupeid larvae collected at WBN to be above Watts Bar Dam. Densities of shad larvae above Watts Bar Dam, Lowe Branch site in 1978, were consistently greater than those at WBN (TVA, 1980a). This, in conjunction with slightly larger mean lengths for clupeids at WBN, implies larval and post larval shad below the dam were there as a result of dam passage.

Lepomis spp.--Lepomid larvae were relatively abundant all years (table 8-6), usually first appearing in samples around mid-May. Densities were typically greatest in June and July and for all years were higher in night samples (table 8-8). Horizontal distributions were uniform in 1976 and 1977 (table 8-9) when all stations sampled were basically riverine. Densities of Lepomis larvae from the shoreline were dramatically higher than other stations in 1978, 1982, and 1985. In 1985 Lepomis densities were also much higher in the intake forebay. Two-way ANOVA for seasonal mean densities among stations, showed significantly ($P < 0.01$) higher densities for Lepomis larvae at both the right shoreline station and in the intake channel than from channel samples. This indicates that these two areas are spawning and nursery areas for lepomids.

Pomoxis spp.--Crappie larvae were collected in greatest densities during May and June for all six years. Day and night densities were similar, but slightly higher at night in those years when greater numbers of crappie were collected (table 8-8). Horizontal distribution patterns were relatively uniform with seasonal densities similar at all stations across the transect (table 8-9). Suitable spawning habitat for crappie in the Watts Bar Dam tailwater is minimal. Size distributions of Pomoxis larvae collected at WBN (table 8-11) show that approximately 32 percent of the total were 4 and 5 mm specimens. Crappie larvae swim up from the nest when total length is between 4.1 and 4.6 mm (Siefert 1968; Carlander 1977). These data present the possibility of crappie spawning below Watts Bar Dam. However, the distance from WBN to the area above Watts Bar Dam where crappie are documented to have spawned is only 2.5 river miles and it is conceivable that even the smaller larvae may have reached WBN via dam passage. A greater mean size of crappie larvae collected at WBN that at Lowe Branch in 1978 (TVA, 1980a) suggests their occurrence at WBN is also via dam passage.

Aplodinotus grunniens--Freshwater drum larvae comprised from 0.3 to 18 percent of total catch at WBN each year (table 8-3) and were present in samples from May through September, with greatest densities in June and July. Mean seasonal densities of this species were the least variable of the abundant taxa and similar densities were observed during day and night samples (table 8-5).

Freshwater drum larvae collected at the WBN site probably came from above Watts Bar Dam. Swedburg and Walburg (1970) reported the incubation period for freshwater drum embryos reared at various water

temperatures was 36 hours at 21°C, 27 hours at 23°C, and 22 hours at 25°C. During this study, freshwater drum eggs were collected at the WBN site in water ranging from 18°C to 27°C. With the rapid transport time of the Watts Bar tailrace, freshwater drum eggs (which are semi-buoyant, therefore planktonic) spawned downstream of the dam would be transported past the plant site before hatching. Low numbers of eggs collected throughout this study (table 8-3) also indicates that the Watts Bar tailwater is not an important spawning area for freshwater drum.

8.2.2 Juvenile and Adult Fish

Experimental Gill Nets and Hoop Nets--A total of 50 species, including the hybrid white x striped bass, from 13 families were collected with experimental gill nets. Hoop net sampling resulted in a total of 45 species from 12 families and also included the white x striped bass hybrid. An unidentified redhorse and hybrid sunfish were recorded for both types of sampling gear, respectively. Other unidentified species collected with experimental gill nets include gar and temperate bass, while an unidentified lamprey was collected with hoop nets. A single highfin carpsucker was recorded for both gear types over the seven-year study period. As this species is very rare and has not been collected by other sampling methods employed during the study (e.g., electrofishing and cove rotenone), it is probable that these specimens were actually river carpsucker which closely resembles the highfin carpsucker in many identifying characteristics.

Experimental Gill Nets--From February 15, 1977 to December 11, 1985, experimental gill nets were fished a total of 892 net nights at

station A and 566 net nights at station B. A total of 20,157 fish was collected, with 9,087 of these at station A and 11,070 at station B (table 8-12). This resulted in an overall c/f of 19.6 at station B, which was 1.9 times greater than that at station A (10.2). The higher c/f at station B was primarily due to greater catches of certain species (e.g., blue catfish), rather than any notable differences in species diversity between the two stations. Clupieds comprised over 53 percent of the total catch for both stations combined. These included skipjack herring (8.38 percent), gizzard shad (14.34 percent), and threadfin shad (31.02 percent). Of the 50 species collected with experimental gill nets, a total of twelve were designated as "important". These were longnose gar, skipjack herring, gizzard shad, threadfin shad, spotted sucker, blue catfish, channel catfish, white bass, yellow bass, logperch, sauger, and freshwater drum. These species comprised 91.7 percent of the total number of fish collected at stations A and B combined (table 8-12).

MANOVA tested influences of year, station, quarter, net pair within station, and variable interactions on the c/f of these important species. Table 8-13 summarizes the results for those terms which proved significant (alpha = 0.05). The parameter with the highest F-value was from stations, which reflects the overall station difference in c/f noted earlier. The next largest F-value was from quarters, a predictable result since catchability of fish in nets is greatly influenced by seasonal changes in distribution and abundance (e.g., spawning migration and recruitment) and varying environmental factors within seasons (e.g., water temperature and velocity) that affect behavior of fish. In descending order, other significant effects were among years and net

pairs (within each station, respectively), followed by quarter x station, year x quarter, year x station, and quarter by net pair (within each station respectively) interactions on c/f of the important species.

ANOVA examined effects of year, station, quarter, net pair, and associated interactions on individual important species (table 8-14). Differences in net pairs within station were significant for channel catfish, and highly significant for blue catfish and freshwater drum. An examination of the mean c/f by net pairs for these species indicates that highest catches occurred at station B on the right descending bank at net sites 5 and 6 (table 8-15). When compared to the left bank at this station, right bank c/f values for channel catfish and freshwater drum were higher by a factor of 1.72 and 1.97, respectively. The greatest difference in c/f values between right and left banks at station B occurred for blue catfish. Catch values for this species were 716 percent greater on the right bank than on the left. An examination of the field records from 1982 through 1985 for these three species indicated that the majority were captured at net number B(5) which is located in a relatively deep overbank area within a large back eddy. During this period, catches of blue catfish at net site B(5) comprised 83.0 percent of the total catch for this species on the right bank. A similar comparison indicated that catches of channel catfish and freshwater drum at this site comprised 57.7 and 82.3 percent of the total number collected. The 25.4 mm and 38.1 mm mesh sizes showed higher catches for all three species indicating that most specimens were relatively small in size. Based on preferences with respect to depth, current, and cover (Pflieger, 1975), it is probable that the higher c/f

values observed resulted from these species being attracted to the relatively unique habitat available at this site.

Year effects were highly significant for longnose gar. This resulted from relatively high catches during 1977 and, to a lesser degree, in 1978 (table 8-16). Highest c/f values during these periods occurred during fall, 1977 and spring, 1978 at station B. No consistent patterns of seasonal abundance were observed for this species which accounts for the highly significant year x quarter and year x quarter x station interactions shown in table 8-14. Generally, c/f values for station B were higher than station A during the first 3 years of sampling (1977-1979) and lower for the remainder of the study period (table 8-17) resulting in a highly significant year x station effect.

Main effects (i.e., year, quarter, and station) were highly significant for skipjack herring. Year effects indicated that relatively high c/f values for this species occurred in 1977 and again in 1985. Mean c/f values for station (table 8-18) and quarter (table 8-19) indicated that skipjack herring were generally more abundant at station B, and that greater catches occurred during the fall and summer months.

Mean annual c/f for gizzard shad, which showed a significant year effect (table 8-14 was lowest during 1979 and 1982. Highly significant quarter effects were related to increased c/f values during the summer and fall months (table 8-19). Station interaction by quarter, which was highly significant for this species, was the result of greater c/f at station B during the summer and fall quarters.

Year, quarter, and year x quarter interaction demonstrated a highly significant effect on threadfin shad c/f values. Greatest mean

annual c/f for this species occurred in 1985. Figure 8-4 indicates that catches during the summer of 1985 at station B comprised a major part of the mean annual c/f for that year. As with gizzard shad, highest mean c/f by quarter for threadfin shad occurred during the summer and fall quarter at station B. Year x quarter interaction effects were primarily due to fluctuating winter through summer c/f values (figure 8-4).

Of the twelve important species, only spotted sucker c/f values showed no significant effects from year, quarter, station or their associated interactions. Generally, peak catches for this species were observed during the spring quarters at station A, but no overall spatial or temporal patterns of relative abundance were noted.

Blue catfish demonstrated a very distinct pattern with respect to spatial relative abundance (figure 8-5). As noted in the discussion on the effects of net pairs within stations, catches for this species were consistently greater at station B causing a highly significant station effect. Habitat preference for the relatively deep back eddy area at net site B(S) would account for the increased c/f values for this species. Temporal patterns of relative abundance were not observed which is in agreement with the highly significant year x quarter and significant year x quarter x station interactions for this species (table 8-14).

As with blue catfish, channel catfish abundance at station B (table 8-18) was significantly higher than station A resulting in a highly significant station effect. Peak catches at station B occurred during the winter and spring quarters. However, catch values for station A were usually greater than those for station B during the summer

quarters with the highest peak occurring during summer, 1985. This pattern between stations is reflected in the significant quarter x station interaction observed in table 8-14.

White bass showed highly significant effects from year and station (table 8-14). Year effects were related to relatively high c/f values during the first three years (i.e., 1977-1979) of the study, while station effects resulted from higher mean catches (all years combined) at station B. Catches during all winter quarters and spring quarters from 1978 through 1982 were higher at station B, accounting for the highly significant quarter x station interaction for this species. Spatial and temporal patterns of relative abundance over all years were not observed which is in agreement with the significant interaction among quarters by years and highly significant interaction among quarters by year for each station.

Greater c/f values during the spring and summer quarter of each year (table 8-19) resulted in a highly significant quarter effect for yellow bass. A highly significant interaction between quarters by years (table 8-14) confirmed observations that no one quarter exhibited a consistently higher c/f value.

Consistently low catches of logperch occurred during winter quarters resulting in a highly significant quarter effect (table 8-14). Mean quarterly c/f (all years combined) indicated that greatest catches of logperch occurred during spring (table 8-19), probably related to the spawning season for this species. No other trends in relative abundance (spatial or temporal) were identified for this species.

Highly significant year and quarter effects for sauger were noted (table 8-14). These were attributed to higher catches during the first three years of the study and to generally higher catches during the winter and spring quarters of each year. These effects indicate that the highly significant year x quarter interactions occurred primarily during the 1982 through 1985 sample period. An examination of temporal trends for this species indicates a general decline in abundance over the sample period (figure 8-6). While causes for this apparent decline are not known, it does not appear to be related to reduction in the sauger population of the reservoir. This interpretation is based on: (1) preliminary results of a sauger tag/recapture study conducted during the spring of 1986 which indicated a relatively large sauger population in the reservoir and (2) quarterly operational gill netting studies (1980-1985) for SQN did not detect any declining trends for this species (TVA 1986).

Lowest mean annual c/f values for freshwater drum occurred during 1982, while maximum catches occurred from 1977 through 1979, accounting for the significant year effect for this species (table 8-14). An examination of quarter effects, which was highly significant, showed that greatest mean c/f values for freshwater drum occurred during summer and winter sampling quarters (table 8-19; figure 8-7). Freshwater drum catches were consistently greater at station B than at station A throughout the study period resulting in a highly significant station effect. Higher c/f for this species at station B appears to be related to habitat preference for the deep, back eddy at net site B(5).

Hoop Nets--Hoop nets were fished from February 9, 1977 through December 18, 1985. Total effort expended at stations A and B was 967 and 632 net nights, respectively. A total of 7,360 fish were netted, 4,464 at station A and 2,896 at station B (table 8-20). Total c/f for stations A and B over the entire study period was very similar with values of 4.62 and 4.58, respectively.

Twelve species comprised more than 92 percent of the total catch at both stations combined (table 8-20). The three most abundant species were bluegill (38.04 percent), redear sunfish (15.91 percent) and white crappie (10.00 percent). These were followed, in decreasing order, by gizzard shad (6.96 percent), white bass (5.97 percent), mooneye (3.68 percent), spotted bass (3.08 percent), channel catfish (2.30 percent), smallmouth buffalo (2.15 percent), spotted sucker (1.98 percent), redbreast sunfish (1.39 percent),and golden redhorse (1.01 percent). Bluegill and redear sunfish comprised over 60 percent of the catch at station A and over 43 percent of the catch at station B.

Table 8-21 provides a summary of significant effects by year, quarter, and station and the interactions for the twelve important species. The effect of net pairs within station did not show a significant effect and therefore is included in the error term. The greatest influence was by quarter. As noted for experimental gill nets, this result is predictable due to seasonally changing abundance/distribution patterns and environmental factors. Year and station showed the next highest effect on important hoop net species followed in descending order by year x quarter, year x station, quarter x station, and year x quarter x station interactions.

Quarter effects (table 8-22) were highly significant for gizzard shad due primarily to increased catches of this species during winter months (table 8-23). Also, year x quarter interaction, which was highly significant for this species, involved all seasons during the first three years of the study and all but the winter quarter from 1983 through 1985 (table 8-24). Peak c/f values for both stations A and B were observed in spring, 1978 and during the winter quarters of 1983 through 1985 (table 8-24). .

Peak catches of mooneye generally occurred during the winter quarters (table 8-23) with 1978 producing the highest mean annual catch (table 8-25). Higher winter catches may be related to prespawning concentrations of this species which spawns relatively early (Pflieger, 1975). However, larval fish sampling in this area has yielded only a few specimens. Interaction by years occurred among all quarters at station A and primarily between spring through fall quarters at station B (table 8-24). These patterns in spatial/temporal abundance for mooneye accounted for the highly significant year x quarter and year x station interactions (table 8-22).

All main effects (i.e., year, quarter, and station) and their associated interactions, with the exception of quarter x station, were highly significant for smallmouth buffalo (table 8-22). Catch was usually higher at station B (table 8-26) with peaks generally occurring during spring months. Mean annual c/f was greater during the first three years of the study (table 8-25). The highest catch of smallmouth buffalo at both stations A and B was during the spring of 1977. Interaction occurred among all quarters for station A, and among summer through winter quarters at station B.

Spotted sucker and golden redhorse catches were similar between stations and did not exhibit any spatial or temporal trends of relative abundance.

Channel catfish c/f was greatest during 1977 and 1983 (table 8-25) with peaks generally occurring during spring and summer quarters (figure 8-8). The main effect of year and quarter, and year x quarter interaction was highly significant (table 8-22).

White bass c/f demonstrated a significant quarter x station interaction, but effects of station and year x station interactions were not significant (table 8-22). Mean quarterly c/f values for white bass were highest during spring and winter seasons with greater annual catches occurring during the first four years (i.e., 1977-1979 and 1982) (table 8-25). Higher c/f during this period were probably associated with prespawning migration of this species. The significant quarter x station interaction resulted from a higher mean c/f at station B during spring, fall, and winter (table 8-24).

Only year effects was significant for c/f of rebreast sunfish (table 8-22) with highest catches occurring in 1983 (table 8-25). Greater c/f values during 1983 was primarily due to unusually high catches during spring and summer quarters at station B. Lowest catches for this species occurred during winter quarters.

Lowest c/f values for bluegill occurred during the winter quarter of each year (table 8-23) and lowest mean annual catches occurred during 1977 and 1978 (table 8-25). Higher catches of bluegill, alternating between spring through fall quarters, during the seven year study, accounted for the significant year by quarter interaction.

Temporal relative abundance patterns for redear sunfish were similar to those for bluegill with low mean annual catches during 1977 and 1978 (table 8-25), and low c/f values during winter quarters of each year (table 8-23). Year and station effects were highly significant for this species (table 8-22).

Mean annual c/f values for spotted bass (table 8-25) were lowest in 1984. Seasonal catches (table 8-23) generally were lowest in winter and increasing through spring, summer, and fall quarters of each year. These patterns resulted in significant year effects and highly significant quarter effects for this species (table 8-22).

White crappie c/f in hoop nets was significantly different for year, quarter, and station; also, year x quarter and year x station interactions were highly significant (table 8-22). Low mean annual c/f during 1984-1985, generally higher seasonal catches during the spring and summer quarters of each year, and the overall greater abundance of this species at station B accounted for these differences.

White crappie were more abundant from 1977 through 1982 at station B, after which mean annual c/f values were higher at station A (figure 8-9). Causes of the apparent spatial/temporal changes in white crappie relative abundance in the WBN vicinity could not be determined. However, these changes appeared to be independent of the cyclic abundance pattern indicated by the reservoir-wide creel survey.

Electrofishing--During the two monitoring periods (1977-1979, 1982-1985) at WBN, 1,439 electrofishing runs yielded 95,265 fish representing 46 species from 12 families (table 8-27). Three species comprised 84 percent of the total catch; gizzard shad (55 percent),

emerald shiner (22 percent), and threadfin shad (7.2 percent). Five additional species exceeded one percent of the total catch and qualified as important species; bluegill (3.8), redear sunfish (2.7), brook silverside (2.0), yellow bass (1.5), and largemouth bass (1.3). White bass (0.51 percent), although not meeting the one percent criterion, were included in the important species analyses. Overall c/f for the important species is listed in table 8-28.

Average c/f during the monitoring period for all species (both stations) was 66 fish per shocking run, with highest catch rate in winter and fall quarters. Total c/f was 86.3 at station A and 46.5 at station B (table 8-29). Comparisons between c/f on left and right banks at stations A and B for nine important species indicated that only white bass were significantly (0.05) higher on one bank. Catch rate for this species was over three times higher (0.13) at the left bank of station A than at the right bank, or at either bank of station B. This might be due to a more suitable substrate (sand, rock) for this species on the left bank of station A (appendix 8-D). Catch data from left and right banks were combined in all remaining analyses.

Mean quarterly c/f by year for the important species is presented in table 8-30. Three-way ANOVA, plus area nested within station, testing revealed significant effects by sample quarter for seven of nine important species (all except gizzard shad and brook silversides). Significant year x quarter interactions were observed for eight of nine (all except yellow bass) important species (table 8-31). Inconsistent quarterly changes during the seven years of sampling are responsible for the significant year x quarter interactions and would

prohibit use of quarterly trends to detect operational impacts at WBN. For example, c/f of emerald shiner was highest during fall in 1978, spring in 1979, and summer in 1982. Similar inconsistencies account for year x quarter interactions for other important species.

Tests for year effect proved highly significant for six of the nine important species (table 8-31), and nonsignificant for the other three (yellow bass, redear sunfish, and largemouth bass). As noted for quarterly effects, differences in c/f among years were not consistent among species. Catch per effort for threadfin shad was highest in 1977, emerald shiner and white bass in 1978, brook silversides in 1979, gizzard shad in 1982, and bluegill in 1983. Lowest c/f was recorded in 1985 for gizzard shad, white bass, and bluegill. White bass and brook silverside showed marked declines in numbers and c/f in the last four years (1982-1985) of sampling.

Station effect was highly ($P < 0.01$) significant for gizzard shad, emerald shiner, and yellow bass and signficant at the 0.05 level for threadfin shad, white bass, and bluegill (table 8-31). Catch per effort for all species was greater at station A than station B. Differences in habitat and food supply probably accounted for higher catch at station A. Analysis of station x quarter interaction revealed only largemouth bass with a significant effect for this variable. Exceptionally high c/f (67.1) during summer quarter at station A is responsible for this difference.

The higher of c/f at station A for all important species and lack of station/quarter interaction (except largemouth bass), suggests that potential changes in distribution of these species due to WBN

operation could be tested by electrofishing. The location of station A immediately adjacent to the plant, further emphasizes the potential for detecting either attraction to, or avoidance of this area by selected species during plant operation.

Significant year, quarter, and year x quarter interaction effects noted for most important species, as well as inconsistent trends among the species for these variables, limits their use in testing for WBN operational effects. Usefulness of electrofishing data, as with that of other gear types, is dependent on efficiency and consistency of sample collection. Factors which influence electrofishing data were described in three categories by Reynolds (1983); fish characteristics, habitat characteristics, and operating conditions. Particularly in a tailwater habitat such as that found near WBN, numbers of species and abundance will vary seasonally and habitat conditions may change abruptly due to changes in water volumn discharged from Watts Bar Dam. However, catch-per unit effort by electrofishing is a useful index to the abundance of the populations of selected fish species in the WBN vicinity.

Reservoir-Wide Creel--Game fish harvest and fishing pressure information have been collected on Chickamauga Reservoir each year since 1972. Anglers consistently harvest 24 species of fish. Of these, nine are considered important (i.e., comprising at least 1 percent of the total biomass or numbers harvested each year). Creel information from January 1972 through June 1976 was reported in the Sequoyah Nuclear Plant (SQN) preoperational report (TVA 1978) and summary data from July 1976 through June 1984 have been reported in the SQN operational monitoring report (TVA 1985).

Numbers--Since 1972 fishermen caught an average of 247,260 fish per year from Chickamauga Reservoir (table 8-32). The lowest catch occurred in 1984 when 138,506 fish were creeled; a high of 336,968 fish was recorded in 1980. Over a 13-year period white crappie was the highest contributor to total catch at 51.1 percent; bluegill was the next highest with 17.2 percent. Other important species in descending order were white bass, channel catfish, largemouth bass, sauger, freshwater drum, blue catfish, redear sunfish, and black crappie.

Several trends in harvest of individual species are evident. Annual catches of largemouth bass (figure 8-10) and yellow perch have shown significant increases ($P > 0.01$ and $P > 0.05$ respectively). Catch levels of bluegill showed a marked decline ($P > 0.05$) over the study period (figure 8-11). The increase in yellow perch is attributed to the fact that it is an invading species, not endemic to the reservoir. Yellow perch was first collected in Chickamauga in 1970 cove rotenone samples, but did not occur in the creel survey until 1972. Catch levels are expected to continue to increase until this species reaches its capacity in suitable habitats. The increase in largemouth bass harvest is probably associated with increase in rooted aquatic vegetation (figure 8-12). Positive relationships between increased acreages of aquatic vegetation and increased largemouth bass production have been reported by Durocher, et al. (1984) and Wiley, et al. (1984). In contrast to increased bluegill production observed in gill net and cove rotenone studies on Chickamauga (TVA 1984), bluegill harvest has declined. It is postulated that submerged vegetation represented a barrier to fishermen, hindering access to shallow shoreline areas where bluegill congregate.

Biomass--An average of 80,022 kg of fish were harvested annually from Chickamauga during the 13 survey years. The lowest estimate was 47,128 kg in 1974 and the highest was 131,098 kg in 1982 (table 8-33). Overall, white crappie accounted for 24.9 percent of total catch. The next closest contributor was channel catfish with 15.1 percent. Other important species were largemouth bass, white bass, blue catfish, bluegill, sauger, freshwater drum, and striped bass.

Regression analysis of biomass of various species versus time yielded results corresponding to the analysis of numbers harvested. Significant trends in harvest were identified for largemouth bass, yellow perch, and bluegill (figures 8-13, 8-14, and 8-15).

Pressure--Fishermen spent an average of 392,625 hours on Chickamauga each year. Lowest pressure observed was 216,868 hours in 1974, in contrast to a high of 523,780 hours in 1982 (table 8-34). Regression analysis identified a significant increase ($P > 0.05$) in hours spent on the reservoir over the 13-year study (figure 8-16). Seasonal patterns of pressure are typical of the region: low in fall and winter and high in spring and summer. Total pressure will vary from year to year and is highly influenced by weather conditions, water levels, and turbidities. The low pressure estimates calculated for 1973 and 1974 are attributed to high rain fall in those years.

Catch Rates--Catch data collected was standardized according to both hours of fishing pressure applied and reservoir surface area to remove the effects of these factors in the analysis. Average annual catch rate since 1972 was 0.63 fish/hr, ranging from 0.34 in 1984 to 1.18 in 1978 (table 8-35). Average rate of biomass harvested was 0.20 kg/hr,

with a low of 0.10 in 1975 and a high of 0.36 in 1973. Harvest per unit surface area ranged from 9.7 fish/ha and 4.3 kg/ha in 1984 to 21.4 fish/ha and 5.9 kg/ha in 1980.

Of the three species showing increasing or decreasing trends in total catch, only bluegill catch showed a significant trend ($P > 0.05$) when the effect of pressure is removed (figure 8-17) Therefore, increases in largemouth bass and yellow perch catch are directly related to increased fishing pressure. Regressions of largemouth bass and yellow perch catch rates against increases in submerged rooted vegetation were conducted. Largemouth bass catch rates showed a high correlation (R^2 = 0.76) (figure 8-12). The lack of strong correlation between yellow perch and rooted vegetation is attributed to the continued expansion of this population.

WBN Vicinity Creel--Recreational fishing harvest data were collected in the vicinity of WBN (TRM 526.8 to TRM 529.2) from April 1982 through December 1985. This area of Chickamauga Reservoir is characterized by lotic flows, no large coves, and less aquatic vegetation. Water released from Watts Bar Dam is generally rich in microscopic fauna and flora, and fish concentration in such areas in generally recognized.

Of twenty-three fish species observed in anglers creel, nine were considered important (comprising at least one percent of total numbers or biomass each year). These were channel catfish, white bass, striped bass, white crappie, bluegill, largemouth bass, smallmouth bass, blue catfish and yellow bass (tables 8-36 through 8-39). Over the 45-month survey period, bluegill was the major contributor (35 percent)

to total creel numbers; channel catfish and white crappie were the next highest contributors. For the same period in the reservoir-wide survey, white crappie was foremost in numbers caught and bluegill second. In terms of biomass channel catfish was the major species harvested (40 percent) in the tailwater. Bluegill and white bass were the second and third in biomass harvested.

Catch rate (fish/hr) in the WBN vicinity was 0.73 in 1982, 0.83 in 1983, 1.00 in 1984 and 1.16 in 1985. By comparison catch rates reservoir-wide were 0.63 in 1982, 0.58 in 1983 and 0.34 in 1984. There is an apparent increasing trend in catch rate in the WBN area. Total biomass harvested per hour fished (kg/hr) for the WBN area was 0.31 in 1982, 0.30 in 1983, 0.29 in 1984 and 0.29 in 1985. These were slightly higher than the 1982, 1983, and 1984 harvest rates observed reservoir-wide (table 8-35), but indicate a slight decreasing trend in harvest rates (kg/hr) since 1982.

Cove Rotenone--In 1985, 37 species representing 11 families were collected in cove rotenone samples in Chickamauga Reservoir. All species collected in 1985 previously had occurred in cove rotenone samples from this reservoir (table 8-4). Numerically, threadfin shad was the most abundant species (49 percent), followed by bluegill (23 percent) and gizzard shad (12 percent). Gizzard shad comprised 51 percent of the total biomass sampled, whereas biomass of threadfin shad and bluegill was 17 percent and 5 percent, respectively. Freshwater drum made up about 6 percent of total biomass, but this species only comprised 0.8 percent of the total number.

Standing stock of all young, intermediate, and harvestable size classes of fish in Chickamauga Reservoir in 1985, determined by five cove rotenone samples, was 46,411 fish/ha with a biomass of 528 kg/ha (table 8-40). Young-of-year fish represented 93 percent of the standing stock by number and 27 percent of the biomass. Whereas harvestable size fish comprised 68 percent of the biomass, numerically this size class was only 5 percent of the standing stock.

Forage species dominated biomass again in 1985 (365 kg/ha; 69 percent; table 8-41). Game and commercial fish comprised about 12 percent (63 kg/ha) and 19 percent (100 kg/ha) of the biomass, respectively. About 30 percent of the fish population by number were young-of-year game fish, primarily bluegill and other sunfish. Young-of-year game fish comprised 3 percent of the total biomass.

Temporal and Spatial Trends--Seventy-one species encompassing 15 families were collected in cove rotenone samples in Chickamauga Reservoir from 1970 through 1985 (table 8-4). Mean numbers per hectare by species and location are shown in appendix 8-F, and mean biomass estimates are shown in appendix 8-G. Bluegill was the predominant species numerically, comprising 41 percent of the total number of fish collected (appendix 8-H). Only three species (gizzard shad, bluegill, and freshwater drum) were present in all cove samples from 1970 through 1985 (appendix 8-I). Appendices J and K show annual mean number and biomass of each species collected in rotenone samples.

Numbers of young fish were highest in 1981, and biomass of harvestable fish was highest in 1984 and 1985 (table 8-40). Table 8-41 shows a general increase in numbers and biomass of game fish from 1970

through 1983 with no distinct trend for either commercial or prey fish groups. Since 1983, forage fish biomass has increased substantially, while biomass of game fish has been stable.

Important Species--Nineteen species were classified as important, or special interest, in cove rotenone samples (table 8-42). Results of linear regression analyses (table 8-43) and numerical abundance and biomass of young, intermediate, and adult size classes of each species through time are discussed below.

Gizzard shad--Adult gizzard shad biomass has increased since 1983 (table 8-44). However, from 1970 through 1985, no statistically significant trends were found for either numbers or biomass of adult gizzard shad in Chickamauga Reservoir. Biomass of young-of-year gizzard shad continued to show a significant increasing trend; it approached 30 kg/ha in 1985. Results of linear regression analysis can be considerably influenced by the most recent values for a given species, particularly if the species exhibits large year class variability as with gizzard shad.

Threadfin shad--Over the period 1970 through 1984, numbers and biomass of young-of-year threadfin shad showed a significant decline. Extremely cold winters in 1977-1978, 1978-1979, and 1983-1984 apparently contributed to this decline. However, following an abrupt increase in 1985 (92 kg/ha), the significant decreasing trend was eliminated. Estimated numbers of threadfin shad in 1984 were about 900/ha compared to about 23,000/ha in 1985 (table 8-45).

Although other environmental/compensatory mechanisms may have influenced the dramatic increase in threadfin shad, more open water along

shorelines and coves in 1985 than in other recent years likely contributed to the record high stock estimate of this species. Increased open water habitat was the direct result of an experimental summer drawdown of Chickamauga Reservoir approximately one month before cove areas were sampled. Houser and Bryant (1968) indicated that, in the absence of aquatic weeds, cove standing stocks of threadfin shad were equal to open water stocks in two Arkansas reservoirs.

Carp--Young-of-year carp increased significantly (both numbers and biomass) in Chickamauga Reservoir over the period of study (1970 through 1985), but no statistically significant trend was observed for numbers or biomass of intermediate or adult carp. However, cove rotenone probably does not provide a representive sample of all size classes of this species (table 8-46), and statistically significant increasing or decreasing trends should be qualified.

Bullhead minnow--Bullhead minnow occurrence prior to 1971 was sporadic but this observation may have been due to misidentification of this species. Since 1971, stocks have been relatively high and have shown an increasing trend through time.

Smallmouth buffalo--Over the period 1970 through 1985, both numbers and biomass of intermediate and adult size classes of this species have declined significantly based on regression analysis. However, total number (40/ha) of smallmouth buffalo increased in 1983 rotenone samples and were similar to levels observed in 1971 and 1972 (table 8-47). The influence of aquatic vegetation on the distribution and abundance of this species in Chickamauga Reservoir has not been established; however, there has been some indication that smallmouth buffalo avoid areas of dense vegetation.

Spotted sucker--Biomass and numbers of young-of-year spotted sucker show a significant decreasing trend. Spotted sucker was not identified in rotenone samples in Chickamauga Reservoir prior to 1959. As noted in a previous report (TVA, 1982) this species may be nearing the end of an expansion phase. However, total biomass increased slightly in 1985 (table 8-48).

Channel catfish--Intermediate size channel catfish (both numbers and biomass) continued to show a decreasing trend, whereas biomass of adults continued to have an increasing trend through time. A declining trend was noted previously for intermediate size channel catfish (TVA, 1978b; 1980; and 1983). Except for 1981, estimated total biomass of this species has been less than 15 kg/ha (table 8-49).

Flathead catfish--Through 1983 no significant trend for biomass or numbers of any size class of this species was determined, but in 1984, numbers of young and numbers and biomass of adults showed a significant decline. In 1985, a significant decline in the intermediate class was noted. However, total biomass estimates for flathead catfish since 1970 have seldom exceeded 1 kg/ha.

White bass--Numbers of young white bass, relatively low throughout the sampling period, showed a significant decreasing trend. Annual biomass estimates for this species have been consistently below 1.0 kg/ha until 1985.

Yellow bass--All size classes of this species increased significantly (both numbers and biomass) for the period 1971-1985. Total biomass for this species was highest (10 kg/ha) in 1981, and total numbers were highest in 1982 (table 8-50).

Warmouth--All three size classes of this species have increased significantly (both numbers and biomass) through time, although numbers and biomass were down in 1985. Warmouth did not meet criteria for "important species" status when SQN preoperational studies were analyzed (TVA, 1978b). When data were analyzed for the initial WBN preoperational report (1970-1979), warmouth abundance had increased to meet these criteria. Linear regression analyses for the previous WBN preoperational monitoring revealed that, with the exception of numbers of young warmouth, all size groups were increasing significantly. Numbers per hectare of young warmouth had increased but the trend was not statistically significant. For five of the past six years, total numbers have exceeded 1,000/ha (table 8-51).

Bluegill--Numbers and biomass of young of year of this species increased significantly through time. A significant increasing or decreasing trend for other size groups was not determined. Estimated total biomass for this species frequently has been above 30 kg/ha (table 8-52). During the preoperational period for SQN (TVA, 1978b) only numbers of young bluegill exhibited a significant increasing trend. The initial preoperational data analyses for WBN (TVA, 1980) indicated numbers of all three size classes increased while biomass of only the young size class showed a similar trend. Based on recent results, it appears that numbers of young-of-year bluegill in Chickamauga have stabilized. As indicated in previous analyses (TVA, 1983), an increase in aquatic vegetation in Chickamauga Reservoir has contributed to higher standing stocks of centrarchids, particularly young-of-year.

Longear sunfish--Neither numbers nor biomass of any size group was found to be increasing or decreasing. Previous analyses (TVA, 1978b and 1980) showed increases for young and intermediate sizes, although adult numbers and biomass exhibited no trend. Total biomass was less than 5 kg/ha for the 1970-1985 period.

Redear sunfish--Total biomass for this species in 1985 was 10 kg/ha (table 8-53). As in previous analyses, biomass and numbers of young redear sunfish showed a significant increasing trend. Biomass and numbers of the intermediate size class also showed a significant increasing trend. This general increasing trend probably has been related to increased aquatic macrophytes in Chickamauga Reservoir.

Largemouth bass--Through 1983, numbers of all three size classes of largemouth bass showed an increasing trend (TVA, 1984). In 1984, biomass of young-of-year and numbers of intermediates continued to show a significant increase. Following 1985, a significant increasing trend for numbers and biomass of adults was established. Total biomass was 18 kg/ha in 1985, and since 1978 it usually has exceeded 10 kg/ha (table 8-54). Abundance of all size classes of largemouth bass appears to be directly related to increases in young bluegill and other centrarchids.

White crappie--Neither increasing nor decreasing trends were found for number or biomass of young white crappie. Biomass of the intermediate size class continued to show a decreasing trend. Also, following 1984, numbers and biomass of adults had a decreasing trend. Previous data analyses for the SQN preoperational report revealed declining numbers and biomass of adults (TVA, 1978b), but more recent

analyses performed for the initial WBN preoperational report (TVA, 1980a) and those for 1983 (TVA, 1984) showed neither increasing nor decreasing trends. Since 1970 total biomass of white crappie estimated by cove rotenone samples has not exceeded 5 kg/ha (table 8-55).

Sauger--Although numbers and biomass of the harvestable size class of sauger had a decreasing trend through 1984, this trend was not apparent in 1985. This species is seldom collected in coves.

Yellow perch--Both numbers and biomass of adults had a significant increasing trend. This species apparently became established in Chickamauga Reservoir sometime after 1959 and first appeared in cove rotenone samples in 1970. Adults were first collected in cove rotenone samples in 1978. At the time data analyses were performed for the SQN preoperational report (TVA, 1978b), only young had been collected, and no trend could be determined. At the time data analyses were performed for the initial WBN preoperational report (TVA, 1980a), intermediate and adult size classes had only been collected for two years, but linear regression analyses showed increasing trends. Most recent results confirm that this species has become established in Chickamauga Reservoir, and the population is expanding, although total biomass has not exceeded 4 kg/ha (table 8-56).

Freshwater drum--For the period 1970 through 1985, linear regression analyses revealed both numbers and biomass of young and intermediate size freshwater drum have declined in Chickamauga Reservoir. These apparent trends were first documented prior to unit 1 fuel load at SQN (TVA, 1980). Mean annual numbers and biomass (table 8-57) show a possibly cyclic pattern for these two size groups;

stocks were high in the early to mid 1970's, then decreasing through the late 1970's and early 1980's, and subsequently increasing through 1985. Young-of-year numbers in 1985 were the highest since 1973, while intermediate numbers in 1985 were the highest since 1977. No similar cyclic pattern is evident for adult freshwater drum; also, linear regression analyses revealed no significant increasing or decreasing trends in adult stocks. The apparent reductions or cycling in young and intermediate stocks are not considered ecologically significant unless they are ultimately reflected in reduced stocks of adults. However, because high entrainment rates of freshwater drum were noted at SQN, TVA has initiated investigations to determine if entrainment losses at SQN provide an explanation of reduced numbers of young and intermediate size freshwater drum. Investigations are planned in two phases: (1) length frequency and age structure of the adult population to determine if recruitment to adult size may be restricted and (2) fish egg and larvae collections at SQN and downstream to determine if significant reproduction occurs beyond the influence of the plant's intake such that eggs and larvae would not be subjected to entrainment. The first phase of the study was conducted in 1986, while the second phase is not planned until SQN resumes operation.

Another plausible explanation for reduced stock estimates of young and intermediate sizes of freshwater drum may be due to increases of aquatic macrophytes in the reservoir since the mid-1970's. From 1976 through 1983 there was a seven-fold increase in the acreage affected by rooted aquatic vegetation in Chickamauga Reservoir. Unlike many of the centrarchids, young and intermediate sizes of freshwater drum seem to

prefer open water areas and appear to avoid coves with dense aquatic vegetation. In support of this premise, young and intermediate freshwater drum have been more abundant in the uppermost sample cove in Sewee Creek at TRM 524.6 where aquatic macrophytes have always been absent.

From 1970 through 1984, numbers and biomass of freshwater drum were found to be most abundant in the upstream portion of Chickamauga Reservoir. Following 1985, however, no differences among areas of the reservoir were not detected. In late July and early August 1985, approximately one month before cove rotenone sampling was performed, TVA conducted an experimental drawdown of Chickamauga Reservoir for aquatic plant control on a broad scale. The drawdown was very effective in reducing aquatic macrophytes in shoreline areas throughout the reservoir, including the coves sampled with rotenone. When the reservoir was refilled following the drawdown, additional open water habitat was available. This change, favorable to those species preferring open water and/or "edge" habitats, appears to have been at least partially responsible for both higher stock estimates of young and intermediate freshwater drum in 1985 and the more even distribution of numbers and biomass of this species among the coves sampled.

8.3 Summary and Conclusions

8.3.1 Eggs and Larvae

Preoperational monitoring for fish eggs and larvae near WBN, from 1976 through 1979 and 1982 through 1985, revealed the presence of few taxa and relatively low seasonal densities. Fish eggs collected at

WBN were those of Morone sp. (tentative identification) and freshwater drum. Morone sp. eggs could possibly have been spawned below Watts Bar Dam and dislodged by turbine discharge, but freshwater drum eggs were apparently spawned above the dam and drifted past WBN via dam passage.

Larval samples at WBN were dominated by clupeids (shad). Lepomis and freshwater drum larvae were next in abundance and were the only other taxa to consistently exceed one percent of the total larval catch throughout the study. Greatest seasonal density of total larvae (2,697/1,000 m^3) occurred in 1977.

Very few eggs or larvae of species known to spawn in tailwaters were collected, indicating most spawning occurred downstream of WBN. One exception to this could be Morone sp., which, based on tentative egg identification, may have spawned to some extent between Watts Bar Dam and WBN. Spawning in the littoral area near WBN (including the plant intake channel) by Lepomis sp. was indicated as larval densities were significantly higher at the shoreline and intake stations.

In summary, the ichthyoplankton assemblage seasonally drifting past WBN represents eggs and larvae spawned primarily in Watts Bar Reservoir and exposed to passage through the turbines at Watts Bar Dam. Some mortality from dam passage probably occurs, but its effect to the fish community of Chickamauga Reservoir has not been determined. Subsequent operational monitoring at WBN will be directed at assessing plant effects to fish eggs and larvae found in and near the plant intake. Other analyses will include continued description of temporal abundance of eggs and larvae passing WBN and determination of any spawning which might occur in the tailwater above WBN.

8.3.2 Juvenile and Adult Fish

Experimental Gill Nets and Hoop Nets--Relative abundance of fish species important (dominant) in gill net catches varied both temporally (i.e., seasonally and yearly) and spatially (i.e., by station). Seven species (longnose gar, skipjack herring, gizzard shad, threadfin shad, white bass, sauger, freshwater drum) showed significant year effects, but only sauger demonstrated a consistent (declining) trend. Although causes for this decline were not apparent, it did not appear to reflect a decline in the total reservoir population. Significant differences by quarter also occurred for seven of the twelve dominant species. Catches of clupeids (i.e., skipjack herring, gizzard shad, and threadfin shad) were generally higher during summer and fall quarters. Yellow bass, logperch, and sauger c/f values were lower during winter, and mean c/f for freshwater drum was highest in winter and summer.

Stations showed a highly significant effect on the c/f of five important species with greater catches occurring at station B (downstream of WBN) than at station A (adjacent to WBN). Three of these species (i.e., blue catfish, channel catfish, and freshwater drum) showed significantly higher catches on the right bank. Habitat preferences (depth, current, and cover) by these species, apparently contributed to the higher c/f at this location.

Of the twelve important species in hoop net catches, all but three species (gizzard shad, spotted sucker and golden redhorse) showed significant year effects. However, none of the species showed any consistent trends, either increasing or decreasing, during the preoperational monitoring period. Quarter effects were highly

significant for nine of the twelve species, with lowest c/f for bluegill, redear sunfish, spotted bass, and white crappie occurring during winter quarter. Winter catches were highest for gizzard shad, mooneye, and white bass but smallmouth buffalo catches were highest during spring. Also, smallmouth buffalo and white crappie were more abundant at station B than station A.

Electrofishing--Electrofishing data supplemented information about adult and juvenile fish distribution and relative abundance, particularly for threadfin shad, emerald shiner, and brook silverside. Catch data varied more temporally (quarterly and yearly) than spatially (by station). Among important species, the most obvious trends throughout the monitoring period were declines in c/f of white bass and brook silverside. The aspect of WBN electrofishing data that may have the greatest potential for measuring plant operational effects is the higher c/f for all important species at station A located adjacent to the plant. Lack of station x quarter interaction and the close proximity of station A to WBN should allow detection of either attraction to, or avoidance of this area during plant operation.

Creel Surveys--Since 1972, angler harvest of largemouth bass and yellow perch has increased, and harvest of bluegill decreased reservoir wide. The increases are associated with increased fishing pressure. Increases in largemouth bass catch (ca. 28,000 kg in 1983) are also correlated with increases in submerged aquatic vegetation; while increases in yellow perch harvest is attributed, in part, to expansion of an invading population. Bluegill harvest may have declined because of dense vegetation hindering fishermen access. Rotenone surveys indicated

that the bluegill standing stock has increased. Overall, white crappie has dominated the reservoir-wide harvest, but numbers and biomass harvested have been cyclic. White crappie harvest was highest in 1973 and 1980 (>30,000 kg) and lowest in 1974 and 1983 (<12,000 kg).

In the WBN vicinity, TRM 526.8 to TRM 529.9, bluegill was the major contributor (35 percent) to creel numbers and channel catfish was the primary producer (40 percent) in terms of biomass, 1982-1985. Seven other species comprised at least 1 percent of the total catch in this area (white bass, yellow bass, striped bass, white crappie, largemouth bass, smallmouth bass, and blue catfish). Since 1982, catch rate (fish/hr) has been higher in the WBN vicinity than reservoir-wide (e.g., in 1984, 1.0/hr vs. 0.34/hr).

Cove Rotenone--Based on cove rotenone sampling since 1970, both increasing and decreasing trends were noted among species ranked dominant and/or important, but total fish biomass has remained relatively stable. Some species (e.g., flathead catfish, sauger, and white crappie) that showed decreases in biomass for one or more size classes were those which cove rotenone generally does not provide a representative sample. On the other hand, species that showed increasing trends (e.g., bluegill, gizzard shad, and largemouth bass) were those which cove rotenone usually provides better estimates of relative abundance.

The overriding influence on standing stock estimates for many of the important fish species appears to be associated with habitat alteration resulting from an increase in aquatic vegetation in shallow overbank and cove areas of Chickamauga Reservoir. From 1976 through 1983 there was a seven-fold increase in the acreage affected by rooted aquatic

vegetation. This has been reflected in higher standing stock estimates for various centrarchids, particularly warmouth, redear sunfish, bluegill, and largemouth bass. Whether or not aquatic vegetation has resulted in a decrease in biomass or numbers of some fish species (e.g., smallmouth buffalo and freshwater drum) is not clear. However, the experimental summer drawdown of Chickamauga Reservoir in 1985 for aquatic weed control produced conditions that supported previous assumptions relative to the influence of aquatic weeds on the distribution of freshwater drum and threadfin shad. Although young-of-year largemouth bass showed a slight decline in 1985, adult stock estimates were the highest recorded (52/ha; 14 kg/ha) since monitoring began in 1970.

Cove rotenone sampling does not provide representative samples of all species; however it remains the best overall fish sampling method for determining quantitative and qualitative (species composition) changes in reservoir fish populations. Cove rotenone sampling will be continued as part of the operational monitoring program for WBN. Because rotenone sampling for WBN will use the same sites as done for SQN, findings will be applicable to either plant. To date, the fish community of Chickamauga Reservoir appears to be predominately affected by habitat alterations related to aquatic macrophytes although there are indications that young and intermediate freshwater drum stocks may have also been affected by entrainment at SQN. Special investigations are being implemented to evaluate SQN's contribution to reduced stocks of young and intermediate freshwater drum.

Table 8-1. Characteristics of Rotenone Sites in Chickamauga Reservoir, 1947 through 1985 (Chickamauga Dam Located at TRM 471.0, Sequoyah Nuclear Plant Located at TRM 484.5, and Watts Bar Nuclear Plant Located at TRM 528.0).

Tennessee River Mile	Date	Area (Hectares)	Mean Depth (m)	Maximum Depth (m)	Surface Temperature (C)
471.7	9/ 9/54	0.81	2.7	-	26.7
472.8	10/12/49	0.61	-	6.1	22.2
472.8	4/26/50	0.40	-	9.2	16.1
472.8	10/17/50	0.61	-	6.1	18.9
472.8	10/16/51	0.61	-	6.1	18.9
475.0	5/ 8/47	0.81	2.4	4.0	15.6
475.0	5/24/50	0.81	2.4	-	22.2
475.0	6/21/50	0.81	1.8	-	27.3
475.0	7/26/50	0.81	2.4	-	27.8
475.2	8/ 3/70	0.90	1.5	3.2	29.5
475.7	8/ 4/70	0.89	1.8	-	29.4
475.7	9/14/71	1.26	2.0	-	25.5
475.7	9/19/72	1.26	2.0	-	-
475.7	9/18/73	1.26	-	6.4	24.8
475.7	9/16/74	1.26	2.0	4.6	25.0
475.7	9/16/75	1.33	2.0	6.1	23.5
475.7	9/14/76	0.93	1.9	4.9	23.5
476.2	9/ 1/77	0.49	1.1	1.9	28.1
476.2	8/22/78	0.29	0.7	1.5	28.5
476.2	8/21/79	0.74	1.2	2.8	28.5
476.2	8/19/80	0.65	0.7	2.2	30.0
476.2	9/ 1/81	0.75	1.1	2.8	27.5
476.2	8/31/82	0.42	0.8	1.4	27.5
476.2	8/30/83	0.42	0.8	1.8	29.5
476.2	8/27/84	0.42	0.7	1.5	26.8
476.2	8/27/85	0.42	0.8	1.5	26.5
478.0	9/11/56	1.81	2.3	4.0	23.3
478.0	9/10/57	1.21	1.9	4.3	25.5
478.0	8/ 5/70	0.45	1.7	-	28.6
478.0	9/16/71	0.97	0.5	-	26.7
478.0	9/21/72	0.97	0.5	-	28.5
478.0	9/20/73	0.97	-	4.0	23.7
478.0	9/18/74	0.97	0.5	1.8	25.0
478.0	9/18/75	0.97	1.4	4.3	23.6
478.0	9/16/76	0.56	1.2	2.4	23.0
478.0	8/30/77	0.35	1.0	2.2	27.0
478.0	8/24/78	0.58	0.9	2.2	30.0
478.0	8/23/79	0.43	1.2	2.5	28.5
478.0	8/21/80	0.65	1.3	2.9	31.0
478.0	9/ 3/81	0.61	1.3	2.8	27.5
478.0	9/ 2/82	0.43	1.0	2.3	28.0
478.0	9/ 1/83	0.44	1.0	2.6	28.5
478.0	8/29/84	0.44	1.1	2.5	28.0

Table 8-1 (Continued)

Tennessee River Mile	Date	Area (Hectares)	Mean Depth (m)	Maximum Depth (m)	Surface Temperature (C)
478.0	8/29/85	0.45	1.0	2.4	28.5
484.7	7/ 6/70	0.49	1.6	-	26.0
487.5	9/20/50	0.40	-	7.0	22.2
487.5	9/ 7/54	0.81	-	5.5	27.8
487.5	9/12/57	0.93	2.5	6.4	25.6
487.5	9/ 9/58	1.05	2.6	6.7	25.6
487.5*	9/11/58	0.40	5.5	11.6	25.6
487.5	8/27/59	1.05	2.6	6.5	27.8
489.6*	10/28/52	0.40	-	4.6	15.6
489.6	10/29/52	0.41	-	3.7	12.2
489.6*	10/28/52	0.40	-	4.6	15.6
489.6	10/29/52	0.41	-	3.7	12.2
492.6	7/ 7/70	0.28	1.4	-	-
495.0	10/21/52	0.61	-	-	14.4
495.0	7/10/70	0.61	1.3	-	-
495.0	9/23/71	0.93	1.4	-	24.4
495.0	9/28/72	0.93	1.4	-	-
495.0	9/27/73	0.93	-	4.0	24.6
495.0	9/23/74	0.93	1.4	3.7	22.0
495.0	9/23/75	0.93	1.4	3.7	22.8
495.0	9/21/76	0.47	1.2	3.7	22.2
495.0	9/13/77	0.39	1.8	5.2	23.4
495.0	8/31/78	0.46	1.3	3.4	29.7
495.0	9/ 5/79	0.52	1.4	3.7	27.5
495.0	8/26/80	0.58	1.6	3.7	30.0
495.0	8/20/81	0.46	1.2	3.1	24.0
495.0	8/19/82	0.46	1.4	3.4	29.0
495.0	8/18/83	0.41	1.2	3.1	28.5
495.0	8/16/84	0.41	1.4	3.2	27.0
495.0	8/22/85	0.44	1.1	3.1	29.0
1.2†	7/27/70	0.55	1.2	3.4	25.3
2.5†	9/13/56	0.81	1.7	3.1	21.7
2.5†	7/28/70	0.96	1.3	-	29.8
3.5†	7/29/70	0.69	1.2	2.5	30.7
505.4	7/14/70	0.18	1.3	-	27.5
506.0	7/13/70	0.28	1.1	-	28.0
507.3	7/14/70	0.27	1.0	2.1	27.3
508.0	9/20/71	0.43	0.9	-	23.9
508.0	9/27/72	0.43	-	-	-
508.0	9/25/73	0.43	-	2.0	24.9
508.0	9/25/74	0.43	0.9	3.1	21.0
508.0	9/25/75	0.42	0.9	3.1	22.3
508.0	9/23/76	0.43	0.9	2.0	22.2
508.0	9/15/77	0.43	0.9	2.2	23.3
508.0	8/29/78	0.57	1.0	1.8	30.5
508.0	8/23/79	0.43	0.9	1.9	27.3
508.0	8/28/80	0.51	0.9	1.7	30.0

Table 8-1 (Continued)

Tennessee River Mile	Date	Area (Hectares)	Mean Depth (m)	Maximum Depth (m)	Surface Temperature (C)
508.0	8/18/81	0.48	1.0	1.9	27.0
508.0	8/17/82	0.46	0.9	1.8	27.0
508.0	8/16/83	0.40	0.8	1.2	29.0
508.0	8/13/84	0.42	1.0	1.8	28.5
508.0	8/20/85	0.44	0.8	1.7	30.0
524.6	9/ 8/76	0.33	0.3	1.0	25.2
524.6	9/ 7/77	0.33	0.5	1.2	26.6
524.6	8/29/78	0.29	0.4	0.6	31.0
524.6	8/21/79	0.38	0.6	1.2	30.0
524.6	9/ 3/80	0.48	0.4	0.8	27.0
524.6	9/ 9/81	0.32	0.2	0.5	-
524.6	9/ 8/82	0.44	0.4	0.9	26.5
524.6	9/ 8/83	0.43	0.4	0.8	26.5
524.6	9/ 4/84	0.45	0.5	1.0	23.0
524.6	9/ 5/85	0.47	0.4	0.8	30.0

*Open water sample.

†Hiwassee River Mile (confluence at TRM 500.0).

Table 8-2. Size Classes* of Fish Species in Rotenone Surveys on Chickamauga Reservoir, 1947-1985.

Species	Young Millimeters (inches)	Intermediate Millimeters (inches)	Adult Millimeters (inches)
Game			
White bass	Less than 150 (5.9)	151-200 (5.9- 7.9)	201 (7.9) and over
Yellow bass	" " 150 (5.9)	151-200 (5.9- 7.9)	201 (7.9) " "
Striped bass	" " 175 (6.9)	176-375 (6.9-14.8)	376 (14.8) " "
Rock bass	" " 75 (3.0)	76-125 (3.0- 4.9)	126 (5.0) " "
Bluegill	" " 75 (3.0)	76-125 (3.0- 4.9)	126 (5.0) " "
Other sunfish	" " 75 (3.0)	76-125 (3.0- 4.9)	126 (5.0) " "
Smallmouth bass	" " 100 (3.9)	101-200 (4.0- 7.9)	201 (7.9) " "
Spotted bass	" " 100 (3.9)	101-200 (4.0- 7.9)	201 (7.9) " "
Largemouth bass	" " 100 (3.9)	101-225 (4.0- 8.9)	226 (8.9) " "
Crappie	" " 75 (3.0)	76-175 (3.0- 6.9)	176 (6.9) " "
Sauger	" " 200 (7.9)	201-275 (7.9-10.8)	276 (10.9) " "
Walleye	" " 200 (7.9)	201-275 (7.9-10.8)	276 (10.9) " "
Commercial			
Lamprey	Less than 50 (2.0)	51-125 (2.0- 4.9)	126 (5.0) and over
Paddlefish	" " 300 (11.8)	301-450 (11.9-17.7)	451 (17.8) " "
Gar	" " 300 (11.8)	301-475 (11.9-18.7)	476 (18.7) " "
Bowfin	" " 200 (7.9)	201-300 (7.9-11.8)	301 (11.9) " "
Skipjack herring	" " 150 (5.9)	151-275 (5.9-10.8)	276 (10.9) " "
Mooneye	" " 150 (5.9)	151-300 (5.9-11.8)	301 (11.9) " "
Carp	" " 200 (7.9)	201-300 (7.9-11.8)	301 (11.9) " "
Goldfish	" " 150 (5.9)	151-250 (5.9- 9.8)	251 (9.9) " "
Buffalo	" " 200 (7.9)	201-300 (7.9-11.8)	301 (11.9) " "
Carpsucker	" " 175 (6.9)	176-250 (6.9- 9.8)	251 (9.9) " "
Redhorses	" " 175 (6.9)	176-250 (6.9- 9.8)	251 (9.9) " "
Other suckers	" " 175 (6.9)	176-250 (6.9- 9.8)	251 (9.9) " "
Blue catfish	" " 125 (4.9)	126-225 (5.0- 8.9)	226 (8.9) " "

Table 8-2 (Continued)

Species	Young Millimeters (inches)	Intermediate Millimeters (inches)	Adult Millimeters (inches)
Commercial (Continued)			
Channel catfish	Less than 125 (4.9)	126-225 (5.0- 8.9)	226 (8.9) and over
Bullheads	" " 100 (3.9)	101-175 (4.0- 6.9)	176 (6.9) " "
Flathead catfish	" " 125 (4.9)	126-275 (5.0-10.8)	276 (10.9) " "
Freshwater drum	" " 125 (4.9)	126-200 (5.0- 7.9)	201 (7.9) " "
Grass pickerel	" " 175 (6.9)	176-300 (6.9-11.8)	301 (11.9) " "
Forage†			
Gizzard shad	Less than 125 (4.9)	-	126 (5.0) and over
Threadfin shad	" " 125 (4.9)	-	126 (5.0) " "
Orangespotted sunfish	" " 50 (2.0)	51- 75 (2.0- 3.0)	76 (3.0) " "
Miscellaneous prey species	All sizes	-	-

*The size class divisions are arbitrary but are based on knowledge of growth rates and information from creel census and commercial harvest records.

†Shad are recorded as young or harvestable; sizes of other forage fish, except orangespotted sunfish, were not differentiated.

Table 8-3. Sample Period, Dates, Number of Samples, and Mean Temperatures for Larval Fish Collections Near Watts Bar Nuclear Plant from 1976-1985

Sample Period	Date	Number 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 8-3. (Continued)

Sample Period	Date	Number Samples	Mean Water Temperatures (°C)
1978			
1	03/28/78	10	10.1
2	04/11/78	10	14.4
3	04/25/78	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	*
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	*
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	
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	

Table 8-3. (Continued)

Sample Period	Date	Number Samples	Mean Water Temperatures (°C)
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	*
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	
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	*
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	

*Temperatures unavailable.

Table 8-4. Common and Scientific Names* of Fishes Collected from Chickamauga Reservoir During 1973 to 1985, Preoperational Monitoring for Watts Bar Nuclear Plant.

Species	Common Name	Group**	Rotenone	Hoop Net	Gill Net	Electro-Fishing	Creel Census	Meter Netting
Icthyomyzon castaneus	Chestnut lamprey	C	X					
Polyodon spathula	Paddlefish	C	X	X	X			
Lepisosteus oculatus	Spotted gar	C	X	X	X	X		
Lepisosteus osseus	Longnose gar	C	X	X	X	X		
Lepisosteus platostomus	Shortnose gar	C	X	X	X			
Alosa chrysochloris	Skipjack herring	C	X	X	X	X		X
Dorosoma cepedianum	Gizzard shad	P	X	X	X	X		X
Dorosoma petenense	Threadfin shad	P	X	X	X	X		X
Hiodon tergisus	Mooneye	C	X	X	X	X		X
Salmo gairdneri	Rainbow trout	G			X			
Campostoma anomalum	Stoneroller	P	X					
Carassius auratus	Goldfish	P	X					
Cyprinus carpio	Carp	C	X	X	X	X	X	X
Hybopsis storeriana	Silver chub	P	X		X	X		X
Notemigonus crysoleucas	Golden shiner	P	X		X	X		
Notropis atherinoides	Emerald shiner	P	X		X	X		X
Notropis buchanani	Ghost shiner	P	X					
Notropis chrysocephalus	Striped shiner	P	X					
Notropis cornutus	Common shiner	P	X					
Notropis emiliae	Pugnose minnow	P	X					
Notropis galacturus	Whitetail shiner	P	X					
Notropis spilopterus	Spotfin shiner	P	X			X		
Notropis volucellus	Mimic shiner	P	X					
Notropis whipplei	Steelcolor shiner	P	X					
Pimephales notatus	Bluntnose minnow	P	X					
Pimephales vigilax	Bullhead minnow	P	X			X		
Pimephales promelas	Fathead minnow	P	X					
Carpiodes carpio	River carpsucker	C	X	X	X	X		X‡
Carpiodes cyprinus	Quillback carpsucker	C	X		X			
Carpiodes velifer	Highfin carpsucker	C		X	X			
Catostomus commersoni	White sucker	C	X		X			
Hypentelium nigricans	Northern hogsucker	C	X	X	X	X		

Table 8-4 (Continued)

Species	Common Name	Group**	Rotenone	Hoop Net	Gill Net	Electro-Fishing	Creel Census	Meter Netting
Ictiobus bubalus	Smallmouth buffalo	C	X	X	X	X		X‡
Ictiobus cyprinellus	Bigmouth buffalo	C	X	X				
Ictiobus niger	Black buffalo	C	X					
Minytrema melanops	Spotted sucker	C	X	X	X	X		X
Moxostoma anisurum	Silver redhorse	C			X			
Moxostoma carinatum	River redhorse	C	X	X	X	X		
Moxostoma duquesnei	Black redhorse	C	X	X	X			
Moxostoma erythrurum	Golden redhorse	C	X	X	X			
Moxostoma macrolepidotum	Shorthead redhorse	C	X		X			
Ictalurus furcatus	Blue catfish	C	X	X	X	X	X	X
Ictalurus melas	Black bullhead	C	X	X	X			X
Ictalurus natalis	Yellow bullhead	C	X	X	X			
Ictalurus nebulosus	Brown bullhead	C	X	X				
Ictalurus punctatus	Channel catfish	C	X	X	X	X	X	X
Pylodictis olivaris	Flathead catfish	C	X	X	X	X	X	X
Anguilla rostrata	American eel	C				X		
Fundulus notatus	Blackstripe topminnow	P	X					
Fundulus olivaceus	Blackspotted topminnow	P	X					
Gambusia affinis	Mosquitofish	P	X					
Labidesthes sicculus	Brook silverside	P	X			X		X
Morone chrysops	White bass	G	X	X	X	X	X	X
Morone mississippiensis	Yellow bass	G	X	X	X	X	X	
Ambloplites rupestris	Rock bass	G	X	X	X	X	X	
Lepomis auritus	Redbreast sunfish	G	X	X	X	X		
Lepomis cyanellus	Green sunfish	G	X	X	X			
Lepomis gulosus	Warmouth	G	X	X	X	X		
Lepomis humilis	Orangespotted sunfish	P	X					
Lepomis macrochirus	Bluegill	G	X	X	X	X	X	
Lepomis megalotis	Longear sunfish	G	X	X		X		
Lepomis microlophus	Redear sunfish	G	X	X	X	X	X	X
Micropterus dolomieui	Smallmouth bass	G	X	X	X	X	X	X
Micropterus punctulatus	Spotted bass	G	X	X	X	X	X	
Micropterus salmoides	Largemouth bass	G	X	X	X	X	X	

Table 8-4 (Continued)

Species	Common Name	Group**	Rotenone	Hoop Net	Gill Net	Electro-Fishing	Creel Census	Meter Netting
Pomoxis annularis	White crappie	G	X	X	X	X	X	X
Pomoxis nigromaculatus	Black crappie	G	X	X	X	X	X	
Etheostoma asprigene	Mud darter	P	X					
Etheostoma caeruleum	Rainbow darter	P	X					
Etheostoma kennicotti	Stripetail darter	P	X					
Etheostoma spectabile	Orangethroat darter	P	X					
Perca flavescens	Yellow perch	G	X	X	X	X	X	X
Percina caprodes	Logperch	P	X		X	X		
Stizostedion canadense	Sauger	G	X	X	X	X	X	X
Stizostedion vitreum	Walleye	G		X	X	X	X	
Aplodinotus grunniens	Freshwater drum	C	X	X	X	X	X	X
Morone saxatilis	Striped Bass	G			X	X	X	
M. chrysops x *M. saxatilis*	Hybrid Bass	G		X	X			

*Taken from *Common and Scientific Names of Fishes*, American Fisheries Society Special Publication No. 12, Fourth Edition, 1980.

**Indicates prey (P), commercial (C), or game (G).

‡Unidentified specimens within family or genus.

Table 8-5. List of Scientific and Common Names for Fish Egg and Larval Taxa Collected Near Watts Bar Nuclear Plant from 1976-1985

TAXON	COMMON NAME
Eggs	
Unidentifiable fish eggs	
Hiodon sp. eggs	Mooneye or Goldeye eggs
Aplodinotus grunniens eggs	Freshwater drum eggs
Larvae	
Unidentifiable fish larvae*	
Clupeidae	
Unspecifiable clupeids	Unspecified shad and/or herring
Alosa chrysochloris	Skipjack herring
Dorosoma sp.	Unspecified shad
Dorosoma cepedianum	Gizzard shad
Dorosoma petenense	Threadfin shad
Hiodontidae	
Hiodon tergisus	Mooneye
Cyprinidae	
Unspecifiable cyprinids	Unspecified minnows or shiners
Cyprinus carpio	Carp
Hybopsis storeriana	Silver chub
Notropis sp.	Unspecified shiner
Notropis atherinoides	Emerald shiner
Catostomidae	
Unspecifiable catostomids	Unspecified suckers
Ictiobus - *Carpiodes* Group	Unspecified Ictiobines**
Minytrema melanops	Spotted sucker
Ictaluridae	
Ictalurus furcatus	Blue catfish
Ictalurus punctatus	Channel catfish
Pylodictis olivaris	Flathead catfish
Atherinidae	
Labidesthes sicculus	Brook silverside
Percichthyidae	
Morone spp.	Unspecified temperate bass
Morone (not *saxatilis*)	Unspecified temperate bass (not striped bass)
Morone chrysops	White bass
Centrarchidae	
Lepomis or *Pomoxis*	Unspecified sunfish or crappie
Lepomis spp.	Unspecified sunfish
Micropterus dolomieui	Smallmouth bass
Pomoxis spp.	Unspecified crappie
Pomoxis annularis	White crappie

Table 8-5. (Continued)

TAXON	COMMON NAME
Percidae	
Unspecified darter	Darter
Perca flavescens	Yellow perch
Stizostedion spp.	Walleye or Sauger
Stizostedion canadense	Sauger
Sciaenidae	
Aplodinotus grunniens	Freshwater drum

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

Table 8-6. List of Taxa, Total Number Collected, and Percent Composition of Fish Eggs and Larvae Collected Near Watts Bar Nuclear Plant Site, 1976-1985

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.	1983 Total Collected	1983 % Comp.	1984 Total Collected	1984 % Comp.	1985 Total Collected	1985 % Comp.
EGGS																
Unidentifiable eggs	5	2.00	40	23.39	722	81.58	4	5.63	8	4.17	1143	87.12	26	27.66	16	51.61
Hiodon sp. eggs	0	0.00	0	0.00	1	0.11	0	0.00	0	0.00	0	0.00	0	0.00	1	3.23
Aplodinotus grunniens eggs	245	98.00	131	76.61	162	18.31	67	94.37	184	95.83	169	12.88	68	72.34	14	45.16
Total	250	100.00	171	100.00	885	100.00	71	100.00	192	100.00	1312	100.00	94	100.00	31	100.00
LARVAE																
Unidentifiable larvae	1	0.01	8	0.02	7	0.19	0	0.00	0	0.00	38	0.49	0	0.00	0	0.00
Clupeidae																
Unspecifiable clupeids	9913	91.17	31679	92.94	1569	42.44	1976	77.04	1259	38.06	5658	73.01	22435	93.33	5890	68.63
Alosa chrysochloris	0	0.00	6	0.02	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Dorosoma spp.	0	0.00	68	0.20	73	1.97	0	0.00	0	0.00	0	0.00	1	T	0	0.00
Dorosoma cepedianum	2	0.02	637	1.87	334	9.03	0	0.00	324	10.00	1	0.01	114	0.47	0	0.00
Dorosoma petenense	32	0.29	1	T	0	0.00	0	0.00	20	0.62	2	0.03	0	0.00	8	0.09
Hiodontidae																
Hiodon tergisus	0	0.00	4	0.01	0	0.00	1	0.04	0	0.00	0	0.00	7	0.03	0	0.00
Cyprinidae																
Unspecifiable cyprinids	1	0.01	14	0.04	28	0.76	5	0.19	5	0.15	110	1.42	0	0	0	0.00
Cyprinus carpio	27	0.25	16	0.05	0	0.00	8	0.31	1	0.03	15	0.19	7	0.03	0	0.00
Hybopsis storeriana	0	0.00	1	T	0	0.00	0	0.00	0	0.00	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	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	0	0.00	0	0.00	0	0.00
Catostomidae																
Unspecifiable catostomids	0	0.00	0	0.00	1	0.03	1	0.04	0	0.00	0	0.00	0	0.00	0	0.00
Ictiobus - Carpiodes group	0	0.00	82	0.24	0	0.00	0	0.00	0	0.00	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	0	0.00	0	0.00	0	0.00

Table 8-6. (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.	1983 Total Collected	1983 % Comp.	1984 Total Collected	1984 % Comp.	1985 Total Collected	1985 % Comp
Ictaluridae																
Ictalurus furcatus	1	0.01	0	0.00	1	0.03	1	0.04	1	0.03	0	0.00	0	0.00	0	0.00
Ictalurus punctatus	45	0.41	27	0.08	38	1.03	8	0.31	9	0.28	11	0.14	0	0.00	2	0.02
Pylodictis olivaris	1	0.01	2	0.01	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Percichthyidae																
Morone spp.	1	0.01	62	0.18	73	1.97	13	0.51	16	0.49	50	0.65	108	0.45	24	0.28
Morone (not *saxatilis*)	5	0.05	50	0.15	7	0.19	31	1.21	199	6.14	244	3.15	283	1.18	29	0.34
Morone chrysops	0	0.00	0	0.00	1	0.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Centrarchidae																
Lepomis or *Pomoxis*	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	20	0.26	0	0.00	0	0.00
Lepomis spp.	209	1.92	428	1.26	873	23.61	57	2.22	857	26.45	309	3.99	247	1.03	2427	28.28
Micropterus dolomieui	0	0.00	0	0.00	0	0.00	0	0.00	1	0.03	0	0.00	0	0.00	0	0.00
Pomoxis spp.	24	0.22	281	0.82	334	9.03	9	0.35	328	10.12	220	2.84	90	0.37	158	1.84
Pomoxis annularis	0	0.00	1	T	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Percidae																
Unspecified darter	0	0.00	4	0.01	5	0.14	1	0.04	4	0.12	4	0.05	0	0.00	0	0.00
Perca flavescens	0	0.00	0	0.00	5	0.14	0	0.00	3	0.09	12	0.15	9	0.04	9	0.10
Stizostedion spp.	1	0.01	5	0.01	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Stizostedion canadense	0	0.00	0	0.00	1	0.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sciaenidae																
Aplodinotus grunniens	601	5.53	704	2.07	310	8.39	454	17.70	205	6.33	1056	13.63	737	3.07	25	0.29
Atherinidae																
Labidesthes sicculus	0	0.00	0	0.00	32	0.87	0	0.00	8	0.25	0	0.00	0	0.00	1	0.01
Total	10873	100.00	34086	100.00	3697	100.00	2565	100.00	3240	100.00	7750	100.00	24039	100.00	8582	100.00

T = Less than 0.01 percent composition.

Table 8-7. Seasonal and Peak Densities (Total Larvae/1,000 m^3) of Fish Larvae Collected Near Watts Bar Nuclear Plant, 1976-1985

	YEAR							
	1976	1977	1978	1979	1982	1983	1984	1985
Seasonal Density (Avg. of all sample periods)	617	2,697	491	293	411	989	1,200	353
Peak Density	1,334	4,559	624	522	731	3,011	10,485	1,007
Date	5/18	4/26	6/6	7/2	6/7	6/14	5/29	6/4
Mean Water Temperature (°C)	19.1	17.2	20.9	23.0	23.9	23.0	18.8	22.6

Table 8-8. Day and Night Seasonal Densities (Number per 1000 m^3) of Fish Eggs and Larvae Collected in the Vicinity of Watts Bar Nuclear Plant, 1976-1985

	1976*		1977		1978		1979		1982		1983		1984		1985	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
EGGS																
Unidentifiable eggs	0.39	0.00	0.87	2.16	57.04	20.64	0.11	0.33	0.47	0.48	55.60	66.11	1.01	1.59	0.99	0.33
Aplodinotus grunniens eggs	6.00	5.54	6.84	3.32	4.21	13.16	4.81	2.66	0.60	21.45	8.90	10.24	0.10	6.64	0.17	0.98
LARVAE																
Clupeidae**	269.00	288.75	1109.72	1363.46	57.37	118.72	72.18	147.59	56.82	96.48	302.75	314.17	1014.65	1223.77	127.93	354.99
Dorosoma cepedianum	0.00	0.00	5.35	43.96	0.22	35.51	0.00	0.00	1.68	37.16	0.00	0.11	10.26	1.19	0.00	0.00
Morone spp.***	0.10	0.00	3.62	5.10	1.08	7.59	2.46	2.44	12.11	13.66	9.71	20.37	16.08	22.90	2.07	2.29
Lepomis spp.	3.68	8.30	14.63	18.39	10.68	82.78	1.45	4.88	16.78	85.94	14.34	20.59	16.69	8.03	45.59	153.33
Pomoxis spp.	0.68	0.40	10.07	11.90	12.62	23.21	0.56	0.44	17.74	21.58	11.10	11.24	3.52	5.45	4.30	8.67
Aplodinotus grunniens	11.52	17.13	20.69	32.37	10.89	22.35	26.15	24.41	6.35	18.22	69.94	50.19	36.50	37.08	0.99	1.06

*Densities for 1976 based on samples taken from diel periods 2 (midday) and 4 (midnight).
**Includes unspecifiable clupeids, *Alosa chrysochloris*, *Dorosoma* spp., and *Dorosoma petenense*.
***Includes all *Morone* spp., *Morone chrysops*, and *Morone* (not *saxatilis*).

Table 8-9. Seasonal Densities (Number/1000 m^3) by Sample Station of Dominant Fish Larvae Collected in the Tennessee River at the Watts Bar Nuclear Plant Site, 1976 Through 1985

Taxon	Year	STATION: Left Shore	Left Channel	Mid-Channel	Right Channel	Right Shore	Right Shallow Shoreline	Epibenthic	Intake
Unspecifiable Clupeids	1976	259.28	261.09	222.70	307.74	366.59	*	*	*
	1977	978.67	1,167.58	1,258.08	1,385.13	1,207.18	*	*	*
	1978	*	83.50	62.73	87.55	*	127.63	*	*
	1979	*	63.87	67.34	82.72	*	263.98	*	*
	1982	*	75.08	64.91	97.00	*	75.21	*	*
	1983	*	306.14	215.16	336.08	*	458.73	*	*
	1984	*	1028.00	889.00	1143.97	*	1262.23	1059.43	1410.86
	1985	*	133.86	143.64	155.14	*	210.74	103.11	526.62
Lepomis spp.	1976	6.86	3.87	4.95	4.95	8.54	*	*	*
	1977	14.32	14.67	15.01	13.05	23.51	*	*	*
	1978	*	8.32	9.86	10.44	*	190.41	*	*
	1979	*	2.42	1.58	1.67	*	8.42	*	*
	1982	*	5.43	8.15	8.68	*	222.09	*	*
	1983	*	23.26	14.84	17.52	*	16.50	*	*
	1984	*	16.90	3.14	8.45	*	11.00	10.72	28.13
	1985	*	20.45	20.25	21.93	*	161.15	23.29	256.92
Pomoxis	1976	.53	.70	.63	.73	.80	*	*	*
	1977	10.08	8.27	11.50	10.48	12.69	*	*	*
	1978	*	13.42	19.43	24.36	*	14.79	*	*
	1979	*	.81	.29	.28	*	.82	*	*
	1982	*	15.08	30.49	13.77	*	8.81	*	*
	1983	*	8.29	10.35	14.02	*	12.80	*	*
	1984	*	4.30	3.43	4.08	*	4.95	3.19	7.92
	1985	*	5.18	7.11	7.01	*	6.05	4.45	8.13

Table 8-9. (Continued)

Taxon	Year	Left Shore	Left Channel	Mid-Channel	Right Channel	Right Shore	Right Shallow Shoreline	Epibenthic	Intake
		STATION							
Aplodinotus grunniens	1976	13.72	15.12	17.64	9.89	9.54	*	*	*
	1977	26.70	33.66	29.63	18.18	24.25	*	*	*
	1978	*	22.02	18.58	22.49	*	3.63	*	*
	1979	*	26.30	33.67	19.99	*	13.58	*	*
	1982	*	15.98	12.83	12.87	*	7.05	*	*
	1983	*	53.74	61.93	67.65	*	54.32	*	*
	1984	*	45.83	42.30	31.18	*	25.84	60.28	7.92
	1985	*	0.82	1.37	2.17	*	0.29	1.05	0.66

*No samples collected.

Table 8-10. Length Frequency of all Unspecified Clupeid Larvae Collected Near Watts Bar Nuclear Plant, 1976-1985

SIZE CLASS (mm TL)	TOTAL NUMBER	RELATIVE ABUNDANCE
3	31	0.04
4	900	1.11
5	9,961	12.26
6	10,481	12.90
7	11,237	13.83
8	12,121	14.91
9	9,443	11.62
10	7,424	9.14
11	5,160	6.35
12	4,141	5.10
13	3,651	4.49
14	2,730	3.36
15	1,898	2.34
16-20	2,091	2.57
Total	81,269	100.00

Table 8-11. Length Frequency of all *Pomoxis* spp. Larvae Collected Near Watts Bar Nuclear Plant, 1976-1985

SIZE CLASS (mm TL)	NUMBER	RELATIVE ABUNDANCE
4	47	3.25
5	416	28.81
6	294	20.36
7	187	12.95
8	133	9.21
9	91	6.30
10	64	4.43
11	73	5.06
12	52	3.60
13	25	1.73
14	19	1.32
15	19	1.32
16-31	24	1.66
Total	1,444	100.00

Table B-12. Number, Percent Composition, and Catch Per Unit Effort (c/f) for Fish Species Collected with Experimental Gill Nets at Two Stations in Chickamauga Reservoir Near Watts Bar Nuclear Plant.

	Station A			Station B			Stations Combined		
Common Name	No.	% Comp.	c/f	No.	% Comp.	c/f	No.	% Comp.	c/f
Chestnut Lamprey	1	0.01	0.001	1	0.01	0.002	2	0.01	0.001
Paddlefish	5	0.06	0.006	40	0.36	0.071	45	0.22	0.031
Unidentified gar	14	0.15	0.016	22	0.20	0.039	36	0.18	0.025
Spotted gar	19	0.21	0.021	14	0.13	0.025	33	0.16	0.023
*Longnose gar	291	3.20	0.326	399	3.60	0.705	690	3.42	0.473
Shortnose gar	11	0.12	0.012	5	0.05	0.009	16	0.08	0.011
*Skipjack herring	780	8.58	0.874	910	8.22	1.608	1690	8.38	1.159
*Gizzard shad	1477	16.25	1.656	1413	12.76	2.497	2890	14.34	1.982
*Threadfin shad	2465	27.13	2.763	3787	34.21	6.691	6252	31.02	4.288
Mooneye	77	0.85	0.086	77	0.70	0.136	154	0.76	0.106
Rainbow trout	1	0.01	0.001	—	—	—	1	0.01	0.001
Carp	8	0.09	0.008	7	0.06	0.012	15	0.07	0.010
Silver chub	4	0.04	0.004	12	0.11	0.021	16	0.08	0.011
Golden shiner	1	0.01	0.001	2	0.02	0.004	3	0.01	0.002
Emerald shiner	7	0.08	0.008	17	0.15	0.030	24	0.12	0.016
River carpsucker	3	0.03	0.003	5	0.05	0.009	8	0.04	0.005
Quillback carpsucker	2	0.02	0.002	2	0.02	0.004	4	0.02	0.003
Highfin carpsucker	1	0.01	0.001	—	—	—	1	0.01	0.001
White sucker	2	0.02	0.002	1	0.01	0.002	3	0.01	0.002
Northern hogsucker	5	0.06	0.006	1	0.01	0.002	6	0.03	0.004
Smallmouth buffalo	12	0.13	0.013	22	0.20	0.039	34	0.17	0.023
*Spotted sucker	208	2.29	0.233	89	0.80	0.157	297	1.47	0.204
Unidentified redhorse	—	—	—	1	0.01	0.002	1	0.01	0.001
Silver redhorse	2	0.02	0.002	1	0.01	0.002	3	0.01	0.002
Shorthead redhorse	—	—	—	2	0.02	0.004	2	0.01	0.001
River redhorse	3	0.03	0.003	1	0.01	0.002	4	0.02	0.003
Black redhorse	4	0.04	0.004	—	—	—	4	0.02	0.003
Golden redhorse	107	1.18	0.120	88	0.80	0.156	195	0.97	0.134
*Blue catfish	91	1.00	0.102	1372	12.39	2.424	1463	7.26	1.003
Black bullhead	1	0.01	0.001	—	—	—	1	0.01	0.001
Yellow bullhead	—	—	—	1	0.01	0.002	1	0.01	0.001
*Channel catfish	790	8.69	0.886	897	8.10	1.585	1687	8.37	1.157
Flathead catfish	26	0.29	0.029	25	0.23	0.044	51	0.25	0.035

Table 8-12 (Continued)

Common Name	Station A			Station B			Stations Combined		
	No.	% Comp.	c/f	No.	% Comp.	c/f	No.	% Comp.	c/f
Unidentified temperate bass	1	0.01	0.001	1	0.01	0.002	2	0.01	0.001
*White bass	283	3.11	0.317	268	2.42	0.474	551	2.73	0.378
*Yellow bass	1105	12.16	1.239	573	5.17	1.012	1678	8.32	1.151
Striped bass	82	0.90	0.092	54	0.49	0.095	136	0.67	0.093
Hybrid white X striped bass	8	0.09	0.009	2	0.02	0.004	10	0.05	0.007
Rock bass	2	0.02	0.002	—	—	—	2	0.01	0.001
Warmouth	5	0.06	0.006	4	0.04	0.007	9	0.04	0.006
Redbreast sunfish	3	0.03	0.003	2	0.02	0.004	5	0.02	0.003
Bluegill	144	1.58	0.161	50	0.45	0.088	194	0.96	0.133
Redear sunfish	117	1.29	0.131	50	0.45	0.088	167	0.83	0.115
Hybrid sunfish	—	—	—	1	0.01	0.002	1	0.01	0.001
Smallmouth bass	19	0.21	0.021	8	0.07	0.014	27	0.13	0.019
Spotted bass	115	1.27	0.129	61	0.55	0.108	176	0.87	0.121
Largemouth bass	11	0.12	0.012	9	0.08	0.016	20	0.10	0.014
White crappie	90	0.99	0.101	73	0.66	0.129	163	0.81	0.112
Black crappie	6	0.07	0.007	2	0.02	0.004	8	0.04	0.005
Yellow perch	24	0.26	0.027	13	0.12	0.023	37	0.18	0.025
*Logperch	176	1.94	0.197	51	0.46	0.090	227	1.13	0.156
*Sauger	374	4.12	0.419	259	2.34	0.458	633	3.14	0.434
Walleye	42	0.46	0.047	13	0.12	0.023	55	0.27	0.038
*Freshwater drum	62	0.68	0.070	362	3.27	0.640	424	2.10	0.291
Totals	9087	99.98		11070	100.02		20157	99.97	

*Important species (i.e., those that occur in both stations and comprise at least one percent of the total number captured).

Table 8-13. Summary of Multivariate Analysis of Variance Testing Influences of Year, Quarter, Station, Net Pair Within Station and Variable Interactions on c/f of Combined Important Species Captured in Experimental Gill Nets in Chickamauga Reservoir Near Watts Bar Nuclear Plant, 1977-1985.

Variable	df	Pillai's Trace*	Probability >F
Year	72/1758	5.22	0.0001
Quarter	36/870	8.36	0.0001
Station	12/288	21.48	0.0001
Net Pair (Station)**	48/1164	4.22	0.0001
Year x Quarter	204/3588	2.27	0.0001
Year x Station	72/1758	1.54	0.0030
Station x Quarter	36/870	3.32	0.0001
Year x Station x Quarter	204/3588	1.51	0.0001

*Provides an approximateion of F-value.
**Refers to net pairs within each station, respectively.

Table B-14. Summary of Univariate Analyses of Variance Testing for Effects of Year, Quarter, Station, Net Pair Within Station, and Variable Interaction of c/f of Important Species Taken in Experimental Gill Nets Set in Chickamauga Reservoir Near Watts Bar Nuclear Plant from 1977-1985.

	F-Values							
Species	Year	Quarter	Station	Net Pair (Within Station)	Year × Quarter	Year × Station	Quarter × Station	Year × Quarter × Station
Longnose gar	6.64†	3.23	2.14	2.99	4.36†	4.68†	3.16	5.73†
Skipjack herring	5.63†	17.02†	16.33†	1.15	3.03†	0.66	0.78	0.97
Gizzard shad	3.90*	16.49†	7.67	0.93	1.46	1.46	13.47†	1.29
Threadfin shad	9.83†	30.86†	4.35	0.11	2.62†	1.19	2.76	0.73
Spotted sucker	2.87	2.32	0.03	2.68	1.49	0.59	0.44	0.77
Blue catfish	1.54	0.28	171.97†	55.72†	2.55†	1.11	1.83	2.46*
Channel catfish	2.75	3.79	21.10†	4.41*	1.83	0.46	4.63*	1.05
White bass	8.78†	2.16	12.16†	1.34	2.29*	1.59	7.23†	2.95†
Yellow bass	2.59	15.13†	0.80	1.20	2.90†	1.83	0.03	0.87
Logperch	2.36	5.91†	6.89	1.91	0.68	0.83	3.41	0.79
Sauger	25.36†	28.48†	0.41	1.03	4.85†	2.27	2.58	1.67
Freshwater drum	3.79*	8.54†	72.19†	7.60†	1.78	1.35	2.75	1.33

Significance levels with Bonferroni's adjustment:
*Significant (alpha <0.05).
†Highly significant (alpha <0.01).

Table 8-15. Mean c/f of Important Species by Net Pairs Taken With Experimental Gill Nets at Two Stations in Chickamauga Reservoir near Watts Bar Nuclear Plant, 1977-1985. Values are Antilogs-1 of $\log_{10}(c/f + 1)$ transformed data.

	Net Pairs					
	Station A				Station B	
	A(1,2)	A(3,4)	A(5,6)	A(7,8)	B(5,6)	B(7,8)
Longnose gar	0.371	0.159	0.182	0.165	0.319	0.196
Skipjack herring	0.551	0.670	0.440	0.737	0.898	1.168
Gizzard shad	1.248	0.964	0.949	1.261	1.595	1.559
Threadfin shad	0.867	0.752	0.877	1.486	1.371	1.194
Spotted sucker	0.201	0.198	0.082	0.073	0.086	0.146
Blue catfish	0.048	0.067	0.164	0.011	2.562	0.358
Channel catfish	0.594	0.545	0.651	0.791	1.443	0.838
White bass	0.248	0.264	0.255	0.055	0.273	0.432
Yellow bass	0.999	0.898	0.702	0.726	0.807	0.630
Logperch	0.159	0.151	0.086	0.323	0.062	0.092
Sauger	0.306	0.268	0.319	0.150	0.320	0.311
Freshwater drum	0.036	0.062	0.091	0.049	0.610	0.309

Table 8-16. Mean Annual c/f of Important Species Taken with Experimental Gill Nets at Two stations in Chickamauga Reservoir near Watts Bar Nuclear Plant, 1977-1985. Values are Antilogs-1 of $\log_{10}(c/f + 1)$ Transformed Data.

	Years						
	1977	1978	1979	1982	1983	1984	1985
Longnose gar	0.890	0.319	0.228	0.043	0.197	0.269	0.173
Skipjack herring	1.206	0.513	0.686	0.756	0.478	0.569	1.237
Gizzard shad	1.078	1.211	0.956	0.954	1.165	1.446	1.747
Threadfin shad	0.492	0.613	0.966	0.658	0.541	0.966	2.886
Spotted sucker	0.057	0.208	0.073	0.072	0.192	0.225	0.102
Blue catfish	0.346	0.405	0.527	0.293	0.496	0.441	0.410
Channel catfish	0.568	0.601	0.909	0.605	0.818	0.746	1.078
White bass	0.438	0.617	0.519	0.168	0.232	0.128	0.147
Yellow bass	1.038	0.756	0.861	1.300	0.798	0.632	0.615
Logperch	0.154	0.206	0.085	0.129	0.033	0.073	0.207
Sauger	0.515	0.705	0.640	0.196	0.078	0.071	0.267
Freshwater drum	0.290	0.352	0.265	0.070	0.130	0.148	0.221

Table B-17. Mean Quarterly Catch Per Unit Effort for Twelve Important Species Collected with Experimental Gill Nets at Two Stations on Chickamauga Reservoir near Watts Bar Nuclear Plant.

	Species											
	Longnose gar		Skipjack herring		Gizzard shad		Threadfin shad		Spotted sucker		Blue catfish	
Quarters	A*	B*	A	B	A	B	A	B	A	B	A	B
Winter, 1977	0.375	2.125	0.125	0.250	0.000	0.375	0.000	0.000	0.375	0.000	0.000	0.875
Spring, 1977	0.500	0.000	0.000	0.500	2.625	0.250	0.000	0.000	0.000	0.000	0.250	0.250
Summer, 1977	0.333	0.130	1.500	3.130	0.417	3.348	0.042	0.043	0.000	0.087	0.000	0.957
Fall, 1977	0.357	13.188	1.929	3.000	1.071	1.938	3.786	8.813	0.000	0.188	0.071	0.875
Winter, 1978	0.000	0.083	1.333	0.833	3.417	0.333	0.417	0.000	0.000	0.000	0.000	4.500
Spring, 1978	0.208	3.000	0.500	0.042	0.958	0.167	0.000	0.000	1.292	0.250	0.000	1.917
Summer, 1978	0.406	0.125	0.438	1.208	0.938	3.792	0.969	1.042	0.063	0.083	0.031	0.417
Fall, 1978	0.278	0.167	0.778	0.833	0.806	5.125	7.306	1.542	0.167	0.250	0.222	1.333
Winter, 1979	0.050	0.125	0.200	0.563	0.750	0.125	0.000	0.000	0.050	0.375	0.000	0.438
Spring, 1979	0.147	1.208	0.588	1.167	0.412	0.458	0.000	0.125	0.382	0.083	0.000	3.292
Summer, 1979	0.314	0.000	0.286	0.227	3.057	4.273	0.886	1.955	0.000	0.000	0.571	1.591
Fall, 1979	0.594	0.136	1.813	2.909	0.688	2.227	14.469	27.864	0.000	0.000	0.063	4.182
No Samples	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spring, 1982	0.000	0.000	0.257	0.500	0.771	0.182	0.000	0.000	0.200	0.046	0.000	1.636
Summer, 1982	0.063	0.000	0.719	2.565	1.156	3.696	0.188	7.783	0.094	0.000	0.156	1.087
Fall, 1982	0.171	0.000	1.486	2.682	0.943	2.273	0.400	24.909	0.143	0.046	0.057	0.773
Winter, 1983	0.056	0.000	0.361	0.200	1.722	0.500	0.889	0.150	0.306	0.100	0.111	8.450
Spring, 1983	1.429	0.083	0.229	0.667	1.171	0.917	0.029	0.000	0.343	0.542	0.086	5.583
Summer, 1983	0.457	0.125	0.857	0.667	1.886	1.292	0.771	1.625	0.143	0.250	0.086	1.375
Fall, 1983	0.333	0.044	0.485	1.870	0.848	7.957	1.667	5.000	0.121	0.261	0.182	0.522
Winter, 1984	0.486	1.227	0.229	1.000	0.829	1.182	2.886	0.955	0.343	0.545	0.000	1.318
Spring, 1984	0.386	0.125	0.227	1.625	1.318	1.917	0.159	0.250	1.000	0.583	0.023	3.375
Summer, 1984	0.319	0.087	0.511	1.043	1.894	5.913	0.915	2.957	0.064	0.043	0.447	2.217
Fall, 1984	0.500	0.042	0.854	1.625	1.146	4.542	2.250	5.500	0.125	0.083	0.021	2.667
Winter, 1985	0.533	0.400	1.133	1.950	1.267	0.550	4.844	1.350	0.178	0.050	0.022	6.250
Spring, 1985	0.091	0.217	0.250	0.783	4.023	1.087	0.000	0.000	0.273	0.000	0.023	3.348
Summer, 1985	0.149	0.091	0.660	3.727	4.596	5.909	8.894	57.046	0.064	0.045	0.106	3.864
Fall, 1985	0.239	0.000	4.370	6.130	3.522	2.217	12.000	22.696	0.174	0.087	0.087	0.565
Winter, 1986	0.063	0.000	1.625	1.000	0.813	0.500	2.250	1.125	0.563	0.000	0.000	2.750

Table 8-17 (Continued)

	Species											
	Channel catfish		White bass		Yellow bass		Log perch		Sauger		Freshwater drum	
Quarters	A*	B*	A	B	A	B	A	B	A	B	A	B
Winter, 1977	0.125	4.250	0.125	3.250	0.000	0.250	0.000	0.000	1.375	2.875	0.000	1.125
Spring, 1977	1.125	0.500	0.000	0.000	1.875	3.750	0.250	0.000	1.125	0.750	0.000	0.250
Summer, 1977	0.792	0.391	0.708	0.217	4.750	2.522	0.250	0.130	0.250	0.261	0.292	0.739
Fall, 1977	0.357	0.313	0.286	0.563	0.214	0.125	0.071	0.563	0.786	0.188	0.000	0.313
Winter, 1978	0.000	0.250	0.083	0.833	0.000	0.000	0.000	0.000	1.750	1.083	0.000	0.167
Spring, 1978	0.417	1.208	0.333	1.375	0.375	0.250	0.292	0.167	1.333	1.000	0.167	0.292
Summer, 1978	0.844	0.792	0.719	0.292	1.844	1.750	0.438	0.208	0.188	0.125	0.250	2.375
Fall, 1978	0.639	1.708	1.472	0.875	1.056	1.125	0.417	0.125	1.444	0.833	0.056	0.625
Winter, 1979	0.750	2.938	0.550	1.813	1.350	0.375	0.050	0.000	1.800	3.438	0.150	0.375
Spring, 1979	1.294	4.250	0.324	0.792	2.471	1.208	0.412	0.000	1.912	0.542	0.088	1.000
Summer, 1979	0.886	0.864	1.343	0.273	0.971	2.227	0.200	0.045	0.200	0.136	0.171	1.273
Fall, 1979	0.469	1.318	0.563	0.091	0.406	0.455	0.031	0.000	0.594	0.136	0.031	0.182
No Samples	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spring, 1982	0.400	1.091	0.057	0.227	1.057	2.000	0.114	0.227	0.200	1.182	0.029	0.091
Summer, 1982	0.969	1.174	0.219	0.261	2.156	1.696	0.125	0.043	0.094	0.261	0.063	0.348
Fall, 1982	0.400	1.136	0.314	0.182	1.086	2.045	0.171	0.182	0.029	0.000	0.000	0.091
Winter, 1983	0.194	2.100	0.222	0.450	1.500	0.300	0.000	0.000	0.250	0.100	0.056	1.250
Spring, 1983	0.971	2.292	0.429	0.167	1.943	1.250	0.057	0.000	0.057	0.250	0.114	0.375
Summer, 1983	1.314	0.917	0.143	0.167	2.257	1.042	0.029	0.083	0.000	0.042	0.000	0.208
Fall, 1983	0.515	1.435	0.152	0.478	0.394	0.696	0.061	0.043	0.000	0.043	0.000	0.087
Winter, 1984	0.029	0.818	0.029	0.136	0.657	0.500	0.000	0.000	0.029	0.091	0.000	0.545
Spring, 1984	0.818	2.000	0.250	0.167	0.545	1.292	0.182	0.125	0.182	0.167	0.023	0.750
Summer, 1984	1.277	2.261	0.128	0.522	1.255	1.652	0.085	0.000	0.043	0.130	0.043	0.522
Fall, 1984	0.417	1.125	0.021	0.167	0.521	0.208	0.146	0.042	0.042	0.000	0.000	0.208
Winter, 1985	0.022	4.000	0.022	0.550	0.578	0.050	0.000	0.000	0.444	0.800	0.044	2.000
Spring, 1985	0.977	1.783	0.068	0.043	1.045	0.304	0.818	0.217	0.591	0.652	0.114	0.913
Summer, 1985	4.723	2.455	0.106	0.864	1.128	0.409	0.468	0.091	0.149	0.045	0.170	0.955
Fall, 1985	0.935	0.261	0.152	0.130	1.761	0.435	0.261	0.087	0.130	0.261	0.022	0.217
Winter, 1986	0.125	0.500	0.063	0.125	0.875	1.250	0.000	0.000	0.313	0.125	0.000	0.000

*Station designations.

Table 8-18. Mean c/f Values for Important Species Taken by Experimental Gill Netting at Two Stations in Chickamauga Reservoir near Watts Bar Nuclear Plant, 1977-1985. Values are Antilogs - 1 of $\log_{10}(c/f + 1)$ Transformed Data.

	Station A	Station B
Longnose gar	0.230	0.256
Skipjack herring	0.572	1.029
Gizzard shad	1.072	1.577
Threadfin shad	0.879	1.281
Spotted sucker	0.155	0.116
Blue catfish	0.081	1.199
Channel catfish	0.610	1.119
White bass	0.236	0.350
Yellow bass	0.858	0.716
Logperch	0.150	0.077
Sauger	0.283	0.315
Freshwater drum	0.060	0.452

Table 8-19. Mean Quarterly c/f of Important Species Taken with Experimental Gill Nets at Two Stations in Chickamauga Reservoir near Watts Bar Nuclear Plant, 1977-1985. Values are Antilogs-1 of $\log_{10}$ (c/f + 1) Transformed Data.

	Quarters			
	Winter	Spring	Summer	Fall
Longnose gar	0.241	0.262	0.158	0.305
Skipjack herring	0.503	0.361	0.713	1.417
Gizzard shad	0.705	0.762	2.040	1.520
Threadfin shad	0.691	0.036	1.141	3.001
Spotted sucker	0.170	0.255	0.059	0.101
Blue catfish	0.490	0.452	0.424	0.368
Channel catfish	0.504	0.904	1.128	0.598
White bass	0.302	0.228	0.310	0.283
Yellow bass	0.411	0.904	1.266	0.591
Logperch	0.003	0.179	0.134	0.133
Sauger	0.499	0.502	0.104	0.207
Freshwater drum	0.211	0.197	0.317	0.086

Table 8-20. Number, Percent Composition, and Catch Per Unit Effort (c/f) for Fish Species Collected with Hoop Nets at Two Stations in Chickamauga Reservoir near Watts Bar Nuclear Plant.

	Station A			Station B			Stations Combined		
Common Name	No.	% Comp.	c/f	No.	% Comp.	c/f	No.	% Comp.	c/f
Lamprey				1	0.04	0.002	1	0.01	0.001
Chestnut Lamprey	1	0.02	0.001	1	0.04	0.002	2	0.03	0.001
Paddlefish	1	0.02	0.001	2	0.07	0.003	3	0.04	0.002
Spotted gar	5	0.11	0.006	17	0.59	0.028	22	0.30	0.015
Longnose gar	30	0.67	0.033	6	0.21	0.010	36	0.49	0.024
Shortnose gar	1	0.02	0.001	1	0.04	0.002	2	0.03	0.001
Skipjack herring	6	0.13	0.007	8	0.28	0.013	14	0.19	0.009
*Gizzard shad	337	7.55	0.371	175	6.04	0.286	512	6.96	0.337
Threadfin shad	1	0.02	0.001	—	--	—	1	0.01	0.001
*Moonaye	117	2.62	0.129	154	5.32	0.252	271	3.68	0.178
Carp	39	0.87	0.043	14	0.48	0.023	53	0.72	0.035
River carpsucker	1	0.02	0.001	—	—	—	1	0.01	0.001
Highfin carpsucker	1	0.02	0.001	—	--	—	1	0.01	0.001
Northern hogsucker	--	--	—	1	0.04	0.002	1	0.01	0.001
*Smallmouth buffalo	60	1.34	0.066	98	3.38	0.160	158	2.15	0.104
Bigmouth buffalo	1	0.02	0.001	5	0.17	0.008	6	0.08	0.004
*Spotted sucker	103	2.31	0.113	43	1.49	0.070	146	1.98	0.096
Unidentified redhorse	--	--	—	1	0.04	0.002	1	0.01	0.001
River redhorse	1	0.02	0.001	—	--	—	1	0.01	0.001
Black redhorse	2	0.05	0.002	1	0.04	0.002	3	0.04	0.002
*Golden redhorse	53	1.19	0.058	21	0.73	0.034	74	1.01	0.049
Blue catfish	14	0.31	0.015	14	0.48	0.023	28	0.38	0.018
Black bullhead	--	--	—	1	0.04	0.002	1	0.01	0.001
Yellow bullhead	2	0.05	0.002	3	0.10	0.005	5	0.07	0.003
Brown bullhead	1	0.02	0.001	—	--	—	1	0.01	0.001
*Channel catfish	111	2.49	0.122	58	2.00	0.095	169	2.30	0.111
Flathead catfish	31	0.69	0.034	34	1.17	0.056	65	0.88	0.043
*White bass	180	4.03	0.198	259	8.94	0.424	439	5.97	0.289
Yellow bass	40	0.90	0.044	23	0.79	0.038	63	0.86	0.042
Striped bass	1	0.02	0.001	2	0.07	0.003	3	0.04	0.002
Hybrid white X striped bass	2	0.05	0.002	1	0.04	0.002	3	0.04	0.002

Table 8-20 (Continued)

Common Name	Station A			Station B			Stations Combined		
	No.	% Comp.	c/f	No.	% Comp.	c/f	No.	% Comp.	c/f
Rock bass	6	0.13	0.007	—	—	—	6	0.08	0.004
Warmouth	18	0.40	0.020	6	0.21	0.010	24	0.33	0.016
*Redbreast sunfish	37	0.83	0.041	65	2.24	0.106	102	1.39	0.067
Green sunfish	1	0.02	0.001	—	—	—	1	0.01	0.001
*Bluegill	2000	44.80	2.202	800	27.62	1.309	2800	38.04	1.843
Longear sunfish	4	0.09	0.004	8	0.28	0.013	12	0.16	0.008
*Redear sunfish	709	15.88	0.781	462	15.95	0.756	1171	15.91	0.771
Hybrid sunfish	1	0.02	0.001	—	—	—	1	0.01	0.001
Smallmouth bass	2	0.05	0.002	1	0.04	0.002	3	0.04	0.002
*Spotted bass	139	3.11	0.153	88	3.04	0.144	227	3.08	0.149
Largemouth bass	35	0.78	0.039	18	0.62	0.029	53	0.72	0.035
*White crappie	303	6.79	0.334	433	14.95	0.709	736	10.00	0.485
Black crappie	29	0.65	0.032	12	0.41	0.020	41	0.56	0.027
Yellow perch	2	0.05	0.002	1	0.04	0.002	3	0.04	0.002
Sauger	18	0.40	0.020	10	0.35	0.016	28	0.38	0.018
Walleye	9	0.20	0.010	5	0.17	0.008	14	0.19	0.009
Freshwater drum	9	0.20	0.010	43	1.49	0.070	52	0.71	0.034
Totals	4464	99.96		2896	100.04		7360	99.98	

*Important species (i.e., those that occur in both stations and comprise at least one percent of the total number captured).

Table 8-21. Summary of Multivariate Analysis of Variance Testing Influences of Year, Quarter, Station, and Variable Interactions on c/f of Combined Important Species Captured in Hoop Nets in Chickamauga Reservoir near Watts Bar Nuclear Plant, 1977-1985.

Variable	df	Pillai's Trace*	Probability >F
Year	72/3636	6.31	0.0001
Quarter	36/1809	8.98	0.0001
Station	12/601	5.36	0.0001
Year x Quarter	204/7344	3.56	0.0001
Year x Station	72/3636	2.08	0.0001
Quarter x Station	36/1809	1.95	0.0007
Year x Quarter x Station	204/7344	1.40	0.0002

*Provides an approximation of F-value.

Table 8-22. Summary of Univariate Analyses of Variance Testing for Effects of Year, Quarter, Station, Net Pair, and Variable Interaction of c/f of Important Species Taken in Hoop Nets Set in Chickamauga Reservoir near Watts Bar Nuclear Plant from 1977-1985.

	F-Values						
Species	Year	Quarter	Station	Year × Quarter	Year × Station	Quarter × Station	Year × Quarter × Station
Gizzard shad	0.83	18.84†	0.85	3.71†	2.91	4.26	1.47
Mooneye	10.96†	33.67†	0.66	10.49†	1.19	2.36	2.30*
Smallmouth buffalo	17.10†	26.67†	21.55†	11.10†	4.75†	2.36	3.08†
Spotted sucker	1.54	3.38	3.69	1.77	0.99	1.08	0.78
Golden redhorse	1.02	3.46	3.49	1.67	1.11	0.22	1.15
Channel catfish	8.28†	8.06†	0.09	2.76†	0.22	2.18	0.93
White bass	8.03†	15.42†	6.50	3.05†	2.00	5.22*	2.52†
Redbreast sunfish	3.88*	1.60	1.61	0.80	2.65	1.02	0.69
Bluegill	16.57†	14.27†	5.13	2.21*	0.37	1.48	1.13
Redear sunfish	5.92†	10.09†	0.58	1.45	0.71	1.73	1.07
Spotted bass	3.66*	7.06†	0.00	1.99	1.89	0.65	0.84
White crappie	18.81†	14.24†	16.09†	6.95†	6.77†	0.46	1.48

Significance levels with Bonferroni's adjustment:
*Significant (alpha <0.05).
†Highly significant (alpha <0.01).

Table 8-23. Mean Quarterly c/f of Important Species Taken with Hoop Nets at Two Stations in Chickamauga Reservoir near Watts Bar Nuclear Plant, 1977-1985. Values are Antilogs-1 of $\log_{10}$ (c/f + 1) Transformed Data.

	Quarters			
	Winter	Spring	Summer	Fall
Gizzard shad	0.207	0.036	0.018	0.013
Mooneye	0.114	0.026	0.002	0.004
Smallmouth buffalo	0.013	0.035	0.023	0.023
Spotted sucker	0.034	0.041	0.013	0.020
Golden redhorse	0.010	0.020	0.017	0.015
Channel catfish	0.008	0.051	0.043	0.010
White bass	0.083	0.096	0.025	0.029
Redbreast sunfish	0.009	0.023	0.025	0.014
Bluegill	0.062	0.327	0.338	0.420
Redear sunfish	0.070	0.155	0.205	0.241
Spotted bass	0.014	0.035	0.047	0.071
White crappie	0.036	0.143	0.127	0.095

Table 8-24. Mean Quarterly Catch Per Unit Effort for Twelve Important Species Collected with Hoop Gill Nets at Two Stations on Chickamauga Reservoir near Watts Bar Nuclear Plant.

	Species											
	Gizzard shad		Mooneye		Smallmouth buffalo		Spotted sucker		Golden redhorse		Channel catfish	
Quarters	A*	B*	A	B	A	B	A	B	A	B	A	B
Winter, 1977	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300
Spring, 1977	0.083	0.273	0.667	0.273	2.833	1.364	0.000	0.000	0.333	0.091	1.250	0.455
Summer, 1977	0.033	0.313	0.000	0.000	0.033	0.094	0.000	0.000	0.033	0.094	0.067	0.094
Fall, 1977	0.083	0.333	0.000	0.000	0.000	0.500	0.000	0.000	0.083	0.000	0.083	0.250
Winter, 1978	0.300	0.467	4.050	2.600	0.000	0.200	0.150	0.000	0.050	0.067	0.000	0.100
Spring, 1978	0.548	1.065	0.097	0.355	0.000	0.226	0.613	0.613	0.032	0.097	0.032	0.129
Summer, 1978	0.000	0.094	0.021	0.000	0.021	0.219	0.043	0.000	0.021	0.000	0.000	0.000
Fall, 1978	0.000	0.000	0.067	0.000	0.000	0.000	0.000	0.000	0.000	0.083	0.000	0.000
Winter, 1979	0.065	0.313	0.043	1.156	0.043	0.250	0.022	0.031	0.087	0.031	0.000	0.031
Spring, 1979	0.150	0.067	0.150	0.000	0.100	0.933	0.350	0.000	0.200	0.200	0.100	0.067
Summer, 1979	0.000	0.063	0.000	0.000	0.043	0.063	0.000	0.000	0.065	0.000	0.022	0.000
Fall, 1979	0.042	0.286	0.000	0.000	0.000	0.429	0.000	0.071	0.000	0.000	0.000	0.000
No Samples	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spring, 1982	0.206	0.048	0.088	0.048	0.000	0.048	0.176	0.048	0.088	0.000	0.088	0.048
Summer, 1982	0.000	0.158	0.000	0.000	0.029	0.053	0.088	0.211	0.029	0.053	0.147	0.000
Fall, 1982	0.034	0.000	0.000	0.000	0.000	0.053	0.138	0.053	0.103	0.000	0.034	0.000
Winter, 1983	2.694	0.750	0.056	0.500	0.000	0.000	0.417	0.042	0.083	0.000	0.056	0.042
Spring, 1983	0.118	0.000	0.118	0.125	0.029	0.083	0.118	0.000	0.029	0.042	1.147	0.208
Summer, 1983	0.065	0.125	0.000	0.000	0.065	0.083	0.032	0.083	0.000	0.042	0.516	0.750
Fall, 1983	0.028	0.043	0.000	0.043	0.056	0.087	0.139	0.087	0.083	0.087	0.028	0.043
Winter, 1984	2.088	2.458	0.029	0.167	0.029	0.000	0.088	0.333	0.029	0.000	0.000	0.000
Spring, 1984	0.000	0.043	0.024	0.000	0.000	0.000	0.098	0.130	0.000	0.000	0.122	0.000
Summer, 1984	0.000	0.000	0.022	0.043	0.000	0.087	0.000	0.000	0.065	0.043	0.130	0.174
Fall, 1984	0.000	0.000	0.043	0.000	0.021	0.087	0.043	0.000	0.064	0.043	0.021	0.043
Winter, 1985	2.289	0.125	0.089	0.042	0.000	0.000	0.133	0.000	0.000	0.000	0.000	0.000
Spring, 1985	0.170	0.000	0.000	0.000	0.000	0.043	0.213	0.000	0.106	0.000	0.085	0.043
Summer, 1985	0.083	0.000	0.000	0.000	0.208	0.043	0.063	0.000	0.146	0.000	0.125	0.087
Fall, 1985	0.021	0.043	0.000	0.000	0.000	0.304	0.085	0.000	0.000	0.000	0.000	0.043
Winter, 1986	0.313	0.125	0.000	0.000	0.000	0.250	0.063	0.000	0.000	0.000	0.000	0.000

Table B-24 (Continued)

Quarters	Species											
	White bass		Redbreast sunfish		Bluegill		Redear sunfish		Spotted bass		White Crappie	
	A*	B*	A	B	A	B	A	B	A	B	A	B
Winter, 1977	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000
Spring, 1977	0.583	1.000	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.000	0.250	0.000
Summer, 1977	0.167	0.094	0.000	0.000	0.100	0.406	0.167	0.750	0.067	0.031	0.467	1.094
Fall, 1977	1.250	0.083	0.000	0.000	1.333	0.083	0.083	0.000	0.583	0.000	0.250	0.750
Winter, 1978	0.700	1.067	0.000	0.000	0.000	0.000	0.000	0.033	0.000	0.000	0.050	0.667
Spring, 1978	0.806	2.387	0.000	0.000	0.323	0.129	0.387	0.516	0.032	0.065	1.258	4.258
Summer, 1978	0.043	0.063	0.000	0.000	0.957	0.313	0.468	0.531	0.277	0.125	0.277	0.563
Fall, 1978	0.000	0.083	0.000	0.000	0.267	0.667	0.400	1.750	0.267	0.250	0.667	2.167
Winter, 1979	0.261	1.531	0.000	0.000	0.348	0.500	0.348	0.563	0.152	0.031	0.065	0.500
Spring, 1979	1.300	0.067	0.000	0.000	3.250	0.533	0.900	0.267	0.300	0.000	0.550	1.067
Summer, 1979	0.261	0.156	0.065	0.531	2.478	0.313	1.043	0.969	0.304	0.250	0.348	1.000
Fall, 1979	0.083	0.000	0.000	0.000	1.667	0.500	1.292	1.429	0.250	0.143	0.208	0.500
No Samples	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spring, 1982	0.647	0.333	0.235	0.000	4.882	1.952	0.618	0.667	0.088	0.333	0.647	0.090
Summer, 1982	0.059	0.158	0.029	0.000	6.676	4.737	1.000	2.474	0.088	0.105	0.706	1.895
Fall, 1982	0.103	0.474	0.103	0.000	2.414	4.526	2.138	1.684	0.000	0.368	0.241	0.526
Winter, 1983	0.056	0.708	0.028	0.125	0.167	0.375	0.167	0.417	0.028	0.208	0.167	0.125
Spring, 1983	0.294	0.792	0.029	0.500	4.882	3.292	2.647	0.625	0.118	0.000	1.118	1.083
Summer, 1983	0.129	0.167	0.097	0.542	2.774	2.375	1.161	1.292	0.161	0.250	0.548	0.083
Fall, 1983	0.000	0.000	0.194	0.174	7.972	3.652	1.472	0.957	0.694	0.609	0.167	0.217
Winter, 1984	0.029	0.167	0.000	0.167	0.353	0.417	0.147	1.708	0.000	0.042	0.029	0.083
Spring, 1984	0.000	0.261	0.000	0.087	1.073	0.870	0.780	0.348	0.000	0.087	0.122	0.043
Summer, 1984	0.043	0.000	0.065	0.043	1.065	1.043	0.848	0.478	0.065	0.043	0.065	0.087
Fall, 1984	0.043	0.000	0.000	0.000	1.596	0.913	1.128	0.261	0.043	0.043	0.170	0.130
Winter, 1985	0.067	0.208	0.000	0.042	0.044	0.417	0.044	0.667	0.022	0.042	0.044	0.000
Spring, 1985	0.064	0.043	0.064	0.130	2.404	1.522	0.404	0.261	0.234	0.435	0.064	0.000
Summer, 1985	0.000	0.000	0.063	0.217	3.104	2.826	0.896	0.696	0.167	0.174	0.500	0.130
Fall, 1985	0.064	0.087	0.021	0.000	4.766	3.696	1.043	0.609	0.277	0.174	0.340	0.478
Winter, 1986	0.188	0.250	0.000	0.000	0.563	0.875	0.375	2.625	0.000	0.125	0.188	0.125

*Station designations.

Table 8-25. Mean Annual c/f of Important Species Taken with Hoop Nets at Two Stations in Chickamauga Reservoir near Watts Bar Nuclear Plant, 1977-1985. Values are Antilogs-1 of $\log_{10}(c/f + 1)$ Transformed Data.

	Years						
	1977	1978	1979	1982	1983	1984	1985
Gizzard shad	0.051	0.066	0.034	0.023	0.092	0.067	0.078
Mooneye	0.034	0.167	0.043	0.008	0.028	0.013	0.006
Smallmouth buffalo	0.097	0.033	0.049	0.010	0.015	0.008	0.020
Spotted sucker	0.000	0.037	0.014	0.034	0.039	0.019	0.024
Golden redhorse	0.026	0.014	0.023	0.016	0.016	0.011	0.014
Channel catfish	0.072	0.011	0.008	0.016	0.073	0.021	0.016
White bass	0.074	0.133	0.114	0.070	0.059	0.016	0.020
Redbreast sunfish	0.000	0.000	0.017	0.022	0.044	0.010	0.018
Bluegill	0.068	0.086	0.220	0.474	0.414	0.206	0.351
Redear sunfish	0.049	0.103	0.204	0.253	0.217	0.154	0.148
Spotted bass	0.027	0.035	0.061	0.043	0.068	0.013	0.051
White crappie	0.112	0.196	0.135	0.169	0.113	0.032	0.058

Table 8-26. Mean c/f Values for Important Species Taken by Hoop Netting at Two Stations in Chickamauga Reservoir near Watts Bar Nuclear Plant, 1977-1985. Values are Antilogs - 1 of $\log_{10}(c/f + 1)$ Transformed Data.

	Station A	Station B
Gizzard shad	0.073	0.049
Mooneye	0.027	0.044
Smallmouth buffalo	0.013	0.040
Spotted sucker	0.032	0.017
Golden redhorse	0.019	0.011
Channel catfish	0.031	0.028
White bass	0.040	0.084
Redbreast sunfish	0.014	0.025
Bluegill	0.321	0.252
Redear sunfish	0.172	0.170
Spotted bass	0.040	0.046
White crappie	0.086	0.129

Table 8-27. List of Fish Species, Total Catch, Relative Abundance, and Number of Occurrences in Electrofishing Samples Taken Near Watts Bar Nuclear Plant 1977 Through 1985

Common Name	Total Number	Percentage of Total Number	Number of Occurrences
Spotted gar	37	0.039	11
Longnose gar	183	0.192	27
Skipjack herring	545	0.572	53
Unidentified shad	42	0.044	1
Gizzard shad	52,469	55.077	1,232
Threadfin shad	6,819	7.158	139
Mooneye	84	0.088	16
Carp	445	0.467	212
Silver chub	1	0.001	1
Golden shiner	64	0.067	23
Unidentified shiner	2	0.002	1
Emerald shiner	20,918	21.958	407
Spotfin shiner	49	0.051	8
Bullhead minnow	11	0.012	6
River carpsucker	1	0.001	1
Northern hogsucker	20	0.021	16
Smallmouth buffalo	11	0.012	11
Spotted sucker	440	0.462	208
Unidentified redhorse	10	0.010	6
River redhorse	2	0.002	1
Golden redhorse	165	0.173	109
Blue catfish	1	0.001	1
Channel catfish	13	0.014	13
Flathead catfish	5	0.005	5
American eel	1	0.001	1
White bass	481	0.505	108
Yellow bass	1,454	1.526	111
Striped bass	18	0.019	10
Rock bass	3	0.003	3
Unidentified sunfish	218	0.229	19
Warmouth	20	0.021	15
Redbreast sunfish	337	0.354	165
Green sunfish	17	0.018	4
Bluegill	3,572	3.750	573
Longear sunfish	59	0.062	30
Redear sunfish	2,588	2.717	550
Smallmouth bass	109	0.114	65
Spotted bass	367	0.385	194
Largemouth bass	1,197	1.256	512
White crappie	294	0.309	60
Black crappie	5	0.005	4

Table 8-27. (Continued)

Common Name	Total Number	Percentage of Total Number	Number of Occurrences
Yellow perch	145	0.152	62
Logperch	18	0.019	14
Sauger	28	0.029	20
Walleye	1	0.001	1
Freshwater drum	71	0.075	50
Brook silverside	1,925	2.021	115
Total	95,265	100.000	

Table 8-28. List of Important Species ranked by c/f in Electrofishing Samples Near Watts Bar Nuclear Plant, 1979 Through 1985

Common Name	c/f (Number Per Electrofishing Run) Total 1,439 Runs
Gizzard shad	36.5
Emerald shiner	14.5
Threadfin shad	4.7
Bluegill	2.5
Redear sunfish	1.8
Brook silverside	1.3
Yellow bass	1.0
Largemouth bass	0.8
White bass*	0.3

*Selected for analysis although not meeting important species criteria.

Table 8-29. Mean c/f by Quarter and Station for Total Fish Collected by Electrofishing Near Watts Bar Nuclear Plant, 1977 Through 1985

Quarter	Station A	Station B	Quarter Total
Spring	86.8	33.4	59.5
Summer	78.2	27.3	52.8
Fall	101.0	51.2	75.4
Winter	78.9	83.0	80.9
Total	86.3	46.5	66.2

Table 8-30. Mean Quarterly c/f by Year for Species Important in Electrofishing in Chickamauga Reservoir, Near Watts Bar Nuclear Plant, 1977 Through 1985

Species	Year	Quarter Spring	Summer	Fall	Winter*
	1977				
Gizzard shad		4.05	20.80	33.41	-
Threadfin shad		0.14	0.00	39.70	-
Emerald shiner		3.81	2.38	0.05	-
White bass		0.12	0.02	0.60	-
Yellow bass		0.02	0.00	0.18	-
Bluegill		0.17	1.36	0.52	-
Redear sunfish		0.14	0.89	0.78	-
Largemouth bass		0.14	1.62	0.23	-
Brook silverside		0.53	0.95	0.05	-
	1978				
Gizzard shad		11.28	17.64	14.24	48.99
Threadfin shad		0.14	0.00	0.35	0.22
Emerald shiner		9.35	15.01	38.41	0.09
White bass		0.08	0.28	0.21	1.74
Yellow bass		0.08	0.00	0.28	0.10
Bluegill		0.99	1.68	1.79	0.17
Redear sunfish		0.76	1.38	3.42	0.45
Largemouth bass		1.02	1.15	0.56	0.07
Brook silverside		0.46	2.33	1.68	0.28
	1979				
Gizzard shad		24.85	15.56	56.60	2.03
Threadfin shad		0.46	1.01	3.73	0.08
Emerald shiner		24.67	0.71	0.92	6.52
White bass		0.46	0.12	0.48	0.17
Yellow bass		2.06	0.19	0.30	0.26
Bluegill		0.49	1.90	1.09	0.29
Redear sunfish		0.42	1.53	1.21	0.47
Largemouth bass		0.67	0.55	0.53	0.16
Brook silverside		0.60	0.62	3.15	0.92
	1982				
Gizzard shad		24.44	25.15	18.98	-
Threadfin shad		0.02	0.10	1.61	-
Emerald shiner		2.91	7.68	5.31	-
White bass		0.20	0.02	0.00	-
Yellow bass		0.81	0.00	0.03	-
Bluegill		1.15	1.38	1.47	-
Redear sunfish		0.25	1.18	1.14	-
Largemouth bass		0.59	1.28	1.39	-
Brook silverside		0.48	0.28	0.00	-

Table 8-30. (Continued)

Species	Year	Quarter Spring	Summer	Fall	Winter*
	1983				
Gizzard shad		11.85	21.71	2.16	66.07
Threadfin shad		0.56	0.00	0.00	5.59
Emerald shiner		7.73	1.26	0.19	0.81
White bass		0.08	0.00	0.00	0.28
Yellow bass		0.28	0.00	0.02	0.61
Bluegill		1.26	8.07	1.27	1.96
Redear sunfish		0.97	1.03	0.61	1.80
Largemouth bass		0.23	1.09	0.20	0.44
Brook silverside		0.00	0.00	0.00	0.00
	1984				
Gizzard shad		7.07	10.21	8.68	4.85
Threadfin shad		0.00	0.58	0.50	0.56
Emerald shiner		1.09	0.82	0.43	0.08
White bass		0.17	0.02	0.07	0.03
Yellow bass		0.30	0.00	0.00	0.06
Bluegill		0.22	1.77	1.35	1.23
Redear sunfish		0.55	2.86	1.76	1.05
Largemouth bass		0.07	1.13	0.82	0.24
Brook silverside		0.15	0.18	0.00	0.00
	1985				
Gizzard shad		2.33	4.37	6.76	9.41
Threadfin shad		0.00	0.37	0.00	0.54
Emerald shiner		2.43	1.18	4.27	0.02
White bass		0.00	0.02	0.00	0.04
Yellow bass		0.18	0.00	0.00	0.43
Bluegill		0.46	0.59	3.97	0.04
Redear sunfish		0.17	0.31	2.71	0.53
Largemouth bass		0.29	0.40	1.17	0.07
Brook silverside		0.02	0.00	0.12	0.02

*No winter samples collected.

Table 8-31. Summary of Three-Way Univariate ANOVA Testing of Effects of Year, Quarter, Station, Area, and Interactions of These Variables on c/f of Each Important Species Taken by Electrofishing Near Watts Bar Nuclear Plant, 1977 Through 1985

Species	Year	Quarter	Station	Area	Year X Quarter	Quarter X Station
Gizzard shad	8.63*	2.42	24.94*	0.37	7.77*	1.03
Threadfin shad	5.79*	15.35*	10.64†	0.15	6.70†	2.81
Emerald shiner	10.79*	11.35*	15.53*	0.14	6.13*	1.34
White bass	5.67*	4.68†	8.34†	6.79†	2.83*	0.62
Yellow bass	2.72	5.71*	15.57*	2.60	1.87	3.10
Bluegill	4.73*	12.98*	9.18†	2.09	3.00*	1.75
Redear sunfish	2.19	10.06*	0.10	0.01	2.33†	2.41
Largemouth bass	2.23	16.79*	4.52	0.78	3.14*	6.21*
Brook silverside	11.51*	1.73	4.95	3.56	2.27†	1.09

*Highly significant effect ($P<0.01$).
†Significant effect ($P<0.05$).

Table 8-32. Estimated Numbers of Fish Harvested for Chickamauga Reservoir, Tennessee (January 1972 Through June 1984)

Species	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
White crappie	99,838	143,392	55,873	66,444	64,985	85,425	108,716	87,831	215,764	136,069	50,729	35,713	43,515
Bluegill	73,845	38,102	75,749	46,348	52,797	34,886	46,694	25,137	29,520	25,547	40,920	41,082	25,448
White bass	29,108	12,005	13,779	10,850	10,730	17,700	67,692	20,819	16,562	26,556	61,571	17,257	1,575
Channel catfish	20,901	13,517	14,213	15,370	30,889	20,461	22,392	18,227	25,051	8,391	22,811	25,068	10,400
Freshwater drum	17,414	4,557	4,229	544	25,606	17,719	4,891	2,894	1,529	1,221	4,806	4,137	1,554
Largemouth bass	15,972	10,066	12,295	16,916	19,311	6,441	23,936	20,536	18,850	29,094	46,562	55,294	32,178
Blue catfish	5,746	5,106	3,108	2,360	6,743	5,132	4,164	4,875	8,924	3,928	33,796	25,416	7,992
Redear sunfish	6,494	3,449	10,446	6,916	12,459	2,330	1,862	893	3,788	291	656	2,434	271
Spotted bass	5,508	3,434	4,025	4,537	1,828	1,212	1,211	848	265	597	1,787	394	-
Smallmouth bass	4,283	97	163	362	280	1,180	444	330	265	1,494	1,659	1,447	-
Black crappie	1,874	2,068	4,215	4,234	6,610	1,705	3,313	4,105	3,204	4,502	3,731	2,721	4,504
Sauger	1,410	3,679	4,737	3,502	8,869	20,772	34,704	20,200	9,115	3,054	3,406	7,443	3,412
Other sunfish*	398	841	259	273	2,978	289	-	5,286	341	9,364	9,240	36,315	273
Yellow perch	564	909	566	-	-	1,737	756	1,946	1,771	1,208	10,645	2,507	3,886
Yellow bass	390	225	475	747	2,876	997	3,009	1,201	57	1,141	3,448	4,108	245
Flathead catfish	633	286	30	497	611	1,397	218	1,464	861	303	503	-	476
Rock bass	323	564	-	-	155	192	62	-	-	77	179	178	1,115
Carp	270	96	28	-	589	481	-	148	-	98	-	-	-
Walleye	68	-	137	-	252	-	215	78	591	-	109	-	-
Striped bass	12	842	33	-	-	844	756	1,381	508	303	726	1,573	1,223
Totals	285,051	243,235	204,360	179,900	248,568	220,910	325,035	218,249	336,968	253,238	297,284	263,087	138,506

*Sunfish other than bluegill and redear.

Table B-33. Estimated Biomass (Kg) Harvested by Anglers on Chickamauga Reservoir, Tennessee (January 1972 Through June 1984)

Species	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
White crappie	23,764	33,145	11,441	13,265	16,933	23,886	19,080	16,423	36,765	28,874	14,533	10,304	11,543
Bluegill	8,913	5,980	9,994	6,942	7,010	4,591	4,839	2,450	2,817	3,129	4,627	5,447	3,166
White bass	10,470	3,857	4,340	2,571	4,483	6,537	22,151	8,569	7,299	9,452	26,659	5,719	638
Channel catfish	9,501	10,541	6,805	7,546	19,023	11,773	11,481	9,404	16,891	6,255	20,680	19,609	8,118
Freshwater drum	6,311	1,479	1,292	127	4,358	5,495	1,300	1,316	862	471	3,019	4,056	1,161
Largemouth bass	8,425	5,286	5,684	9,076	4,289	3,609	10,207	10,902	10,780	17,326	22,711	28,288	17,035
Blue catfish	2,432	24,947	1,147	753	5,037	1,707	2,090	3,064	6,656	6,352	24,666	10,895	7,495
Redear sunfish	1,007	610	1,630	1,348	1,763	350	245	117	480	56	121	71	41
Spotted bass	1,845	1,427	1,554	1,526	780	469	488	721	175	310	708	262	-
Smallmouth bass	1,827	42	91	101	448	693	196	415	107	1,123	755	929	-
Black crappie	440	474	948	1,072	1,908	517	892	974	669	1,271	1,729	997	1,217
Sauger	981	1,374	1,651	887	5,858	4,766	10,972	8,501	3,320	1,635	2,109	2,117	786
Other sunfish*	53	123	21	33	403	53	-	929	108	1,751	1,124	6,166	38
Yellow perch	73	179	111	-	-	153	118	275	402	352	1,753	651	906
Yellow bass	70	79	98	84	362	178	433	130	10	130	509	796	12
Flathead catfish	364	216	14	955	780	740	58	6,491	2,073	543	666	-	216
Rock bass	138	103	-	-	26	23	10	-	-	25	53	46	245
Carp	704	185	57	-	971	1,470	-	558	-	405	-	-	-
Walleye	124	-	188	-	565	-	193	57	310	-	94	-	-
Striped bass	16	1,243	62	-	-	1,193	1,787	7,651	2,815	2,694	4,582	6,000	4,203
Totals	77,458	91,290	47,128	46,286	75,487	68,203	86,540	78,947	92,539	82,170	131,098	102,353	60,797

*[illegible]

Table 8-34. Fishing Pressure (Hours) by Season for Chickamauga Reservoir, Tennessee (1972 Through 1983)

Year	Spring	Summer	Fall	Winter	Total
1972	154,861	141,494	33,882	8,698	338,935
1973	90,724	87,735	51,499	22,098	252,056
1974	68,692	79,893	46,220	22,063	216,868
1975	179,544	162,679	54,927	66,705	463,855
1976	175,752	134,055	66,384	36,580	412,771
1977	133,380	108,615	23,760	8,127	273,882
1978	98,562	147,412	59,844	26,169	331,987
1979	141,809	186,461	55,866	32,465	416,601
1980	173,243	136,482	104,454	49,504	463,683
1981	206,352	181,705	78,675	24,439	491,171
1982	124,302	181,994	100,916	47,529	454,741
1983	233,038	137,987	46,473	75,580	523,780
1984	225,826	100,601	75,076	62,292	463,795

Table 8-35. Harvest Rates of Sport Fish for Chickamauga Reservoir, Tennessee (1972 Through 1984)

Date	Number Per Hour	Kilograms Per Hour	Number Per Hectare	Kilograms Per Hectare
1972	0.85	0.23	20.1	5.5
1973	0.97	0.36	17.1	6.4
1974	0.94	0.22	14.3	3.3
1975	0.39	0.10	12.6	3.2
1976	0.60	0.18	17.4	5.3
1977	0.78	0.23	14.1	4.3
1978	1.18	0.31	20.6	5.5
1979	0.58	0.21	13.9	5.0
1980	0.87	0.21	21.4	5.9
1981	0.58	0.20	16.1	5.2
1982	0.63	0.28	18.8	8.4
1983	0.58	0.21	16.7	6.5
1984	0.34	0.16	9.7	4.3

Table 8-36. Creel Sampling of 1,490 Fisherman Hours in the Vicinity of Watts Bar Nuclear Plant, Tennessee River Mile 526.8-529.2 (April 1982 Through December 1982)

Species	Number Caught	Biomass Caught (kg)	Average Biomass (kg)	Number Per Hour	Biomass Per Hour (kg)	Percent By Number	Percent Biomass
Paddlefish	1	10.1	10.14	0.001	0.067	0.09	2.14
Flathead catfish	1	0.7	0.68	0.001	>0.001	0.09	0.14
Blue catfish	51	47.2	0.93	0.034	0.032	4.67	9.99
Channel catfish	153	120.6	0.79	0.103	0.081	14.01	25.50
Skipjack herring	15	0.9	0.86	0.010	>0.001	1.37	0.18
Drum	47	12.3	0.26	0.032	0.008	4.30	2.60
Hybrid rockfish	5	4.7	0.94	0.003	0.003	0.46	0.99
Rockfish	21	81.1	3.86	0.014	0.055	1.92	17.13
White bass	116	49.5	0.43	0.078	0.033	10.62	10.47
Yellow bass	169	28.0	0.17	0.113	0.019	15.48	5.91
Sauger	9	5.9	0.66	0.006	0.004	0.82	1.25
Yellow perch	15	1.8	0.12	0.010	0.001	1.37	0.38
Largemouth bass	23	8.7	0.38	0.015	0.006	2.11	1.84
Smallmouth bass	6	3.9	0.65	0.004	0.003	0.55	0.83
Spotted bass	3	1.0	0.35	0.002	0.001	0.27	0.22
White crappie	225	61.8	0.28	0.151	0.041	20.60	13.07
Black crappie	6	1.7	0.28	0.004	0.001	0.55	0.36
Bluegill	197	28.0	0.14	0.132	0.019	18.04	5.93
Redear sunfish	22	2.1	0.09	0.015	0.001	2.01	0.44
Warmouth bass	3	0.6	0.02	0.002	>0.001	0.27	0.12
Rock bass	4	2.4	0.60	0.003	0.002	0.37	0.51
Totals	1,092	473.3	0.43	0.733	0.318		

Table 8-37. Creel Sampling of 1,387 Fisherman Hours in the Vicinity of Watts Bar Nuclear Plant, Tennessee River Mile 526.8-529.2 (January 1983 Through December 1983)

Species	Number Caught	Biomass Caught (kg)	Average Biomass (kg)	Number Per Hour	Biomass Per Hour (kg)	Percent By Number	Percent Biomass
Carp	1	0.4	0.36	0.001	>0.001	0.09	0.08
Blue cat	100	42.5	0.42	0.072	0.030	8.69	9.89
Channel cat	107	89.9	0.84	0.077	0.065	9.30	20.96
Skipjack herring	2	2.9	1.47	0.001	0.002	0.17	0.69
Drum	19	13.5	0.70	0.014	0.010	1.65	3.13
Rainbow trout	2	0.8	0.40	0.001	>0.001	0.17	0.19
Hybrid rockfish	2	3.5	1.77	0.001	0.003	0.17	0.83
Rockfish	3	9.1	3.03	0.002	0.006	0.26	2.12
White bass	267	11.9	0.44	0.193	0.085	23.20	27.65
Yellow bass	36	9.4	0.26	0.026	0.007	3.13	2.19
Sauger	3	1.8	0.60	0.002	0.001	0.26	0.42
Yellow perch	46	6.5	0.14	0.033	0.005	4.00	1.51
Largemouth bass	55	24.5	0.44	0.040	0.018	4.78	5.70
Smallmouth bass	5	5.2	1.04	0.004	0.004	0.43	1.22
Spotted bass	10	4.7	0.47	0.007	0.003	0.87	1.10
White crappie	106	32.9	0.34	0.076	0.024	9.21	7.66
Black crappie	2	0.5	0.22	0.001	>0.001	0.17	0.11
Bluegill	374	60.9	0.16	0.270	0.043	32.49	14.00
Redear sunfish	9	1.7	0.19	0.006	0.001	0.78	0.40
Rock bass	2	0.6	0.29	0.001	>0.001	0.17	0.14
Totals	1,151	429.2	0.37	0.830	0.310		

Table 8-38. Creel Sampling of 893 Fisherman Hours in the Vicinity of Watts Bar Nuclear Plant, Tennessee River Mile 526.8-529.2 (January 1984 Through December 1984)

Species	Number Caught	Biomass Caught (kg)	Average Biomass (kg)	Number Per Hour	Biomass Per Hour (kg)	Percent By Number	Percent Biomass
Carp	1	0.4	0.40	0.001	>0.001	0.11	0.16
Flathead	3	1.7	0.56	0.003	0.002	0.33	0.64
Blue cat	7	6.8	1.10	0.008	0.008	0.77	2.60
Channel cat	76	51.6	0.68	0.085	0.058	8.39	19.66
Drum	51	36.9	0.72	0.057	0.041	5.63	14.06
Hybrid rockfish	2	7.5	3.72	0.002	0.008	0.22	2.84
Rockfish	7	19.6	2.80	0.008	0.022	0.77	7.48
White bass	63	24.7	0.39	0.071	0.028	6.95	9.42
Yellow bass	70	11.5	0.16	0.078	0.013	7.73	4.36
Sauger	18	8.5	0.47	0.020	0.010	1.99	3.22
Yellow perch	19	2.0	0.10	0.021	0.002	2.10	0.78
Largemouth bass	23	10.5	0.45	0.026	0.012	2.54	4.00
Smallmouth bass	8	3.8	0.47	0.009	0.004	0.88	1.44
Spotted bass	1	0.3	0.31	0.001	>0.001	0.11	0.12
White crappie	67	10.0	0.14	0.075	0.011	7.40	3.79
Black crappie	6	1.5	0.25	0.007	0.002	0.66	0.57
Unidentified sunfish	2	0.7	0.34	0.002	0.001	0.22	0.26
Bluegill	446	59.1	0.13	0.500	0.066	49.23	22.50
Redear sunfish	34	5.3	0.15	0.038	0.006	3.75	2.01
Warmouth bass	2	0.3	0.13	0.002	>0.001	0.22	0.10
Totals	906	262.6	0.29	1.015	0.294		

Table 8-39. Creel Sampling of 975 Fisherman Hours in the Vicinity of Watts Bar Nuclear Plant, Tennessee River Mile 526.8-529.2 (January 1985 Through December 1985)

Species	Number Caught	Biomass Caught (kg)	Average Biomass (kg)	Number Per Hour	Biomass Per Hour (kg)	Percent By Number	Percent Biomass
Flathead	1	0.2	0.23	0.001	>0.001	0.09	0.08
Blue cat	44	23.5	0.53	0.045	0.024	3.89	8.53
Channel cat	47	38.6	0.82	0.048	0.040	4.16	14.06
Drum	5	2.4	0.47	0.005	0.002	0.44	0.86
Rockfish	5	8.2	1.65	0.005	0.009	0.44	2.99
White bass	37	10.7	0.29	0.038	0.011	3.27	3.90
Yellow bass	38	7.0	0.19	0.039	0.007	3.36	2.56
Sauger	292	69.6	0.24	0.299	0.071	25.82	25.32
Yellow perch	18	2.7	0.15	0.018	0.003	1.59	0.98
Largemouth bass	19	10.0	0.53	0.019	0.010	1.68	3.64
Smallmouth bass	6	5.5	0.91	0.006	0.005	0.53	1.98
Spotted bass	1	0.3	0.32	0.001	>0.001	0.09	0.12
White crappie	119	32.0	0.27	0.122	0.032	10.52	11.64
Bluegill	450	57.5	0.13	0.461	0.059	39.79	20.92
Redear sunfish	46	6.2	0.14	0.047	0.006	4.07	2.27
Warmouth bass	1	0.2	0.23	0.001	>0.001	0.09	0.08
Rock bass	2	0.1	0.07	0.002	>0.001	0.18	0.05
Totals	1,131	274.8	0.24	1.160	0.282		

Table 8-40. Number of Samples and Mean Annual Standing Stock (no./ha and kg/ha) of of all Young, Intermediate, and Harvestable Size Fish Collected in Cove Rotenone Samples from Chickamauga Reservoir, 1970 through 1985.

Year	No. Samples	Young		Intermediate		Harvestable		Total	
		Number	kg	Number	kg	Number	kg	Number	kg
1970	12	7,353	12.61	534	24.80	931	182.49	8,819	219.91
1971	4	7,018	17.27	724	97.95	863	168.04	8,604	283.26
1972	4	12,872	63.06	932	30.96	1,394	271.21	15,199	365.23
1973	4	13,092	72.52	955	36.44	1,572	290.20	15,619	399.16
1974	4	9,737	34.23	673	21.98	1,263	194.91	11,673	251.13
1975	4	12,684	37.18	443	14.94	1,364	187.09	14,491	239.21
1976	5	14,662	37.20	1,179	26.39	1,400	272.84	17,241	336.43
1977	5	33,121	96.18	1,164	26.41	1,441	223.97	35,981	346.56
1978	5	19,883	31.70	960	19.98	2,584	184.51	23,427	236.19
1979	5	17,973	22.91	1,375	27.41	2,872	209.04	22,220	259.36
1980	5	34,424	44.71	537	10.08	1,020	132.58	35,981	187.37
1981	5	53,515	66.21	1,590	34.14	2,278	327.68	57,383	428.03
1982	5	33,655	56.23	977	24.37	1,919	209.92	36,551	209.52
1983	5	46,500	70.74	1,209	26.60	2,513	344.07	50,223	441.41
1984	5	24,814	43.58	937	22.47	3,545	383.25	29,296	449.30
1985	5	43,064	143.49	986	26.88	2,361	357.54	46,411	527.91
TOTAL	82								

Table 8-41. Mean Annual Standing Stock (no./ha and kg/ha) of Game, Commercial, and Forage Fish Collected in Cove Rotenone Samples from Chickamauga Reservoir, 1970 through 1985.

Year	Game Fish		Commercial Fish		Forage Fish	
	Number	kg	Number	kg	Number	kg
1970	2,288.22	27.42	548.18	109.55	5,982.24	82.93
1971	2,778.21	41.27	421.52	165.43	5,404.62	76.57
1972	3,764.61	58.53	769.14	140.99	10,665.19	165.72
1973	4,427.42	59.13	979.55	158.12	10,212.52	181.92
1974	2,637.81	33.32	396.25	79.74	8,638.84	138.07
1975	5,489.16	37.06	269.92	78.42	8,731.57	123.73
1976	8,624.39	57.53	474.81	147.02	8,141.71	131.88
1977	22,477.22	72.79	443.34	94.65	12,805.99	179.13
1978	18,340.44	57.57	228.17	52.31	4,859.39	126.30
1979	18,590.09	69.87	281.76	92.03	3,347.66	97.46
1980	33,026.90	80.19	225.13	66.67	2,728.00	40.51
1981	51,074.50	116.51	504.41	131.19	5,804.83	180.33
1982	24,734.58	67.64	451.39	57.10	11,365.07	165.79
1983	33,984.29	75.73	486.75	93.60	15,751.63	272.05
1984	18,575.99	60.79	359.68	42.90	10,360.50	345.60
1985	14,844.74	62.58	473.53	100.18	31,092.40	365.15

Table 8-42. Listing of Important Species Collected in Rotenone Samples from Chickamauga Reservoir, 1970-1985.*

Common Name	Scientific Name	Percent Occurrence	Percent Number	Percent Biomass
Game				
White bass†	Morone chrysops	41.463	0.0595	0.0752
Yellow bass†	Morone mississippienis	76.829	0.3579	0.6091
Warmouth	Lepomis gulosus	95.122	3.1115	0.6342
Bluegill	Lepomis macrochirus	100.000	41.3854	8.9215
Longear sunfish	Lepomis megalotis	74.390	1.4890	0.6167
Redear sunfish	Lepomis microlophus	97.561	11.6904	3.0114
Largemouth bass	Micropterus salmoides	98.780	1.4683	3.1042
White crappie†	Pomoxis annularis	95.122	0.3083	0.6748
Yellow perch†	Perca flavescens	76.829	0.3119	0.3391
Sauger†	Stizostedion canadense	29.268	0.0058	0.0648
Commercial				
Carp	Cyprinus carpio	81.707	0.0581	7.8641
Smallmouth buffalo	Ictiobus bubalus	67.073	0.0583	5.9456
Spotted sucker	Minytrema melanops	86.585	0.1469	2.3119
Channel catfish	Ictalurus punctatus	93.902	0.0886	3.4626
Flathead catfish†	Pylodictis olivaris	64.634	0.0159	0.1886
Freshwater drum	Aplodinotus grunniens	100.000	1.1865	7.9654
Forage				
Gizzard shad	Dorosoma cepedianum	100.000	12.9565	43.7561
Threadfin shad	Dorosoma petenense	92.683	16.9210	5.5218
Bullhead minnow	Pimephales vigilax	70.732	2.1047	0.1601

*Based on 82 samples.

†Species of special interest that did not meet important criteria.

Table 8-43. Linear Regression Analyses of Numbers/ha and kg/ha of Each Size Group of Each Important Fish Species Collected in Cove Rotenone Samples from Chickamauga Reservoir, 1970-1985.

Species	Group*	Slope	F-Value	PR>F†
Gizzard shad	YNG-WT.	0.04	10.38	0.0018
Carp	YNG-NO.	0.01	13.69	0.0004
Carp	YNG-WT.	0.01	5.13	0.0262
Bullhead minnow	YNG-NO.	0.12	21.67	0.0001
Smallmouth buffalo	INT-NO.	-0.03	13.34	0.0005
Smallmouth buffalo	INT-WT.	-0.03	10.88	0.0015
Smallmouth buffalo	HAR-NO.	-0.05	12.51	0.0007
Smallmouth buffalo	HAR-WT.	-0.05	10.96	0.0014
Spotted sucker	YNG-NO.	-0.04	7.56	0.0074
Spotted sucker	YNG-WT.	-0.01	6.56	0.0123
Channel catfish	INT-NO.	-0.05	27.52	0.0001
Channel catfish	INT-WT.	-0.01	20.34	0.0001
Channel catfish	HAR-WT.	0.03	6.23	0.0146
Flathead catfish	YNG-NO.	-0.02	6.89	0.0104
Flathead catfish	INT-NO.	-0.01	4.53	0.0363
Flathead catfish	INT-WT.	-0.01	5.10	0.0266
Flathead catfish	HAR-NO.	-0.02	11.73	0.0010
Flathead catfish	HAR-WT.	-0.01	9.47	0.0029
White bass	YNG-NO.	-0.06	16.57	0.0001
Yellow bass	YNG-NO.	0.09	22.52	0.0001
Yellow bass	YNG-WT.	0.02	12.90	0.0006
Yellow bass	INT-NO.	0.06	23.68	0.0001
Yellow bass	INT-WT.	0.03	22.78	0.0001
Yellow bass	HAR-NO.	0.04	32.33	0.0001
Yellow bass	HAR-WT.	0.02	26.89	0.0001
Warmouth	YNG-NO.	0.17	70.97	0.0001
Warmouth	YNG-WT.	0.03	31.01	0.0001
Warmouth	INT-NO.	0.04	10.11	0.0021

Table 8-43 (Continued)

Species	Group*	Slope	F-Value	PR>F†
Warmouth	INT-WT.	0.01	17.15	0.0001
Warmouth	HAR-NO.	0.03	9.40	0.0030
Warmouth	HAR-WT.	0.01	8.52	0.0046
Bluegill	YNG-NO.	0.07	22.62	0.0001
Bluegill	YNG-WT.	0.04	17.25	0.0001
Redear sunfish	YNG-NO.	0.18	71.89	0.0001
Redear sunfish	YNG-WT.	0.04	31.67	0.0001
Redear sunfish	INT-NO.	0.04	7.04	0.0096
Redear sunfish	INT-WT.	0.02	10.73	0.0016
Largemouth bass	YNT-WT.	0.02	13.16	0.0005
Largemouth bass	INT-NO.	0.03	4.94	0.0291
Largemouth bass	ADT-NO.	0.02	5.21	0.0251
Largemouth bass	ADT-WT.	0.02	4.80	0.0314
White crappie	INT-WT.	-0.01	8.42	0.0048
White crappie	HAR-NO.	-0.03	7.40	0.0080
White crappie	HAR-WT.	-0.02	8.59	0.0044
Yellow perch	YNG-NO.	0.04	4.75	0.0323
Yellow perch	HAR-NO.	0.04	7.15	0.0091
Yellow perch	HAR-WT.	0.01	7.56	0.0074
Freshwater drum	YNG-NO.	-0.10	36.71	0.0001
Freshwater drum	YNG-WT.	-0.02	17.24	0.0001
Freshwater drum	INT-NO.	-0.04	12.26	0.0008
Freshwater drum	INT-WT.	-0.03	14.36	0.0003

*YNG-NO. = Young (numbers/ha)
INT-NO. = Intermediate (numbers/ha)
HAR-NO. = Harvestable (numbers/ha)
YNG-WT. = Young (kg/ha)
INT-WT. = Intermediate (kg/ha)
HAR-WT. = Harvestable (kg/ha)

†Probability of obtaining a value ≥F. Only those values with a probability level of 0.05 or less are listed.

Table 8-44. Numbers and Biomass (kg) Per Hectare of Each Size Group of Gizzard Shad in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate*		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	1,129.74	2.24	0.00	0.00	645.34	75.49	1,775.08	77.73
1971	329.03	2.27	0.00	0.00	561.91	65.51	890.94	67.78
1972	0.52	0.01	0.00	0.00	836.35	119.52	836.87	119.53
1973	0.65	0.01	0.00	0.00	1,034.97	127.41	1,035.63	127.42
1974	5.23	0.07	0.00	0.00	912.33	107.61	917.56	107.69
1975	109.44	1.44	0.00	0.00	946.20	90.71	1,055.64	92.15
1976	1,140.28	9.83	0.00	0.00	844.93	105.62	1,985.21	115.45
1977	8,624.47	44.57	0.00	0.00	928.02	112.60	9,552.49	157.17
1978	1,894.39	7.74	0.00	0.00	2,177.57	115.17	4,071.96	122.92
1979	54.15	0.68	0.00	0.00	2,315.58	92.12	2,369.73	92.80
1980	953.30	2.63	0.00	0.00	503.02	34.73	1,456.32	37.36
1981	507.50	1.73	0.00	0.00	1,484.11	164.41	1,991.61	166.14
1982	7,913.77	20.23	0.00	0.00	1,530.03	140.19	9,443.80	161.89
1983	1,994.09	9.93	0.00	0.00	1,981.22	232.46	3,975.31	242.39
1984	3,606.31	8.79	0.00	0.00	3,192.03	329.83	6,798.33	338.63
1985	3,873.29	29.29	0.00	0.00	1,898.52	239.89	5,771.81	269.18

*No intermediate size class considered.

Table 8-45. Numbers and Biomass (kg) Per Hectare of Each Size Group of Threadfin Shad in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate*		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	2,732.68	2.94	0.00	0.00	0.31	0.01	2,732.99	2.95
1971	3,351.72	7.19	0.00	0.00	0.00	0.00	3,351.72	7.19
1972	8,094.18	41.72	0.00	0.00	52.33	1.46	8,146.51	43.18
1973	7,248.00	50.51	0.00	0.00	6.21	0.20	7,254.21	50.72
1974	6,916.67	28.02	0.00	0.00	3.10	0.13	6,919.78	28.16
1975	3,906.97	23.05	0.00	0.00	122.96	4.07	4,029.94	27.12
1976	3,401.95	11.75	0.00	0.00	0.00	0.00	3,401.95	11.75
1977	1,566.42	17.31	0.00	0.00	0.00	0.00	1,566.42	17.31
1978	53.10	0.34	0.00	0.00	0.00	0.00	53.10	0.34
1979	363.60	0.80	0.00	0.00	0.47	0.01	364.06	0.81
1980	448.09	0.79	0.00	0.00	0.00	0.00	448.09	0.79
1981	3,294.25	8.29	0.00	0.00	0.00	0.00	3,294.25	8.29
1982	368.97	1.00	0.00	0.00	1.43	0.03	370.40	1.03
1983	8,838.26	23.67	0.00	0.00	0.00	0.00	8,838.26	23.67
1984	866.60	2.13	0.00	0.00	0.00	0.00	866.60	2.13
1985	22,913.04	92.19	0.00	0.00	0.48	0.02	22,913.52	92.21

*No intermediate size class considered.

Table 8-46. Numbers and Biomass (kg) Per Hectare of Each Size Group of Carp in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	0.84	0.00	0.15	0.06	4.77	7.04	5.77	7.09
1971	0.00	0.00	0.20	0.05	27.46	53.85	27.66	53.89
1972	0.00	0.00	0.00	0.00	14.66	31.59	14.66	31.59
1973	0.00	0.00	0.00	0.00	21.49	48.42	21.49	48.42
1974	0.00	0.00	0.52	0.09	8.28	20.18	8.79	20.27
1975	0.00	0.00	0.00	0.00	12.65	28.93	12.65	28.93
1976	0.00	0.00	0.22	0.05	22.16	46.72	22.37	46.77
1977	0.00	0.00	0.00	0.00	14.26	31.39	14.26	31.39
1978	2.09	0.11	2.16	0.31	5.21	14.43	9.46	14.86
1979	0.54	0.01	0.00	0.00	16.93	38.02	17.47	38.04
1980	4.21	0.13	0.31	0.04	7.98	24.01	12.49	24.18
1981	34.52	2.02	3.79	0.61	4.04	11.94	42.35	14.57
1982	7.02	0.14	0.48	0.12	4.92	8.91	12.41	9.16
1983	0.98	0.01	0.00	0.00	12.81	29.61	13.78	29.62
1984	1.45	0.11	0.00	0.00	1.46	3.45	2.92	3.56
1985	1.39	0.11	2.72	0.56	15.04	37.42	19.14	38.09

Table 8-47. Numbers and Biomass (kg) Per Hectare of Each Size Group of Smallmouth Buffalo in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	1.96	0.01	3.04	0.75	23.28	34.87	28.28	35.64
1971	0.58	0.02	36.05	71.13	0.00	0.00	36.63	71.15
1972	8.68	0.64	2.53	0.98	26.48	41.51	37.69	43.14
1973	1.74	0.15	1.39	0.40	21.21	40.84	24.34	41.39
1974	0.00	0.00	0.00	0.00	6.40	12.52	6.40	12.52
1975	1.79	0.15	0.78	0.16	6.39	18.86	8.96	19.17
1976	0.61	0.01	0.00	0.00	12.41	28.93	13.02	28.94
1977	2.33	0.16	1.82	0.72	7.49	9.93	11.64	10.82
1978	0.00	0.00	0.00	0.00	0.35	1.84	0.35	1.84
1979	0.00	0.00	0.00	0.00	3.31	4.57	3.31	4.57
1980	0.31	0.01	0.00	0.00	1.67	3.35	1.97	3.35
1981	0.00	0.00	0.43	0.15	1.58	2.75	2.01	2.90
1982	0.00	0.00	0.45	0.17	6.85	10.83	7.31	11.00
1983	36.77	0.81	0.00	0.00	3.30	5.59	40.07	6.41
1984	0.00	0.00	0.00	0.00	0.48	2.57	0.48	2.57
1985	3.64	0.16	1.73	0.53	4.86	4.30	10.23	4.98

Table 8-48. Numbers and Biomass (kg) Per Hectare of Each Size Group of Spotted Sucker in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	18.02	0.10	0.68	0.07	0.47	0.23	19.17	0.40
1971	21.16	0.30	0.00	0.00	8.76	2.76	29.92	3.06
1972	38.06	0.81	2.00	0.32	19.79	6.68	59.85	7.82
1973	162.46	3.28	7.13	1.08	17.56	5.95	187.14	10.32
1974	23.71	0.36	26.16	3.54	39.10	13.07	88.97	16.96
1975	10.71	0.17	10.98	1.41	19.72	8.84	41.42	10.42
1976	15.29	0.28	3.15	0.51	35.12	17.17	53.55	17.96
1977	18.19	0.30	2.84	0.37	23.23	11.41	44.26	12.08
1978	6.23	0.09	5.25	0.64	14.85	7.48	26.33	8.21
1979	8.99	0.07	6.05	0.80	11.20	5.73	26.23	6.60
1980	3.09	0.02	0.31	0.05	10.61	7.24	14.01	7.31
1981	0.00	0.00	0.00	0.00	12.47	9.34	12.47	9.34
1982	0.43	0.02	0.43	0.03	5.83	3.45	6.70	3.50
1983	5.37	0.01	3.90	0.46	2.82	2.58	12.09	3.05
1984	12.20	0.06	19.02	2.48	8.63	3.87	39.85	6.41
1985	0.91	0.02	11.82	1.43	8.64	5.91	21.36	7.36

Table 8-49. Numbers and Biomass (kg) Per Hectare of Each Size Group of Channel Catfish in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	3.27	0.02	10.10	0.62	5.71	2.35	19.07	2.98
1971	0.99	0.01	12.73	0.86	20.19	9.89	33.91	10.76
1972	1.05	0.01	12.32	0.79	23.20	7.33	36.57	8.12
1973	1.23	0.01	12.07	0.71	29.68	9.64	42.98	10.36
1974	0.52	0.01	3.21	0.19	8.41	3.92	12.14	4.12
1975	1.03	0.01	2.39	0.11	10.27	4.13	13.69	4.25
1976	1.63	0.00	6.26	0.32	17.67	12.11	25.56	12.43
1977	2.75	0.02	4.55	0.27	12.14	7.12	19.44	7.40
1978	1.38	0.00	0.35	0.01	13.45	4.17	15.18	4.18
1979	1.05	0.01	1.40	0.04	22.35	14.19	24.80	14.24
1980	2.90	0.01	0.42	0.02	11.34	7.70	14.65	7.73
1981	6.41	0.06	4.17	0.12	67.02	59.00	77.60	59.17
1982	0.00	0.00	0.91	0.03	6.21	5.98	7.12	6.01
1983	0.00	0.00	0.00	0.00	11.22	12.69	11.22	12.69
1984	0.00	0.00	0.45	0.02	9.80	11.62	10.25	11.64
1985	0.44	0.00	8.40	0.45	7.32	8.97	16.16	9.42

Table 8-50. Numbers and Biomass (kg) Per Hectare of Each Size Group of Yellow Bass in Cove Rotenone Samples, Chickamauga Reservoir, 1971-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1971	0.91	0.00	0.27	0.02	0.00	0.00	1.18	0.02
1972	21.90	0.15	0.26	0.02	0.54	0.06	22.70	0.23
1973	16.65	0.19	4.65	0.28	0.00	0.00	21.30	0.47
1974	6.63	0.11	1.92	0.14	0.00	0.00	8.55	0.25
1975	19.37	0.33	12.01	0.95	2.01	0.26	33.39	1.54
1976	48.09	0.19	8.76	0.59	3.82	0.47	60.67	1.26
1977	238.76	0.94	6.52	0.56	2.62	0.30	247.91	1.80
1978	106.99	0.29	5.90	0.45	2.70	0.33	115.59	1.06
1979	3.84	0.05	0.38	0.03	0.38	0.04	4.61	0.13
1980	121.22	0.48	5.46	0.50	1.18	0.15	127.85	1.13
1981	187.95	4.29	69.19	4.56	10.23	1.26	267.37	10.11
1982	232.81	1.15	37.20	2.94	6.04	0.77	276.05	4.86
1983	95.83	0.80	16.34	1.46	12.62	1.68	124.79	3.94
1984	100.14	0.56	9.70	0.70	1.82	0.25	111.65	1.50
1985	84.19	0.46	32.09	2.58	9.64	1.20	125.92	4.24

Table 8-51. Numbers and Biomass (kg) Per Hectare of Each Size Group of Warmouth in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	7.18	0.03	4.44	0.11	2.30	0.17	13.92	0.30
1971	37.62	0.09	10.65	0.23	0.00	0.00	48.27	0.32
1972	39.04	0.13	14.26	0.38	1.88	0.15	55.18	0.66
1973	195.94	1.09	9.40	0.25	8.17	0.65	213.51	2.00
1974	8.92	0.02	3.79	0.07	0.98	0.07	13.68	0.16
1975	38.28	0.06	4.67	0.08	2.82	0.27	45.77	0.41
1976	54.55	0.07	12.34	0.26	5.68	0.41	72.57	0.74
1977	233.55	0.41	9.93	0.15	6.12	0.46	249.60	1.02
1978	313.63	0.31	26.19	0.54	9.05	0.79	348.87	1.64
1979	844.05	0.95	34.19	0.65	18.29	1.55	896.53	3.15
1980	1,282.81	1.67	13.77	0.32	7.42	0.64	1,304.00	2.64
1981	2,733.15	5.32	56.63	1.12	32.43	2.21	2,822.21	8.65
1982	1,712.30	1.92	45.06	0.77	10.92	0.76	1,768.28	3.45
1983	3,463.73	2.50	53.73	0.84	9.38	0.79	3,526.84	4.13
1984	1,579.34	2.20	74.19	0.92	6.69	0.45	1,660.22	3.58
1985	311.27	0.40	24.55	0.39	0.45	0.03	336.27	0.81

Table 8-52. Numbers and Biomass (kg) Per Hectare of Each Size Group of Bluegill in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	1,243.26	2.46	193.31	5.27	70.03	5.28	1,506.60	13.01
1971	1,669.92	3.18	345.20	8.84	94.88	6.68	2,110.00	18.70
1972	2,296.39	10.96	495.25	9.53	171.22	11.80	2,962.87	32.30
1973	2,214.82	5.97	374.95	7.81	186.17	12.13	2,775.94	25.91
1974	1,447.34	1.77	296.85	4.90	105.55	5.68	1,849.74	12.36
1975	4,073.41	4.83	237.89	4.18	108.32	5.96	4,419.62	14.97
1976	5,812.86	6.67	674.71	10.08	186.81	11.33	6,674.38	28.09
1977	18,963.39	20.64	519.75	7.96	185.11	11.21	19,668.26	39.81
1978	15,302.81	15.89	552.57	7.87	119.50	7.06	15,974.88	30.82
1979	13,121.79	11.47	953.28	13.59	213.18	12.11	14,288.25	37.16
1980	26,776.07	27.42	257.12	4.01	231.35	16.66	27,264.54	48.08
1981	23,622.21	16.68	979.89	15.16	277.70	19.30	24,879.80	51.13
1982	13,088.58	14.52	497.85	6.96	94.39	5.91	13,680.82	27.39
1983	16,134.86	16.37	663.92	9.47	118.91	7.97	16,917.69	33.81
1984	11,698.16	18.59	412.78	6.20	136.40	9.24	12,247.35	34.03
1985	10,131.34	10.35	420.46	5.81	109.76	8.28	10,661.56	24.44

Table 8-53. Numbers and Biomass (kg) Per Hectare of Each Size Group of Redear Sunfish in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	9.09	0.02	15.23	0.40	16.65	1.69	40.97	2.11
1971	80.79	0.25	25.28	0.65	33.08	4.52	139.14	5.42
1972	46.02	0.26	40.65	1.14	62.42	6.90	149.09	8.30
1973	614.75	3.64	36.64	0.89	43.59	5.35	694.98	9.88
1974	66.12	0.19	62.88	1.39	61.86	6.80	190.86	8.37
1975	160.80	0.53	17.09	0.40	62.77	6.86	240.66	7.79
1976	187.48	0.53	62.79	1.46	93.81	9.28	344.09	11.28
1977	851.95	3.03	49.23	1.10	77.90	8.60	979.08	12.73
1978	361.20	0.53	31.23	0.60	72.46	6.41	464.89	7.54
1979	1,017.73	1.26	92.27	2.13	50.44	4.57	1,160.45	7.95
1980	2,650.56	4.17	9.33	0.21	52.48	5.90	2,712.38	10.29
1981	21,860.89	17.35	40.38	0.87	62.62	5.51	21,963.89	23.73
1982	4,866.27	6.29	118.54	1.59	35.41	2.63	5,020.22	10.50
1983	10,137.85	5.94	210.69	3.95	109.94	8.16	10,458.48	18.05
1984	2,582.35	1.93	162.19	2.82	57.19	4.52	2,801.73	9.26
1985	2,712.33	3.55	116.17	1.89	81.81	4.80	2,910.31	10.24

Table 8-54. Numbers and Biomass (kg) Per Hectare of Each Size Group of Largemouth Bass in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	263.10	0.69	22.41	2.05	9.58	2.89	295.09	5.63
1971	64.88	0.35	35.72	1.89	20.59	6.67	121.20	8.90
1972	21.16	0.17	60.90	4.08	14.62	4.94	96.68	9.18
1973	66.45	0.43	69.09	4.86	26.93	6.71	162.46	12.01
1974	27.57	0.11	20.43	1.73	19.07	4.91	67.08	6.76
1975	65.56	0.23	23.82	1.68	17.35	6.32	106.74	8.23
1976	38.80	0.19	34.59	1.36	13.53	5.86	86.92	7.41
1977	251.89	1.07	130.99	3.77	16.76	3.92	399.64	8.76
1978	506.83	1.91	54.77	1.82	19.98	4.96	581.58	8.69
1979	784.76	2.25	27.21	2.00	22.44	7.40	834.42	11.65
1980	863.78	3.82	101.05	1.78	12.01	5.47	976.84	11.08
1981	468.11	2.98	219.40	5.76	28.02	8.13	715.53	16.87
1982	321.76	1.08	91.40	5.62	29.53	6.18	442.69	12.88
1983	259.60	1.37	71.27	2.67	30.79	6.91	361.67	10.95
1984	379.15	1.36	40.84	2.48	10.93	3.39	430.92	7.23
1985	136.96	0.77	115.07	3.65	51.78	13.73	303.81	18.15

Table 8-55. Numbers and Biomass (kg) Per Hectare of Each Size Group of White Crappie in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Weight	Numbers	Weight	Numbers	Weight	Numbers	Biomass
1970	89.00	0.11	28.51	1.19	20.68	3.09	138.18	4.39
1971	7.90	0.05	13.69	1.04	17.95	3.14	39.54	4.23
1972	29.80	0.10	13.33	0.48	12.55	2.52	55.68	3.11
1973	24.31	0.07	15.29	0.69	16.30	2.94	55.90	3.70
1974	0.60	0.00	2.14	0.07	7.15	1.15	9.88	1.22
1975	1.13	0.00	4.31	0.27	7.80	1.07	13.25	1.35
1976	26.53	0.06	14.70	0.24	7.65	1.25	48.88	1.55
1977	66.00	0.18	16.16	0.18	8.59	1.20	90.75	1.56
1978	116.93	0.27	26.24	0.98	12.34	1.46	155.50	2.71
1979	57.10	0.12	26.41	0.59	28.16	2.87	111.67	3.58
1980	9.31	0.02	8.42	0.09	12.86	1.74	30.59	1.85
1981	10.43	0.02	14.13	0.15	5.59	0.99	30.16	1.17
1982	118.97	0.21	4.57	0.05	3.25	0.60	126.79	0.86
1983	99.81	0.22	15.32	0.14	0.49	0.04	115.62	0.40
1984	80.87	0.17	5.77	0.14	0.98	0.10	87.61	0.41
1985	43.88	0.10	32.34	0.36	2.64	0.40	78.86	0.86

Table 8-56. Numbers and Biomass (kg) Per Hectare of Each Size Group of Yellow Perch in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	11.81	0.04	4.92	0.04	0.21	0.01	16.94	0.10
1971	0.00	0.00	28.77	0.29	4.26	0.28	33.03	0.57
1972	0.00	0.00	26.89	0.30	5.37	0.27	32.25	0.57
1973	0.00	0.00	7.68	0.09	15.73	0.76	23.41	0.85
1974	0.00	0.00	2.08	0.03	6.22	0.41	8.30	0.44
1975	0.27	0.00	3.18	0.03	0.91	0.06	4.36	0.09
1976	0.00	0.00	28.35	0.28	3.84	0.21	32.19	0.49
1977	42.99	0.11	89.64	0.54	15.01	0.61	147.65	1.25
1978	195.38	0.50	96.60	0.56	36.33	1.67	328.31	2.72
1979	0.38	0.00	26.80	0.19	43.06	2.11	70.25	2.31
1980	95.76	0.26	65.24	0.38	31.77	2.39	192.76	3.03
1981	39.05	0.12	56.11	0.36	25.35	1.17	120.50	1.64
1982	26.96	0.06	18.87	0.11	19.30	1.11	65.12	1.28
1983	49.27	0.13	33.27	0.20	22.59	0.97	105.14	1.30
1984	28.29	0.07	19.02	0.11	15.59	0.79	62.90	0.98
1985	59.09	0.17	26.41	0.14	3.20	0.28	88.70	0.58

Table 8-57. Numbers and Biomass (kg) Per Hectare of Each Size Group of Freshwater Drum in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1985.

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	109.45	0.76	211.63	12.38	96.91	16.34	417.99	29.48
1971	72.45	0.93	139.24	8.21	58.07	8.40	269.77	17.54
1972	305.07	3.72	153.91	9.71	127.07	25.45	586.05	38.88
1973	228.57	1.87	307.13	15.63	125.75	21.71	661.45	39.21
1974	27.10	0.21	165.60	7.68	62.02	10.33	254.72	18.22
1975	33.86	0.29	68.26	3.96	37.15	8.09	139.26	12.35
1976	77.81	0.52	125.65	7.08	119.88	19.32	323.34	26.92
1977	62.65	0.60	116.64	6.73	127.61	17.95	306.90	25.28
1978	0.34	0.00	73.93	4.46	82.26	11.23	156.54	15.70
1979	5.87	0.06	68.65	4.15	100.96	13.30	175.47	17.51
1980	2.76	0.02	27.73	1.74	116.01	15.76	146.50	17.51
1981	6.31	0.04	57.13	3.52	247.53	38.22	310.97	41.78
1982	1.39	0.02	68.89	3.96	152.82	20.98	223.10	24.96
1983	50.62	0.36	95.04	5.61	166.78	24.21	312.44	30.18
1984	36.37	0.22	102.86	4.86	90.94	12.36	230.17	17.44
1985	102.65	0.69	116.16	6.81	142.92	22.59	361.73	30.10

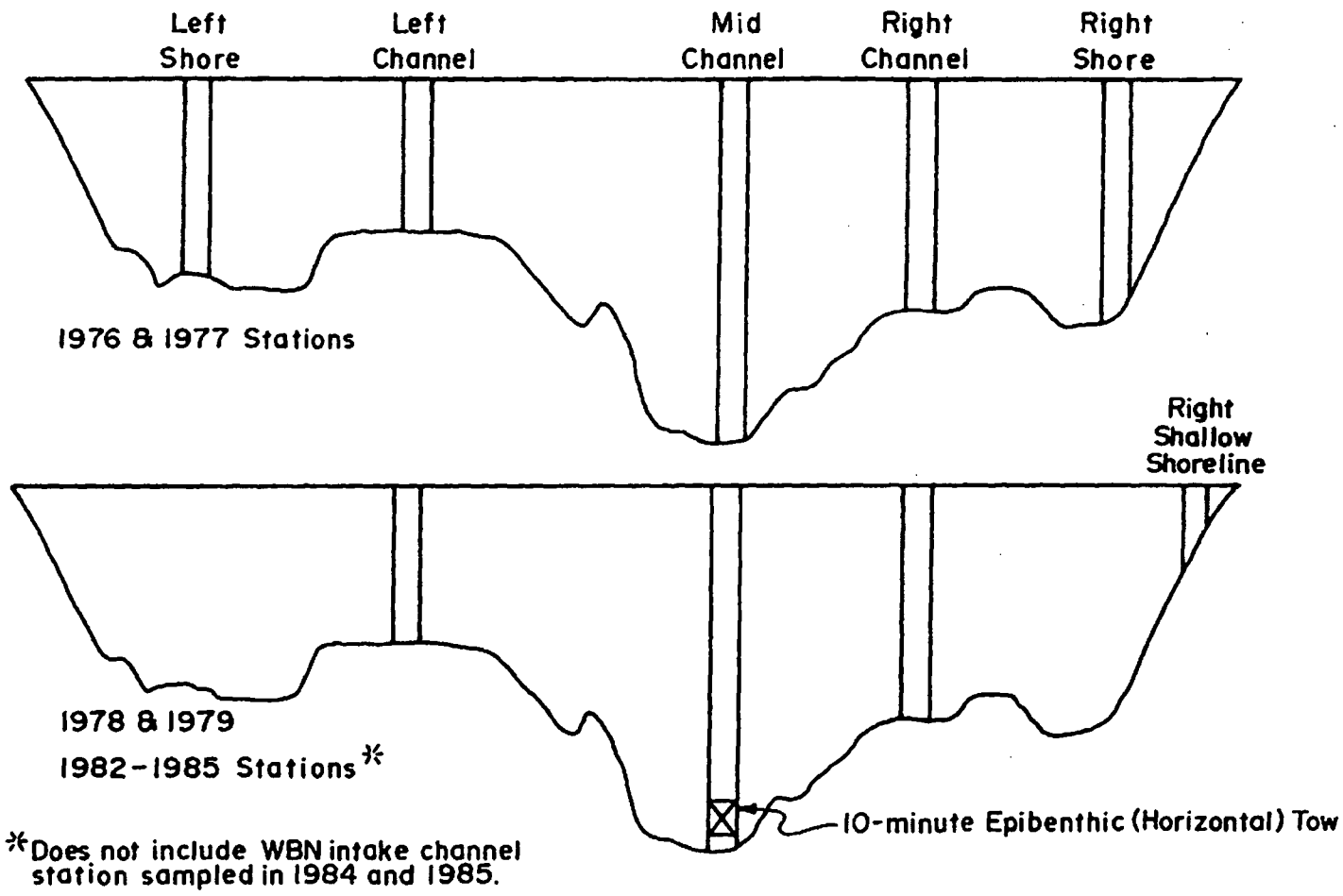


FIGURE 8-1. DIAGRAMMATIC REPRESENTATION OF BOTTOM CONTOUR AT WATTS BAR NUCLEAR PLANT SITE (TRM 528.0) SHOWING STATIONS SAMPLED FOR ICHTHYOPLANKTON FROM 1976 THROUGH 1985.

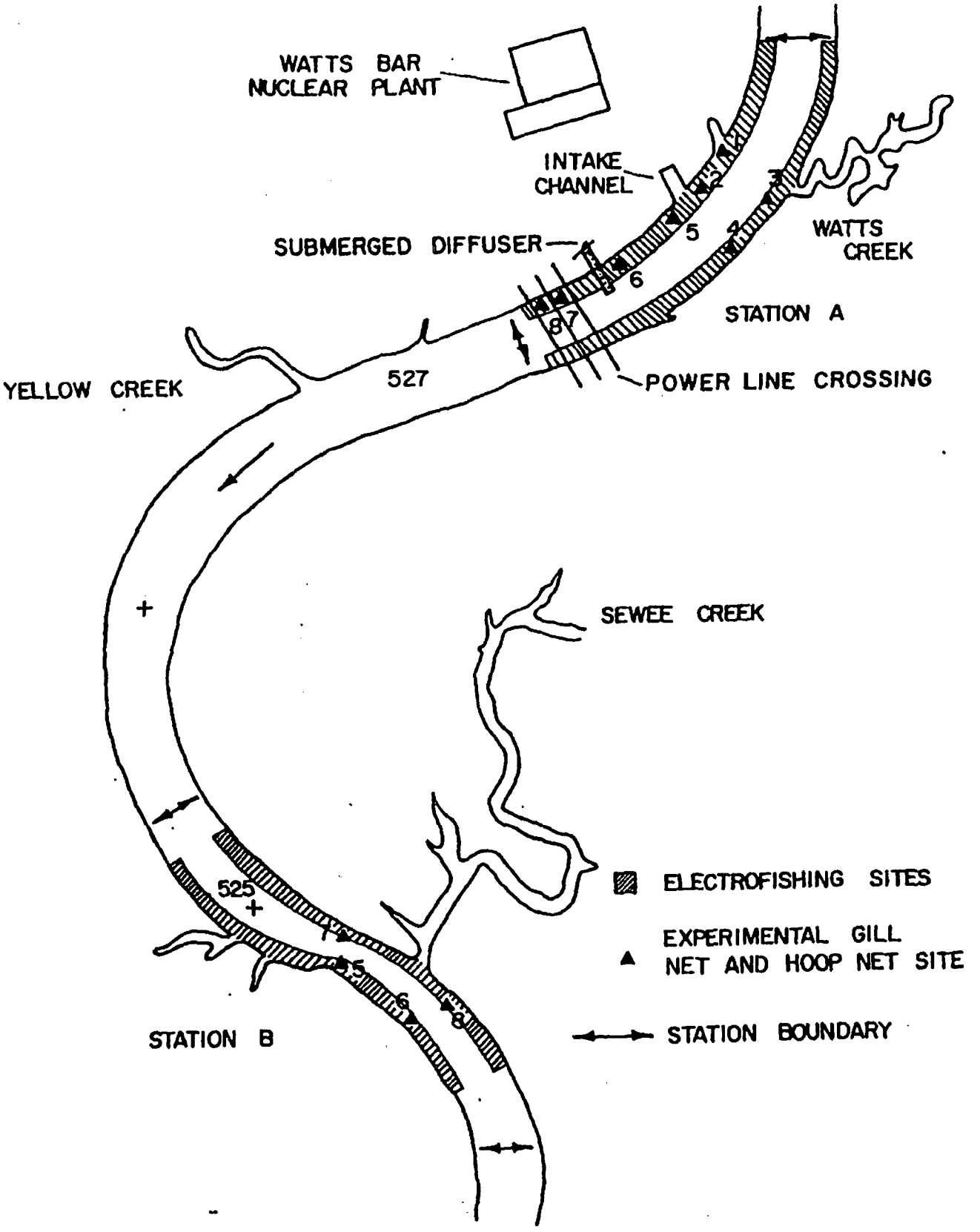


Figure 8-2. Location of netting and electrofishing stations in Chickamauga Reservoir near Watts Bar Nuclear Plant.

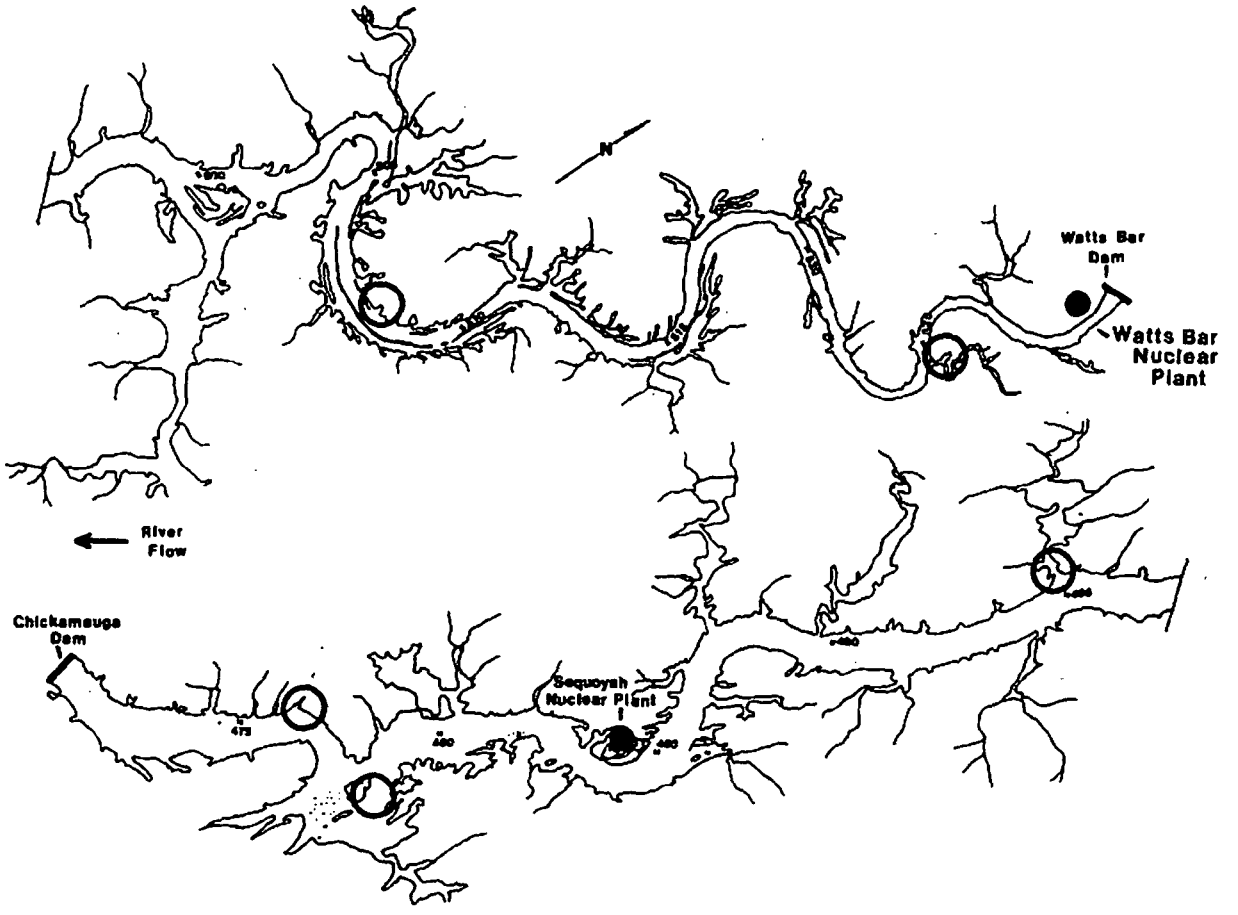


Figure 8-3. Location of Cove Rotenone Sample Sites in Chickamauga Reservoir, 1970 through 1985.

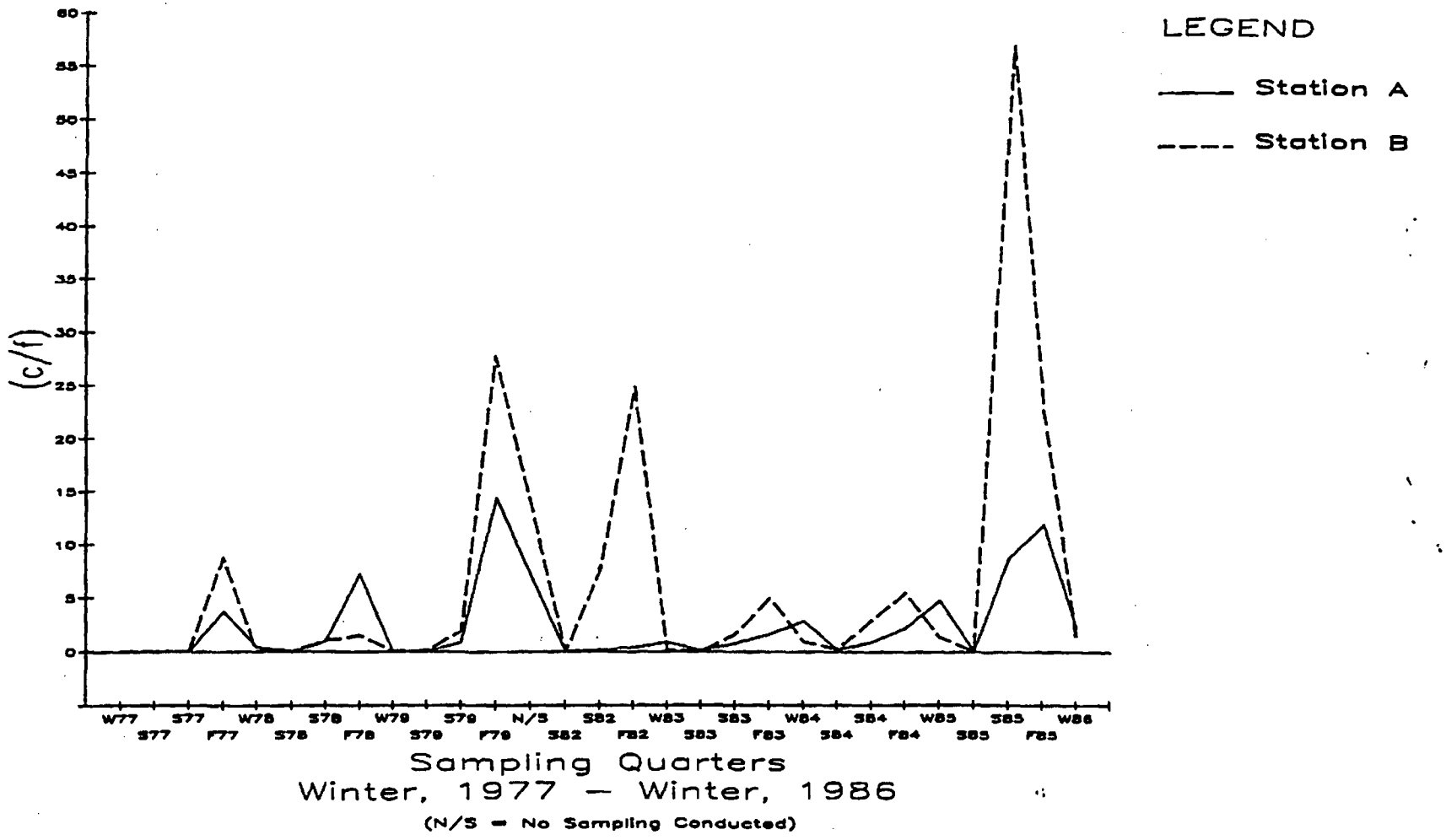


Figure 8-4. Experimental gill net catch/unit effort (c/f) for threadfin shad collected in Chickamauga Reservoir near Watts Bar Nuclear Plant

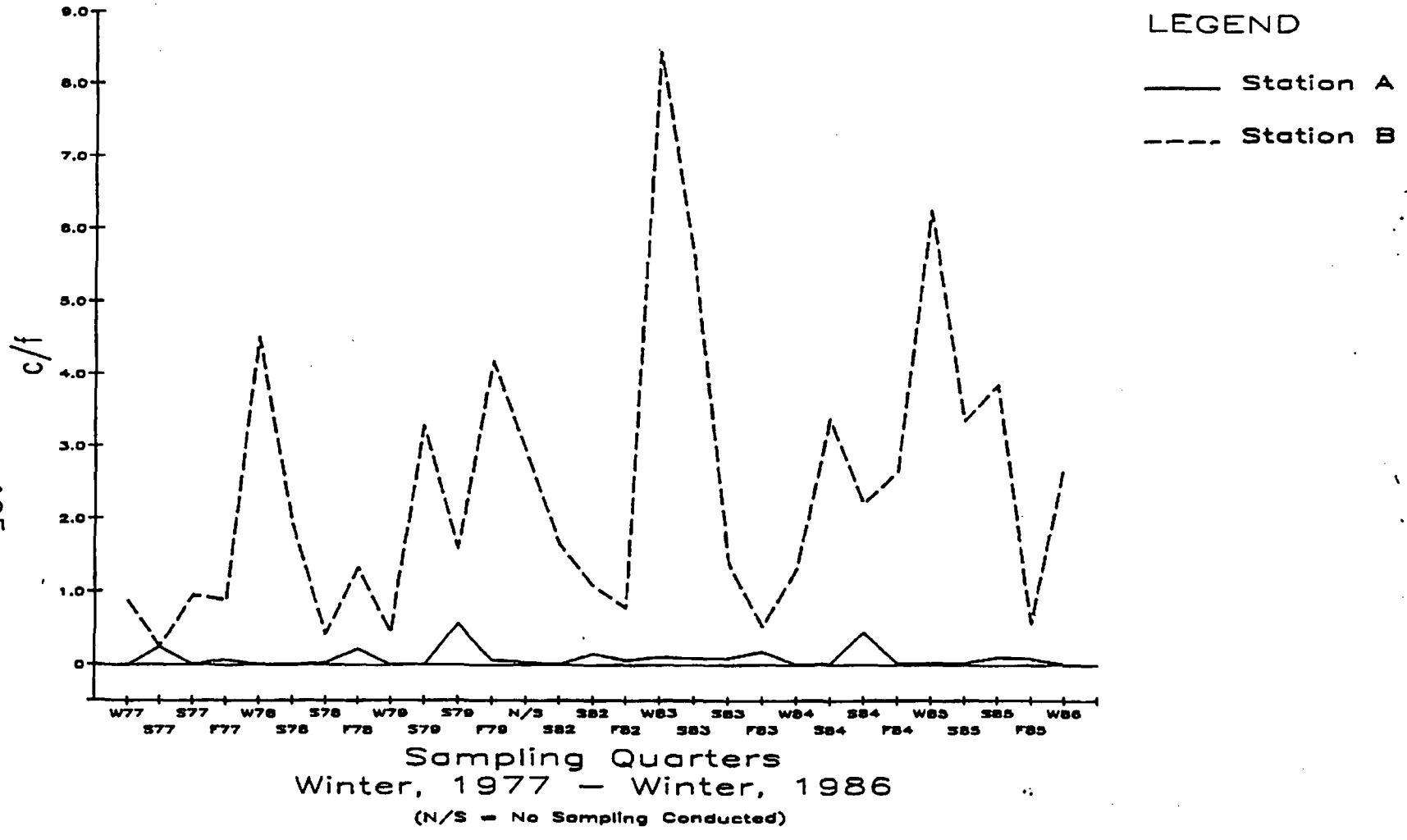


Figure 8-5. Experimental gill net catch/unit effort (c/f) for blue catfish collected in Chickamauga Reservoir near Watts Bar Nuclear Plant

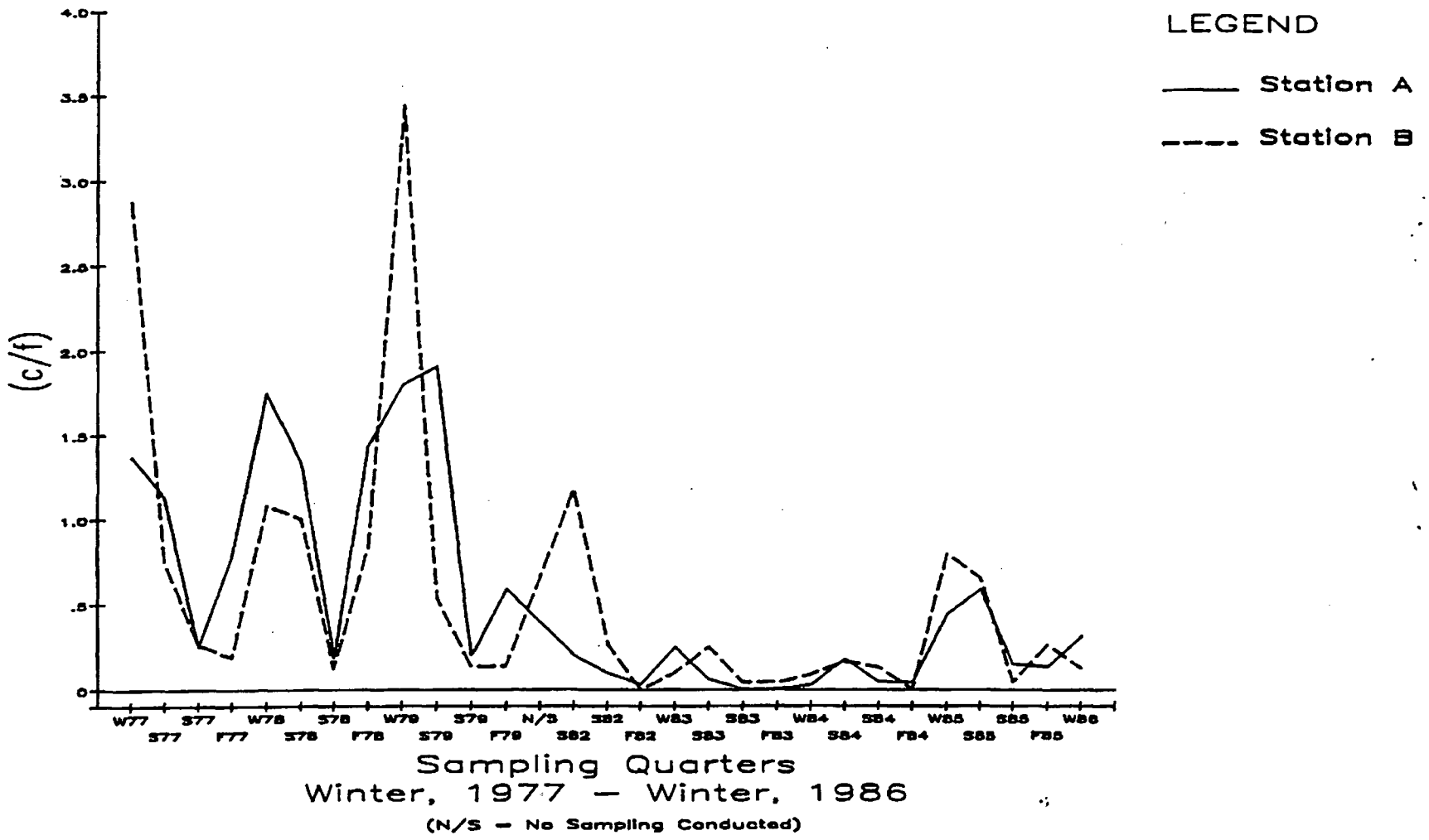


Figure 8-6. Experimental gill net catch/unit effort (c/f) for sauger collected in Chickamauga Reservoir near Watts Bar Nuclear Plant

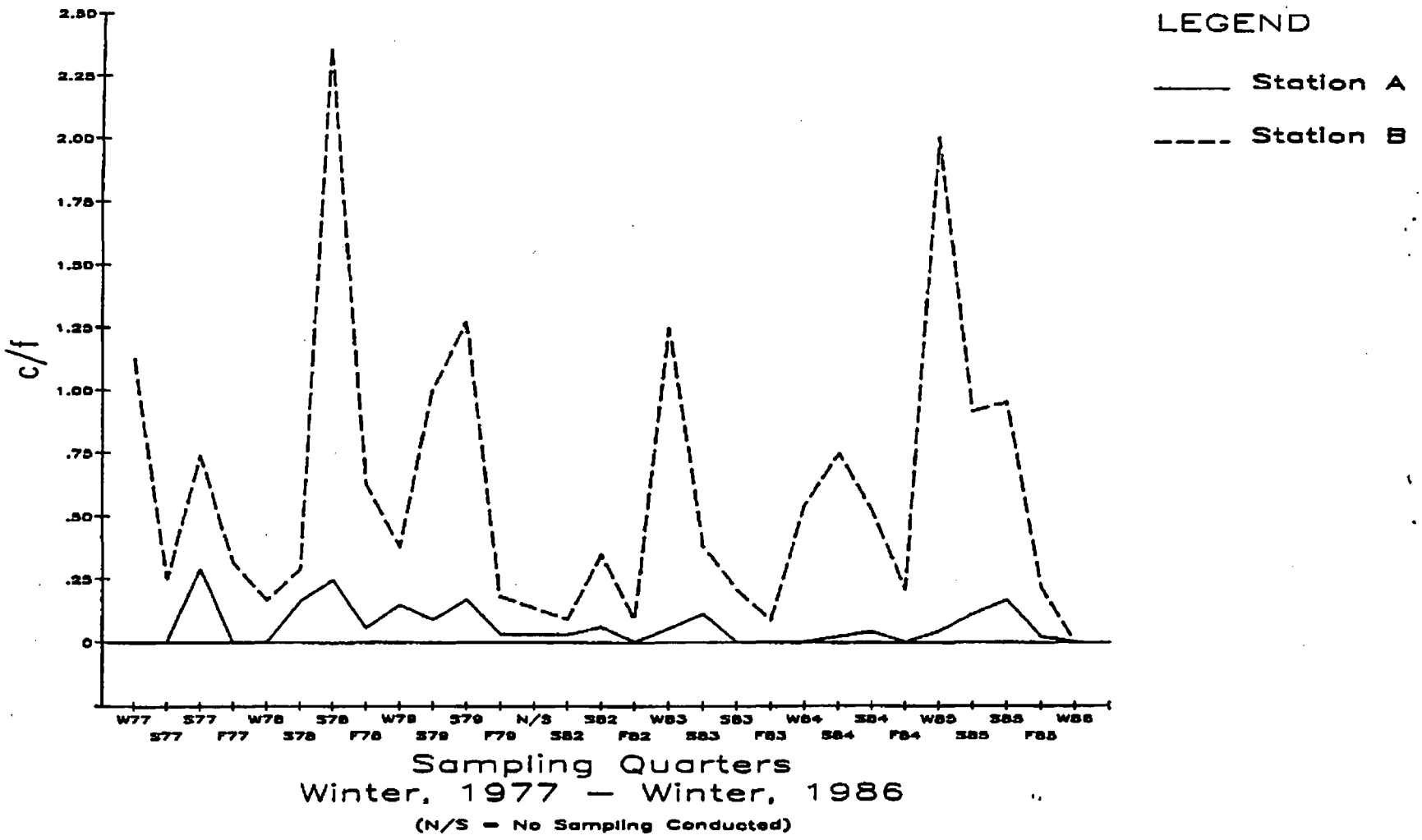


Figure 8-7. Experimental gill net catch/unit effort (c/f) for freshwater drum collected in Chickamauga Reservoir near Watts Bar Nuclear Plant

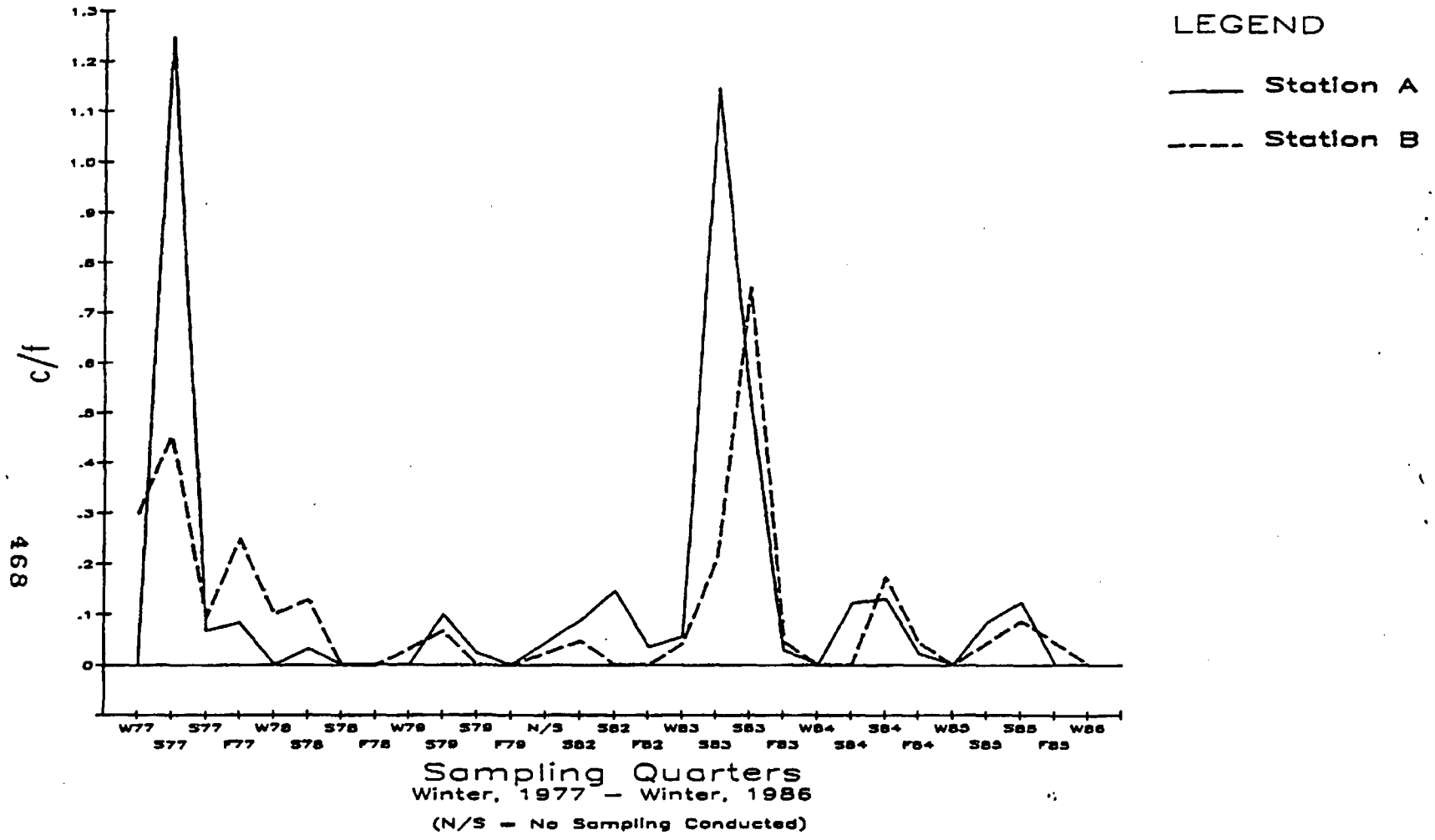


Figure 8-8. Hoop net catch/unit effort (c/f) for channel catfish collected in Chickamauga Reservoir near Watts Bar Nuclear Plant

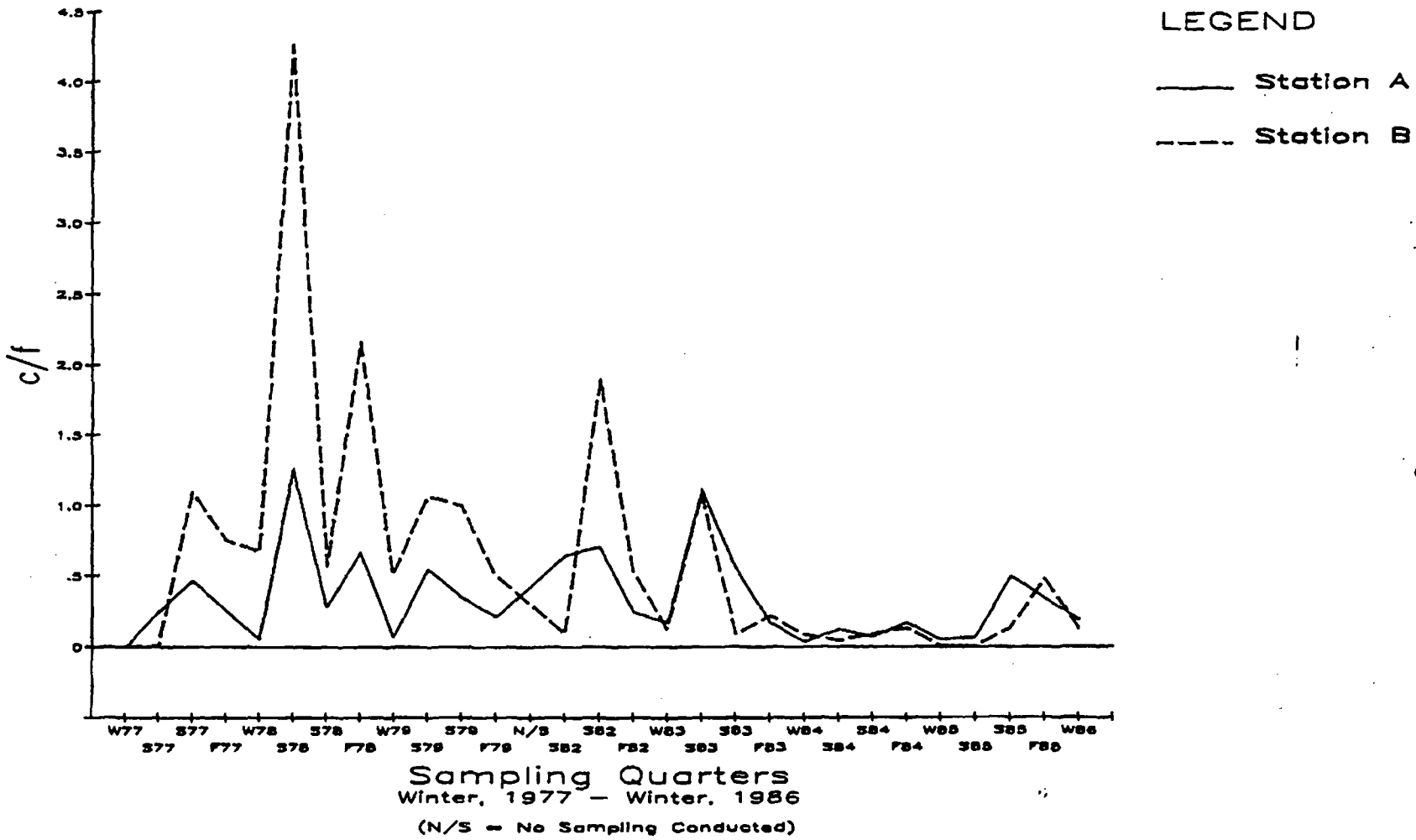


Figure 8-9. Hoop net catch/unit effort (c/f) for white crappie collected in Chickamauga Reservoir near Watts Bar Nuclear Plant

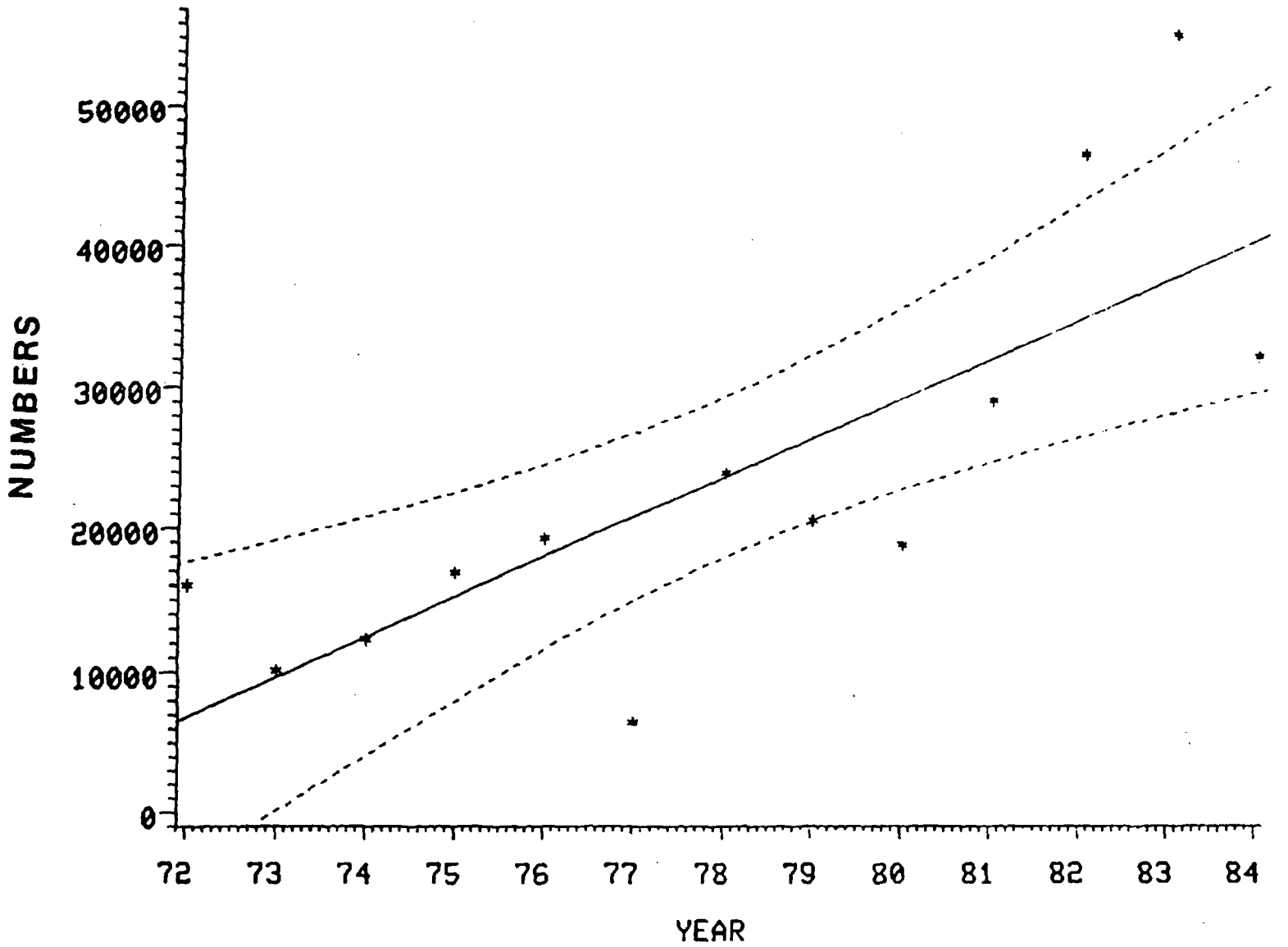


Figure 8-10. Annual Estimated Catch (Numbers) of Largemouth Bass from Chickamauga Reservoir, 1972-1984.

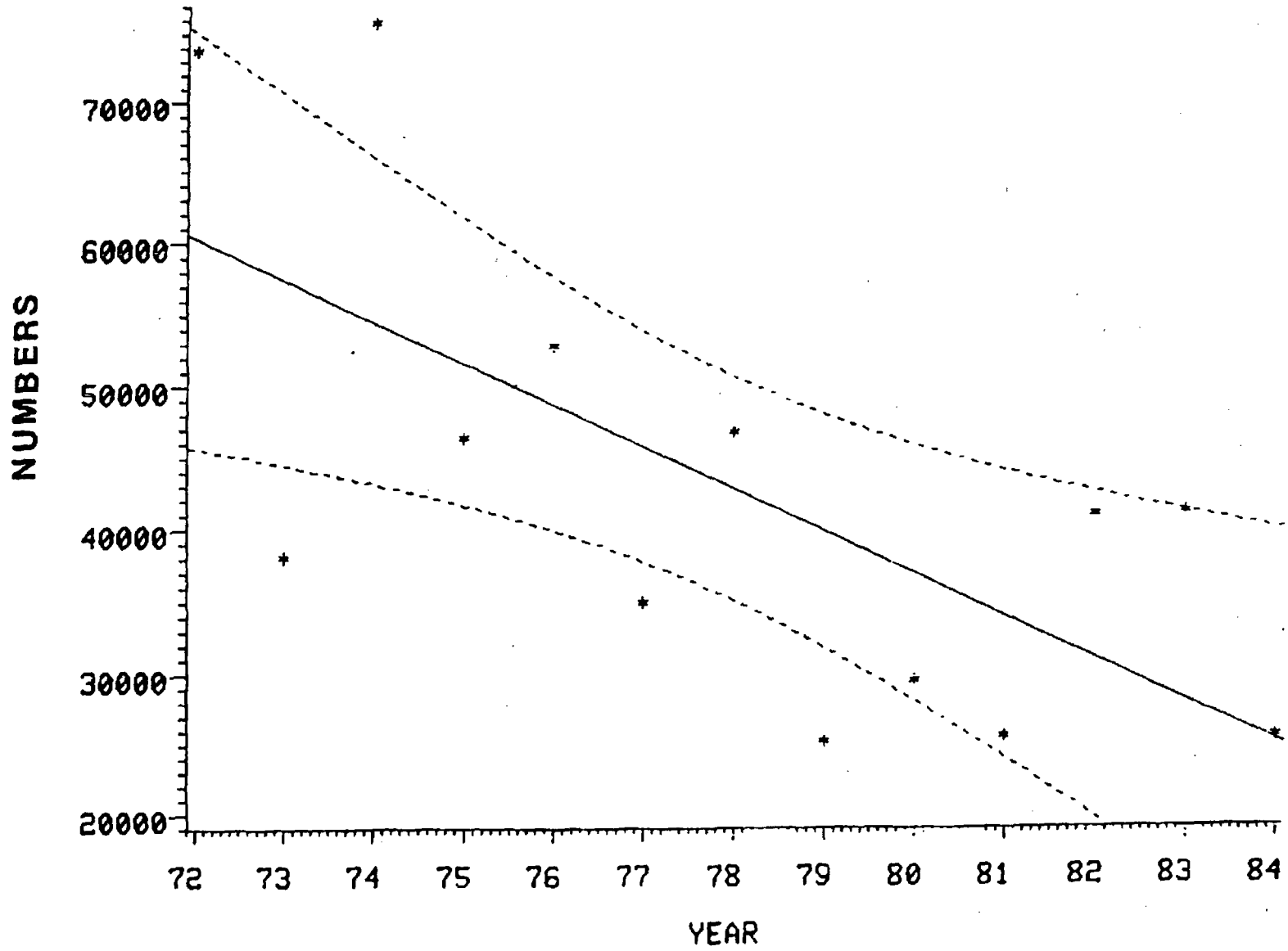


Figure 8-11. Annual Estimated Catch (Numbers) of Bluegill from Chickamauga Reservoir, 1972-1984.

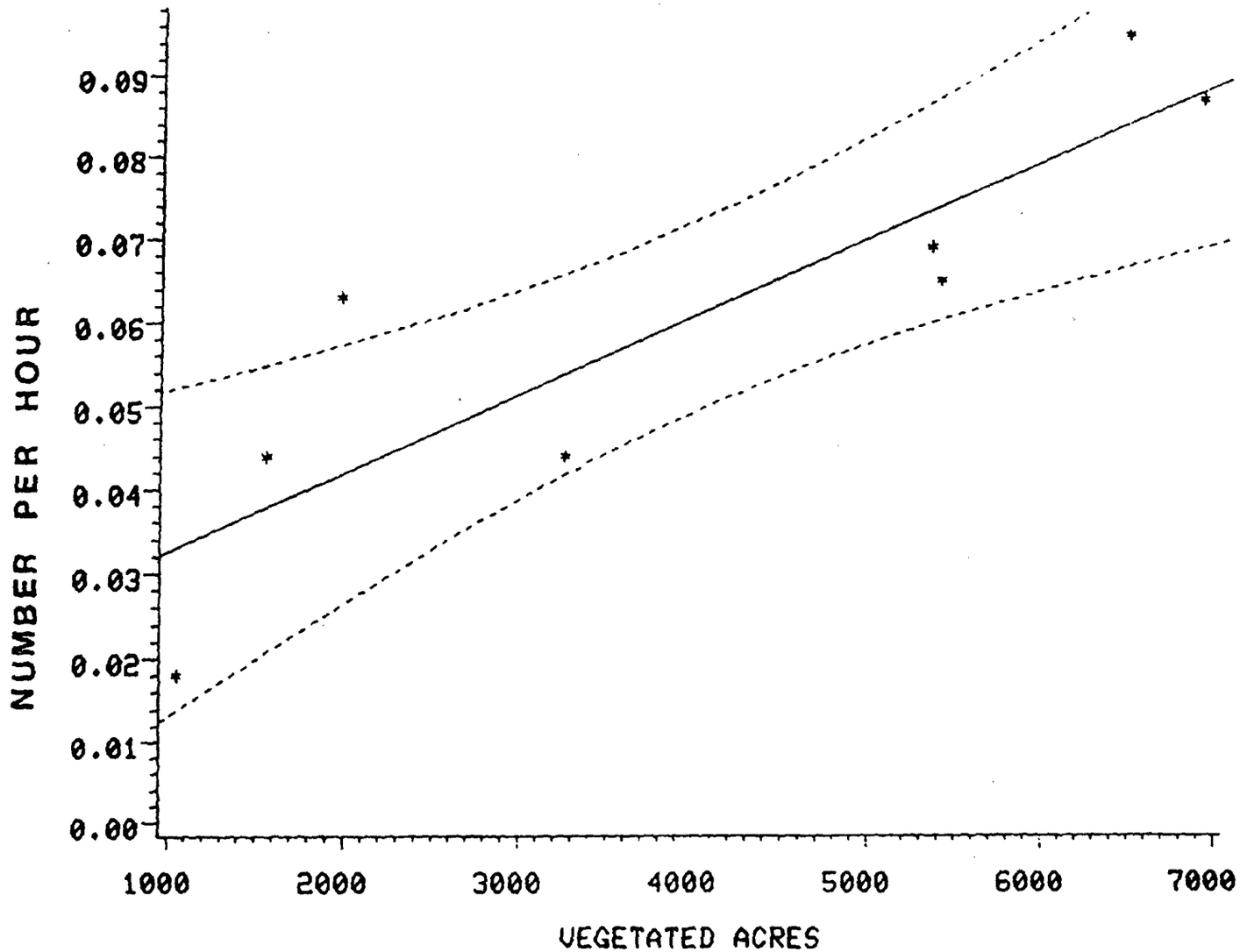


Figure 8-12. Correlation of Largemouth Bass Harvest Rates (Number Per Hour) with Aquatic Vegetation Coverage (Acres) in Chickamauga Reservoir, 1977-1985.

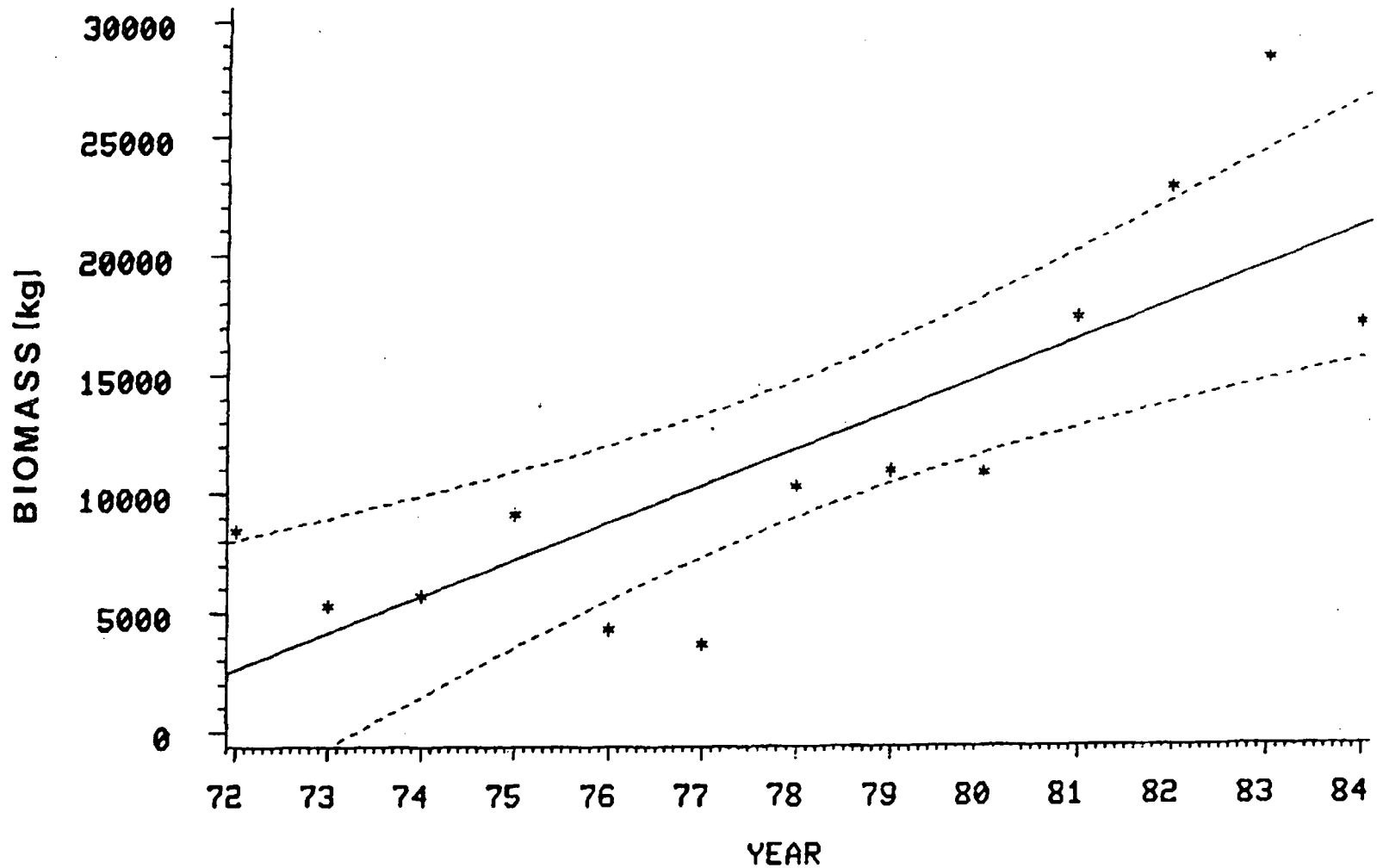


Figure 8-13. Increasing Annual Harvest of Largemouth Bass Biomass (kg) from Chickamauga Reservoir, 1972-1984.

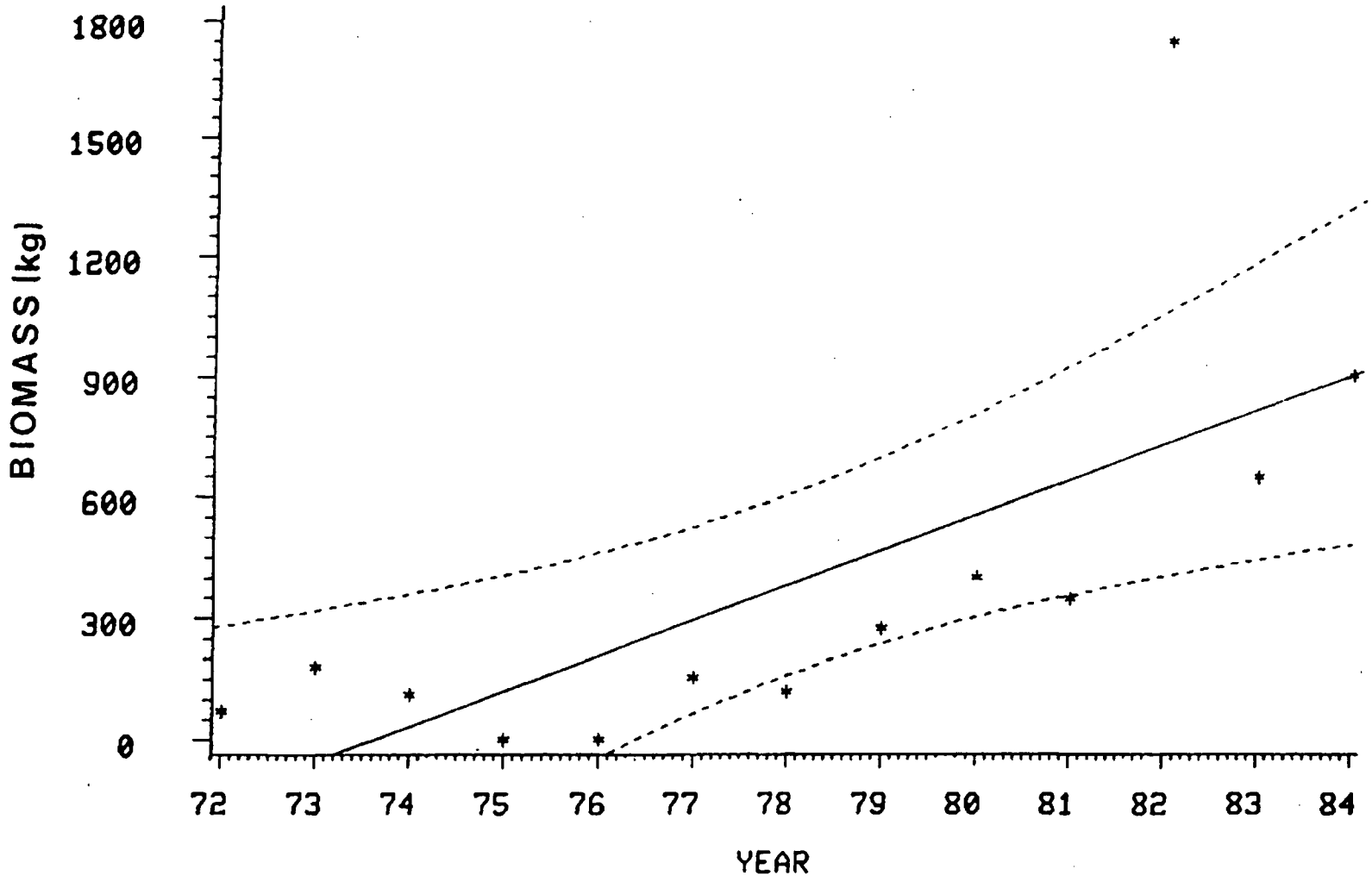


Figure 8-14. Increasing Annual Harvest of Yellow Perch Biomass (kg) from Chickamauga Reservoir, 1972-1984.

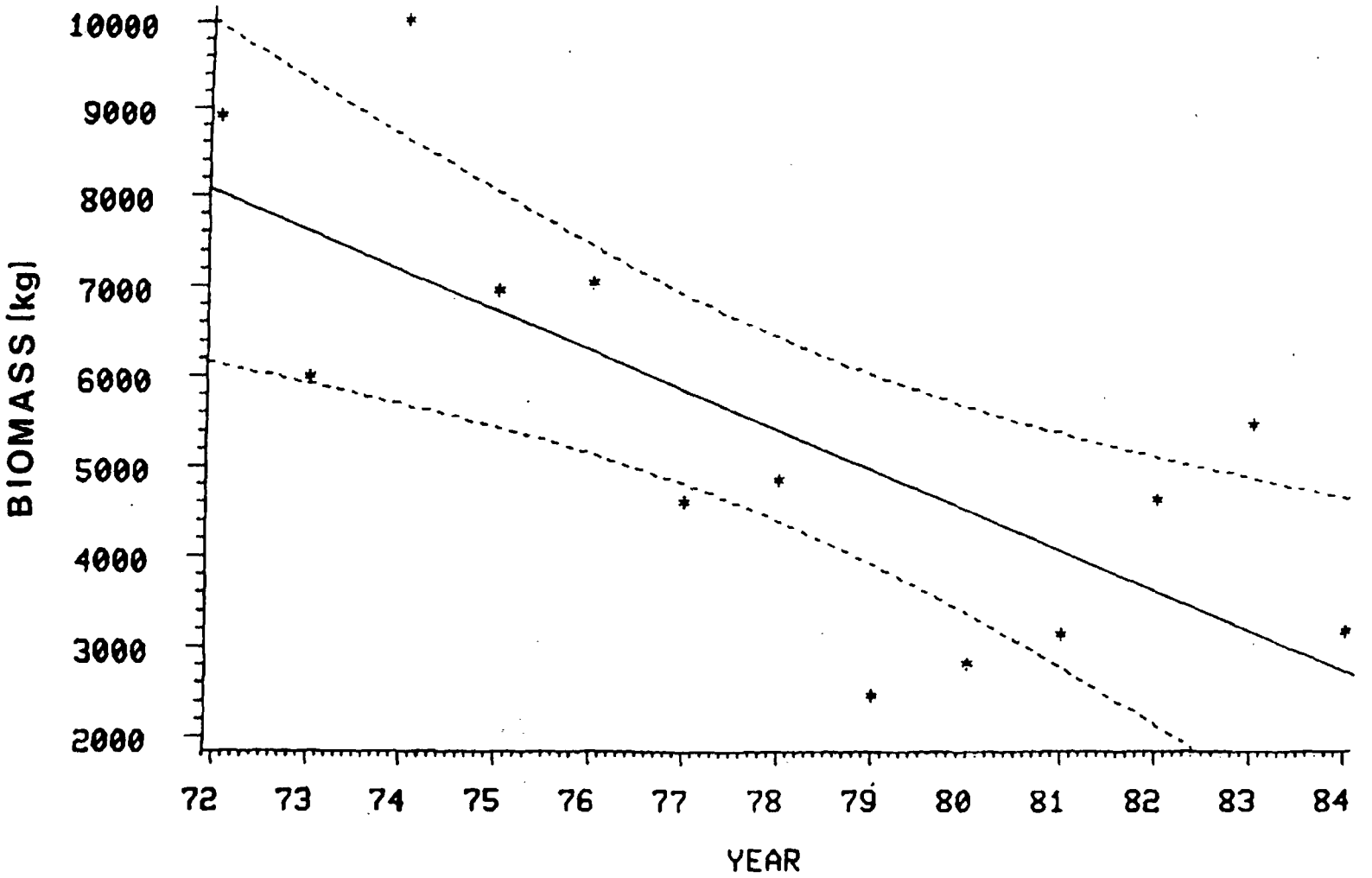


Figure 8-15. Decreasing Annual Harvest of Bluegill Biomass (kg) from Chickamauga Reservoir, 1972-1984.

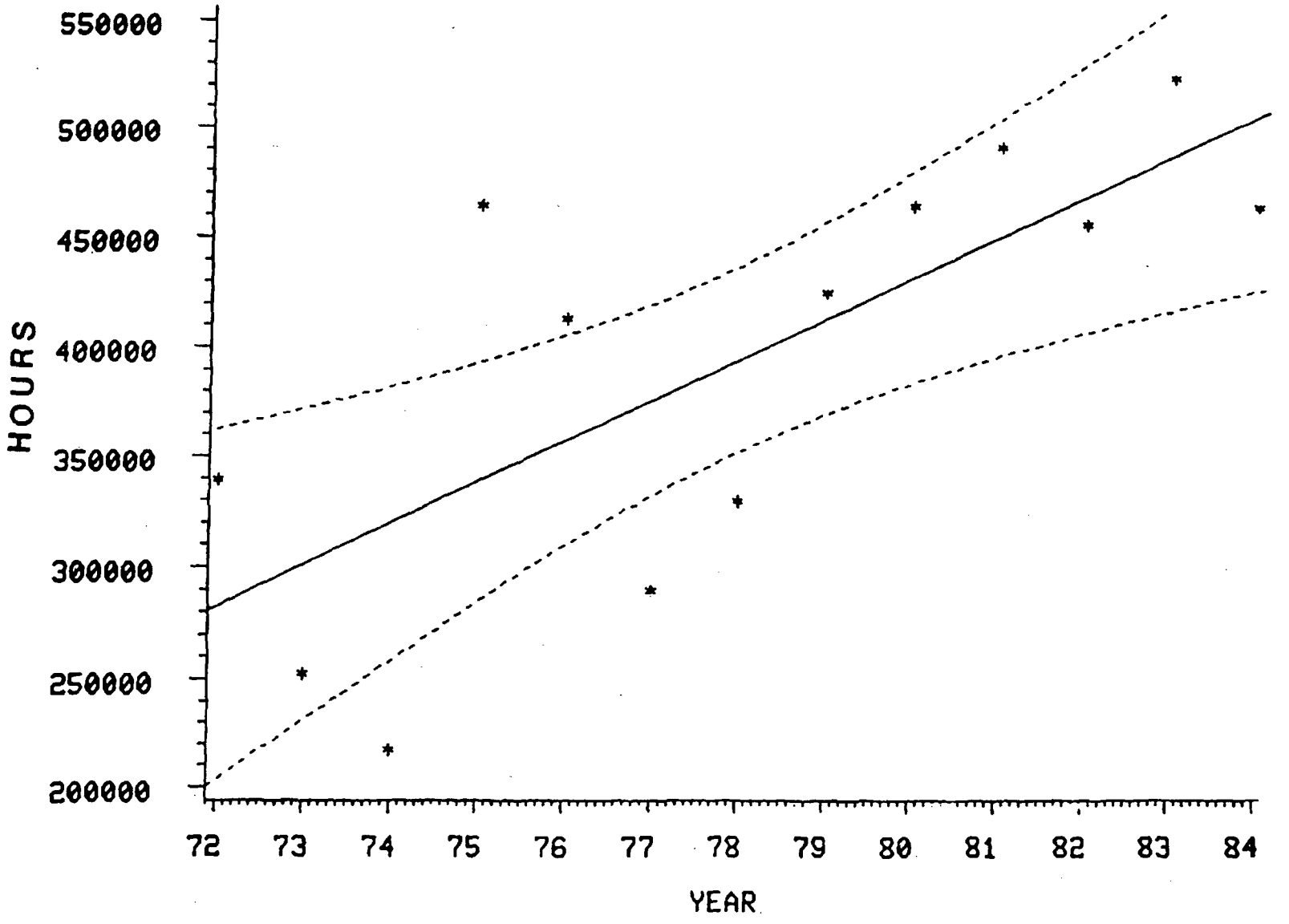


Figure 8-16. Growth in Annual Fishing Pressure (Hours) on Chickamauga Reservoir, 1972-1984.

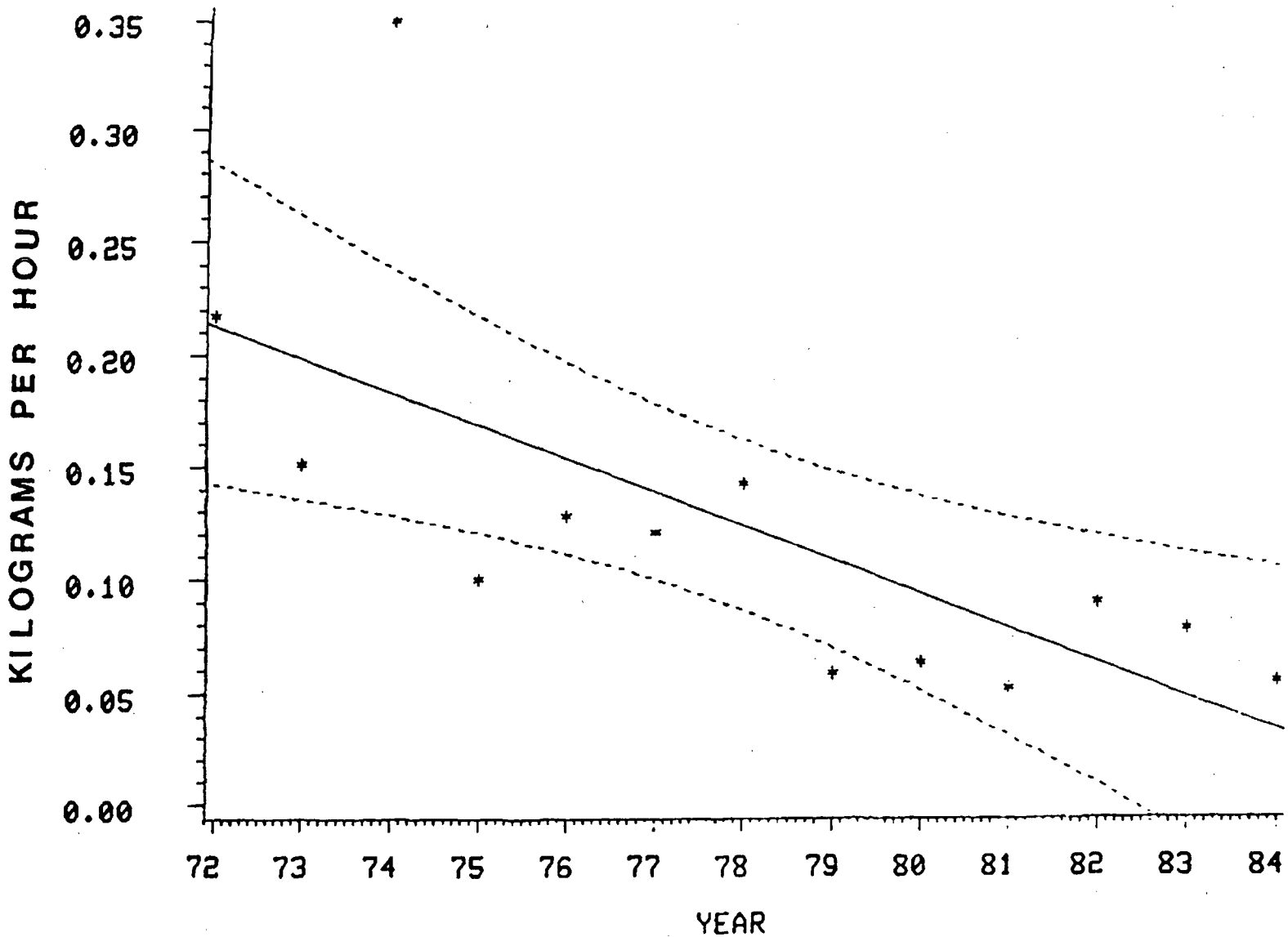


Figure 8-17. Decreasing Annual Harvest Rate (kg/hr) of Bluegill from Chickamauga Reservoir, 1972-1984.

9.0 SUMMARY

As required by the National Pollutant Discharge Elimination System Permit (TN0020168) for operation of Watts Bar Nuclear Plant (WBN), results of nonradiological preoperational aquatic monitoring are reported. This is a composite evaluation of monitoring conducted initially in 1973 through 1979 but resumed in 1982 through 1985 because of delays in operation of WBN. Baseline biological, physical, and water quality conditions in Chickamauga Reservoir (Tennessee River) in the vicinity of WBN (located at TRM 528) are described. The following biological components are included: phytoplankton, zooplankton, periphyton, benthic macroinvertebrates (including freshwater mussels), ichthyoplankton (fish eggs and larvae), and juvenile and adult fish. Because Sequoyah Nuclear Plant (SQN) also is located on Chickamauga Reservoir (TRM 484), results of various aspects of preoperational and operational monitoring for SQN are included for a more comprehensive assessment of reservoir-wide conditions.

1. Discharge from Watts Bar Dam, located about 3 km upstream from WBN, was the major influence on both physical and water quality conditions in the WBN vicinity. Typically, releases from the five-turbine hydropower plant ranged from 710 to 1,275 m^3/S (25,000 to 45,000 cfs). During flood control operations, releases well above 1,275 m^3/S occurred. During summer, releases from the dam generally inhibited stratification and establishment of a thermocline in the upper 48 km of Chickamauga Reservoir. However, releases from Watts Bar Dam, which reflect water quality in Watts Bar Reservoir and

upstream tributary reservoirs, showed periodic deficiences (<5.0 mg/L) in dissolved oxygen (DO) during May through September throughout the WBN preoperational monitoring period. As a result of drought which began in June 1984, 81 percent of the weekly DO measurements were <5.0 mg/L during summer 1985, in contrast to a combined summer mean of 37 percent for the entire preoperational period, 1973-1985.

2. Although numerous spatial and temporal variations in the biotic community were identified during preoperational monitoring, none appeared to be related to fluctuations in dissolved oxygen. Generally, diversity and abundance of taxa in all biological communities examined were typical for mainstream reservoirs on the Tennessee River. Spatial analyses indicated that river flow was the dominant factor influencing abundance and occurrence of macroinvertebrates, phytoplankton, zooplankton, ichthyoplankton and periphyton in WBN vicinity, upstream and downstream. Temporal analyses showed that seasonal and yearly changes in abundance and other variables for all component populations, except freshwater mussels, were common. Abundance trends for several communities (macroinvertebrates, plankton, and periphyton) were more cyclic than linear, indicating that preoperational monitoring for WBN covered a wide range of flow and climatic conditions.

3. The influence of flow on phytoplankton and zooplankton was clearly demonstrated. Densities typically were highest in the forebay of Watts Bar Reservoir, decreased substantially in the WBN area and well downstream, then increased to levels comparable to those in the Watts

Bar Reservoir forebay. Also, the ichthyoplankton assemblage seasonally drifting past WBN represented eggs and larvae spawned primarily in Watts Bar Reservoir. Very few eggs or larvae of fish species known to spawn in tailwaters were collected, inferring that most spawning occurred downstream of WBN.

4. Freshwater mussel fauna, monitored on three beds in the riverine reach downstream of WBN, consisted of approximately 30 species. Data on age/length for most species revealed that this population is quite old and that successful reproduction has not have occurred in the past 40 years, coinciding with the closure of Watts Bar Dam and Chickamauga Dam.

5. Relative abundance (c/f) of fish species ranked important in gill net, hoop net, and electrofishing samples, at two stations in the WBN vicinity, varied both spatially and temporally. In gill net samples, c/f of seven species varied significantly by year, but only sauger demonstrated a consistent declining trend. Causes for this decline were not apparent, but it did not appear to reflect a decline in the total reservoir population. Five species in gill net catches (particularly blue catfish, channel catfish, and freshwater drum) were more abundant at the sampling station downstream of WBN than at the station adjacent to the plant. In hoop net catches, smallmouth buffalo and white crappie were more abundant at the downstream station. However, electrofishing samples yielded consistently higher c/f for all important species (e.g., threadfin shad, emerald shiner, and brook silverside) at the station adjacent to WBN.

6. Results of reservoir-wide creel surveys since 1972 showed both cyclic and linear trends in the harvest of fish species. Overall, white crappie has dominated fish harvest from Chickamauga Reservoir, but numbers and biomass have been cyclic. For example, white crappie harvest (biomass) was highest in 1973 and 1980 (>30,000 kg) and lowest in 1974 and 1983 (<12,000 kg). Angler harvest of largemouth bass and yellow perch had a significant linear increase (1972-1985), while harvest of bluegill decreased. Increases in largemouth bass catch were correlated with increases in submerged aquatic vegetation, while increase in yellow perch harvest was attributed, in part, to expansion of an invading population. Bluegill harvest may have declined because of dense vegetation hindering fishermen access. Rotenone surveys indicated that bluegill stocking stock increased over the same time period. In the creel survey conducted in the vicinity of WBN since 1982, bluegill dominated numbers (35 percent) of fish creeled, and channel catfish dominated biomass (40 percent). Since 1982, catch rate has been higher in the WBN vicinity than reservoir wide (e.g., in 1984, 1.0 fish/hr in the plant area versus 0.34 fish/hr reservoir wide). Regression analysis indicated that, since 1972, fishing pressure (total hours per year) on Chickamauga Reservoir has increased signficantly. For example, lowest fishing pressure was 216,868 hours in 1974, in contrast to a high of 523,780 hours in 1982.

7. Based on cove rotenone sampling since 1970, some increasing and some decreasing trends were noted among important species, but total fish biomass remained relatively stable. Total biomass of 37 species in

1985 cove samples was 528 kg/ha. Some species (e.g., flathead catfish, sauger and white crappie) that showed decreases in biomass for one or more size classes were those which cove rotenone generally does not provide a representative sample. On the other hand, species that showed increasing trends (e.g., bluegill, gizzard shad, and largemouth bass) were those which cove rotenone usually provides better estimates of relative abundance. Cove rotenone sampling does not provide representative samples of all species; however, it remains the best overall fish sampling method for determining quantitative and qualitative (species composition) changes in reservoir fish populations. The overriding influence on standing stock estimates for many of the important fish species appears to be associated with habitat alteration resulting from an increase in aquatic vegetation in shallow overbank and cove areas of Chickamauga Reservoir. From 1976 through 1983 there was a seven-fold increase in the acreage affected by rooted aquatic vegetation. This has resulted in higher standing stock estimates for various centrarchids, particularly warmouth, redear sunfish, bluegill, and largemouth bass. Whether or not aquatic vegetation has resulted in a decrease in biomass or numbers of some fish species (e.g., smallmouth buffalo and freshwater drum) is not clear. However the experimental summer drawdown of Chickamauga Reservoir in 1985 for aquatic weed control produced conditions that supported previous assumptions relative to the influence of aquatic weeds on the distribution of freshwater drum and threadfin shad. Both species (number and biomass) increased in

1985 cove samples. Although young-of-year largemouth bass showed a slight decline in 1985, adult stock estimates were the highest recorded (52/ha; 14 kg/ha) since monitoring began in 1970.

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Attachment 2

(Paper Copy and on Enclosed OSM)

Figure 1

Tennessee River Downstream from Watts Bar Dam Showing the Locations of the Three Mussel Sampling Stations

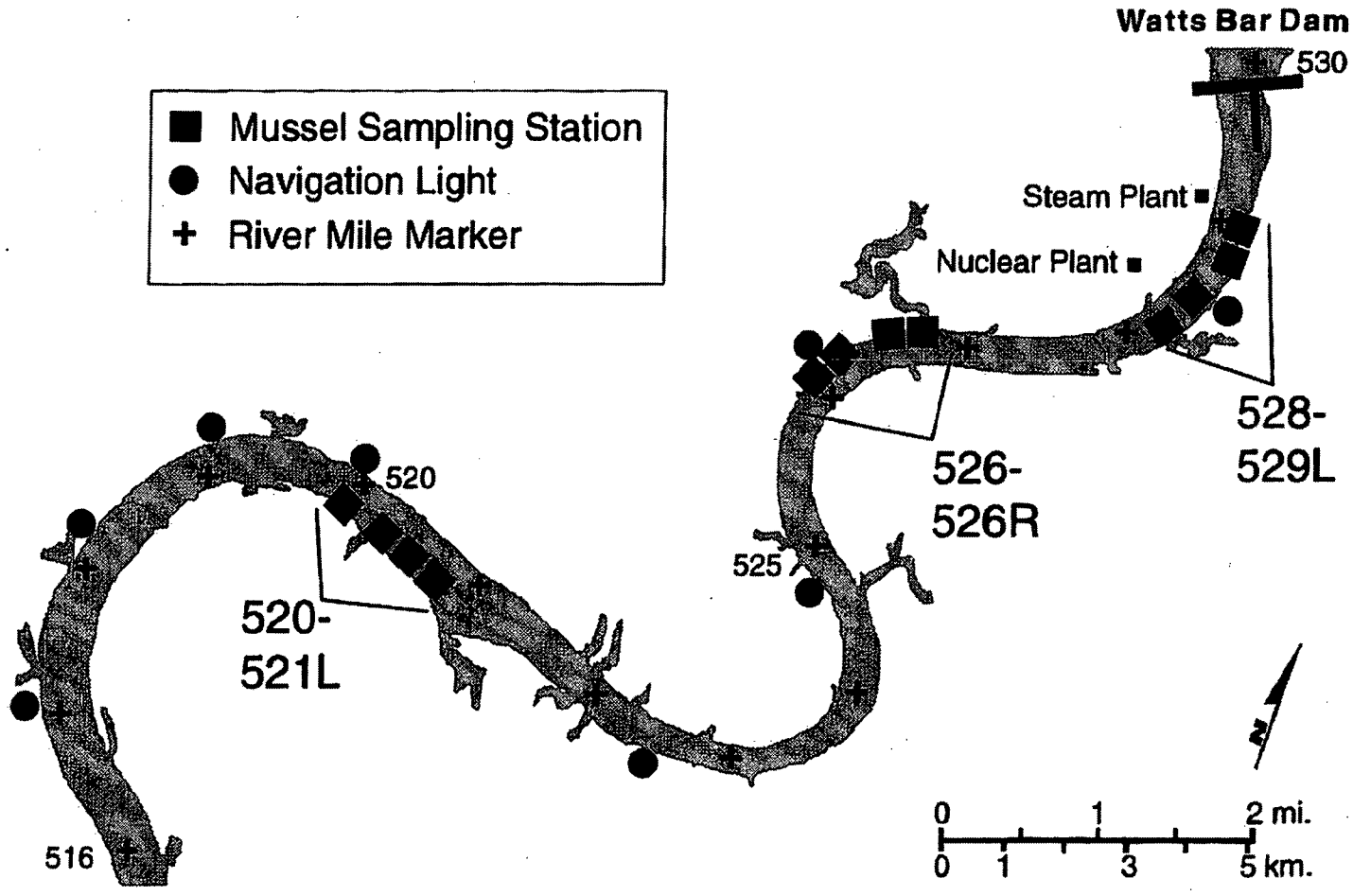

Figure 1. Tennessee River downstream from Watts Bar Dam showing the locations of the three mussel sampling stations.

Attachment 3

(Paper Copy and on Enclosed OSM)

Tennessee Valley Authority

Resource Group

Water Management

Aquatic Environmental Conditions
In the Vicinity of Watts Bar Nuclear Plant
During Two Years of Operation, 1996-1997

Norris, Tennessee

June 1998
(Revised 06/07/2010)

TENNESSEE VALLEY AUTHORITY

RESOURCE GROUP
WATER MANAGEMENT

AQUATIC ENVIRONMENTAL CONDITIONS IN THE VICINITY OF WATTS BAR NUCLEAR PLANT DURING TWO YEARS OF OPERATION, 1996-1997

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TENNESSEE VALLEY AUTHORITY

Revisions (06/07/2010)

In section 2.1, Entrainment-Larval Fish (and Eggs), clerical errors were discovered that prompted a thorough review of the raw data and calculations to verify the earlier entrainment rate estimate. Fish and egg density values and CCW intake and river flow data for 1996 and 1997 used to calculate percent entrainment were re-evaluated based on the seasonality of ichthyoplankton occurrence and reservoir releases from Watts Bar Dam. Section 2.1 was revised using actual intake water demand and reservoir river flow values for each sample period. This is a more accurate method for estimating percent entrainment of fish eggs and larvae than was used in the original report, which used mean annual flow rates for plant intake and river flow past the plant. Table 2-4 in the original report ("Day and night densities (number per 1,000 m3) of larval fish collected during preoperational and operational monitoring in the vicinity of Watts Bar Nuclear Plant") was removed because diel densities were variable and no trend was apparent, and because the table did not contribute to the entrainment analysis. Tables 2-5 and 2-6 in the original report have been combined into a single table, number Table 2-4. Tables 2-7 and 2-8 have been renumbered as Tables 2-5 and 2-6. A new Table 2-7 has been added to show estimated entrainment results of fish eggs and larvae during 1996 and 1997 at Watts Bar Nuclear Plant based on intake and reservoir flow, number of days sampled, average densities, total numbers and percent entrained and total numbers transported past WBN. The remaining tables in Section 2, Tables 2-9 through 2-26, have been renumbered as Tables 2-8 through 2-25. This revision confirms that the following conclusion regarding entrainment in the original 1998 report remains valid. Overall, low entrainment percentages for fish eggs and larvae transported past WBN and minimal hydraulic entrainment by WBN, suggest no impact to the ichthyoplankton populations of Chickamauga Reservoir from the operation of WBN.

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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 1996-1997. The primary objective of the WBN Nonradiological Operational Monitoring Program is to evaluate and compare specific biological and chemical parameters during the first two years of operation of WBN to those reported in the WBN Nonradiological Preoperational Assessment. Biological and chemical components monitored to detect and evaluate significant effects, if any, of WBN during the first two years of operation included: juvenile and adult fish, entrainment of fish eggs and larvae, fish impingement, tailwater fishery creel survey, benthic macroinvertebrate communities, native mussel fauna, and various water quality parameters.

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. A combination of low densities and number of taxa of ichthyoplankton passing the WBN water intake and the low volume of hydraulic entrainment required by the plant resulted in insignificant losses due to plant operation. Relative abundance and species composition of benthic macroinvertebrates and juvenile and adult fish were also primarily influenced by releases from Watts Bar Dam. Temporal analyses showed that

seasonal and yearly changes in abundance and other variables for all component populations, except freshwater mussels, were common.

It is apparent based on comparisons of species composition, relative abundance, catch per unit effort (CPUE), and Reservoir Fish Assemblage Index (RFAI) scores between preoperational and operational monitoring, WBN has not adversely impacted the tailwater fish population below Watts Bar Dam during the first two years of operation. Comparison of fish community sampling during preoperational and operational monitoring showed minimal variations comparing 12 important species. Reservoir RFAI values also remained relatively stable.

Comparisons of angling effort between preoperational and operational periods were not possible as this information was not available during the preoperational period. During the two years of tailwater creel surveys (April 1996-April 1998), a total of 392,807 fishing hours and 88,151 angler trips were estimated. Catfish, sauger, white bass, crappie, sunfish, striped bass/cherokee bass, and black bass were the most sought after species by fishermen. An estimated of 341,106 fish were caught and 165,128 fish harvested from April 1996-April 1998. Peak angling effort (30,218 hours) and number of trips (9,717) occurred in April 1996. Angling trips ranged from 9,717 in April 1996 to 1,456 trips in November 1997. Annual catch rate (number per hour) in the vicinity of WBN during operational monitoring has increased to 1.54 (fish per hour) compared to the highest catch rate during the preoperational monitoring of 1.16 (fish per hour).

The first two years of operation of WBN has not impacted the benthic macroinvertebrate community. During operational monitoring, densities of benthic macroinvertebrates collected near WBN nearly doubled from those observed during preoperational monitoring. In addition to

the increased number of taxa found during this period, zebra mussel average densities increased from 26.5/m^2 in 1996 to 41/m^2 in 1997 and were most abundant (72/m^2) at TRM 528.5 (upstream of the WBN intake channel). Freshwater mussels in the vicinity of WBN are slow growing and quite old. Many of the 30 species found below Watts Bar Dam appear to have not reproduced in the past 50 years. Declining abundance trends were noted during preoperational assessment for several communities of macroinvertebrates, plankton and periphyton. 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 system in the forebay of Watts Bar Reservoir to reduce stratification in the vicinity of Watts Bar Dam during summer and fall. This has resulted in higher dissolved oxygen levels in hydro releases. During the first two years of operation, WBN has not impacted the water quality in Chickamauga Reservoir.

WBN operation has had no effect on the aquatic communities nor water quality in upper Chickamauga Reservoir.

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1.0 INTRODUCTION

1.1 Purpose and Objective

The Tennessee Valley Authority (TVA), in accordance with the NPDES Permit Number TN0020168, conducted 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 conducted 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 during both monitoring periods. TVA completed one reactor unit and began testing Unit 1 in March 1996 and first generated commercial power on May 27, 1996. This unit operated at 84% capacity and generated more than 8.5 billion kilowatt-hours of electricity during the first year of commercial operation (May 27, 1996 through September 5, 1997) and at or near forecast net capacity through the first quarter of 1998.

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 from Wilson C. McArthur to Thomas Roehm). This operational monitoring plan was revised from previous versions based on numerous aquatic biological investigations conducted in the vicinity of WBN and throughout Chickamauga Reservoir since the original operational monitoring plan was prepared in 1977. These investigations focused on selected fish species and other specific problem areas (e.g., dissolved oxygen, aquatic vegetation) identified 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 reduced 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 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 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 differences were determined by comparing data from stations upstream

and downstream of WBN. Temporal changes were determined by comparing operational (1996 through 1998) 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.

1.2 Plant Description

WBN is located on the west bank of upper 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 from the cooling tower is discharged through multiport diffusers located in the main river channel at TRM 527.8. Makeup water and other water supply requirements are obtained from an intake channel and pumping station at TRM 528. These intake and discharge structures are shown in Figure 1-1.

The WBN intake channel cross-section opening is approximately 155 m^2 (1,650 ft^2) at Chickamauga Reservoir winter pool elevation of 206m (675 ft) mean sea level, and 293 m^2 (3,159 ft^2) at summer pool level of 208m (682.5 ft). Corresponding average velocities in 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). Maximum intake pumping flowrate is 4.5 m^3/s (160 cfs) or 0.6 % of the long-term average flow past WBN of 767 m^3/s (27,100 cfs).

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

The diffuser system consists of two pipes extending into the main channel. The downstream pipe segment extends 90m into the channel with a 50m long, 1.35m diameter diffuser section located in the deepest (5-6 m) portion of the 400m wide channel. The upstream pipe segment extends 140m with a 25m long, 1.0m diameter diffuser section beginning where the downstream diffuser section ends. The diffuser sections are half buried in the river bottom with two rows of 2.5cm (1 in) diameter ports oriented at a 45° angle in the downstream direction. The exit jet velocity is approximately 2 m/s. The expected discharge temperature varies, depending on cooling tower performance, from 17°C in January to 35°C in July. The maximum blowdown temperature is 35°C, so the expected monthly average temperature difference between the discharge and the river varies from 10°C during winter and spring to 5°C during summer and fall. The diffuser system will result in a near-field dilution of at least 15. 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 river 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 and 1997 to determine and assess any effects of plant operation. This sampling provided estimates of density and 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 (1976-1979, 1984 and 1985) and operational (1996 and 1997) monitoring were collected biweekly (weekly during part of preoperational monitoring) on a diel schedule (day and night), during March-August (preoperational) and April-June (operational) at TRM 528.0 (Table 2-1). This sampling provided temporal abundance of larval fish at five stations along a transect perpendicular to river flow just upstream of the plant intake channel (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. The volume of water filtered through the net was measured with a large-vaned General Oceanics Inc.® flowmeter. Approximately 150 m^3 of water were filtered per ten minute sample. Water temperature was recorded using a mercury thermometer calibrated to the tenth degree.

Beginning in 1984 and during operational monitoring, additional towed samples were collected in the plant cooling water intake channel. Preoperational (1984-1985) intake channel samples consisted of four, 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 four, one-minute samples taken from the trash boom to the mouth of the intake channel. Approximately 40-50 m^3 of water were filtered per intake sample.

Laboratory Analysis

Larval fish 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 (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 herring), (Table 2-2). Any clupeid specimen identified to species level represents a postlarva or juvenile 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 5 mm or less in total length (hence, the taxonomic designation *Morone*, not *saxatilis*). Specimens identified as *Morone* sp. are greater than 5 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 periods. Densities of fish eggs and larvae are expressed as numbers per 1,000 m^3.

Estimated entrainment of fish eggs and larvae at WBN 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 from the formula:

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

Where: D_i is the mean density (number/1,000 m^3) of eggs or larvae in intake samples;

D_r is the mean density (number/1,000 m^3) of eggs or larvae in the river transect at TRM 528;

Q_i is the plant intake water demand (m^3/d); and

Q_r is the river flow (m^3/d).

The annual entrainment rate is the average of the percent entrained during each of the 24-hour sampling periods.

Results and Discussion

Fish Eggs

During the two preoperational study periods, 3,005 fish eggs were collected in WBN ichthyoplankton samples. This total consisted of 65% unidentified eggs and 34% freshwater drum eggs and one *Hiodon sp.* egg (probably *Hiodon tergisus*) collected in 1985 sampling. (Table 2-3) presents total numbers and percent composition of fish eggs and larvae collected during 1976-1985 and 1996-1997. Drum eggs occurred in samples from early May to early September with peak abundance occurring from May through early July (TVA 1986).

Less than 1% of the 4534 fish eggs collected during operational monitoring were identifiable (Table 2-4). All identifiable eggs were freshwater drum, 21 in 1996, and 14 in 1997. During both operational years, drum eggs were first collected after the water temperatures reached 20°C. 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, freshwater 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. It is very likely that the large number of unidentified eggs collected are freshwater drum eggs that were damaged via dam passage and thus unidentifiable. Further evidence is that freshwater drum are essentially the only abundant reservoir species which are pelagic spawners with non-adhesive, semi-buoyant eggs. Large numbers of freshwater drum larvae were collected at the Lowe Branch site above Watts Bar Dam in 1978 (TVA 1980b), indicating considerable drum spawning occurs above the dam.

Fish Larvae

Taxonomic composition of larval fish samples during preoperational and operational monitoring consisted of 20 and 18 taxa, respectively, is presented in (Table 2-3). During both years of operational monitoring (1996 and 1997) clupeid larvae represented 86 and 82 percent of the larval fish community collected, respectively, and were present eleven of thirteen sample periods (Tables 2-4). Percent composition of the remaining taxa exceeding 1% in 1996 and 1997 were freshwater drum (6.6%, 2.7%) *Morone* (4.5%, 12.3%) and sunfishes (1.9%, 1.3%), respectively. Gizzard shad (1.5%) and threadfin shad (1.0%) exceeded 1% during 1996 and crappie (1.3%) exceeded 1% during 1997. During 1996 and 1997 *Morone* (not *saxatilis*) and *Percidae* (not *Stizostedion*) occurred during the first three sample periods (Table 2-4). Six yellow perch larvae were collected during 1996, but none were collected during 1997. No sauger larvae were collected during 1996, but two were collected during the first sample period of 1997. *Morone* were present during all sample periods in 1996 and 1997 and increased in composition from

0.83% (41 larvae) during 1996 to 8.3% (820 larvae) during 1997. Percent composition of crappie larvae increased from 0.2% during 1996 (8 8 larvae) to 1.3% (125 larvae) during 1997 (Table 2-4).

During preoperational monitoring, average larval densities, measured from April-June, were highest (2,119/1,000 m^3) in 1984 and lowest (146/1,000 m^3) in 1979 (Table 2-5) with an average preoperational density of 822/1,000 m^3. The highest and lowest peak density occurred May 29, 1984 (10,485/1,000 m^3) and July 02, 1979 (522/1,000 m^3), respectively. During operational monitoring 1996 and 1997 average larval densities were 525/1,000 m^3 and 924/1,000 m^3, respectively. Peak densities of 1,387/1,000 m^3 and 1,699/1,000 m^3 occurred on June 3, 1996 and May 15, 1997, respectively (Table 2-5). Peak densities typically reflected periods of greatest larval shad abundance. During both preoperational and operational periods, seasonal larval densities were positively correlated with mean water temperatures ($r = 0.80$).

Larvae of migratory taxa (species known to have distinct spawning migrations) reported to spawn in tailwaters were not numerous in preoperational or operational monitoring samples. Specimens of *Stizostedion* sp. collected during preoperational monitoring, 1976-1978 (Table 2-3), were the result of dam passage as they were too large (10-18 mm TL) to have hatched below Watts Bar Dam in the vicinity of WBN. Priegel (1969) reported that sauger hatch at 5-7 mm total length. Neither *Stizostedion* sp. nor *S. canadense* (sauger) larvae were collected in the last five years of preoperational monitoring, nor during the first year of operational monitoring. During the second year of operational monitoring two *Stizostedion* sp. were collected during the first sampling period (Table 2-4). Both individuals were 7 mm in length (Table 2-6) indicating

these could have been walleye larvae that hatched above Watts Bar Dam or possibly incidental spawnning by sauger in the tailwater. Priegel (1970) found that walleye hatch at 6.0-6.8 mm total length. Previous investigations (Hickman et al. 1990) have determined that sauger in Chickamauga Reservoir spawn at Hunter Shoals (TRM 521), and therefore larvae hatched downstream from WBN would not be subjected to entrainment by WBN.

Temperate basses (*Morone.*), also migratory spawners, accounted for more than 1% of total larvae during five of the last six years of preoperational monitoring and during both years of operational monitoring. White and yellow bass (not striped bass), comprise the majority of this taxon. Temperate basses as a whole made up 0.06% in 1976 to 6.63% of the ichthyoplankton community in 1982 (Table 2-3). During operational monitoring (1996 and 1997), percent composition of the sum of *Morone* larvae ranged from 4.5% to 12.3%, respectively (Table 2-3). Table 2-6 illustrates a wide range of larval and postlarval *Morone* sizes in ichthyoplankton samples during the two years of operational monitoring. This suggests a combination of both *Morone* spawning in the tailwater and dam passage of larvae produced in Watts Bar Reservoir.

Perca flavescens, (yellow perch), larvae were first collected in Chickamauga Reservoir in 1978, and were subsequently collected throughout preoperational monitoring. Adult yellow perch are common in Chickamauga and Watts Bar Reservoirs. Larvae collected in the vicinity of WBN likely result from dam passage. Yellow perch made up 0.12% of larval densities during the first year of operational monitoring (1996) which was consistent with the relative abundance observed during preoperational monitoring (Table 2-3). During the second year of operational

monitoring (1997) larval yellow perch were not collected. It can be concluded that the tailwater habitat is not conducive to yellow perch spawning.

Due to their high reproductive potential, clupeids were consistently the most numerous larval fish taxon captured during both preoperational and operational periods (Table 2-3). It is unlikely that the Watts Bar Tailwater is an important spawning area for shad. Eggs of gizzard and threadfin shad are demersal and adhesive, and larvae of both species hatch at approximately 3.5 mm total length (Shelton 1972). Shelton also reported growth of both species to be 1 mm or more the first day at 23^0C. Typically, water transport time from Watts Bar Dam to the plant site would not exceed five to six hours (TVA 1986). Operational monitoring revealed that most clupeids collected were greater than 6mm (Table 2-6). This implies that larval and postlarval shad below the dam were there as a result of dam passage.

Two Centrarchids, 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 greater near the shoreline and in intake samples, indicating that these two areas serve as spawning and nursery areas for sunfish.

Crappie larvae were collected during May and June for all of preoperational and operational monitoring (Tables 2-4). Size distributions of crappie larvae collected at WBN (Table 2-6) show that approximately 63% of the larvae collected were 5 or 6 mm specimens in 1996 and 84% in 1997. 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 mainly via dam passage.

Freshwater drum comprised 5% of the total catch during operational monitoring 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 (TVA 1986). As mentioned previously, freshwater drum were primarily spawned above Watts Bar Dam.

Estimated Entrainment of Eggs and Fish Larvae

Estimated average hydraulic entrainment by WBN (proportion of the Tennessee River flow entrained through the intake pumping station) during operation was very low (0.6%) compared to 13% by Sequoyah Nuclear Plant (SQN), (TVA 1996). These percentages are derived from measured intake volumes and river flow at each plant. Estimated percentage entrainment of fish eggs and larvae being transported past WBN during 1996 was 0.29% and 0.57%, respectively (Table 2-7), compared to 7.5% estimated entrainment of larvae at SQN during 1980-1984 (TVA 1984). During 1997, entrainment of fish eggs and larvae was estimated to be 0.02% and 0.22%, respectively. Total transport of fish eggs and larvae past WBN during six sample periods in 1996 was estimated to be 1.09×10^8 and 1.63×10^8, respectively. During the seven sample periods in 1997, the total transport of fish eggs and larvae past WBN was estimated to be 1.20×10^8 and 4.2×10^8, respectively. Corresponding numbers entrained at WBN in 1996 were 2.05×10^4 fish eggs and 1.4×10^6 larvae. During 1997, the estimated total entrainment was 1.94×10^4

eggs and 9.29 x 10^5 larvae. Due to the low hydraulic entrainment at WBN, larvae residing in the intake channel are most susceptible to entrainment. Larval shad represented 91% in 1996 and 84% in 1997 of all larvae collected in the intake channel, followed in abundance by sunfish (7.6% and 8.1%), freshwater drum (0.8% and 0. 3%), and *Morone* (0.2% and 6.4%), respectively (Table 2-8).

The higher composition of sunfish (*Lepomis*) larvae in the intake basin was likely a result of resident populations using this area as a spawning and nursery habitat. *Lepomis* was ranked fourth in combined percent composition of total larvae in reservoir and intake samples during 1996 (1.9%) and during 1997 (1.3%) (Tables 2- 3 and 2-4). Overall, low entrainment percentages for fish eggs and larvae transported past WBN and minimal hydraulic entrainment by WBN, suggest no impact to the ichthyoplankton populations of Chickamauga Reservoir from the operation of WBN.

2.2 Electrofishing

Introduction

Preoperational fish community sampling at WBN was initiated in March 1977, continued through November 1979, and resumed from March 1982 to December 1985. Additional preoperational fish community 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 from 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 different, 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 comparisons between 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 proportionally 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 samples were also available for the 1977-1985 preoperational period). Another operational difference was the start-up of WBN in 1996, and this was the focus of determining plant impacts. Particularly in a tailwater habitat such as that found near WBN, numbers of species and abundance will vary seasonally.

Materials and Methods

Fish stunned by a boat electrofishing unit were captured, identified, enumerated, and recorded prior to release. During vital signs monitoring samples (1990-1997), 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 contribution 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 from all density and percent composition results from all data sets.

Data collected from 1977-1979 were based on timed (three minute duration) electrofishing runs, while samples collected during 1982-1985 were distance based (100 m). Five electrofishing runs were collected monthly during both of these time periods. Vital signs samples were collected once during each fall (15 electrofishing runs) and were distance-based (300 meters of shoreline/run). Species occurrence and percent composition between the two preoperational sample sets and operational results, after elimination of shad, are comparable. Since operational data are limited to two annual samples (1996 and 1997), vital signs preoperational data (1990-1995) 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 1996-1997 (operational) vital signs monitoring results.

General comparisons were made between the 1977-1985 preoperational, 1990-1995 preoperational, and 1996-1997 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 an univariate Analysis of Variance (ANOVA) to determine if there were significant ($P = 0.05$) differences. 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 two years 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 (1996-1997) electrofishing data. During the 1977-1985 preoperational monitoring period at WBN, monthly electrofishing yielded 43 species from 12 families (Table 2-9). Fall vital signs electrofishing preoperational monitoring resulted in the collection of 39 species from 10 families while 34 species (9 families) were captured during fall 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 a total of two samples, fall 1996 and 1997 however; species occurrence was just slightly lower than 1990-1995 preoperational results, which included a total of six 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 from 1977-1997 (Table 2-9). Only emerald shiners appear to have declined substantially in numerical importance over the course of the sample periods; making up 58.6% of the community during 1977-1985, 17.1% from 1990-1995, and only 1.5% during 1996-1997. 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. Bluegill and smallmouth bass increased 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, golden

redhorse, freshwater drum, brook silversides, logperch, smallmouth bass, spotted bass, and black crappie. Brook silversides were not collected during either year of operational monitoring, while golden redhorse, freshwater drum, and black crappie increased somewhat in importance to the community after WBN became operational.

Comparisons of CPUE (catch per electrofishing run) results between vital signs preoperational (1990-1995) and operational (1996-1997) monitoring are listed in Table 2-10. Mean CPUE for all species during preoperational and operational monitoring was 76 and 53 fish per shocking run, respectively. 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, spotted bass, and smallmouth 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 an average score of 45 in the operational period (1996-1997). Scores ranged from a maximum score of 56 in 1993 to a minimum of 33 in 1991 (Figure 2-2). The maximum RFAI score of 56 obtained in 1993 was followed by a gradual decline to 38 by 1996. This decline began two years before WBN became operational and

rebounded to a score of 52 during the second year of operation. Reasons for the 1993-1996 decline are unknown, but it is apparent WBN operation was not responsible.

Conclusions

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 two samples.

Comparison of catch per electrofishing run (CPUE) during 1990-1995 preoperational and 1996-1997 operational monitoring also showed minimal variation (76 and 53 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.

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 an average score of 45 in 1996-1997.

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 two years 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 operates 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 and second year (partial) of fish impingement monitoring at WBN are compared with standing stocks of fish in Chickamauga Reservoir and previous impingement estimates from SQN. The Tennessee Department of Environment and Conservation (TDEC) Division of Water Pollution Control approved TVA's request in the first annual report (Baxter et.al 1997) to discontinue impingement sampling due to extremely low numbers of fish impinged. Sampling was suspended October 7, 1997.

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 consisted 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 recorded. Thirty-six samples were collected between March 15, 1996, through February 28, 1997 and 21 samples were obtained from March 4, 1997 through September 30, 1997. Estimates of total annual impingement were calculated by multiplying average number of fish impinged per sample by the number of days in each month and year.

Results and Discussion

Fifty-five impingement samples, collected between March 15, 1996 and September 30, 1997, yielded only 20 fish representing nine species (Table 2-12). Numbers of impinged fish were consistently low due to the low volume of water withdrawn through the intake channel. Total annual estimated number of fish impinged during 1996 and 1997 was 162.2 and 40.8, respectively (Table 2-12). This rate was extremely low compared to 70,022, 40,944 and 14,960 fish estimated impinged at SQN during 1981-1983, respectively (Table 2-13). None of the species were impinged at WBN in sufficient numbers to impact Chickamauga Reservoir

populations. 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.

2.4 Fishery Creel Survey

Introduction

The specific objectives 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 survey (1982-1985), only annual catch rates could be compared with data obtained during the more intensive operational survey. Therefore, results of the operational monitoring creel survey are reported as a "baseline". Creel results (collected by Tennessee Wildlife Resources Agency) from subsequent years could be used to further determine impacts of WBN on the Watts Bar Tailwater fishery.

Materials and Methods

Recreational fishing data in the vicinity of WBN (TRM 523.2 to TRM 529.9) were 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-April 1998), 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 2-15). 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 (one weekend and two 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 from April 1996 through June 1997 and three times per day from July 1997 through April 1998 at randomly assigned periods. The clerk counted all fisherman at Watts Bar Dam, including those boat and bank anglers visible 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 by TVA (1986) for preoperational monitoring and by Pollock et al. (1994) for operational monitoring. Monthly catch and harvest rates were determined for generalist anglers fishing for any species group, and for anglers directing their efforts toward a particular species group (i.e., black bass, crappie, catfish, etc.) during operational monitoring. To analyze 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 a specific directed species group was determined by partitioning the annual effort estimate by the proportion of effort accounted for by

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. All estimated values are reported with a standard error of the mean as a measurement of variation.

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

Results

During preoperational monitoring, April 1982-December 1985, 4,745 individual fishermen were interviewed. Interviews were taken from 3,555 angling parties during operational monitoring (April 1996-April 1998). Monthly interviews exceeded 100 except during December 1996, and September, November and December of 1997 (Table 2-15).

Boat versus bank angler information was not collected during preoperational monitoring. During the WBN operational creel, 69% of angling parties interviewed were fishing from the bank. A majority of both bank (60%) and boat (75%) anglers were fishing for a specific group of species. Bank anglers primarily sought catfish (13%), sauger (11%) and white bass (10%). Boat anglers primarily sought catfish (27%), sauger (13%), white bass (11%), and black bass (10%). (Table 2-16).

Of the six locations 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 95% 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 392,807 hours during the WBN operational period (April 1996-April 1998). Mean length of an angling trip was 4.62 hours. Daily effort was 386.9 hours on weekdays and 865.5 hours on weekend days. An estimated 88,151 angling trips were conducted during the 25-month period.

Monthly angling effort varied from 30,218 hours in April 1996 to 7,395 hours in November 1997 (Table 2-18). Angling trips ranged from 9,717 in April 1996 to 1,456 trips in November1997 (Table 2-18). Mean length of angling trip ranged from 5.85 hours in April 1997 to 3.11 hours in April 1996.

Anglers seeking any species expended an estimated 129,313 hours or 29,116 trips (Table 2-19). Directed species groups expending greater than 40,000 hours included catfish (89,707 hours), white bass (42,473 hours) and sauger (40,670 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 except December 1997. Catfish angler effort peaked during the summer months. Sauger angler effort was greatest in November-January. Bank anglers expended an estimated 271,037 hours or 60,824 angling trips, as compared to 121,770 hours or 27,327 angling trips for boat anglers. Mean length of angling trips for bank anglers was 2.90 hours and 5.09 hours for boat anglers. An estimated 57,783 angling trips were taken at the two access points located at the dam.

Catch and Harvest

Overall annual catch rates (number of fish caught 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 during operational monitoring (1996-1997) was 0.61 (fish/hour).

Annual mean catch and harvest rates (Tables 2-20 and 2-22) and estimated numbers caught and harvested (Tables 2-21 and 2-23) were determined for both directed species group anglers and any species group anglers. In addition, the total number of fish caught and harvested for the fishery was estimated (Table 2-24). An estimated 41,331 sauger were caught from April 1996 through April 1998 of which 20% were harvested. Estimated number of blue catfish caught was 50,825 representing the largest portion of any catfish species. Bluegill represented the greatest single species caught with 140,764 caught and 63,502 harvested.

The greater catch and harvest rates for directed species group anglers allowed for a greater annual catch and harvest by this group. Interestingly, yellow bass was the only species for which a greater portion of the catch and harvest was attributed to the any species group (Figure 2-5).

Monthly catch and harvest rates for directed species group anglers varied with season for sauger, blue catfish, and white bass during operational monitoring (Figure 2-6 and 2-7). 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, nor 1998. Blue catfish catch and harvest rates were fairly consistent except during winter months. White bass catch and harvest rates peaked in the spring of 1996 and 1997, but did reach similar levels in 1998. The poor angling success in spring of 1998 was attributed to low water in the early spring followed by record flooding in April.

Catch rate comparisons for each species collected between preoperational and operational monitoring are listed in Table 2-25. During operational monitoring, harvest rates exceeded those for the preoperational survey for all species compared.

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 WBN operational, but not during preoperational survey.

Length frequency of the three 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

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 frequency of both blue catfish and channel catfish were similar. Anglers harvested more individuals from 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 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 frequency of harvested sauger was dominated by 3-5 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 olds (Figure 2-16). Striped bass harvested were generally greater than 650 mm, but some as small as 250 mm were harvested (Figure 2-17). Age frequency displayed a wide range of ages (2-11) with most harvested striped bass being between the ages of 4 and 8 (Figure 2-18).

Fishing effort, catch rates and total harvest data indicate a viable and popular tailwater fishery below Watts Bar Dam. It is apparent, during the first two years of operational monitoring, that WBN did not impact the tailwater fishery in the vicinity of the plant.

3.0 AQUATIC MACROINVERTEBRATES

3.1 Hess Sampling

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 patterns 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, floods, proximity of suitable habitats, temperature, and dissolved substances. The most obvious influential factors in the vicinity of WBN are flow and substrate composition. Traveling downstream from WBN, there is a lessening of current velocity which is accompanied by a transition from hard rock and sand to softer, more silty

substrates (TVA 1986). These factors strongly influence spatial distribution 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 (1996-1997) periods.

Divers collected ten 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 (0.0856 m^2) 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 stream 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 from 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, organisms

removed from the detritus and preserved in 85% ethanol. Organisms were then identified to the lowest practical taxonomic level.

Data Analysis

Results of summer and fall operational monitoring Hess samples (1996-1997) were compared with those collected during preoperational monitoring (1983-1985). Sorensen's Quotient of Similarity (McCain 1975) and Percentage Similarity (Pielou 1975) used to evaluate similarity among stations were inconsistent during preoperational and the first year of operational monitoring. Baxter et al. 1997 suggested that comparisons between preoperational and operational results must be made on an individual station to station basis. Therefore community diversity (D-Bar, diversity index) (Patten 1962), one-way ANOVA and Duncan's Multiple Range Test (Steel and Torrie 1960) were used to evaluate 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

Table 3-1 compared occurrence of 59 macroinvertebrate taxa were collected during preoperational (1973-1985) monitoring in the vicinity of WBN. During operational monitoring (1996 and 1997), Hess samples collected a total of 104 taxa.

Densities of benthic macroinvertebrates also increased considerably at all five stations (Table 3-2) after WBN became operational. These increases are likely due to aforementioned

improvements in dissolved oxygen levels in water released through Watts Bar Dam as a result of the aeration system in the forebay of Watts Bar Reservoir beginning in early summer, 1996.

Three of the 59 taxa collected during preoperational monitoring, *Corbicula fluminea*, Asiatic clam (formerly *C. manilensis*), *Crynellus fraternus*, and Oligochaeta, comprised approximately 85% of the total community (Table 3-2). During operational monitoring, four of 104 taxa collected, *Corbicula fluminea*, *Dugesia tigrina*, *Gammarus minus* and Oligochaeta, comprised 87.5% of the total community. *Corbicula fluminea* was consistently the most abundant taxon during preoperational monitoring, but was less dominant during operational monitoring (Table 3-2). *Dugesia tigrina* was the most abundant taxon during operational monitoring, especially in fall samples (Table 3-2) (Appendix A). *C. fraternus* (caddisfly) met the dominant taxon criterion (Table 3-2) during preoperational monitoring and comprised 5% of the total community and was found at each station during fall 1997 operational monitoring (Appendix A). *Hydra americana* also was dominant during the summer of operational monitoring but did not exceed 5% of the total community during the fall samples (Appendix A).

Average number of taxa collected in preoperational summer and fall Hess samples (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 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 community was composed of *Corbicula fluminea* (TVA 1986).

During operational monitoring, an average of 28.3 (summer and fall combined) taxa were collected per station, which was significantly greater ($\alpha = 0.001$) than average of 15 collected during preoperational monitoring. The greatest number of taxa collected at a single station in summer 1997 was 35 at TRM 528.0. Community diversity 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 during operational monitoring. The number of taxa found at TRM's 527.4, 528.0 and 528.5 nearly doubled during operational monitoring, yet the diversity index stayed relatively the same (Table 3-3). These results indicate negative no impacts on the benthic community of upper Chickamauga Reservoir due to operation of WBN.

Analysis of variance and Duncan's Multiple Range Test of total benthic macroinvertebrate standing crop were used to compare stations (Table 3-4). 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 were more pronounced in summer 1984, with densities again strongly influenced by abundance of *Corbicula fluminea*. In summer, 1985, abundance of macroinvertebrates again changed, with abundance much higher at TRM 526.3 than at other stations (Table 3-5). This station contained exceptionally large numbers (540 per m^2) of the silt tolerant midge, *Chironomus* sp., and other silt-tolerant 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) of silt/clay at this site.

During both summer and fall quarters of operational monitoring, stations that had similar benthic communities varied with preoperational results (Table 3-4). Benthic community standing crops at stations adjacent to WBN and upstream (528.0 and 528.5) were significantly higher than stations below the plant during fall of 1996 but not during fall of 1997. These annual differences are likely caused by fluctuating discharges from Watts Bar Dam and not related to the operation of WBN. Station similarities in total benthic macroinvertebrate densities were primarily due to abundance of *Corbicula fluminea*, *Dugesia tigrina*, *Gammarus minus* and Oligochaeta, (Table 3-2).

Silt-tolerant organisms such as *Branchiura sowerbyi*, Tubificidae, and *Limnodrilus hoffmeisteri*, were also somewhat abundant at TRM's 521.0, 526.3, and 527.4, (Appendix A). 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 3-4). In 1984, total abundance in fall was greater upstream of TRM 526.3, resulting from a large increase in the caddisfly, *Cyrnellus fraternus*, and amphipod, *Crangonyx*. During operational monitoring (1996 and 1997), 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 sampling collected Zebra Mussels (*Dreissena polymorpha*) at each station (Appendix A). Zebra mussels were most abundant (72 /m^2) in the fall of 1997 at TRM 528.5 upstream of the WBN intake channel (Appendix A). Zebra mussels were first found near WBN on June 1, 1995, at TRM 528.0 (adjacent to the WBN intake channel). Samples collected on that date indicated a density of 4.8/m^2 (TVA 1995). During operational monitoring (1996 and 1997), average densities of zebra mussels increased to 26.5/m^2 and 41/m^2, respectively.

Based on comparisons of species composition, occurrence, and densities of aquatic macroinvertebrates between preoperational and operational monitoring periods, WBN has not impacted the tailwater benthic macroinvertebrate community during the first two years of operation.

3.2 Native Mussel Fauna

Introduction

Preoperational monitoring of freshwater mussels in the vicinity of WBN was conducted 12 times during the years 1983 through 1994. On each occasion, the same sites on each of three mussel beds were examined by divers. Results of the preoperational surveys of these beds have been presented in various reports (TVA 1986; Ahlstedt 1989, 1991; Ahlstedt and McDonough 1996). The first year of WBN operational monitoring of the mussel fauna was conducted during 1996 at the same sites following the same techniques used during the preoperational period. Results of that study were presented in the WBN first annual operational monitoring report (Baxter, et al., 1997).

In July1997, a second operational monitoring survey of the native mussel fauna was conducted in the Watts Bar Tailwater. This report also includes an evaluation of the long-term population trends on these three mussel beds throughout the 15-year period they have been monitored. The purposes of this evaluation are to identify how the mussel resources on these beds have changed and to determine if operation of WBN has had any obvious effect on the mussel resources in this part of the Tennessee River.

Study Area Description

In 1983, mussel monitoring sites were established in three known concentrations of mussels (mussel beds) in the reach of the Tennessee River downstream from Watts Bar Dam near WBN: TRM 520-521L (left descending bank), TRM 526-527R (right descending bank), and TRM 528-529L (Figure 3-2). The most upstream of these beds (TRM 528-529L) is located on the opposite side of the river from WBN and upstream from its discharges. The middle bed (TRM 526-527R) is on the same side of the river as WBN and is just downstream from the confluence of Yellow Creek and all WBN 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 three to seven meters deep.

Four sampling sites were established along the length of each bed (Figure 3-2). Initially, each site was located as precisely as possible using river mile markers, navigation buoys, and bankside landmarks. During the 1996 survey, original notes and the original field crew leader assisted in adding global positioning system coordinates to these site locations.

Methods

Between 1983 and 1985, the examination of each site was conducted by two pairs of SCUBA divers collecting mussels for 11 minutes each (for an aggregate total of approximately 45 minutes of diver search time). Over the years, improvements in communications and diver equipment have allowed this search commitment to be met using two independent divers, each collecting mussels for 22 minutes of bottom time.

During the 1997 survey, two divers collected all of the live native mussels (thus excluding the Asiatic clam, *Corbicula manilensis*) they encountered during 22 minutes of bottom time at each of the 12 sampling sites. All of the mussels found at each site were brought to the surface where they were sorted by species, identified, and counted. Up to 50 live animals of each species from each bed were then measured in three dimensions (length, height, and thickness). All mussels were returned to the river in the vicinity of the site from which they were collected. The numbers of each species found at each site and the measurement data from each bed were recorded on field sheets and, later, added to the existing WBN mussel database.

Summary results for the 1997 survey were prepared from the database using the same format included in previous reports. A variety of statistical analyses were used to examine the combined sets of survey results, and the 5 percent significance level ($\alpha = 0.05$) was used as a decision point in all analyses. Prior to any analysis, the abundance data were transformed to approximate a normal distribution using a $\log_{10}(x + 1)$ transformation.

For both the abundance and measurement data sets, regression analyses were used initially to test if the results on each mussel bed differed among the sampling sites or between years. If the slopes of all sites on a bed were not different from zero, then analysis of variance and Fishers Least Significant Difference Test were used to test for differences between sites. If the slopes were different from zero, and found to be parallel in a homogeneity of slopes test, covariance analysis and Fishers Least Significant Difference Test were used to identify differences between the sites. When appropriate, the nature of long-term trends was identified by plotting pertinent yearly mean values.

Results and Discussion

1997 Survey Results

Results during the 1997 survey of these three mussel beds (Table 3-6) indicate that 697 live mussels, representing 14 native species, were collected. Of this total, 199 mussels (28.5 percent) were found on the downstream bed (TRM 520-521), 154 (22.1 percent) were found on the middle bed (TRM 526-527), and 344 (49.4 percent) were found on the upstream bed (TRM 528-529). Six of the 14 species were found on all three beds, and five species each were found on only one of the beds.

With regard to individual species, the most abundant species on each bed was the elephantear, *Elliptio crassidens* (70.2 percent of the combined total). On the upstream and middle beds, the second most abundant species was the Ohio pigtoe, *Pleurobema cordatum* (14.5 percent of the

combined total); however, the purple wartyback, *Cyclonaias tuberculata*, occupied second place on the downstream bed (15.6 percent on this bed, 6.7 percent overall) and *Pleurobema cordatum* was a close third (14.1 percent). No specimens of the pink mucket, *Lampsilis abrupta*, or any other federal endangered species were encountered on any of the three beds during this survey (however, TVA divers did encounter live pink muckets in the Watts Bar tailwater in 1997 during other survey activities).

In the way of a short-term comparison, 846 live mussels representing 17 native species were encountered on these three mussel beds during the survey conducted in 1996 (Appendix A, Table 3-7). That total is approximately 20 percent higher than the number found during the 1997 survey. Numerical results from each of the three beds indicate that substantially more live mussels were found on the downstream and middle beds in 1996 than in 1997 (35 and 34 percent, respectively, more than in 1997). On the upstream bed, the 1996 survey yielded only slightly more (8 percent) live mussels than were found there in 1997.

With regard to individual species, even though three more species were found during the 1996 survey than in 1997, relative abundance of the common species changed very little between these two most recent surveys. As in 1997, the elephantear was the most abundant species encountered during the 1996 survey (70.2 percent of the combined total in both years), followed by the Ohio pigtoe (11.1 percent in 1996; 14.5 percent in 1997) and the purple wartyback (4.5 percent in 1996; 6.7 percent in 1997). In 1996, the pink heelsplitter, *Potamilus alatus*, was fourth in overall abundance (4.1 percent of the total) and the pimpleback, *Quadrula pustulosa*, was fifth (3.6 percent). Results from the 1997 survey show that the pink heelsplitter dropped to

fifth place (1.7 percent of the total) while the pimpleback moved up to fourth place (3.4 percent of the total).

Long-term Evaluation

For reference purposes both in this report and during any future studies, results from all 14 surveys at the 12 sites on these three mussel beds are presented in Appendix A. The information presented in that appendix and the following analyses are both divided into sections discussing separately the abundance and measurement data from these surveys.

Abundance Analysis

As an initial step in evaluating abundance data, Table 3-7 presents the total numbers of each mussel species found on all three beds during each of the 14 surveys. The greatest number of species collected in a year was 22 during 1983, 1988 and 1990. A total of 30 native mussel species was found during all of the surveys combined, ranging in abundance from over 10,000 specimens of the most common species (*Elliptio crassidens*, 63.6 percent of the overall total) to single specimens of two species (*Dromus dromus* and *Lasmigona complanata*). The species totals presented in this table showed that the five most abundant species made up 91.5 percent of the overall total, and the next five most abundant species raise that percentage to 97.3 percent of the total. All of the 20 other species encountered during these surveys represent just 2.7 percent of the total number of mussels found.

With regard to species occurrence patterns, Table 3-7 indicates that 12 species have been encountered during all of the 14 surveys, and six more have been found on at least half of the

surveys. Each of the 12 species encountered in seven or fewer of the surveys is represented by fewer than ten animals. Three of the extremely uncommon species on these beds (*Elliptio dilatata*, *Pleurobema oviforme*, and *Plethobasus cyphyus*) were seen last in 1996 and 1994, four of them (*Anodonta imbecillis*, *Pleurobema rubrum*, *Anodonta suborbiculata*, and *Ptychobranchus fasciolaris*) were encountered last in 1990 or 1988, three (*Cyprogenia stegaria*, *Pleurobema plenum*, and *Lasmigona complanata*) were last found on these beds in summer 1985 (Table 3-7), and the final two (*Fusconaia subrotunda* and *Dromus dromas*) were encountered only during the first survey in Summer 1983. Of these 12 rarely-encountered species, those found several times throughout this series of surveys may be simply extremely rare members of these mussel beds. Others of these species (perhaps those represented by one or two animals encountered only once or twice) appear to be the last survivors of populations nearly extirpated from this part of the river.

Table 3-8 presents rank order information for the 12 species that were found during all 14 surveys of these mussel beds. These rank order numbers were nearly always assigned based on how many members of a species were encountered during a given survey; however, when two or more species were represented by equal numbers of animals, alphabetical order of the scientific names was used to avoid assigning some sort of tie ranks.

The survey-by-survey rankings presented in Table 3-8 demonstrate considerable consistency in the relative abundance of these routinely-encountered species. During each of the 14 surveys, *Elliptio crassidens* was the most abundant species and *Pleurobema cordatum* was second in abundance. In all but one survey, third and fourth places were occupied by *Cyclonaias*

tuberculata and *Quadrula pustulosa* (mean ranks 3.4 and 3.7, respectively), even though five times out of the 14 surveys, their order was reversed. Similarly, rank order places five through seven typically were occupied by *Potamilus alatus*, *Ellipsaria lineolata*, and *Amblema plicata* (mean ranks of 5.7, 6.2, and 6.5, respectively). While these three species swapped rank order places during several surveys, other species occupied one of these three places only on six out of the possible 42 opportunities. The other five species found during every survey (mean ranks of 9.3 through 11.0) also routinely swapped rank order places among themselves; however, one of them occupied some other rank order spot only on five out of the 70 possible opportunities. The consistency of these rank order relationships suggests that the data sets from the 14 surveys are, at least, all valid representations of the mussel abundance patterns on these three beds.

Statistical analysis of the mussel abundance information from the 15-year study period was performed only on the data collected during the first (summer) survey conducted each year. Exclusion of the four second (fall) surveys conducted during a given year (in years 1983 through 1986) removed much of the early-year weighting in the data set and simplified the identification of long-term trends. Table 3-9 presents a summary of data used in the statistical analyses of mussel abundance. As indicated in the first section of this table, the divers encountered a total of 10,481 live native mussels on the three beds during these 10 surveys (66.0 percent of the 14-survey total). Overall, 33.0 percent of the mussels were found on the downstream bed, 21.0 percent were found on the middle bed, and 46.0 percent occurred on the upstream bed. The standard deviation information presented in Table 3-9 indicates that variations in the survey results on the middle and upstream beds were relatively similar (SDEV values are 31.9 and 38.6

percent of the means, respectively) but results on the downstream bed were nearly twice as variable (62.4 percent of that mean).

Statistical analysis of the all-species abundance data is presented in the first row of Table 3-10. The initial regression analysis indicated that a statistically significant trend was present in the data for the downstream bed (TRM 520-521, $p = 0.004$) but no trend was present in the data for the middle or upstream beds (TRM 526-527 and TRM 528-529). On the beds where no trend was present, analysis of variance indicated statistically significant differences among the sites on both beds, and Fishers Least Significant Distance tests indicated the relationships in abundance at those sites. In Table 3-10, these relationships are indicated by the order and underlining of the site locations. For example, the underline linking the site on the middle bed (TRM 526-527) with the lowest mean number of mussels present (TRM 526.3) with the next lowest mean (TRM 526.5) indicates these two values are not statistically different from each other. Similarly, the line linking TRM 526.5 and both of the other sites on that bed indicates that all three of those mean values are not statistically different from each other; however, the means for both TRM 526.8 and TRM 526.0 are statistically different from the mean for TRM 526.3.

For the downstream bed where the all-species analysis indicated a trend was present, covariance analysis indicated that the slopes of the abundance lines for each site mean were not different from each other ($p = 0.48$) and there was no significant difference between the sites ($p = 0.31$), but there was a significant relationship among the years ($p = 0.002$). The yearly mean values are listed in Table 3-9 and the general (downward) trend in these overall abundance values is illustrated on Figure 3-3.

Table 3-10 also presents the results of similar analyses for the five most abundant species encountered during these surveys. Similar analyses were not conducted for less-abundant species because of the large number of zeros present in the site-by-site survey data for those species. The analysis results presented in Table 3-10 indicate that the three most abundant species (*Elliptio crassidens*, *Pleurobema cordatum*, and *Quadrula pustulosa*) all showed statistically significant year trends on the downstream bed (TRM 520-521). For *Pleurobema cordatum* and *Quadrula pustulosa*, these trends included all four sites; however, the trend for *Elliptio crassidens* at TRM 520.0 was parallel, but different from the trend at the other three sites ($p = 0.02$). These trends, which are all downward, are illustrated on Figures 3-4, 3-5, and 3-6.

On the middle bed (TRM 526-527), only *Quadrula pustulosa* exhibited a significant year-related trend ($p = 0.05$), a downward trend illustrated on Figure 3-7. Like *Elliptio crassidens* on the downstream bed, the *Quadrula pustulosa* trend at TRM 526.0 was parallel but different from the other three sites on the middle bed ($p = 0.0007$).

On the upstream bed (TRM 528-529), none of these three species exhibited any year-related trends. For *Elliptio crassidens* and *Pleurobema cordatum*, however, the downstream site (TRM 528.2) was substantially different from the others ($p = 0.0001$ and 0.03, respectively)(Table 3-10).

Data for the fourth most abundant species (*Cyclonaias tuberculata*) indicated that trends were present on the downstream bed; however, the covariance analysis indicated that the lines for the

four sites were not parallel ($p = 0.009$). Figure 3-7 illustrates the complex patterns produced by the abundance of this species at each of the four sites on this bed.

Abundance information for the fifth most abundant species (*Potamilus alatus*), did not indicate that any trend was present in the abundance data or any difference in its abundance among sites on any of the three beds.

Considered together, this analysis indicates that the abundance of the three most common species and, probably because of the dominance of these species, the all-species totals demonstrated statistically significant declines over the years on the downstream bed (TRM 520-521). In contrast to this, only the third most abundant species (*Quadrula pustulosa*) showed a similar decline on the middle bed (TRM 526-527), and none of the five showed a statistically significant decline on the upstream bed (TRM 528-529). All other statistically significant analysis results on these beds were associated with variations in abundance between individual sampling sites. Where statistically significant declines did occur, plots of the mean values illustrate that those declines were gradual throughout the 15 year period, with no sharp breaks that might indicate a response to some specific adverse impact.

The statistically significant (declining) abundance trends among the three most abundant mussel species on the downstream bed and, for one of those species, on the middle bed, differ from the general impression presented by Ahlstedt and McDonough (1997). That report included data from the years 1983 through 1992 and was prepared before the 1994, 1996, and 1997 surveys were conducted. While some significant trends were present in the results of that earlier

analysis, the general pattern was not particularly apparent and was overshadowed by the substantial variations among the survey results.

The statistically significant trends present on the downstream and middle beds probably account for some of the survey-to-survey variations included in this data set. The amount of year-to-year variations in abundance represented on Figures 3-3 through 3-8, however, seems unusually large for these beds of sedentary, long-lived animals living in a managed river reach. Some of the variations present in these survey results might be related to differences in diver harvest speed and the relatively short time (22 minutes) involved in each timed dive. Other possible sources of the observed variations in abundance could be related to the fact that these 14 surveys were focused on examining the exact same sites on these mussel beds, but no concerted effort was always made to return the animals to the precise location where they had been found.

Measurement Analysis

As indicated in Methods, analysis of the measurement data followed the same format used for the abundance data. Like both earlier evaluations of the measurement data from these three beds (TVA 1986, Ahlstedt and McDonough 1997), these analyses were conducted only on the lengths of the mussel shells. Length, alone, was analyzed largely because that measurement appeared to be less affected by the extensive amount of shell erosion and other damage exhibited by the mussels living on these beds.

Results of the measurement component of each survey of these three mussel beds, including the 1997 survey, are presented in Appendix A. As a partial summary of these data, Table 3-11

presents the mean lengths of each mussel species measured during each year in which one or more surveys were conducted. It is important to note that each mean value in this summary table is based on a different number of measured mussels, and includes measurements from all three beds. The chief value of Table 3-11 is that it provides a concise indication of the range of length measurements for each species and the relationship of those measurements to an overall mean for the survey period. The general impression presented in this table is that virtually all of the mean values are relatively large for each species, and relatively little variation exists for nearly all of the routinely-encountered species.

Table 3-12 presents the results of the statistical analyses of the length data for the five most abundant species, the same species included in the abundance analysis. As indicated in the table, regression analysis indicated statistically significant trends were present for three of these species. The most abundant species (*Elliptio crassidens*) showed statistically significant year trends on both the downstream (TRM 520-521, $p = 0.002$) and middle beds (TRM 526-527, $p = 0.0004$). These trends, both of which are illustrated on Figure 3-9, indicate very similar, gradual increases in length over the 15-year period. Mean length on the middle bed is rather consistently 8 to 10 millimeters larger than on the downstream bed.

The second most abundant species (*Pleurobema cordatum*) exhibited statistically significant trends on two of the three mussel beds (TRM 526-527, $p = 0.0002$; and TRM 528-529, $p = 0.002$); however, Fishers Least Significant Difference Tests indicated that sites on the upstream bed represented statistically different length groupings. Figure 3-10 includes the mean length plots for *Pleurobema cordatum* on both of these beds (with all sites included). Both of these

plots include somewhat more year-to-year variation than was present in the *Elliptio crassidens* data, but still illustrate slight increases in shell length over the study period.

The only other statistically significant trend for the fourth most abundant species (*Cyclonaias tuberculata*) was on the downstream bed (TRM 520-521, $p = 0.003$). The plot of the yearly mean lengths for this species (presented on Figure 3-8) indicates a very slight increase (approximately 2 millimeters) over the 15-year survey period.

Neither of the other two common species (*Quadrula pustulosa* and *Potamilus alatus*) demonstrated statistically significant year-related trends on any of the three beds. *Quadrula pustulosa* did not yield any type of statistically significant relationships on any of the beds, but *Potamilus alatus* produced significant differences between sites on both the downstream and middle beds.

As a whole, this analysis of length data for the five most abundant species indicates that, when statistically significant trends were present, each species exhibited a very slow, steady increase in shell length over the 15-year period. Overall, this data set also appears to include considerably less variation than is present in the abundance data collected during these surveys.

Summary and Conclusions

This study has examined the native mussel resources in the Tennessee River near WBN during the second year the plant was operating (1997) following the same techniques used in 1996 and

during the preoperational monitoring period. In 1997, the three mussel beds involved in this survey program (TRM 520-521, TRM 526-527, and TRM 528-529) yielded 697 live mussels, representing 14 native species. In the way of a short-term comparison, approximately 20 percent more mussels were found on these beds during the 1996 survey (846 animals), and three more species were found on these beds in 1996 than in 1997. Substantially more live mussels were found on the downstream and middle beds in 1996 than in 1997 (35 and 34 percent, respectively, more than in 1997), but only slightly more (8 percent) live mussels than were found on the upstream bed in 1996 than in 1997.

One part of the long-term evaluation of this 14-survey, 15-year monitoring program was the analysis of the mussel abundance data. Over the years, 30 native mussel species have been encountered on these three mussel beds. Twelve of these species have been found on all of the surveys, and six more have been found on at least half of them. Five of the 12 rarely-encountered species have not been found on these beds since 1985 or 1983. Relative abundance ranks of the 12 most abundant species have changed very little over the 15-year monitoring period.

Statistical analysis of the mussel abundance data indicates that the three most common species and, probably because of the dominance of those species, the all-species totals demonstrated statistically significant declines in abundance over the years on the downstream bed (TRM 520-521). In contrast to this, only the third most abundant species (*Quadrula pustulosa*) showed a similar statistically significant decline on the middle bed (TRM 526-527), and none of the five showed a statistically significant decline on the upstream bed (TRM 528-529). Where the

statistically significant declines did occur, the data indicate those declines were gradual throughout the 15 year period, with no sharp breaks that might indicate a response to some specific adverse impact.

An analysis of length data for the five most abundant species demonstrated some very slow, steady increases in shell lengths throughout the survey period. The length data also indicated that virtually all of the animals are relatively large for each species.

In general, these results and analyses indicate that individual mussels in the Tennessee River near WBN are continuing to grow slowly, but some species are disappearing from the communities and the some more abundant populations are demonstrating statistically significant declines. 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 data also indicate that these population declines are gradual, and have been occurring throughout the 15-year monitoring period. There is no indication that operation of WBN during the last two years has had any effect on mussel resources in the river.

4.0 INSTREAM WATER QUALITY MONITORING

4.1 Water Quality Analysis

Introduction

Preoperational instream water quality monitoring data collected during the period 1982-1991 were compared to 1996 and 1997 operational monitoring data to determine if any significant changes have occurred to the nonradiological water quality of Watts Bar Tailwater since WBN became operational. Data obtained prior to 1982 were not included in the comparative analysis because improvements in the analytical detection limits since then could bias results.

Materials and Methods

Water samples for chemical analysis were collected monthly from April to September during 1996 and 1997 at four locations in the vicinity of WBN. The locations sampled correspond to the preoperational sampling locations at TRMs 529.9 (Watts Bar Forebay), 529.5 (upstream of WBN), 527.4, and 518.0 (downstream of WBN) (Figure 4-1).

Samples were collected during May, June, and July of 1996 and 1997 and analyzed for 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 were also collected during April, May, June, and July of 1996 and 1997 for chlorophyll-a analysis. Samples for pH, turbidity, and total solids were collected at a depth of 1 meter. All other samples were collected from multiple depths down to 5 meters at each location and the data averaged for analysis purposes. During April, August, and September 1996 and 1997, one mid-depth grab sample was collected from the four stations for

metals analysis, including: calcium, magnesium, arsenic, boron, cadmium, chromium, copper, iron, lead, nickel, zinc, aluminum, selenium, mercury, and hardness.

Results and Discussion

In Tables 4-1 and 4-2, average values are presented for the preoperational and operational nonmetals data for each of the four sampling locations. All monthly values for preoperational and operational data were averaged for analysis. The individual concentrations measured for each parameter during preoperational and operational monitoring were also plotted for each sampling location over time (see Appendices B1 through B4). The plots of the preoperational nonmetals data exhibit high variability for all parameters at all locations. The operational (nonmetals) data tended to be less variable than the preoperational data. Dissolved phosphorous and chlorophyll-a were exceptions by being highly variable, which could be an artifact of the sample size. The reason for the difference in the preoperational and operational variability is not known, but the limited number of operational data points is probably a major factor. The significant observation regarding the data plots is that the range of operational data points fall well within the range of the preoperational data.

A statistical comparative analysis of the preoperational and operational nonmetals water quality data was performed using the Analysis of Variance (ANOVA) with Duncan's Multiple Range Test. The results of these analyses are shown in Tables 4-3, 4-4, and 4-5. In Table 4-3, the 1996 data are compared to the preoperational data; Table 4-4 compares the 1997 data, and Table 4-5 compares the combined 1996-1997 data to the preoperational data. The analysis indicates that, for most parameters, no significant differences (α=0.05) exist between preoperational and

operational data. The only constituent with a consistent significant difference is chlorophyll-a, which shows an increase 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 Appendices B5 through B7. 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 metals 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 4-6 and 4-7.

Although operational data sample size limits the extent of data analysis, it is apparent that during the first two years of operation, 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 in 1996, and 1911 and 120,000 in 1997. Larval shad represented 91% of the sample in 1996 and 85% in 1997. 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 two samples.

Comparison of catch per electrofishing run (CPUE) during 1990-1995 preoperational and 1996-1997 operational monitoring also showed minimal variation (76 and 53 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 an average score of 45 in 1996-1997. A gradual decline in RFAI values occurred from 1993-1996. Since this decline began prior to WBN becoming operational, and as a result of the 1997 RFAI rebounding to a score of 52, 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 two years of operation.

Fish impingement on the WBN cooling water intake traveling screens was virtually nonexistent. A total of 203 fish was estimated to be impinged during the first two years of operation.

Impingement at WBN has obviously not affected the fish community in Chickamauga Reservoir. This monitoring activity was suspended October 7, 1997 by the Tennessee Department of Environment and Conservation, Division of Water Pollution Control.

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 24 years. A total of 392,807 fishing hours and 88,151 angler trips were estimated during the first two years of WBN operation. Catfish, sauger, white bass, crappie, sunfish, striped bass/Cherokee bass, and black bass were the most sought after species by anglers. An estimate of 341,106 fish were caught and an estimated 165,128 fish were harvested from April 1996-April 1998. Peak angling effort (hours) and trips occurred both in April 1996 with 30,218 and 9,717, respectively. Angling trips ranged from 9,717 in April 1996 to 1,456 trips in November 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 taxa collected in Watts Bar Tailwater has increased from 59 recorded during preoperational monitoring to 104 collected during operational monitoring. The average number of taxa per station during operational monitoring was 29.8 which almost doubled 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 addition to the increased number of taxa found during operational monitoring, zebra mussels were found at each station at an average density of

$28.6/m^2$ in 1996 and $41/m^2$ in 1997. Zebra mussels were most abundant ($72/m^2$) in the fall of 1997 at TRM 528.5 (upstream to the WBN intake channel). Temporal analyses showed that seasonal and yearly changes in abundance and other variables for benthic macroinvertebrate 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. A total of 15,878 live mussels were encountered during the 15-year monitoring program. On each mussel bed, the most abundant species was the elephantear, *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 and changed very little over the 15-year monitoring period. These results indicate the two years of operation of WBN has not impacted the aquatic macroinvertebrate resources 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 could 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 two years of operation of WBN has not impacted the nonradiological water quality in upper Chickamauga Reservoir.

Overall, it was concluded that WBN had no effect on either the aquatic communities or the water quality in upper Chickamauga Reservoir from the first two years of operation.

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Table 2-1. Sample periods, 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 and 1997.

PREOPERATIONAL MONITORING			
Sample period	Date	Number of Samples	Mean Water Temperature (°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 Temperature (°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 Temperature (°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 Temperature (°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 Temperature (°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**	
Sample period	Date	Number of Samples	Mean Water Temperatures (°C)
1997			
1	03/31/97	18	15.0
2	04/14/97	18	17.0
3	04/28/97	18	17.1
4	05/15/97	18	19.5
5	05/27/97	18	20.4
6	06/09/97	18	20.5
7	06/23/97	18	22.4
	Total	**126**	

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 and 1997.

Scientific Name	Common Name
Eggs	
Unidentifiable fish eggs	
Hiodon spp. eggs	Unidentifiable mooneye or goldeye 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
Notropis volucellus	Mimic shiner
Catostomidae	
Unspecifiable catostomids	Unspecified suckers
Ictiobinae	Unspecified Ictiobines**
Minytrema melanops	Spotted sucker
Ictaluridae	
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 sp.	Unspecifies bass
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 1976-1982 1985 and 1996-1997 in the vicinity of Watts Bar Nuclear Plant.

	1976		1977		1978		1979		1982	
Taxon	**Total Collected**	**% Comp**	**Total Collected**	**% Comp**	**Total Collected**	**% Comp**	**Total Collected**	**% Comp**	**Total Collected**	**% Comp**
EGGS										
Unidentifiable fish eggs	5	2.00%	40	23.39%	722	81.67%	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	18.33%	67	94.37%	184	95.83%
Total	250		171		884		71		192	
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	0.00%	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	0.00%	0	0.00%	0	0.00%	0	0.00%
Notropis sp.	0	0.00%	1	0.00%	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	0.00%	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 or 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	0.00%	0	0.00%	0	0.00%	0	0.00%
Percidae										
Unidentifiable darter	0	0.00%	4	0.01%	5	0.14%	1	0.04%	4	0.12%
Perca flavescens	0	0.00%	0	0.00%	5	0.14%	0	0.00%	3	0.09%
Stizostedion sp.	1	0.01%	5	0.01%		0.00%		0.00%		0.00%
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		34086		3697		2565		3240	

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

Table 2-3. (Continuted)

Taxon	1983		1984		1985		1996		1997	
	Total Collected	% Comp	Total Collected	% Comp	Total Collected	% Comp	Total Collected	% Comp	Total Collected	% Comp
EGGS										
Unidentifiable fish eggs	1143	87.12%	26	27.66%	16	51.61%	2908	99.28%	1591	99.13%
*Hiodon spp.*eggs	0	0.00%	0	0.00%	1	3.23%	0	0.00%	0	0.00%
Aplodinotus grunniens eggs	169	12.88%	68	72.34%	14	45.16%	21	0.72%	14	0.87%
Total	1312		94		31		2929		1605	
LARVAE										
Unidentified fish	38	0.49%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Clupeidae										
Unspecifiable clupeids	5658	73.01%	22435	93.33%	5890	68.63%	4132	83.88%	8083	82.07%
Alosa chrysochloris	0	0.00%	0	0.00%	0	0.00%	0	0.00%	8	0.08%
Dorosoma sp.	0	0.00%	1	0.00%	0	0.00%	0	0.00%	0	0.00%
Dorosoma cepedianum	1	0.01%	114	0.47%	0	0.00%	74	1.50%	1	0.01%
Dorosoma petenense	2	0.03%	0	0.00%	8	0.09%	50	1.02%	2	0.02%
Hiodontidae										
Hiodon tergisus	0	0.00%	7	0.03%	0	0.00%	0	0.00%	0	0.00%
Cyprinidae										
Unspecifiable cyprinids	110	1.42%	1	0.00%	9	0.10%	2	0.04%	6	0.06%
Cyprinus carpio	15	0.19%	7	0.03%	0	0.00%	2	0.04%	2	0.02%
*Macrhybopsis storeriana***	0	0.00%	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%	0	0.00%
Notropis atherinoides	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Notropis volucellus	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.02%
Catostomidae										
Unspecifiable catostomids	0	0.00%	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%	0	0.00%
Minytrema melanops	0	0.00%	0	0.00%	0	0.00%	3	0.06%	0	0.00%
Ictaluridae										
Ictalurus furcatus	0	0.00%	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%	0	0.00%
Pylodictis olivaris	0	0.00%	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%	820	8.33%
Morone chrysops	0	0.00%	0	0.00%	0	0.00%	5	0.10%	2	0.02%
Morone mississippiensis	0	0.00%	0	0.00%	0	0.00%	16	0.32%	6	0.06%
Morone (not *saxatilis*)	244	3.15%	283	1.18%	29	0.34%	161	3.27%	382	3.88%
Centrarchidae										
Lepomis or Pomoxis	20	0.26%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Lepomis sp.	309	3.99%	247	1.03%	2427	28.28%	95	1.93%	130	1.32%
Micropterus sp.	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.03%
Micropterus dolomieu	0	0.00%	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%	125	1.27%
Pomoxis annularis	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Percidae										
Unidentifiable darter	4	0.05%	0	0.00%	0	0.00%	5	0.10%	8	0.08%
Perca flavescens	12	0.15%	9	0.04%	9	0.10%	6	0.12%	0	0.00%
Stizostedion sp.	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.02%
Stizostedion canadense	0	0.00%	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	6.58%	267	2.71%
Atherinidae										
Labidesthes sicculus	0	0.00%	0	0.00%	1	0.01%	0	0.00%	0	0.00%
Total	7750		24039		8582		4926		9849	

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

Table 2-4. Species list, total number collected, percent composition and occurrence spans of fish eggs and larvae collected during operational monitoring at Watts Bar Nuclear Plant, 1996 and 1997.

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	100						
FISH LARVAE								
Clupeidae	4132	83.88			x	x	x	x
Dorosoma cepedianum	74	1.50					x	x
Dorosoma petenense	50	1.02					x	x
Cyprinidae	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 flavescens	6	0.12		x	x			
Aplodinotus grunniens	324	6.58				x	x	x
TOTAL	4926	100						

1997									
TAXON	TOTAL COLLECTED	PERCENT COMPOSITION	SAMPLING PERIODS						
FISH EGGS			1	2	3	4	5	6	7
Unidentifiable fish eggs	1591	99.13	x	x	x	x			x
Aplodinotus grunniens eggs	14	0.87					x		x
Total	1605	100							
FISH LARVAE									
Clupeidae	8083	82.07	x	x	x	x	x	x	x
Alosa chrysochloris	8	0.08					x	x	
Dorosoma cepedianum	1	0.01							x
Dorosoma petenense	2	0.02						x	x
Cyprinidae	6	0.06						x	x
Cyprinus carpio	2	0.02						x	
Notropis volucellus	2	0.02		x	x				
Morone sp.	820	8.33		x	x	x	x	x	x
Morone chrysops	2	0.02				x	x		
Morone mississippiensis	6	0.06					x	x	x
Morone (not saxatilis)	382	3.88	x	x	x	x		x	
Lepomis sp.	130	1.32					x	x	x
Micropterus sp.	3	0.03					x		x
Pomoxis sp.	125	1.27			x	x	x	x	x
Percidae (not stizostedion)	8	0.08	x	x	x				
Stizostedion sp.	2	0.02	x						
Aplodinotus grunniens	267	2.71				x	x	x	x
TOTAL	9849	100							

Table 2-5. 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.

	PREOPERATIONAL								OPERATIONAL	
	1976	**1977**	**1978**	**1979**	**1982**	**1983**	**1984**	**1985**	**1996**	**1997**
Average Density	444	1,960	358	146	365	835	2,119	347	525	924
Mean Water Temperature (°C)	19.1	19.3	18.3	17.7	19.0	17.3	23.9	18.5	18.4	22.4
Peak Density	1,334	4,559	624	522	731	3,011	10,485	1,007	1387	1699
Date of Peak Density	5/19	4/26	6/6	7/2	6/7	6/14	5/29	6/4	6/3	5/15

Table 2-6. Distribution of larval fishes by size group (mm) collected at Watts Bar Nuclear Plant, during 1996 and 1997.

1996	Size Group (mm)															
TAXON	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16-19**	**20-30**	**>30**
Clupeidae		10	172	345	365	496	561	527	460	367	253	119	111	346		
Dorosoma cepedianum															73	1
Dorosoma petenense															50	
Cyprinidae			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 2-6 (Continued)

1997	Size Group (mm)																
TAXON	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16-19**	**20-30**	**>30**
Clupeidae			6	247	1014	1104	1575	1663	1205	597	300	123	79	52	45		
Alosa chrysochloris																8	
Dorosoma cepedianum																1	
Dorosoma petenense																2	
Cyprinidae					2	3					1						
Cyprinus carpio							1										
Notropis volucellus																	2
Morone sp.				2	349	245	115	42	20	34	8	2		1			
Morone chrysops											1	1					
Morone mississippienis												5				1	
Morone (not saxatilis)		133	57	169													
Lepomis sp.			1	55	55	15	1	1									
Micropterus sp.					2	1											
Pomoxis sp.	2			65	40	8	5	3	2								
Unidentified Darter							1	2		3	1	1					
Stizostedion sp.						2											
Aplodinotus grunniens			2	176	81	4	4	2									

NOTE: These numbers represent expanded subsample measurements

Table 2-7. Estimated entrainment results of fish eggs and larvae during 1996 and 1997 at Watts Bar Nuclear Plant including intake and reservoir flow, number of days sampled, average densities, and total numbers and percent entrained and transported past WBN.

1996-Eggs									
			Intake			Reservoir			
Date	Sample Period	Density 1000/m3	Water Demand m3/d	Estimated Number Entrained	Density 1000/m3	River Flow m3/d	Estimated Number Transported		Percent Entrained
		D_i	Q_i		D_r	Q_r			
April 8	1	17.1	1.27E+05	2.18E+03	382.2	2.04E+07	7.80E+06		0.03%
Aprill 22	2	108.9	7.10E+04	7.73E+03	1527.5	6.29E+07	9.61E+07		0.01%
May 6	3	58.8	1.62E+05	9.54E+03	25.7	2.41E+07	6.17E+05		1.55%
May 20	4	0.0	1.54E+05	0.00E+00	83.6	4.36E+07	3.64E+06		T
June 3	5	8.8	1.17E+05	1.03E+03	9.5	8.20E+07	7.80E+05		0.13%
June 17	6	0.0	2.26E+05	0.00E+00	7.0	6.94E+07	4.84E+05		0.00%
			Total:	2.05E+04		**Total:**	1.09E+08		0.29%

1996-Larvae									
			Intake			Reservoir			
Date	Sample Period	Density 1000/m3	Water Demand m3/d	Estimated Number Entrained	Density 1000/m3	River Flow m3/d	Estimated Number Transported		Percent Entrained
		D_i	Q_i		D_r	Q_r			
April 8	1	0.0	1.27E+05	0.00E+00	1.4	2.04E+07	2.93E+04		T
Aprill 22	2	0.0	7.10E+04	0.00E+00	22.1	6.29E+07	1.39E+06		T
May 6	3	294.1	1.62E+05	4.77E+04	426.2	2.41E+07	1.03E+07		0.47%
May 20	4	1348.2	1.54E+05	2.08E+05	594.2	4.36E+07	2.59E+07		0.80%
June 3	5	5575.2	1.17E+05	6.51E+05	1065.3	8.20E+07	8.73E+07		0.75%
June 17	6	2354.0	2.26E+05	5.32E+05	550.6	6.94E+07	3.82E+07		1.39%
			Total:	1.44E+06		**Total:**	1.63E+08		0.57%

1997-Eggs									
			Intake			Reservoir			
Date	Sample Period	Density 1000/m3	Water Demand m3/d	Estimated Number Entrained	Density 1000/m3	River Flow m3/d	Estimated Number Transported		Percent Entrained
		D_i	Q_i		D_r	Q_r			
March 21	1	177.0	1.03E+05	1.82E+04	1069.8	1.09E+08	1.17E+08		0.02%
April 14	2	0.0	1.24E+05	0.00E+00	16.0	2.38E+07	3.80E+05		T
April 28	3	0.0	1.01E+05	0.00E+00	10.5	5.43E+07	5.72E+05		T
May 15	4	0.0	1.04E+05	0.00E+00	0.7	4.96E+07	3.35E+04		T
May 27	5	0.0	1.10E+05	0.00E+00	2.7	4.63E+07	1.25E+05		T
June 9	6	0.0	1.19E+05	0.00E+00	0.0	7.49E+07	0.00E+00		T%
June 23	7	9.1	1.23E+05	1.12E+03	18.1	9.99E+07	1.81E+06		0.06%
			Total:	1.94E+04		**Total:**	1.20E+08		0.02%

1997-Larvae									
			Intake			Reservoir			
Date	Sample Period	Density 1000/m3	Water Demand m3/d	Estimated Number Entrained	Density 1000/m3	River Flow m3/d	Estimated Number Transported		Percent Entrained
		D_i	Q_i		D_r	Q_r			
March 21	1	35.4	1.03E+05	3.65E+03	52.1	1.09E+08	5.70E+06		0.06%
April 14	2	232.1	1.24E+05	2.89E+04	318.5	2.38E+07	7.59E+06		0.38%
April 28	3	427.4	1.01E+05	4.30E+04	1115.3	5.43E+07	6.05E+07		0.07%
May 15	4	1822.0	1.04E+05	1.89E+05	1688.9	4.96E+07	8.37E+07		0.23%
May 27	5	625.0	1.10E+05	6.88E+04	550.0	4.63E+07	2.55E+07		0.27%
June 9	6	2260.4	1.19E+05	2.70E+05	1032.2	7.49E+07	7.74E+07		0.35%
June 23	7	2645.5	1.23E+05	3.25E+05	1600.0	9.99E+07	1.60E+08		0.20%
			Total:	9.29E+05		**Total:**	4.20E+08		0.22%

T=less than 0.01 percent composition

Table 2-8. Percent composition of dominant larval fish taxa collected in the cooling water intake channel at the Watts Bar Nuclear Plant Site, 1984 through 1985, and 1996 through 1997.

	Preoperational		Operational	
TAXON	Year	Percent Composition	Year	Percent Composition
A. grunniens	1984	0.1	1996	0.8
	1985	0.2	1997	0.3
Centrachidae	1984	0.9	1996	7.6
	1985	12.5	1997	8.1
Clupeidae	1984	97.8	1996	90.5
	1985	86.4	1997	83.7
Dorosoma sp.	1984	0.09	1996	0.8
	1985	--------	1997	0.2
Morone (not saxatilis)	1984	0.6	1996	0.1
	1985	0.5	1997	1.0
Morone sp.	1984	0.5	1996	0.1
	1985	0.5	1997	5.4

Table 2-9. Comparison of percent composition of the catch from preoperational (1977-1985 and 1990-1995) and operational (1996-1997) monitoring periods.

Common Name	1977-1985 Preoperational	1990-1995 Preoperational	1996-1997 Operational
Chestnut lamprey			0.1%
Spotted gar	0.1%	--	--
Longnose gar	0.5%	0.0%	0.1%
Mooneye	0.2%	--	0.1%
American eel	0.0%	--	--
Skipjack herring	1.5%	0.7%	--
Gizzard shad	*	*	*
Threadfin shad	*	*	*
Spotfin shiner	0.1%	1.8%	0.4%
Steelcolor shiner	--	2.5%	--
Common carp	1.2%	1.0%	3.8%
Striped shiner	--	0.0%	--
Silver chub	0.0%	--	--
Golden shiner	0.2%	0.4%	0.1%
Emerald shiner	58.6%	17.1%	1.5%
Bluntnose minnow	--	0.1%	0.1%
Bullhead minnow	0.0%	0.1%	--
River carpsucker	0.0%	--	--
Northern hogsucker	0.1%	0.1%	0.1%
Smallmouth buffalo	0.0%	0.1%	--
Spotted sucker	1.2%	1.3%	2.0%
River redhorse	0.0%	--	0.1%
Black redhorse	--	0.2%	0.3%
Golden redhorse	0.5%	0.5%	1.2%
Blue catfish	0.0%	0.1%	--
Channel catfish	0.0%	1.6%	0.6%
Flathead catfish	0.0%	0.6%	0.9%
Brook silversides	5.4%	1.1%	--
White bass	1.3%	1.7%	1.8%
Yellow bass	4.1%	4.3%	8.5%
Striped bass	0.1%	0.2%	0.2%
Rock bass	0.0%	--	--
Redbreast sunfish	0.9%	1.3%	0.4%
Green sunfish	0.0%	0.4%	0.3%
Warmouth	0.1%	0.7%	0.2%
Bluegill	10.0%	32.4%	45.1%
Longear sunfish	0.2%	0.1%	0.3%
Redear sunfish	7.2%	13.4%	12.5%
Hybrid sunfish	--	0.0%	0.2%
Smallmouth bass	0.3%	1.8%	3.5%
Spotted bass	1.0%	3.1%	3.2%
Largemouth bass	3.4%	7.8%	6.9%
White crappie	0.8%	0.2%	0.4%
Black crappie	0.0%	0.8%	1.8%
Yellow perch	0.4%	0.4%	0.6%
Logperch	0.1%	1.5%	1.3%
Sauger	0.1%	0.1%	0.4%
Walleye	0.0%	--	--
Freshwater drum	0.2%	0.6%	1.0%

* Numbers not included.

Table 2-10. Comparison by species of average catch per electrofishing run (CPUE) and percent composition of the catch from vital signs preoperational (1990-1995) and operational (1996-1997) results.

	1990-1995 Preoperational		1996-1997 Operational	
Common Name	Average CPUE	Percentage of CPUE	CPUE	Percentage of CPUE
Chestnut lamprey	--	--	0.03	0.06%
Longnose gar	0.03	0.04%	0.07	0.13%
Mooneye	--	--	0.07	0.13%
Skipjack herring	0.51	0.67%	--	--
Gizzard shad	*		*	
Threadfin shad	*		*	
Spotfin shiner	1.41	1.85%	0.23	0.44%
Steelcolor shiner	1.91	2.51%	--	--
Common carp	0.76	1.00%	2.00	3.82%
Striped shiner	0.03	0.04%	--	--
Golden shiner	0.28	0.37%	0.07	0.13%
Emerald shiner	13.03	17.13%	0.80	1.53%
Bluntnose minnow	0.04	0.05%	0.07	0.13%
Bullhead minnow	0.04	0.05%	--	--
Northern hogsucker	0.07	0.09%	0.07	0.13%
Smallmouth buffalo	0.07	0.09%	--	--
Spotted sucker	0.97	1.27%	1.03	1.97%
River redhorse	--	--	0.03	0.06%
Black redhorse	0.18	0.24%	0.17	0.32%
Golden redhorse	0.41	0.54%	0.63	1.20%
Blue catfish	0.05	0.07%	--	--
Channel catfish	1.19	1.56%	0.30	0.57%
Flathead catfish	0.49	0.64%	0.47	0.90%
Brook silverside	0.82	1.08%	--	--
White bass	1.26	1.66%	0.93	1.78%
Yellow bass	3.26	4.28%	4.47	8.54%
Striped bass	0.18	0.24%	0.10	0.19%
Redbreast sunfish	0.97	1.27%	0.23	0.44%
Green sunfish	0.30	0.39%	0.13	0.25%
Warmouth	0.50	0.66%	0.10	0.19%
Bluegill	24.68	32.44%	23.60	45.10%
Longear sunfish	0.08	0.11%	0.13	0.25%
Redear sunfish	10.20	13.41%	6.57	12.55%
Hybrid sunfish	0.03	0.04%	0.10	0.19%
Smallmouth bass	1.36	1.79%	1.83	3.50%
Spotted bass	2.35	3.09%	1.67	3.19%
Largemouth bass	5.92	7.78%	3.60	6.88%
White crappie	0.12	0.16%	0.23	0.44%
Black crappie	0.61	0.80%	0.93	1.78%
Yellow perch	0.28	0.37%	0.30	0.57%
Logperch	1.16	1.52%	0.67	1.28%
Sauger	0.11	0.14%	0.20	0.38%
Freshwater drum	0.42	0.55%	0.53	1.01%
Total	**76**	**100%**	**52**	**100%**
Average RFAI score	**44**		**45**	

* Densities not included.

Table 2-11. Summary of one-way univariate ANOVA testing of effects of 1990-1995 preoperational compared to 1996-1997 operational monitoring results and interactions of these for variables on CPUE of each important species collected by electrofishing near Watts Bar Nuclear Plant.

Species	P-Value	Preoperational CPUE 1990-1995	Operational CPUE 1996-1997
Largemouth Bass	0.0711	5.9	3.6
Redear Sunfish	0.1183	10.2	6.6
Emerald Shiner	0.2441	13.0	0.8
Brook Silversides	0.3676	0.8	0
Bluegill	0.5120	24.7	23.6
Spotted Sucker	0.6556	1.3	1
Spotted Bass	0.7367	2.4	1.7
White Bass	0.7498	1.3	0.9
Common Carp	0.8137	0.8	2
Logperch	0.8761	1.2	0.7
Smallmouth Bass	0.9359	1.4	1.8
Yellow Bass	0.9379	3.3	4.5

Table 2-12. Actual and estimated numbers of fish impinged at Watts Bar Nuclear Plant during two sample periods, March 1996 through March 1997 and March 1997 through September 30, 1997.

Common Name	Total Number of Fish Impinged		Estimated Number of Fish Impinged		Percentage Composition	
	Sample Period		Sample Period		Sample Period	
	1	2	1	2	1	2
Gizzard shad	4	0	40.6	0	25.0	0
Threadfin shad	2	0	20.3	0	12.5	0
Freshwater drum	3	3	30.4	30.6	18.7	75.0
Channel catfish	1	0	10.1	0	6.3	0
Flathead catfish	1	0	10.1	0	6.3	0
Bluegill	2	0	20.3	0	12.5	0
Redear sunfish	1	0	10.1	0	6.2	0
White crappie	2	0	20.3	0	12.5	0
Log Perch	0	1	0	10.2	0	25.0
Total	**16**	**4**	**162.2**	**40.8**	**100.3**	**100.0**

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
Bank @ Lock	30	Bank
Bank @ Power Plant	40	Bank
TVA Ramp	20	Boat/Bank
Unimproved Ramp	5	Bank
TWRA Sewee Creek Ramp	10	Boat/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 April 1998.

Month	Number of Days Surveyed	Number of Interviews
1996		
April	14	152
May	15	208
June	13	168
July	14	144
August	12	120
September	12	115
October	12	128
November	13	128
December	8	80
1997		
January	16	182
February	16	211
March	16	228
April	12	143
May	15	172
June	14	188
July	10	111
August	14	145
September	12	98
October	15	118
November	12	64
December	9	57
1998		
January	13	148
February	11	146
March	14	157
April	13	144

Table 2-16. Directed species effort for bank and boat fishermen during the Watts Bar Tailwater creel survey, April 1996 through April 1998.

Directed Species Group	Percent Participation		
	Bank	Boat	Overall
Any Species	40	25	35
Black Bass	1	10	4
Catfish	13	27	18
Crappie	7	4	6
Sauger	11	13	11
Striped Bass/Cherokee Bass	9	6	8
Sunfish	9	4	7
White Bass	10	11	11

Table 2-17. Number of interviews and percent angler use at six access points within the Watts Bar Tailwater survey, April 1996 through April 1998.

Access Point	Number of Interviews	Percent Participation
Bank Anglers		
Bank@Lock	1315	52
Bank@Power Plant	1051	43
TVA Ramp	49	2
TWRA Sewee Creek Ramp	39	2
Eaves Ferry Ramp	13	1
Boat Anglers		
TVA Ramp	1047	96
Unimproved Ramp	2	< 1
TWRA Sewee Creek Ramp	10	1
Eaves Ferry Ramp	29	3

Table 2-18. Monthly estimated effort, percent effort, and estimated number of angling trips for the Watts Bar Tailwater survey, April 1996 through April 1998.

Month	Estimated Effort (hrs)	Standard Error	Percent Effort	Estimated Trips	Standard Error
1996					
April	30,218	1,362	8	9,717	438
May	20,526	826	5	4,970	200
June	24,157	694	6	6,178	178
July	21,758	687	6	5,193	164
August	15,190	700	4	3,714	171
September	10,002	357	3	2,037	73
October	16,951	409	4	3,229	78
November	11,884	569	3	2,285	109
December	15,641	795	4	3,724	189
1997					
January	12,204	660	3	2,885	156
February	16,365	610	4	2,976	111
March	20,781	921	5	3,906	173
April	19,988	749	5	3,417	128
May	17,014	626	4	3,389	125
June	24,481	674	6	5,165	142
July	15,456	285	4	3,816	70
August	9,333	230	2	2,333	57
September	11,052	341	3	2,303	71
October	10,814	338	3	1,975	62
November	7,395	127	2	1,456	25
December	8,718	273	2	1,851	58
1998					
January	9,636	120	2	2,190	27
February	9,894	466	3	2,401	113
March	14,542	699	4	3,438	165
April	18,780	621	5	3,603	113

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 April 1998.

Directed Species Group	Percent Effort	Estimated Effort (hrs)	Estimated Trips	Mean Length of Trip (hrs)	Standar d Error	Number of Trips Creeled
Any Species	33	129,313	29,116	4.5	0.1	1251
Black Bass	5	20,024	4,451	5.1	0.2	140
Catfish	23	89,707	20,409	4.8	0.1	618
Crappie	4	15,789	3,679	3.7	0.3	224
Sauger	10	40,670	9,163	4.6	0.2	406
Striped Bass/Cherokee Bass	8	31,363	6,550	4.5	0.3	279
Sunfish	6	23,467	5,085	4.4	0.3	262
White Bass	11	42,473	9,695	4.8	0.2	375

Table 2-20. Mean catch and harvest rate with standard errors, and percent harvested for directed species group anglers in the Watts Bar Tailwater fishery, April 1996 through April 1998.

Species	Mean Catch Rate (No/hr)	Standard Error	Mean Harvest Rate (No/hr)	Standard Error	Percent Harvested
Largemouth Bass	0.56	0.06	0.08	0.03	15
Smallmouth Bass	0.26	0.05	0.02	0.01	9
Spotted Bass	0.18	0.04	0.03	0.01	14
Blue Catfish	0.55	0.06	0.36	0.07	67
Channel Catfish	0.43	0.10	0.34	0.09	79
Black Crappie	0.51	0.13	0.31	0.07	61
White Crappie	1.17	0.26	0.68	0.15	58
Sauger	0.88	0.14	0.15	0.03	18
Striped Bass	0.18	0.02	0.08	0.02	42
Bluegill	4.98	0.63	2.34	0.29	47
White Bass	1.60	0.21	0.80	0.14	50
Yellow Bass	0.56	0.16	0.25	0.11	45

Table 2-21. Estimated number of fish caught and harvested with standard errors for directed species group anglers in the Watts Bar Tailwater fishery, April 1996 through April 1998.

Species	Estimated Number Caught	Standard Error	Estimated Number Harvested	Standard Error
Largemouth Bass	9,072	6,628	1,236	1,959
Smallmouth Bass	1,684	550	198	306
Spotted Bass	1,726	1,653	290	436
Blue Catfish	46,650	46,558	26,622	23,953
Channel Catfish	26,831	19,522	18,349	13,219
Black Crappie	5,522	6,141	3,917	4,863
White Crappie	11,141	8,962	6,758	5,898
Sauger	33,390	51,382	7,426	11,511
Striped Bass	3,104	2,136	1,543	1,482
Bluegill	123,391	128,857	56,832	59,715
White Bass	67,976	79,450	38,046	51,109
Yellow Bass	10,619	10,798	3,911	5,538

Table 2-22. Mean catch and harvest rate with standard errors, and percent harvested for any species anglers in the Watts Bar Tailwater fishery, April 1996 through April 1998.

Species	Mean Catch Rate (No./hr)	Standard Error	Mean Harvest Rate (No./hr)	Standard Error	Percent Harvested
Largemouth Bass	0.02	< 0.01	< 0.01	< 0.01	21
Smallmouth Bass	0.02	< 0.01	< 0.01	< 0.01	15
Blue Catfish	0.04	0.01	0.02	< 0.01	47
Channel Catfish	0.02	< 0.01	0.01	< 0.01	36
Black Crappie	0.03	< 0.01	0.02	< 0.01	61
White Crappie	0.04	0.01	0.02	< 0.01	46
Sauger	0.05	0.01	0.01	< 0.01	16
Bluegill	0.16	0.04	0.06	0.02	39
White Bass	0.12	0.02	0.04	0.01	34
Yellow Bass	0.11	0.02	0.03	0.01	25

Table 2-23. Estimated number of fish caught and harvested with standard errors for any species anglers in the Watts Bar Tailwater fishery, April 1996 through April 1998.

Species	Estimated Number Caught	Standard Error	Estimated Number Harvested	Standard Error
Largemouth Bass	2,564	1,155	554	466
Smallmouth Bass	3,017	3,038	460	464
Blue Catfish	4,175	2,554	1,942	1,721
Channel Catfish	2,666	1,161	979	659
Black Crappie	4,189	2,795	2,467	2,000
White Crappie	4,772	3,287	2,365	2,333
Sauger	7,942	6.250	1,075	1,353
Bluegill	17,373	13,474	6,670	6,214
White Bass	15,814	12,771	5,893	7,755
Yellow Bass	15,540	19,741	4,604	9,372

Table 2-24. Estimated number of fish caught and harvested with standard errors by all anglers in the Watts Bar Tailwater fishery, April 1996 through April 1998.

Species	Estimated Number Caught	Standard Error	Estimated Number Harvested	Standard Error
Largemouth Bass	11,635	6,728	1,790	2,014
Smallmouth Bass	4,701	3,087	657	556
Spotted Bass	1,726	1,653	290	435
Blue Catfish	50,825	46,628	28,564	24,015
Channel Catfish	29,496	19,557	19,328	13,236
Black Crappie	9,710	6,748	6,383	5,258
White Crappie	15,914	9,546	9,122	5,343
Sauger	41,331	51,762	8,501	11,591
Striped Bass	3,104	2,136	1,542	1,482
Bluegill	140,764	42,918	63,502	60,038
White Bass	83,791	79,450	43,938	51,695
Yellow Bass	26,158	22,501	8,515	10,869

Table 2-25. A comparison of harvest rates from preoperational and operational creel surveys conducted in the Watts Bar Tailwater.

Species	Operational 1982-1985		Preoperational 1996-1998
	Harvest Rate	Standard Error	Harvest Rate
Largemouth Bass	0.08	0.03	0.03
Smallmouth Bass	0.02	0.01	0.01
Spotted Bass	0.03	0.01	< 0.01
Blue Catfish	0.36	0.05	0.04
Channel Catfish	0.34	0.09	0.08
Black Crappie	0.36	0.05	< 0.01
White Crappie	0.68	0.15	0.11
Sauger	0.15	0.03	0.11
Striped Bass	0.08	0.02	-
Bluegill	2.34	0.29	0.34
White Bass	0.80	0.14	0.10
Yellow Bass	0.25	0.11	0.06

Table 3-1. Benthic macroinvertebrate taxa collected during preoperational (1973 through 1985) and operational (1996 and 1997) monitoring at Watts Bar Nuclear Plant.

	Preoperational	Operational
Nematoda		X
Coelenterata		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 sp.		X
Nais communis		X
Nais simplex		X
Pristina sp.		X
Pristina leidyi		
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 sp.		X
Helobdella triserialis		X
Pharyngobdellida		
Erpobdellidae	X	
Erpobdella sp.		X
Erpobdella punctata		X

Table 3-1 (Continued)

	Preoperational	Operational
Crustacea		
Isopoda		
Asellidae		
Caecidotea sp.	X	X
Lirceus sp.	X	
Amphipoda		
Crangonyctidae		
Crangonyx sp.	X	
Gammaridae		
Gammarus sp.	X	
Gammarus minus		X
Decapoda		
Cambaridae		
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	
Corduliidae		
Neurocordlia molesta		X
Gomphidae		
Dromogomphus sp.	X	
Gomphus sp.	X	
Ephemeroptera		
Baetidae		X
Baetis amplus		X
Caenidae		

Table 3-1 (Continued)

	Preoperational	Operational
Caenis sp.	X	
Ephemeridae		
Hexagenia sp.	X	
Heptageniidae		X
Stenacron sp.	X	X
Stenacron interpunctatum		X
Stenonema sp.		X
Leptophlebiidae		
Paraleptophlebia 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	X
Ablabesmyia annulata		X
Ablabesmyia mallochi		X
Ablabesmyia parajanta		X
Chironomus sp.	X	X
Cladotanytarsus sp.		X

Table 3-1 (Continued)

	Preoperational	Operational
Clinotanypus pinguis		X
Coelotanypus sp.	X	
Coelotanypus tricolor		X
Conchapelopia sp.	X	
Cricotopus bicinctus		X
Cryptochironomus sp.	X	
Cryptochironomus fulvus		X
Dicrotendipes sp.	X	X
Glyptotendipes sp.	X	X
Harnischia sp.		X
Microtendipes sp.		X
Nanocladius sp.		X
Parachironomus sp.	X	X
Paratanytarsus sp.		
Paratendipes sp.		
Phaenopsectra obediens		X
Polypedilum sp.		X
Polypedilum convictum		X
Polypedilum halterale		X
Polypedilum illinoense		
Procladius sp.	X	
Pseudochironomus sp.		X
Rheotanytarsus sp.		X
Stenochironomus sp.		X
Stictochironomus sp.		X
Synorthocladius semivirens		X
Tanytarsus sp.		X
Thienemanniella xena		X
Thienemannimyia sp.		X
Tvetenia discoloripes sp. gp.		X
Coleoptera		
Elmidae		
Dubiraphia sp.		X
Macronychus sp.	X	
Stenelmis sp.		X
Arachnoidea		
Hydrachnellae		
Hydrachnidae	X	
Gastropoda		

Table 3-1. (Continued)

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	
Campeloma decisum		X
Basommatophora		
Ancylidae		
Ferrissia rivularis		X
Physidae		
Physa sp.	X	
Physella sp.		X
Planorbidae		X
Gyraulus sp.	X	
Gyraulus parvus		X
Menetus sp.		X
Micromenetus dilatatus		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	
Lampsilis abrupta		X
Obliquaria reflexa	X	X
Pleurobema cordatum	X	
Pleurobema pyramidatum	X	
Potamilus alatus		X
Quadrula pustulosa pustulosa	X	X

Table 3-1. (Continued)

Veneroida		
Corbiculidae		
Corbicula fluminea	X	X
Dreissenidae		
Dreissena polymorpha		X
Sphaeriidae		X
Musculium transversum		X
Sphaerium sp.	X	
TOTAL	**59**	**104**

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 and 1997 (operational).

		Tennessee River Mile				
Season	Organism	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
1996-1997 (Operational)						
Summer*	Corbicula fluminea	594	725	867	1604	886
	Dugesia tigrina	622	675	1468	1226	855
	Gammarus minus	829	441	1002	1014	1122
	Oligochaeta	285	164	159	60	38
	Hydra americana	153	66	13	48	709
	Total	2636	2157	3596	3978	3612
*90% of Total Benthic Community						
Fall*	Corbicula fluminea	350	318	739	1042	597
	Dugesia tigrina	1294	1085	1118	1189	1678
	Gammarus minus	386	58	126	126	347
	Oligochaeta❖	352	75	54	133	282
	Cyrnellus fraternus	14	39	414	647	409
	Total	2396	1716	2471	3190	3313
*85% of Total Benthic Community						

❖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 and 1997) at Watts Bar Nuclear Plant.

		Tennessee River Mile									
		521.0		526.3		527.4		528.0		528.5	
Year	Quarter	No. taxa	$\overline{d}$	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
1997	**Summer**	28	2.23	32	2.13	28	2.25	35	2.35	29	2.50
	Fall	31	2.27	24	2.02	25	2.19	26	2.26	27	2.29

*Data collected from TRM 528.8 in summer 1983.

Table 3-4. 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 samples during preoperational (1983 through 1985) and operational (1996 through 1997) 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								
1996	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
1997	Summer	4.13	0.0062	528.5	528.0	527.4	521.0	526.3
	Fall	5.9	0.0007	528.5	521.0	528.0	527.4	526.3

*No significant difference.

Table 3-5. 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 and 1997 (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
Summer	1997	3014	2926	4207	5596	6226
Fall	1997	3335	2835	2981	3321	3649

*Collected at TRM 528.8

Table 3-6. Results of the 1997survey of native mussels in three monitored beds near the Watts Bar Nuclear Plant.

Native Mussel Species	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	24	13	51	35	123	45	33	17	14	109	20	66	126	45	257	489	70.16
Pleurobema cordatum	4	4	9	11	28	2	16	0	0	18	3	33	7	12	55	101	14.49
Cyclonaias tuberculata	1	16	9	5	31	1	2	0	0	3	2	7	4	0	13	47	6.74
Quadrula pustulosa	0	5	2	2	9	1	0	2	3	6	1	7	1	0	9	24	3.44
Potamilus alatus	0	0	1	1	2	0	1	4	1	6	4	0	0	0	4	12	1.72
Ellipsaria lineolata	1	0	2	2	5	0	0	0	1	1	1	0	1	0	2	8	1.15
Amblema plicata	0	0	0	0	0	0	0	3	1	4	0	0	1	0	1	5	0.72
Obliquaria reflexa	0	0	0	1	1	0	0	0	2	2	0	0	0	0	0	3	0.43
Leptodea fragilis	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	2	0.29
Quadrula metanevra	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	2	0.29
Anodonta grandis	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0.14
Lampsilis ovata	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0.14
Ligumia recta	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.14
Tritogonia verrucosa	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0.14
Grand Total	30	38	74	57	199	49	53	26	26	154	32	114	141	57	344	697	100.00
Number of Species Collected	4	4	6	7	7	4	5	4	9	12	7	5	7	2	10	14	

Table 3-7. Total numbers of each native mussel species collected during preoperational (1983-1994) and operational (1996-1997) surveys near Watts Bar Nuclear Plant.

	Preoperational												Operational			
	1983	1983 Fall	1984	1984 Fall	1985	1985 Fall	1986	1986 Fall	1988	1990	1992	1994	1996	1997	Totals	Times Found
Elliptio crassidens	754	836	779	984	738	929	734	765	970	524	424	583	594	489	10103	14
Pleurobema cordatum	264	275	220	156	113	177	110	169	224	139	82	95	94	101	2219	14
Cyclonaias tuberculata	88	70	73	62	60	66	55	76	93	90	68	64	38	47	950	14
Quadrula pustulosa	99	75	85	53	53	85	31	41	80	79	48	65	30	24	848	14
Potamilus alatus	14	29	18	29	34	43	41	27	55	45	16	10	35	12	408	14
Ellipsaria lineolata	24	29	24	25	8	27	19	18	23	28	14	11	15	8	273	14
Amblema plicata	18	33	19	11	17	25	23	24	49	10	13	13	11	5	271	14
Anodonta grandis	18	10	5	4	3	7	9	7	29	20	5	7	7	1	132	14
Quadrula metanevra	14	24	11	13	6	10	7	7	8	8	8	4	2	2	124	14
Tritogonia verrucosa	6	12	5	5	4	15	8	13	18	9	9	7	4	1	116	14
Obliquaria reflexa	14	6	8	3	7	5	9	3	7	11	6	11	6	3	99	14
Ligumia recta	6	3	4	10	3	8	8	10	7	2	3	1	2	1	68	14
Lampsilis abrupta	3	7	6	2	1	7	6	2	12	4	6	2	4	-	62	13
Leptodea fragilis	1	3	4	2	3	2	6	3	12	8	-	3	1	2	50	13
Actinonaias ligamentina	3	2	2	-	4	7	-	8	3	5	1	-	-	-	35	9
Megalonaias nervosa	2	1	-	1	1	4	5	1	9	3	4	2	1	-	34	12
Lampsilis ovata	3	1	1	4	5	4	1	2	3	1	-	-	-	1	26	11
Elliptio dilatata	4	2	1	1	-	2	2	1	3	1	-	-	1	-	18	10
Pleurobema oviforme	-	-	2	-	-	1	-	2	2	1	-	1	-	-	9	6
Anodonta imbecillis	-	-	-	2	-	-	-	1	1	1	-	-	-	-	5	4
Cyprogenia stegaria	2	1	-	1	1	-	-	-	-	-	-	-	-	-	5	4
Pleurobema plenum	1	1	2	-	1	-	-	-	-	-	-	-	-	-	5	4
Plethobasus cyphyus	-	2	-	-	-	-	-	-	-	-	1	1	-	-	4	3
Pleurobema rubrum	-	-	-	-	-	3	-	-	1	-	-	-	-	-	4	2
Anodonta suborbiculata	-	-	-	-	-	-	-	-	1	1	-	-	-	-	2	2
Fusconaia subrotunda	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
Lasmigona costata	-	-	-	-	-	-	1	-	-	-	-	-	1	-	2	2
Ptychobranchus fasciolaris	-	-	1	-	-	-	-	-	-	1	-	-	-	-	2	2
Dromus dromas	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Lasmigona complanata	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1
Total Mussels	1341	1422	1270	1368	1063	1427	1075	1180	1610	991	708	880	846	697	15878	
Number of Species Collected	22	21	20	19	20	20	18	20	22	22	16	17	17	14	30	

Table 3-8. Rank order relationships among the 12 mussel species encountered during all 14 surveys of three mussel beds near Watts Bar Nuclear Plant. Most rank order assignments were based on the total number of a species found during each survey; however, alphabetical order of scientific names was used to avoid ties when two or more species were represented by the same number of animals.

	1983	1983 Fall	1984	1984 Fall	1985	1985 Fall	1986	1986 Fall	1988	1990	1992	1994	1996	1997	Mean Rank	Overall Totals
Elliptio crassidens	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1.0	10103
Pleurobema cordatum	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2.0	2219
Cyclonaias tuberculata	4	4	4	3	3	4	3	3	3	3	3	4	3	3	3.4	848
Quadrula pustulosa	3	3	3	4	4	3	4	4	4	4	4	3	5	4	3.7	950
Potamilus alatus	9	7	7	5	5	5	5	5	5	5	5	8	4	5	5.7	124
Ellipsaria lineolata	5	6	5	6	7	6	7	7	8	6	6	6	6	6	6.2	408
Amblema plicata	6	5	6	8	6	7	6	6	6	9	7	5	7	7	6.5	273
Anodonta grandis	7	10	10	11	11	11	8	10	7	7	11	9	8	10	9.3	271
Obliquaria reflexa	8	11	9	12	8	12	9	12	12	8	10	7	9	8	9.6	132
Quadrula metanevra	10	8	8	7	9	9	12	11	10	11	9	11	12	9	9.7	116
Tritogonia verrucosa	12	9	11	10	10	8	11	8	9	10	8	10	10	12	9.9	68
Ligumia recta	11	12	12	9	12	10	10	9	11	12	12	12	11	11	11.0	99

Table 3-9. Numbers of all native mussel species and each of the five most abundant species encountered on each of the three mussel beds near Watts Bar Nuclear Plant during the 10 summer surveys used in the statistical analyses.

All Species	**1983**	**1984**	**1985**	**1986**	**1988**	**1990**	**1992**	**1994**	**1996**	**1997**	**Mean**	**SDEV**
TRM 520-521	625	467	296	331	418	364	220	299	268	199	348.7	127.5
TRM 526-527	375	161	193	244	271	216	135	212	207	154	216.8	69.2
TRM 528-529	341	642	574	500	921	411	353	369	371	344	482.6	186.4
Totals	**1341**	**1270**	**1063**	**1075**	**1610**	**991**	**708**	**880**	**846**	**697**	**1048.1**	**291.2**
Percent @ TRM 520-521	46.6	36.8	27.8	30.8	26.0	36.7	31.1	34.0	31.7	28.6	33.3	6.0
Percent @ TRM 526-527	28.0	12.7	18.2	22.7	16.8	21.8	19.1	24.1	24.5	22.1	20.7	4.4
Percent @ TRM 528-529	25.4	50.6	54.0	46.5	57.2	41.5	49.9	41.9	43.9	49.4	46.0	8.8
Elliptio crassidens	**1983**	**1984**	**1985**	**1986**	**1988**	**1990**	**1992**	**1994**	**1996**	**1997**	**Mean**	**SDEV**
TRM 520-521	414	232	203	224	236	195	110	197	212	123	214.6	82.2
TRM 526-527	132	81	95	142	87	85	42	110	114	109	99.7	28.5
TRM 528-529	208	466	440	368	647	244	272	276	268	257	344.6	136.7
Totals	**754**	**779**	**738**	**734**	**970**	**524**	**424**	**583**	**594**	**489**	**658.9**	**164.8**
Percent @ TRM 520-521	54.9	29.8	27.5	30.5	24.3	37.2	25.9	33.8	35.7	25.2	32.6	9.0
Percent @ TRM 526-527	17.5	10.4	12.9	19.3	9.0	16.2	9.9	18.9	19.2	22.3	15.1	4.7
Percent @ TRM 528-529	27.6	59.8	59.6	50.1	66.7	46.6	64.2	47.3	45.1	52.6	52.3	11.5
Pleurobema cordatum	**1983**	**1984**	**1985**	**1986**	**1988**	**1990**	**1992**	**1994**	**1996**	**1997**	**Mean**	**SDEV**
TRM 520-521	90	107	36	55	68	34	26	35	27	28	50.6	28.8
TRM 526-527	109	12	23	8	44	24	27	19	20	18	30.4	29.3
TRM 528-529	65	101	54	47	112	81	29	41	47	55	63.2	26.8
Totals	**264**	**220**	**113**	**110**	**224**	**139**	**82**	**95**	**94**	**101**	**144.2**	**66.1**
Percent @ TRM 520-521	34.1	48.6	31.9	50.0	30.4	24.5	31.7	36.8	28.7	27.7	35.1	8.5
Percent @ TRM 526-527	41.3	5.5	20.4	7.3	19.6	17.3	32.9	20.0	21.3	17.8	21.1	10.6
Percent @ TRM 528-529	24.6	45.9	47.8	42.7	50.0	58.3	35.4	43.2	50.0	54.5	43.8	9.7

Table 3-9. (Continued)

Quadrula pustulosa	**1983**	**1984**	**1985**	**1986**	**1988**	**1990**	**1992**	**1994**	**1996**	**1997**	**Mean**	**SDEV**
TRM 520-521	32	27	7	3	5	17	14	6	1	9	12.1	10.4
TRM 526-527	45	20	18	12	21	26	16	30	9	6	20.3	11.4
TRM 528-529	22	38	28	16	54	36	18	29	20	9	27.0	13.1
Totals	**99**	**85**	**53**	**31**	**80**	**79**	**48**	**65**	**30**	**24**	**59.4**	**26.2**
Percent @ TRM 520-521	32.3	31.8	13.2	9.7	6.3	21.5	29.2	9.2	3.3	37.5	20.4	12.5
Percent @ TRM 526-527	45.5	23.5	34.0	38.7	26.3	32.9	33.3	46.2	30.0	25.0	34.2	7.9
Percent @ TRM 528-529	22.2	44.7	52.8	51.6	67.5	45.6	37.5	44.6	66.7	37.5	45.5	13.6
Cyclonaias tuberculata	**1983**	**1984**	**1985**	**1986**	**1988**	**1990**	**1992**	**1994**	**1996**	**1997**	**Mean**	**SDEV**
TRM 520-521	45	62	34	23	56	71	44	46	18	31	43.0	16.9
TRM 526-527	18	2	7	8	8	5	12	8	7	3	7.8	4.6
TRM 528-529	25	9	19	24	29	14	12	10	13	13	16.8	7.0
Totals	**88**	**73**	**60**	**55**	**93**	**90**	**68**	**64**	**38**	**47**	**67.6**	**18.6**
Percent @ TRM 520-521	51.1	84.9	56.7	41.8	60.2	78.9	64.7	71.9	47.4	66.0	63.6	13.7
Percent @ TRM 526-527	20.5	2.7	11.7	14.5	8.6	5.6	17.6	12.5	18.4	6.4	11.5	6.0
Percent @ TRM 528-529	28.4	12.3	31.7	43.6	31.2	15.6	17.6	15.6	34.2	27.7	24.9	10.1
Potamilus alatus	**1983**	**1984**	**1985**	**1986**	**1988**	**1990**	**1992**	**1994**	**1996**	**1997**	**Mean**	**SDEV**
TRM 520-521	6	7	3	4	10	13	6	2	3	2	5.6	3.6
TRM 526-527	7	9	25	23	30	28	5	5	28	6	16.6	11.0
TRM 528-529	1	2	6	14	15	4	5	3	4	4	5.8	4.8
Totals	**14**	**18**	**34**	**41**	**55**	**45**	**16**	**10**	**35**	**12**	**28.0**	**16.0**
Percent @ TRM 520-521	42.9	38.9	8.8	9.8	18.2	28.9	37.5	20.0	8.6	16.7	20.0	13.1
Percent @ TRM 526-527	50.0	50.0	73.5	56.1	54.5	62.2	31.3	50.0	80.0	50.0	59.3	13.7
Percent @ TRM 528-529	7.1	11.1	17.6	34.1	27.3	8.9	31.3	30.0	11.4	33.3	20.7	11.0

Table 3-10. Results of statistical analyses of native mussel abundance on three beds monitored near Watts Bar Nuclear Plant during 1983 through 1997. Only the summer sample data were used in these analyses to equalize the weight associated with each year. The significance level used in these analyses was $\alpha = 0.05$.

Test Subject	Trend Present	Trend not Significant (ANOVA)		Significant Trend Present (Covariance)			
		Site	Multiple Range Results	Parallel	Site	Year	Multiple Range Results
All Species							
TRM 520-521	0.004			0.477	0.312	0.002	
TRM 526-527	0.381	0.034	526.3 526.5 526.8 526.0				
TRM 528-529	0.427	0.002	528.8 528.9 528.5 528.2				
Elliptio crassidens							
TRM 520-521	0.02			0.17	0.02	0.01	520.0 520.8 520.6 520.3
TRM 526-527	0.79	0.30					
TRM 528-529	0.50	0.0001	528.9 528.8 528.5 528.2				
Pleurobema cordatum							
TRM 520-521	0.004			0.13	0.72	0.001	?
TRM 526-527	0.42	0.0002	526.3 526.5 526.0 526.8				
TRM 528-529	0.31	0.03	528.9 528.5 528.8 528.2				
Quadrula pustulosa							
TRM 520-521	0.05			0.13	0.16	0.05	
TRM 526-527	0.04			0.18	0.0007	0.02	526.6 526.8 526.3 526.0
TRM 528-529	0.10	0.50					
Cyclonaias tuberculata							
TRM 520-521	0.02			0.009			Trends at sites not parallel
TRM 526-527	0.77	0.0009	526.5 526.3 526.0 526.8				
TRM 528-529	0.47	0.04	528.5 528.8 528.2 528.9				
Potamilus alatus							
TRM 520-521	0.75	0.27					
TRM 526-527	0.32	0.07					
TRM 528-529	0.58	0.78					

Table 3-11. Mean lengths (in millimeters) of each native mussel species encountered during surveys conducted near Watts Bar Nuclear Plant during 1983-1997. As a general rule, no more than 50 members of each species were measured from each bed during any given survey.

Species	1983	1984	1985	1986	1988	1990	1992	1994	1996	1997	Number Measured	Overall Mean
Actinonaias ligamentina	104.00	109.55	104.72	99.23	97.87	110.38	94.80				35	103.57
Amblema plicata	96.86	98.18	103.37	103.36	102.47	102.16	105.46	106.79	104.90	96.00	272	101.52
Anodonta grandis	121.88	124.58	123.14	122.18	126.85	135.42	130.06	135.29	141.10	147.00	132	127.57
Anodonta imbecillis		53.60		39.20	54.00	52.00					5	50.48
Anodonta suborbiculata					107.80	126.20					2	117.00
Cyclonaias tuberculata	79.14	76.09	78.39	76.16	79.12	79.65	80.10	78.52	83.00	81.50	897	79.30
Cyprogenia stegaria	54.83	52.90	57.70								5	55.02
Dromus dromas	60.10										1	60.10
Ellipsaria lineolata	85.29	82.92	87.83	84.30	87.22	85.42	90.49	87.68	92.20	81.80	265	85.90
Elliptio crassidens	107.96	109.58	110.22	110.53	110.06	115.21	112.26	113.88	112.90	113.10	2182	111.08
Elliptio dilatata	103.32	96.35	98.80	109.23	101.10	94.60			95.40		17	101.64
Fusconaia subrotunda	66.09										1	66.09
Lampsilis abrupta	94.39	96.66	101.94	100.44	100.78	105.95	108.85	105.05	110.20		62	101.18
Lampsilis ovata	124.93	127.98	127.36	141.40	130.37	121.70	157.27			115.30	26	128.39
Lasmigona complanata			180.20								1	180.20
Lasmigona costata				122.10					118.40		2	120.25
Leptodea fragilis	84.13	111.33	100.28	96.87	99.81	110.46		117.67	126.20	92.20	50	102.46
Ligumia recta	155.34	157.96	165.39	147.23	160.27	172.60		161.40	157.50	160.00	67	156.70
Megalonaias nervosa	13.83	180.00	173.70	152.35	160.61	166.60	173.35	174.45	180.00		34	166.23
Obliquaria reflexa	53.80	53.63	55.72	55.11	54.84	55.06	57.17	57.30	56.10	54.10	99	55.12
Plethobasus cyphyus	91.80						91.40	88.60			4	90.90
Pleurobema cordatum	95.39	95.08	96.42	92.87	96.57	97.37	98.53	97.71	99.40	98.20	1628	96.06
Pleurobema oviforme		69.80	72.90	68.90	72.20	72.80		71.90			9	71.04
Pleurobema plenum	58.10	60.10	84.60								4	65.73
Pleurobema rubrum			87.97		88.30						4	88.05
Potamilus alatus	135.39	142.73	139.79	139.66	142.76	142.78	142.99	149.92	145.90	146.40	407	141.46
Ptychobranchus fasciolaris		94.40				116.80					2	105.60
Quadrula metanevra	76.52	78.68	78.07	74.75	83.34	84.28	78.61	74.18	81.90	88.00	122	78.24
Quadrula pustulosa	55.91	56.75	57.98	54.97	58.73	57.56	56.37	58.02	60.80	59.00	827	57.18
Tritogonia verrucosa	110.06	110.44	124.66	110.36	112.68	107.59	106.24	115.60	109.70	109.60	116	112.77

Table 3-12. Statistical analyses of mean lengths of native mussels collected near Watts Bar Nuclear Plant during the period 1983 through 1997. Only the summer sample data were used in these analyses to equalize the weight associated with each year. The significance level used in these analyses was $\alpha = 0.05$.

	Trend	Trend not Significant (ANOVA)		Significant Trend Present (Covariance)			
Test Subject	Present	Site	Multiple Range Results	Parallel	Site	Year	Multiple Range Results
Elliptio crassidens							
TRM 520-521	0.02			0.45	0.65	0.002	
TRM 526-527	0.002			0.18	0.12	0.0004	
TRM 528-529	0.10	0.52					
Pleurobema cordatum							
TRM 520-521	0.02			0.05	0.001	0.06	520.0 520.3 520.8 520.6
TRM 526-527	0.002			0.36	0.10	0.0002	
TRM 528-529	0.02			0.42	0.03	0.002	528.5 528.8 528.2 528.9
Quadrula pustulosa							
TRM 520-521	0.14	0.98					
TRM 526-527	0.65	0.09					
TRM 528-529	0.13	0.42					
Cyclonaias tuberculata							
TRM 520-521	0.01			0.22	0.11	0.003	
TRM 526-527	0.82	0.46					
TRM 528-529	0.21	0.15					
Potamilus alatus							
TRM 520-521	0.23	0.01	520.3 520.0 520.6 520.8				
TRM 526-527	0.34	0.02	526.5 526.3 526.8 526.0				
TRM 528-529	0.18	0.18					

Table 4-1. Preoperational water quality monitoring summary statistics for parameters measured during 1982-1987 at WBN

Tennessee River Mile 518.0					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
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+Nitrate 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	19.1
Tennessee River Mile 527.4					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
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+Nitrate 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	2.3	17.8

Table 4-1. (Continued)

Tennessee River Mile 529.5					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
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+Nitrate 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	19.3
Tennessee River Mile 529.9					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
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+Nitrate 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 Phosphorus (mg/L)	51	0.0320	0.0165	0.010	0.100
Dissolved Phosphorus (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	9.0	.	9	9
Total Alkalinity (mg/L)	38	64.7	9.8	41	82
Chlorophyll a (ug/L)	17	5.4	2.6	2	12

Table 4-2. Operational water quality monitoring summary statistics for parameters measured during 1996-1997 at WBN

Tennessee River Mile 518.0					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
pH (standard units)	12	7.47	0.14	7.2	7.7
Turbidity (NTU)	11	3.36	1.21	2.0	6.0
Total Solids (mg/L)	11	107.3	15.6	80	130
Suspended Solids (mg/L)	0	-	-	-	-
Volatile Suspended Solids (mg/L)	0	-	-	-	-
Dissolved Solids (mg/L)	11	90.0	14.8	70	110
Ammonia Nitrogen (mg/L)	38	0.039	0.015	0.01	0.06
Nitrate+Nitrate Nitrogen (mg/L)	38	0.284	0.076	0.18	0.43
Organic Nitrogen (mg/L)	38	0.165	0.063	0.07	0.27
Total Phosphorus (mg/L)	38	0.0311	0.0118	0.008	0.070
Dissolved Phosphorus (mg/L)	38	0.0155	0.0060	0.002	0.030
Total Organic Carbon (mg/L)	38	1.68	0.17	1.4	2.0
COD (mg/L)	11	5.5	1.5	5	10
Total Alkalinity (mg/L)	12	65.1	6.8	54	74
Chlorophyll a (ug/L)	80	5.8	2.9	2	18
Tennessee River Mile 527.4					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
pH (standard units)	12	7.63	0.22	7.3	8.0
Turbidity (NTU)	11	3.55	0.69	3.0	5.0
Total Solids (mg/L)	12	104.2	16.2	80	130
Suspended Solids (mg/L)	0	-	-	-	-
Volatile Suspended Solids (mg/L)	0	-	-	-	-
Dissolved Solids (mg/L)	12	90.8	13.8	80	120
Ammonia Nitrogen (mg/L)	41	0.030	0.014	0.01	0.05
Nitrate+Nitrate Nitrogen (mg/L)	41	0.272	0.075	0.19	0.42
Organic Nitrogen (mg/L)	41	0.176	0.055	0.02	0.26
Total Phosphorus (mg/L)	41	0.0273	0.0059	0.020	0.040
Dissolved Phosphorus (mg/L)	41	0.0127	0.0045	0.008	0.020
Total Organic Carbon (mg/L)	41	1.71	0.18	1.5	2.2
COD (mg/L)	12	5.8	1.7	5	10
Total Alkalinity (mg/L)	12	63.9	8.0	52	74
Chlorophyll a (ug/L)	80	7.7	3.2	4	18

Table 4-2. (Continued)

Tennessee River Mile 529.5					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
pH (standard units)	10	7.61	0.22	7.1	7.9
Turbidity (NTU)	10	3.50	0.97	2.0	5.0
Total Solids (mg/L)	11	102.7	14.2	90	130
Suspended Solids (mg/L)	0	-	-	-	-
Volatile Suspended Solids (mg/L)	0	-	-	-	-
Dissolved Solids (mg/L)	11	92.7	11.0	80	120
Ammonia Nitrogen (mg/L)	33	0.029	0.014	0.01	0.06
Nitrate+Nitrate Nitrogen (mg/L)	33	0.267	0.077	0.16	0.41
Organic Nitrogen (mg/L)	33	0.189	0.067	0.07	0.29
Total Phosphorus (mg/L)	33	0.0252	0.0083	0.020	0.060
Dissolved Phosphorus (mg/L)	33	0.0091	0.0029	0.002	0.010
Total Organic Carbon (mg/L)	33	1.74	0.20	1.5	2.1
COD (mg/L)	11	5.8	1.3	5	8
Total Alkalinity (mg/L)	10	63.0	6.8	55	73
Chlorophyll a (ug/L)	69	8.0	3.0	3	15
Tennessee River Mile 529.9					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
pH (standard units)	11	8.55	0.56	7.3	9.2
Turbidity (NTU)	11	1.73	0.79	1.0	3.0
Total Solids (mg/L)	11	101.8	14.0	80	130
Suspended Solids (mg/L)	0	-	-	-	-
Volatile Suspended Solids (mg/L)	0	-	-	-	-
Dissolved Solids (mg/L)	11	90.9	14.5	70	110
Ammonia Nitrogen (mg/L)	42	0.014	0.007	0.01	0.03
Nitrate+Nitrate Nitrogen (mg/L)	42	0.189	0.107	0.03	0.42
Organic Nitrogen (mg/L)	42	0.242	0.201	0.08	1.40
Total Phosphorus (mg/L)	42	0.0212	0.0055	0.010	0.030
Dissolved Phosphorus (mg/L)	42	0.0100	0.0022	0.005	0.020
Total Organic Carbon (mg/L)	42	1.92	0.38	1.5	3.1
COD (mg/L)	11	9.0	6.2	5	26
Total Alkalinity (mg/L)	11	65.8	5.5	56	74
Chlorophyll a (ug/L)	81	11.3	5.1	1	28

Table 4-3. Statistical Comparison of WBN 1996 Operational Water Quality Data to Pre-operational Data using Anova w/Duncan's Multiple Range Test

1996 Compared to Pre-Op Period	TRM 518.0	TRM 527.4	TRM 529.5	TRM 529.9	All
pH	-	-	-	Up	Up
Turbidity	-	-	-	Down	Down
Dissolved Solids	-	-	-	-	-
Ammonia Nitrogen	-	-	-	Down	-
Nitrite+Nitrate Nitrogen	-	-	-	Down	-
Organic Nitrogen	Down	-	-	-	-
Total Phosphorus	-	-	-	Down	Down
Dissolved Phosphorus	-	-	Down	-	-
Total Organic Carbon	Down	-	Down	-	Down
Chemical Oxygen Demand	-	-	-	-	-
Total Alkalinity	-	-	-	-	-
Chlorophyll a	Up	Up	Up	Up	Up

Table 4-4. Statistical Comparison of WBN 1997 Operational Water Quality Data to Pre-operational Data using Anova w/Duncan's Multiple Range Test

1997 Compared to Pre-Op Period	TRM 518.0	TRM 527.4	TRM 529.5	TRM 529.9	All
pH	-	-	-	Up	Up
Turbidity	Down	-	-	Down	Down
Dissolved Solids	-	-	-	-	Down
Ammonia Nitrogen	Down	Down	Down	Down	Down
Nitrite+Nitrate Nitrogen	-	-	Down	Down	Down
Organic Nitrogen	[illegible]	-	-	-	-
Total Phosphorus	-	-	-	Down	Down
Dissolved Phosphorus	-	Up	Down	-	-
Total Organic Carbon	Down	Down	Down	Down	Down
Chemical Oxygen Demand	Down	-	-	-	-
Total Alkalinity	-	-	-	-	-
Chlorophyll a	[illegible]	Up	Up	Up	Up

Table 4-5. Statistical Comparison of WBN Combined 1996-97 Operational Water Quality Data to Pre-operational Data using Anova w/Duncan's Multiple Range Test

1996-97 Compared to Pre-Op Period	TRM 518.0	TRM 527.4	TRM 529.5	TRM 529.9	All
pH	-	-	-	Up	Up
Turbidity	Down	Down	Down	Down	Down
Dissolved Solids	-	-	-	-	Down
Ammonia Nitrogen	-	Down	Down	Down	Down
Nitrite+Nitrate Nitrogen	-	-	-	Down	Down
Organic Nitrogen	Down	-	-	-	-
Total Phosphorus	-	-	-	Down	Down
Dissolved Phosphorus	-	-	Down	Down	Down
Total Organic Carbon	Down	Down	Down	Down	Down
Chemical Oxygen Demand	Down	-	-	-	-
Total Alkalinity	-	-	-	-	-
Chlorophyll a	Up	Up	Up	Up	Up

Table 4-3. Statistical Comparison of WBN 1996 Operational Water Quality Data to Pre-operational Data using Anova w/Duncan's Multiple Range Test

1996 Compared to Pre-Op Period	TRM 518.0	TRM 527.4	TRM 529.5	TRM 529.9	All
pH	-	-	-	Up	Up
Turbidity	-	-	-	Down	Down
Dissolved Solids	-	-	-	-	-
Ammonia Nitrogen	-	-	-	Down	-
Nitrite+Nitrate Nitrogen	-	-	-	Down	-
Organic Nitrogen	Down	-	-	-	-
Total Phosphorus	-	-	-	Down	Down

Shaded boxes indicate differences from those identified in 1996 comparisons in top table. "-" indicates no significant (p=>.05) difference between pre-operational and post-operational periods. "Up" indicates a statistically significant increase in the indicated parameter. "Down" indicates a statistical decrease in the indicated parameter

Table 4-6. Preoperational (1982-1991) water quality monitoring summary values for metals at WBN

Tennessee River Mile 518.0					
Parameter	N	Mean	Std Dev	Minimum	Maximum
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 Aluminum (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	N	Mean	Std Dev	Minimum	Maximum
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 Aluminum (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 4-6 (Continued)

Tennessee River Mile 529.5					
Parameter	N	Mean	Std Dev	Minimum	Maximum
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 Aluminum (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	N	Mean	Std Dev	Minimum	Maximum
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 Aluminum (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

Table 4-7. Operational (1996-1997) water quality monitoring summary values for metals at WBN

Tennessee River Mile 518.0					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
Total Calcium (mg/L)	13	19.5	4.0	12.0	23.0
Total Magnesium (mg/L)	13	5.6	0.6	4.4	6.2
Total Arsenic (ug/L)	13	1.0	0.0	1.0	1.0
Total Boron (ug/L)	13	500.0	0.0	500.0	500.0
Total Cadmium (ug/L)	13	0.1	0.0	0.1	0.2
Total Chromium (ug/L)	13	1.0	0.0	1.0	1.0
Total Copper (ug/L)	13	10.0	0.0	10.0	10.0
Total Iron (ug/L)	13	490.8	583.0	150.0	1800.0
Total Lead (ug/L)	13	1.0	0.0	1.0	1.0
Total Manganese (ug/L)	13	63.7	24.9	30.0	110.0
Total Nickel (ug/L)	13	1.0	0.0	1.0	1.0
Total Zinc (ug/L)	13	10.0	0.0	10.0	10.0
Total Aluminum (ug/L)	13	170.0	76.9	50.0	280.0
Total Selenium (ug/L)	13	1.0	0.0	1.0	1.0
Total Mercury (ug/L)	13	0.2	0.0	0.2	0.2
Ca/Mg Hardness (mg/L)	13	71.6	10.7	55.5	82.5
Tennessee River Mile 527.4					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
Total Calcium (mg/L)	14	21.1	2.3	16.0	23.0
Total Magnesium (mg/L)	14	5.5	0.6	4.4	6.1
Total Arsenic (ug/L)	14	1.1	0.3	1.0	2.0
Total Boron (ug/L)	14	500.0	0.0	500.0	500.0
Total Cadmium (ug/L)	14	0.1	0.0	0.1	0.1
Total Chromium (ug/L)	14	1.0	0.0	1.0	1.0
Total Copper (ug/L)	14	10.0	0.0	10.0	10.0
Total Iron (ug/L)	14	237.1	43.6	180.0	320.0
Total Lead (ug/L)	14	1.0	0.0	1.0	1.0
Total Manganese (ug/L)	14	60.1	20.4	20.0	85.0
Total Nickel (ug/L)	14	1.1	0.3	1.0	2.0
Total Zinc (ug/L)	14	10.7	2.7	10.0	20.0
Total Aluminum (ug/L)	14	175.0	44.3	120.0	280.0
Total Selenium (ug/L)	14	1.0	0.0	1.0	1.0
Total Mercury (ug/L)	14	0.2	0.0	0.2	0.2
Ca/Mg Hardness (mg/L)	14	75.4	8.1	58.1	82.5

Table 4-7 (Continued)

Tennessee River Mile 529.5					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
Total Calcium (mg/L)	12	21.5	2.8	16.0	25.0
Total Magnesium (mg/L)	12	5.5	0.6	4.4	6.4
Total Arsenic (ug/L)	12	1.0	0.0	1.0	1.0
Total Boron (ug/L)	12	500.0	0.0	500.0	500.0
Total Cadmium (ug/L)	12	0.1	0.0	0.1	0.1
Total Chromium (ug/L)	12	1.0	0.0	1.0	1.0
Total Copper (ug/L)	12	10.0	0.0	10.0	10.0
Total Iron (ug/L)	12	215.8	49.4	140.0	300.0
Total Lead (ug/L)	12	1.0	0.0	1.0	1.0
Total Manganese (ug/L)	12	60.9	21.1	25.0	91.0
Total Nickel (ug/L)	12	1.0	0.0	1.0	1.0
Total Zinc (ug/L)	12	10.0	0.0	10.0	10.0
Total Aluminum (ug/L)	12	170.8	36.3	110.0	220.0
Total Selenium (ug/L)	12	1.0	0.0	1.0	1.0
Total Mercury (ug/L)	12	0.2	0.0	0.2	0.3
Ca/Mg Hardness (mg/L)	12	76.4	9.5	58.1	88.8
Tennessee River Mile 529.9					
Parameter	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
Total Calcium (mg/L)	15	21.1	2.8	16.0	24.0
Total Magnesium (mg/L)	15	5.4	0.6	4.4	6.0
Total Arsenic (ug/L)	15	1.0	0.0	1.0	1.0
Total Boron (ug/L)	15	500.0	0.0	500.0	500.0
Total Cadmium (ug/L)	15	0.1	0.0	0.1	0.1
Total Chromium (ug/L)	15	1.0	0.0	1.0	1.0
Total Copper (ug/L)	15	10.0	0.0	10.0	10.0
Total Iron (ug/L)	15	184.0	57.4	100.0	300.0
Total Lead (ug/L)	15	1.0	0.0	1.0	1.0
Total Manganese (ug/L)	15	41.5	9.9	24.0	52.0
Total Nickel (ug/L)	15	1.0	0.0	1.0	1.0
Total Zinc (ug/L)	15	10.0	0.0	10.0	10.0
Total Aluminum (ug/L)	15	127.3	64.2	50.0	270.0
Total Selenium (ug/L)	15	1.0	0.0	1.0	1.0
Total Mercury (ug/L)	15	0.2	0.0	0.2	0.2
Ca/Mg Hardness (mg/L)	15	75.1	9.2	58.1	83.8

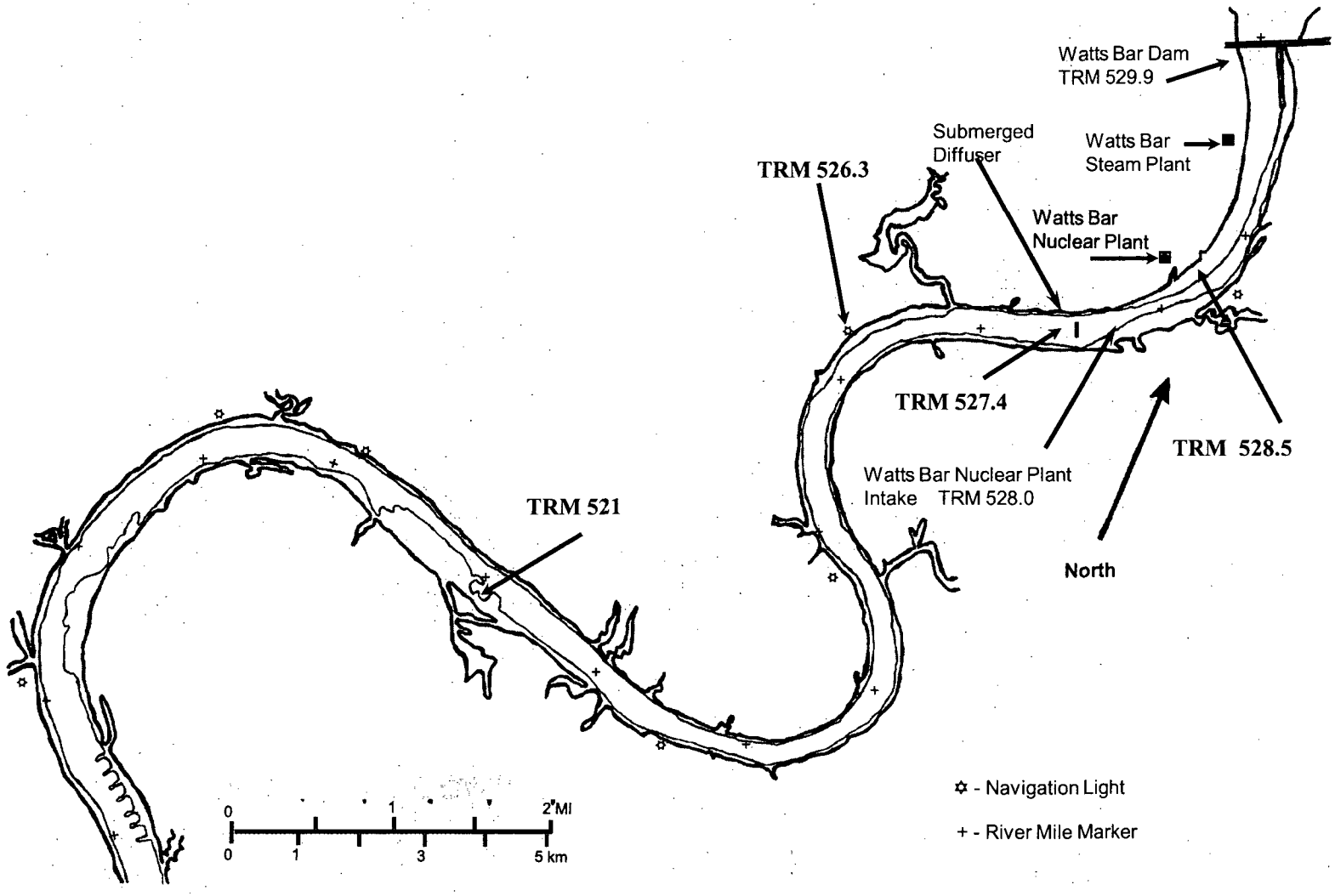


Figure 1-1. Location of Watts Bar Nuclear Plant on Chickamauga Reservoir.

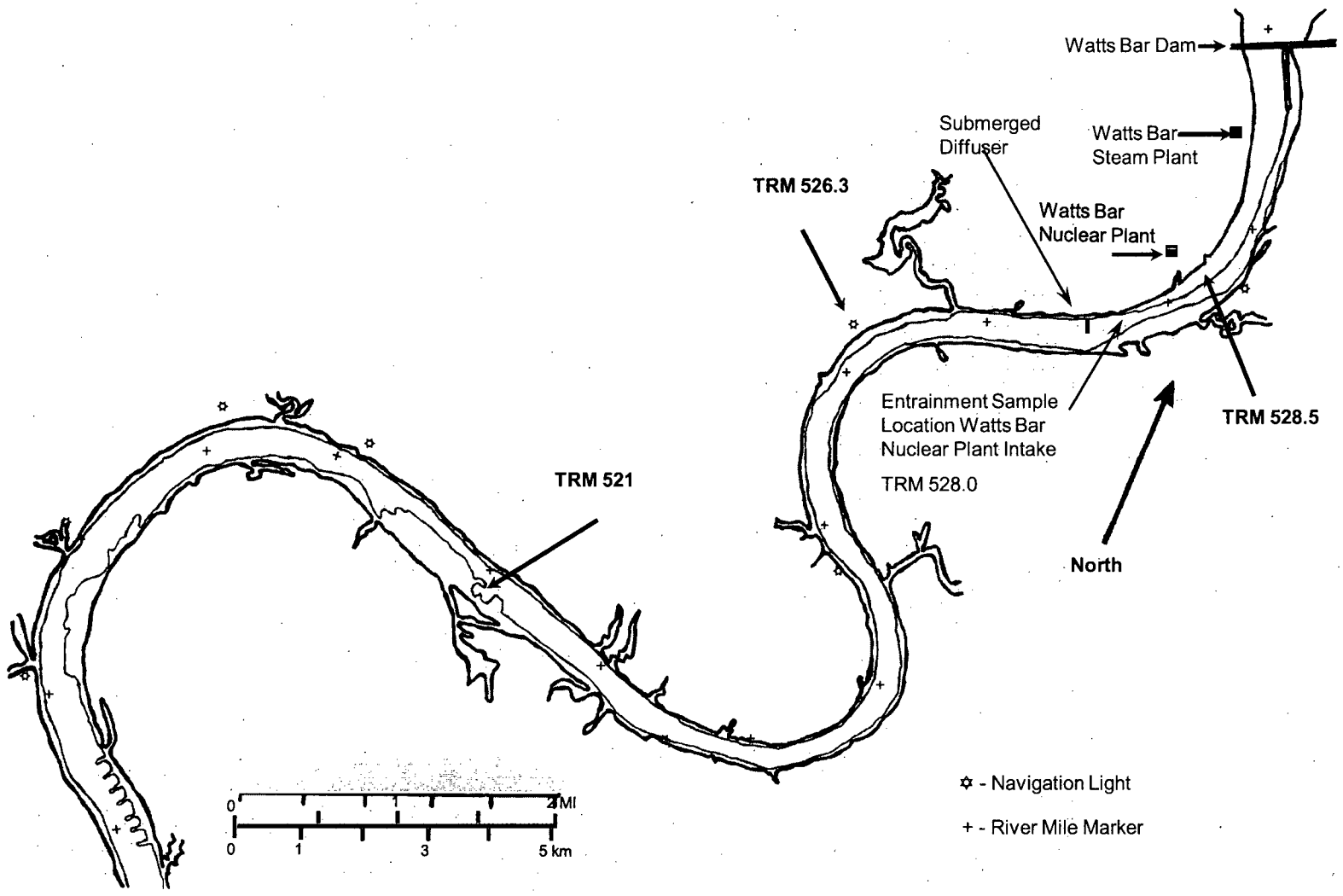


Figure 2-1. Sample Locations for Entrainment Samples in the vicinity of Watts Bar Nuclear Plant, 1996-1997.

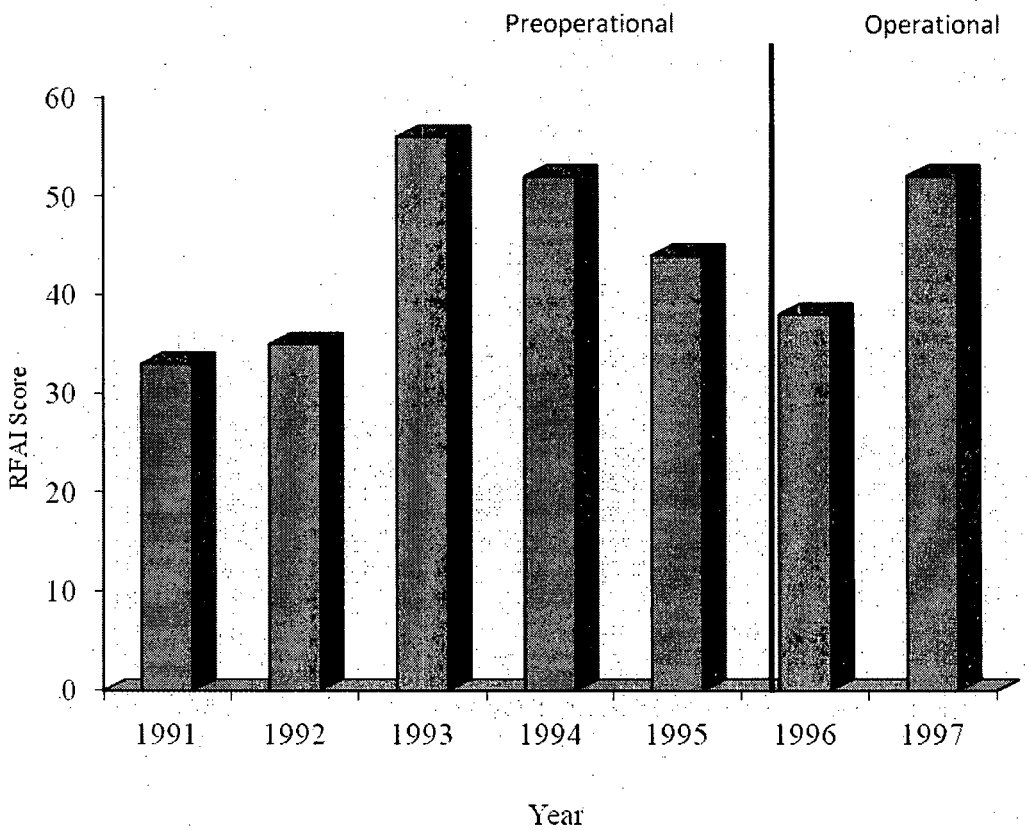


Figure 2-2. Reservoir Fish Assemblage Index (RFAI) scores from preoperational (1991-1995) and operational (1996-1997) periods on Chickamauga Reservoir in the vicinity of Watts Bar Nuclear Plan

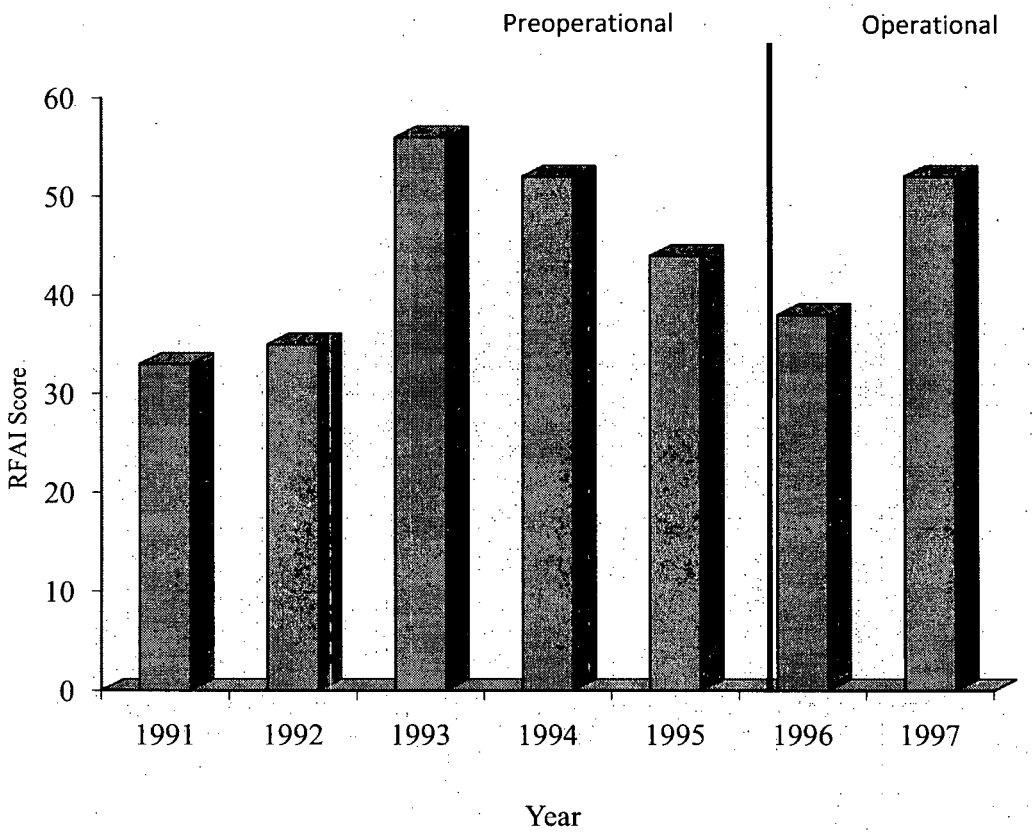


Figure 2-2. Reservoir Fish Assemblage Index (RFAI) scores from preoperational (1991-1995) and operational (1996-1997) periods on Chickamauga Reservoir in the vicinity of Watts Bar Nuclear Plan

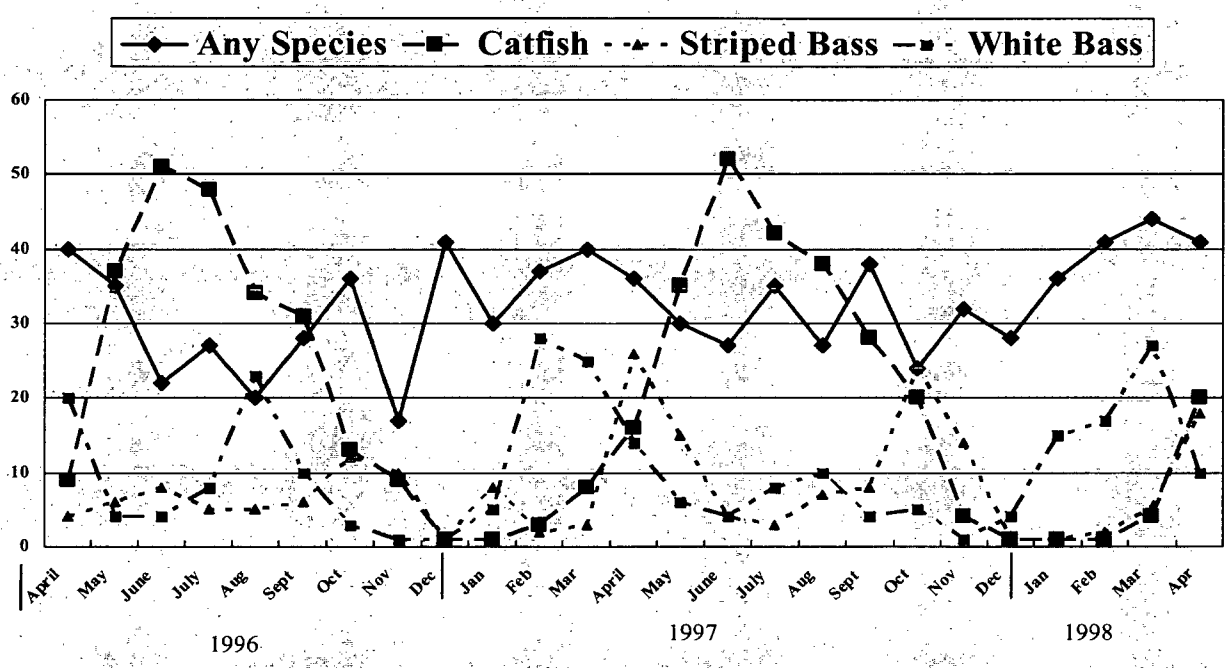


Figure 2-3. Percent of angler effort for selected directed species groups from the Watts Bar tailwater fishery. April 1996 through April 1998.

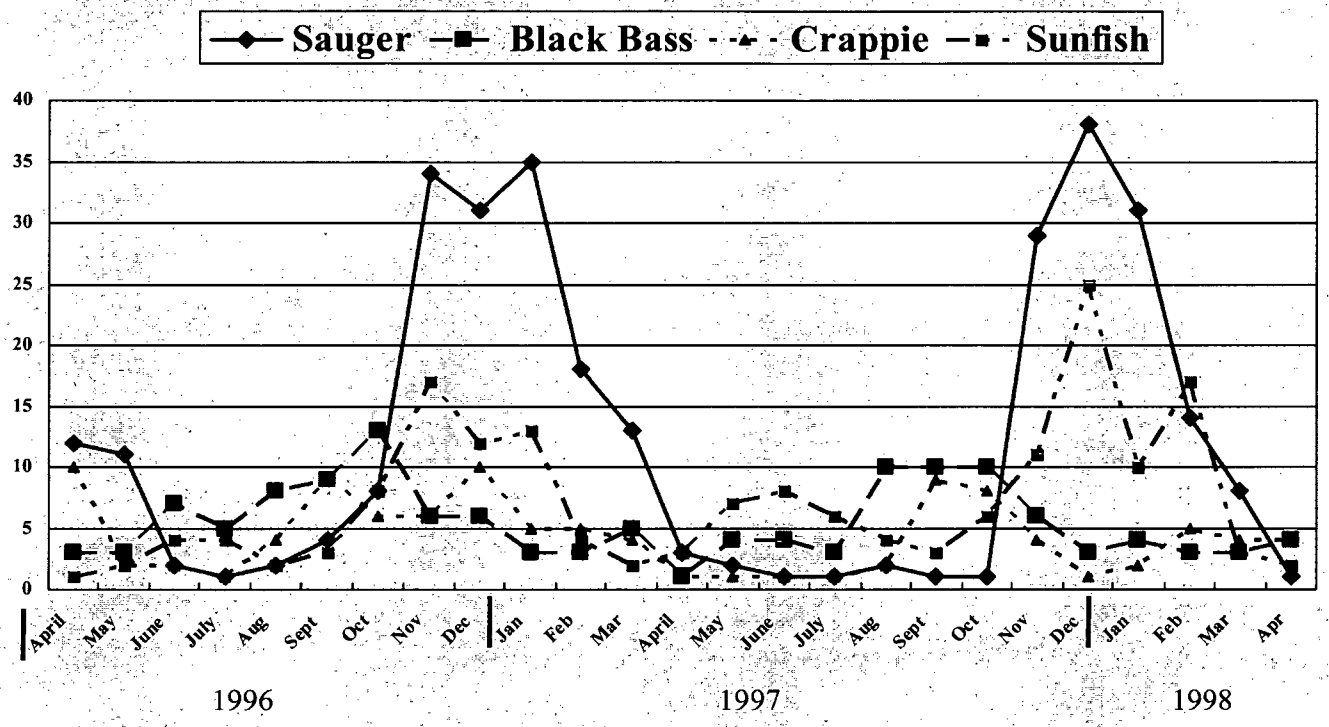


Figure 2-4. Percent of angler effort for selected directed species groups from the Watts Bar tailwater fishery. April 1996 through April 1998.

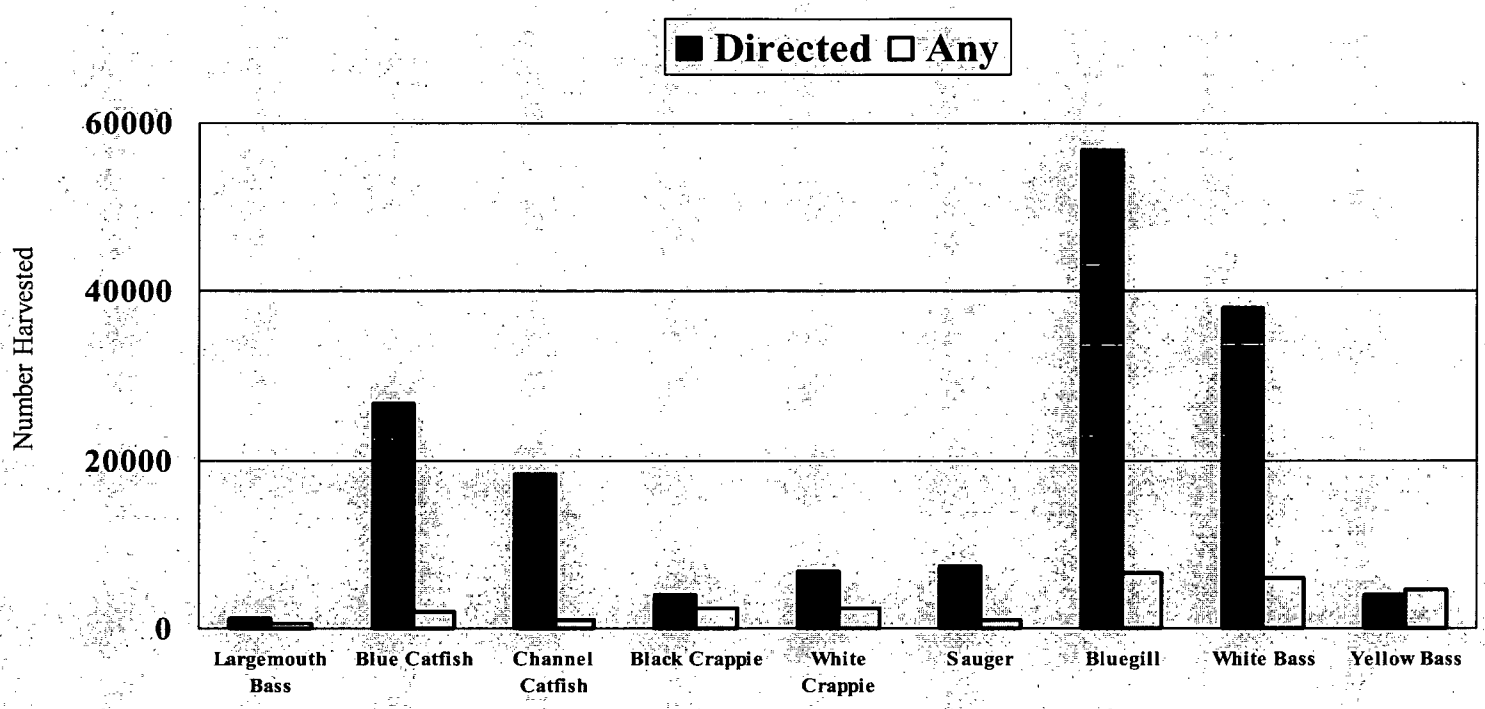


Figure 2-5. Estimated number of fish harvested in Watts Bar Tailwater by directed and any species groups, April 1996 through April 1998.

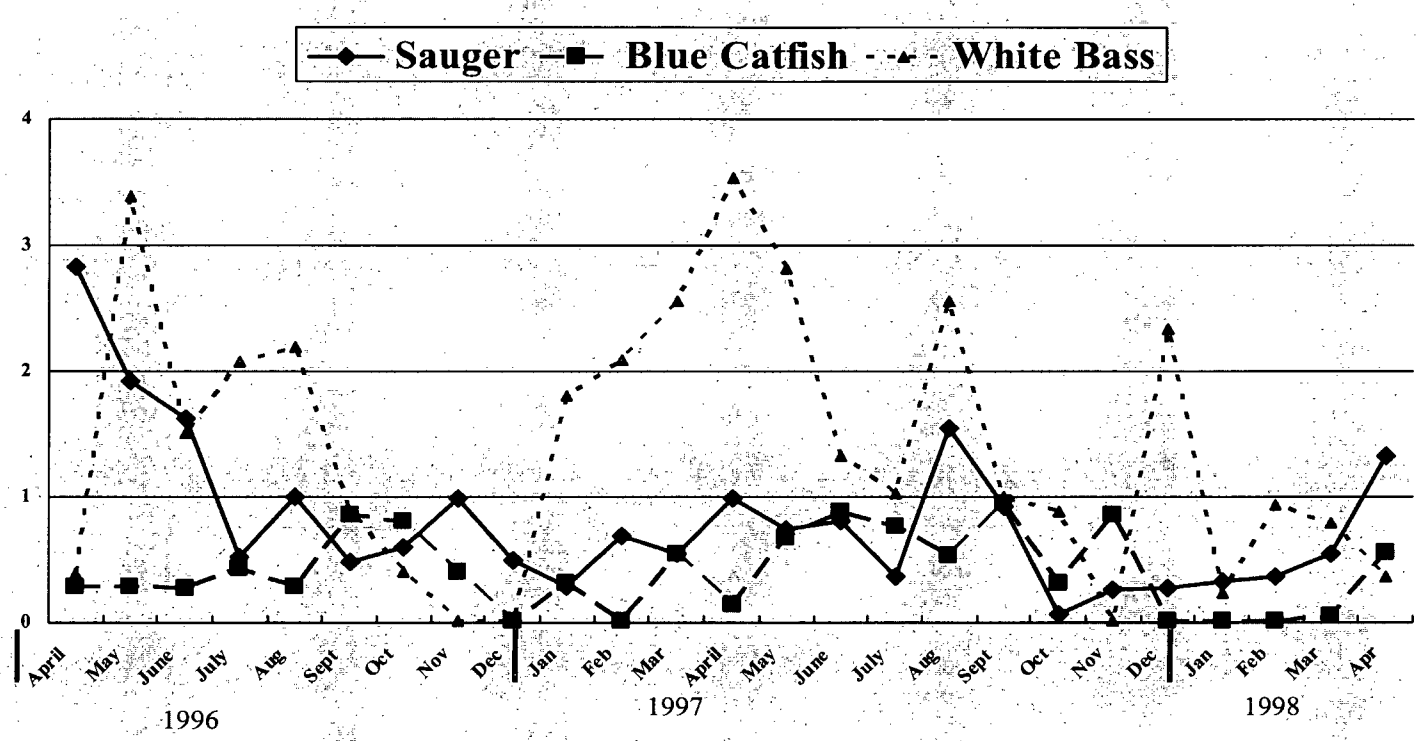


Figure 2-6. Monthly catch rate for selected species from the Watts Bar tailwater fishery. April 1996 through April 1998.

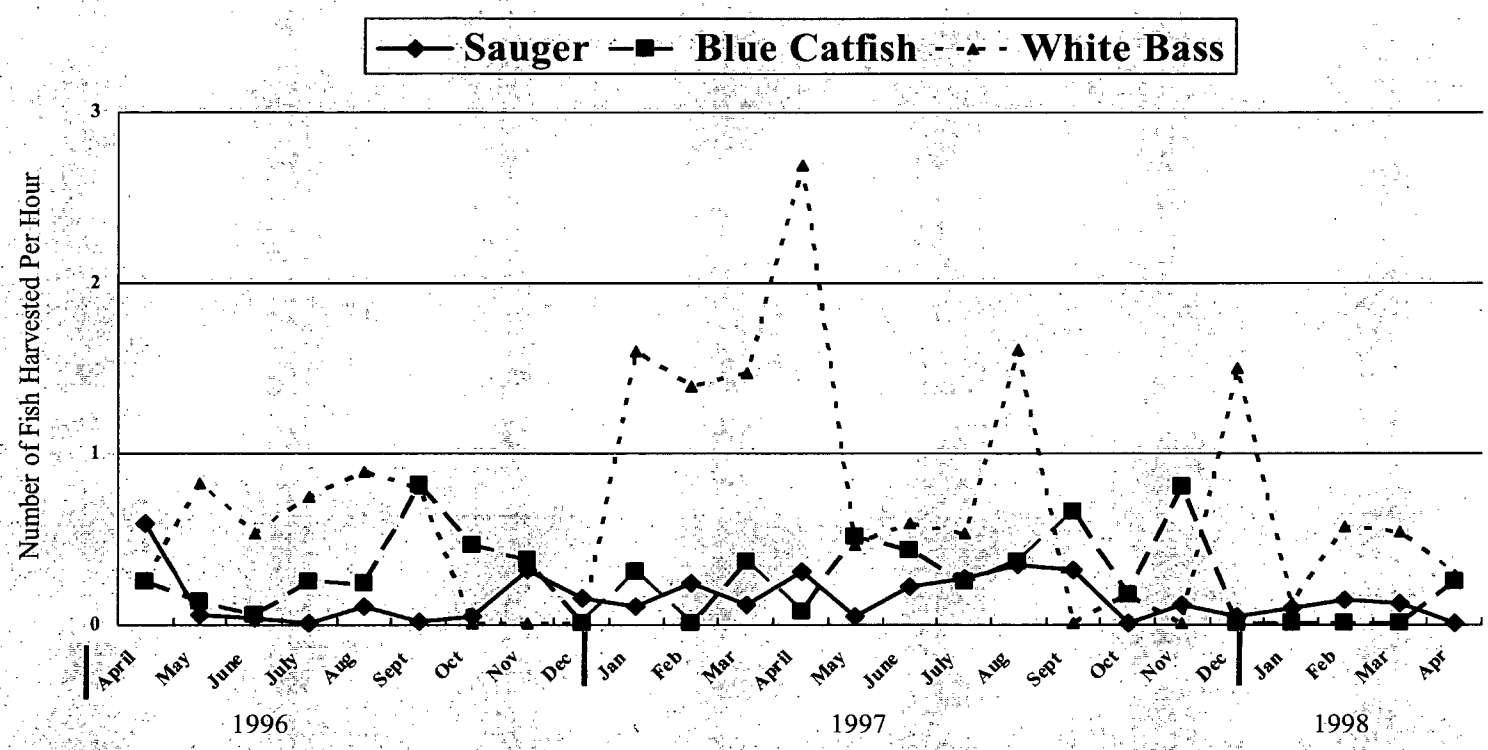


Figure 2-7. Monthly harvest rate for selected species from the Watts Bar tailwater fishery. April 1996 through April 1998.

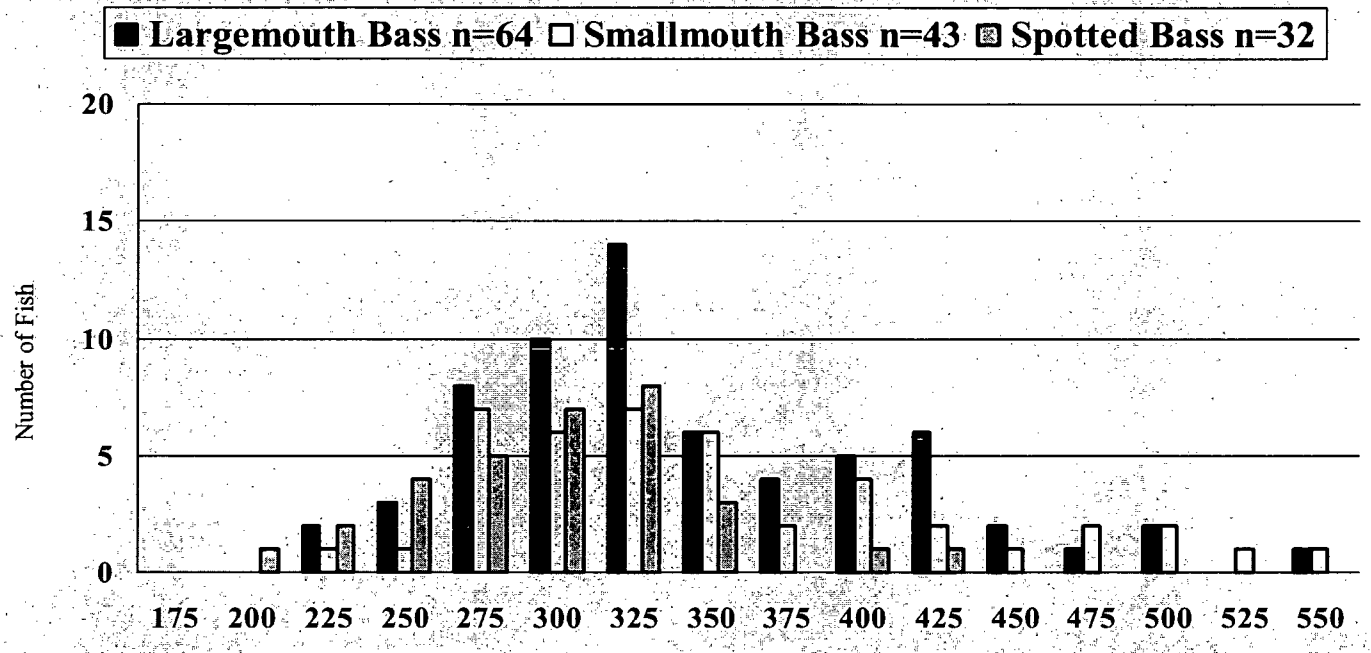
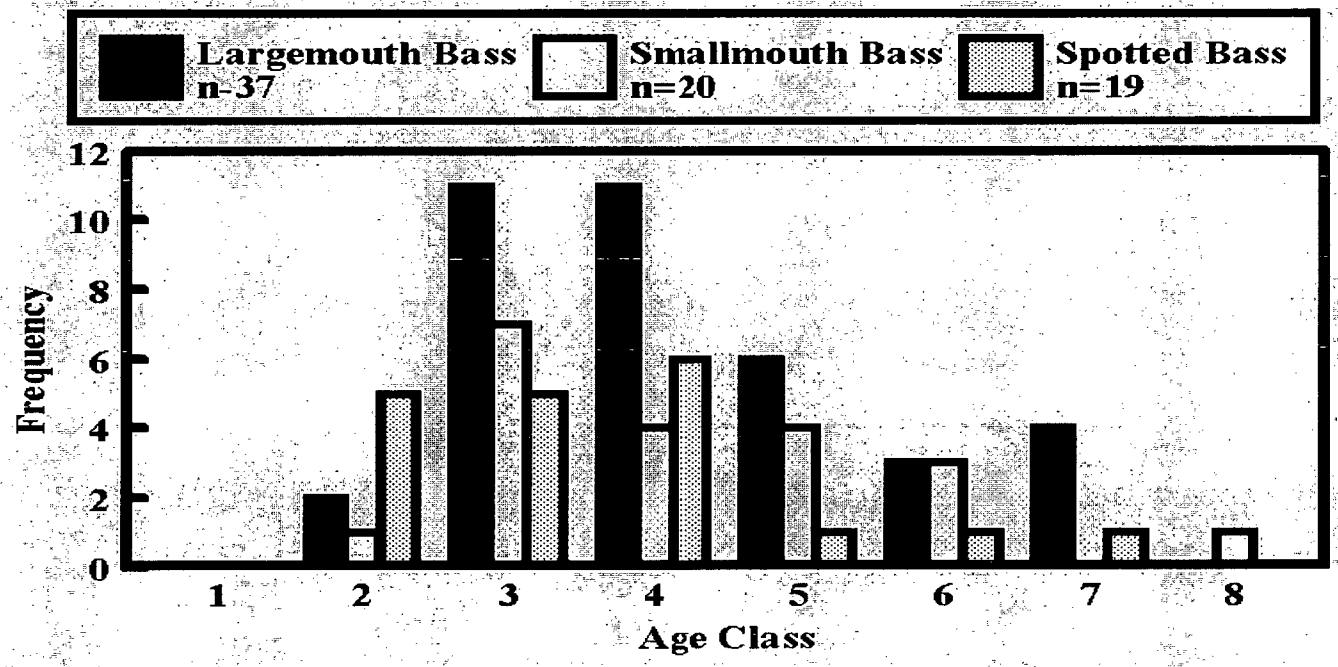


Figure 2-8. Length frequency of angler –harvested black basses sampled during creel surveys in Watts Bar Tailwater, April 1996 through April 1998.


Largemouth Bass
n=37
Smallmouth Bass
n=20
Spotted Bass
n=19
Frequency
0
2
4
6
8
10
12
1
2
3
4
5
6
7
8
Age Class

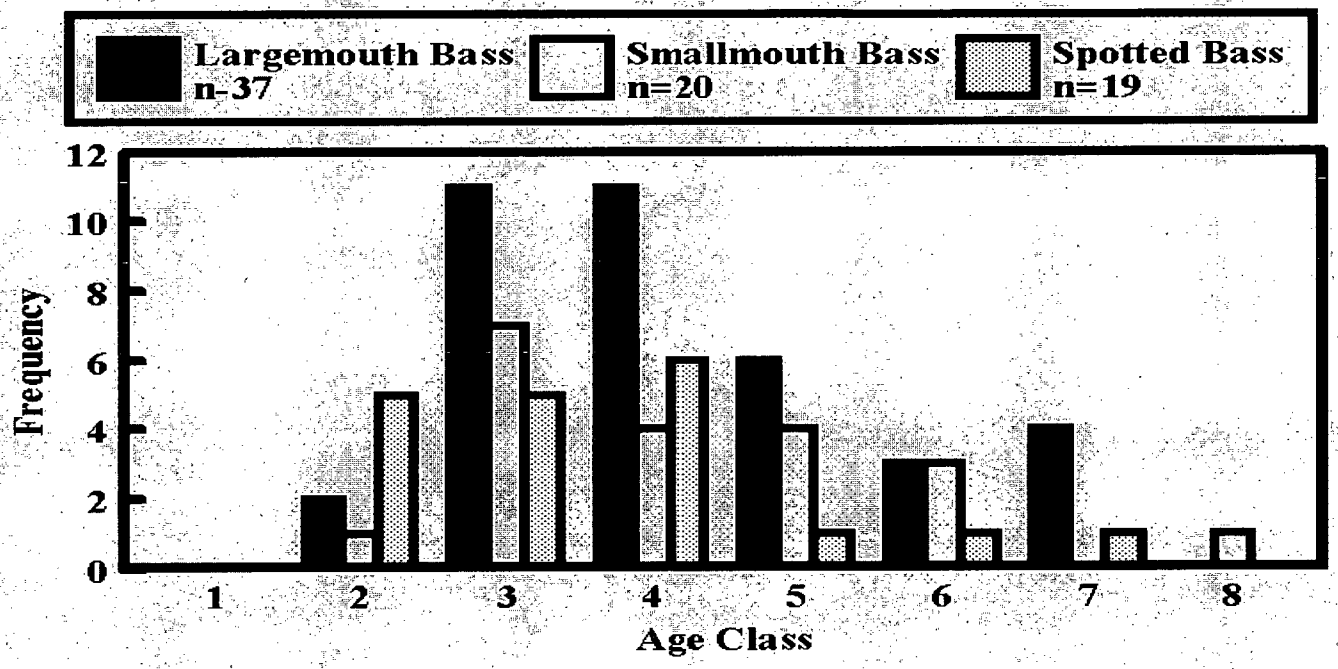


Figure 2-9. Age frequency of harvested largemouth bass, smallmouth bass, and spotted bass from the Watts Bar Tailwater. April 1996 though March 1997.

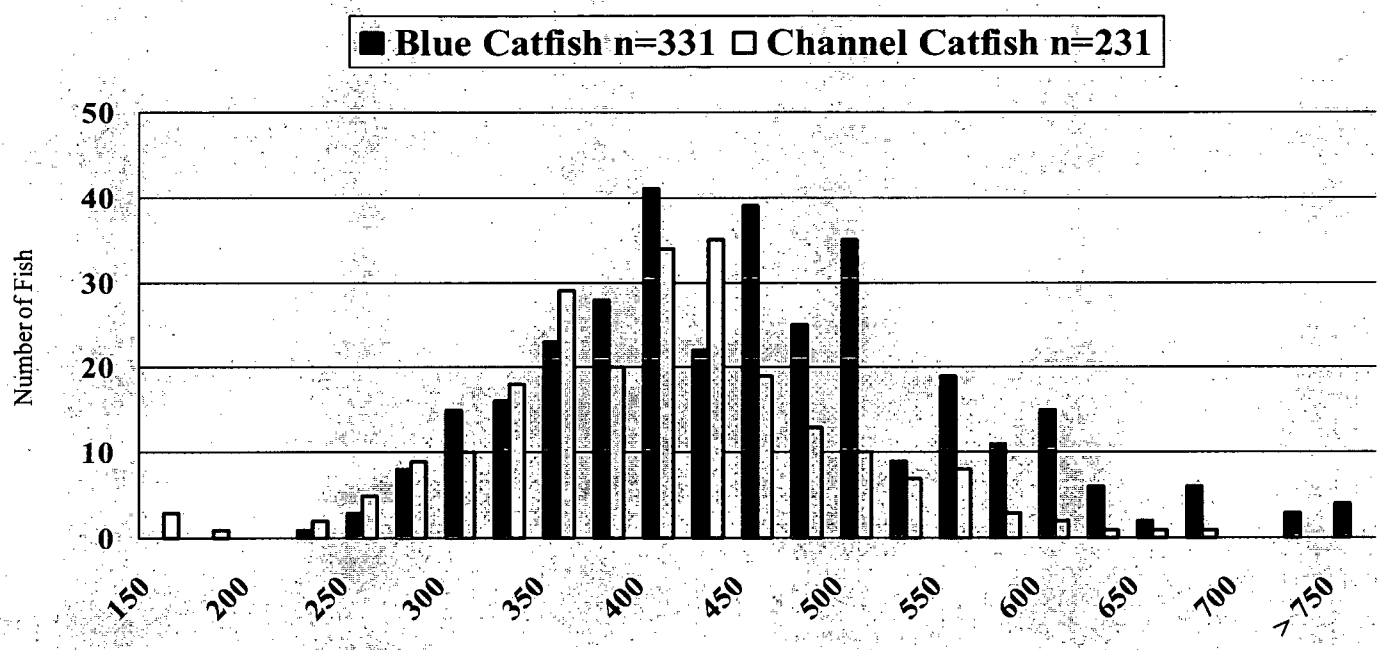


Figure 2-10. Length frequency of angler-harvested blue catfish and channel catfish from Watts Bar Tailwater, April 1996 through April 1998.

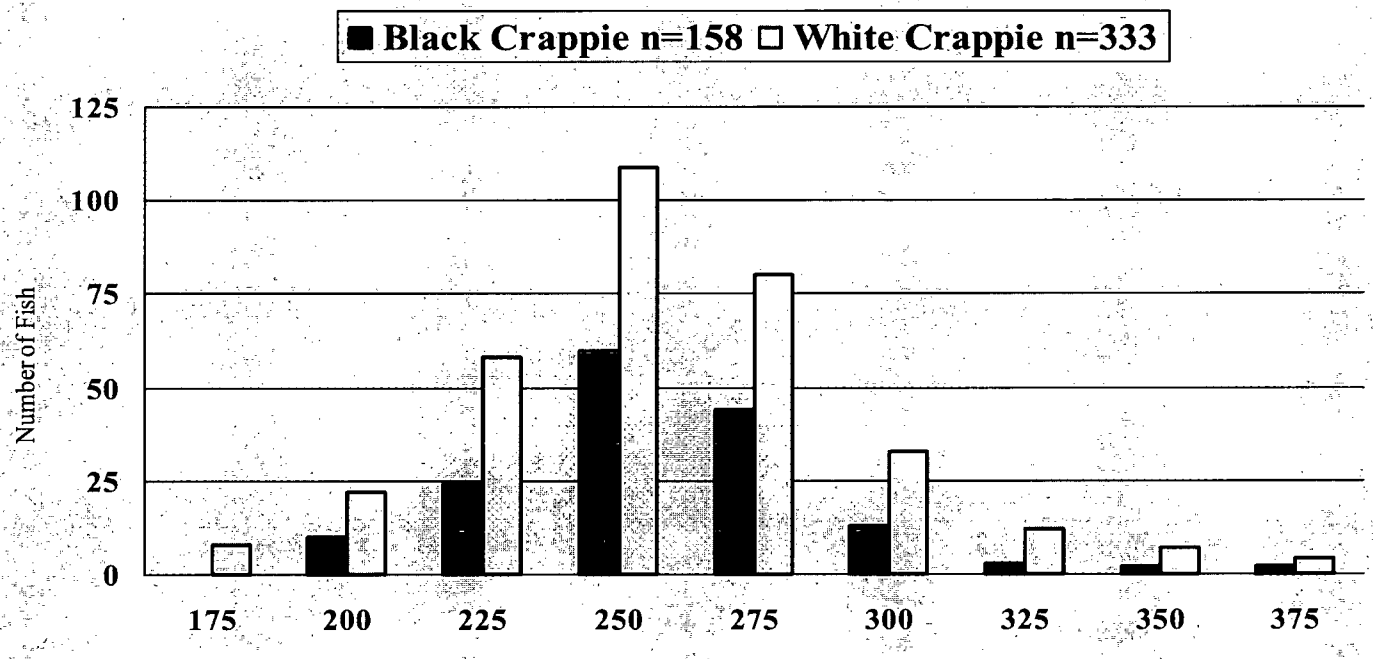


Figure 2-11. Length frequency of angler-harvested black and white crappie from Watts Bar Tailwater, April 1996 through April 1998.

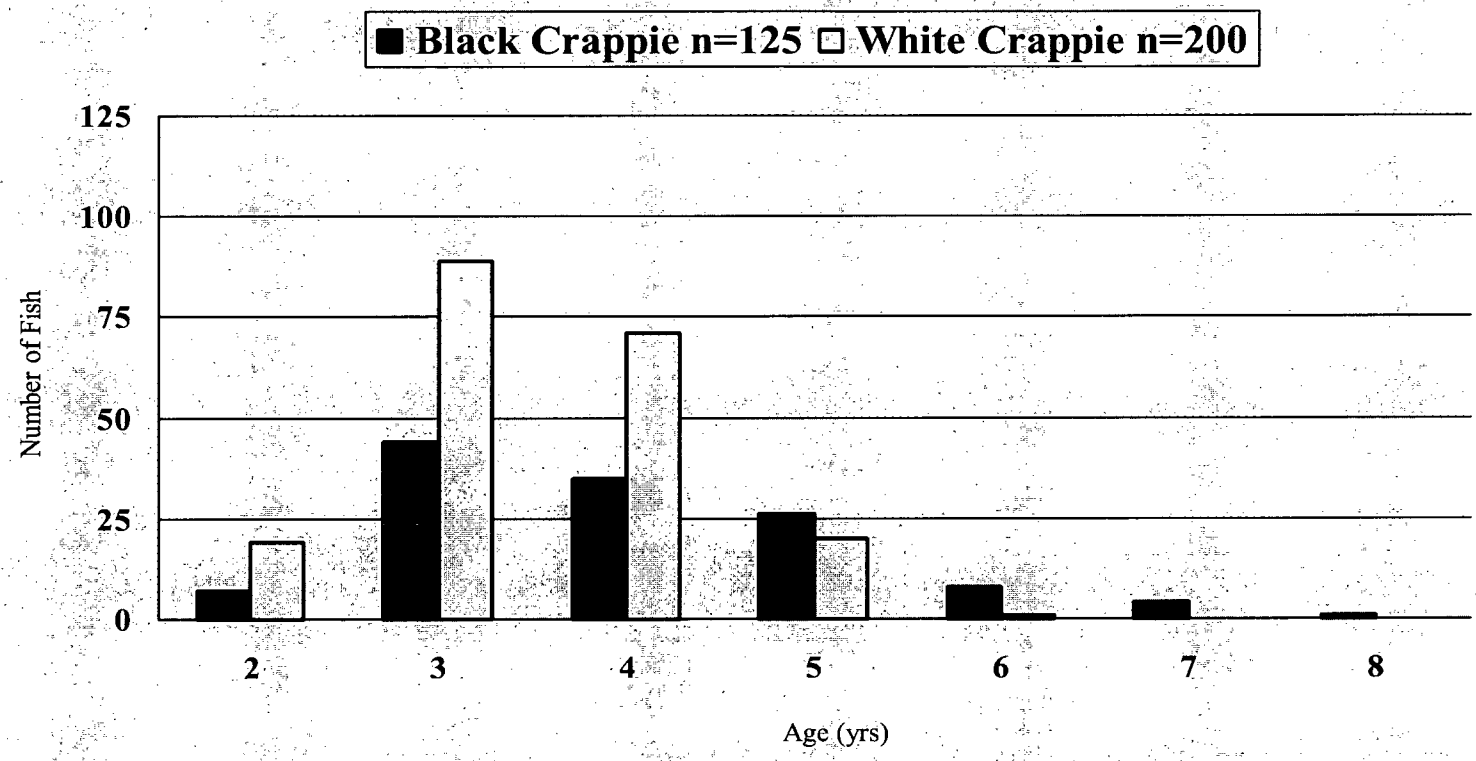


Figure 2-12. Age distribution of angler-harvested black and white crappie from the Watts Bar Tailwater, April 1996 through April 1998.

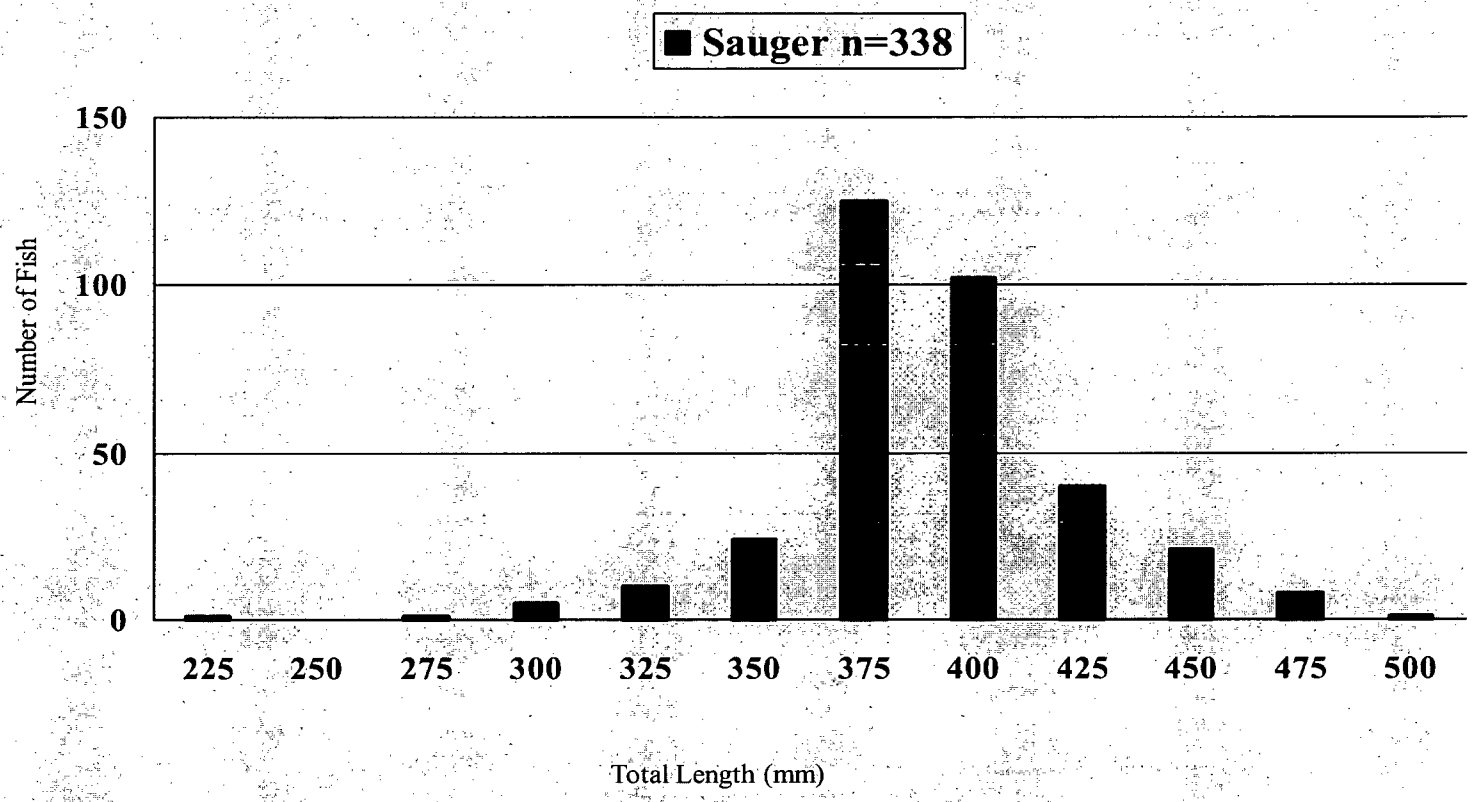


Figure 2-13. Length frequency of angler-harvested sauger from Watts Bar Tailwater, April 1996 through April 1998.

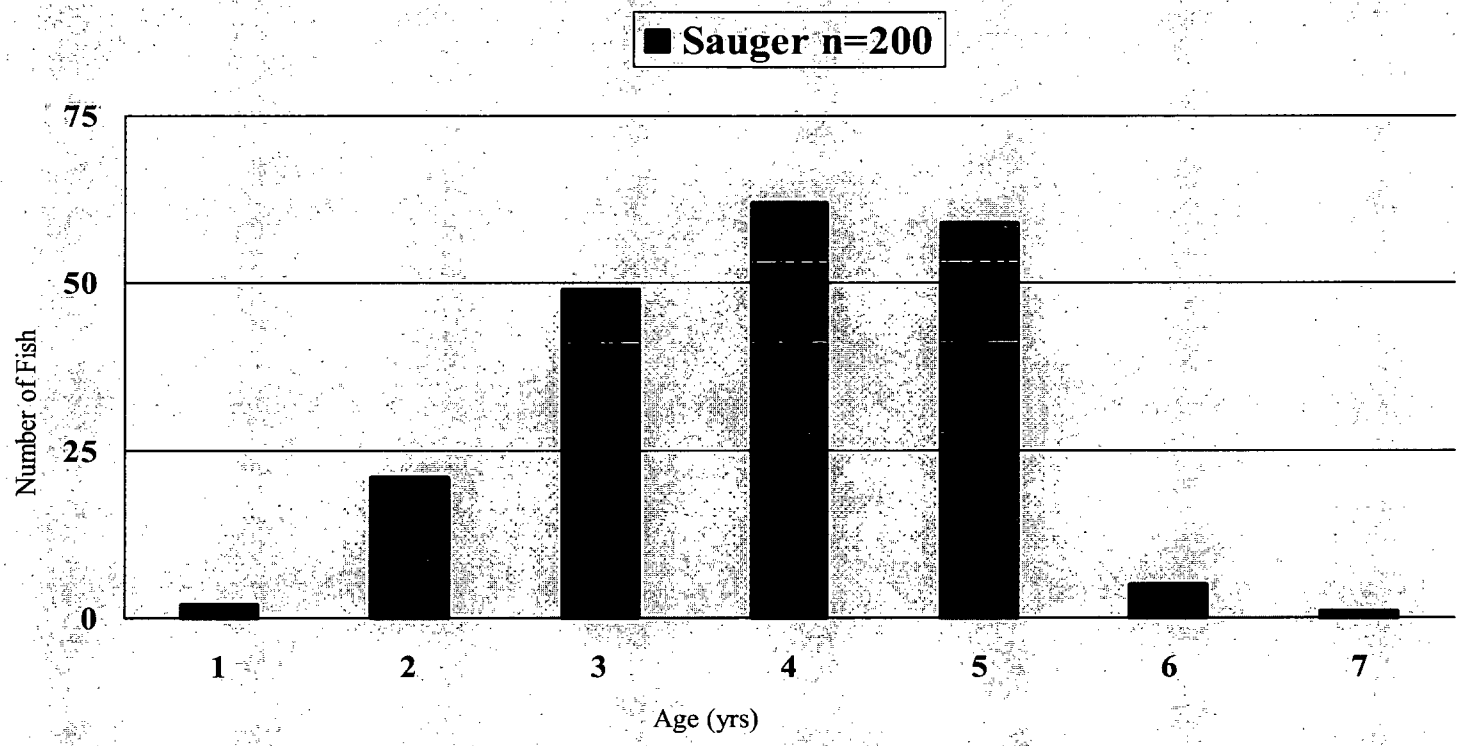


Figure 2-14. Age distribution of angler-harvested sauger from Watts bar Tailwater, April 1996 through April 1998.

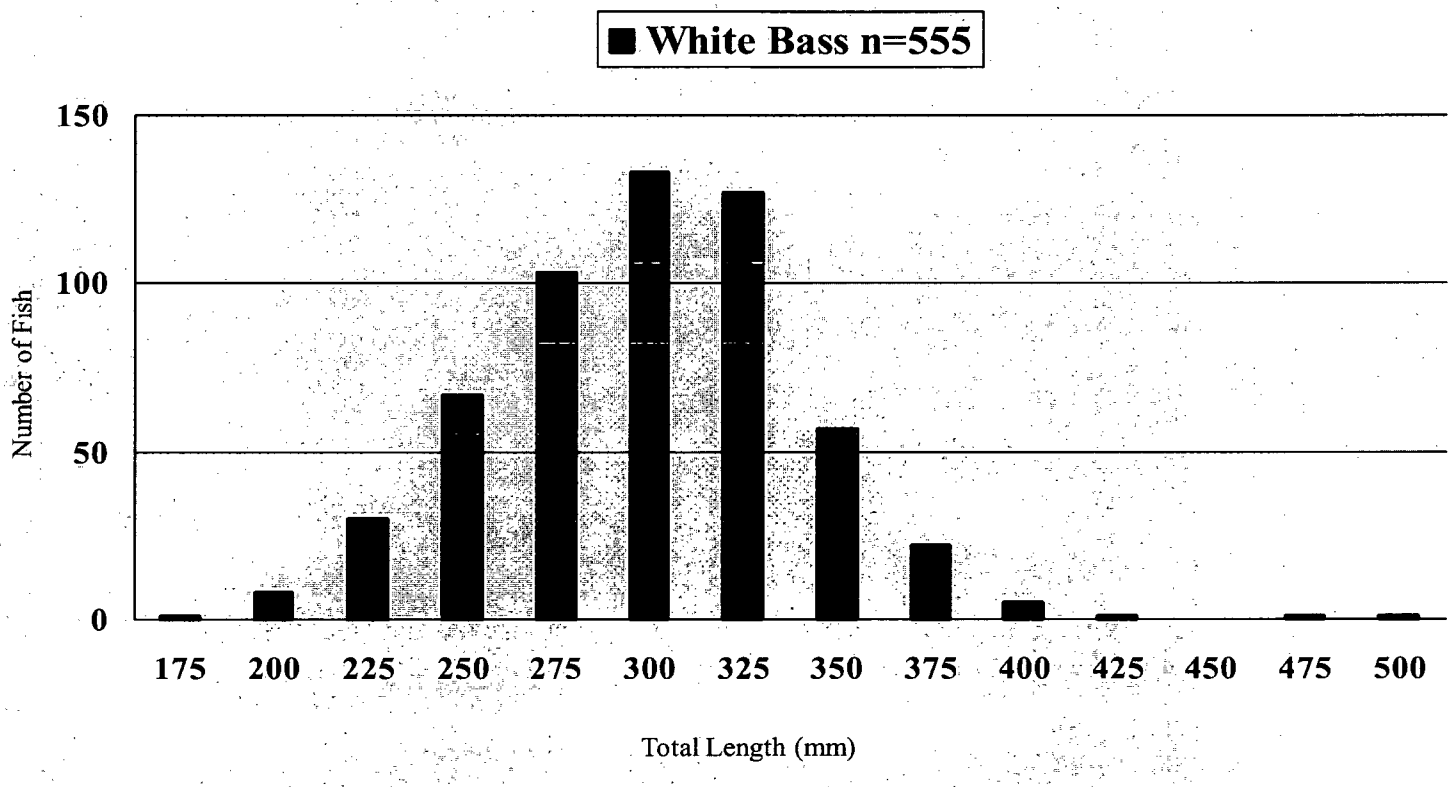


Figure 2-15. Length frequency of angler-harvested white bass from Watts Bar Tailwater, April 1996 through April 1998.

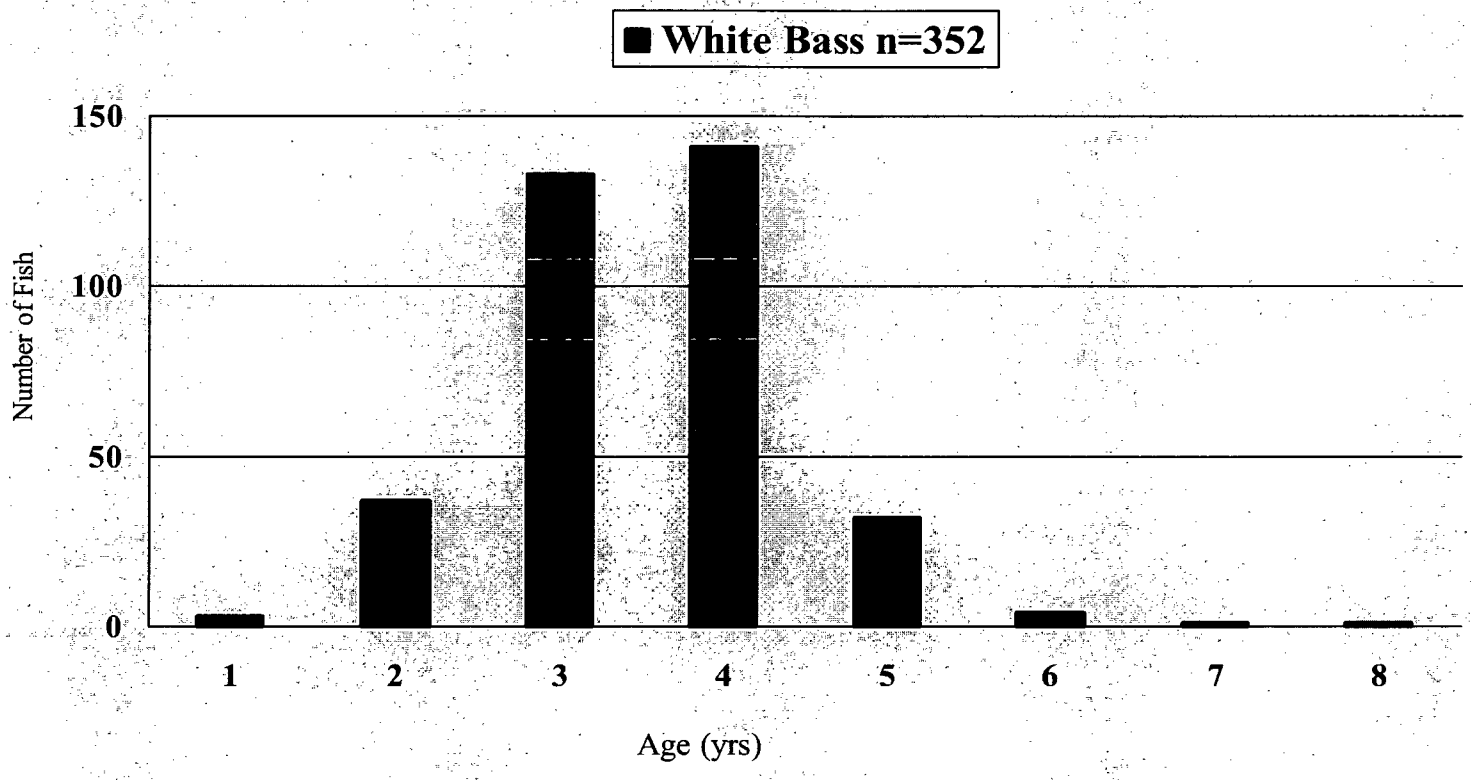


Figure 2-16. Age frequency of angler-harvested white bass from Watts Bar Tailwater, April 1996 through April 1998.

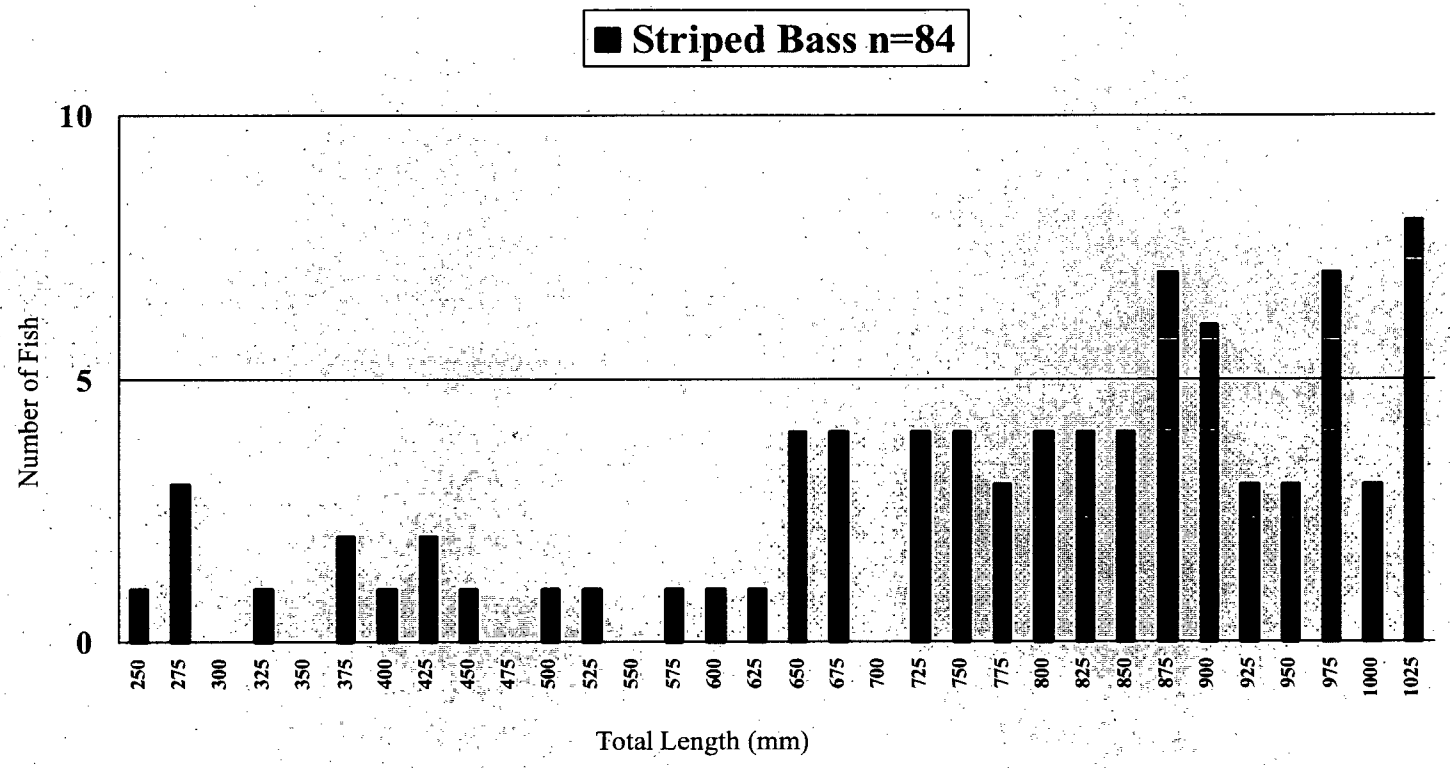


Figure 2-17. Length frequency of angler-harvested striped bass from Watts Bar Tailwaer, April 1996 through April 1998.

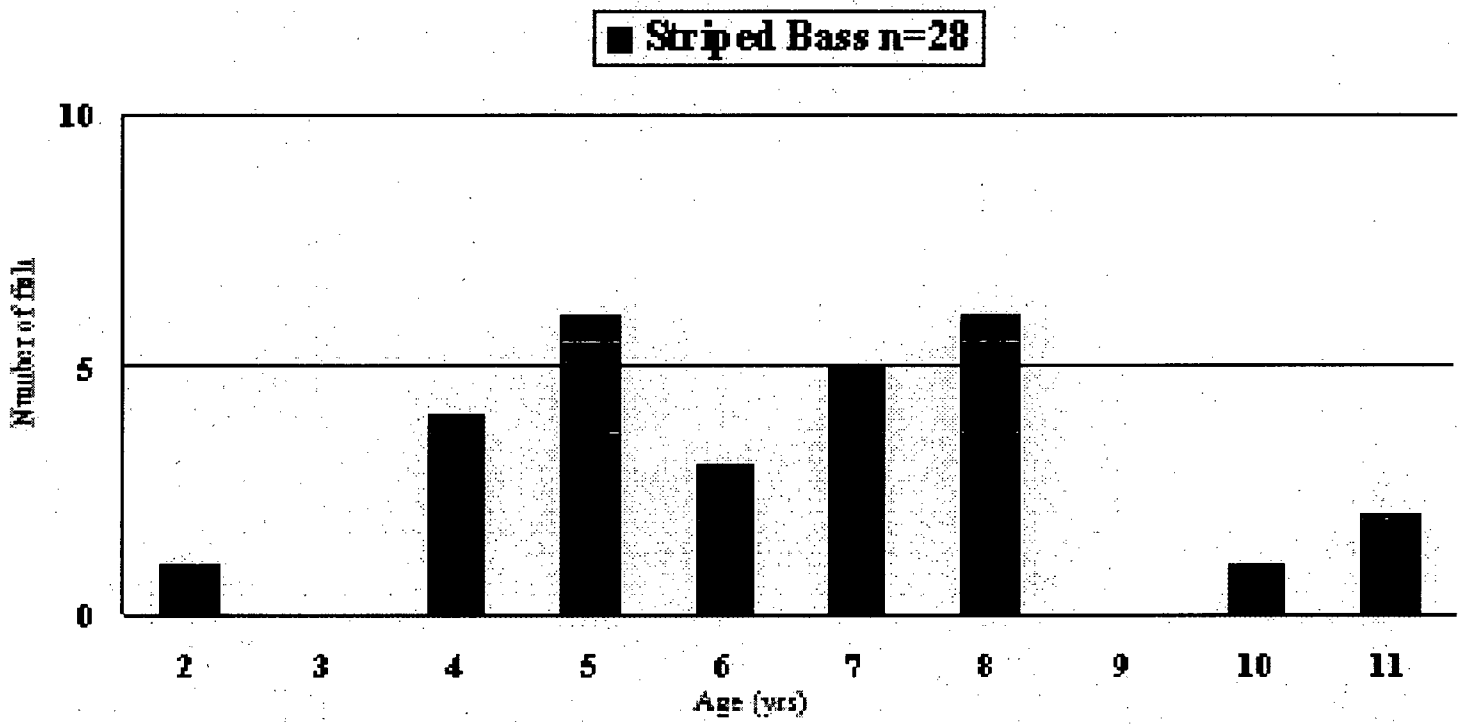


Figure 2-18. Age distribution of angler-harvested striped bass from Watts Bar Tailwater, April 1996 through April 1998.

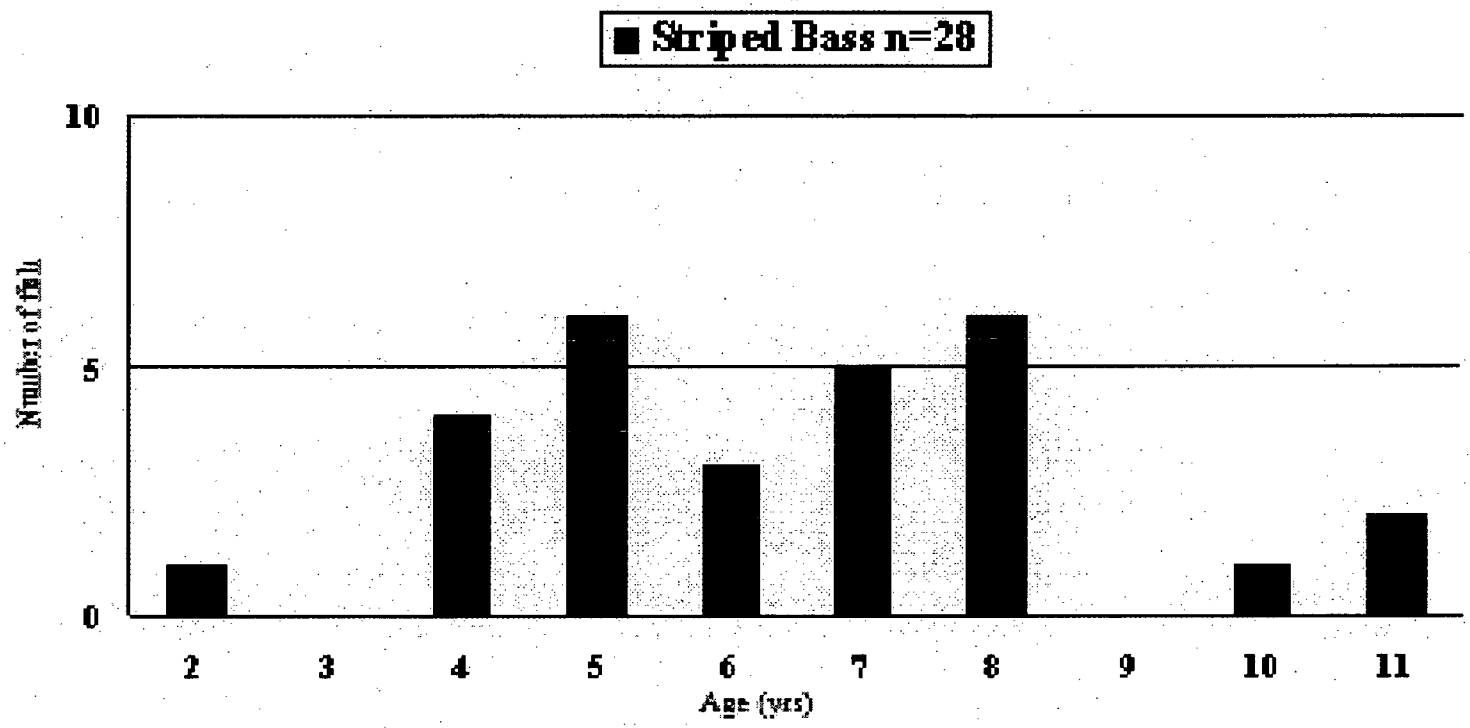


Figure 2-18. Age distribution of angler-harvested striped bass from Watts Bar Tailwater, April 1996 through April 1998.

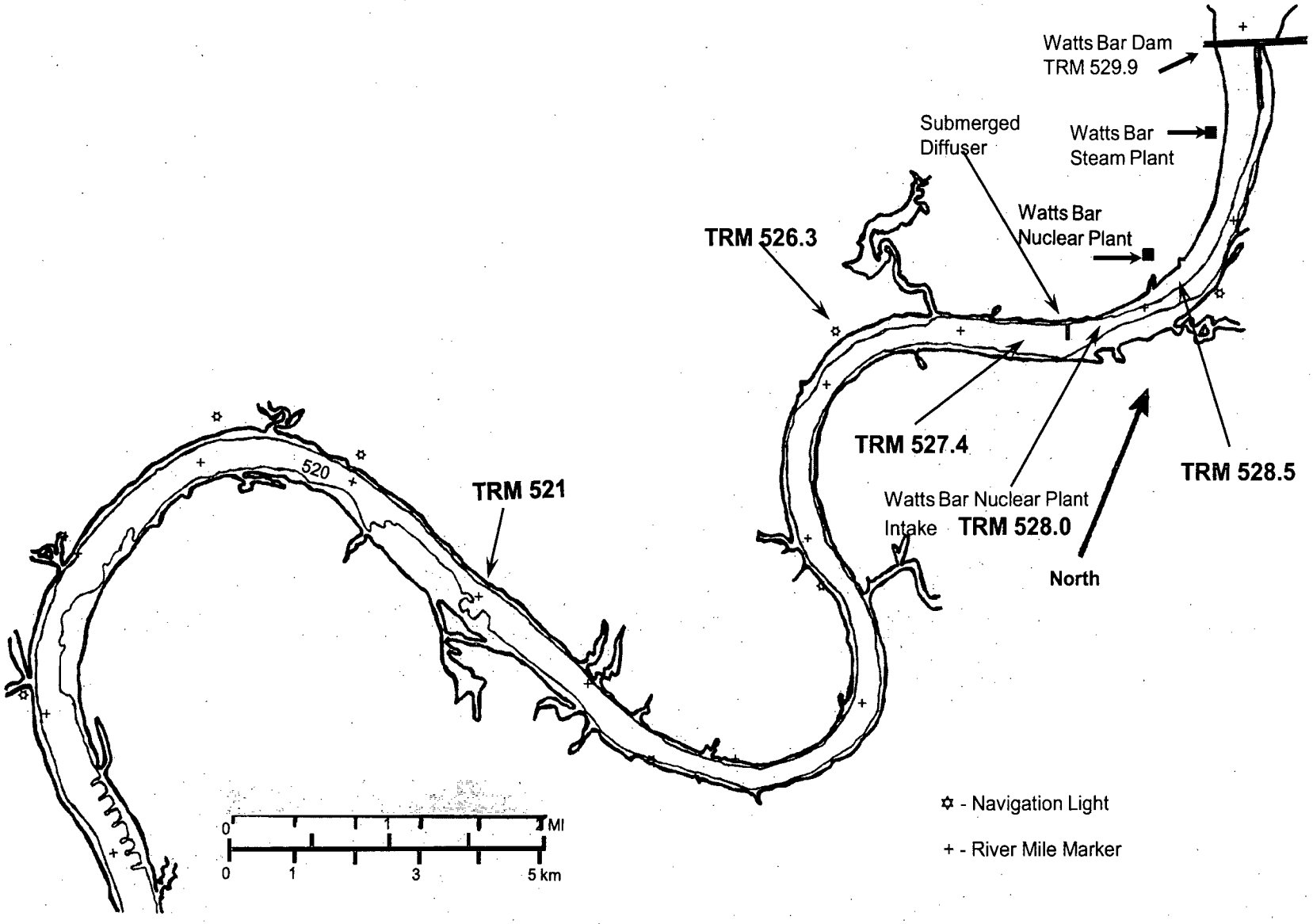


Figure 3-1. Sample locations for benthic macroinvertebrates near Watts Bar Nuclear Plant , 1996-1997.

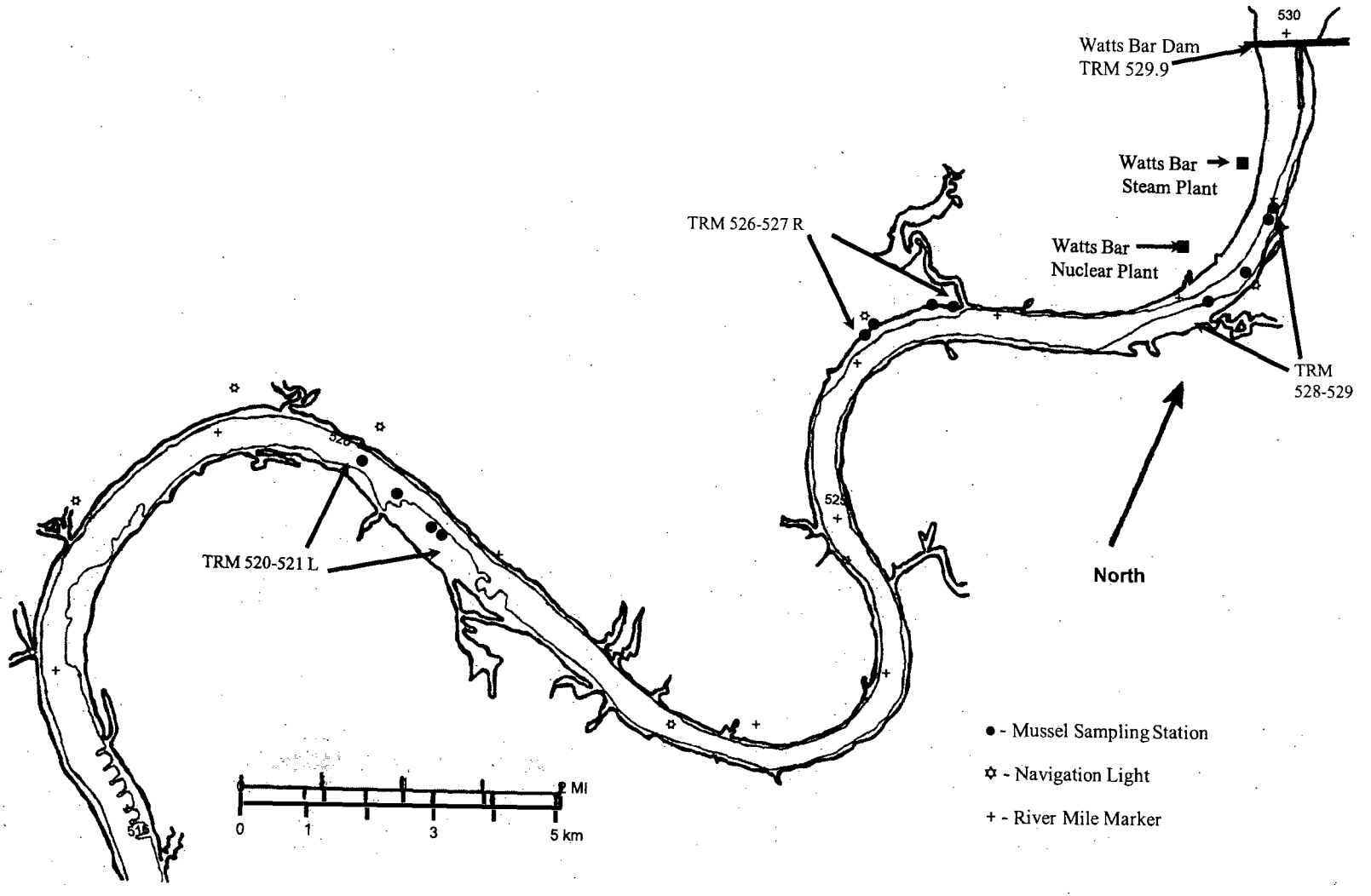


Figure 3-2. Locations of sampling stations at three native mussel beds surveyed during the preoperational (1983-1994) and operational (1996 and 1997) monitoring program for Watts Bar Nuclear Plant.

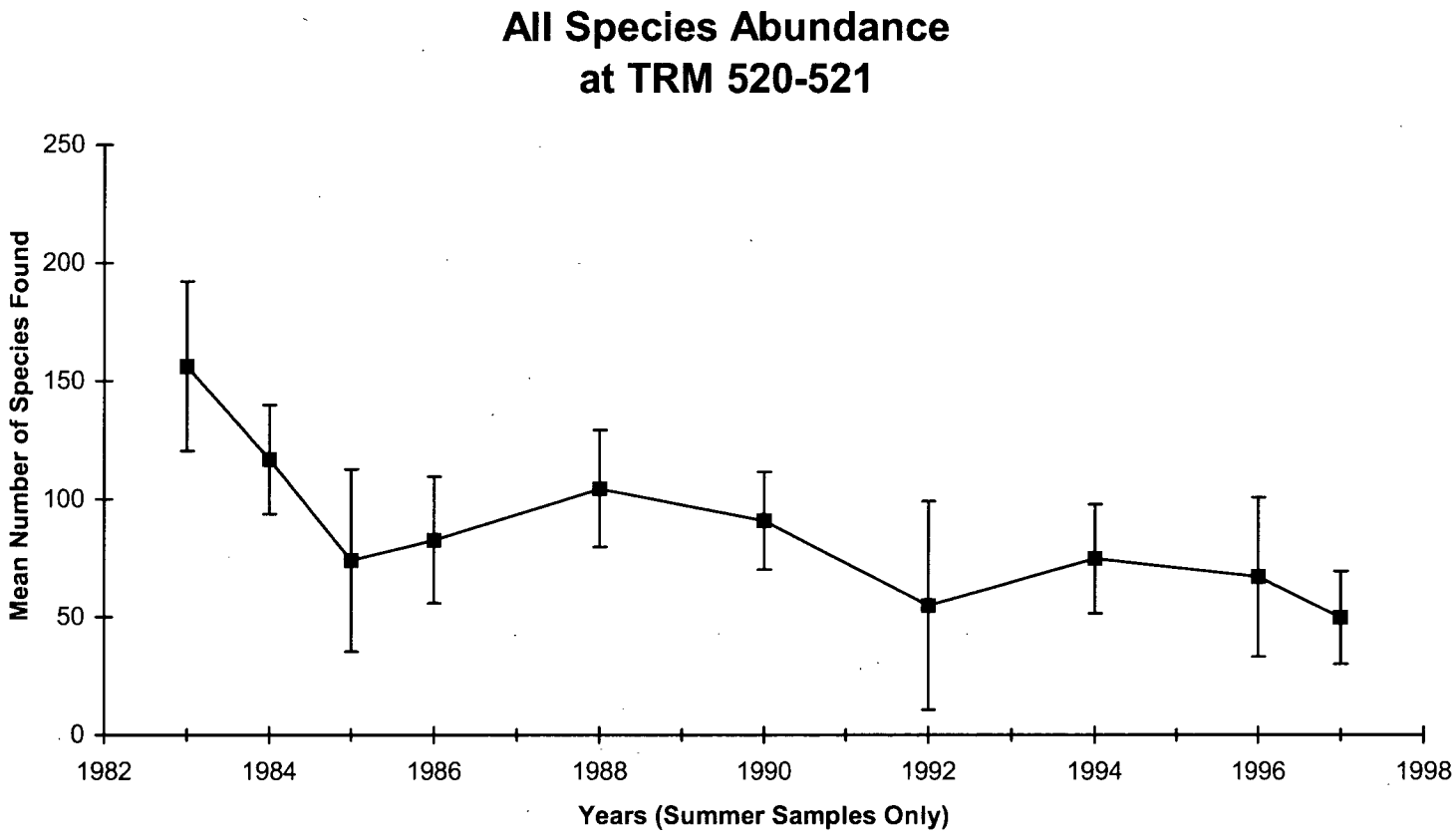


Figure 3-3. Relationships among the mean numbers of all mussel species encountered on the bed at Tennessee River Mile 520-521 during the 10 surveys conducted in the summers of 1983-1997. Vertical bars indicate one standard deviation above and below the mean values.

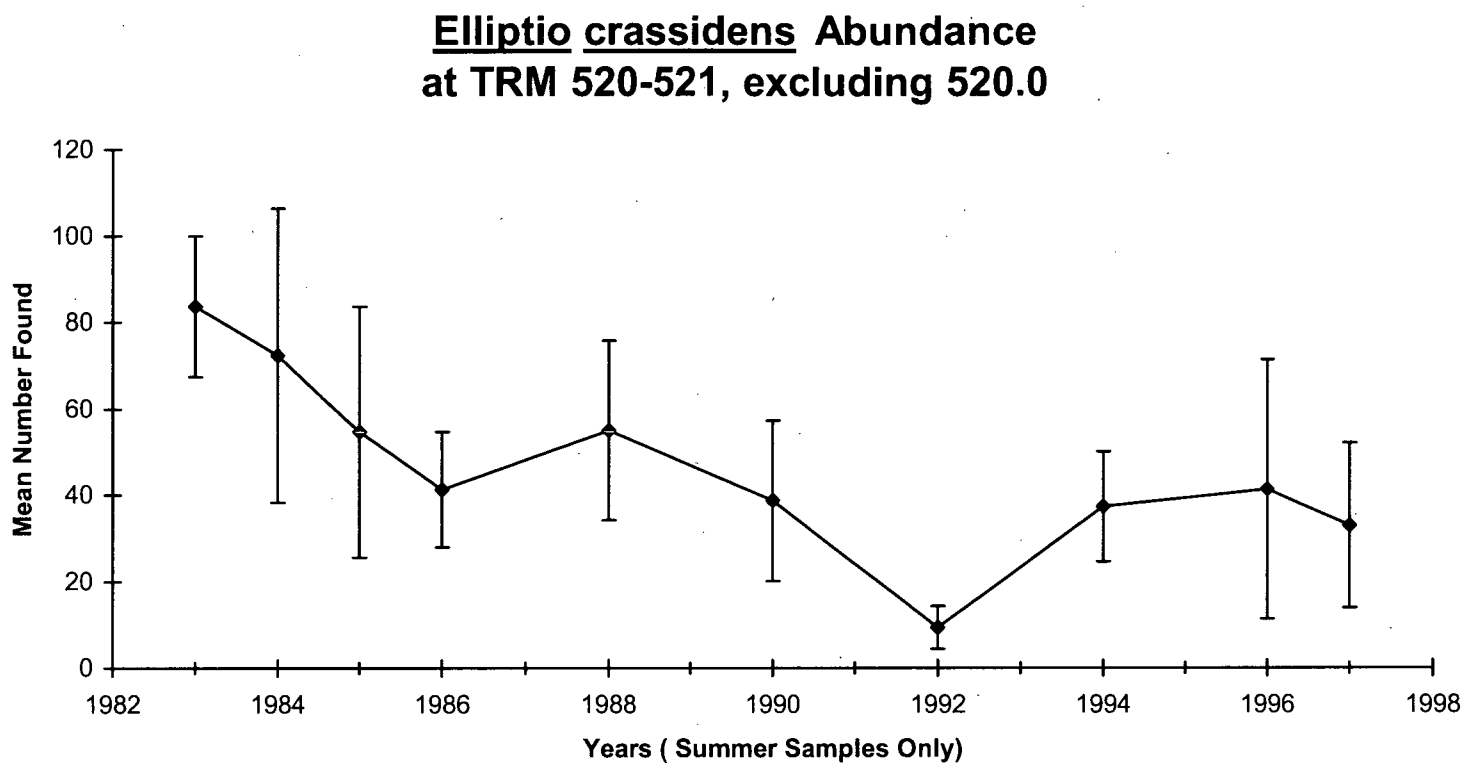


Figure 3-4. Relationships among the mean numbers of Elliptio crassidens encountered on three of the four sampling sites on the mussel bed at Tennessee River Mile 520-521 during the 10 surveys conducted in the summers of 1983-1997. Vertical bars indicate one standard deviation above and below the mean values.

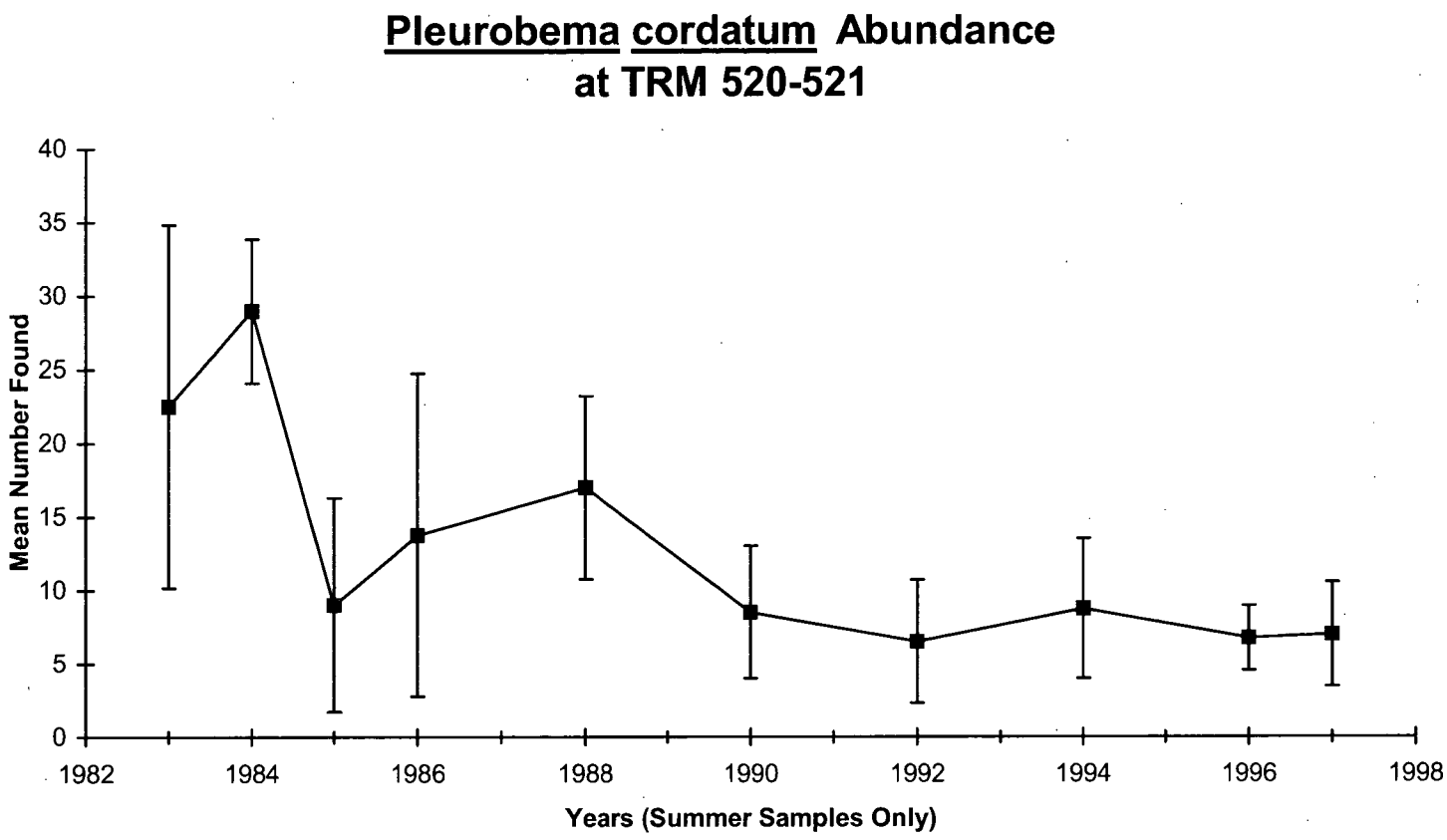


Figure 3-5. Relationships among the mean numbers of Pleurobema cordatum encountered on the mussel bed at Tennessee River Mile 520-521 during the 10 surveys conducted in the summers of 1983-1997. Vertical bars indicate one standard deviation above and below the mean values.

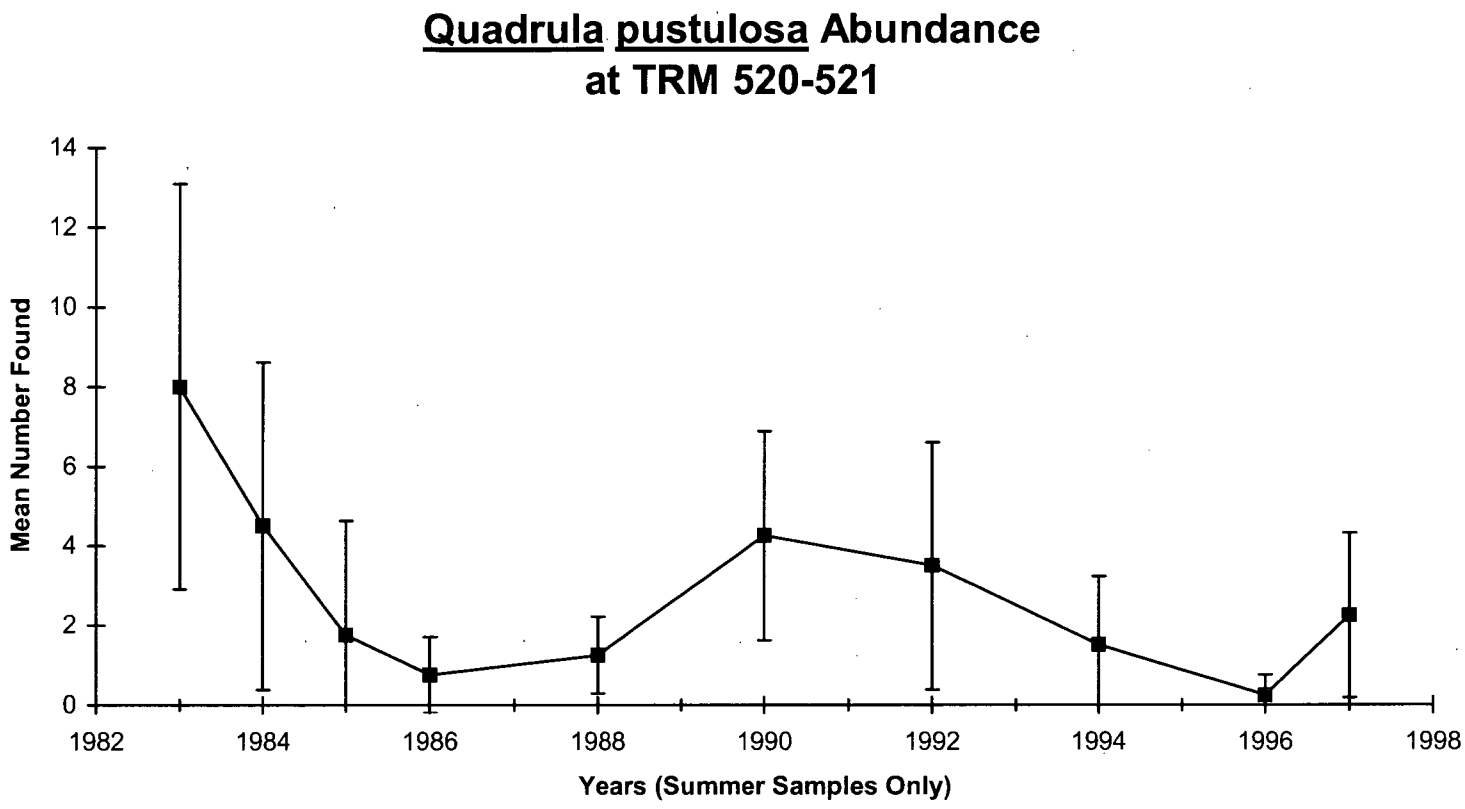


Figure 3-6. Relationships among the mean numbers of Quadrula pustulosa encountered on the mussel bed at Tennessee River Mile 520-521 during the 10 surveys conducted in the summers of 1983-1997. Vertical bars indicate one standard deviation above and below the mean values.

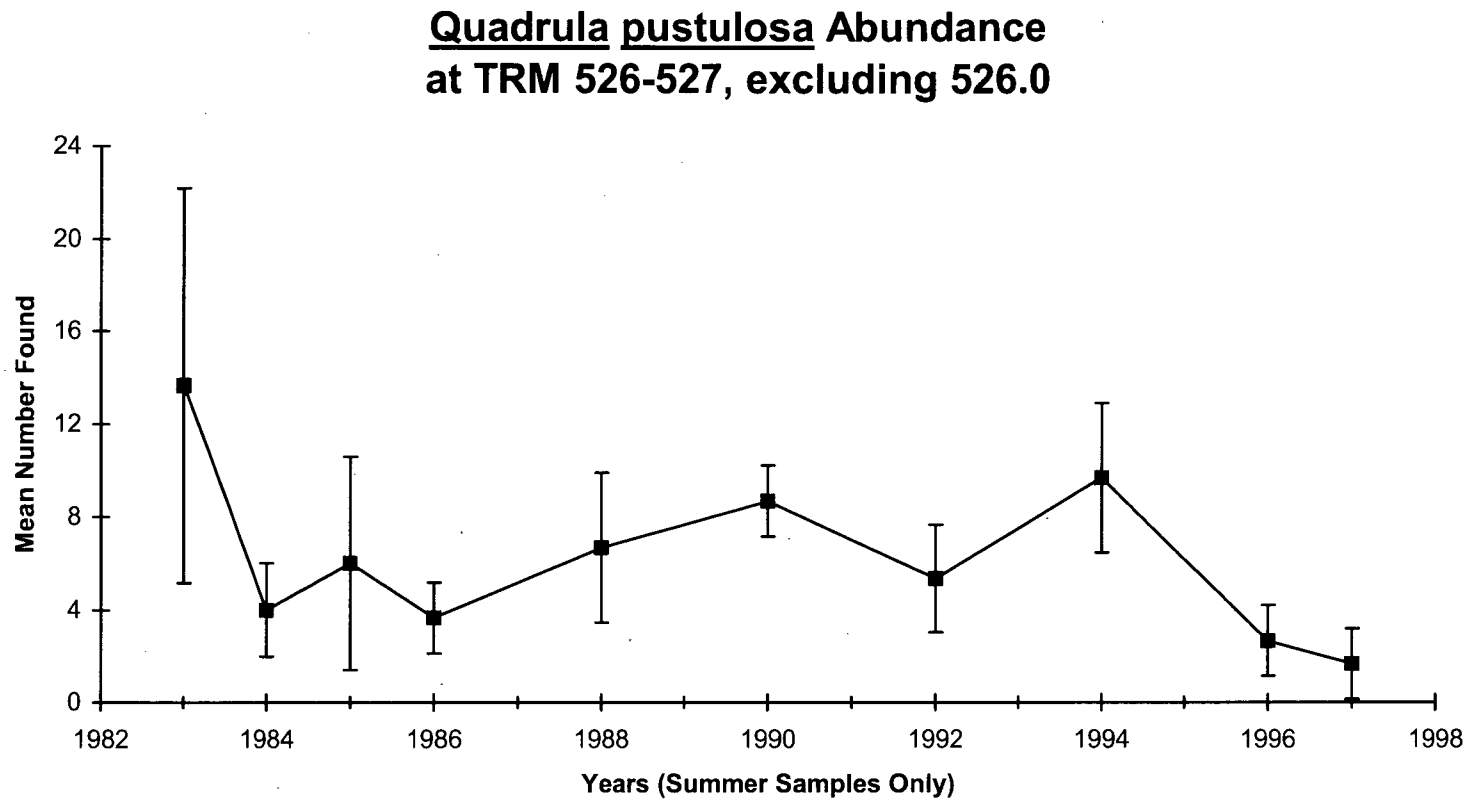


Figure 3-7. Relationships among the mean numbers of Quadrula pustulosa encountered on three of the four sampling sites on the mussel bed at Tennessee River Mile 526-527 during the 10 surveys conducted in the summers of 1983-1997. Vertical bars indicate one standard deviation above and below the mean values.

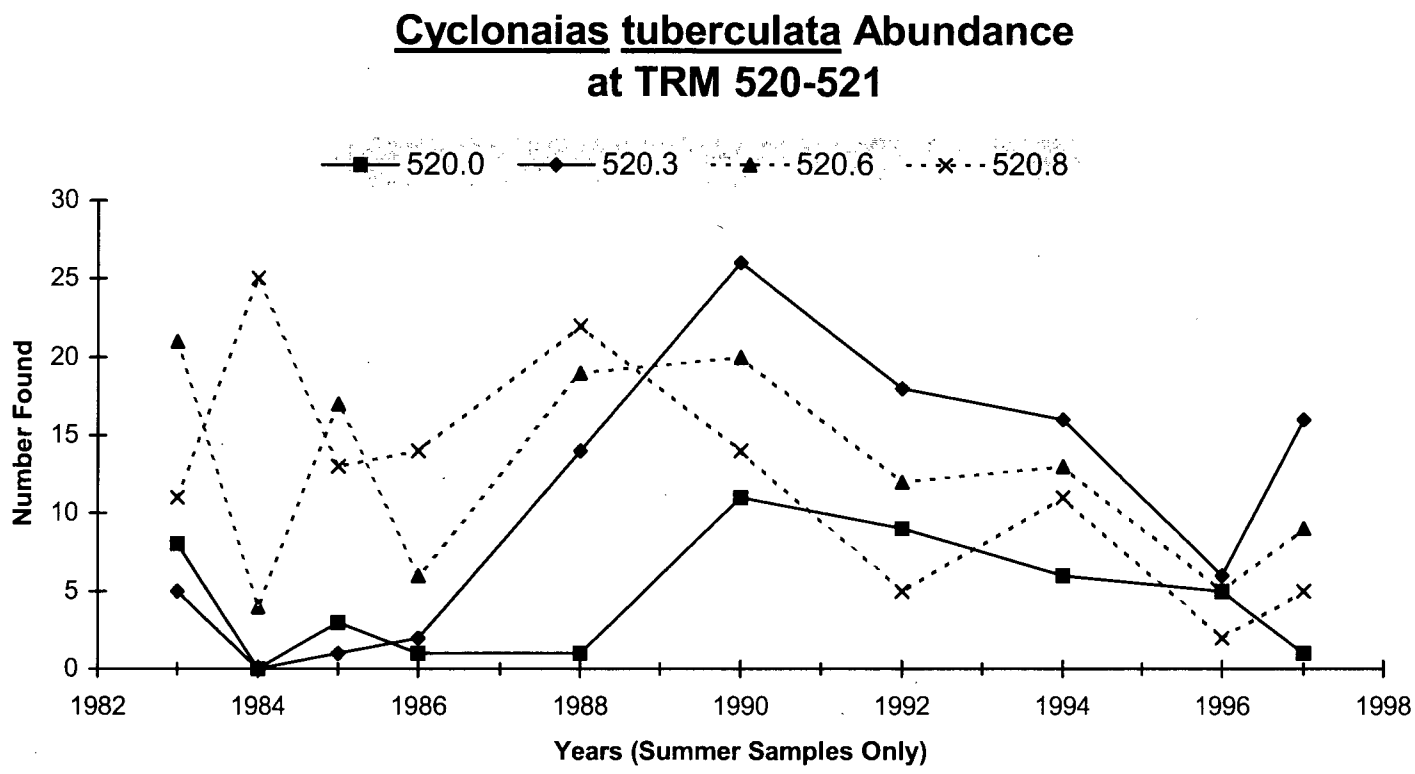


Figure 3-8. Relationships among the numbers of Cyclonaias tuberculata encountered at the four sampling sites on the mussel bed at Tennessee River Mile 520-521 during the 10 surveys conducted in the summers of 1983-1997. While statistically significant trends are present in these data, the slopes of those trends are not parallel with each other.

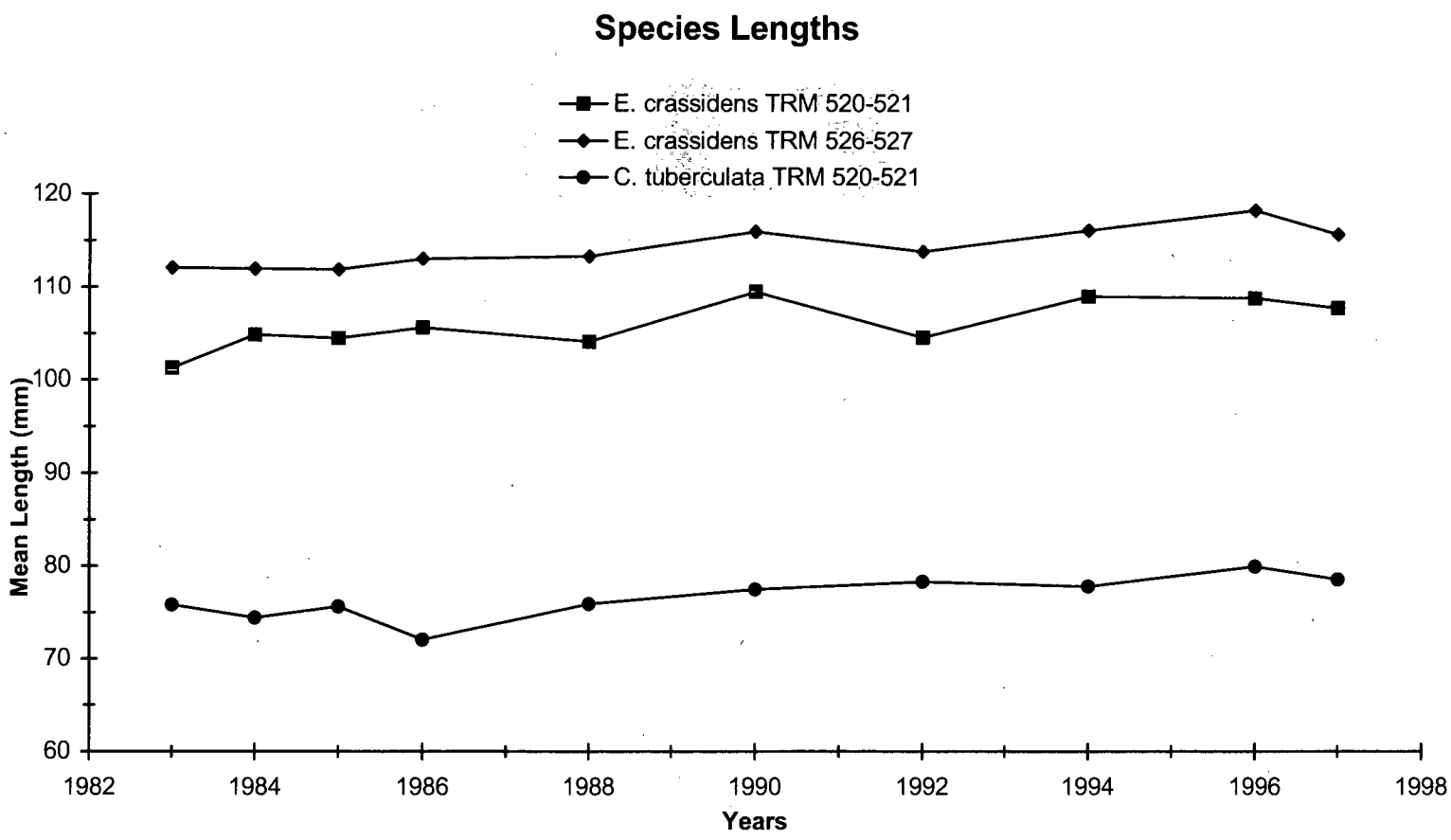


Figure 3-9. Mean lengths of Elliptio crassidens and Cyclonaias tuberculata on the mussel bed at Tennessee River Miles (TRM) 520-521, and Elliptio crassidens on the bed at TRM 526-527 during 1983-1997.

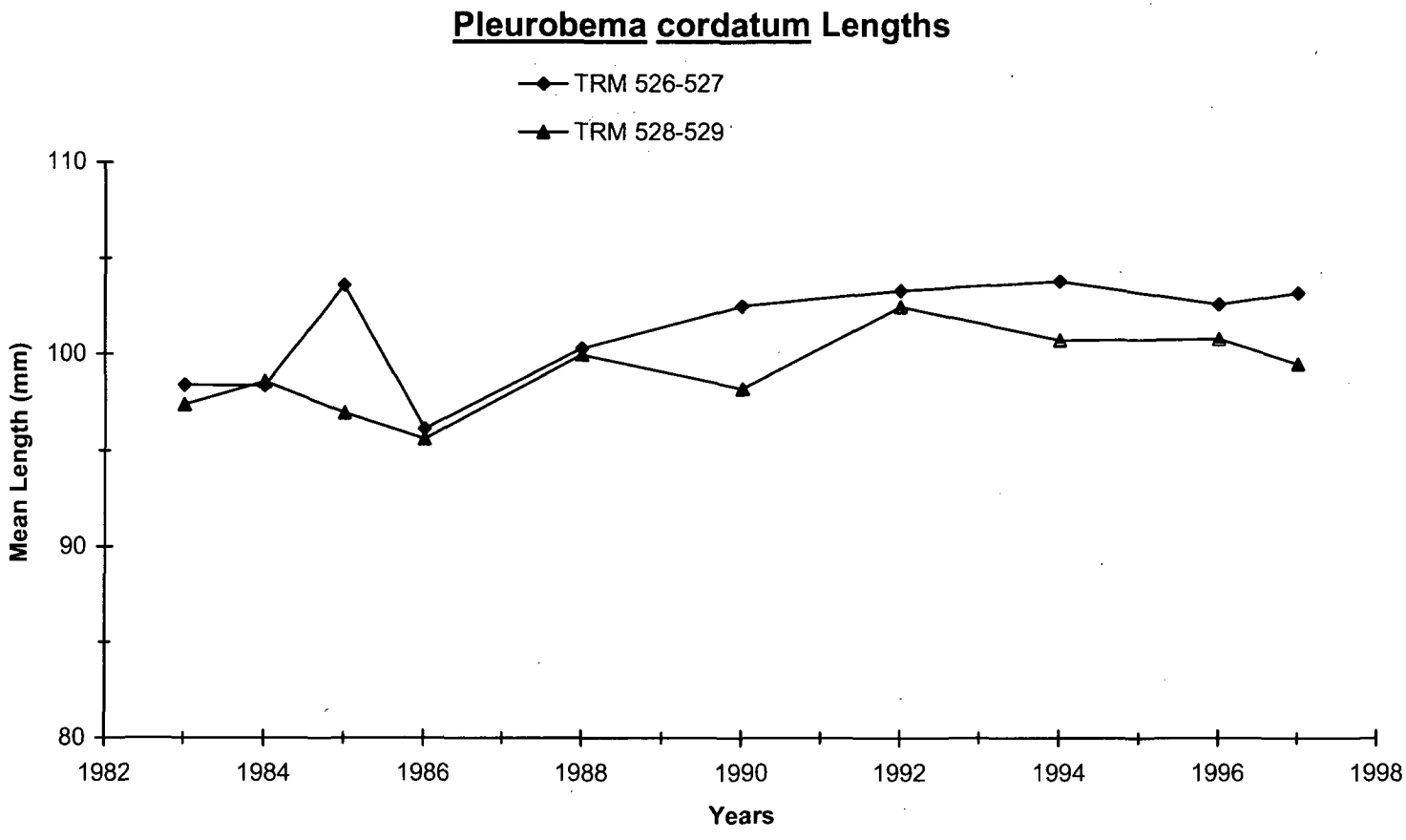


Figure 3-10. Mean lengths of Pleurobema cordatum on two mussel beds, Tennessee River Miles (TRM) 526-527 and TRM 528-529, during 1983-1997.

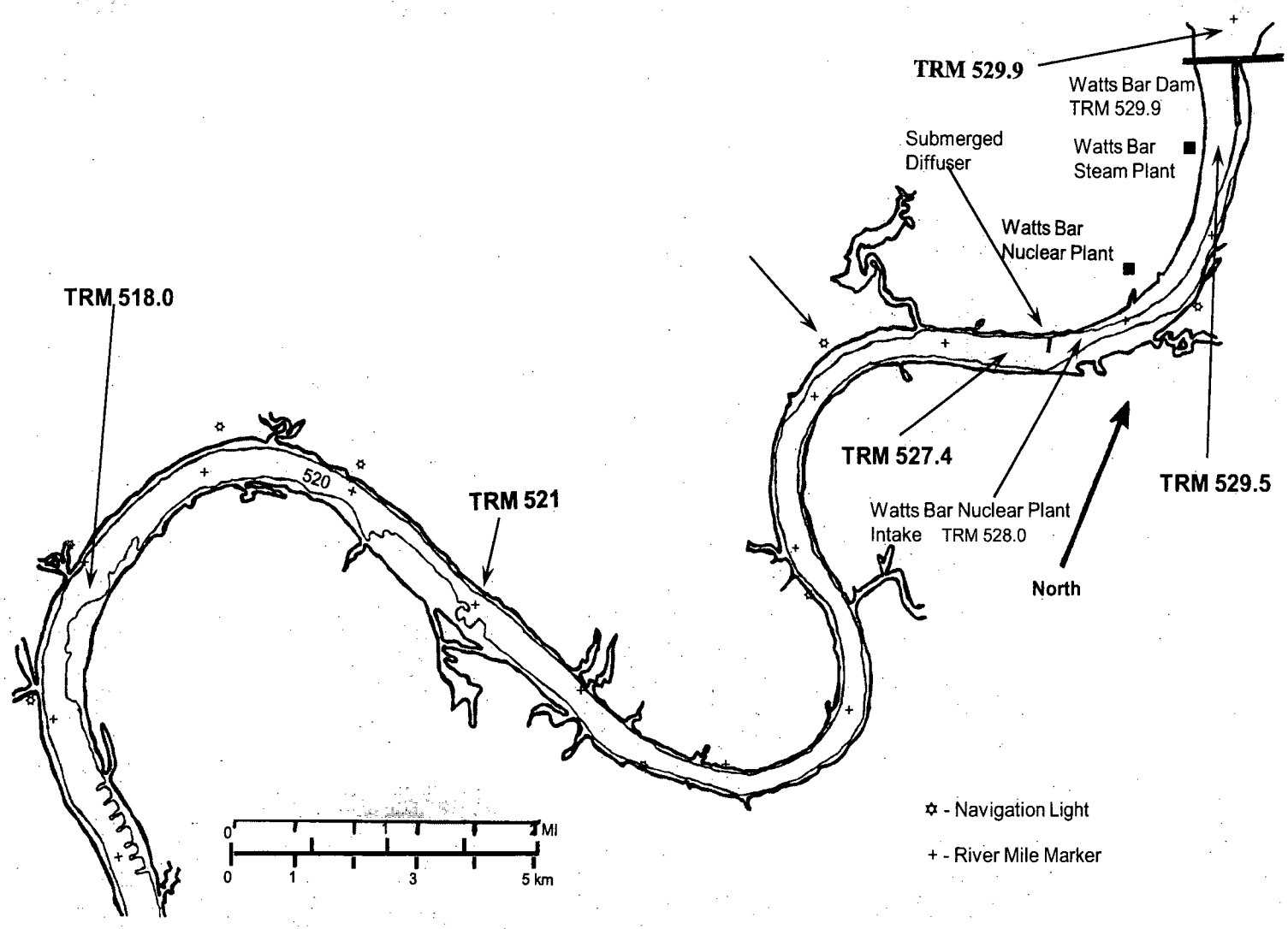


Figure 4-1. Water quality sampling locations during operational monitoring at Watts Bar Nuclear Plant, 1996 and 1997.

Appendices A

Appendix A-1. 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 1996-1997.

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
Taxon										
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
Slavina 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-1. (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
Taxon										
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-1. (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
Taxon										
Heptageniidae				1	1	2			1	1
Stenacron sp.		2							1	
Stenacron interpunctatum	3		1		1	2		7	19	28
Stenonema sp.					1					
Heteroptera										
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-1. (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
Taxon										
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									
Gastropoda										
Mesogastropoda										
Hydrobiidae								1		
Amnicola sp.									1	1
Somatogyrus sp.									1	93
Pleuroceridae										
Leptoxis praerosa						1				
Pleurocera sp.					9					

Appendix A-1. (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
Taxon										
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 A-1. (Continued)

Date	July 1997					October 1997				
Tennessee River Mile	521.0	526.3	527.4	528.0	528.5	521.0	526.3	527.4	528.0	528.5
Taxon										
Nematoda				1			1			
Coelenterata						34		2		21
Hydrozoa										
Hydroida										
Hydridae										
Hydra americana	301	66	24	91	1414	209	210	38	24	245
Turbellaria										
Tricladida										
Planariidae										
Dugesia tigrina	611	1141	1643	1489	1414	1457	750	1132	1093	1906
Oligochaeta										
Haplotaxida										
Naididae					1	4		1	9	10
Dero sp.	1	1				11	98	18	12	12
Nais sp.										1
Pristina leidyi										2
Slavina appendiculata				1				1		
Tubificidae	311	69	162	49	68	430	114	21	187	64
Branchiura sowerbyi	2					39	5		3	
Limnodrilus sp.			25		1					
Limnodrilus hoffmeisteri	36	12	150	4	11	49	26	4	17	4
Lumbriculida										
Lumbriculidae	9	14	15	4	4				6	

Appendix A-1. (Continued)

Date	July 1997					October 1997				
Tennessee River Mile	521.0	526.3	527.4	528.0	528.5	521.0	526.3	527.4	528.0	528.5
Taxon										
Hirudinea		1		1	1					6
Rhynchobdellida										
Glossiphoniidae		1	3	14						
Helobdella sp.				2			1			
Helobdella triserialis				13	3	5	2	1	5	2
Pharyngobdellida										
Erpobdellidae	3	2	7	6	8	67	5	39	21	8
Erpobdella sp.			1	1						
Crustacea										
Isopoda										
Asellidae										
Caecidotea sp.		1	2	12	84				3	8
Amphipoda										
Gammaridae										
Gammarus sp.	734	574	937	1178	1485	492	77	113	110	277
Gammarus minus	138				207					
Insecta										
Odonata										
Coenagrionidae						1			1	
Corduliidae										
Neurocordulia molesta										1
Ephemeroptera										
Heptageniidae						1			1	
Stenacron interpunctatum						1		2		3
Leptophlebiidae										
Paraleptophlebia sp.							1			

Appendix A-1. (Continued)

Date	July 1997					October 1997				
Tennessee River Mile	521.0	526.3	527.4	528.0	528.5	521.0	526.3	527.4	528.0	528.5
Taxon										
Trichoptera	1									
Hydropsychidae					1				4	1
Cheumatopsyche sp.	3	3	2	7	20				1	3
Leptoceridae					3					
Ceraclea sp.		5	4	2	3	2				
Polycentropodidae										
Cyrnellus fraternus	2			3	5	21	35	548	514	340
Diptera										
Chironomidae	16	5	5	12	8	1	2	2	6	1
Ablabesmyia annulata										1
Ablabesmyia sp.		1							1	
Ablabesmyia mallochi				1						
Ablabesmyia parajanta		1								
Clinotanypus pinguis.					1					
Cricotopus bicinctus	1									
Cryptochironomus fulvus	26	11	7			5	2		1	
Dicrotendipes sp.	60	129	51	29	35	38	56	49	82	46
Glyptotendipes sp.	15	70	15	9	10	1	3	6	18	
Nanocladius sp.	7	9	6	48	83	64	87	85	133	74
Parachironomus sp.	41	10	14	47	50	19	40	15	22	55
Paratanytarsus sp.										6
Paratendipes sp.	4									
Polypedilum sp.		1								
Polypedilum convictum				1						
Polypedilum illinoense	1			1						
Procladius sp.		1	1							
Pseudochironomus sp.		1								
Rheotanytarsus sp.	1		2	5		1		1	1	

Appendix A-1. (Continued)

Date	July 1997					October 1997				
Tennessee River Mile	521.0	526.3	527.4	528.0	528.5	521.0	526.3	527.4	528.0	528.5
Taxon										
Synorthocladius semivirens	1									
Tanytarsus sp.			1	1		1				
Thienemanniella xena	1	1								
Thienemannimyia sp.				2						
Coleoptera										
Elmidae										
Dubiraphia sp.						1				
Stenelmis sp.									1	
Gastropoda										
Mesogastropoda										
Hydrobiidae										
Amnicola sp.				3	5			9		
Somatogyrus sp.					11	3		1		16
Pleuroceridae										
Pleurocera canaliculata	175	23	27	1	2	71	17	1	22	
Viviparidae										
Campeloma decisum							1			
Basommatophora										
Ancylidae										
Ferrissia rivularis	20	5	2	3	2	5		3		1
Physidae										
Physella sp.	6	12	50	27	68	2	2	2	2	14
Planorbidae										
Micromenetus dilatatus	1	4	4			1		1		

Appendix A-1. (Continued)

Date	July 1997					October 1997				
Tennessee River Mile	521.0	526.3	527.4	528.0	528.5	521.0	526.3	527.4	528.0	528.5
Taxon										
Bivalvia										
Unionoida										
Unionidae										
Elliptio crassidens	5	1	1		1	3	2	1		3
Lampsilis abrupta			1							
Pleurobema cordatum		1		2	1		1			
Potamilus alatus		1								
Quadrula pustulosa pustu			1	1		1				
Veneroida										
Corbiculidae										
Corbicula fluminea	475	724	1018	2440	1138	290	283	835	992	438
Dreissenidae										
Dreissena polymorpha	6	10	26	65	42	4	13	39	17	72
Sphaeriidae										
Musculium transversum		15		20	37		1	11	12	8
Number of samples	10	10	10	10	10	10	10	10	10	10
Sum (Total number)	3014	2926	4207	5596	6226	3335	1835	2981	3321	3649
Number of species	32	35	31	38	33	35	27	29	31	32

Appendix A-2. Results of 14 native mussel surveys at 12 sites in the vicinity of Watts Bar Nuclear Plant, 1983-1997.

September 13-14,1983					Bed					Bed					Bed	Survey	
Species	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	Total	Percent
Elliptio crassidens	163	71	78	102	414	21	65	12	34	132	53	43	69	43	208	754	56.23
Pleurobema cordatum	17	41	16	16	90	17	82	7	3	109	12	18	20	15	65	264	19.69
Quadrula pustulosa	8	3	6	15	32	4	22	14	5	45	6	5	9	2	22	99	7.38
Cyclonaias tuberculata	8	5	21	11	45	3	7	4	4	18	5	8	8	4	25	88	6.56
Ellipsaria lineolata	2	3	2	8	15	1	4	2	1	8	0	1	0	0	1	24	1.79
Amblema plicata	0	0	1	0	1	0	5	5	5	15	0	1	1	0	2	18	1.34
Anodonta grandis	0	0	0	0	0	4	1	3	6	14	0	0	1	3	4	18	1.34
Obliquaria reflexa	1	0	0	0	1	0	4	6	2	12	0	1	0	0	1	14	1.04
Potamilus alatus	2	1	3	0	6	3	0	1	3	7	0	0	1	0	1	14	1.04
Quadrula metanevra	1	0	5	2	8	2	0	2	0	4	1	1	0	0	2	14	1.04
Ligumia recta	1	1	0	1	3	0	0	0	1	1	0	1	1	0	2	6	0.45
Tritogonia verrucosa	0	0	0	0	0	2	1	0	2	5	0	0	1	0	1	6	0.45
Elliptio dilatata	1	0	1	1	3	0	0	0	0	0	0	0	0	1	1	4	0.30
Actinonaias ligamentina	1	0	0	0	1	0	1	0	0	1	0	1	0	0	1	3	0.22
Lampsilis abrupta	0	0	0	0	0	0	1	0	0	1	0	1	1	0	2	3	0.22
Lampsilis ovata	1	0	1	0	2	0	0	0	0	0	0	0	1	0	1	3	0.22
Cyprogenia stegaria	0	0	1	0	1	0	0	0	0	0	0	0	1	0	1	2	0.15
Fusconaia subrotunda	0	0	0	1	1	0	0	0	0	0	0	0	1	0	1	2	0.15
Megalonaias nervosa	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0	2	0.15
Dromus dromas	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Leptodea fragilis	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0.07
Pleurobema plenum	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Grand Total	206	125	136	158	625	58	194	57	66	375	77	81	115	68	341	1341	100.00
Species Count	12	7	12	10	17	10	12	11	11	16	5	11	13	6	18	22	

Appendix A-2. (Continued)

November 1-2,1983 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	0	145	100	102	347	21	52	26	72	171	54	108	91	65	318	836	58.79
Pleurobema cordatum	32	13	13	24	82	9	24	22	2	57	8	51	46	31	136	275	19.34
Quadrula pustulosa	6	0	6	10	22	4	8	6	0	18	12	7	1	15	35	75	5.27
Cyclonaias tuberculata	5	4	14	15	38	1	8	5	0	14	1	4	4	9	18	70	4.92
Amblema plicata	2	0	3	1	6	6	6	10	2	24	0	1	0	2	3	33	2.32
Ellipsaria lineolata	1	2	4	6	13	1	1	0	3	5	1	7	0	3	11	29	2.04
Potamilus alatus	1	1	3	0	5	7	0	6	7	20	1	1	1	1	4	29	2.04
Quadrula metanevra	5	2	1	2	10	1	2	0	0	3	2	5	1	3	11	24	1.69
Tritogonia verrucosa	0	0	0	0	0	7	0	2	3	12	0	0	0	0	0	12	0.84
Anodonta grandis	0	0	0	0	0	4	0	1	3	8	0	1	1	0	2	10	0.70
Lampsilis abrupta	0	1	1	0	2	0	0	0	0	0	1	1	1	2	5	7	0.49
Obliquaria reflexa	0	0	0	0	0	1	1	2	2	6	0	0	0	0	0	6	0.42
Leptodea fragilis	0	0	1	1	2	0	0	0	0	0	0	0	0	1	1	3	0.21
Ligumia recta	0	1	0	0	1	0	1	0	0	1	0	0	1	0	1	3	0.21
Actinonaias ligamentina	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	2	0.14
Elliptio dilatata	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	2	0.14
Plethobasus cyphyus	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	2	0.14
Cyprogenia stegaria	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.07
Lampsilis ovata	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Megalonaias nervosa	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.07
Pleurobema plenum	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Grand Total	53	172	146	161	532	65	104	80	94	343	81	186	147	133	547	1422	100.00
Species Count	8	11	10	8	15	13	10	9	8	15	9	10	9	11	14	21	

Appendix A-2. (Continued)

July 11-12, 1984 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	110	63	15	44	232	9	33	21	18	81	11	88	195	172	466	779	61.34
Pleurobema cordatum	33	27	24	23	107	4	7	1	0	12	3	18	55	25	101	220	17.32
Quadrula pustulosa	4	0	13	10	27	8	2	6	4	20	5	13	9	11	38	85	6.69
Cyclonaias tuberculata	0	4	33	25	62	0	0	2	0	2	0	3	6	0	9	73	5.75
Ellipsaria lineolata	1	2	7	3	13	2	1	0	1	4	1	4	2	0	7	24	1.89
Amblema plicata	0	0	4	0	4	4	1	7	0	12	1	1	1	0	3	19	1.50
Potamilus alatus	0	2	3	2	7	2	1	0	6	9	0	1	1	0	2	18	1.42
Quadrula metanevra	0	2	2	2	6	0	0	1	0	1	0	2	2	0	4	11	0.87
Obliquaria reflexa	0	0	1	0	1	1	0	5	1	7	0	0	0	0	0	8	0.63
Lampsilis abrupta	0	1	0	0	1	1	1	0	0	2	0	0	2	1	3	6	0.47
Anodonta grandis	0	0	0	0	0	1	2	2	0	5	0	0	0	0	0	5	0.39
Tritogonia verrucosa	0	0	1	0	1	3	0	0	0	3	0	1	0	0	1	5	0.39
Leptodea fragilis	0	0	0	0	0	0	1	0	2	3	0	1	0	0	1	4	0.31
Ligumia recta	2	0	0	0	2	0	0	0	0	0	0	0	2	0	2	4	0.31
Actinonaias ligamentina	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	2	0.16
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0.16
Pleurobema plenum	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	2	0.16
Elliptio dilatata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.08
Lampsilis ovata	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.08
Ptychobranchus fasciolaris	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.08
Grand Total	151	101	106	109	467	35	49	45	32	161	23	133	275	211	642	1270	100.00
Species Count	6	7	12	7	15	10	9	8	6	13	7	11	10	5	15	20	

Appendix A-2. (Continued)

November 1-2, 1984 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	128	58	92	102	380	41	60	36	67	204	18	31	200	151	400	984	71.93
Pleurobema cordatum	12	13	25	20	70	3	27	0	1	31	3	12	25	15	55	156	11.40
Cyclonaias tuberculata	2	11	20	10	43	1	3	1	0	5	1	0	11	2	14	62	4.53
Quadrula pustulosa	3	7	7	9	26	0	7	1	1	9	1	0	10	7	18	53	3.87
Potamilus alatus	1	0	2	4	7	4	0	2	8	14	3	4	1	0	8	29	2.12
Ellipsaria lineolata	0	1	6	3	10	2	2	0	4	8	1	1	4	1	7	25	1.83
Quadrula metanevra	0	4	1	3	8	0	0	0	0	0	1	0	4	0	5	13	0.95
Amblema plicata	0	1	0	1	2	1	1	0	2	4	2	0	2	1	5	11	0.80
Ligumia recta	0	0	1	2	3	0	0	0	0	0	0	5	1	1	7	10	0.73
Tritogonia verrucosa	0	0	0	0	0	2	0	1	0	3	1	1	0	0	2	5	0.37
Anodonta grandis	0	0	0	0	0	2	0	0	1	3	0	0	0	1	1	4	0.29
Lampsilis ovata	0	0	0	0	0	0	0	1	0	1	0	3	0	0	3	4	0.29
Obliquaria reflexa	0	0	0	0	0	0	1	1	0	2	0	0	0	1	1	3	0.22
Anodonta imbecillis	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	2	0.15
Lampsilis abrupta	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	2	0.15
Leptodea fragilis	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	2	0.15
Cyprogenia stegaria	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Elliptio dilatata	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Megalonaias nervosa	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.07
Grand Total	146	96	156	154	552	56	104	44	85	289	31	57	259	180	527	1368	100.00
Species Count	5	8	10	9	12	8	10	8	8	15	9	7	10	9	14	19	

Appendix A-2. (Continued)

July 31-August 1, 1985 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	39	41	35	88	203	38	25	8	24	95	44	91	150	155	440	738	69.43
Pleurobema cordatum	1	13	5	17	36	2	18	2	1	23	5	11	13	25	54	113	10.63
Cyclonaias tuberculata	3	1	17	13	34	0	5	1	1	7	0	5	11	3	19	60	5.64
Quadrula pustulosa	0	0	1	6	7	0	11	5	2	18	2	4	15	7	28	53	4.99
Potamilus alatus	0	0	0	3	3	3	0	5	17	25	0	0	5	1	6	34	3.20
Amblema plicata	0	0	0	0	0	0	2	7	0	9	2	0	5	1	8	17	1.60
Ellipsaria lineolata	0	0	3	1	4	0	2	0	0	2	0	0	2	0	2	8	0.75
Anodonta grandis	0	0	0	0	0	1	0	0	0	1	0	1	1	0	2	3	0.28
Obliquaria reflexa	0	0	0	0	0	0	2	4	0	6	0	0	0	1	1	7	0.66
Tritogonia verrucosa	0	0	0	0	0	2	0	2	0	4	0	0	0	0	0	4	0.38
Quadrula metanevra	1	1	2	2	6	0	0	0	0	0	0	0	0	0	0	6	0.56
Lampsilis abrupta	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.09
Leptodea fragilis	0	0	0	0	0	0	0	0	2	2	0	0	1	0	1	3	0.28
Ligumia recta	0	0	0	0	0	0	0	0	0	0	1	1	1	0	3	3	0.28
Megalonaias nervosa	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.09
Actinonaias ligamentina	0	0	0	1	1	0	0	0	0	0	0	0	3	0	3	4	0.38
Lampsilis ovata	1	0	0	0	1	0	0	0	0	0	2	0	2	0	4	5	0.47
Cyprogenia stegaria	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.09
Pleurobema plenum	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.09
Lasmigona complanata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.09
Grand Total	45	56	64	131	296	46	66	34	47	193	56	113	211	194	574	1063	100.00
Species Count	5	4	7	8	10	5	8	8	6	12	6	6	14	8	16	20	

Appendix A-2. (Continued)

October 16-17,1985 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	79	128	73	47	327	23	32	29	32	116	8	70	182	226	486	929	65.10
Pleurobema cordatum	22	17	10	18	67	2	26	3	9	40	0	18	31	21	70	177	12.40
Quadrula pustulosa	2	7	1	9	19	6	5	6	8	25	0	14	16	11	41	85	5.96
Cyclonaias tuberculata	3	7	6	24	40	0	2	1	1	4	2	9	10	1	22	66	4.63
Potamilus alatus	1	1	5	5	12	7	3	14	0	24	0	3	2	2	7	43	3.01
Ellipsaria lineolata	2	0	0	1	3	2	4	2	3	11	0	3	4	6	13	27	1.89
Amblema plicata	1	1	1	0	3	2	1	3	5	11	0	3	5	3	11	25	1.75
Tritogonia verrucosa	0	0	0	1	1	8	1	2	2	13	1	0	0	0	1	15	1.05
Quadrula metanevra	0	0	1	4	5	2	1	0	0	3	0	0	0	2	2	10	0.70
Ligumia recta	0	1	2	1	4	0	0	1	0	1	0	0	2	1	3	8	0.56
Actinonaias ligamentina	2	0	2	0	4	0	0	0	0	0	0	1	2	0	3	7	0.49
Anodonta grandis	0	0	0	0	0	4	0	0	1	5	0	1	0	1	2	7	0.49
Lampsilis abrupta	0	1	1	0	2	0	0	0	0	0	0	1	4	0	5	7	0.49
Obliquaria reflexa	1	0	0	0	1	1	0	1	0	2	1	0	1	0	2	5	0.35
Lampsilis ovata	0	0	0	0	0	0	2	0	0	2	0	0	2	0	2	4	0.28
Megalonaias nervosa	0	1	0	1	2	0	0	0	0	0	0	0	0	2	2	4	0.28
Pleurobema rubrum	0	1	0	0	1	0	0	0	0	0	0	1	1	0	2	3	0.21
Elliptio dilatata	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	2	0.14
Leptodea fragilis	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	2	0.14
Pleurobema oviforme	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Grand Total	114	165	103	111	493	57	78	63	62	260	12	124	262	276	674	1427	100.00
Species Count	10	10	11	10	17	10	11	11	9	15	4	11	13	11	17	20	

Appendix A-2. (Continued)

July 9-10, 1986 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	100	56	38	30	224	28	23	47	44	142	86	86	34	162	368	734	68.28
Pleurobema cordatum	7	30	7	11	55	2	1	3	2	8	15	16	4	12	47	110	10.23
Cyclonaias tuberculata	1	2	6	14	23	2	2	4	0	8	9	7	2	6	24	55	5.12
Quadrula pustulosa	1	0	0	2	3	1	4	5	2	12	7	6	1	2	16	31	2.88
Potamilus alatus	2	1	0	1	4	3	6	5	9	23	1	1	4	8	14	41	3.81
Amblema plicata	1	0	0	2	3	1	5	7	1	14	4	2	0	0	6	23	2.14
Ellipsaria lineolata	1	0	1	3	5	0	2	4	0	6	1	2	0	5	8	19	1.77
Anodonta grandis	0	0	0	0	0	1	2	1	0	4	0	0	1	4	5	9	0.84
Obliquaria reflexa	0	0	0	0	0	2	2	4	0	8	0	0	0	1	1	9	0.84
Tritogonia verrucosa	0	0	0	0	0	2	4	1	1	8	0	0	0	0	0	8	0.74
Quadrula metanevra	0	0	1	3	4	0	1	0	0	1	1	0	1	0	2	7	0.65
Lampsilis abrupta	1	2	0	0	3	0	0	0	1	1	1	1	0	0	2	6	0.56
Leptodea fragilis	0	0	0	0	0	0	4	1	0	5	0	0	1	0	1	6	0.56
Ligumia recta	1	0	2	0	3	0	0	0	1	1	0	2	1	1	4	8	0.74
Megalonaias nervosa	1	1	1	0	3	0	1	1	0	2	0	0	0	0	0	5	0.47
Lampsilis ovata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.09
Elliptio dilatata	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	2	0.19
Lasmigona costata	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0.09
Grand Total	116	92	56	67	331	42	57	84	61	244	126	123	50	201	500	1075	100.00
Species Count	10	6	7	9	12	9	13	13	8	16	10	9	10	9	15	18	

Appendix A-2. (Continued)

October 16-17, 1986 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	97	29	73	61	260	14	30	20	28	92	13	100	132	168	413	765	64.83
Pleurobema cordatum	6	18	21	9	54	3	28	1	1	33	1	22	34	25	82	169	14.32
Cyclonaias tuberculata	0	5	28	16	49	0	2	7	0	9	3	1	13	1	18	76	6.44
Quadrula pustulosa	3	0	0	11	14	0	1	6	1	8	4	4	10	1	19	41	3.47
Potamilus alatus	0	1	3	3	7	3	4	4	4	15	5	0	0	0	5	27	2.29
Amblema plicata	0	0	1	1	2	1	6	6	0	13	3	0	4	2	9	24	2.03
Ellipsaria lineolata	2	1	3	4	10	0	0	0	1	1	0	2	3	2	7	18	1.53
Tritogonia verrucosa	0	0	0	0	0	5	2	1	4	12	0	1	0	0	1	13	1.10
Ligumia recta	0	1	2	1	4	0	0	0	1	1	0	3	2	0	5	10	0.85
Actinonaias ligamentina	0	1	1	2	4	0	0	0	0	0	0	2	2	0	4	8	0.68
Anodonta grandis	0	2	0	0	2	2	1	0	1	4	0	0	1	0	1	7	0.59
Quadrula metanevra	1	0	1	3	5	0	0	0	0	0	0	1	1	0	2	7	0.59
Leptodea fragilis	0	0	0	0	0	0	1	0	0	1	0	0	2	0	2	3	0.25
Obliquaria reflexa	0	0	0	0	0	0	1	1	0	2	0	1	0	0	1	3	0.25
Lampsilis abrupta	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	2	0.17
Lampsilis ovata	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0	2	0.17
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	2	0.17
Anodonta imbecillis	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0.08
Elliptio dilatata	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.08
Megalonaias nervosa	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.08
Grand Total	109	59	134	113	415	28	77	46	41	192	29	139	204	201	573	1180	100.00
Species Count	5	9	10	12	15	6	11	8	8	13	6	11	11	8	17	20	

Appendix A-2. (Continued)

July 12 & 14, 1988 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Total	Survey Percent
Elliptio crassidens	71	43	43	79	236	14	28	25	20	87	76	80	248	243	647	970	60.25
Pleurobema cordatum	8	22	18	20	68	10	28	6	0	44	16	22	38	36	112	224	13.91
Cyclonaias tuberculata	1	14	19	22	56	1	1	3	3	8	4	4	17	4	29	93	5.78
Quadrula pustulosa	0	2	1	2	5	1	3	9	8	21	11	9	25	9	54	80	4.97
Potamilus alatus	0	2	5	3	10	5	4	9	12	30	9	3	0	3	15	55	3.42
Amblema plicata	1	4	4	3	12	4	0	10	9	23	10	1	3	0	14	49	3.04
Ellipsaria lineolata	2	1	2	4	9	0	4	0	0	4	3	3	3	1	10	23	1.43
Anodonta grandis	0	1	2	0	3	9	1	4	5	19	2	0	1	4	7	29	1.80
Obliquaria reflexa	0	0	0	0	0	1	0	3	3	7	0	0	0	0	0	7	0.43
Tritogonia verrucosa	0	0	1	2	3	4	5	0	4	13	0	1	0	1	2	18	1.12
Quadrula metanevra	0	2	3	1	6	0	0	0	0	0	0	0	2	0	2	8	0.50
Lampsilis abrupta	0	0	0	0	0	1	0	1	0	2	4	1	3	2	10	12	0.75
Leptodea fragilis	0	0	0	0	0	1	1	1	6	9	2	1	0	0	3	12	0.75
Ligumia recta	1	0	1	0	2	0	0	0	0	0	0	1	3	1	5	7	0.43
Megalonaias nervosa	0	1	1	2	4	0	0	0	0	0	4	0	1	0	5	9	0.56
Actinonaias ligamentina	0	0	0	2	2	0	0	0	1	1	0	0	0	0	0	3	0.19
Lampsilis ovata	0	1	0	0	1	0	0	1	0	1	0	1	0	0	1	3	0.19
Elliptio dilatata	0	0	1	0	1	0	0	0	0	0	0	0	2	0	2	3	0.19
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0.12
Anodonta imbecillis	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0.06
Anodonta suborbiculata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.06
Pleurobema pyramidatum	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.06
Grand Total	84	93	101	140	418	51	76	72	72	271	142	127	346	306	921	1610	100.00
Species Count	6	11	13	11	15	11	10	11	11	16	12	12	12	11	18	22	

Appendix A-2. (Continued)

July 24-25, 1990 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	79	21	37	58	195	23	17	18	27	85	25	67	84	68	244	524	52.88
Pleurobema cordatum	11	2	12	9	34	3	13	8	0	24	9	33	19	20	81	139	14.03
Cyclonaias tuberculata	11	26	20	14	71	1	2	2	0	5	6	4	4	0	14	90	9.08
Quadrula pustulosa	2	4	8	3	17	0	9	10	7	26	9	9	13	5	36	79	7.97
Potamilus alatus	2	2	5	4	13	8	2	8	10	28	1	0	2	1	4	45	4.54
Amblema plicata	0	1	0	4	5	0	1	2	1	4	0	1	0	0	1	10	1.01
Ellipsaria lineolata	4	1	8	3	16	3	0	0	0	3	3	3	2	1	9	28	2.83
Anodonta grandis	0	0	0	1	1	5	4	3	5	17	0	1	1	0	2	20	2.02
Obliquaria reflexa	0	1	0	1	2	0	1	2	3	6	0	0	2	1	3	11	1.11
Tritogonia verrucosa	0	1	0	0	1	2	3	0	2	7	1	0	0	0	1	9	0.91
Quadrula metanevra	1	1	0	0	2	1	1	0	0	2	0	1	3	0	4	8	0.81
Lampsilis abrupta	0	0	0	0	0	0	0	0	1	1	0	1	2	0	3	4	0.40
Leptodea fragilis	0	0	2	0	2	3	1	1	0	5	0	0	1	0	1	8	0.81
Ligumia recta	0	0	0	0	0	0	0	1	0	1	0	0	0	1	1	2	0.20
Megalonaias nervosa	1	0	1	0	2	0	0	0	0	0	0	0	0	1	1	3	0.30
Actinonaias ligamentina	0	2	0	0	2	1	0	0	0	1	1	0	1	0	2	5	0.50
Lampsilis ovata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.10
Elliptio dilatata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.10
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0.10
Anodonta imbecillis	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0.10
Anodonta suborbiculata	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0.10
Ptychobranchus fasciolaris	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0.10
Grand Total	111	62	93	98	364	50	54	56	56	216	55	122	135	99	411	991	100.00
Species Count	8	11	8	10	15	10	11	11	8	16	8	11	13	9	20	22	

Appendix A-2. (Continued)

Summer 1992 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	82	15	6	7	110	19	8	13	2	42	6	49	118	99	272	424	59.89
Pleurobema cordatum	11	9	2	4	26	3	7	4	13	27	6	6	8	9	29	82	11.58
Cyclonaias tuberculata	9	18	12	5	44	2	4	6	0	12	1	2	6	3	12	68	9.60
Quadrula pustulosa	3	8	2	1	14	0	8	4	4	16	1	1	14	2	18	48	6.78
Potamilus alatus	2	2	0	2	6	1	0	1	3	5	0	3	1	1	5	16	2.26
Amblema plicata	1	0	0	1	2	1	1	2	2	6	1	1	3	0	5	13	1.84
Ellipsaria lineolata	7	1	0	0	8	3	0	0	0	3	0	0	2	1	3	14	1.98
Anodonta grandis	0	0	0	1	1	1	1	0	2	4	0	0	0	0	0	5	0.71
Obliquaria reflexa	0	1	0	0	1	0	1	1	2	4	0	0	0	1	1	6	0.85
Tritogonia verrucosa	1	0	0	1	2	0	2	4	1	7	0	0	0	0	0	9	1.27
Quadrula metanevra	0	0	2	0	2	0	2	1	0	3	0	0	2	1	3	8	1.13
Lampsilis abrupta	0	0	0	0	0	0	0	1	1	2	0	2	2	0	4	6	0.85
Ligumia recta	2	0	0	0	2	0	0	0	0	0	0	0	1	0	1	3	0.42
Megalonaias nervosa	0	0	0	1	1	0	0	2	1	3	0	0	0	0	0	4	0.56
Actinonaias ligamentina	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.14
Plethobasus cyphyus	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0.14
Grand Total	118	54	25	23	220	31	34	39	31	135	15	64	157	117	353	708	100.00
Species Count	9	7	6	9	14	8	9	11	10	14	5	7	10	8	11	16	

Appendix A-2. (Continued)

Summer 1994 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	85	31	52	29	197	24	50	11	25	110	23	56	75	122	276	583	66.25
Pleurobema cordatum	14	3	7	11	35	1	13	2	3	19	8	6	12	15	41	95	10.80
Quadrula pustulosa	0	1	1	4	6	1	6	11	12	30	1	14	3	11	29	65	7.39
Cyclonaias tuberculata	6	16	13	11	46	1	2	3	2	8	0	6	1	3	10	64	7.27
Amblema plicata	0	1	0	1	2	3	2	4	2	11	0	0	0	0	0	13	1.48
Ellipsaria lineolata	1	0	4	2	7	0	0	0	1	1	0	2	0	1	3	11	1.25
Obliquaria reflexa	0	0	0	0	0	0	1	7	3	11	0	0	0	0	0	11	1.25
Potamilus alatus	0	1	0	1	2	2	1	1	1	5	1	1	0	1	3	10	1.14
Anodonta grandis	0	0	0	0	0	2	0	1	4	7	0	0	0	0	0	7	0.80
Tritogonia verrucosa	0	0	0	0	0	0	0	1	4	5	0	0	1	1	2	7	0.80
Quadrula metanevra	0	1	1	1	3	0	0	0	0	0	0	0	0	1	1	4	0.45
Leptodea fragilis	0	0	0	0	0	0	1	1	0	2	0	1	0	0	1	3	0.34
Lampsilis abrupta	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	2	0.23
Megalonaias nervosa	0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	2	0.23
Ligumia recta	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0.11
Plethobasus cyphyus	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.11
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.11
Grand Total	106	54	78	61	299	34	77	43	58	212	33	87	92	157	369	880	100.00
Species Count	4	7	6	9	9	7	9	11	11	14	4	8	5	10	12	17	

Appendix A-2. (Continued)

July 22-23, 1996 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	88	22	76	26	212	10	54	27	23	114	24	71	73	100	268	594	70.21
Pleurobema cordatum	6	4	8	9	27	0	12	7	1	20	9	10	7	21	47	94	11.11
Cyclonaias tuberculata	5	6	5	2	18	0	3	4	0	7	3	6	1	3	13	38	4.49
Potamilus alatus	0	0	2	1	3	8	6	9	5	28	0	0	1	3	4	35	4.14
Quadrula pustulosa	0	0	0	1	1	1	1	3	4	9	8	10	0	2	20	30	3.55
Ellipsaria lineolata	0	0	1	1	2	1	3	0	0	4	0	4	4	1	9	15	1.77
Amblema plicata	0	0	0	2	2	1	4	1	0	6	1	2	0	0	3	11	1.30
Anodonta grandis	0	0	0	0	0	3	0	2	1	6	0	0	0	1	1	7	0.83
Obliquaria reflexa	0	0	0	0	0	0	0	6	0	6	0	0	0	0	0	6	0.71
Lampsilis abrupta	1	0	0	0	1	0	1	1	0	2	0	0	1	0	1	4	0.47
Tritogonia verrucosa	0	0	0	0	0	1	1	0	1	3	0	0	1	0	1	4	0.47
Ligumia recta	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	2	0.24
Quadrula metanevra	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	2	0.24
Elliptio dilatata	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.12
Lasmigona costata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.12
Leptodea fragilis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.12
Megalonaias nervosa	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.12
Grand Total	100	33	92	43	268	25	86	61	35	207	47	104	89	131	371	846	100.00
Species Count	4	4	5	8	10	7	10	10	6	13	7	7	8	7	14	17	

Appendix A-2. (Continued)

July 7-8, 1997 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	24	13	51	35	123	45	33	17	14	109	20	66	126	45	257	489	70.16
Pleurobema cordatum	4	4	9	11	28	2	16	0	0	18	3	33	7	12	55	101	14.49
Cyclonaias tuberculata	1	16	9	5	31	1	2	0	0	3	2	7	4	0	13	47	6.74
Quadrula pustulosa	0	5	2	2	9	1	0	2	3	6	1	7	1	0	9	24	3.44
Potamilus alatus	0	0	1	1	2	0	1	4	1	6	4	0	0	0	4	12	1.72
Ellipsaria lineolata	1	0	2	2	5	0	0	0	1	1	1	0	1	0	2	8	1.15
Amblema plicata	0	0	0	0	0	0	0	3	1	4	0	0	1	0	1	5	0.72
Obliquaria reflexa	0	0	0	1	1	0	0	0	2	2	0	0	0	0	0	3	0.43
Leptodea fragilis	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	2	0.29
Quadrula metanevra	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	2	0.29
Anodonta grandis	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0.14
Lampsilis ovata	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0.14
Ligumia recta	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.14
Tritogonia verrucosa	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0.14
Grand Total	30	38	74	57	199	49	53	26	26	154	32	114	141	57	344	697	100.00
Species Count	4	4	6	7	7	4	5	4	9	12	7	5	7	2	10	14	

Appendix A-2. (Continued)

TRM 520-521 and Year 1983	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	2	104.30	102.6	106.0	76.50	72.9	80.1	49.50	46.8	52.2
Amblema plicata	7	85.33	74.4	96.1	64.81	56.8	72.3	40.49	36.1	48.7
Cyclonaias tuberculata	72	75.80	62.1	92.6	65.60	52.1	80.2	38.20	32.4	44.1
Cyprogenia stegaria	1	51.60	51.6	51.6	49.70	49.7	49.7	36.00	36.0	36.0
Dromus dromas	1	60.10	60.1	60.1	58.30	58.3	58.3	32.80	32.8	32.8
Ellipsaria lineolata	20	78.94	56.8	94.5	61.21	44.6	72.0	37.78	30.1	48.8
Elliptio crassidens	102	101.28	87.5	125.5	63.90	54.0	80.5	40.59	21.0	50.3
Elliptio dilatata	3	106.37	102.3	113.3	45.70	42.2	48.8	33.40	30.9	34.7
Lampsilis abrupta	2	91.40	83.7	99.1	67.05	61.4	72.7	44.75	43.4	46.1
Lampsilis ovata	3	122.47	122.0	123.2	84.40	74.7	92.3	65.87	62.0	69.4
Leptodea fragilis	2	71.20	59.6	82.8	41.35	34.6	48.1	23.10	20.1	26.1
Ligumia recta	3	150.60	145.1	154.9	59.70	56.6	63.4	45.93	42.5	48.6
Obliquaria reflexa	1	48.30	48.3	48.3	24.10	24.1	24.1	24.60	24.6	24.6
Pleurobema cordatum	102	90.57	72.1	108.8	72.31	60.6	84.8	45.72	31.4	59.8
Pleurobema plenum	1	58.10	58.1	58.1	52.90	52.9	52.9	36.40	36.4	36.4
Potamilus alatus	11	122.31	46.9	156.9	88.34	71.1	104.9	35.58	30.6	40.9
Quadrula metanevra	16	73.55	63.5	85.3	58.82	52.3	68.0	43.65	38.3	49.2
Quadrula pustulosa	38	52.02	43.7	61.7	49.89	40.5	59.6	31.92	26.3	36.9

Appendix A-2. (Continued)

TRM 520-521 and Year 1984	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	6	96.08	80.5	107.3	72.63	62.6	80.4	42.58	34.6	46.6
Anodonta imbecillis	1	52.50	52.5	52.5	24.70	24.7	24.7	14.30	14.3	14.3
Cyclonaias tuberculata	101	74.39	59.1	92.2	63.86	52.2	76.5	37.48	29.5	44.9
Cyprogenia stegaria	1	52.90	52.9	52.9	51.40	51.4	51.4	36.40	36.4	36.4
Ellipsaria lineolata	23	77.57	56.6	102.2	58.68	44.0	74.2	35.53	26.3	42.0
Elliptio crassidens	101	104.82	89.2	122.7	66.24	56.3	78.4	41.70	24.4	60.9
Elliptio dilatata	1	100.10	100.1	100.1	42.20	42.2	42.2	28.00	28.0	28.0
Lampsilis abrupta	1	90.60	90.6	90.6	60.70	60.7	60.7	48.10	48.1	48.1
Lampsilis ovata	1	102.10	102.1	102.1	72.90	72.9	72.9	56.50	56.5	56.5
Ligumia recta	5	149.30	140.9	155.9	57.52	50.5	60.3	46.68	40.0	49.7
Obliquaria reflexa	1	36.50	36.5	36.5	32.90	32.9	32.9	22.90	22.9	22.9
Pleurobema cordatum	100	90.46	62.1	112.9	71.74	44.7	86.7	44.20	32.8	52.8
Pleurobema plenum	2	60.10	51.3	68.9	57.70	49.4	66.0	44.00	39.4	48.6
Potamilus alatus	14	126.87	96.7	160.0	90.56	74.4	108.0	36.16	30.0	42.5
Ptychobranchus fasciolaris	1	94.40	94.4	94.4	56.70	56.7	56.7	34.80	34.8	34.8
Quadrula metanevra	14	74.78	64.5	82.8	59.29	52.6	66.6	40.09	32.4	50.6
Quadrula pustulosa	53	53.28	40.0	74.1	50.63	39.5	64.1	31.69	22.0	40.1
Tritogonia verrucosa	1	76.70	76.7	76.7	42.70	42.7	42.7	19.70	19.7	19.7

Appendix A-2. (Continued)

TRM 520-521 and Year 1985	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	5	105.42	97.4	112.3	75.42	70.6	78.9	52.78	50.2	54.9
Amblema plicata	3	94.77	92.1	97.9	69.83	69.1	70.3	39.80	36.6	42.8
Cyclonaias tuberculata	72	75.62	60.5	86.6	65.14	54.7	74.5	36.95	30.6	43.1
Cyprogenia stegaria	1	57.70	57.7	57.7	55.60	55.6	55.6	44.10	44.1	44.1
Ellipsaria lineolata	7	79.13	62.3	92.5	61.27	46.9	69.9	34.84	32.0	36.2
Elliptio crassidens	101	104.43	90.1	122.5	65.82	54.1	88.5	41.43	29.5	50.9
Elliptio dilatata	1	96.80	96.8	96.8	44.20	44.2	44.2	29.80	29.8	29.8
Lampsilis abrupta	2	96.45	82.3	110.6	71.65	69.8	73.5	51.95	43.5	60.4
Lampsilis ovata	1	121.20	121.2	121.2	86.50	86.5	86.5	62.30	62.3	62.3
Ligumia recta	4	158.93	142.2	170.2	59.88	57.2	60.8	45.15	41.3	48.5
Megalonaias nervosa	2	165.15	160.1	170.2	109.35	102.3	116.4	54.45	52.4	56.5
Obliquaria reflexa	1	46.60	46.6	46.6	36.10	36.1	36.1	23.40	23.4	23.4
Pleurobema cordatum	88	91.57	70.4	108.5	73.40	58.2	89.5	43.91	30.2	52.7
Pleurobema oviforme	1	72.90	72.9	72.9	56.50	56.5	56.5	40.20	40.2	40.2
Pleurobema rubrum	1	80.70	80.7	80.7	64.30	64.3	64.3	44.50	44.5	44.5
Potamilus alatus	15	128.51	98.0	150.7	87.92	76.5	106.7	36.53	30.9	40.7
Quadrula metanevra	11	75.45	67.3	88.2	60.21	56.1	70.3	40.83	36.8	46.2
Quadrula pustulosa	26	54.20	46.3	72.8	51.48	44.7	64.3	31.89	25.7	37.4
Tritogonia verrucosa	1	104.10	104.1	104.1	52.80	52.8	52.8	36.10	36.1	36.1

Appendix A-2. (Continued)

TRM 520-521 and Year 1986	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	4	94.93	91.3	97.5	68.15	65.3	71.6	46.03	40.3	53.8
Amblema plicata	5	102.18	90.3	112.9	72.96	66.4	78.2	44.38	39.3	52.1
Anodonta grandis	2	123.05	119.4	126.7	70.00	63.3	76.7	47.05	43.4	50.7
Anodonta imbecillis	1	39.20	39.2	39.2	17.40	17.4	17.4	7.10	7.1	7.1
Cyclonaias tuberculata	72	72.03	56.9	85.1	61.53	47.6	76.6	34.82	23.7	44.9
Ellipsaria lineolata	15	73.42	51.8	86.9	54.71	39.2	65.3	30.81	22.6	42.0
Elliptio crassidens	100	105.59	87.2	151.8	64.88	55.9	82.5	40.83	31.1	51.4
Elliptio dilatata	1	109.40	109.4	109.4	45.50	45.5	45.5	39.90	39.9	39.9
Lampsilis abrupta	4	98.43	86.1	104.7	72.45	66.3	80.7	50.15	48.3	52.2
Lampsilis ovata	1	139.10	139.1	139.1	90.30	90.3	90.3	55.90	55.9	55.9
Lasmigona costata	1	122.10	122.1	122.1	69.90	69.9	69.9	25.50	25.5	25.5
Ligumia recta	7	133.40	107.7	150.2	51.84	45.0	55.9	40.80	33.1	48.6
Megalonaias nervosa	3	148.97	146.9	150.3	102.27	97.6	109.3	57.37	53.9	63.2
Pleurobema cordatum	94	88.69	54.9	109.6	70.34	49.7	88.5	42.39	25.2	54.6
Potamilus alatus	11	127.29	93.4	144.9	84.49	67.9	95.8	32.73	26.8	40.0
Quadrula metanevra	9	69.98	54.9	80.9	54.79	42.4	64.3	37.06	31.0	42.4
Quadrula pustulosa	17	48.40	38.2	55.9	45.26	37.2	52.8	27.30	20.5	35.7

Appendix A-2. (Continued)

TRM 520-521 and Year 1988	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	2	93.00	90.9	95.1	71.65	71.3	72.0	49.35	47.6	51.1
Amblema plicata	12	97.95	73.2	115.3	72.45	53.0	86.1	43.01	33.3	52.1
Anodonta grandis	3	101.60	81.7	119.9	59.83	53.6	65.3	44.00	34.5	50.4
Cyclonaias tuberculata	50	75.88	64.3	88.6	64.96	55.2	75.2	38.08	32.2	44.9
Ellipsaria lineolata	9	79.49	65.1	100.0	59.98	47.5	70.6	37.53	32.7	50.3
Elliptio crassidens	52	104.08	92.4	124.5	66.17	60.1	84.9	42.50	34.1	50.7
Elliptio dilatata	1	96.80	96.8	96.8	45.40	45.4	45.4	26.90	26.9	26.9
Lampsilis ovata	1	110.70	110.7	110.7	76.90	76.9	76.9	61.80	61.8	61.8
Ligumia recta	2	156.05	144.4	167.7	57.45	54.2	60.7	48.65	44.4	52.9
Megalonaias nervosa	4	155.25	144.2	170.2	109.25	100.8	117.2	59.88	53.3	65.6
Pleurobema cordatum	52	91.03	68.5	110.1	73.16	54.9	83.6	46.47	38.2	54.8
Potamilus alatus	10	132.07	114.9	151.0	96.46	76.3	113.4	39.75	34.4	48.3
Quadrula metanevra	6	80.70	66.7	92.1	63.15	54.2	70.1	43.43	38.4	47.3
Quadrula pustulosa	5	57.08	52.2	68.8	52.20	46.9	61.3	34.66	31.3	37.3
Tritogonia verrucosa	3	101.07	91.8	109.4	55.10	50.5	57.4	27.93	23.2	34.0

TRM 520-521 and Year 1990	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	2	97.35	96.0	98.7	72.15	71.4	72.9	49.60	47.6	51.6
Amblema plicata	5	100.30	76.6	120.1	71.08	54.5	87.2	41.74	33.6	47.2
Anodonta grandis	1	136.30	136.3	136.3	76.70	76.7	76.7	51.00	51.0	51.0
Anodonta imbecillis	1	52.00	52.0	52.0	24.80	24.8	24.8	14.30	14.3	14.3
Cyclonaias tuberculata	50	77.43	62.0	111.0	65.32	52.1	92.1	37.12	28.0	46.5
Ellipsaria lineolata	16	85.20	64.2	94.8	63.94	51.6	71.3	37.67	32.1	44.6
Elliptio crassidens	50	109.49	87.5	130.1	68.71	62.4	79.9	42.94	36.3	50.2
Leptodea fragilis	2	100.15	89.9	110.4	67.65	62.7	72.6	37.85	36.5	39.2
Megalonaias nervosa	2	164.85	155.6	174.1	115.65	110.7	120.6	56.20	56.2	56.2
Obliquaria reflexa	2	45.40	44.5	46.3	36.80	36.7	36.9	26.60	25.4	27.8
Pleurobema cordatum	34	91.89	75.6	110.1	71.37	59.5	82.4	42.27	32.9	52.0
Potamilus alatus	13	141.24	131.6	152.9	105.18	83.3	120.9	55.30	37.2	139.8
Quadrula metanevra	2	73.35	65.2	81.5	53.60	48.1	59.1	39.40	35.5	43.3
Quadrula pustulosa	17	52.47	45.7	64.1	49.12	42.8	55.7	31.34	25.3	37.5
Tritogonia verrucosa	1	94.00	94.0	94.0	52.20	52.2	52.2	32.50	32.5	32.5

Appendix A-2. (Continued)

TRM 520-521 and Year 1992	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	1	94.80	94.8	94.8	65.40	65.4	65.4	49.60	49.6	49.6
Amblema plicata	2	119.45	114.2	124.7	85.55	84.7	86.4	51.95	49.1	54.8
Anodonta grandis	1	131.50	131.5	131.5	84.90	84.9	84.9	57.20	57.2	57.2
Cyclonaias tuberculata	44	78.27	63.2	89.0	65.77	53.4	87.1	37.92	30.8	44.7
Ellipsaria lineolata	8	86.17	69.6	95.5	65.55	49.7	75.1	38.46	31.3	44.8
Elliptio crassidens	43	104.55	88.4	116.5	65.75	55.6	74.3	42.35	27.2	51.7
Ligumia recta	2	153.05	148.0	158.1	59.65	56.9	62.4	48.50	47.3	49.7
Megalonaias nervosa	1	182.10	182.1	182.1	116.20	116.2	116.2	58.40	58.4	58.4
Obliquaria reflexa	1	52.70	52.7	52.7	41.60	41.6	41.6	29.80	29.8	29.8
Pleurobema cordatum	26	89.13	64.7	104.0	70.92	60.9	82.9	43.46	37.5	51.2
Potamilus alatus	6	141.35	124.8	155.3	105.82	98.1	114.8	42.15	35.2	45.4
Quadrula metanevra	2	82.65	82.5	82.8	62.55	61.7	63.4	42.80	42.0	43.6
Quadrula pustulosa	14	52.09	45.3	57.4	48.60	40.2	54.9	31.74	25.2	37.9
Tritogonia verrucosa	2	108.60	100.9	116.3	60.15	59.4	60.9	33.45	31.3	35.6

TRM 520-521 and Year 1994	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	2	97.85	84.7	111.0	65.95	59.2	72.7	43.10	35.0	51.2
Cyclonaias tuberculata	46	77.77	66.2	91.1	65.59	58.4	74.3	38.82	32.9	48.9
Ellipsaria lineolata	7	82.13	76.1	89.6	63.57	57.7	69.0	37.46	32.9	42.1
Elliptio crassidens	65	108.95	96.8	128.7	68.19	61.3	88.6	43.51	36.6	50.4
Megalonaias nervosa	1	180.20	180.2	180.2	119.70	119.7	119.7	69.00	69.0	69.0
Pleurobema cordatum	35	90.84	59.8	107.7	72.35	58.1	86.8	45.37	35.5	53.0
Potamilus alatus	2	129.80	128.3	131.3	103.60	99.6	107.6	38.90	38.5	39.3
Quadrula metanevra	3	71.60	68.4	75.5	56.63	54.4	59.5	40.67	39.9	42.2
Quadrula pustulosa	6	55.28	52.1	57.3	51.02	46.6	54.5	32.85	28.9	35.1

Appendix A-2. (Continued)

TRM 520-521 and Year 1996	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	2	101.80	78.2	125.4	68.60	52.4	84.9	36.70	26.7	46.7
Cyclonaias tuberculata	18	79.90	73.0	91.3	67.10	58.4	75.6	39.30	34.6	45.3
Ellipsaria lineolata	2	79.50	69.7	89.3	59.90	48.0	71.9	37.60	30.8	44.3
Elliptio crassidens	61	108.80	97.8	127.2	66.30	56.9	75.2	43.50	34.2	50.2
Elliptio dilatata	1	95.40	95.4	95.4	41.00	41.0	41.0	29.70	29.7	29.7
Lampsilis abrupta	1	99.40	99.4	99.4	73.10	73.1	73.1	55.30	55.3	55.3
Ligumia recta	1	160.00	160.0	160.0	61.10	61.1	61.1	49.40	49.4	49.4
Pleurobema cordatum	27	94.50	82.8	107.7	72.50	67.2	79.2	46.20	39.0	53.0
Potamilus alatus	3	117.10	98.2	133.0	70.40	60.1	79.9	36.80	28.9	45.5
Quadrula pustulosa	1	56.60	56.6	56.6	54.90	54.9	54.9	34.50	34.5	34.5

TRM 520-521 and Year 1997	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Cyclonaias tuberculata	31	78.50	67.0	91.4	65.40	56.5	73.7	41.60	35.6	49.8
Ellipsaria lineolata	5	83.10	56.4	105.5	61.00	45.9	71.6	41.60	33.8	52.6
Elliptio crassidens	52	107.70	92.2	120.8	64.90	53.7	73.1	44.40	34.7	51.1
Obliquaria reflexa	1	50.60	50.6	50.6	34.70	34.7	34.7	33.90	33.9	33.9
Pleurobema cordatum	28	93.40	83.1	117.2	71.70	60.2	92.3	47.50	41.7	52.8
Potamilus alatus	2	113.60	105.7	121.4	70.00	63.3	76.6	36.00	33.3	38.8
Quadrula pustulosa	9	56.60	49.7	65.2	51.50	45.2	57.9	36.00	30.9	45.6

Appendix A-2. (Continued)

TRM 520-521 and Years 1983-1997	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	16	99.43	90.9	112.3	72.23	65.3	80.1	49.66	40.3	54.9
Amblema plicata	44	97.36	73.2	125.4	71.11	52.4	87.2	42.46	26.7	54.8
Anodonta grandis	7	116.96	81.7	136.3	68.73	53.6	84.9	47.76	34.5	57.2
Anodonta imbecillis	3	47.90	39.2	52.5	22.30	17.4	24.8	11.90	7.1	14.3
Cyclonaias tuberculata	556	75.83	56.9	111.0	64.66	47.6	92.1	37.61	23.7	49.8
Cyprogenia stegaria	3	54.07	51.6	57.7	52.23	49.7	55.6	38.83	36.0	44.1
Dromus dromas	1	60.10	60.1	60.1	58.30	58.3	58.3	32.80	32.8	32.8
Ellipsaria lineolata	112	79.78	51.8	105.5	60.54	39.2	75.1	36.80	22.6	52.6
Elliptio crassidens	727	105.54	87.2	151.8	65.89	53.7	88.6	42.08	21.0	60.9
Elliptio dilatata	8	102.20	95.4	113.3	44.42	41.0	48.8	31.81	26.9	39.9
Lampsilis abrupta	10	95.94	82.3	110.6	70.10	60.7	80.7	49.74	43.4	60.4
Lampsilis ovata	7	120.07	102.1	139.1	82.83	72.9	92.3	62.01	55.9	69.4
Lasmigona costata	1	122.10	122.1	122.1	69.90	69.9	69.9	25.50	25.5	25.5
Leptodea fragilis	4	85.67	59.6	110.4	54.50	34.6	72.6	30.48	20.1	39.2
Ligumia recta	24	147.75	107.7	170.2	56.85	45.0	63.4	45.05	33.1	52.9
Megalonaias nervosa	13	160.78	144.2	182.1	109.98	97.6	120.6	58.48	52.4	69.0
Obliquaria reflexa	7	46.50	36.5	52.7	34.72	24.1	41.6	26.83	22.9	33.9
Pleurobema cordatum	586	90.78	54.9	117.2	72.00	44.7	92.3	44.50	25.2	59.8
Pleurobema oviforme	1	72.90	72.9	72.9	56.50	56.5	56.5	40.20	40.2	40.2
Pleurobema plenum	3	59.43	51.3	68.9	56.10	49.4	66.0	41.47	36.4	48.6
Pleurobema rubrum	1	80.70	80.7	80.7	64.30	64.3	64.3	44.50	44.5	44.5
Potamilus alatus	87	129.80	46.9	160.0	92.11	60.1	120.9	39.49	26.8	139.8
Ptychobranchus fasciolaris	1	94.40	94.4	94.4	56.70	56.7	56.7	34.80	34.8	34.8
Quadrula metanevra	63	74.52	54.9	92.1	58.85	42.4	70.3	41.10	31.0	50.6
Quadrula pustulosa	186	52.89	38.2	74.1	49.94	37.2	64.3	31.68	20.5	45.6
Tritogonia verrucosa	8	99.40	76.7	116.3	54.16	42.7	60.9	29.87	19.7	36.1

Appendix A-2. (Continued)

TRM 526-527 and Year 1983	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	1	105.50	105.5	105.5	70.30	70.3	70.3	53.60	53.6	53.6
Amblema plicata	41	98.06	76.5	121.1	73.71	56.6	99.7	46.80	34.8	56.9
Anodonta grandis	22	124.84	101.6	154.6	68.28	55.3	89.6	53.76	39.6	67.9
Cyclonaias tuberculata	32	82.55	66.4	94.7	70.40	60.8	78.1	40.98	34.2	49.8
Ellipsaria lineolata	13	90.57	71.1	96.5	71.33	61.5	78.6	42.22	36.6	50.9
Elliptio crassidens	104	112.07	93.1	134.2	69.83	59.4	79.1	44.82	36.3	52.5
Elliptio dilatata	1	102.20	102.2	102.2	46.30	46.3	46.3	31.20	31.2	31.2
Lampsilis abrupta	1	103.10	103.1	103.1	84.40	84.4	84.4	58.20	58.2	58.2
Leptodea fragilis	1	112.40	112.4	112.4	66.40	66.4	66.4	32.70	32.7	32.7
Ligumia recta	2	162.50	160.0	165.0	66.05	63.8	68.3	55.35	54.0	56.7
Megalonaias nervosa	3	173.83	164.4	180.6	117.43	111.7	120.7	60.50	57.2	63.0
Obliquaria reflexa	18	54.35	45.1	64.1	44.40	35.3	51.5	34.88	25.5	41.4
Plethobasus cyphyus	2	91.80	89.3	94.3	64.55	62.8	66.3	45.00	43.6	46.4
Pleurobema cordatum	94	98.39	81.1	129.1	78.17	62.2	99.5	49.67	39.0	62.9
Potamilus alatus	27	142.29	96.6	162.8	104.00	79.3	120.9	38.95	24.1	46.5
Quadrula metanevra	7	84.54	75.1	92.2	64.21	60.1	71.1	47.81	44.0	50.9
Quadrula pustulosa	63	57.01	46.2	66.0	55.09	46.3	66.0	35.49	28.2	43.8
Tritogonia verrucosa	17	110.26	96.0	128.7	58.53	54.3	64.1	36.48	30.1	42.7

Appendix A-2. (Continued)

TRM 526-527 and Year 1984	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	16	100.54	84.8	120.1	73.24	62.3	88.0	44.96	38.9	52.4
Anodonta grandis	8	127.31	104.3	144.3	68.77	56.6	74.1	50.76	42.1	54.6
Anodonta imbecillis	1	54.70	54.7	54.7	23.20	23.2	23.2	16.90	16.9	16.9
Cyclonaias tuberculata	7	80.50	66.6	92.6	70.53	60.5	80.9	37.67	31.5	43.1
Ellipsaria lineolata	12	90.98	62.7	109.7	70.40	50.4	86.0	40.49	31.3	50.2
Elliptio crassidens	100	111.95	96.9	130.8	70.98	60.5	82.4	44.64	38.2	53.1
Lampsilis abrupta	3	98.63	96.4	100.2	70.80	66.1	74.8	57.07	54.7	60.2
Lampsilis ovata	1	139.80	139.8	139.8	92.60	92.6	92.6	68.80	68.8	68.8
Leptodea fragilis	5	109.62	104.5	118.1	65.02	62.1	68.4	35.10	30.9	38.4
Megalonaias nervosa	1	180.00	180.0	180.0	130.20	130.2	130.2	63.00	63.0	63.0
Obliquaria reflexa	9	55.80	49.2	64.0	43.27	36.1	52.3	34.44	26.3	39.8
Pleurobema cordatum	31	98.37	82.0	119.1	77.38	69.3	99.8	47.24	40.6	58.7
Potamilus alatus	23	153.90	132.3	182.1	105.20	80.5	134.5	41.12	36.8	46.5
Quadrula metanevra	1	79.10	79.1	79.1	64.60	64.6	64.6	54.90	54.9	54.9
Quadrula pustulosa	29	59.12	50.2	66.8	55.92	49.5	61.7	34.46	29.4	40.8
Tritogonia verrucosa	6	118.87	94.2	134.9	61.53	56.1	66.8	38.98	29.3	44.8

Appendix A-2. (Continued)

TRM 526-527 and Year 1985	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	20	100.06	84.1	119.5	71.56	58.2	84.8	43.86	36.1	56.7
Anodonta grandis	6	122.98	108.7	142.6	72.18	62.9	80.4	50.47	41.9	58.7
Cyclonaias tuberculata	11	82.09	73.5	91.5	70.28	62.1	76.6	39.97	35.6	42.7
Ellipsaria lineolata	13	89.20	80.9	100.4	69.52	62.3	76.9	39.52	34.9	46.8
Elliptio crassidens	105	111.88	90.7	134.8	70.36	60.1	82.9	43.96	34.2	53.7
Elliptio dilatata	1	100.80	100.8	100.8	44.20	44.2	44.2	34.80	34.8	34.8
Lampsilis ovata	2	127.20	120.8	133.6	81.15	76.1	86.2	63.05	61.5	64.6
Leptodea fragilis	4	103.30	86.9	114.7	61.30	55.4	66.8	34.38	30.2	39.8
Ligumia recta	1	170.10	170.1	170.1	72.40	72.4	72.4	50.10	50.1	50.1
Megalonaias nervosa	1	190.80	190.8	190.8	121.10	121.1	121.1	57.10	57.1	57.1
Obliquaria reflexa	8	57.25	52.4	66.9	43.74	40.1	50.8	33.39	30.1	36.6
Pleurobema cordatum	52	103.59	83.6	160.2	81.47	66.5	134.9	46.31	34.3	54.4
Potamilus alatus	49	143.15	104.7	170.2	103.43	81.6	125.6	40.52	28.4	49.6
Quadrula metanevra	3	85.90	80.6	88.9	67.27	64.7	70.3	43.80	40.2	50.3
Quadrula pustulosa	43	60.61	46.3	72.3	57.34	32.1	68.1	36.61	28.9	44.2
Tritogonia verrucosa	17	125.20	92.3	148.8	61.35	40.6	70.0	40.43	34.1	48.7

Appendix A-2. (Continued)

TRM 526-527 and Year 1986	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	27	97.68	66.7	121.4	69.54	50.6	84.9	44.09	26.8	57.4
Anodonta grandis	8	125.85	80.9	147.8	70.95	50.7	82.0	52.32	35.1	63.2
Cyclonaias tuberculata	17	79.26	63.2	96.7	67.04	55.9	80.2	39.89	33.1	51.0
Ellipsaria lineolata	7	96.04	83.6	112.3	70.80	61.5	78.2	43.99	34.1	52.5
Elliptio crassidens	105	113.05	92.3	145.2	68.73	59.1	87.1	43.35	35.1	54.1
Elliptio dilatata	1	107.10	107.1	107.1	50.00	50.0	50.0	35.40	35.4	35.4
Lampsilis abrupta	1	114.80	114.8	114.8	77.70	77.7	77.7	57.20	57.2	57.2
Lampsilis ovata	1	132.90	132.9	132.9	91.30	91.3	91.3	72.60	72.6	72.6
Leptodea fragilis	6	100.25	80.1	112.1	57.62	46.6	67.5	31.87	25.3	36.0
Ligumia recta	2	158.55	153.1	164.0	67.00	66.4	67.6	49.75	48.8	50.7
Megalonaias nervosa	2	145.80	124.6	167.0	103.25	87.2	119.3	58.35	57.0	59.7
Obliquaria reflexa	10	55.84	46.6	66.7	44.39	34.1	52.4	34.92	25.7	41.2
Pleurobema cordatum	38	96.12	75.7	117.9	75.20	63.2	83.5	47.08	42.4	56.3
Potamilus alatus	38	142.16	79.8	174.0	90.65	56.7	112.8	40.22	26.7	57.9
Quadrula metanevra	1	81.40	81.4	81.4	70.40	70.4	70.4	55.30	55.3	55.3
Quadrula pustulosa	20	57.10	42.4	67.0	54.51	42.4	66.1	33.57	25.7	40.0
Tritogonia verrucosa	20	111.93	87.1	133.0	56.05	47.6	66.7	33.90	24.7	42.9

Appendix A-2. (Continued)

TRM 526-527 and Year 1988	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	1	107.60	107.6	107.6	76.80	76.8	76.8	55.40	55.4	55.4
Amblema plicata	22	105.73	64.8	117.6	77.38	51.1	89.3	49.21	34.8	56.9
Anodonta grandis	19	131.44	101.0	155.1	72.65	56.1	89.9	55.26	43.5	71.2
Anodonta imbecillis	1	54.00	54.0	54.0	24.10	24.1	24.1	16.20	16.2	16.2
Cyclonaias tuberculata	8	82.56	63.4	94.7	71.49	60.7	78.1	41.26	31.3	45.0
Ellipsaria lineolata	4	88.22	81.7	94.3	68.20	61.5	72.8	40.80	38.4	42.3
Elliptio crassidens	51	113.30	100.1	129.2	70.47	44.2	79.3	45.82	39.9	55.3
Lampsilis abrupta	2	96.10	93.4	98.8	69.75	69.5	70.0	57.50	51.4	63.6
Lampsilis ovata	1	139.90	139.9	139.9	90.40	90.4	90.4	77.30	77.3	77.3
Leptodea fragilis	9	98.76	70.4	126.3	61.44	44.9	76.0	32.27	23.8	39.8
Obliquaria reflexa	7	54.84	44.2	62.7	43.20	36.2	49.6	32.27	24.4	36.0
Pleurobema cordatum	31	100.33	83.4	113.9	79.15	70.3	89.2	49.45	43.1	54.5
Pleurobema rubrum	1	88.30	88.3	88.3	69.50	69.5	69.5	46.70	46.7	46.7
Potamilus alatus	29	147.89	110.3	187.7	109.59	86.7	131.2	41.57	31.0	50.3
Quadrula pustulosa	21	58.90	52.6	64.0	55.89	46.6	64.1	36.14	30.0	40.6
Tritogonia verrucosa	13	114.88	96.3	140.8	64.74	50.1	76.3	41.53	29.7	50.7

Appendix A-2. (Continued)

TRM 526-527 and Year 1990	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	1	115.40	115.4	115.4	82.60	82.6	82.6	58.30	58.3	58.3
Amblema plicata	4	102.48	87.2	112.4	73.68	66.7	80.7	48.68	43.4	50.9
Anodonta grandis	17	136.27	108.7	159.1	76.23	61.5	99.9	56.54	44.4	68.8
Anodonta suborbiculata	1	126.20	126.2	126.2	96.40	96.4	96.4	48.30	48.3	48.3
Cyclonaias tuberculata	5	80.92	73.5	86.7	69.12	64.2	72.2	39.28	35.8	43.2
Ellipsaria lineolata	3	87.13	64.7	101.6	67.33	53.1	76.9	41.37	39.5	42.3
Elliptio crassidens	50	115.95	104.0	149.3	71.21	61.4	82.1	45.56	38.3	51.0
Lampsilis abrupta	1	98.10	98.1	98.1	83.70	83.7	83.7	62.10	62.1	62.1
Leptodea fragilis	5	111.74	101.8	130.1	69.30	61.0	89.5	36.24	32.8	40.0
Ligumia recta	1	173.10	173.1	173.1	73.50	73.5	73.5	59.90	59.9	59.9
Obliquaria reflexa	6	57.62	48.5	64.6	45.73	39.6	49.9	36.08	29.9	45.1
Pleurobema cordatum	24	102.52	90.2	120.7	78.21	69.0	90.6	48.51	41.7	52.8
Potamilus alatus	28	146.09	120.1	169.1	108.90	88.4	126.3	40.99	33.1	47.7
Quadrula metanevra	2	84.35	77.9	90.8	66.20	62.3	70.1	50.65	49.9	51.4
Quadrula pustulosa	26	60.05	50.1	74.4	55.38	44.9	66.9	35.37	28.0	42.1
Tritogonia verrucosa	7	105.43	78.1	130.1	56.16	43.4	65.9	35.67	26.6	42.5

Appendix A-2. (Continued)

TRM 526-527 and Year 1992	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	6	99.72	94.7	105.1	73.83	65.5	82.1	47.28	44.7	51.6
Anodonta grandis	4	129.70	122.0	136.8	73.85	67.3	79.2	58.88	54.0	65.1
Cyclonaias tuberculata	12	84.87	75.5	92.4	70.85	64.1	75.4	40.52	36.5	43.2
Ellipsaria lineolata	3	95.83	94.6	96.7	73.90	71.1	77.2	41.23	36.1	44.5
Elliptio crassidens	42	113.78	100.1	126.7	71.49	63.2	81.6	45.96	39.1	52.3
Lampsilis abrupta	2	107.55	99.8	115.3	72.35	66.3	78.4	52.55	52.2	52.9
Megalonaias nervosa	3	170.43	155.9	183.2	122.43	112.2	128.2	61.77	53.1	69.3
Obliquaria reflexa	4	57.75	52.0	61.5	44.05	40.9	47.9	33.78	30.9	36.7
Plethobasus cyphyus	1	91.40	91.4	91.4	64.80	64.8	64.8	50.30	50.3	50.3
Pleurobema cordatum	27	103.31	82.5	127.9	78.67	68.5	90.7	45.82	39.5	49.7
Potamilus alatus	5	142.44	116.6	161.2	106.72	94.0	116.9	40.20	35.1	47.4
Quadrula metanevra	3	79.53	75.7	87.2	61.43	58.3	66.5	44.37	40.9	48.2
Quadrula pustulosa	16	58.32	51.5	64.7	54.97	50.1	62.7	35.34	30.3	44.8
Tritogonia verrucosa	7	105.57	77.0	127.3	58.67	43.1	66.7	37.10	21.7	48.3

TRM 526-527 and Year 1994	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	11	108.42	97.6	119.1	78.67	72.2	89.7	49.41	45.2	54.7
Anodonta grandis	7	135.29	121.4	142.7	79.13	66.7	85.1	57.84	47.6	64.6
Cyclonaias tuberculata	8	79.01	72.0	85.1	68.94	63.7	73.5	38.94	34.8	41.6
Ellipsaria lineolata	1	96.10	96.1	96.1	76.70	76.7	76.7	42.30	42.3	42.3
Elliptio crassidens	85	116.05	96.5	129.8	72.99	62.5	82.4	46.66	39.4	52.9
Lampsilis abrupta	1	101.20	101.2	101.2	86.10	86.1	86.1	65.40	65.4	65.4
Leptodea fragilis	2	117.15	112.2	122.1	74.05	71.2	76.9	39.70	39.4	40.0
Ligumia recta	1	161.40	161.4	161.4	73.30	73.3	73.3	61.20	61.2	61.2
Obliquaria reflexa	11	57.30	52.8	69.5	45.68	41.4	51.7	35.04	29.6	42.7
Plethobasus cyphyus	1	88.60	88.6	88.6	59.40	59.4	59.4	46.20	46.2	46.2
Pleurobema cordatum	19	103.80	83.1	116.5	79.25	69.1	90.1	48.48	37.4	57.6
Potamilus alatus	5	153.00	131.9	168.6	117.24	109.4	128.5	43.88	38.4	46.5
Quadrula pustulosa	30	57.93	49.5	66.0	54.34	45.7	64.1	35.61	27.1	49.9
Tritogonia verrucosa	5	113.86	95.8	127.7	56.80	52.4	60.6	36.54	30.7	39.9

Appendix A-2. (Continued)

TRM 526-527 and Year 1996	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	6	103.30	84.0	117.1	73.70	59.1	86.5	49.20	41.0	57.3
Anodonta grandis	6	144.90	130.6	160.0	84.20	71.9	102.4	58.50	52.1	64.2
Cyclonaias tuberculata	7	84.50	75.5	87.9	69.80	67.8	71.5	42.30	40.0	46.5
Ellipsaria lineolata	4	94.40	89.0	100.9	71.10	66.5	75.6	43.30	42.0	44.4
Elliptio crassidens	29	118.20	101.4	151.1	73.10	63.5	82.5	48.40	42.3	56.9
Lampsilis abrupta	2	115.70	109.1	122.4	84.30	83.0	85.5	63.00	59.1	66.9
Megalonaias nervosa	1	180.00	180.0	180.0	123.60	123.6	123.6	66.00	66.0	66.0
Obliquaria reflexa	6	56.10	51.8	59.6	43.90	39.8	50.1	36.40	33.4	40.3
Pleurobema cordatum	20	102.60	77.1	120.9	79.30	65.2	91.2	50.20	41.2	56.0
Potamilus alatus	28	148.90	125.9	180.0	83.90	70.8	97.3	41.30	32.2	51.5
Quadrula metanevra	1	77.80	77.8	77.8	61.00	61.0	61.0	51.60	51.6	51.6
Quadrula pustulosa	9	59.60	50.6	68.6	55.40	48.9	60.0	38.10	31.3	47.7
Tritogonia verrucosa	3	101.60	88.5	127.5	54.20	49.4	60.8	35.50	29.6	40.3

TRM 526-527 and Year 1997	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	4	100.60	73.5	123.0	71.90	57.0	78.9	47.40	35.1	53.2
Anodonta grandis	1	147.00	147.0	147.0	81.00	81.0	81.0	63.40	63.4	63.4
Cyclonaias tuberculata	3	86.20	75.3	96.8	71.10	60.4	78.8	42.70	37.8	49.4
Ellipsaria lineolata	1	85.10	85.1	85.1	71.60	71.6	71.6	41.50	41.5	41.5
Elliptio crassidens	50	115.60	96.7	131.5	71.50	58.8	80.5	46.90	39.6	59.8
Leptodea fragilis	2	92.20	69.3	115.0	56.10	40.5	71.7	26.90	21.5	37.3
Obliquaria reflexa	2	55.80	54.2	57.4	45.70	44.6	46.7	34.80	33.0	36.6
Pleurobema cordatum	18	103.20	93.5	112.6	77.60	70.5	83.9	52.40	43.8	57.3
Potamilus alatus	6	154.00	142.4	166.9	87.10	78.4	95.8	43.20	39.7	48.9
Quadrula metanevra	1	85.00	85.0	85.0	65.70	65.7	65.7	45.40	45.4	45.4
Quadrula pustulosa	6	60.50	53.7	65.3	55.80	51.6	58.9	37.20	31.9	42.0
Tritogonia verrucosa	1	109.60	109.6	109.6	52.80	52.8	52.8	38.30	38.3	38.3

Appendix A-2. (Continued)

TRM 526-527 and Years 1983-1997	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	3	109.50	105.5	115.4	76.57	70.3	82.6	55.77	53.6	58.3
Amblema plicata	157	100.74	64.8	123.0	73.92	50.6	99.7	46.47	26.8	57.4
Anodonta grandis	98	130.67	80.9	160.0	73.11	50.7	102.4	54.85	35.1	71.2
Anodonta imbecillis	2	54.35	54.0	54.7	23.65	23.2	24.1	16.55	16.2	16.9
Anodonta suborbiculata	1	126.20	126.2	126.2	96.40	96.4	96.4	48.30	48.3	48.3
Cyclonaias tuberculata	110	82.01	63.2	96.8	69.81	55.9	80.9	40.37	31.3	51.0
Ellipsaria lineolata	61	91.17	62.7	112.3	70.50	50.4	86.0	41.38	31.3	52.5
Elliptio crassidens	721	113.59	90.7	151.1	70.76	44.2	87.1	45.15	34.2	59.8
Elliptio dilatata	3	103.37	100.8	107.1	46.83	44.2	50.0	33.80	31.2	35.4
Lampsilis abrupta	13	103.98	93.4	122.4	76.00	66.1	86.1	58.47	51.4	65.4
Lampsilis ovata	5	133.40	120.8	139.9	87.32	76.1	92.6	68.96	61.5	77.3
Leptodea fragilis	34	104.16	69.3	130.1	63.01	40.5	89.5	33.58	21.5	40.0
Ligumia recta	7	163.81	153.1	173.1	69.33	63.8	73.5	54.49	48.8	61.2
Megalonaias nervosa	11	170.47	124.6	190.8	118.27	87.2	130.2	60.87	53.1	69.3
Obliquaria reflexa	81	56.00	44.2	69.5	44.35	34.1	52.4	34.63	24.4	45.1
Plethobasus cyphyus	4	90.90	88.6	94.3	63.33	59.4	66.3	46.63	43.6	50.3
Pleurobema cordatum	354	100.51	75.7	160.2	78.49	62.2	134.9	48.39	34.3	62.9
Pleurobema rubrum	1	88.30	88.3	88.3	69.50	69.5	69.5	46.70	46.7	46.7
Potamilus alatus	238	145.99	79.8	187.7	91.15	56.7	134.5	40.76	24.1	57.9
Quadrula metanevra	19	83.16	75.1	92.2	64.72	58.3	71.1	47.77	40.2	55.3
Quadrula pustulosa	263	58.64	42.4	74.4	55.53	32.1	68.1	35.59	25.7	49.9
Tritogonia verrucosa	96	113.63	77.0	148.8	59.09	40.6	76.3	37.46	21.7	50.7

Appendix A-2. (Continued)

TRM 528-529 and Year 1983	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	2	102.95	92.5	113.4	72.95	69.3	76.6	53.40	48.3	58.5
Amblema plicata	5	103.20	84.7	132.3	75.74	64.1	94.6	40.42	30.4	51.3
Anodonta grandis	6	111.01	83.0	128.0	63.24	46.1	72.3	46.23	35.4	54.9
Cyclonaias tuberculata	43	82.19	66.8	96.5	69.89	57.3	79.9	40.56	32.6	46.6
Cyprogenia stegaria	2	56.45	52.9	60.0	51.14	50.9	51.4	38.71	36.8	40.6
Ellipsaria lineolata	12	90.16	66.4	108.8	67.22	52.4	76.8	42.40	36.6	51.3
Elliptio crassidens	105	110.49	86.8	134.6	68.14	54.4	89.9	43.39	34.9	56.1
Elliptio dilatata	1	95.30	95.3	95.3	44.10	44.1	44.1	30.50	30.5	30.5
Fusconaia subrotunda	1	66.09	66.1	66.1	53.56	53.6	53.6	36.58	36.6	36.6
Lampsilis abrupta	7	94.00	70.5	106.4	70.46	59.4	80.4	51.68	39.8	60.1
Lampsilis ovata	1	132.30	132.3	132.3	91.64	91.6	91.6	76.30	76.3	76.3
Leptodea fragilis	1	81.70	81.7	81.7	48.20	48.2	48.2	29.50	29.5	29.5
Ligumia recta	3	155.31	145.8	160.1	62.95	60.3	65.1	51.84	50.6	53.8
Obliquaria reflexa	1	49.00	49.0	49.0	39.70	39.7	39.7	34.30	34.3	34.3
Pleurobema cordatum	105	97.39	73.3	114.2	76.61	59.3	86.7	49.44	32.3	61.2
Potamilus alatus	5	126.89	110.3	141.8	88.62	69.1	119.8	39.26	34.5	44.1
Quadrula metanevra	13	75.86	46.9	92.6	59.96	42.2	74.4	42.98	26.2	54.7
Quadrula pustulosa	57	57.27	44.8	69.9	54.45	42.1	66.9	35.05	28.8	43.5
Tritogonia verrucosa	1	106.72	106.7	106.7	62.81	62.8	62.8	32.64	32.6	32.6

Appendix A-2. (Continued)

TRM 528-529 and Year 1984	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	2	109.55	99.4	119.7	81.00	74.0	88.0	53.25	53.1	53.4
Amblema plicata	8	95.05	73.6	113.8	71.76	59.5	84.3	37.02	26.8	48.4
Anodonta grandis	1	102.70	102.7	102.7	56.90	56.9	56.9	39.60	39.6	39.6
Cyclonaias tuberculata	23	82.19	69.4	99.1	69.40	60.3	79.1	39.06	33.5	46.3
Ellipsaria lineolata	14	84.82	63.6	108.7	63.59	50.1	78.3	39.51	34.1	46.3
Elliptio crassidens	101	112.00	94.7	129.8	69.07	58.0	78.5	43.58	36.0	54.5
Elliptio dilatata	1	92.60	92.6	92.6	43.70	43.7	43.7	21.50	21.5	21.5
Lampsilis abrupta	4	96.70	86.8	106.8	68.78	64.6	74.0	57.80	52.9	62.4
Lampsilis ovata	3	132.67	118.5	142.7	88.90	82.0	102.7	70.83	63.5	76.7
Leptodea fragilis	1	119.90	119.9	119.9	66.50	66.5	66.5	40.80	40.8	40.8
Ligumia recta	9	162.78	146.6	185.2	60.77	56.1	66.6	51.30	44.0	54.9
Obliquaria reflexa	1	51.20	51.2	51.2	40.20	40.2	40.2	30.80	30.8	30.8
Pleurobema cordatum	103	98.58	76.1	132.6	77.42	52.1	90.6	47.97	34.2	79.9
Pleurobema oviforme	2	69.80	63.5	76.1	55.70	50.6	60.8	40.35	40.0	40.7
Potamilus alatus	10	139.25	110.2	163.2	91.64	72.5	102.3	40.80	34.3	44.8
Quadrula metanevra	9	84.71	72.5	94.8	67.19	56.9	76.1	46.33	39.7	50.9
Quadrula pustulosa	56	58.80	46.4	72.0	55.34	44.4	64.8	34.54	20.2	40.9
Tritogonia verrucosa	3	104.83	84.6	121.4	59.37	49.5	64.4	29.40	24.3	32.4

Appendix A-2. (Continued)

TRM 528-529 and Year 1985	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	6	104.13	92.7	113.4	72.30	66.8	80.3	50.88	46.6	54.6
Amblema plicata	19	108.21	76.3	132.5	79.99	62.9	94.9	42.61	30.5	54.4
Anodonta grandis	4	123.38	107.9	130.1	65.80	60.9	69.6	46.20	40.7	50.1
Cyclonaias tuberculata	41	82.26	70.5	94.6	68.68	59.5	78.4	38.85	32.0	44.9
Ellipsaria lineolata	15	90.71	70.1	98.4	68.05	52.2	76.1	40.40	36.4	44.7
Elliptio crassidens	100	114.33	99.1	130.5	69.92	20.1	84.7	44.20	36.1	52.4
Lampsilis abrupta	6	103.77	92.6	113.3	75.07	64.4	81.1	56.83	50.6	64.4
Lampsilis ovata	6	128.43	114.0	142.0	84.58	70.0	103.4	62.65	57.3	70.2
Lasmigona complanata	1	180.20	180.2	180.2	114.30	114.3	114.3	40.30	40.3	40.3
Leptodea fragilis	1	88.20	88.2	88.2	50.20	50.2	50.2	28.60	28.6	28.6
Ligumia recta	6	168.92	154.4	180.3	64.07	60.2	72.4	53.33	49.9	60.4
Megalonaias nervosa	2	173.70	172.2	175.2	118.25	116.8	119.7	66.15	60.9	71.4
Obliquaria reflexa	3	54.67	50.5	58.8	43.13	40.2	46.8	33.50	30.9	36.7
Pleurobema cordatum	105	96.94	76.3	112.2	76.82	60.6	89.9	46.09	34.1	59.1
Pleurobema plenum	1	84.60	84.6	84.6	70.20	70.2	70.2	50.60	50.6	50.6
Pleurobema rubrum	2	91.60	90.4	92.8	73.20	71.6	74.8	50.60	49.8	51.4
Potamilus alatus	13	140.13	102.6	155.2	102.73	80.6	119.5	41.25	30.6	46.8
Quadrula metanevra	2	80.70	76.9	84.5	63.45	62.8	64.1	48.90	43.6	54.2
Quadrula pustulosa	69	57.78	48.5	80.5	54.68	44.8	68.8	34.83	26.3	42.8
Tritogonia verrucosa	1	136.10	136.1	136.1	72.00	72.0	72.0	34.00	34.0	34.0

Appendix A-2. (Continued)

TRM 528-529 and Year 1986	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	4	103.52	88.2	116.3	71.28	63.2	75.7	48.63	43.4	52.8
Amblema plicata	15	113.97	80.9	137.4	79.28	58.0	94.9	43.03	27.8	55.3
Anodonta grandis	6	117.00	102.2	135.2	64.53	57.0	79.4	46.35	37.2	56.7
Cyclonaias tuberculata	42	81.98	68.4	94.3	69.32	57.0	79.3	39.83	33.0	48.1
Ellipsaria lineolata	15	89.69	63.9	110.8	66.99	50.1	78.8	41.21	35.1	53.3
Elliptio crassidens	99	112.84	93.4	136.2	68.64	53.8	85.2	42.61	31.0	55.5
Elliptio dilatata	1	111.20	111.2	111.2	52.60	52.6	52.6	42.20	42.2	42.2
Lampsilis abrupta	3	98.33	90.3	108.6	72.07	66.4	76.2	53.30	50.7	56.7
Lampsilis ovata	1	152.20	152.2	152.2	101.40	101.4	101.4	72.00	72.0	72.0
Leptodea fragilis	3	90.10	79.4	111.1	51.33	47.3	59.1	29.23	26.7	33.1
Ligumia recta	9	155.47	135.3	173.1	58.03	48.0	64.5	50.77	44.5	55.9
Megalonaias nervosa	1	175.60	175.6	175.6	117.90	117.9	117.9	58.00	58.0	58.0
Obliquaria reflexa	2	51.45	50.7	52.2	36.15	32.0	40.3	25.75	21.6	29.9
Pleurobema cordatum	99	95.61	74.4	116.0	74.47	57.4	84.8	46.86	36.2	61.9
Pleurobema oviforme	2	68.90	68.4	69.4	50.70	48.6	52.8	35.60	33.0	38.2
Potamilus alatus	19	141.82	112.8	164.1	90.17	72.9	123.6	41.89	30.9	79.6
Quadrula metanevra	4	83.83	75.7	91.2	68.80	61.1	84.2	50.20	46.4	54.1
Quadrula pustulosa	35	56.95	46.5	71.6	53.18	43.4	64.2	33.65	24.7	42.1
Tritogonia verrucosa	1	78.80	78.8	78.8	41.40	41.4	41.4	26.70	26.7	26.7

Appendix A-2. (Continued)

TRM 528-529 and Year 1988	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	14	101.22	82.3	119.8	74.19	63.5	89.8	44.59	32.1	52.0
Anodonta grandis	7	125.20	109.7	136.1	66.87	57.6	81.3	52.64	48.4	58.7
Anodonta suborbiculata	1	107.80	107.8	107.8	79.20	79.2	79.2	38.70	38.7	38.7
Cyclonaias tuberculata	29	83.77	67.2	97.5	69.95	58.9	97.7	41.00	36.1	49.3
Ellipsaria lineolata	10	93.77	83.5	102.8	69.20	62.1	77.4	41.00	36.1	44.5
Elliptio crassidens	51	112.93	99.6	136.4	69.48	61.3	76.2	44.49	36.3	54.6
Elliptio dilatata	2	103.25	95.6	110.9	45.45	40.8	50.1	29.15	27.5	30.8
Lampsilis abrupta	10	101.72	86.8	119.8	72.11	62.7	79.8	57.43	51.9	60.9
Lampsilis ovata	1	140.50	140.5	140.5	87.70	87.7	87.7	58.00	58.0	58.0
Leptodea fragilis	3	102.97	98.2	106.4	60.70	56.7	63.0	31.67	28.8	34.0
Ligumia recta	5	161.96	146.6	175.1	64.36	62.0	68.7	53.08	50.2	55.1
Megalonaias nervosa	5	164.90	155.1	170.8	118.14	110.4	126.6	61.18	53.6	68.7
Pleurobema cordatum	50	99.99	86.1	119.1	78.51	69.2	87.5	48.33	39.4	58.6
Pleurobema oviforme	2	72.20	70.2	74.2	55.00	54.0	56.0	40.70	40.7	40.7
Potamilus alatus	15	139.96	118.6	155.2	107.58	90.1	120.9	40.10	34.8	49.3
Quadrula metanevra	2	91.25	90.7	91.8	67.40	67.2	67.6	52.10	50.6	53.6
Quadrula pustulosa	51	58.83	36.1	81.1	55.00	40.7	98.4	35.02	26.2	43.1
Tritogonia verrucosa	2	115.75	98.3	133.2	56.80	51.4	62.2	43.55	26.7	60.4

Appendix A-2. (Continued)

TRM 528-529 and Year 1990	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	2	120.90	120.8	121.0	81.30	80.1	82.5	60.95	60.1	61.8
Amblema plicata	1	110.20	110.2	110.2	75.70	75.7	75.7	38.50	38.5	38.5
Anodonta grandis	2	127.75	126.4	129.1	74.10	69.2	79.0	52.95	46.8	59.1
Cyclonaias tuberculata	14	87.13	76.3	94.9	73.68	66.8	83.3	40.56	34.1	49.6
Ellipsaria lineolata	9	85.23	72.7	102.3	64.28	53.2	74.6	41.13	36.2	47.4
Elliptio crassidens	60	119.35	104.6	134.7	72.48	61.1	82.7	46.00	38.2	51.6
Elliptio dilatata	1	94.60	94.6	94.6	46.90	46.9	46.9	28.60	28.6	28.6
Lampsilis abrupta	3	108.57	101.0	120.6	83.23	81.8	86.0	62.17	55.7	67.7
Lampsilis ovata	1	121.70	121.7	121.7	78.10	78.1	78.1	68.30	68.3	68.3
Leptodea fragilis	1	124.70	124.7	124.7	69.60	69.6	69.6	39.70	39.7	39.7
Ligumia recta	1	172.10	172.1	172.1	68.30	68.3	68.3	58.70	58.7	58.7
Megalonaias nervosa	1	170.10	170.1	170.1	118.40	118.4	118.4	57.10	57.1	57.1
Obliquaria reflexa	3	56.40	54.8	58.0	42.90	40.3	46.4	30.37	28.5	31.7
Pleurobema cordatum	74	98.21	85.4	116.8	76.30	67.2	90.1	47.50	39.6	56.9
Pleurobema oviforme	1	72.80	72.8	72.8	56.00	56.0	56.0	41.70	41.7	41.7
Potamilus alatus	4	124.70	83.2	147.6	101.20	72.6	116.9	36.65	21.5	43.5
Ptychobranchus fasciolaris	1	116.80	116.8	116.8	61.40	61.4	61.4	44.70	44.7	44.7
Quadrula metanevra	4	89.70	85.3	100.7	66.98	60.2	71.5	48.43	46.3	51.8
Quadrula pustulosa	35	58.17	44.1	82.8	54.31	43.3	67.4	34.77	25.2	45.4
Tritogonia verrucosa	1	136.30	136.3	136.3	70.90	70.9	70.9	34.70	34.7	34.7

Appendix A-2. (Continued)

TRM 528-529 and Year 1992	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	5	106.76	89.9	118.2	78.08	68.4	88.8	39.76	24.9	50.4
Cyclonaias tuberculata	12	82.04	70.3	97.1	70.42	59.6	79.4	39.90	29.5	44.5
Ellipsaria lineolata	3	96.67	90.8	99.6	68.43	67.9	69.1	40.80	39.6	42.2
Elliptio crassidens	52	117.40	99.7	136.6	71.86	63.2	83.3	45.77	39.2	53.3
Lampsilis abrupta	4	109.50	96.8	116.3	75.78	68.8	83.4	55.78	50.7	59.8
Ligumia recta	1	165.70	165.7	165.7	60.70	60.7	60.7	59.90	59.9	59.9
Obliquaria reflexa	1	59.30	59.3	59.3	42.90	42.9	42.9	28.90	28.9	28.9
Pleurobema cordatum	29	102.50	86.8	119.8	78.50	72.0	94.2	49.27	39.3	59.8
Potamilus alatus	5	145.50	139.3	150.1	103.32	90.6	109.4	42.50	39.0	46.8
Quadrula metanevra	3	75.00	61.9	84.7	61.57	60.7	62.0	44.23	37.4	47.7
Quadrula pustulosa	18	57.97	52.2	66.9	53.86	47.6	59.7	33.30	28.2	40.3

TRM 528-529 and Year 1994	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Cyclonaias tuberculata	10	81.57	58.4	91.2	67.30	50.3	72.9	39.50	28.3	46.9
Ellipsaria lineolata	3	97.83	94.0	100.2	71.60	69.5	73.1	46.57	44.4	48.6
Elliptio crassidens	66	115.95	104.6	129.2	71.54	62.5	84.7	45.53	39.2	50.8
Lampsilis abrupta	1	108.90	108.9	108.9	82.30	82.3	82.3	65.90	65.9	65.9
Leptodea fragilis	1	118.70	118.7	118.7	70.50	70.5	70.5	39.40	39.4	39.4
Megalonaias nervosa	1	168.70	168.7	168.7	119.20	119.2	119.2	58.70	58.7	58.7
Pleurobema cordatum	41	100.75	84.4	110.7	77.52	68.1	86.3	47.35	34.3	62.7
Pleurobema oviforme	1	71.90	71.9	71.9	59.80	59.8	59.8	41.70	41.7	41.7
Potamilus alatus	3	158.20	145.7	172.3	119.43	108.8	128.6	45.40	43.6	46.5
Quadrula metanevra	1	81.90	81.9	81.9	60.20	60.2	60.2	39.30	39.3	39.3
Quadrula pustulosa	29	58.69	46.2	66.6	54.43	43.8	64.8	35.44	29.8	42.5
Tritogonia verrucosa	2	119.95	99.6	140.3	64.15	58.7	69.6	36.90	31.8	42.0

Appendix A-2. (Continued)

TRM 528-529 and Year 1996	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Amblema plicata	3	109.90	100.4	122.5	76.50	72.1	79.0	46.30	38.0	52.3
Anodonta grandis	1	118.10	118.1	118.1	67.70	67.7	67.7	47.40	47.4	47.4
Cyclonaias tuberculata	13	86.50	75.3	94.9	71.90	65.1	80.8	42.50	35.5	47.7
Ellipsaria lineolata	9	94.00	72.6	107.5	68.30	49.7	80.7	44.70	34.5	50.7
Elliptio crassidens	50	114.90	88.9	131.3	68.90	53.5	85.7	46.30	39.4	61.7
Lampsilis abrupta	1	110.10	110.1	110.1	75.70	75.7	75.7	60.30	60.3	60.3
Lasmigona costata	1	118.40	118.4	118.4	60.60	60.6	60.6	35.20	35.2	35.2
Leptodea fragilis	1	126.20	126.2	126.2	71.30	71.3	71.3	40.70	40.7	40.7
Ligumia recta	1	155.00	155.0	155.0	61.90	61.9	61.9	49.50	49.5	49.5
Pleurobema cordatum	46	100.80	85.3	112.5	78.90	65.4	90.5	49.60	38.3	59.6
Potamilus alatus	4	145.90	135.5	154.1	110.60	86.7	131.7	44.20	39.2	46.8
Quadrula metanevra	1	86.10	86.1	86.1	66.10	66.1	66.1	47.70	47.7	47.7
Quadrula pustulosa	19	61.60	53.0	77.3	56.00	49.6	62.5	38.20	31.1	49.5
Tritogonia verrucosa	1	134.10	134.1	134.1	61.30	61.3	61.3	31.60	31.6	31.6

Appendix A-2. (Continued)

TRM 528-529 and Year 1997	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	1	77.60	77.6	77.6	57.10	57.1	57.1	31.50	31.5	31.5
Cyclonaias tuberculata	13	87.40	79.3	96.2	72.70	65.4	78.8	44.10	38.5	51.9
Ellipsaria lineolata	2	77.00	69.4	84.6	57.70	54.3	61.0	38.80	35.5	42.2
Elliptio crassidens	50	116.10	101.7	134.5	68.40	59.1	83.4	45.80	33.5	65.0
Lampsilis ovata	1	115.30	115.3	115.3	74.10	74.1	74.1	69.50	69.5	69.5
Ligumia recta	1	160.00	160.0	160.0	71.50	71.5	71.5	59.60	59.6	59.6
Pleurobema cordatum	36	99.50	87.1	107.9	77.30	68.7	88.4	50.50	42.9	57.1
Potamilus alatus	4	151.50	122.0	168.8	85.00	74.6	92.9	44.90	42.4	46.6
Quadrula metanevra	1	91.00	91.0	91.0	63.50	63.5	63.5	46.40	46.4	46.4
Quadrula pustulosa	9	60.50	49.2	67.3	55.60	48.7	60.7	35.80	28.4	41.8

Appendix A-2. (Continued)

TRM 528-529 and Years 1983-1997	N	Length Mean	Length Min	Length Max	Height Mean	Height Min	Height Max	Thickness Mean	Thickness Min	Thickness Max
Actinonaias ligamentina	16	106.61	88.2	121.0	74.34	63.2	88.0	52.19	43.4	61.8
Amblema plicata	71	105.77	73.6	137.4	76.80	57.1	94.9	42.13	24.9	55.3
Anodonta grandis	27	119.14	83.0	136.1	65.58	46.1	81.3	48.21	35.4	59.1
Anodonta suborbiculata	1	107.80	107.8	107.8	79.20	79.2	79.2	38.70	38.7	38.7
Cyclonaias tuberculata	240	83.12	58.4	99.1	69.95	50.3	97.7	40.27	28.3	51.9
Cyprogenia stegaria	2	56.45	52.9	60.0	51.14	50.9	51.4	38.71	36.8	40.6
Ellipsaria lineolata	92	89.83	63.6	110.8	66.77	50.1	80.7	41.39	34.1	53.3
Elliptio crassidens	734	114.11	86.8	136.6	69.70	20.1	89.9	44.44	31.0	65.0
Elliptio dilatata	6	100.03	92.6	111.2	46.37	40.8	52.6	30.18	21.5	42.2
Fusconaia subrotunda	1	66.09	66.1	66.1	53.56	53.6	53.6	36.58	36.6	36.6
Lampsilis abrupta	39	101.59	70.5	120.6	73.51	59.4	86.0	56.51	39.8	67.7
Lampsilis ovata	14	130.76	114.0	152.2	86.23	70.0	103.4	66.60	57.3	76.7
Lasmigona complanata	1	180.20	180.2	180.2	114.30	114.3	114.3	40.30	40.3	40.3
Lasmigona costata	1	118.40	118.4	118.4	60.60	60.6	60.6	35.20	35.2	35.2
Leptodea fragilis	12	103.22	79.4	126.2	59.36	47.3	71.3	33.45	26.7	40.8
Ligumia recta	36	161.29	135.3	185.2	61.85	48.0	74.1	52.42	44.0	60.4
Megalonaias nervosa	10	168.63	155.1	175.6	118.27	110.4	126.6	61.20	53.6	71.4
Obliquaria reflexa	11	54.15	49.0	59.3	41.20	32.0	46.8	30.65	21.6	36.7
Pleurobema cordatum	688	98.28	73.3	132.6	76.89	52.1	94.2	47.97	32.3	79.9
Pleurobema oviforme	8	70.81	63.5	76.1	54.82	48.6	60.8	39.59	33.0	41.7
Pleurobema plenum	1	84.60	84.6	84.6	70.20	70.2	70.2	50.60	50.6	50.6
Pleurobema rubrum	2	91.60	90.4	92.8	73.20	71.6	74.8	50.60	49.8	51.4
Potamilus alatus	82	140.65	83.2	172.3	98.58	69.1	131.7	41.34	21.5	79.6
Ptychobranchus fasciolaris	1	116.80	116.8	116.8	61.40	61.4	61.4	44.70	44.7	44.7
Quadrula metanevra	40	81.77	46.9	100.7	64.09	42.2	84.2	45.96	26.2	54.7
Quadrula pustulosa	378	58.29	36.1	82.8	54.64	40.7	98.4	34.90	20.2	49.5
Tritogonia verrucosa	12	114.82	78.8	140.3	60.70	41.4	72.0	34.06	24.3	60.4

Appendix A-2. (Continued)

Three Bed Composite and Year 1983	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	5	104.00	92.5	113.4	73.84	69.3	80.1	51.88	46.8	58.5
Amblema plicata	53	96.86	74.4	132.3	72.73	56.6	99.7	45.37	30.4	56.9
Anodonta grandis	28	121.88	83.0	154.6	67.20	46.1	89.6	52.15	35.4	67.9
Cyclonaias tuberculata	147	79.14	62.1	96.5	67.90	52.1	80.2	39.50	32.4	49.8
Cyprogenia stegaria	3	54.83	51.6	60.0	50.66	49.7	51.4	37.81	36.0	40.6
Dromus dromas	1	60.10	60.1	60.1	58.30	58.3	58.3	32.80	32.8	32.8
Ellipsaria lineolata	45	85.29	56.8	108.8	65.74	44.6	78.6	40.30	30.1	51.3
Elliptio crassidens	311	107.96	86.8	134.6	67.29	54.0	89.9	42.93	21.0	56.1
Elliptio dilatata	5	103.32	95.3	113.3	45.50	42.2	48.8	32.38	30.5	34.7
Fusconaia subrotunda	1	66.09	66.1	66.1	53.56	53.6	53.6	36.58	36.6	36.6
Lampsilis abrupta	10	94.39	70.5	106.4	71.17	59.4	84.4	50.94	39.8	60.1
Lampsilis ovata	4	124.93	122.0	132.3	86.21	74.7	92.3	68.48	62.0	76.3
Leptodea fragilis	4	84.13	59.6	112.4	49.33	34.6	66.4	27.10	20.1	32.7
Ligumia recta	8	155.34	145.1	165.0	62.50	56.6	68.3	50.50	42.5	56.7
Megalonaias nervosa	3	173.83	164.4	180.6	117.43	111.7	120.7	60.50	57.2	63.0
Obliquaria reflexa	20	53.78	45.1	64.1	43.15	24.1	51.5	34.33	24.6	41.4
Plethobasus cyphyus	2	91.80	89.3	94.3	64.55	62.8	66.3	45.00	43.6	46.4
Pleurobema cordatum	301	95.39	72.1	129.1	75.65	59.3	99.5	48.25	31.4	62.9
Pleurobema plenum	1	58.10	58.1	58.1	52.90	52.9	52.9	36.40	36.4	36.4
Potamilus alatus	43	135.39	46.9	162.8	98.20	69.1	120.9	38.12	24.1	46.5
Quadrula metanevra	36	76.52	46.9	92.6	60.28	42.2	74.4	44.22	26.2	54.7
Quadrula pustulosa	158	55.91	43.7	69.9	53.61	40.5	66.9	34.47	26.3	43.8
Tritogonia verrucosa	18	110.06	96.0	128.7	58.77	54.3	64.1	36.27	30.1	42.7

Appendix A-2. (Continued)

Three Bed Composite and Year 1984	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	2	109.55	99.4	119.7	81.00	74.0	88.0	53.25	53.1	53.4
Amblema plicata	30	98.18	73.6	120.1	72.73	59.5	88.0	42.37	26.8	52.4
Anodonta grandis	9	124.58	102.7	144.3	67.46	56.6	74.1	49.52	39.6	54.6
Anodonta imbecillis	2	53.60	52.5	54.7	23.95	23.2	24.7	15.60	14.3	16.9
Cyclonaias tuberculata	131	76.09	59.1	99.1	65.19	52.2	80.9	37.77	29.5	46.3
Cyprogenia stegaria	1	52.90	52.9	52.9	51.40	51.4	51.4	36.40	36.4	36.4
Ellipsaria lineolata	49	82.92	56.6	109.7	62.95	44.0	86.0	37.88	26.3	50.2
Elliptio crassidens	302	109.58	89.2	130.8	68.75	56.3	82.4	43.30	24.4	60.9
Elliptio dilatata	2	96.35	92.6	100.1	42.95	42.2	43.7	24.75	21.5	28.0
Lampsilis abrupta	8	96.66	86.8	106.8	68.52	60.7	74.8	56.31	48.1	62.4
Lampsilis ovata	5	127.98	102.1	142.7	86.44	72.9	102.7	67.56	56.5	76.7
Leptodea fragilis	6	111.33	104.5	119.9	65.27	62.1	68.4	36.05	30.9	40.8
Ligumia recta	14	157.96	140.9	185.2	59.61	50.5	66.6	49.65	40.0	54.9
Megalonaias nervosa	1	180.00	180.0	180.0	130.20	130.2	130.2	63.00	63.0	63.0
Obliquaria reflexa	11	53.63	36.5	64.0	42.05	32.9	52.3	33.06	22.9	39.8
Pleurobema cordatum	234	95.08	62.1	132.6	74.99	44.7	99.8	46.26	32.8	79.9
Pleurobema oviforme	2	69.80	63.5	76.1	55.70	50.6	60.8	40.35	40.0	40.7
Pleurobema plenum	2	60.10	51.3	68.9	57.70	49.4	66.0	44.00	39.4	48.6
Potamilus alatus	47	142.73	96.7	182.1	97.96	72.5	134.5	39.57	30.0	46.5
Ptychobranchus fasciolaris	1	94.40	94.4	94.4	56.70	56.7	56.7	34.80	34.8	34.8
Quadrula metanevra	24	78.68	64.5	94.8	62.47	52.6	76.1	43.05	32.4	54.9
Quadrula pustulosa	138	56.75	40.0	74.1	53.65	39.5	64.8	33.43	20.2	40.9
Tritogonia verrucosa	10	110.44	76.7	134.9	59.00	42.7	66.8	34.18	19.7	44.8

Appendix A-2. (Continued)

Three Bed Composite and Year 1985	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	11	104.72	92.7	113.4	73.72	66.8	80.3	51.75	46.6	54.9
Amblema plicata	42	103.37	76.3	132.5	75.25	58.2	94.9	43.01	30.5	56.7
Anodonta grandis	10	123.14	107.9	142.6	69.63	60.9	80.4	48.76	40.7	58.7
Cyclonaias tuberculata	124	78.39	60.5	94.6	66.76	54.7	78.4	37.85	30.6	44.9
Cyprogenia stegaria	1	57.70	57.7	57.7	55.60	55.6	55.6	44.10	44.1	44.1
Ellipsaria lineolata	35	87.83	62.3	100.4	67.24	46.9	76.9	38.96	32.0	46.8
Elliptio crassidens	306	110.22	90.1	134.8	68.72	20.1	88.5	43.21	29.5	53.7
Elliptio dilatata	2	98.80	96.8	100.8	44.20	44.2	44.2	32.30	29.8	34.8
Lampsilis abrupta	8	101.94	82.3	113.3	74.21	64.4	81.1	55.61	43.5	64.4
Lampsilis ovata	9	127.36	114.0	142.0	84.03	70.0	103.4	62.70	57.3	70.2
Lasmigona complanata	1	180.20	180.2	180.2	114.30	114.3	114.3	40.30	40.3	40.3
Leptodea fragilis	5	100.28	86.9	114.7	59.08	50.2	66.8	33.22	28.6	39.8
Ligumia recta	11	165.39	142.2	180.3	63.30	57.2	72.4	50.06	41.3	60.4
Megalonaias nervosa	5	173.70	160.1	190.8	115.26	102.3	121.1	59.66	52.4	71.4
Obliquaria reflexa	12	55.72	46.6	66.9	42.95	36.1	50.8	32.58	23.4	36.7
Pleurobema cordatum	245	96.42	70.4	160.2	76.58	58.2	134.9	45.35	30.2	59.1
Pleurobema oviforme	1	72.90	72.9	72.9	56.50	56.5	56.5	40.20	40.2	40.2
Pleurobema plenum	1	84.60	84.6	84.6	70.20	70.2	70.2	50.60	50.6	50.6
Pleurobema rubrum	3	87.97	80.7	92.8	70.23	64.3	74.8	48.57	44.5	51.4
Potamilus alatus	77	139.79	98.0	170.2	100.29	76.5	125.6	39.87	28.4	49.6
Quadrula metanevra	16	78.07	67.3	88.9	61.94	56.1	70.3	42.39	36.8	54.2
Quadrula pustulosa	138	57.98	46.3	80.5	54.91	32.1	68.8	34.83	25.7	44.2
Tritogonia verrucosa	19	124.66	92.3	148.8	61.46	40.6	72.0	39.86	34.0	48.7

Appendix A-2. (Continued)

Three Bed Composite and Year 1986	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	8	99.23	88.2	116.3	69.71	63.2	75.7	47.32	40.3	53.8
Amblema plicata	47	103.36	66.7	137.4	73.01	50.6	94.9	43.79	26.8	57.4
Anodonta grandis	16	122.18	80.9	147.8	68.42	50.7	82.0	49.42	35.1	63.2
Anodonta imbecillis	1	39.20	39.2	39.2	17.40	17.4	17.4	7.10	7.1	7.1
Cyclonaias tuberculata	131	76.16	56.9	96.7	64.74	47.6	80.2	37.08	23.7	51.0
Ellipsaria lineolata	37	84.30	51.8	112.3	62.73	39.2	78.8	37.52	22.6	53.3
Elliptio crassidens	304	110.53	87.2	151.8	67.43	53.8	87.1	42.28	31.0	55.5
Elliptio dilatata	3	109.23	107.1	111.2	49.37	45.5	52.6	39.17	35.4	42.2
Lampsilis abrupta	8	100.44	86.1	114.8	72.96	66.3	80.7	52.21	48.3	57.2
Lampsilis ovata	3	141.40	132.9	152.2	94.33	90.3	101.4	66.83	55.9	72.6
Lasmigona costata	1	122.10	122.1	122.1	69.90	69.9	69.9	25.50	25.5	25.5
Leptodea fragilis	9	96.87	79.4	112.1	55.52	46.6	67.5	30.99	25.3	36.0
Ligumia recta	18	147.23	107.7	173.1	56.62	45.0	67.6	46.78	33.1	55.9
Megalonaias nervosa	6	152.35	124.6	175.6	105.20	87.2	119.3	57.80	53.9	63.2
Obliquaria reflexa	12	55.11	46.6	66.7	43.02	32.0	52.4	33.39	21.6	41.2
Pleurobema cordatum	231	92.87	54.9	117.9	72.90	49.7	88.5	45.07	25.2	61.9
Pleurobema oviforme	2	68.90	68.4	69.4	50.70	48.6	52.8	35.60	33.0	38.2
Potamilus alatus	68	139.66	79.8	174.0	89.52	56.7	123.6	39.47	26.7	79.6
Quadrula metanevra	14	74.75	54.9	91.2	59.91	42.4	84.2	42.11	31.0	55.3
Quadrula pustulosa	72	54.97	38.2	71.6	51.68	37.2	66.1	32.13	20.5	42.1
Tritogonia verrucosa	21	110.36	78.8	133.0	55.36	41.4	66.7	33.56	24.7	42.9

Appendix A-2. (Continued)

Three Bed Composite and Year 1988	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	3	97.87	90.9	107.6	73.37	71.3	76.8	51.37	47.6	55.4
Amblema plicata	48	102.47	64.8	119.8	75.22	51.1	89.8	46.31	32.1	56.9
Anodonta grandis	29	126.85	81.7	155.1	69.93	53.6	89.9	53.46	34.5	71.2
Anodonta imbecillis	1	54.00	54.0	54.0	24.10	24.1	24.1	16.20	16.2	16.2
Anodonta suborbiculata	1	107.80	107.8	107.8	79.20	79.2	79.2	38.70	38.7	38.7
Cyclonaias tuberculata	87	79.12	63.4	97.5	67.22	55.2	97.7	39.34	31.3	49.3
Ellipsaria lineolata	23	87.22	65.1	102.8	65.42	47.5	77.4	39.61	32.7	50.3
Elliptio crassidens	154	110.06	92.4	136.4	68.69	44.2	84.9	44.26	34.1	55.3
Elliptio dilatata	3	101.10	95.6	110.9	45.43	40.8	50.1	28.40	26.9	30.8
Lampsilis abrupta	12	100.78	86.8	119.8	71.72	62.7	79.8	57.44	51.4	63.6
Lampsilis ovata	3	130.37	110.7	140.5	85.00	76.9	90.4	65.70	58.0	77.3
Leptodea fragilis	12	99.81	70.4	126.3	61.26	44.9	76.0	32.12	23.8	39.8
Ligumia recta	7	160.27	144.4	175.1	62.39	54.2	68.7	51.81	44.4	55.1
Megalonaias nervosa	9	160.61	144.2	170.8	114.19	100.8	126.6	60.60	53.3	68.7
Obliquaria reflexa	7	54.84	44.2	62.7	43.20	36.2	49.6	32.27	24.4	36.0
Pleurobema cordatum	133	96.57	68.5	119.1	76.57	54.9	89.2	47.87	38.2	58.6
Pleurobema oviforme	2	72.20	70.2	74.2	55.00	54.0	56.0	40.70	40.7	40.7
Pleurobema rubrum	1	88.30	88.3	88.3	69.50	69.5	69.5	46.70	46.7	46.7
Potamilus alatus	54	142.76	110.3	187.7	106.60	76.3	131.2	40.82	31.0	50.3
Quadrula metanevra	8	83.34	66.7	92.1	64.21	54.2	70.1	45.60	38.4	53.6
Quadrula pustulosa	77	58.73	36.1	81.1	55.06	40.7	98.4	35.31	26.2	43.1
Tritogonia verrucosa	18	112.68	91.8	140.8	62.25	50.1	76.3	39.49	23.2	60.4

Appendix A-2. (Continued)

Three Bed Composite and Year 1990	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	5	110.38	96.0	121.0	77.90	71.4	82.6	55.88	47.6	61.8
Amblema plicata	10	102.16	76.6	120.1	72.58	54.5	87.2	44.19	33.6	50.9
Anodonta grandis	20	135.42	108.7	159.1	76.04	61.5	99.9	55.90	44.4	68.8
Anodonta imbecillis	1	52.00	52.0	52.0	24.80	24.8	24.8	14.30	14.3	14.3
Anodonta suborbiculata	1	126.20	126.2	126.2	96.40	96.4	96.4	48.30	48.3	48.3
Cyclonaias tuberculata	69	79.65	62.0	111.0	67.29	52.1	92.1	37.97	28.0	49.6
Ellipsaria lineolata	28	85.42	64.2	102.3	64.41	51.6	76.9	39.18	32.1	47.4
Elliptio crassidens	160	115.21	87.5	149.3	70.91	61.1	82.7	44.91	36.3	51.6
Elliptio dilatata	1	94.60	94.6	94.6	46.90	46.9	46.9	28.60	28.6	28.6
Lampsilis abrupta	4	105.95	98.1	120.6	83.35	81.8	86.0	62.15	55.7	67.7
Lampsilis ovata	1	121.70	121.7	121.7	78.10	78.1	78.1	68.30	68.3	68.3
Leptodea fragilis	8	110.46	89.9	130.1	68.93	61.0	89.5	37.08	32.8	40.0
Ligumia recta	2	172.60	172.1	173.1	70.90	68.3	73.5	59.30	58.7	59.9
Megalonaias nervosa	3	166.60	155.6	174.1	116.57	110.7	120.6	56.50	56.2	57.1
Obliquaria reflexa	11	55.06	44.5	64.6	43.34	36.7	49.9	32.80	25.4	45.1
Pleurobema cordatum	132	97.37	75.6	120.7	75.38	59.5	90.6	46.34	32.9	56.9
Pleurobema oviforme	1	72.80	72.8	72.8	56.00	56.0	56.0	41.70	41.7	41.7
Potamilus alatus	45	142.78	83.2	169.1	107.14	72.6	126.3	44.74	21.5	139.8
Ptychobranchus fasciolaris	1	116.80	116.8	116.8	61.40	61.4	61.4	44.70	44.7	44.7
Quadrula metanevra	8	84.28	65.2	100.7	63.44	48.1	71.5	46.72	35.5	51.8
Quadrula pustulosa	78	57.56	44.1	82.8	53.53	42.8	67.4	34.22	25.2	45.4
Tritogonia verrucosa	9	107.59	78.1	136.3	57.36	43.4	70.9	35.21	26.6	42.5

Appendix A-2. (Continued)

Three Bed Composite and Year 1992	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	1	94.80	94.8	94.8	65.40	65.4	65.4	49.60	49.6	49.6
Amblema plicata	13	105.46	89.9	124.7	77.27	65.5	88.8	45.11	24.9	54.8
Anodonta grandis	5	130.06	122.0	136.8	76.06	67.3	84.9	58.54	54.0	65.1
Cyclonaias tuberculata	68	80.10	63.2	97.1	67.49	53.4	87.1	38.73	29.5	44.7
Ellipsaria lineolata	14	90.49	69.6	99.6	67.96	49.7	77.2	39.56	31.3	44.8
Elliptio crassidens	137	112.26	88.4	136.6	69.83	55.6	83.3	44.75	27.2	53.3
Lampsilis abrupta	6	108.85	96.8	116.3	74.63	66.3	83.4	54.70	50.7	59.8
Ligumia recta	3	157.27	148.0	165.7	60.00	56.9	62.4	52.30	47.3	59.9
Megalonaias nervosa	4	173.35	155.9	183.2	120.88	112.2	128.2	60.93	53.1	69.3
Obliquaria reflexa	6	57.17	52.0	61.5	43.45	40.9	47.9	32.30	28.9	36.7
Plethobasus cyphyus	1	91.40	91.4	91.4	64.80	64.8	64.8	50.30	50.3	50.3
Pleurobema cordatum	82	98.53	64.7	127.9	76.15	60.9	94.2	46.29	37.5	59.8
Potamilus alatus	16	142.99	116.6	161.2	105.32	90.6	116.9	41.65	35.1	47.4
Quadrula metanevra	8	78.61	61.9	87.2	61.76	58.3	66.5	43.92	37.4	48.2
Quadrula pustulosa	48	56.37	45.3	66.9	52.70	40.2	62.7	33.52	25.2	44.8
Tritogonia verrucosa	9	106.24	77.0	127.3	59.00	43.1	66.7	36.29	21.7	48.3

Appendix A-2. (Continued)

Three Bed Composite and Year 1994	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	13	106.79	84.7	119.1	76.72	59.2	89.7	48.44	35.0	54.7
Anodonta grandis	7	135.29	121.4	142.7	79.13	66.7	85.1	57.84	47.6	64.6
Cyclonaias tuberculata	64	78.52	58.4	91.2	66.28	50.3	74.3	38.94	28.3	48.9
Ellipsaria lineolata	11	87.68	76.1	100.2	66.95	57.7	76.7	40.38	32.9	48.6
Elliptio crassidens	216	113.88	96.5	129.8	71.10	61.3	88.6	45.37	36.6	52.9
Lampsilis abrupta	2	105.05	101.2	108.9	84.20	82.3	86.1	65.65	65.4	65.9
Leptodea fragilis	3	117.67	112.2	122.1	72.87	70.5	76.9	39.60	39.4	40.0
Ligumia recta	1	161.40	161.4	161.4	73.30	73.3	73.3	61.20	61.2	61.2
Megalonaias nervosa	2	174.45	168.7	180.2	119.45	119.2	119.7	63.85	58.7	69.0
Obliquaria reflexa	11	57.30	52.8	69.5	45.68	41.4	51.7	35.04	29.6	42.7
Plethobasus cyphyus	1	88.60	88.6	88.6	59.40	59.4	59.4	46.20	46.2	46.2
Pleurobema cordatum	95	97.71	59.8	116.5	75.96	58.1	90.1	46.85	34.3	62.7
Pleurobema oviforme	1	71.90	71.9	71.9	59.80	59.8	59.8	41.70	41.7	41.7
Potamilus alatus	10	149.92	128.3	172.3	115.17	99.6	128.6	43.34	38.4	46.5
Quadrula metanevra	4	74.18	68.4	81.9	57.53	54.4	60.2	40.33	39.3	42.2
Quadrula pustulosa	65	58.02	46.2	66.6	54.08	43.8	64.8	35.28	27.1	49.9
Tritogonia verrucosa	7	115.60	95.8	140.3	58.90	52.4	69.6	36.64	30.7	42.0

Appendix A-2. (Continued)

Three Bed Composite and Year 1996	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	11	104.90	78.2	125.4	73.50	52.4	86.5	46.10	26.7	57.3
Anodonta grandis	7	141.10	118.1	160.0	81.80	67.7	102.4	56.90	47.4	64.2
Cyclonaias tuberculata	38	83.00	73.0	94.9	69.20	58.4	80.8	40.90	34.6	47.7
Ellipsaria lineolata	15	92.20	69.7	107.5	67.90	48.0	80.7	43.40	30.8	50.7
Elliptio crassidens	140	112.90	88.9	151.1	68.60	53.5	85.7	45.50	34.2	61.7
Elliptio dilatata	1	95.40	95.4	95.4	41.00	41.0	41.0	29.70	29.7	29.7
Lampsilis abrupta	4	110.20	99.4	122.4	79.30	73.1	85.5	60.40	55.3	66.9
Lasmigona costata	1	118.40	118.4	118.4	60.60	60.6	60.6	35.20	35.2	35.2
Leptodea fragilis	1	126.20	126.2	126.2	71.30	71.3	71.3	40.70	40.7	40.7
Ligumia recta	2	157.50	155.0	160.0	61.50	61.1	61.9	49.40	49.4	49.5
Megalonaias nervosa	1	180.00	180.0	180.0	123.60	123.6	123.6	66.00	66.0	66.0
Obliquaria reflexa	6	56.10	51.8	59.6	43.90	39.8	50.1	36.40	33.4	40.3
Pleurobema cordatum	93	99.40	77.1	120.9	77.20	65.2	91.2	48.70	38.3	59.6
Potamilus alatus	35	145.90	98.2	180.0	85.80	60.1	131.7	41.30	28.9	51.5
Quadrula metanevra	2	81.90	77.8	86.1	63.50	61.0	66.1	49.60	47.7	51.6
Quadrula pustulosa	29	60.80	50.6	77.3	55.80	48.9	62.5	38.10	31.1	49.5
Tritogonia verrucosa	4	109.70	88.5	134.1	56.00	49.4	61.3	34.50	29.6	40.3

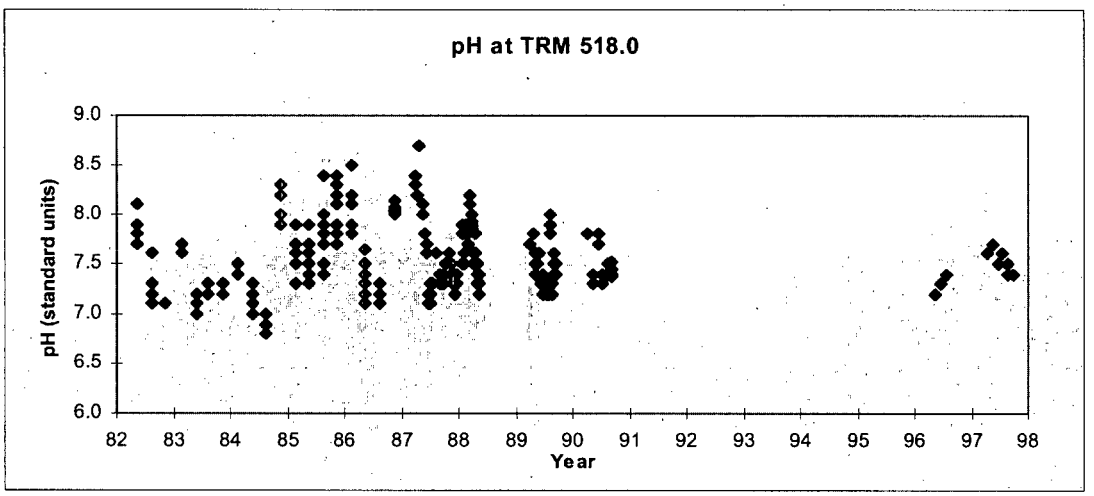
Appendix A-2. (Continued)

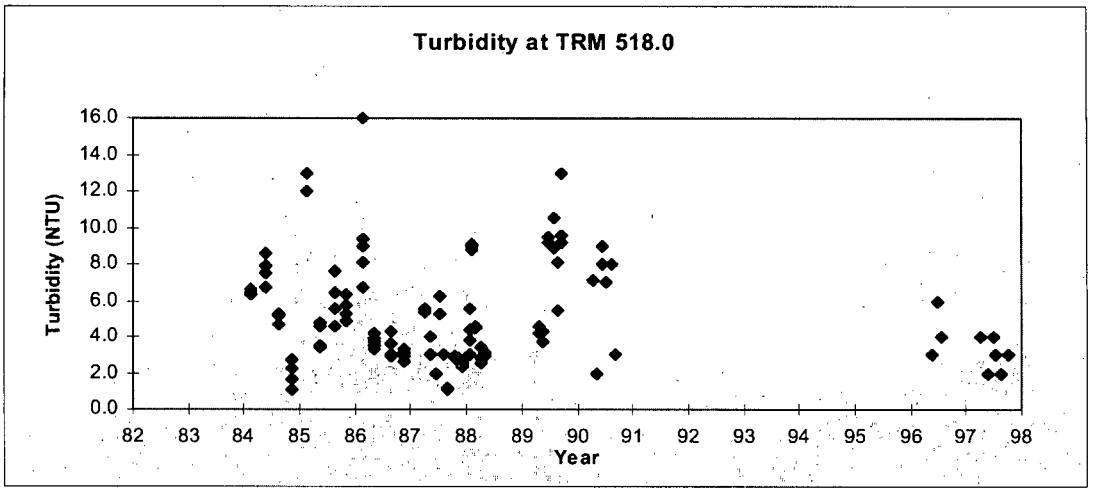
Three Bed Composite and Year 1997	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	5	96.00	73.5	123.0	68.90	57.0	78.9	44.20	31.5	53.2
Anodonta grandis	1	147.00	147.0	147.0	81.00	81.0	81.0	63.40	63.4	63.4
Cyclonaias tuberculata	47	81.50	67.0	96.8	67.80	56.5	78.8	42.40	35.6	51.9
Ellipsaria lineolata	8	81.80	56.4	105.5	61.50	45.9	71.6	40.90	33.8	52.6
Elliptio crassidens	152	113.10	92.2	134.5	68.20	53.7	83.4	45.70	33.5	65.0
Lampsilis ovata	1	115.30	115.3	115.3	74.10	74.1	74.1	69.50	69.5	69.5
Leptodea fragilis	2	92.20	69.3	115.0	56.10	40.5	71.7	26.90	21.5	37.3
Ligumia recta	1	160.00	160.0	160.0	71.50	71.5	71.5	59.60	59.6	59.6
Obliquaria reflexa	3	54.10	50.6	57.4	42.00	34.7	46.7	34.50	33.0	36.6
Pleurobema cordatum	82	98.20	83.1	117.2	75.50	60.2	92.3	49.90	41.7	57.3
Potamilus alatus	12	146.40	105.7	168.8	83.50	63.3	95.8	42.60	33.3	48.9
Quadrula metanevra	2	88.00	85.0	91.0	64.60	63.5	65.7	45.90	45.4	46.4
Quadrula pustulosa	24	59.00	49.2	67.3	54.10	45.2	60.7	36.20	28.4	45.6
Tritogonia verrucosa	1	109.60	109.6	109.6	52.80	52.8	52.8	38.30	38.3	38.3

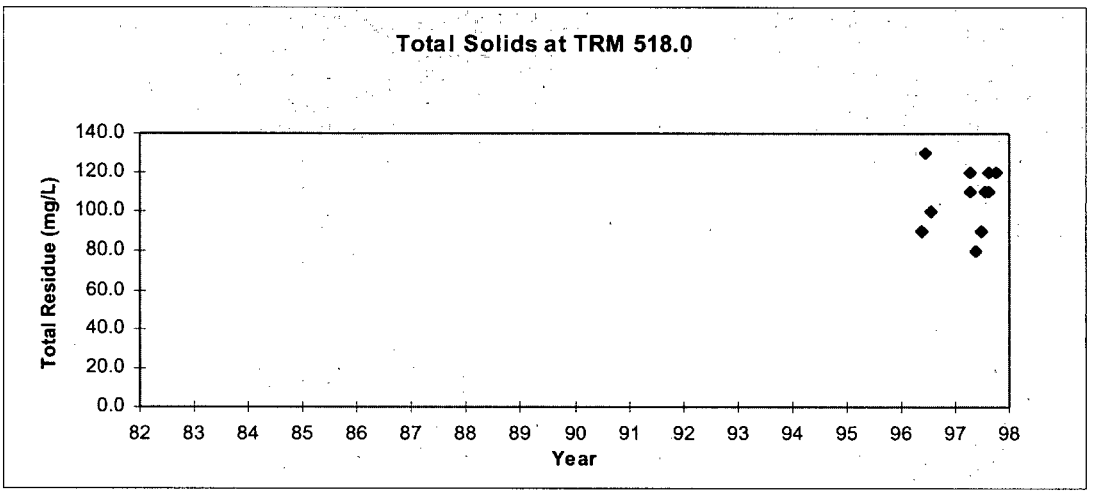
Appendix A-2. (Continued)

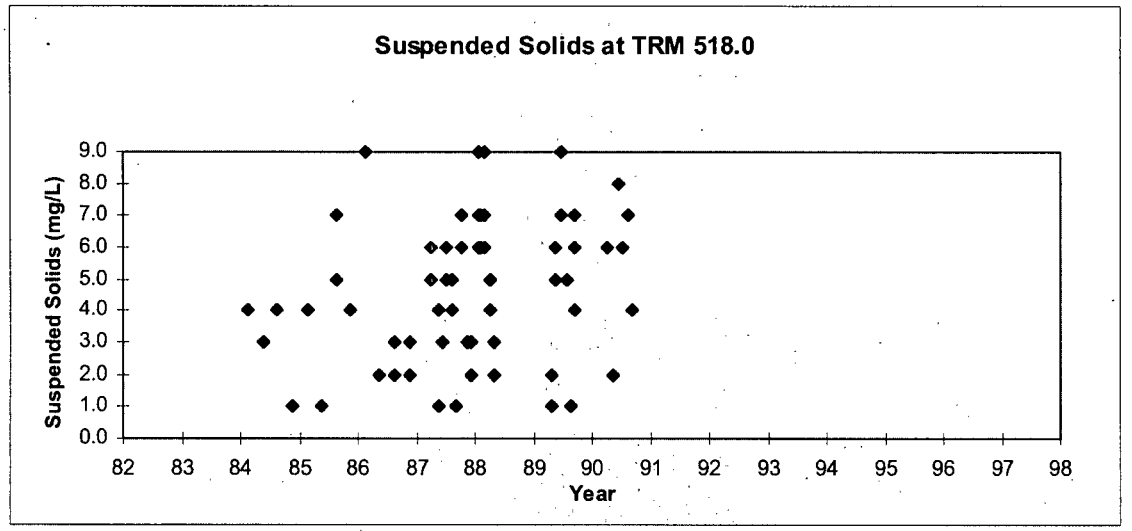
Three Bed Composite and Years 1983-1997	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	35	103.57	88.2	121.0	73.57	63.2	88.0	51.34	40.3	61.8
Amblema plicata	272	101.52	64.8	137.4	73.97	50.6	99.7	44.66	24.9	57.4
Anodonta grandis	132	127.57	80.9	160.0	71.34	46.1	102.4	53.12	34.5	71.2
Anodonta imbecillis	5	50.48	39.2	54.7	22.84	17.4	24.8	13.76	7.1	16.9
Anodonta suborbiculata	2	117.00	107.8	126.2	87.80	79.2	96.4	43.50	38.7	48.3
Cyclonaias tuberculata	897	79.30	56.9	111.0	67.36	47.6	97.7	39.04	23.7	51.9
Cyprogenia stegaria	5	55.02	51.6	60.0	51.80	49.7	55.6	38.78	36.0	44.1
Dromus dromas	1	60.10	60.1	60.1	58.30	58.3	58.3	32.80	32.8	32.8
Ellipsaria lineolata	265	85.90	51.8	112.3	64.99	39.2	86.0	39.27	22.6	53.3
Elliptio crassidens	2182	111.08	86.8	151.8	68.76	20.1	89.9	43.88	21.0	65.0
Elliptio dilatata	17	101.64	92.6	113.3	45.54	40.8	52.6	31.59	21.5	42.2
Fusconaia subrotunda	1	66.09	66.1	66.1	53.56	53.6	53.6	36.58	36.6	36.6
Lampsilis abrupta	62	101.18	70.5	122.4	73.62	59.4	86.1	55.83	39.8	67.7
Lampsilis ovata	26	128.39	102.1	152.2	85.52	70.0	103.4	65.83	55.9	77.3
Lasmigona complanata	1	180.20	180.2	180.2	114.30	114.3	114.3	40.30	40.3	40.3
Lasmigona costata	2	120.25	118.4	122.1	65.25	60.6	69.9	30.35	25.5	35.2
Leptodea fragilis	50	102.46	59.6	130.1	61.45	34.6	89.5	33.30	20.1	40.8
Ligumia recta	67	156.70	107.7	185.2	60.84	45.0	73.5	49.99	33.1	61.2
Megalonaias nervosa	34	166.23	124.6	190.8	115.10	87.2	130.2	60.06	52.4	71.4
Obliquaria reflexa	99	55.12	36.5	69.5	43.32	24.1	52.4	33.63	21.6	45.1
Plethobasus cyphyus	4	90.90	88.6	94.3	63.33	59.4	66.3	46.63	43.6	50.3
Pleurobema cordatum	1628	96.06	54.9	160.2	75.48	44.7	134.9	46.52	25.2	79.9
Pleurobema oviforme	9	71.04	63.5	76.1	55.01	48.6	60.8	39.66	33.0	41.7
Pleurobema plenum	4	65.73	51.3	84.6	59.63	49.4	70.2	43.75	36.4	50.6
Pleurobema rubrum	4	88.05	80.7	92.8	70.05	64.3	74.8	48.10	44.5	51.4
Potamilus alatus	407	141.46	46.9	187.7	98.42	56.7	134.5	40.60	21.5	139.8
Ptychobranchus fasciolaris	2	105.60	94.4	116.8	59.05	56.7	61.4	39.75	34.8	44.7
Quadrula metanevra	122	78.24	46.9	100.7	61.48	42.2	84.2	43.73	26.2	55.3
Quadrula pustulosa	827	57.18	36.1	82.8	53.87	32.1	98.4	34.39	20.2	49.9
Tritogonia verrucosa	116	112.77	76.7	148.8	58.92	40.6	76.3	36.59	19.7	60.4

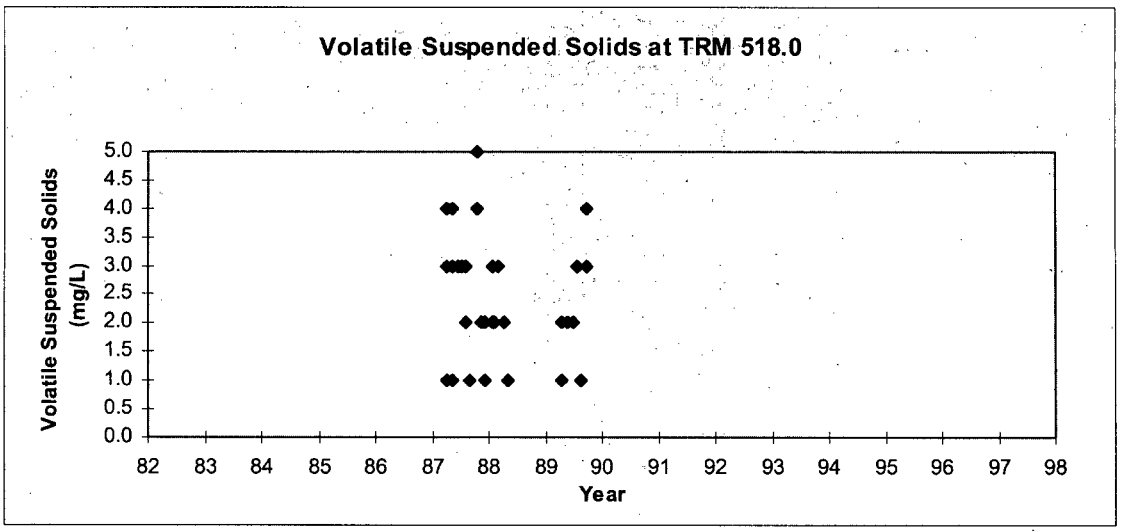
Appendix B-1. Selected water quality values measured during preoperational (1982-1991) and operational (1996-1997) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 518.0

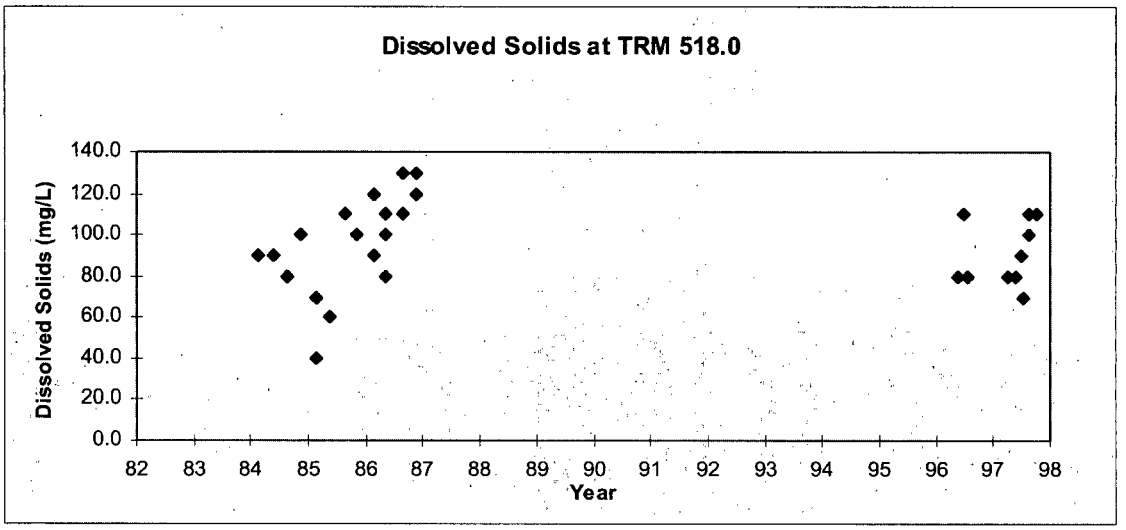


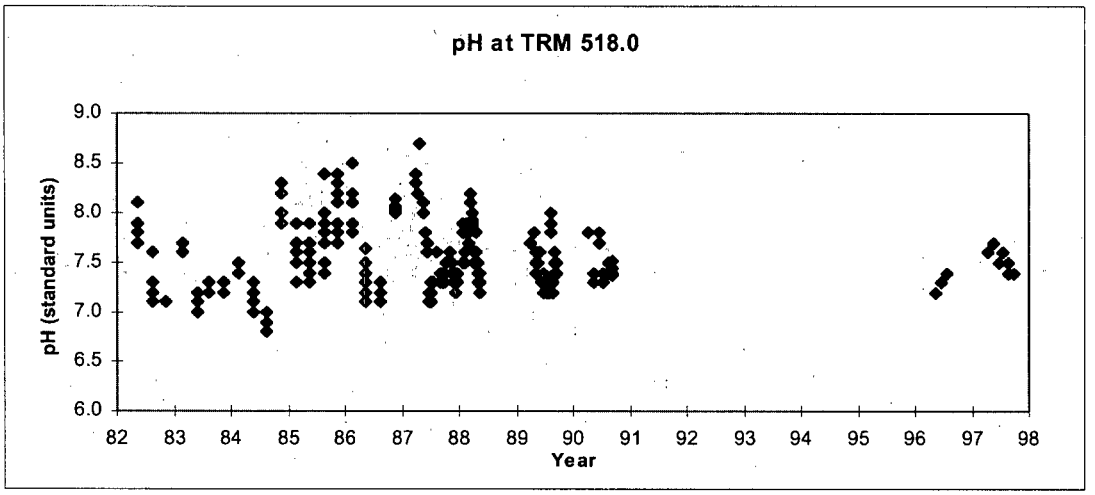


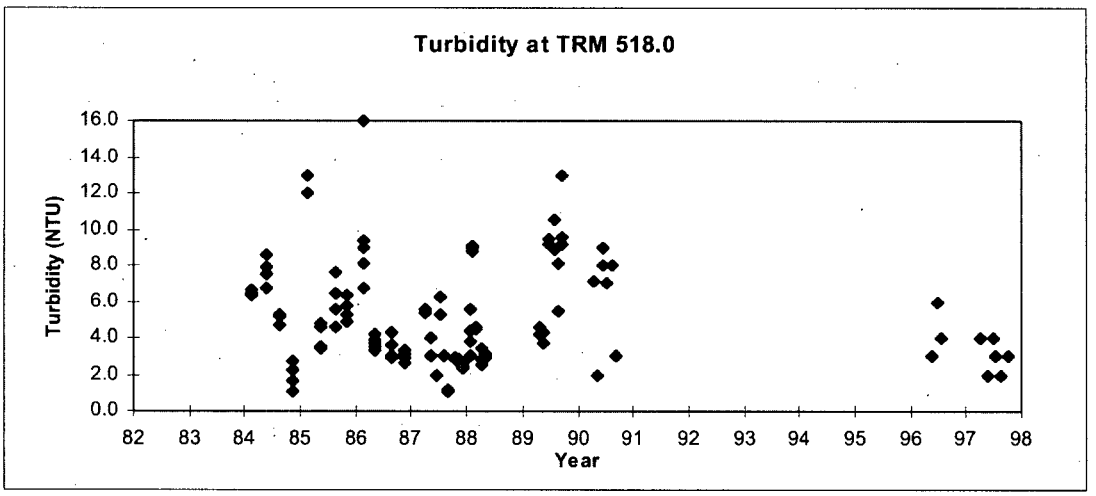


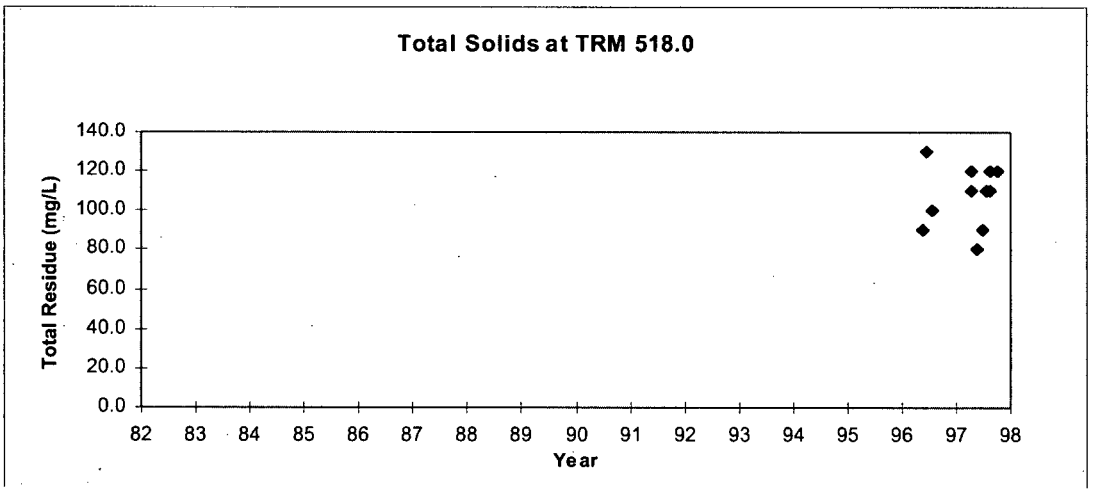

Suspended Solids at TRM 518.0
Suspended Solids (mg/L)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year


Volatile Suspended Solids at TRM 518.0
Volatile Suspended Solids (mg/L)
5.0
4.5
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 98
Year

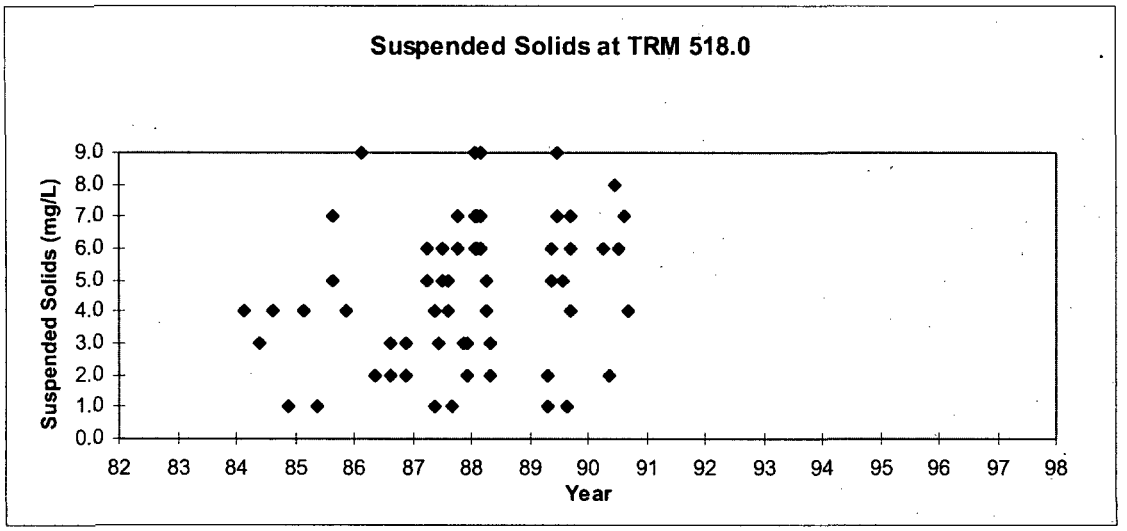

Dissolved Solids at TRM 518.0
Dissolved Solids (mg/L)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

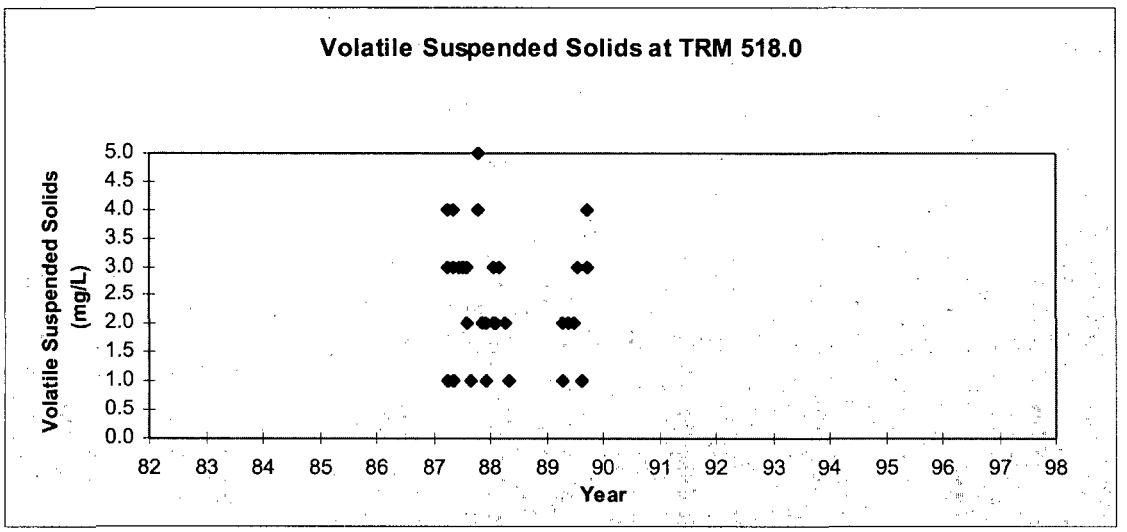

pH at TRM 518.0
pH (standard units)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

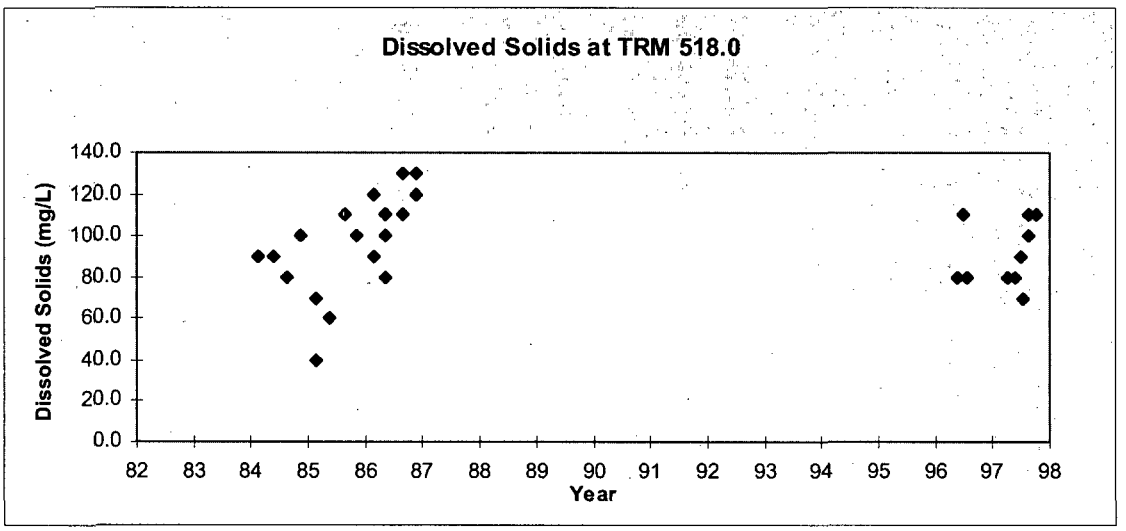

Turbidity at TRM 518.0
Turbidity (NTU)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

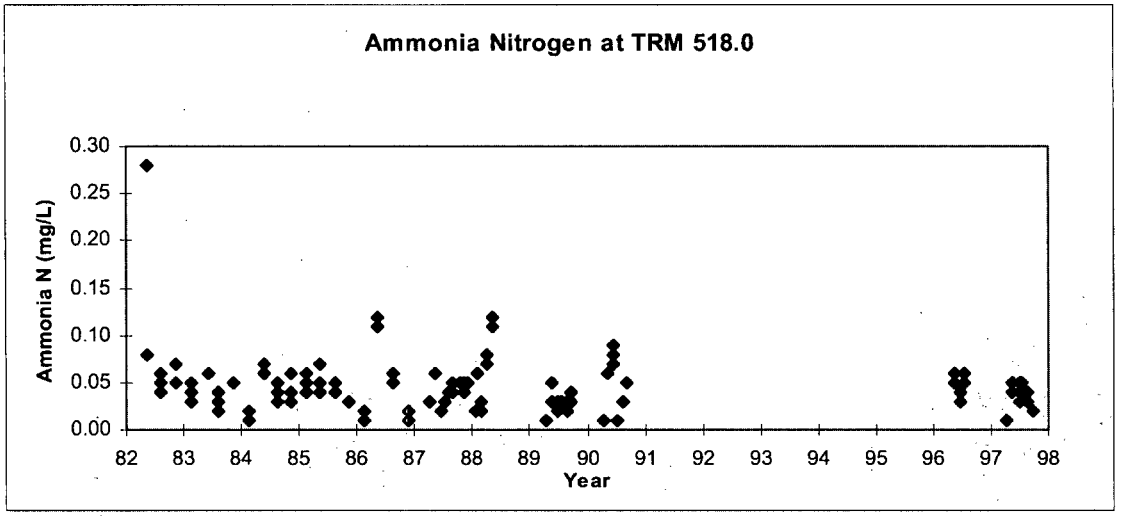

Total Solids at TRM 518.0
Total Residue (mg/L)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

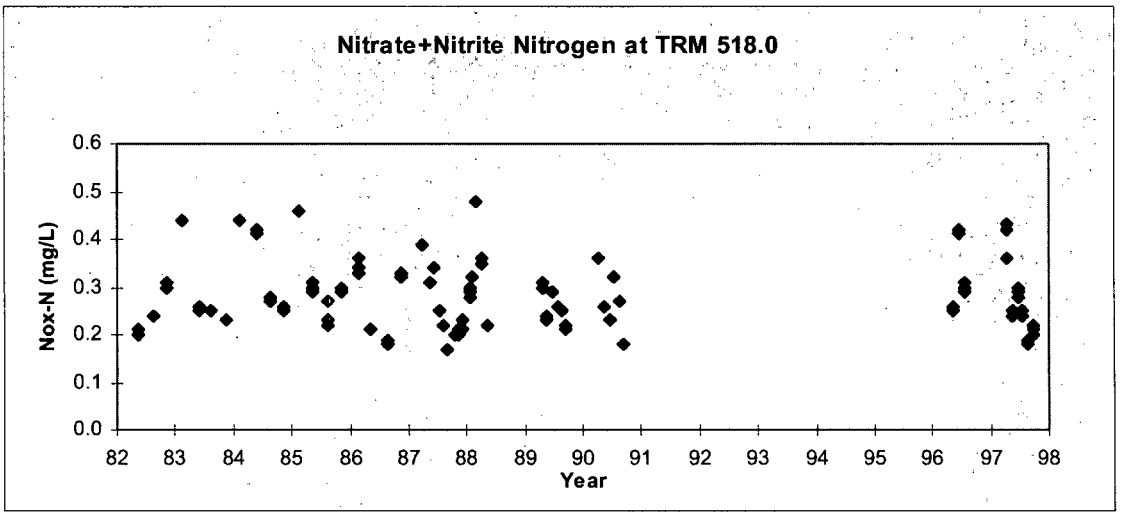
Appendix B-1 (Continued)

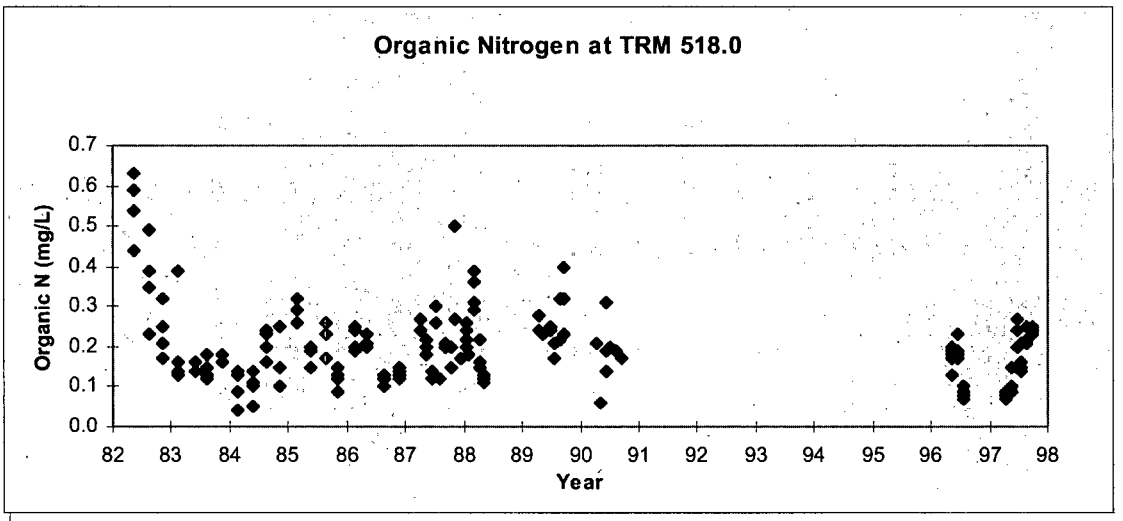


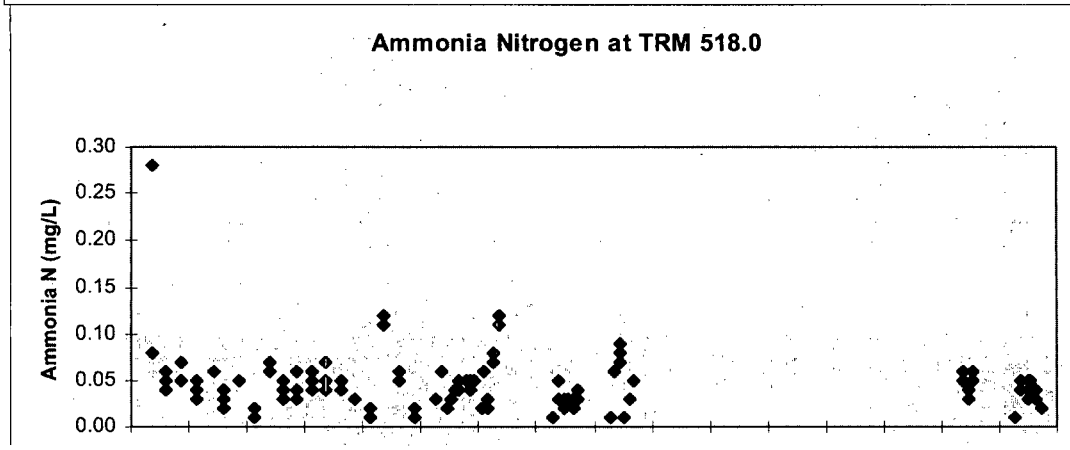





Ammonia Nitrogen at TRM 518.0
Ammonia N (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

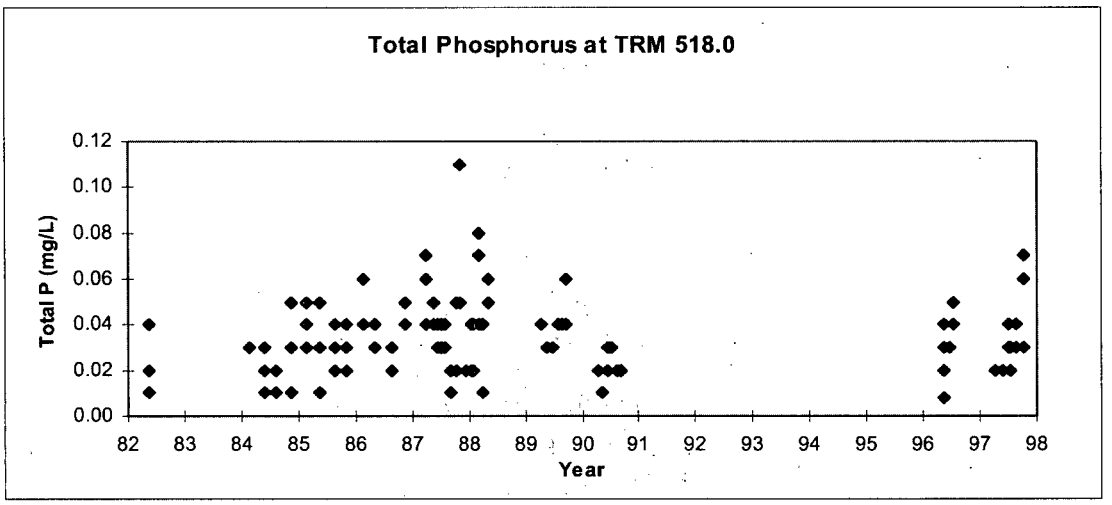

Nitrate+Nitrite Nitrogen at TRM 518.0
Nox-N (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

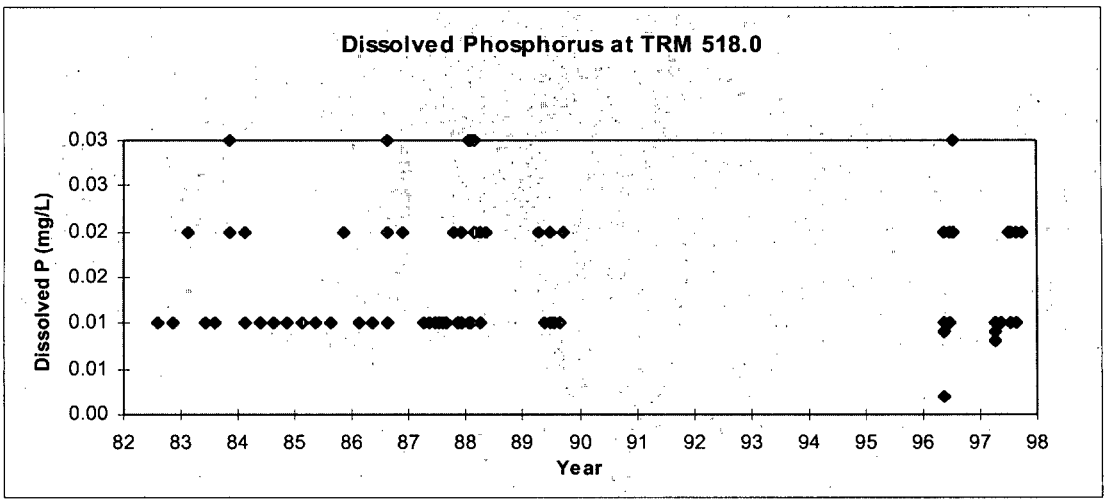

Organic Nitrogen at TRM 518.0
Organic N (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

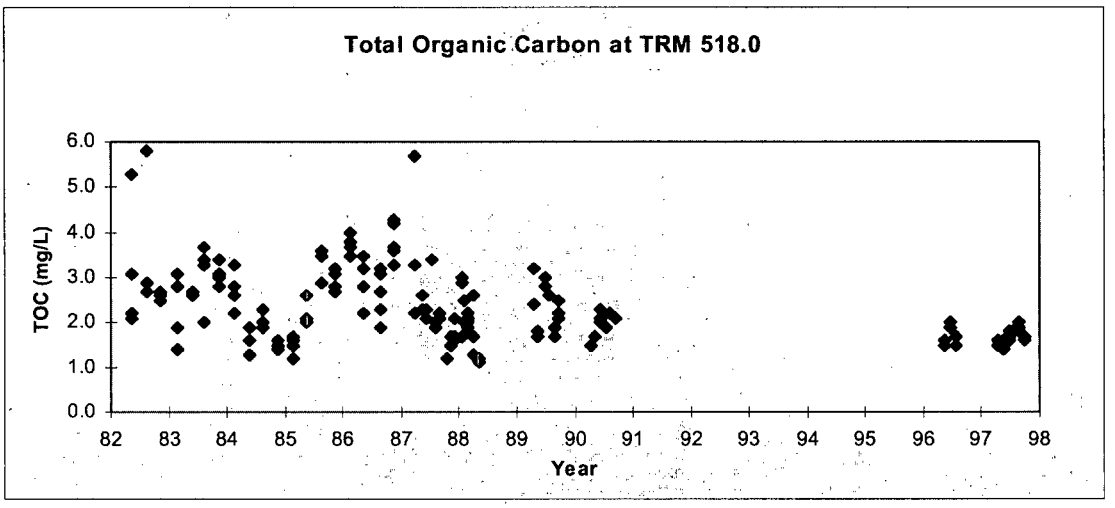

Ammonia Nitrogen at TRM 518.0
Ammonia N (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00

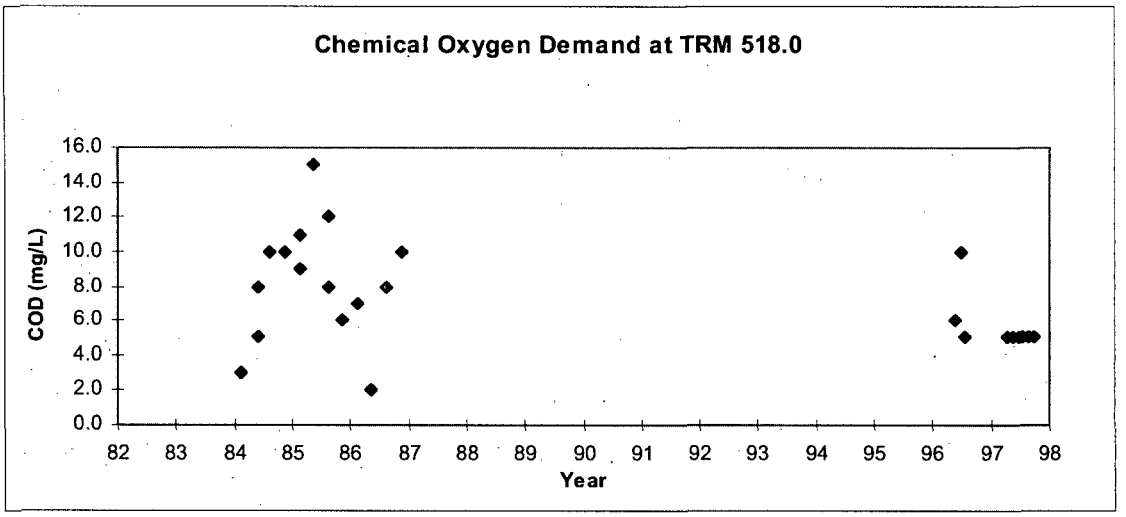
Appendix B-1 (Continued)

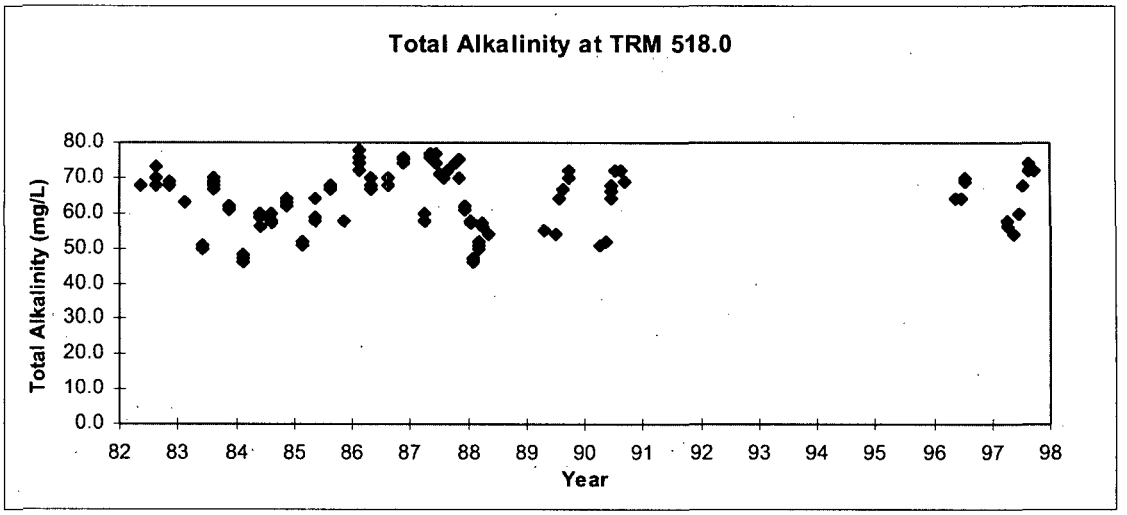
Appendix B-1 (Continued)

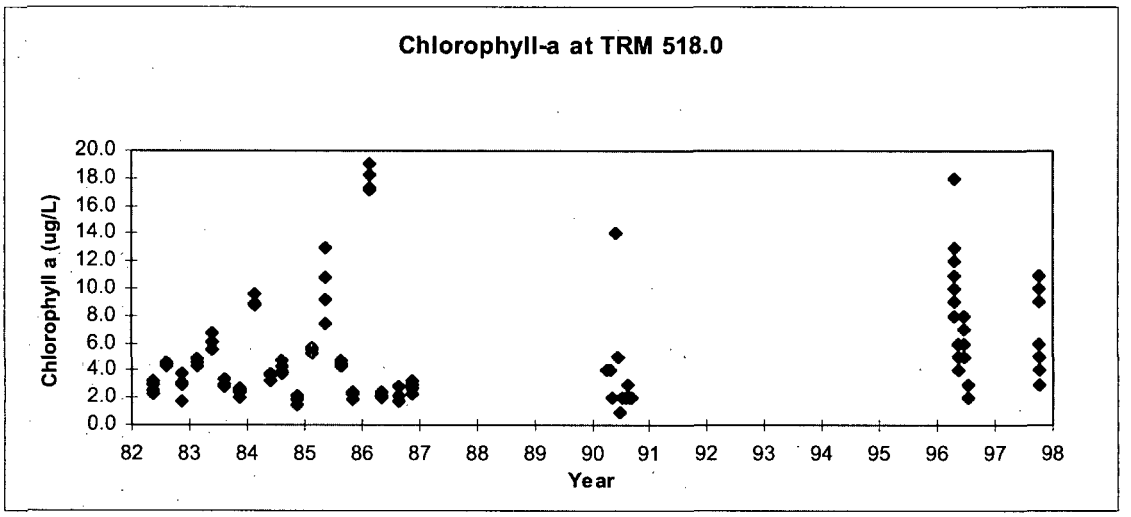

Total Phosphorus at TRM 518.0
Total P (mg/L)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

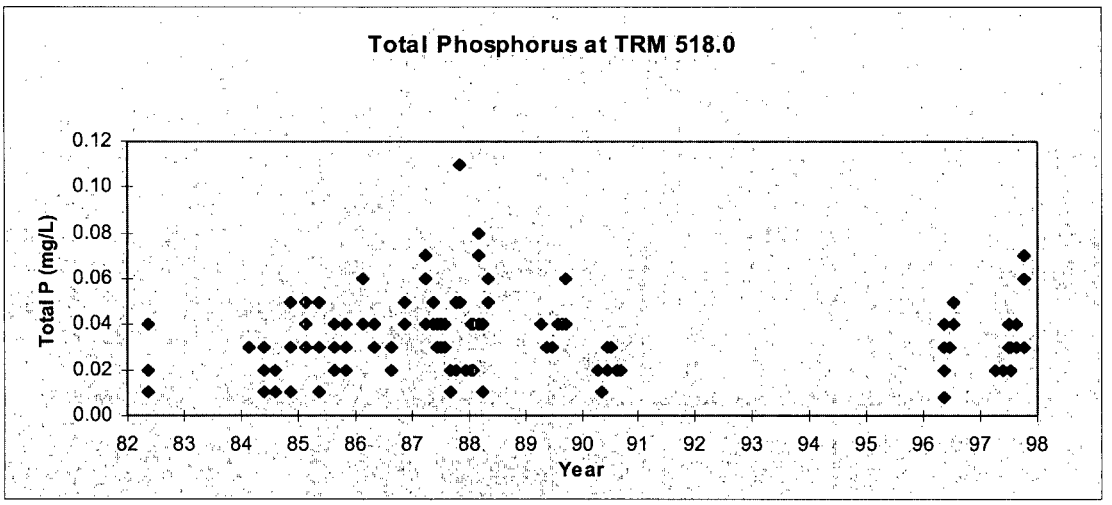

Dissolved Phosphorus at TRM 518.0
Dissolved P (mg/L)
0.03
0.03
0.02
0.02
0.01
0.01
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

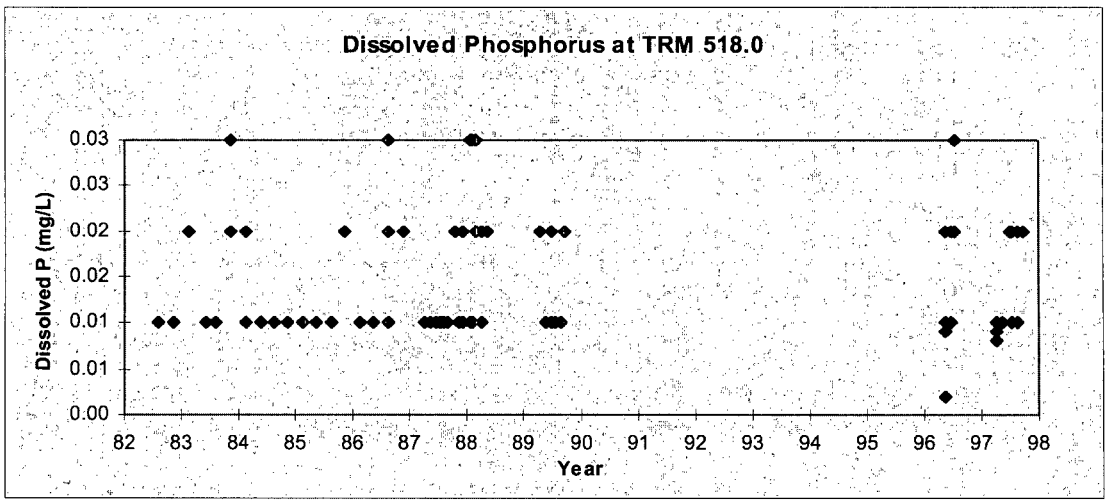

Total Organic Carbon at TRM 518.0
TOC (mg/L)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

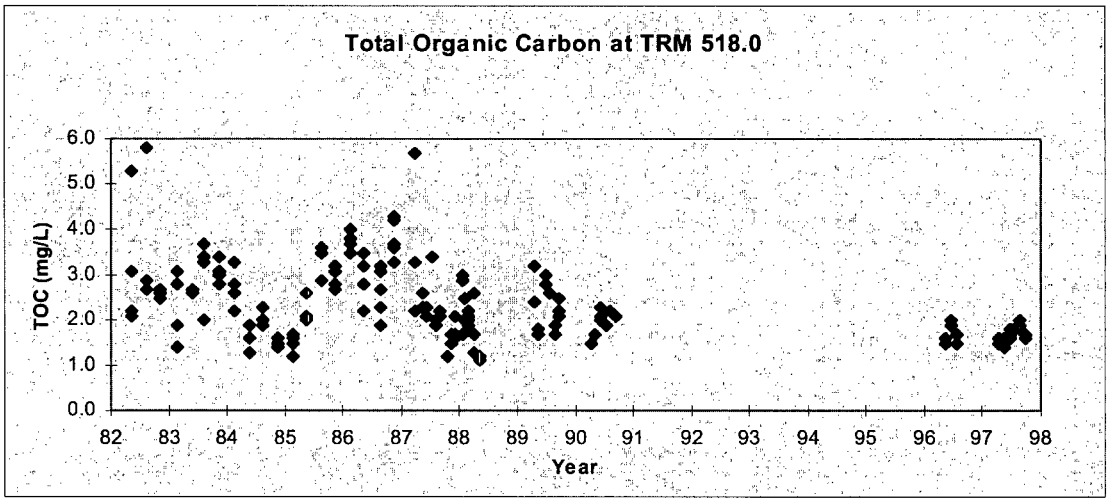

Chemical Oxygen Demand at TRM 518.0
COD (mg/L)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year


Total Alkalinity at TRM 518.0
Total 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 98
Year

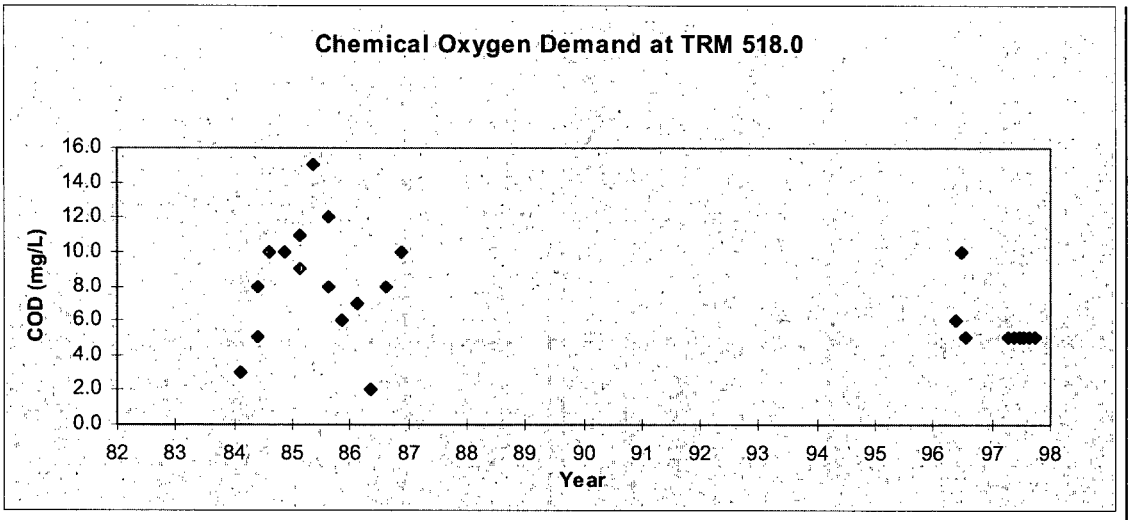

Chlorophyll-a at TRM 518.0
Chlorophyll a (ug/L)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

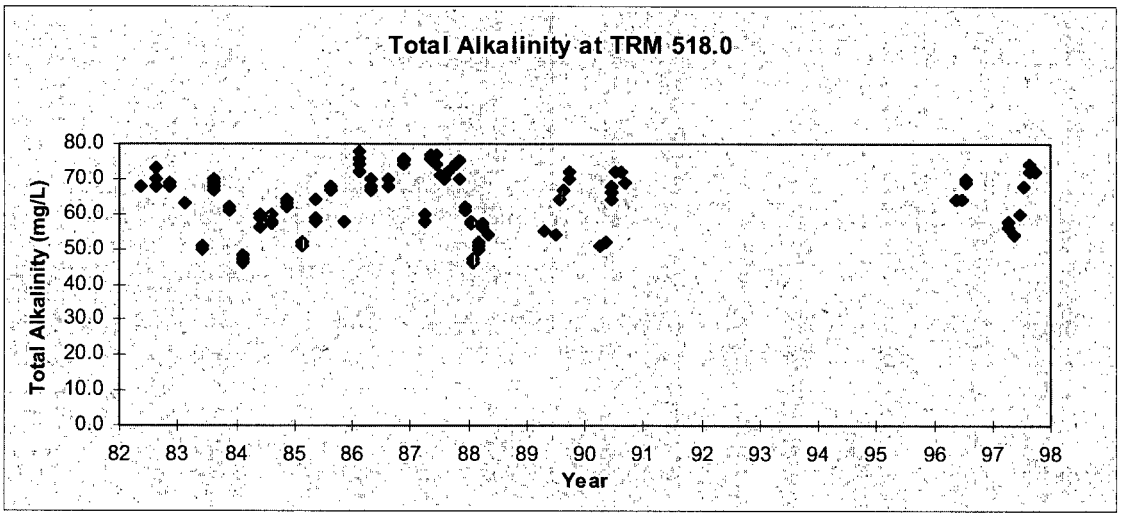

Total Phosphorus at TRM 518.0
Total P (mg/L)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

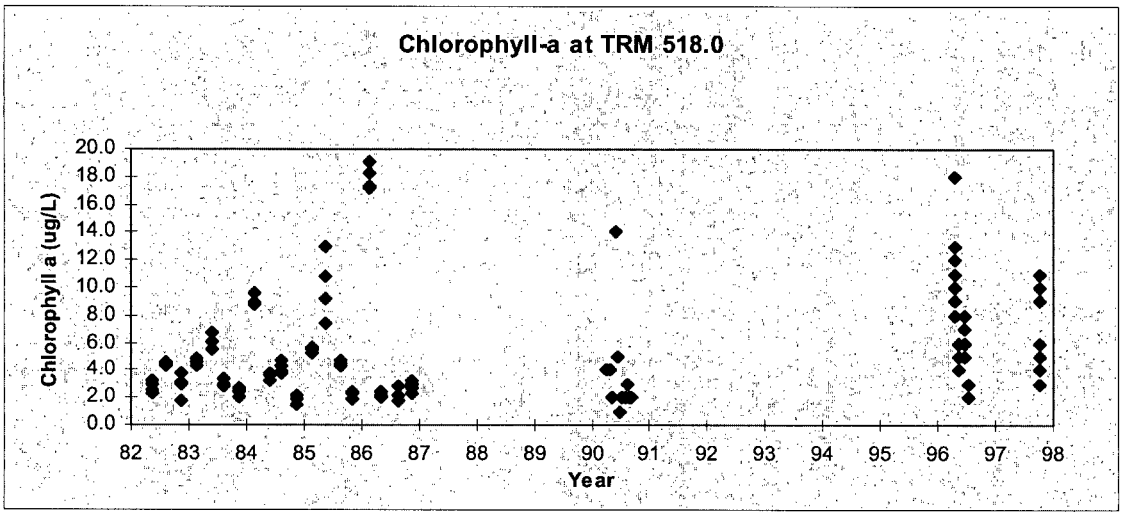

Dissolved Phosphorus at TRM 518.0
Dissolved P (mg/L)
0.03
0.03
0.02
0.02
0.01
0.01
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year


Total Organic Carbon at TRM 518.0
TOC (mg/L)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

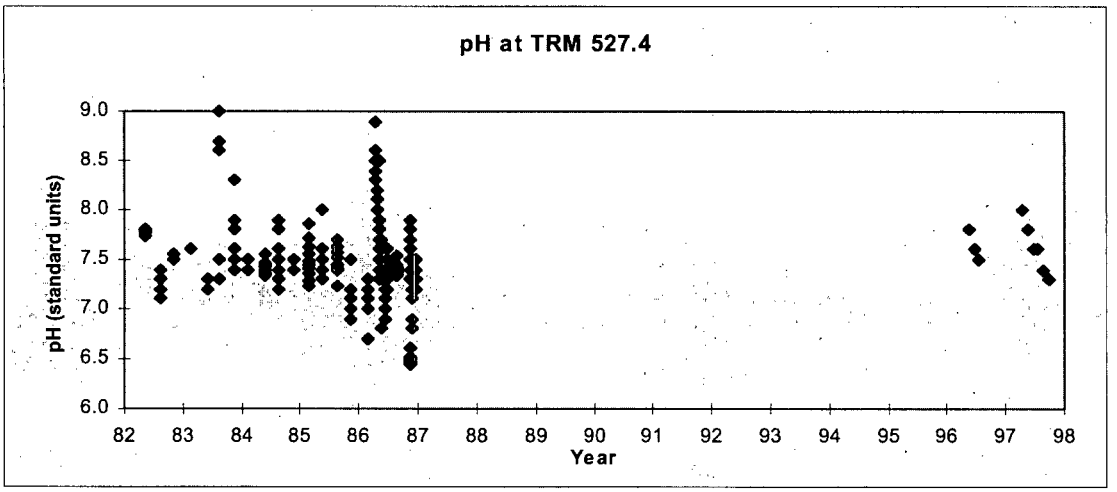
Appendix B-1 (Continued)

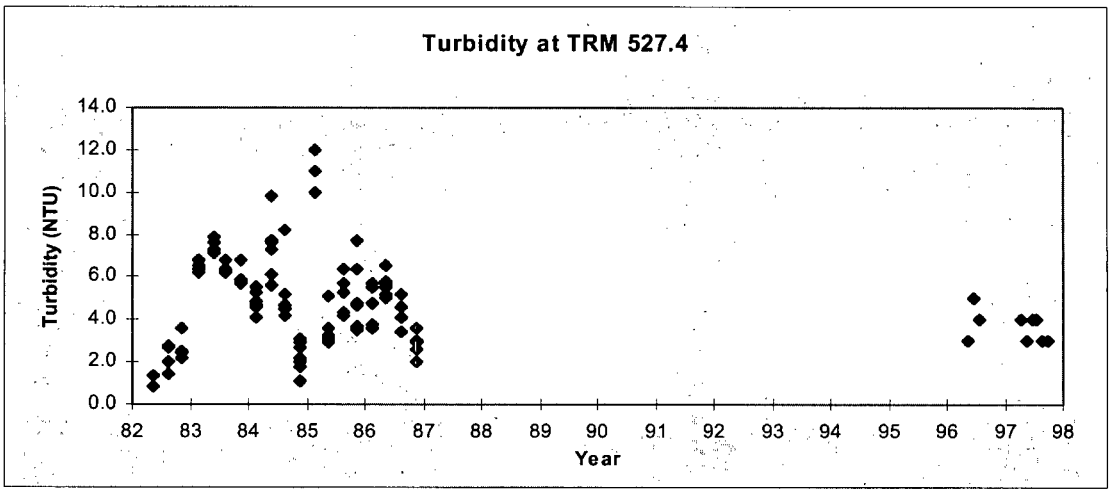


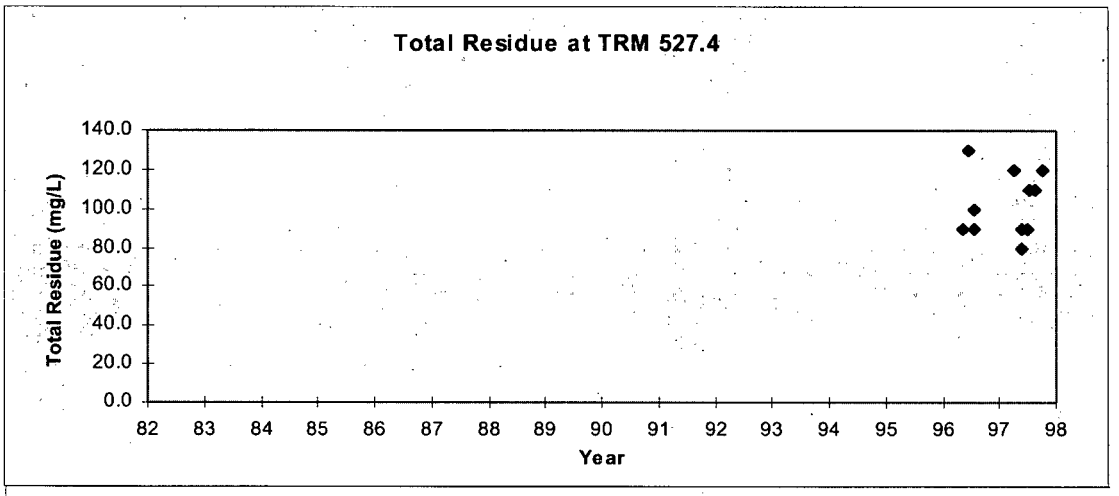


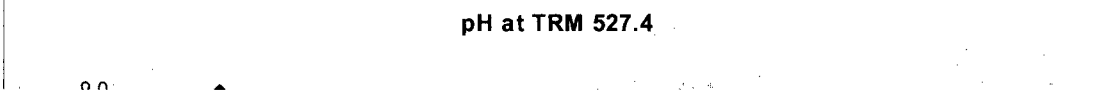


Appendix B-2. Selected water quality values measured during preoperational (1982-1987) and operational (1996-1997) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 527.4

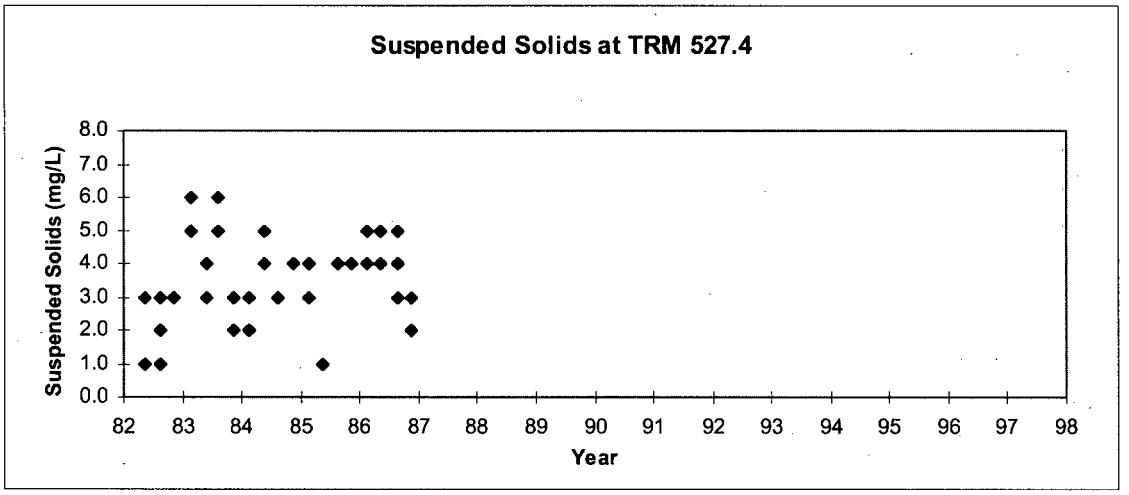


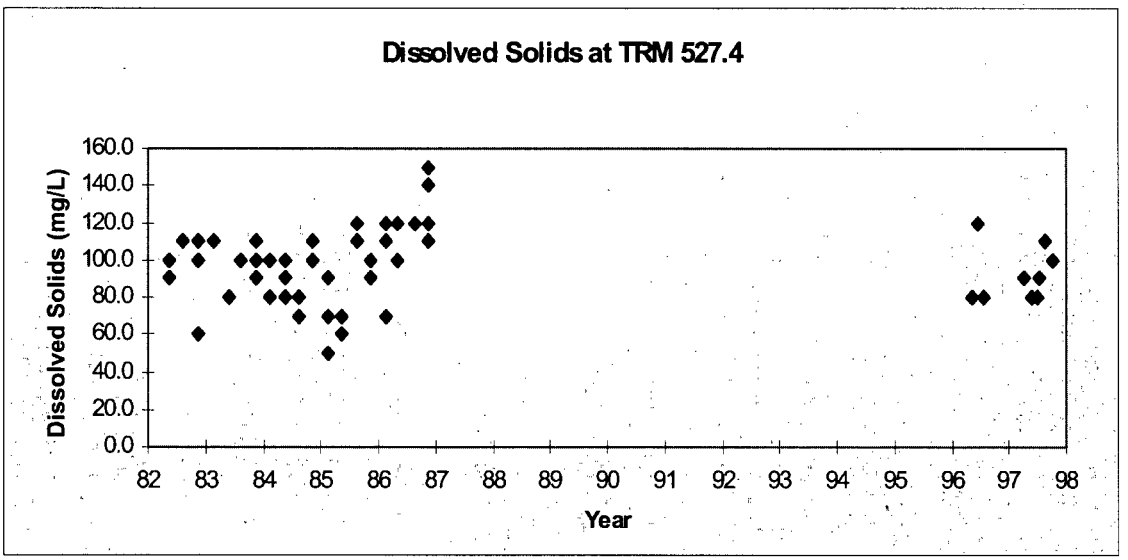


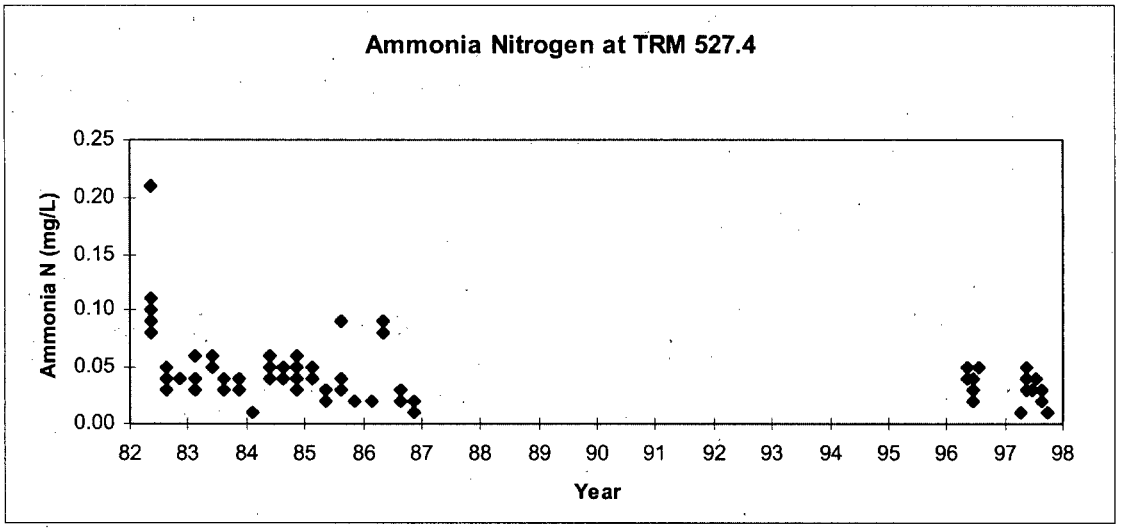


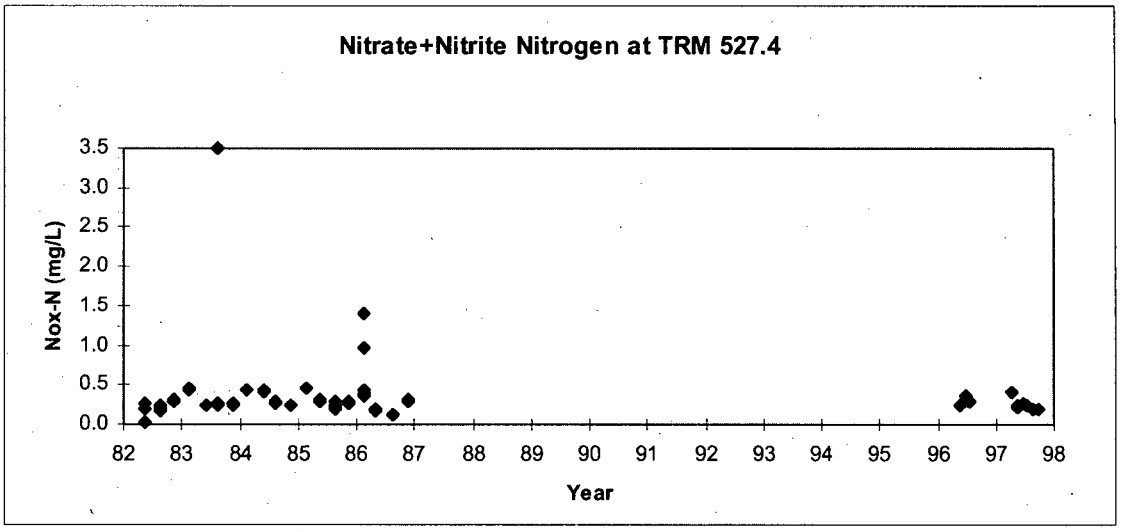


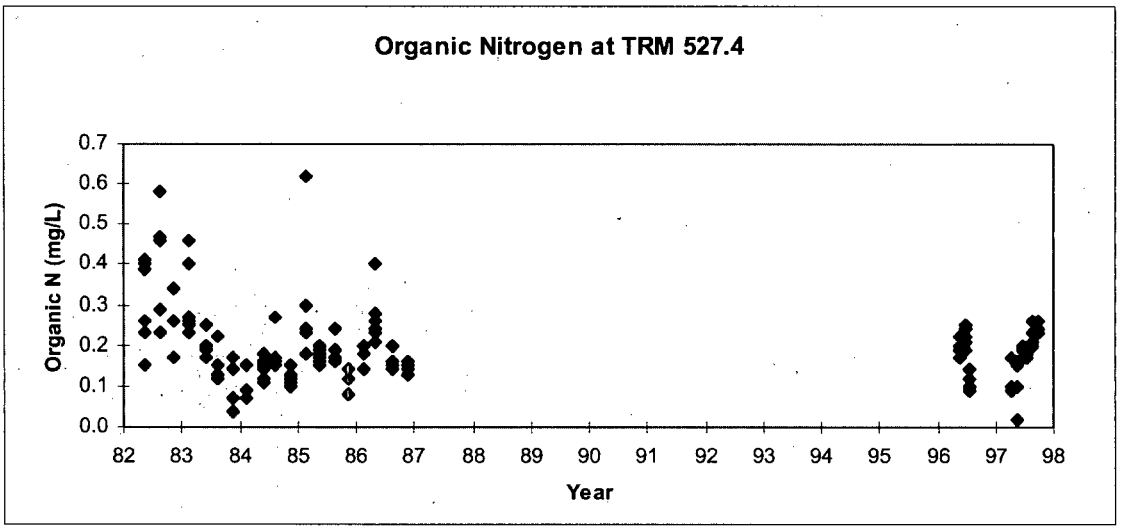
Appendix B-2 (Continued)

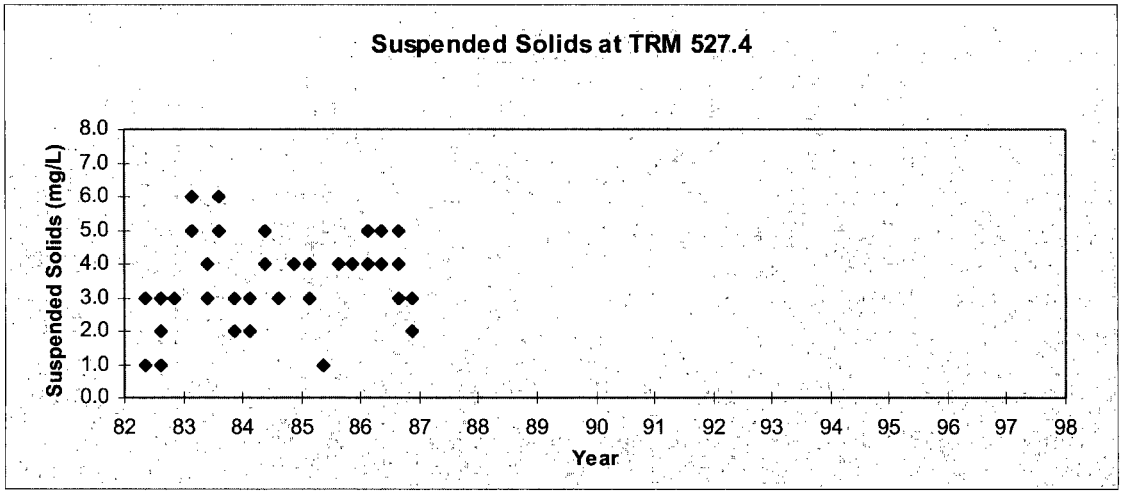


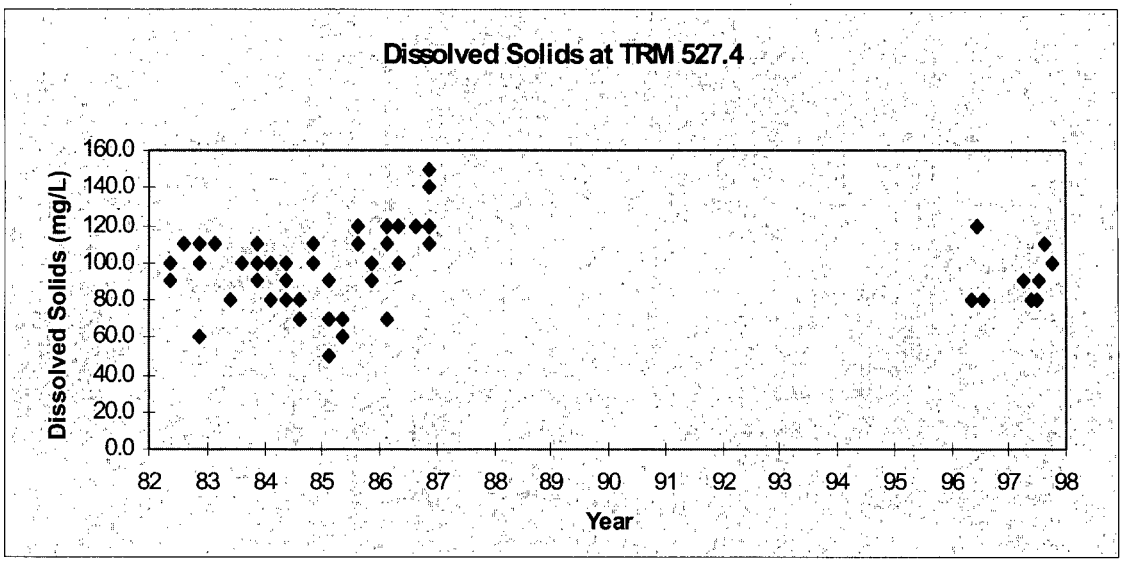



Ammonia Nitrogen at TRM 527.4
Ammonia N (mg/L)
0.25
0.20
0.15
0.10
0.05
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

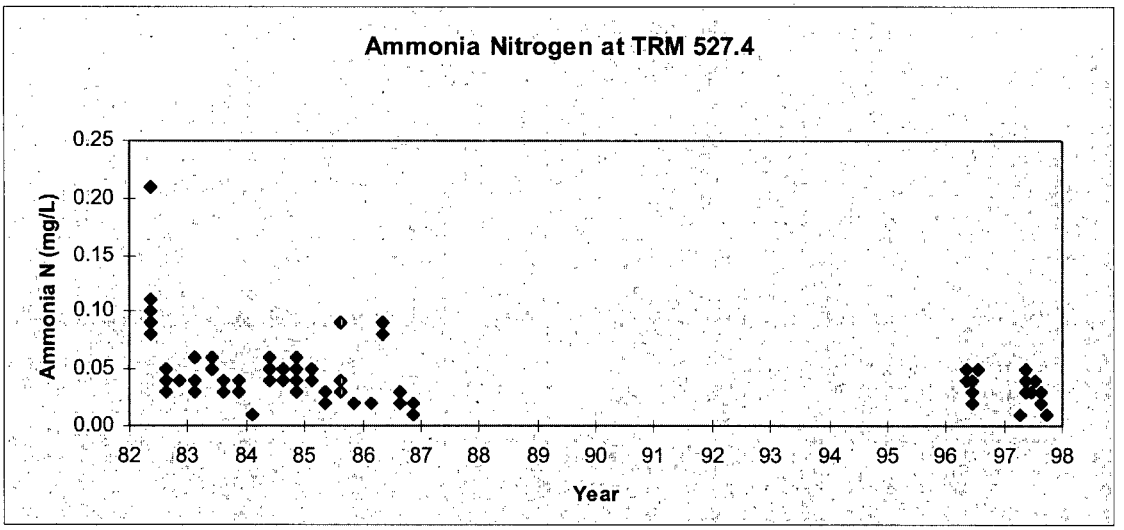

Nitrate+Nitrite Nitrogen at TRM 527.4
Nox-N (mg/L)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

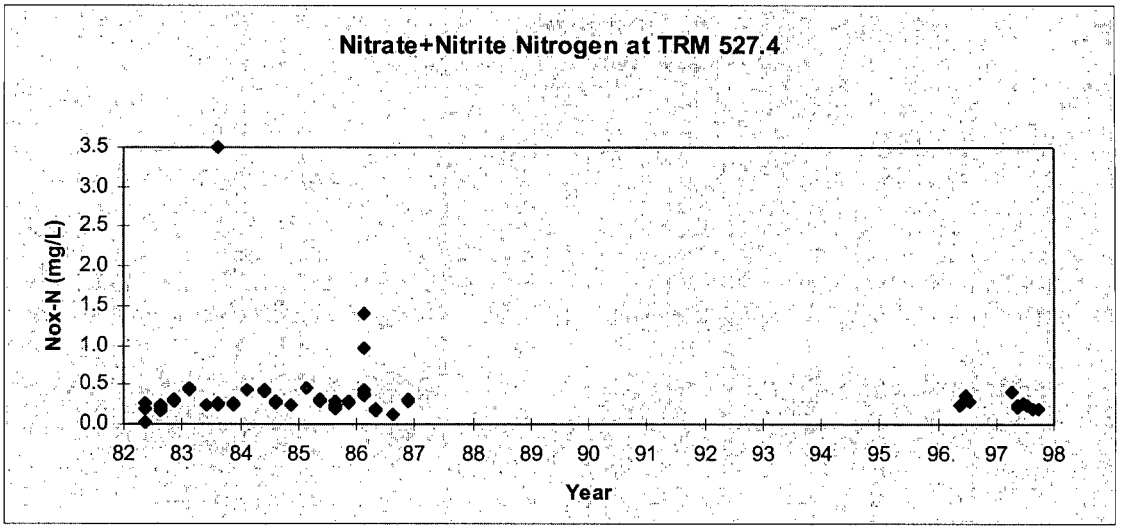

Organic Nitrogen at TRM 527.4
Organic N (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

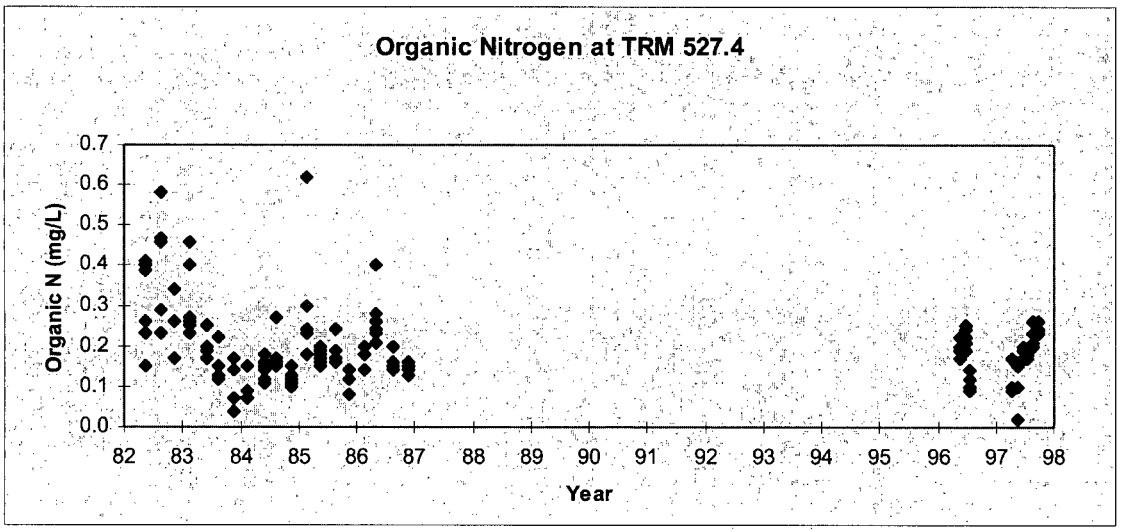

Suspended Solids at TRM 527.4
Suspended Solids (mg/L)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year


Dissolved Solids at TRM 527.4
Dissolved Solids (mg/L)
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 98
Year

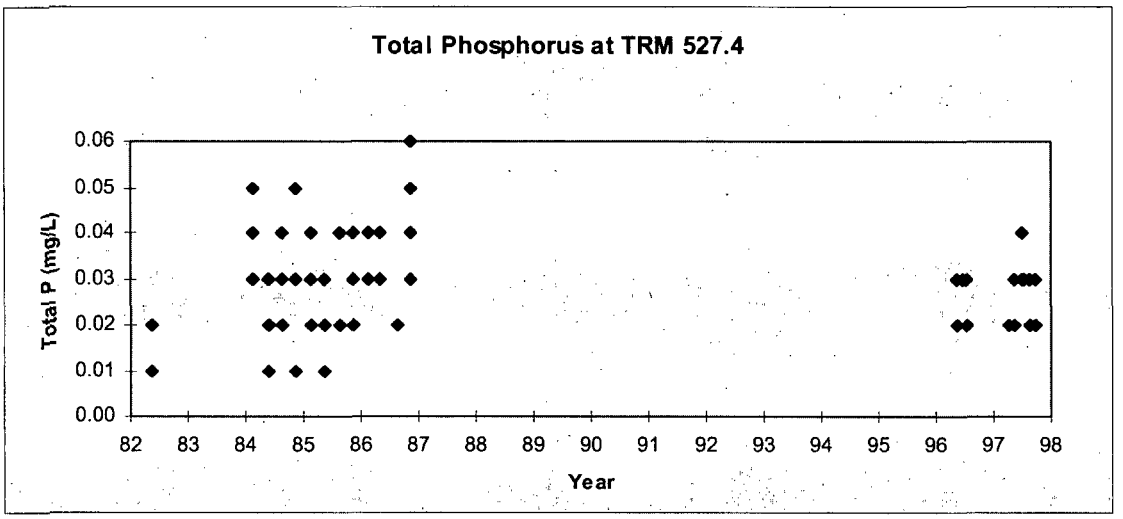
Appendix B-2 (Continued)

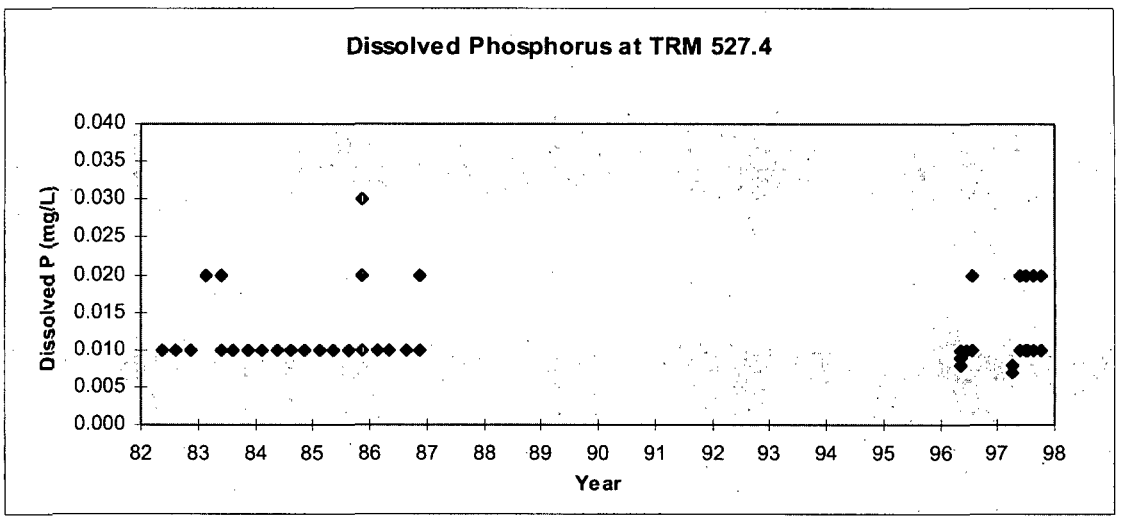


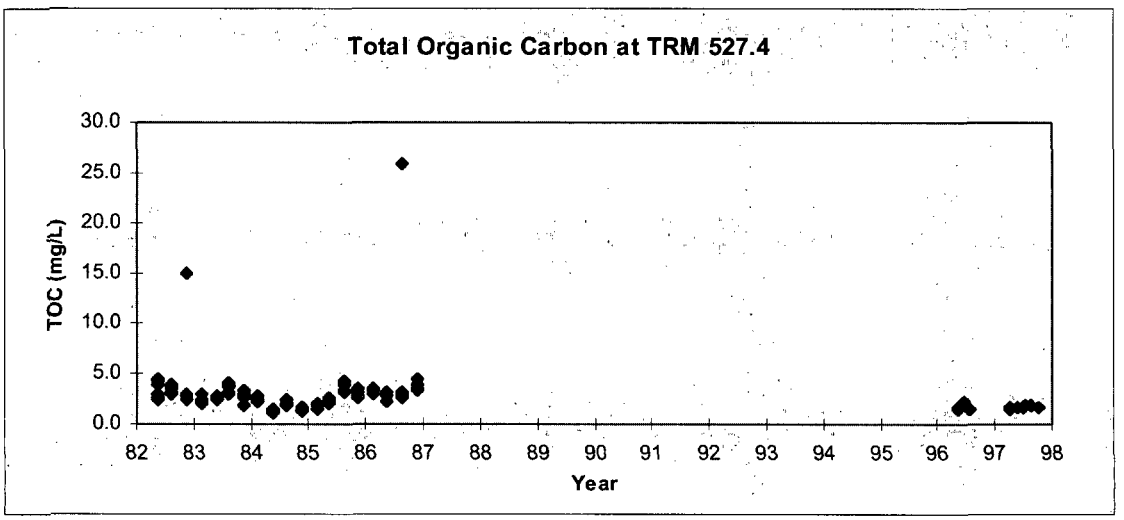


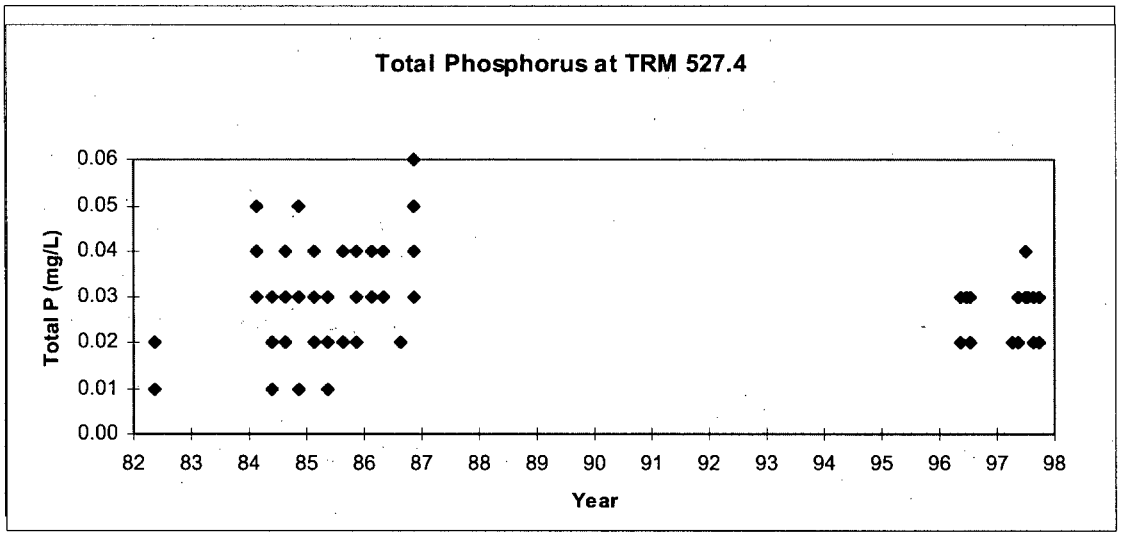


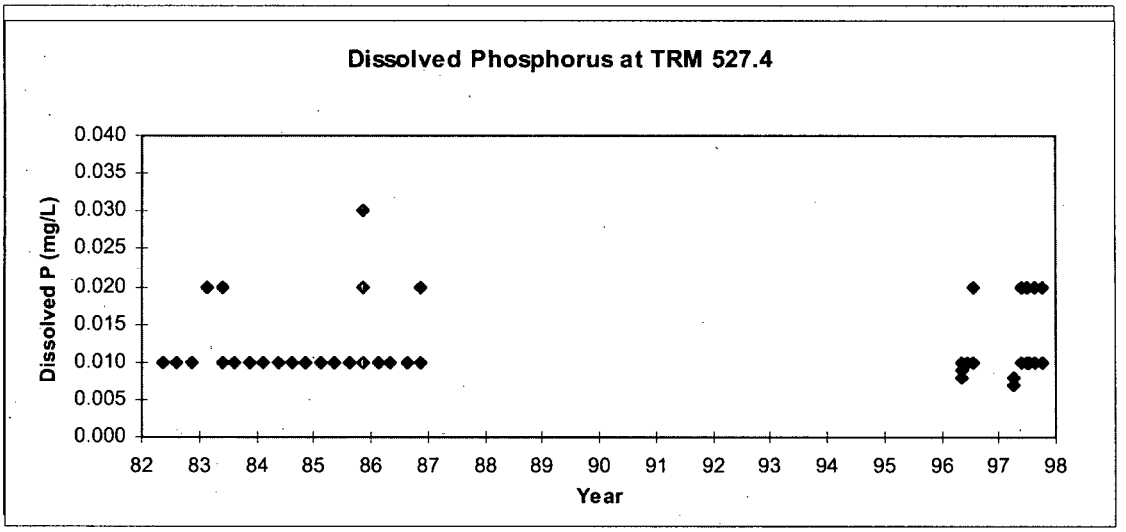
Appendix B-2 (Continued)

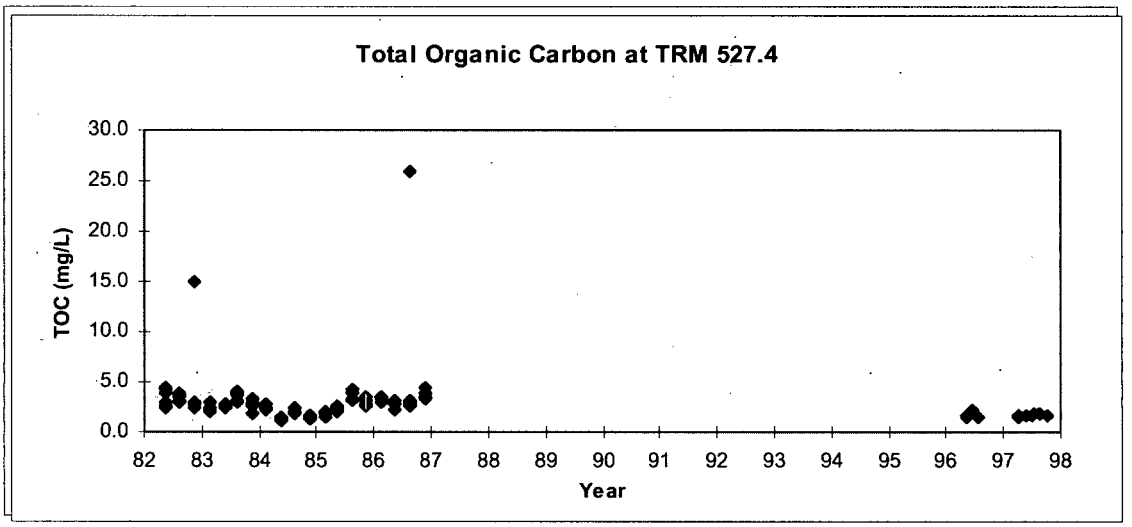




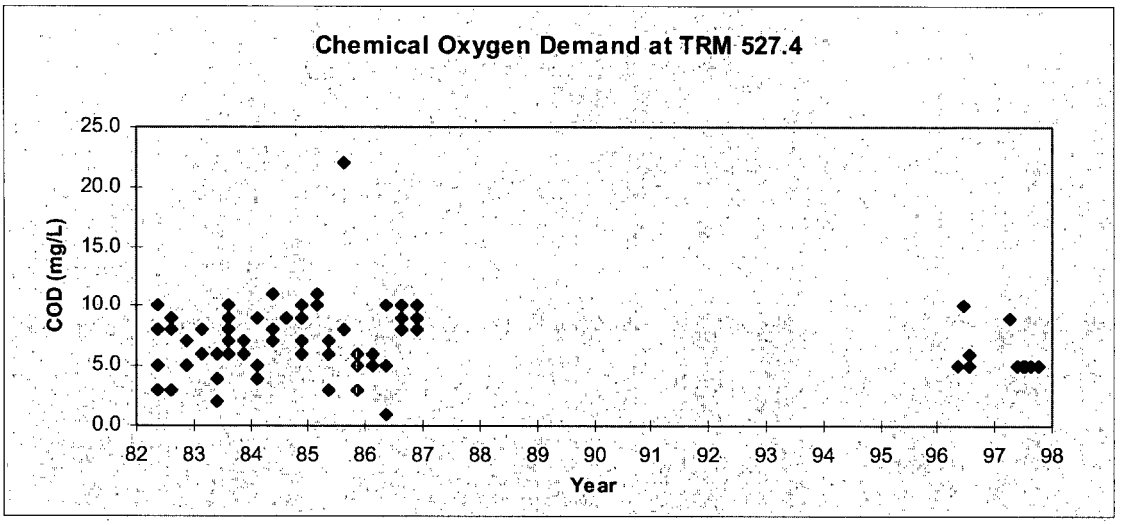


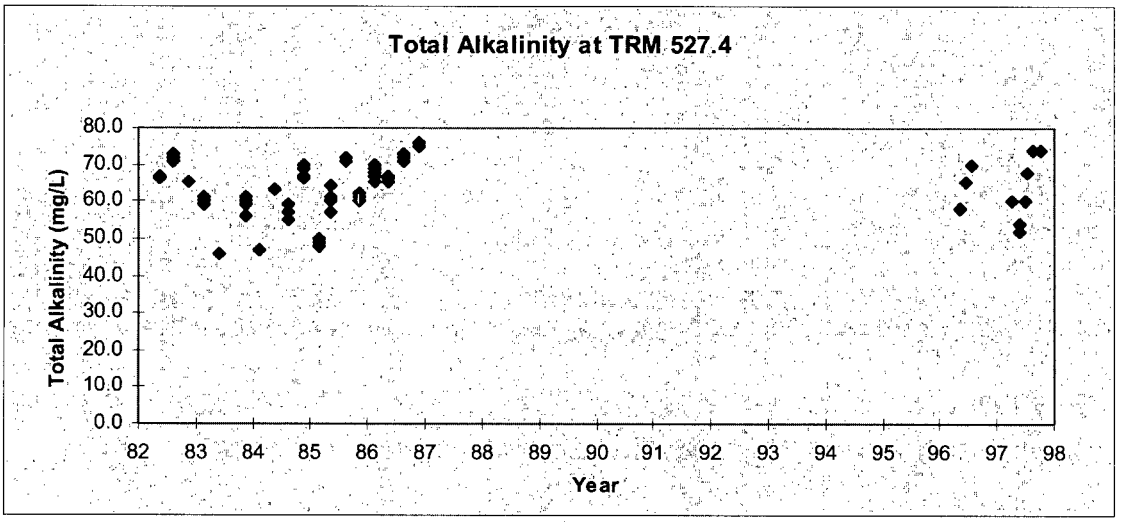

Total Phosphorus at TRM 527.4
Total P (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

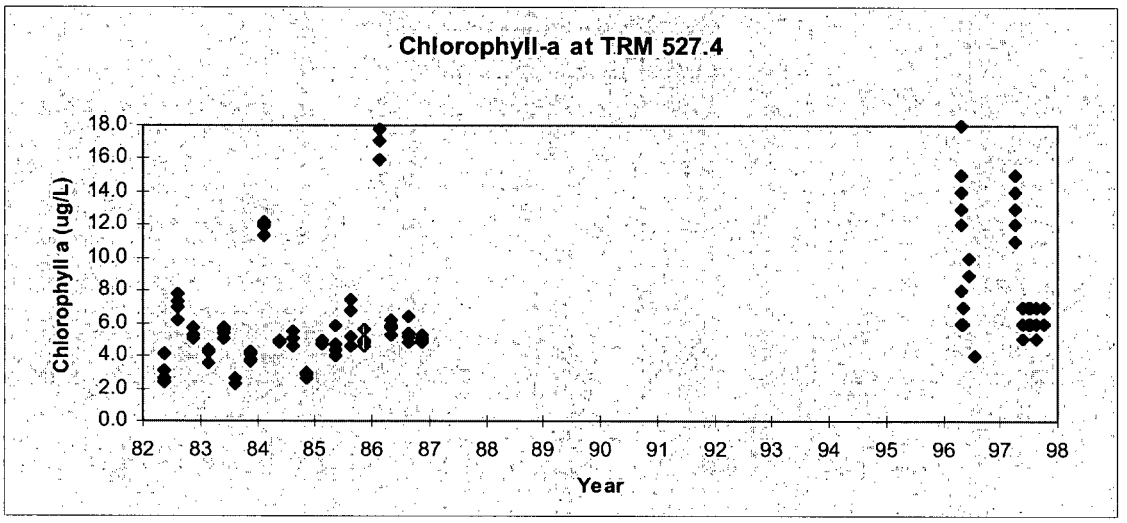

Dissolved Phosphorus at TRM 527.4
Dissolved P (mg/L)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year


Total Organic Carbon at TRM 527.4
TOC (mg/L)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

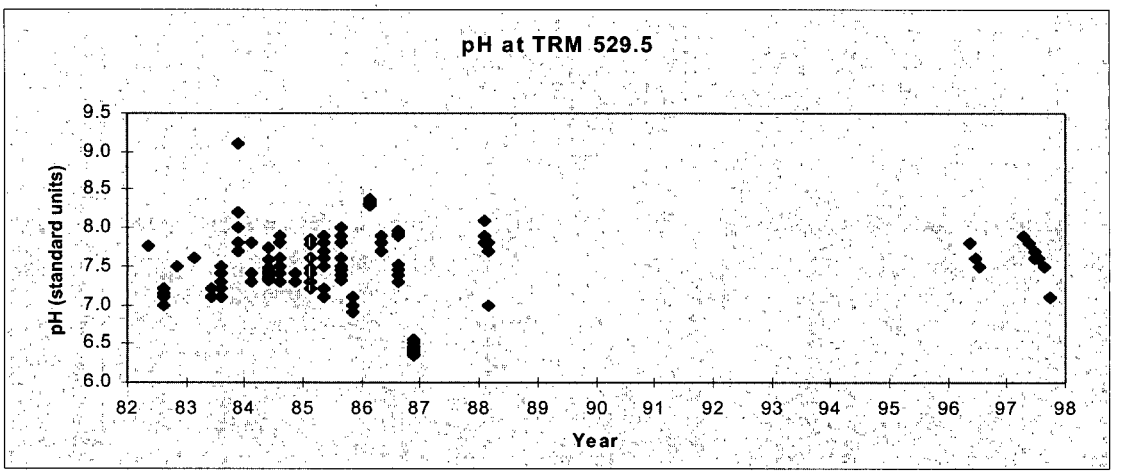
Appendix B-2 (Continued)

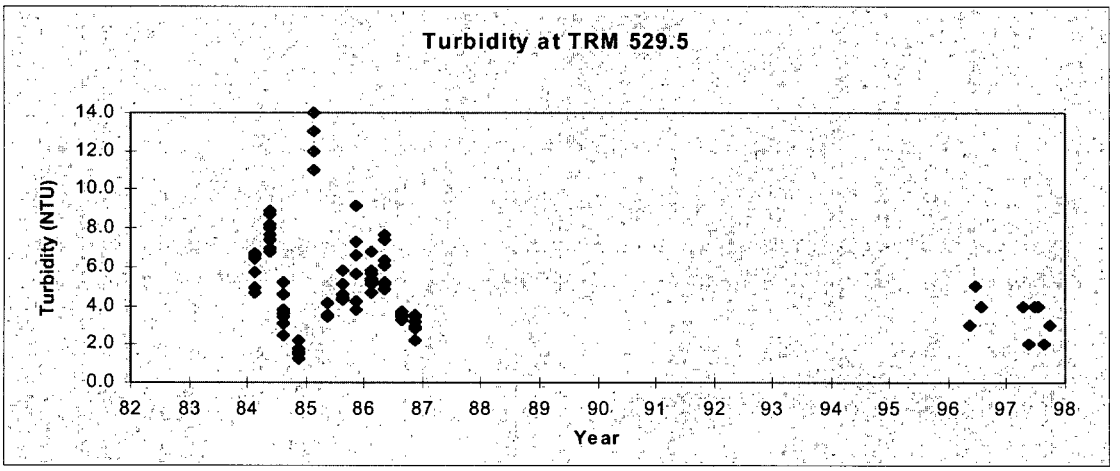


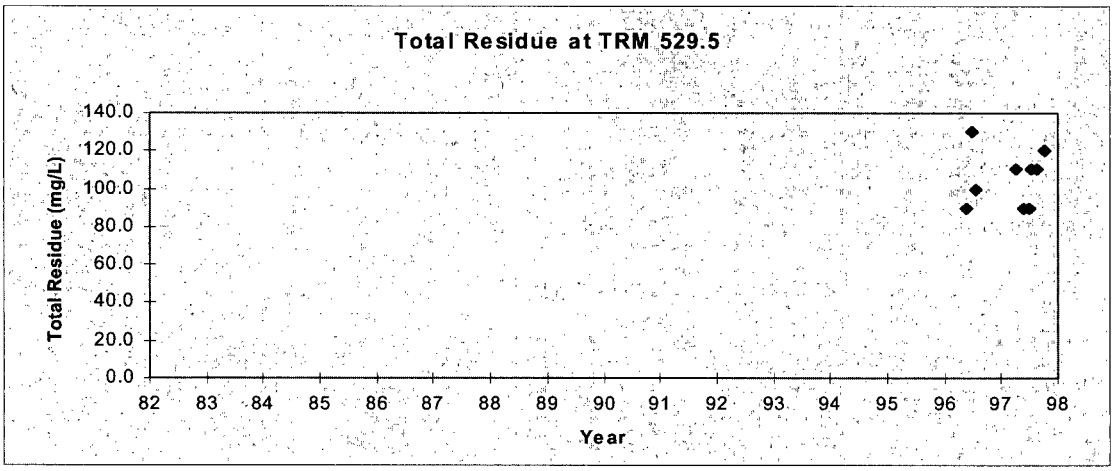


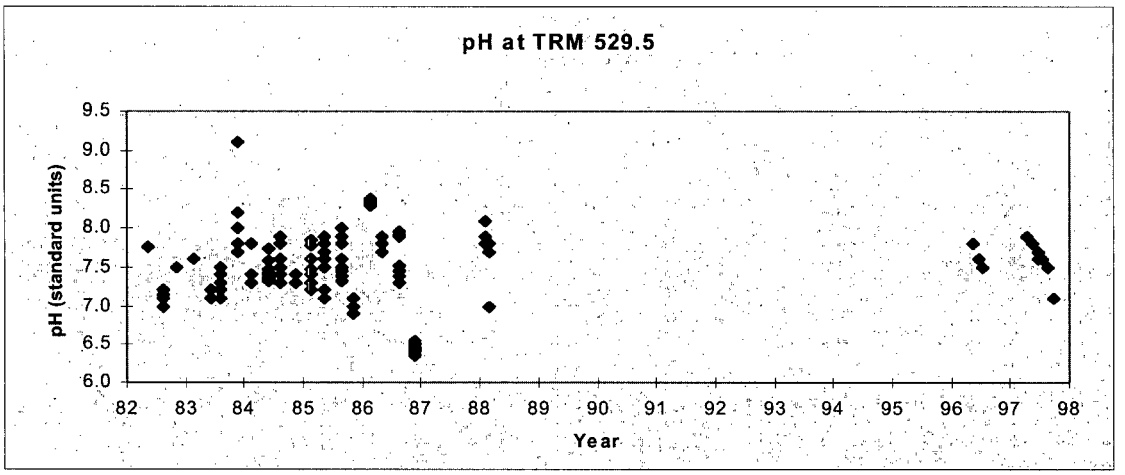


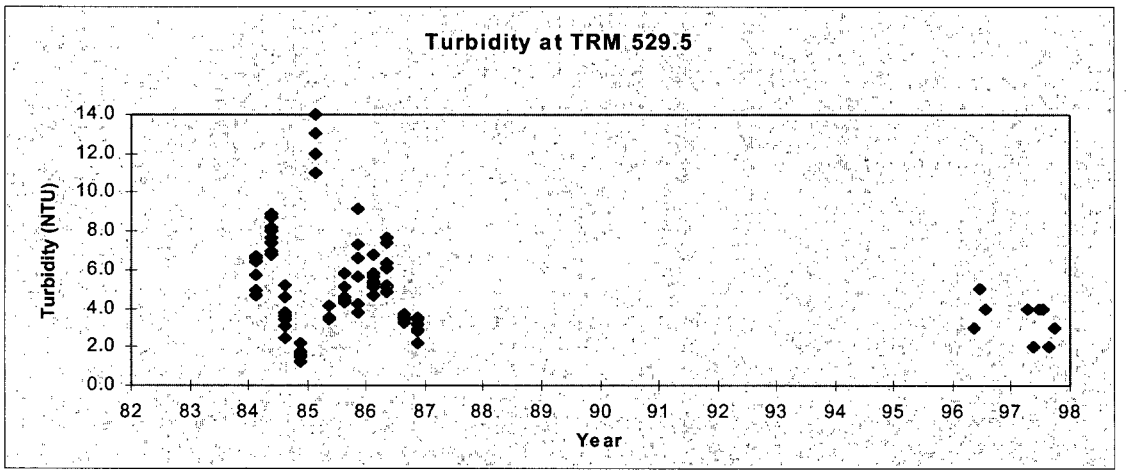
Appendix B-3. Selected water quality values measured during preoperational (1982-1987) and operational (1996-1997) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 529.5

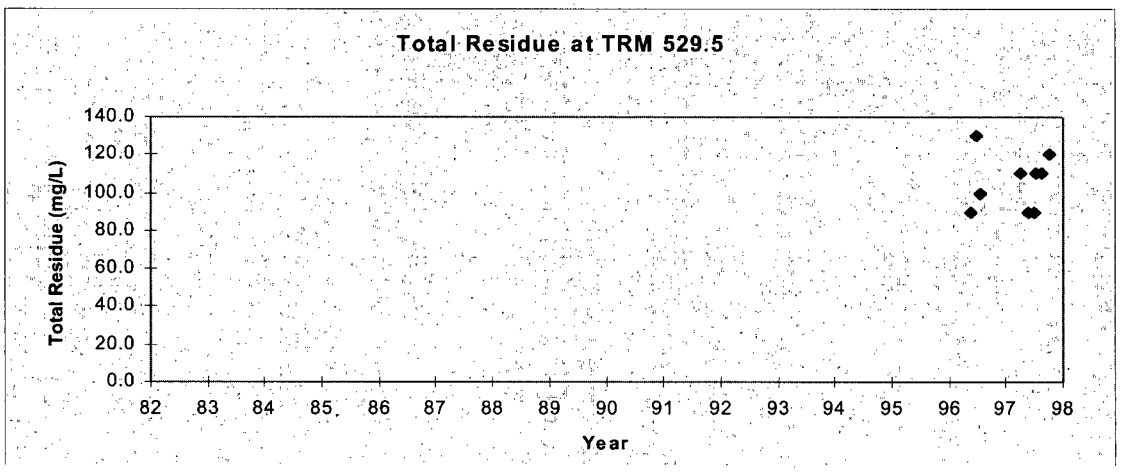




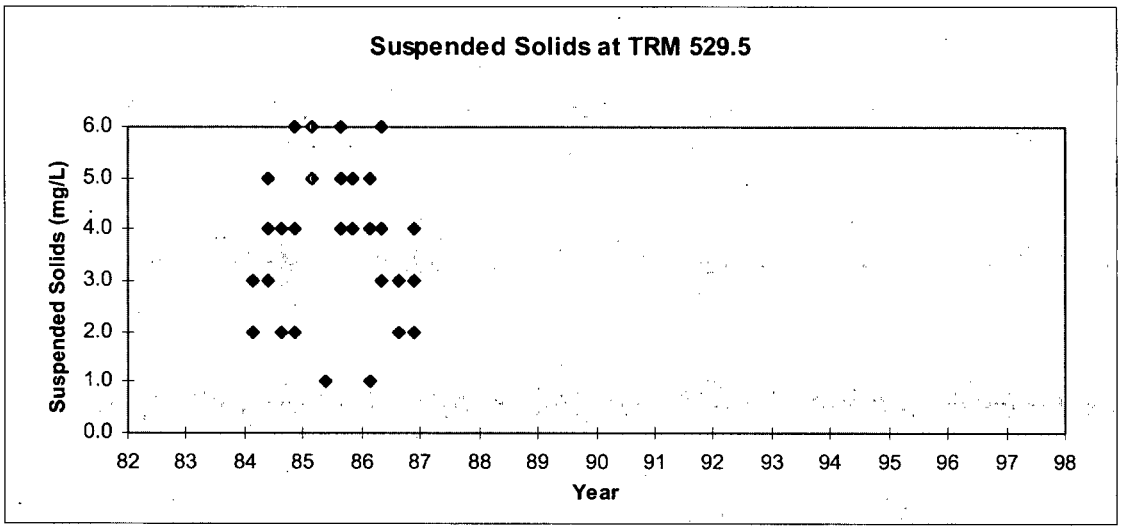


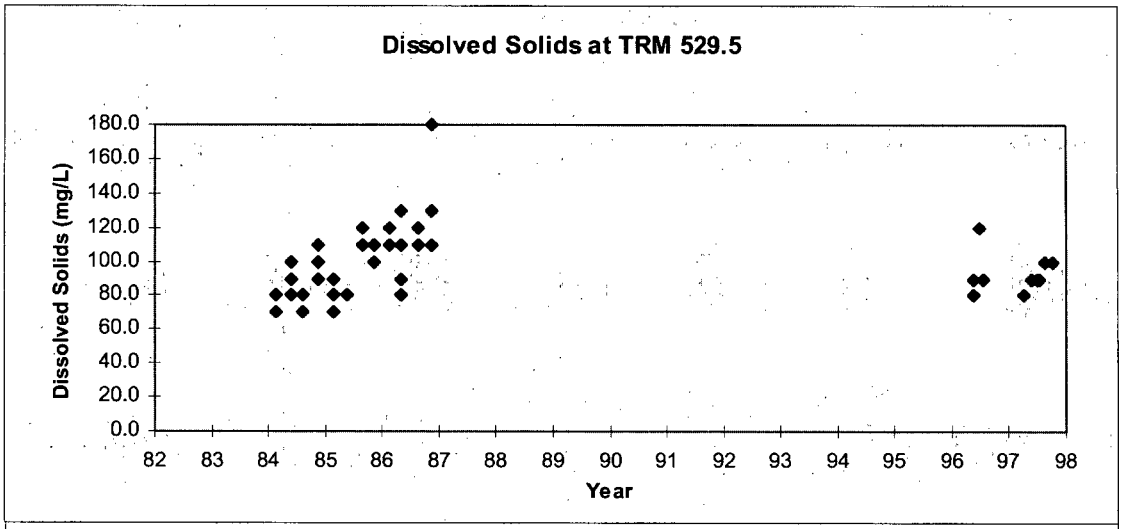


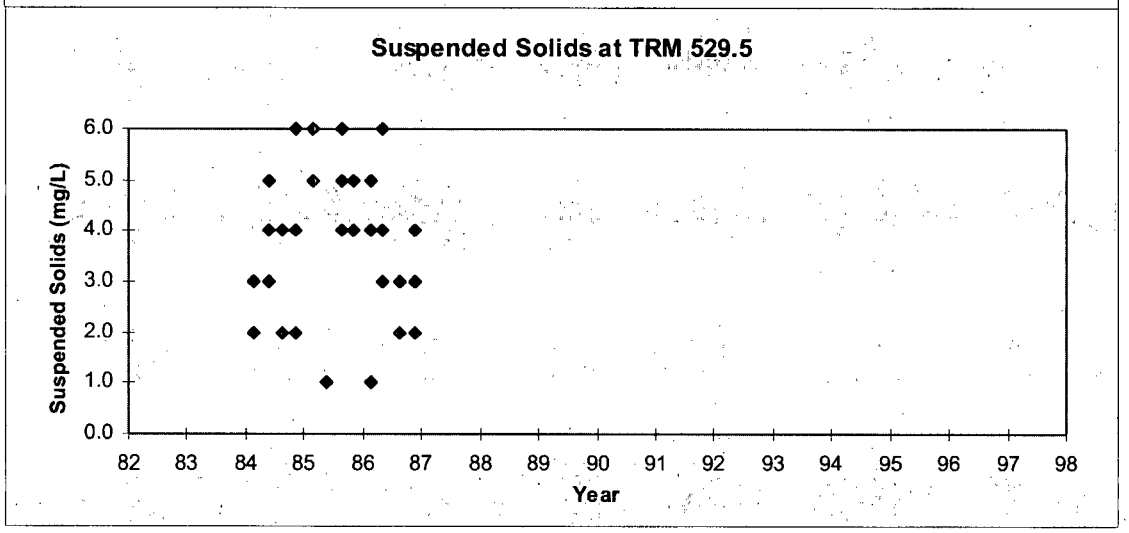


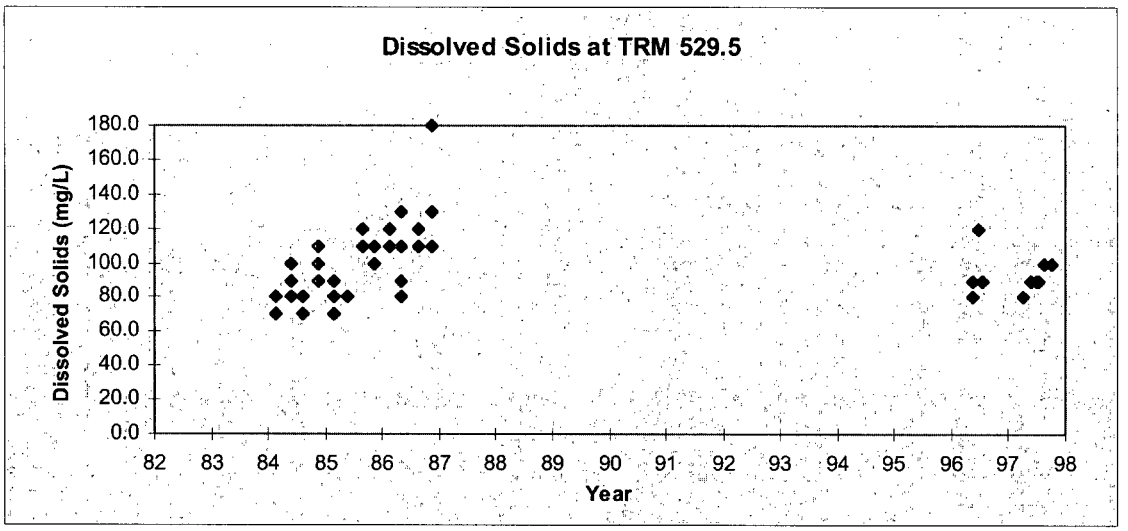


Appendix B-3 (Continued)

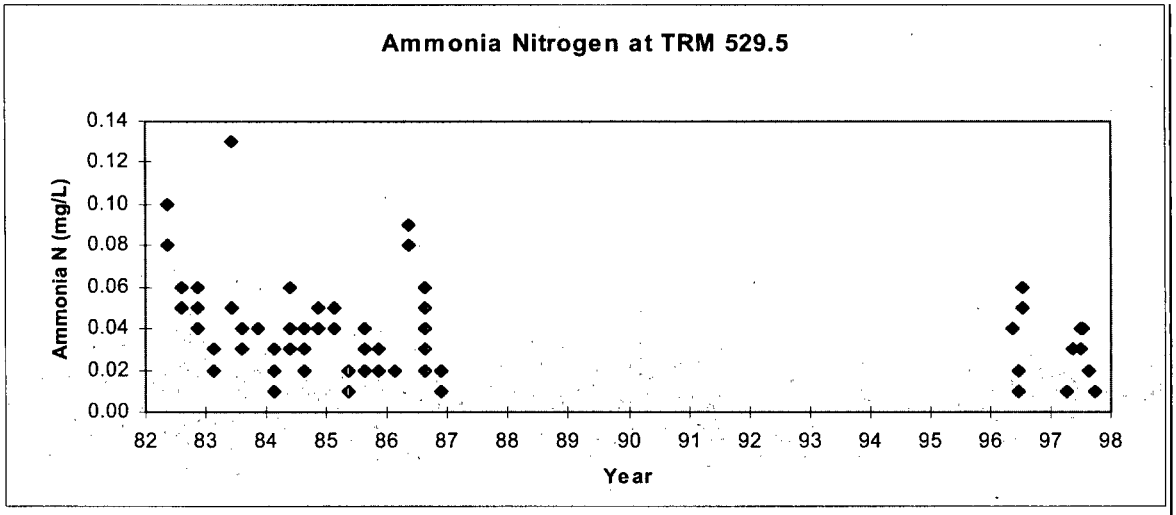

Suspended Solids at TRM 529.5
Suspended Solids (mg/L)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

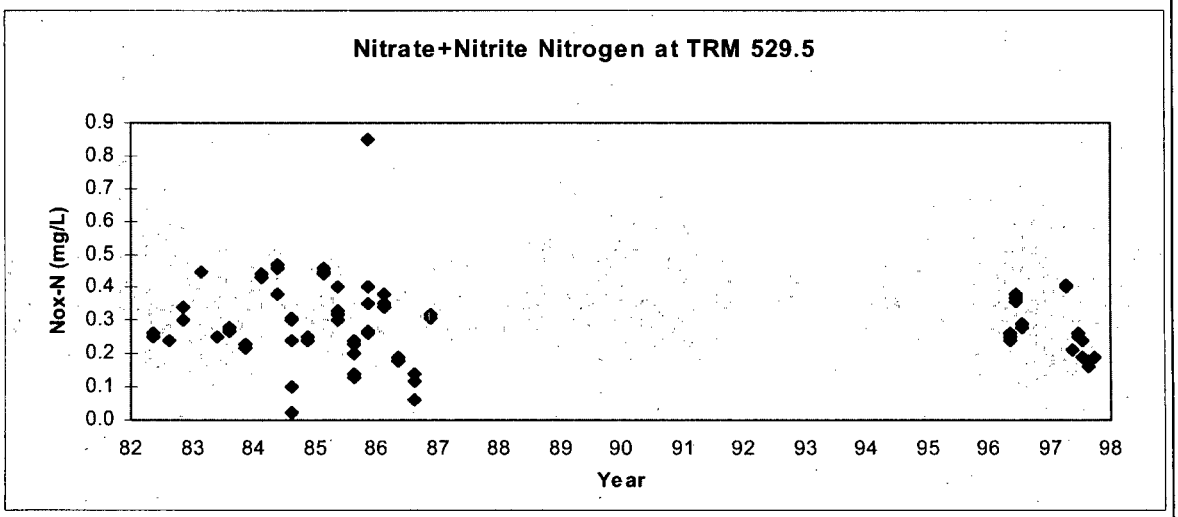

Dissolved Solids at TRM 529.5
Dissolved Solids (mg/L)
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

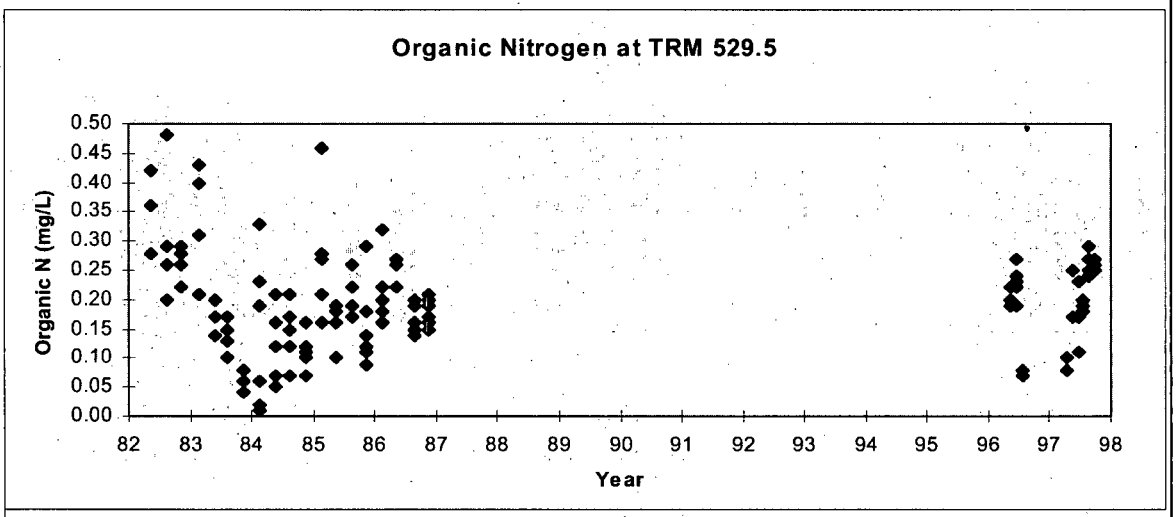

Suspended Solids at TRM 529.5
Suspended Solids (mg/L)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

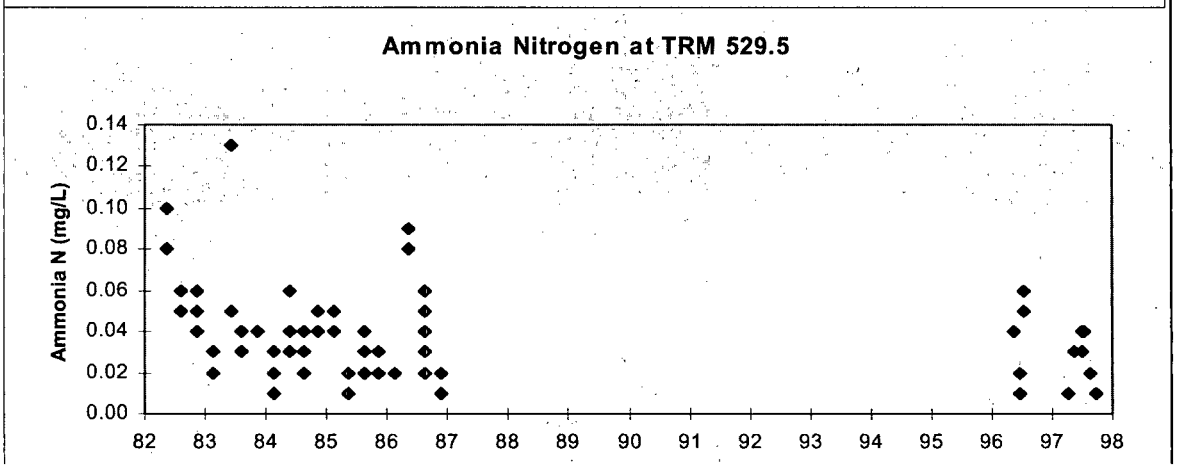

Dissolved Solids at TRM 529.5
Dissolved Solids (mg/L)
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
Year

Appendix B-3 (Continued)

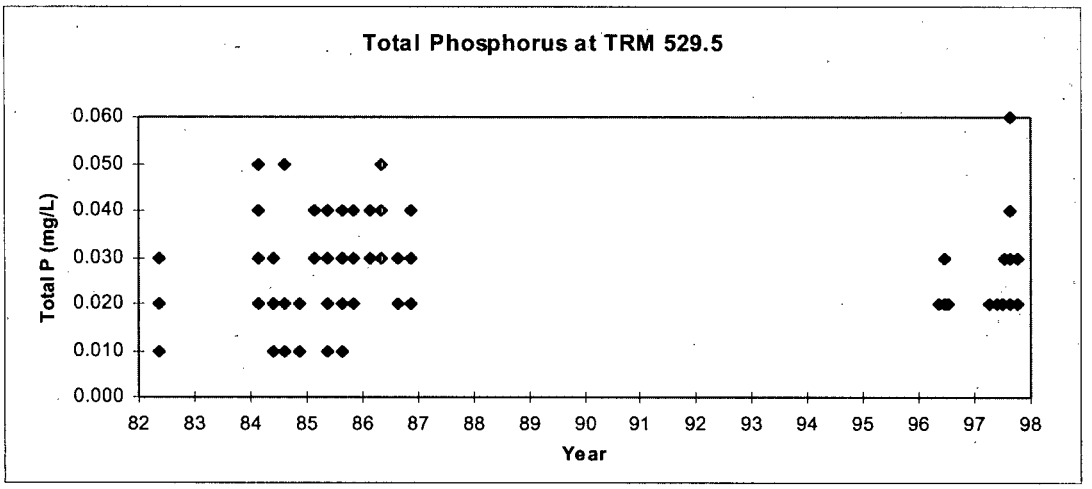

Ammonia Nitrogen at TRM 529.5
Ammonia N (mg/L)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

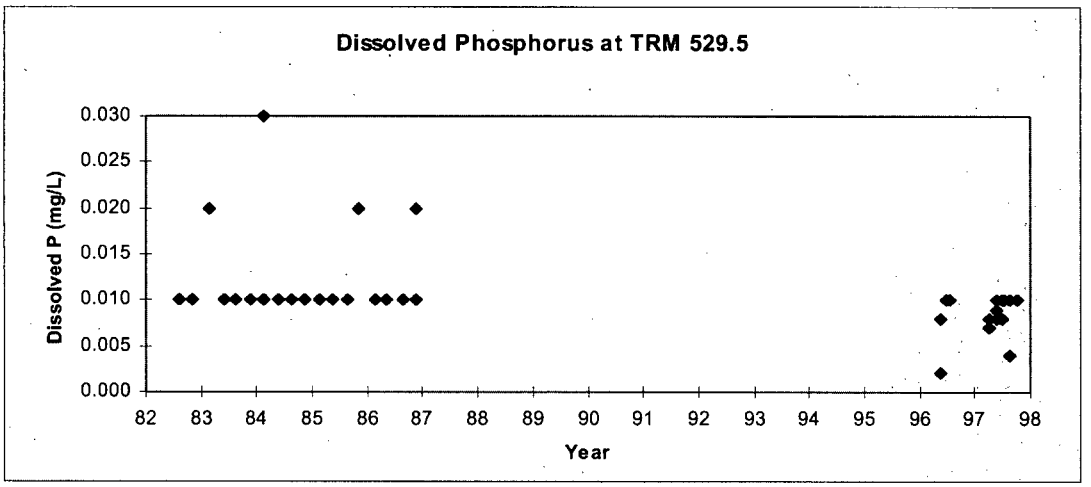

Nitrate+Nitrite Nitrogen at TRM 529.5
Nox-N (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

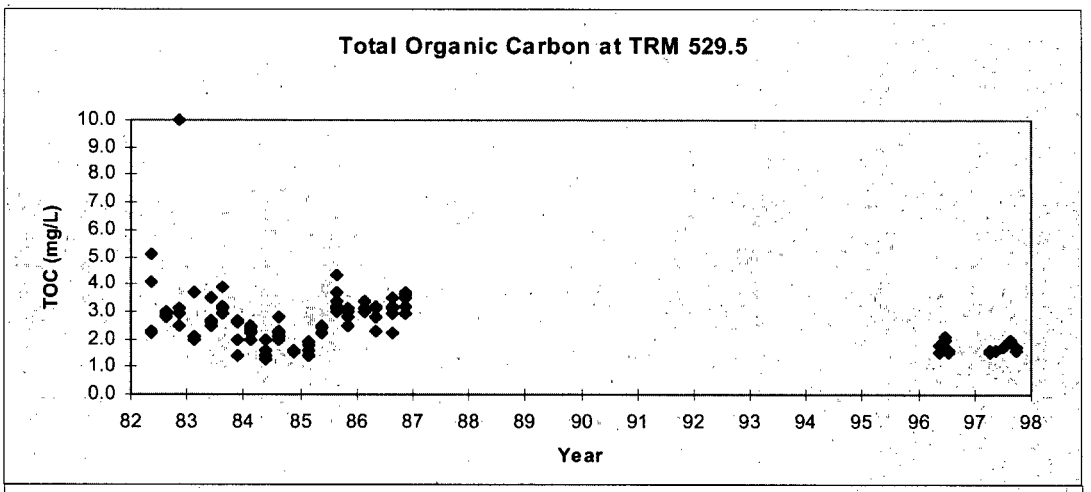

Organic Nitrogen at TRM 529.5
Organic N (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

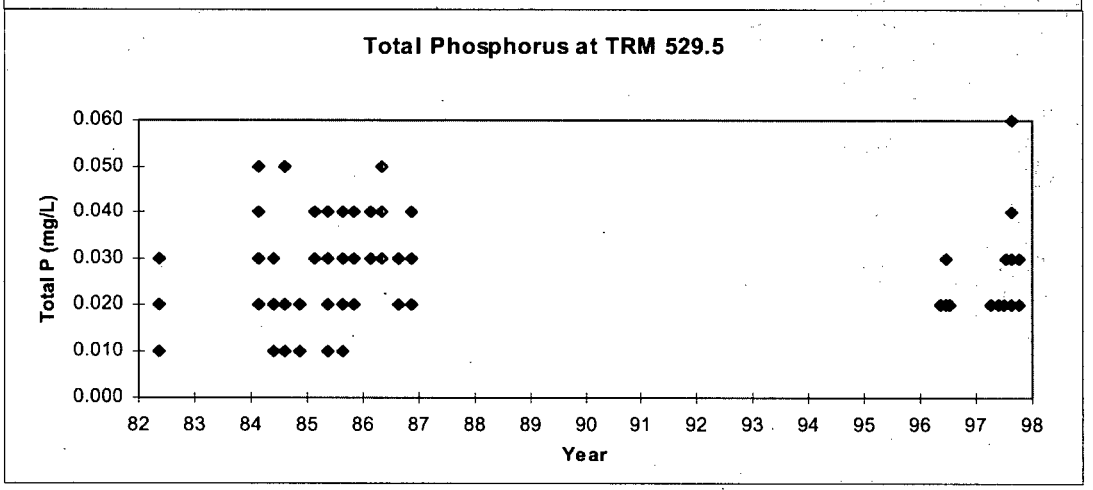

Ammonia Nitrogen at TRM 529.5
Ammonia N (mg/L)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98

Appendix B-3 (Continued)

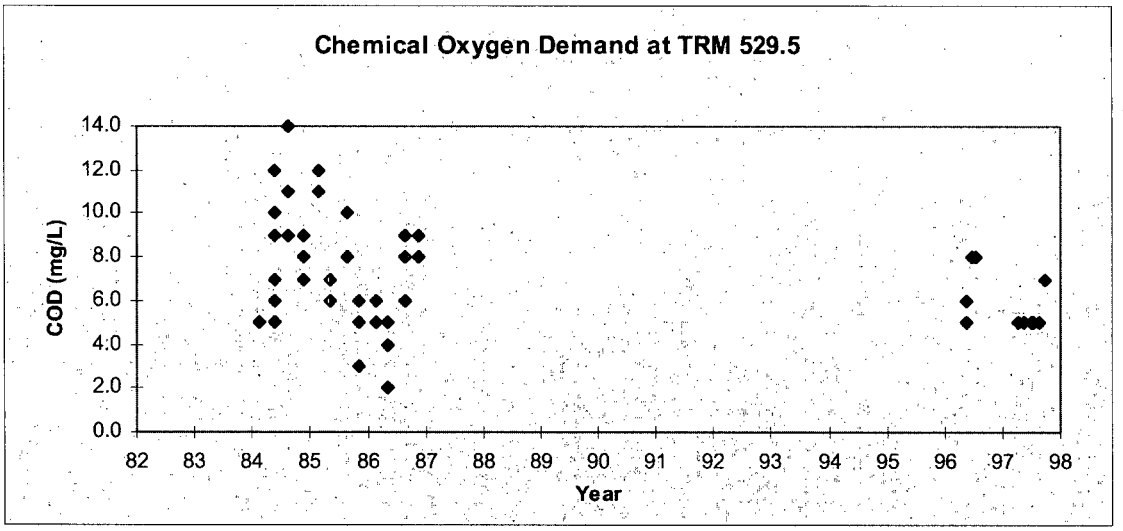

Total Phosphorus at TRM 529.5
Total P (mg/L)
0.060
0.050
0.040
0.030
0.020
0.010
0.000
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

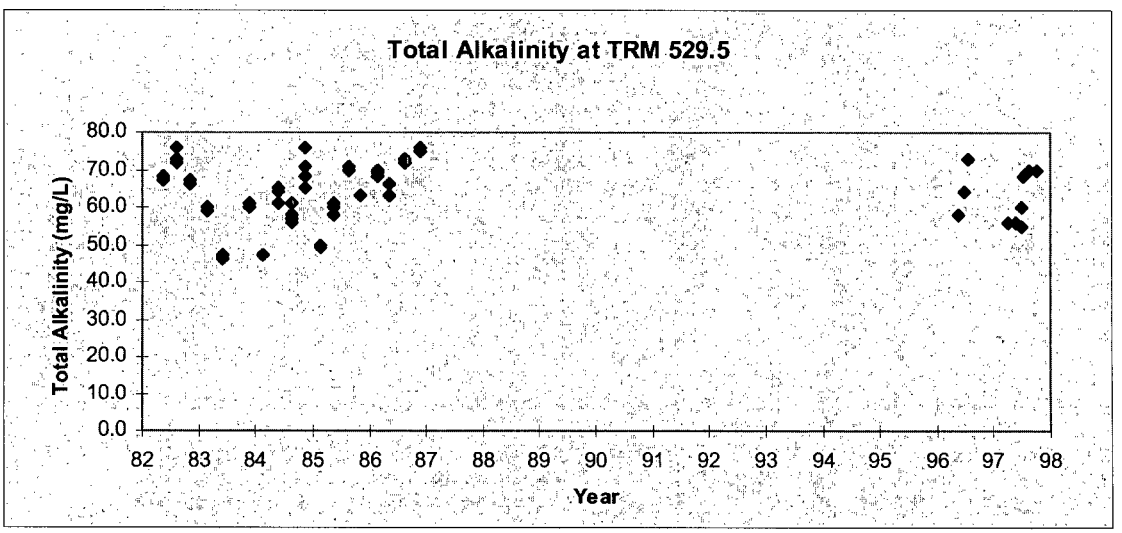

Dissolved Phosphorus at TRM 529.5
Dissolved P (mg/L)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

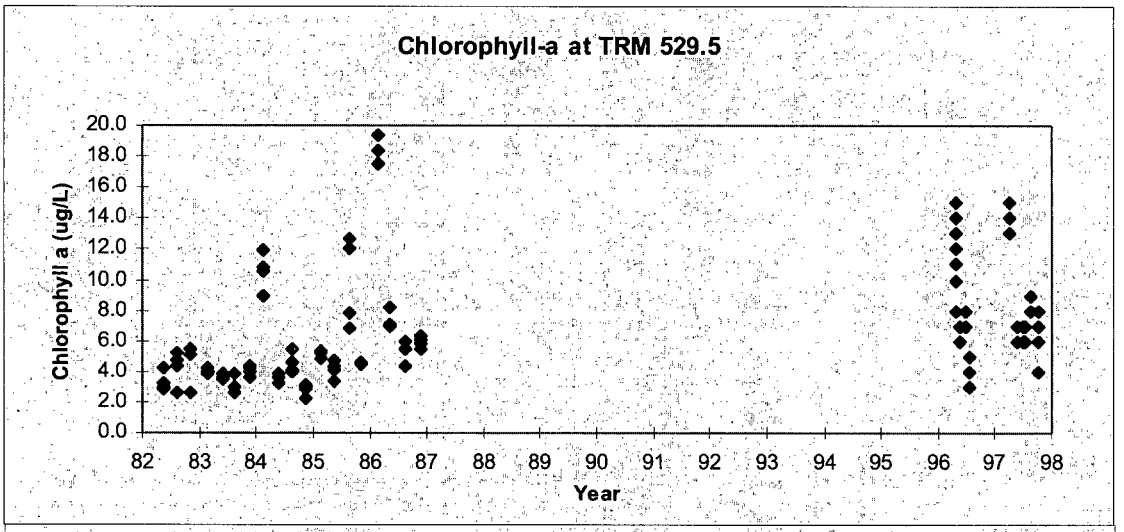

Total Organic Carbon at TRM 529.5
TOC (mg/L)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

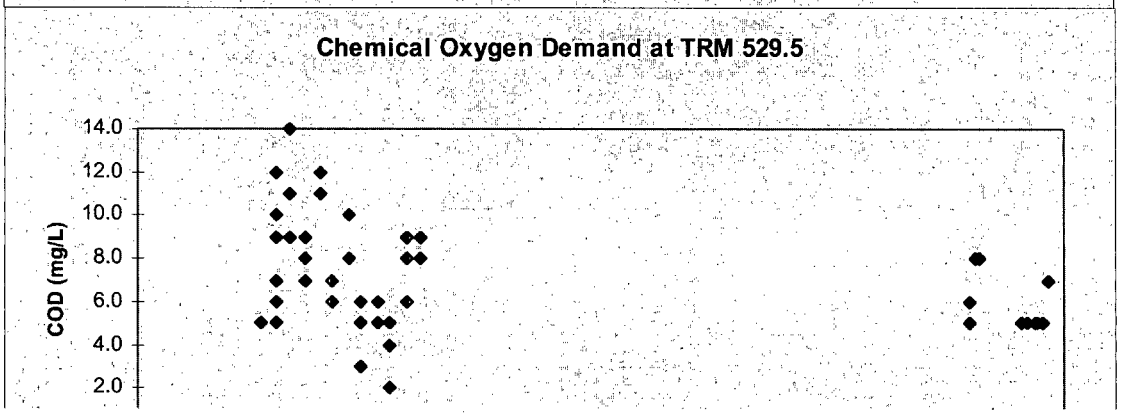

Total Phosphorus at TRM 529.5
Total P (mg/L)
0.060
0.050
0.040
0.030
0.020
0.010
0.000
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

Appendix B-3 (Continued)

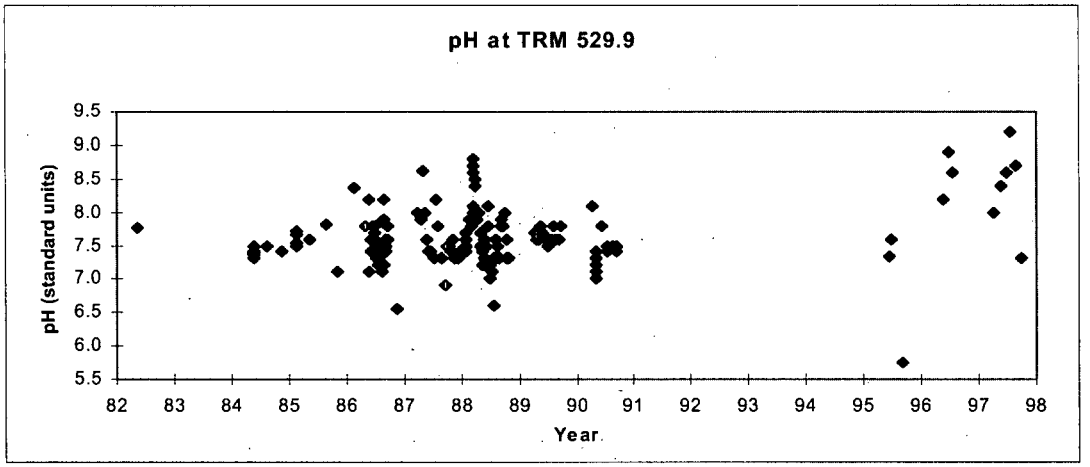

Chemical Oxygen Demand at TRM 529.5
COD (mg/L)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

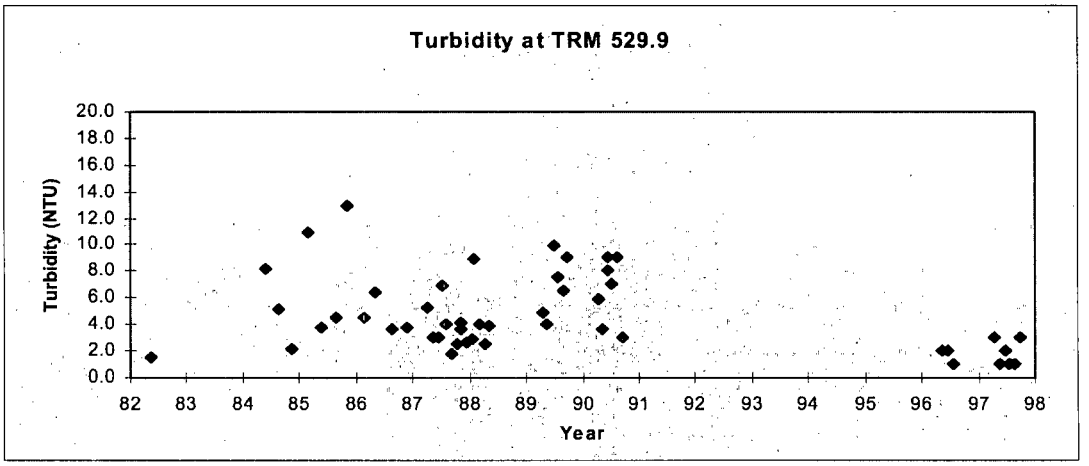

Total Alkalinity at TRM 529.5
Total Alkalinity (mg/L)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

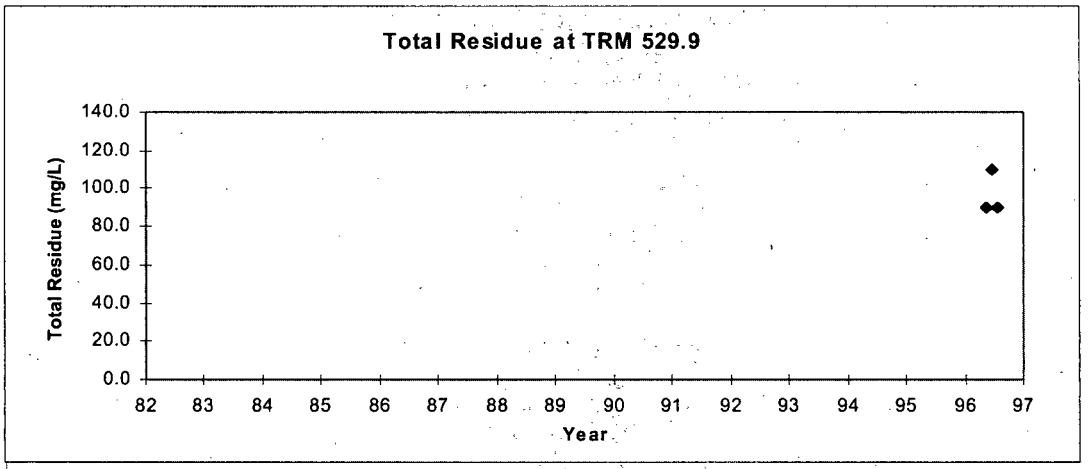

Chlorophyll-a at TRM 529.5
Chlorophyll a (ug/L)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

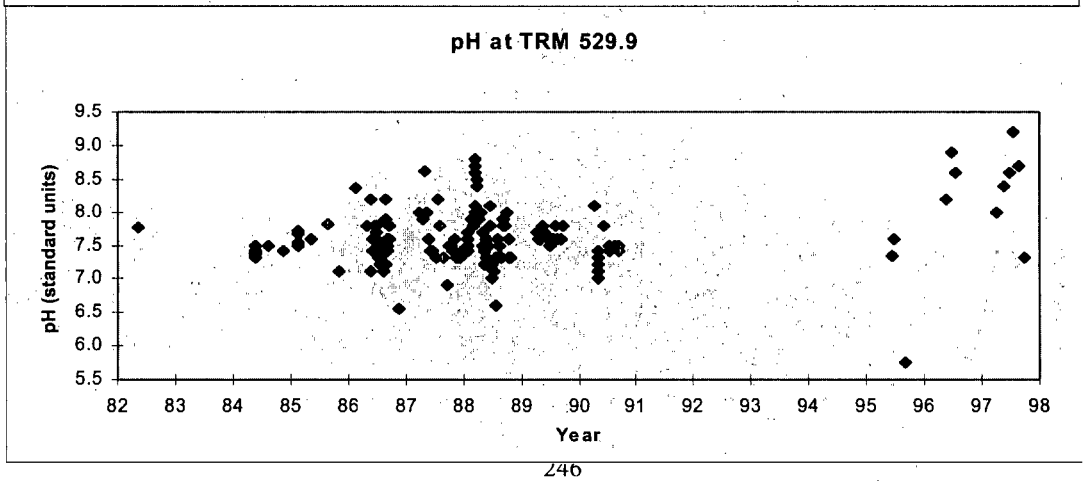

Chemical Oxygen Demand at TRM 529.5
COD (mg/L)
14.0
12.0
10.0
8.0
6.0
4.0
2.0

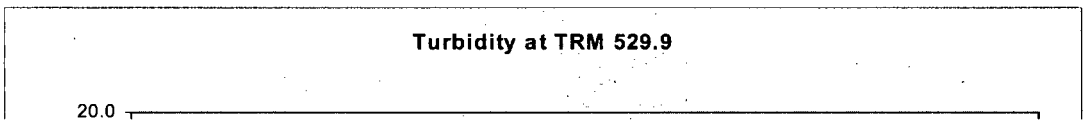
Appendix B-4. Selected water quality values measured during preoperational (1982-1991) and operational (1996-1997) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 529.9


pH at TRM 529.9
pH (standard units)
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

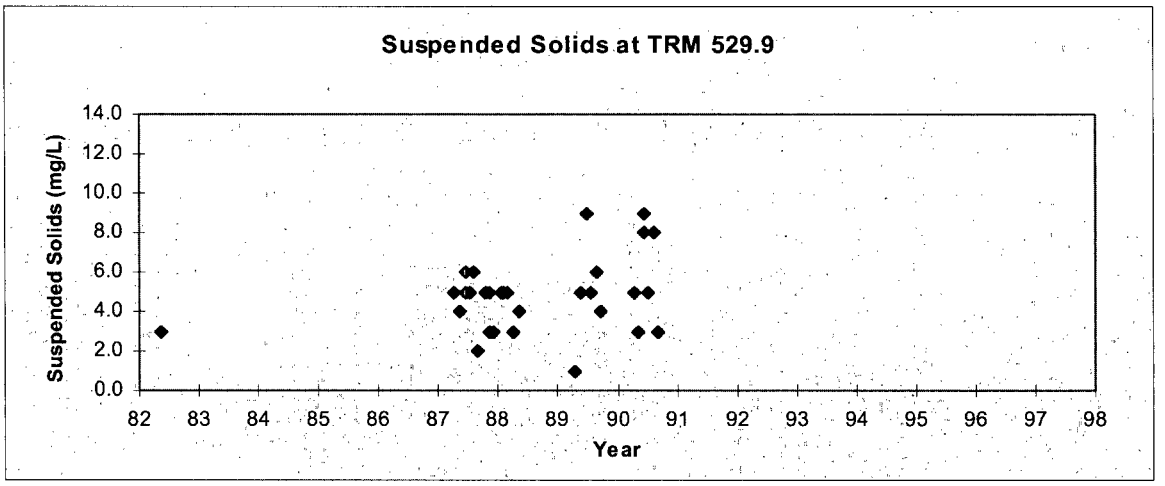

Turbidity at TRM 529.9
Turbidity (NTU)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

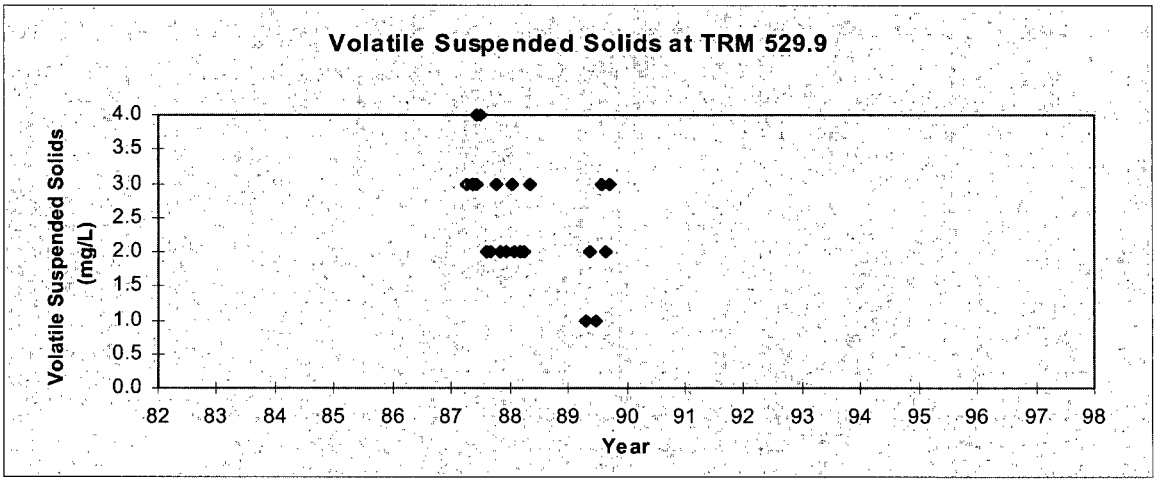

Total Residue at TRM 529.9
Total Residue (mg/L)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
Year

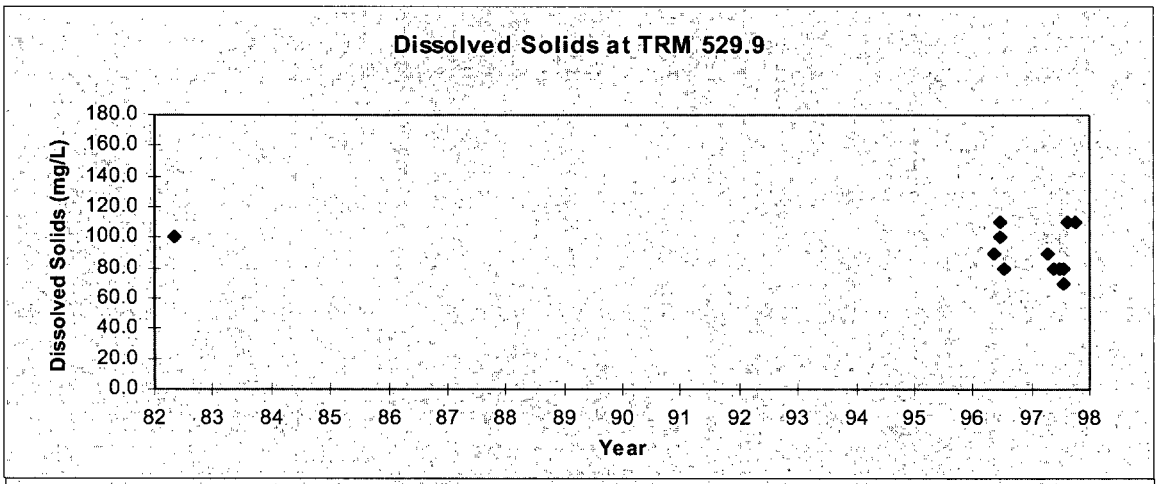

pH at TRM 529.9
pH (standard units)
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

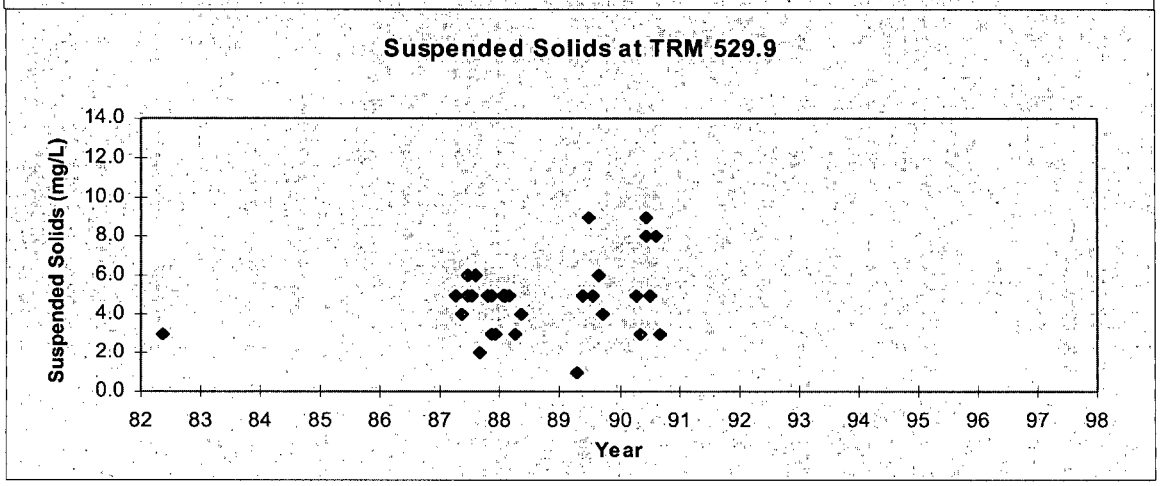

Turbidity at TRM 529.9
20.0

Appendix B-4 (Continued)


Suspended Solids at TRM 529.9
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 98
Year

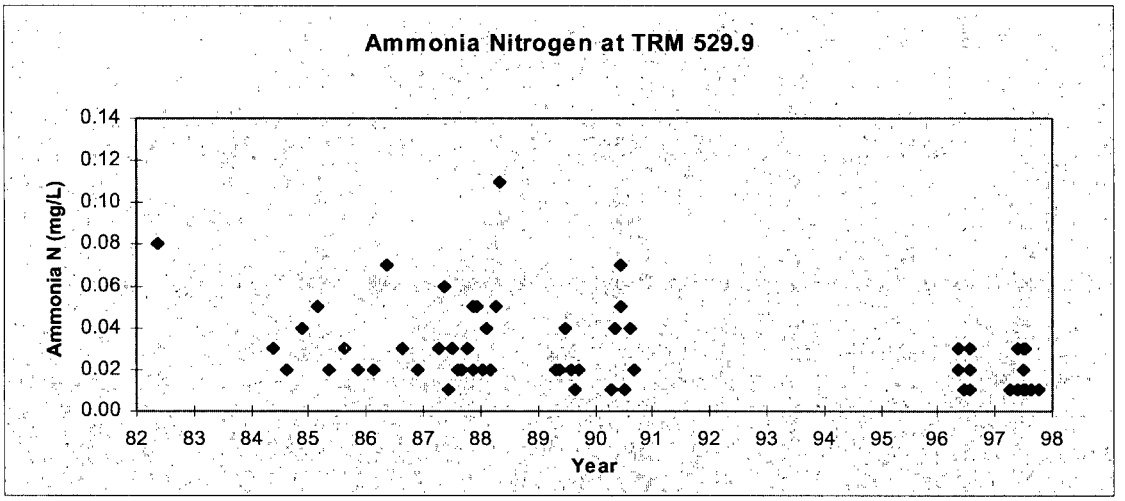

Volatile Suspended Solids at TRM 529.9
Volatile Suspended Solids (mg/L)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

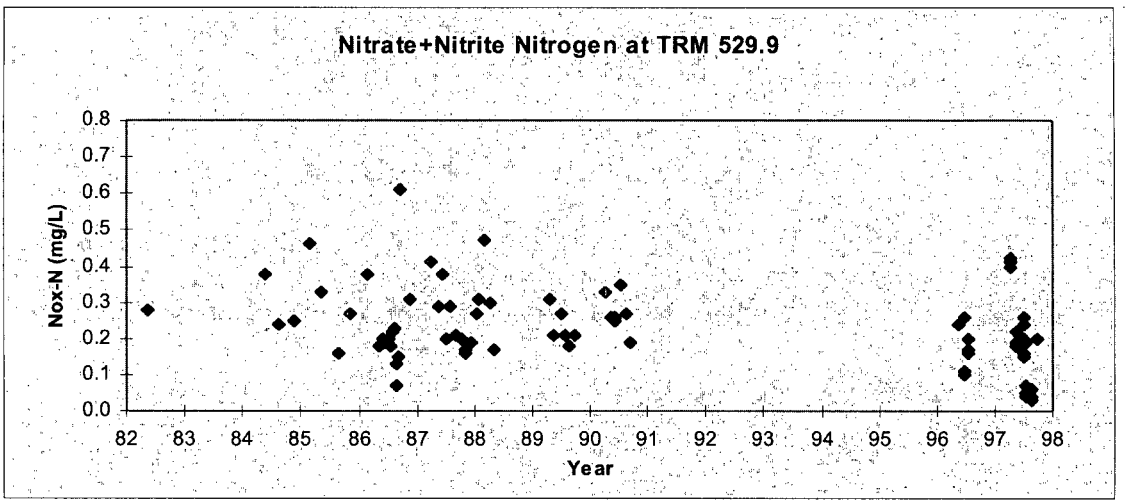

Dissolved Solids at TRM 529.9
Dissolved Solids (mg/L)
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

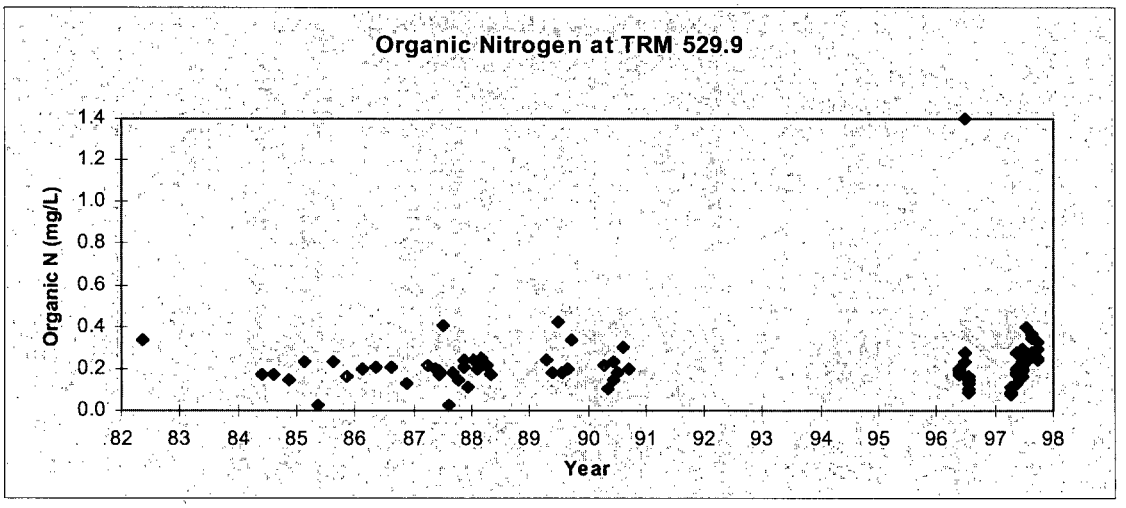

Suspended Solids at TRM 529.9
Suspended Solids (mg/L)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

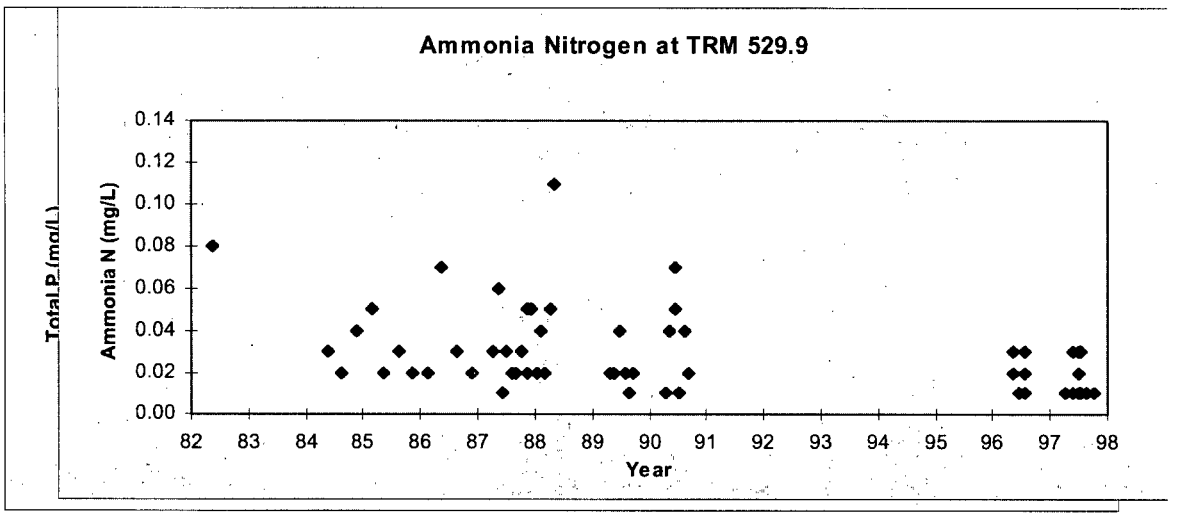
Volatile Suspended Solids at TRM 529.9

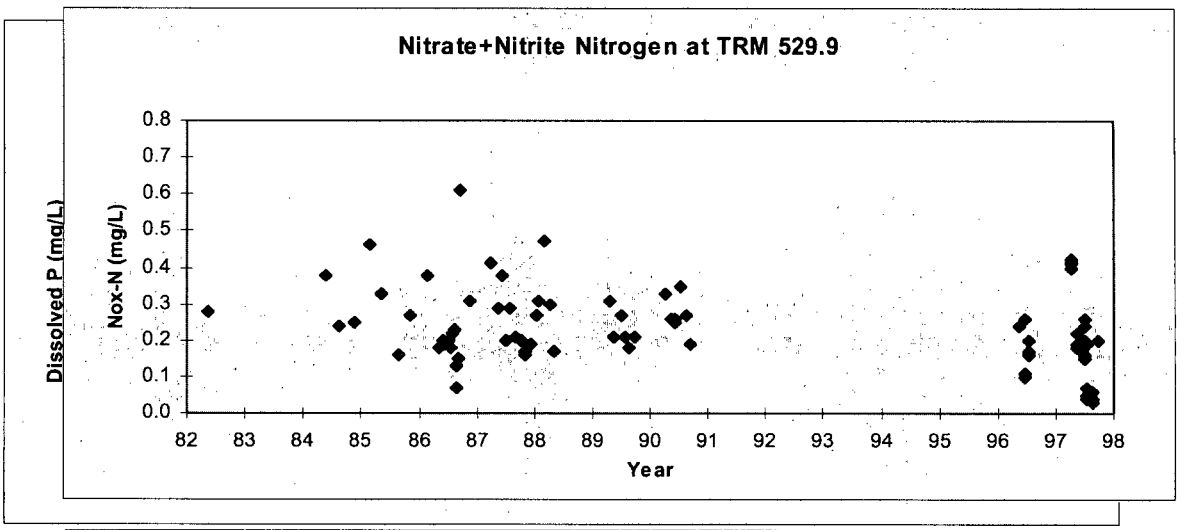
Appendix B-4 (Continued)

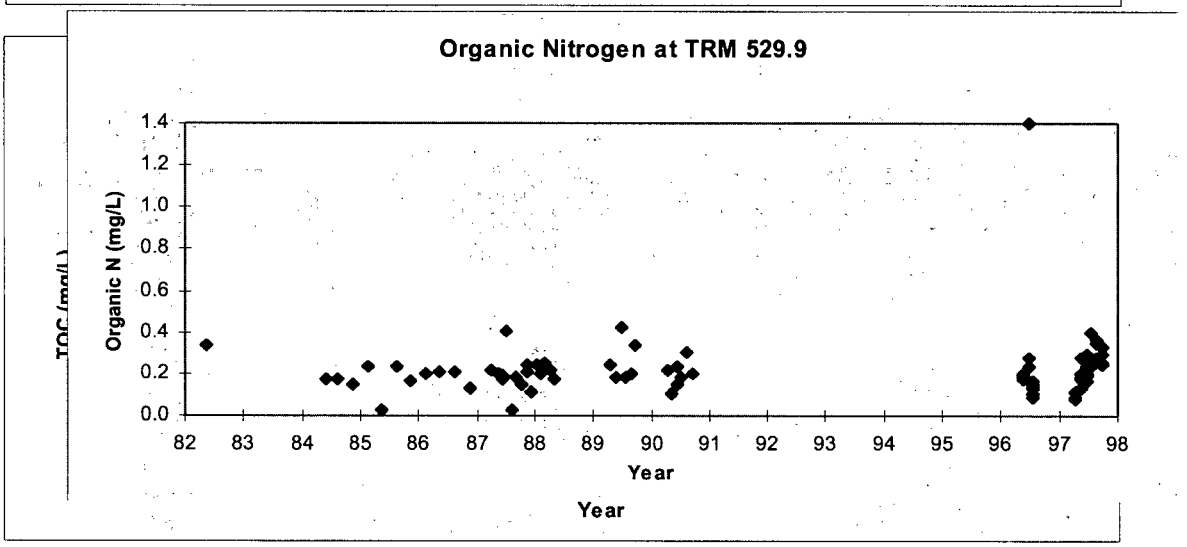




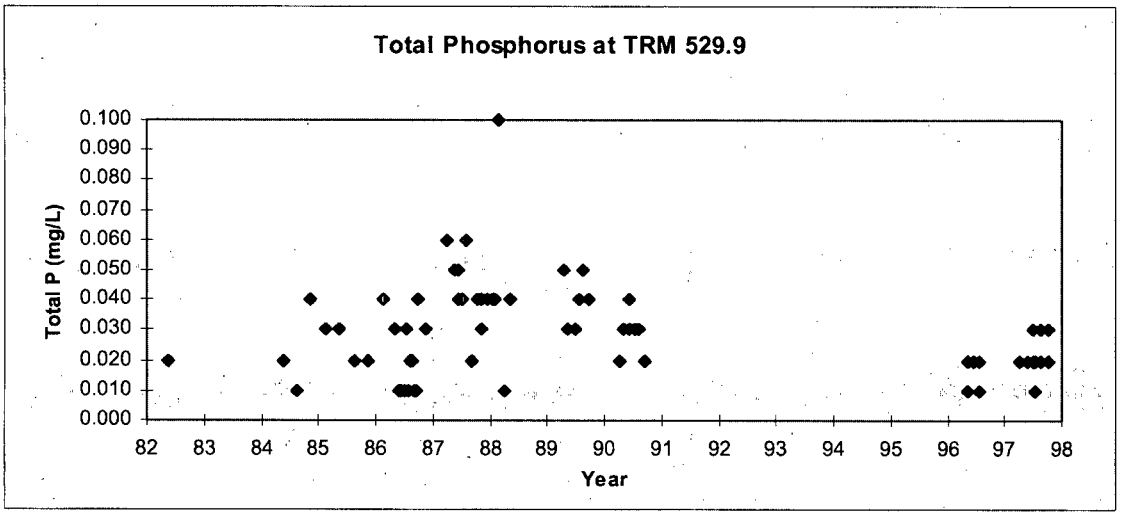


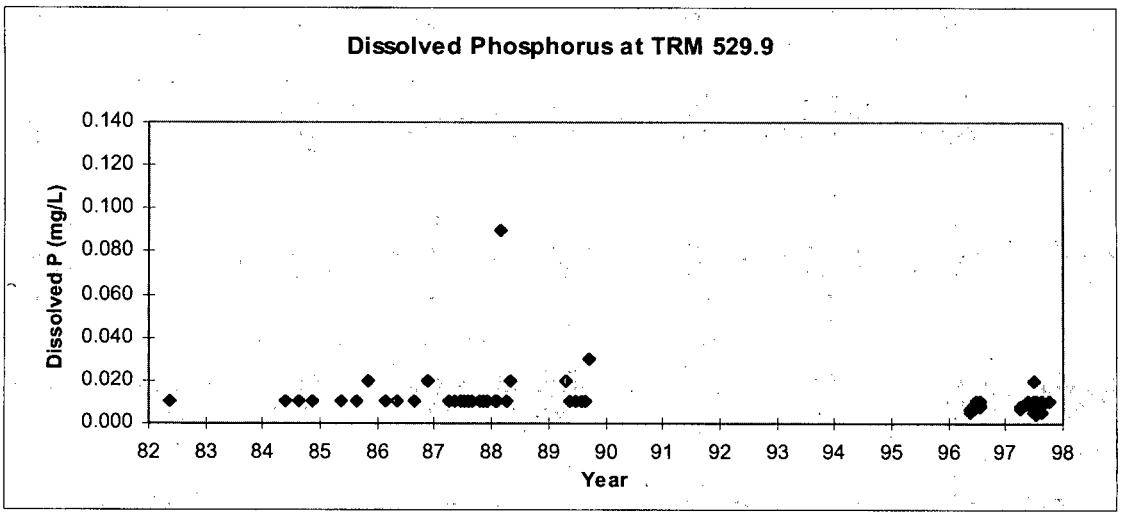

Ammonia Nitrogen at TRM 529.9
Ammonia N (mg/L)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

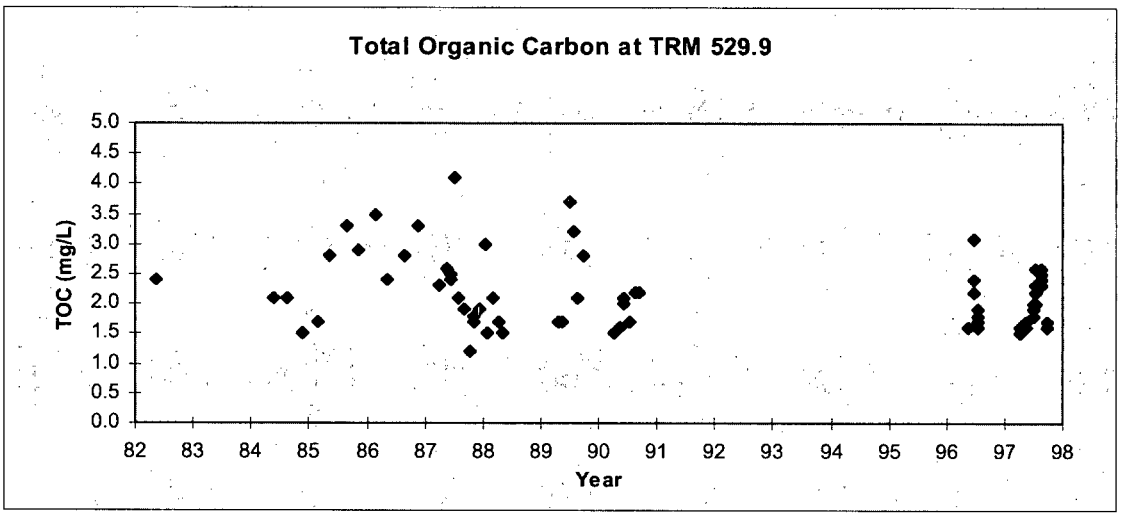

Nitrate+Nitrite Nitrogen at TRM 529.9
Nox-N (mg/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year


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 98
Year
Year

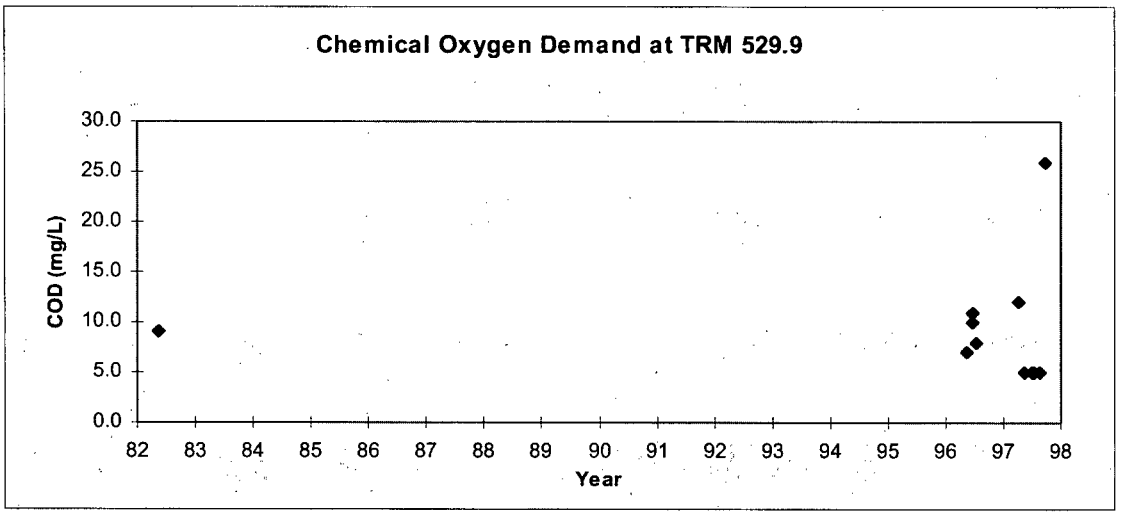
Appendix B-4 (Continued)

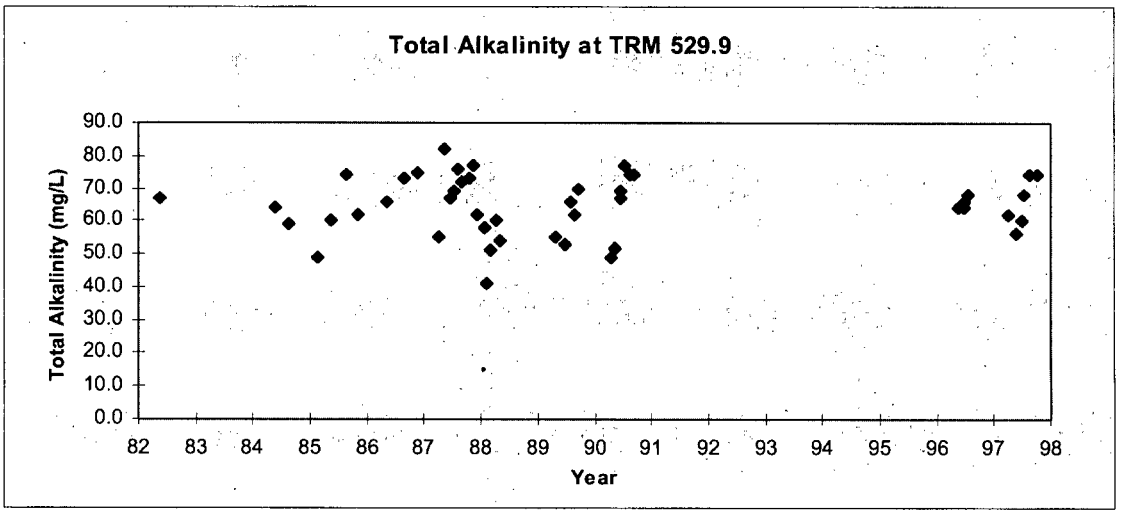


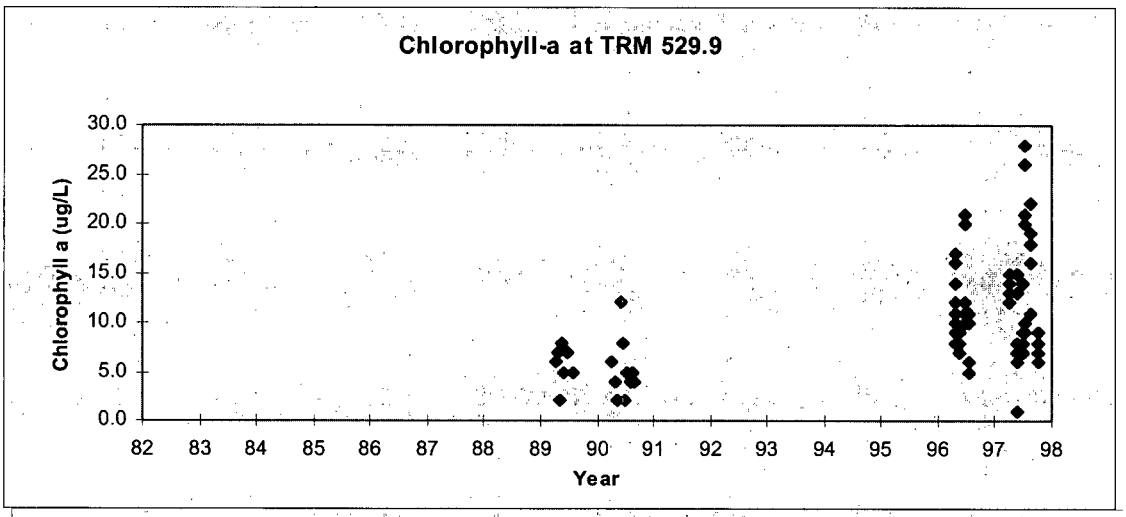


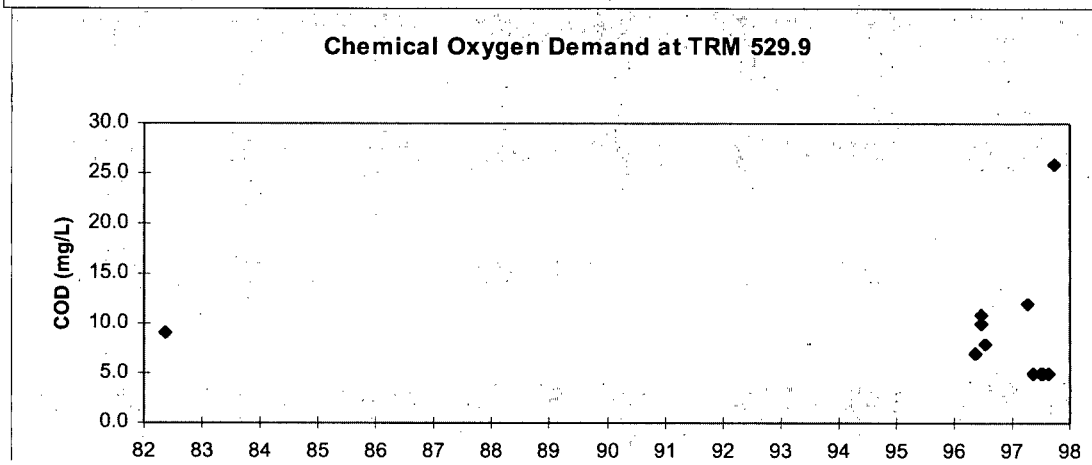


Appendix B-4 (Continued)

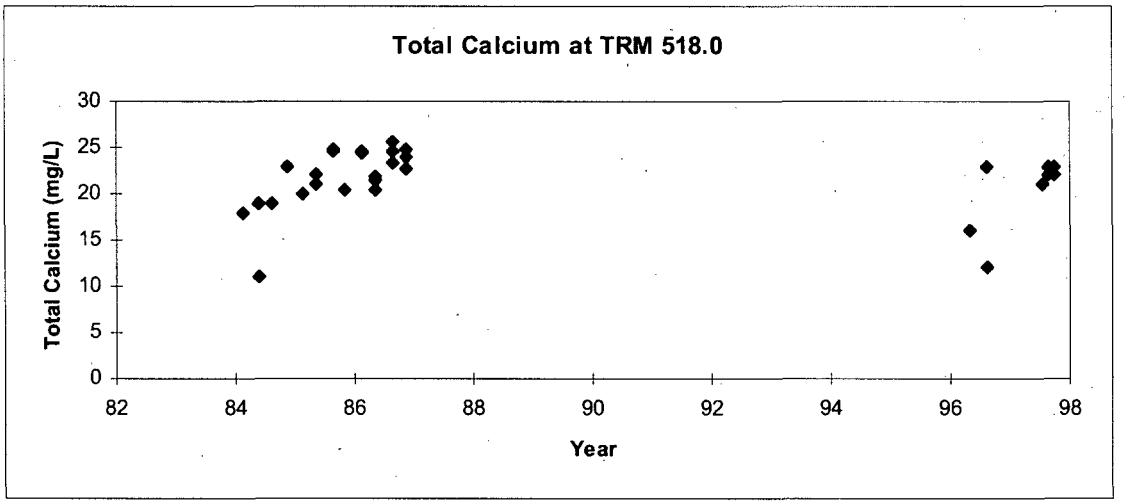

Chemical Oxygen Demand at TRM 529.9
COD (mg/L)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

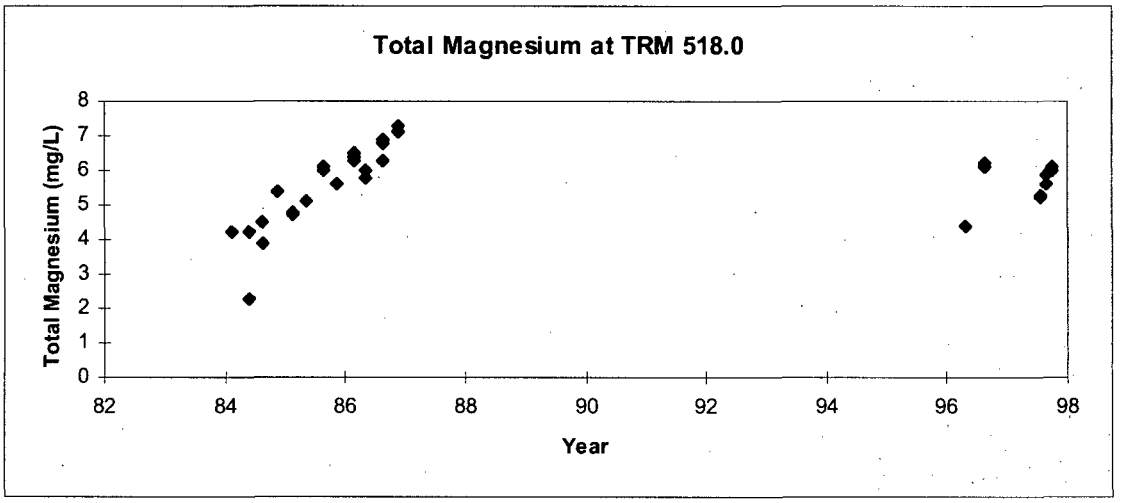

Total Alkalinity at TRM 529.9
Total Alkalinity (mg/L)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

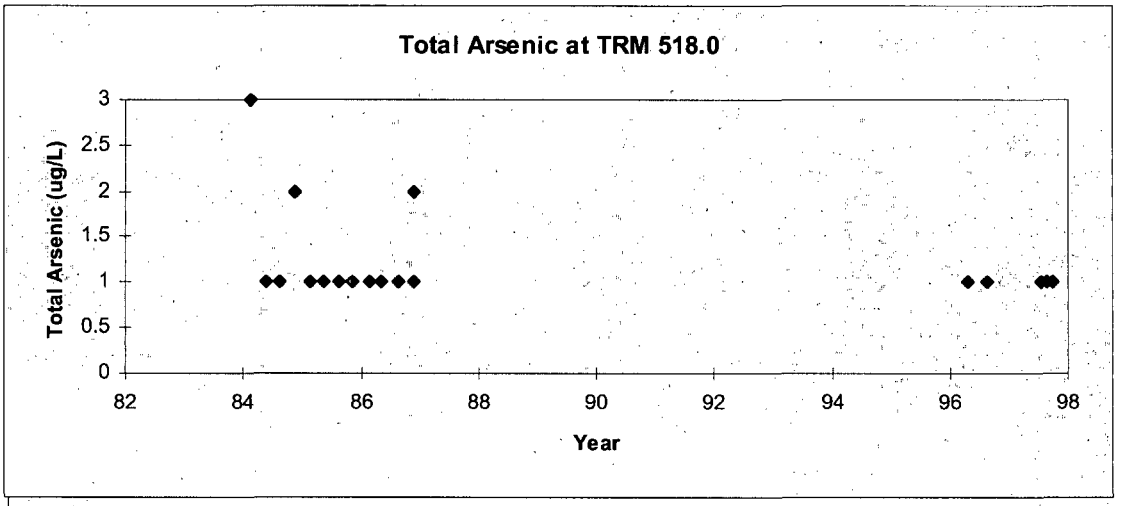

Chlorophyll-a at TRM 529.9
Chlorophyll a (ug/L)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Year

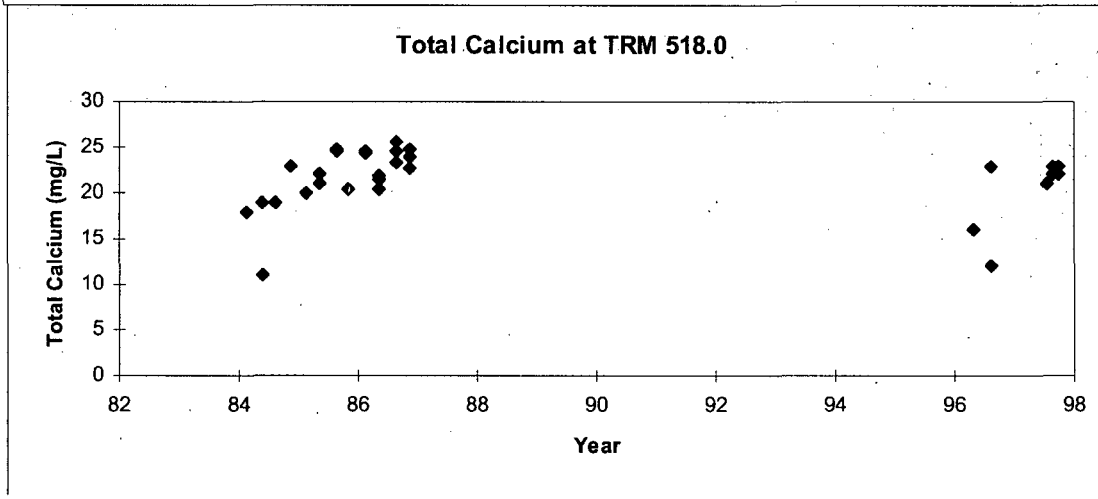

Chemical Oxygen Demand at TRM 529.9
COD (mg/L)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98

Appendix B-5. Concentrations of selected metals during preoperational (1982-1987) and operational (1996-1997) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 518.0

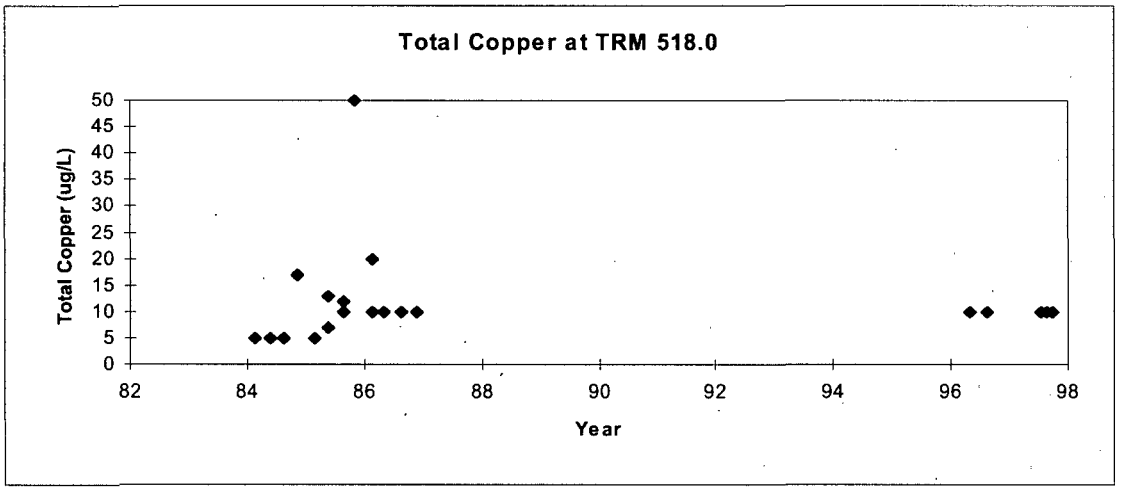

Total Calcium at TRM 518.0
Total Calcium (mg/L)
30
25
20
15
10
5
0
82
84
86
88
90
92
94
96
98
Year

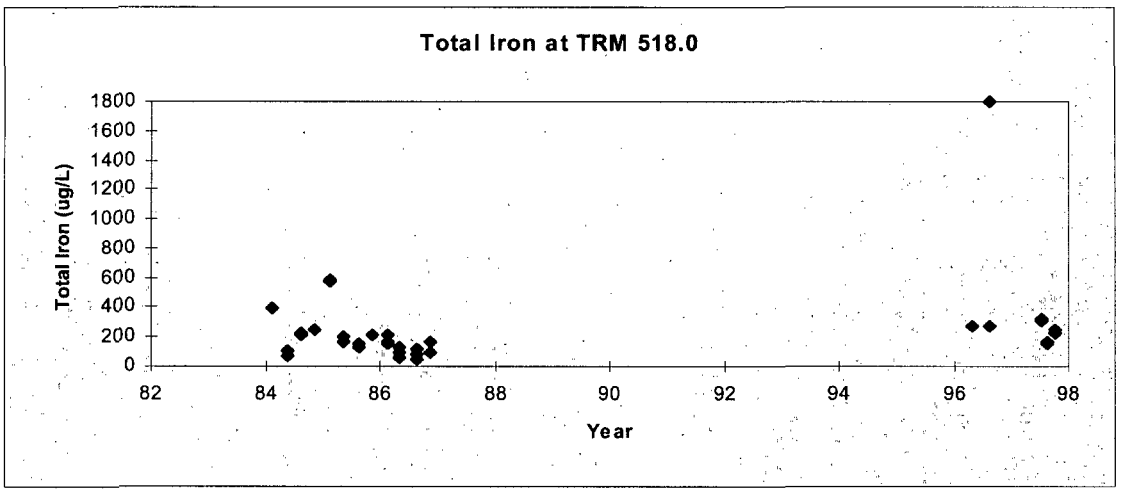

Total Magnesium at TRM 518.0
Total Magnesium (mg/L)
8
7
6
5
4
3
2
1
0
82
84
86
88
90
92
94
96
98
Year

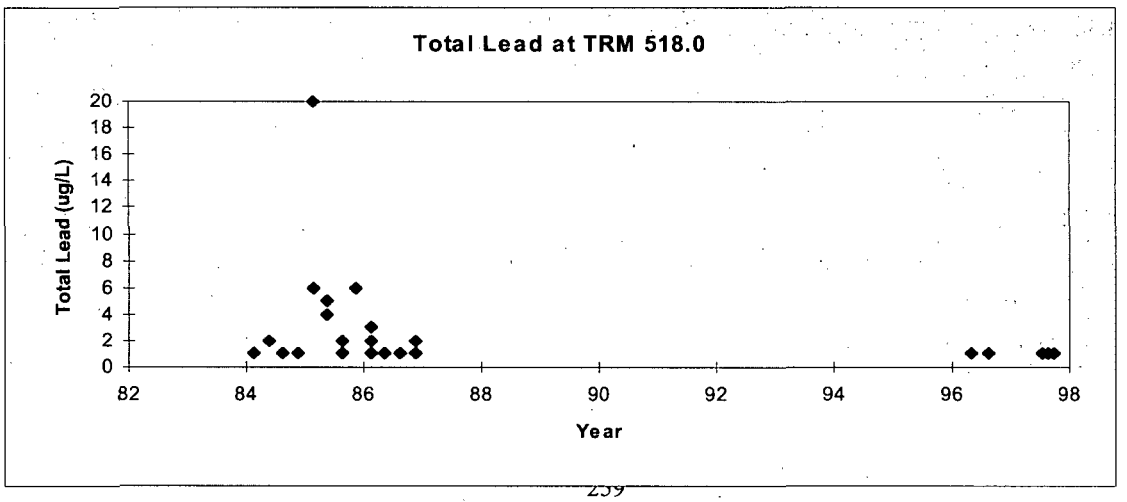

Total Arsenic at TRM 518.0
Total Arsenic (ug/L)
3
2.5
2
1.5
1
0.5
0
82
84
86
88
90
92
94
96
98
Year

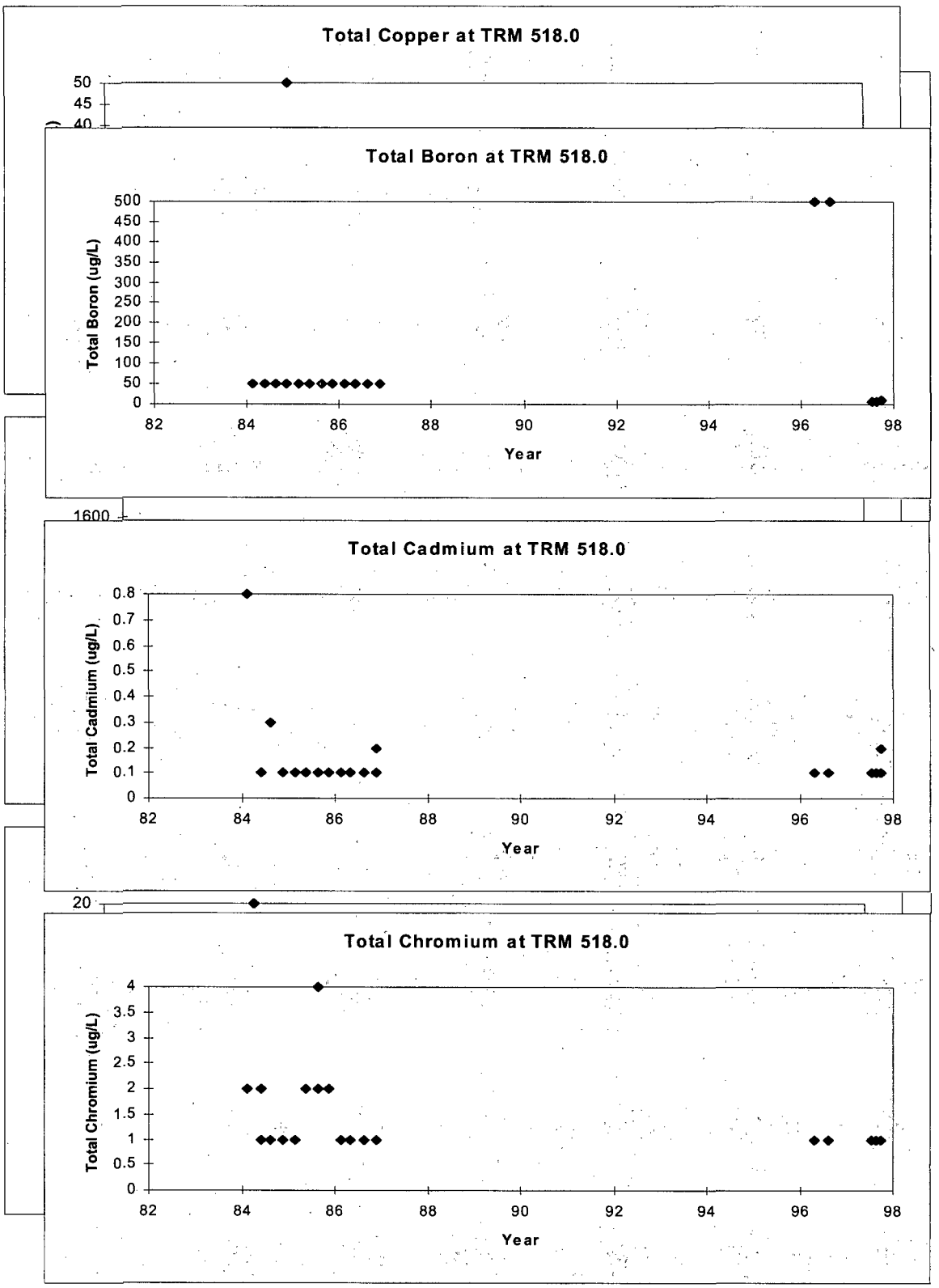

Total Calcium at TRM 518.0
Total Calcium (mg/L)
30
25
20
15
10
5
0
82
84
86
88
90
92
94
96
98
Year

Appendix B-5 (Continued)

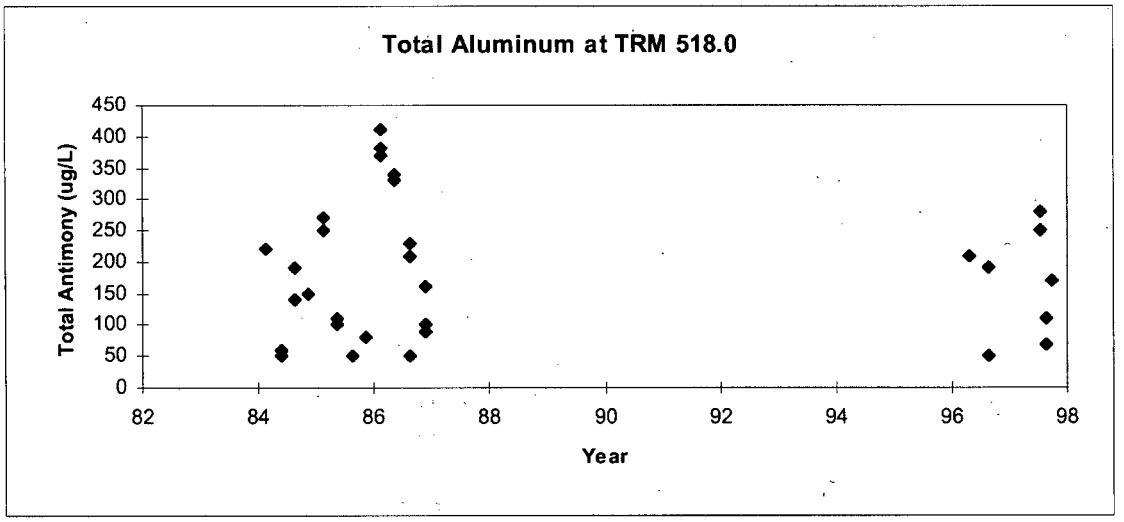


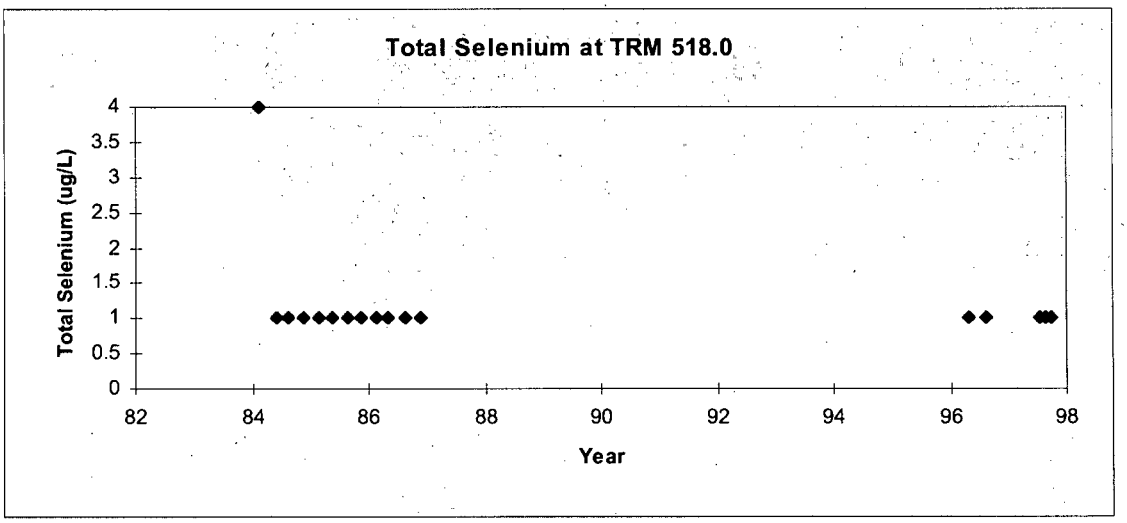


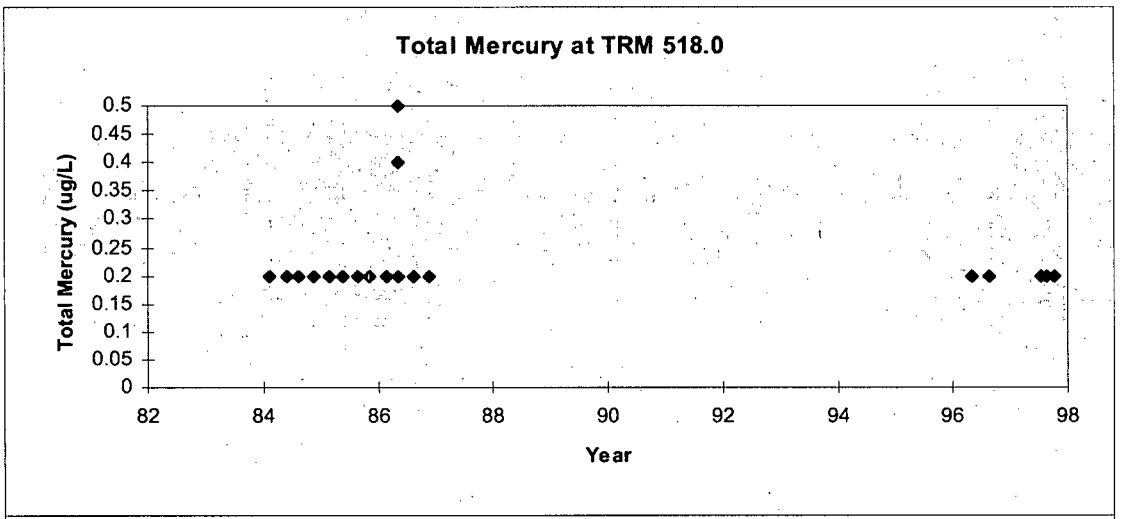


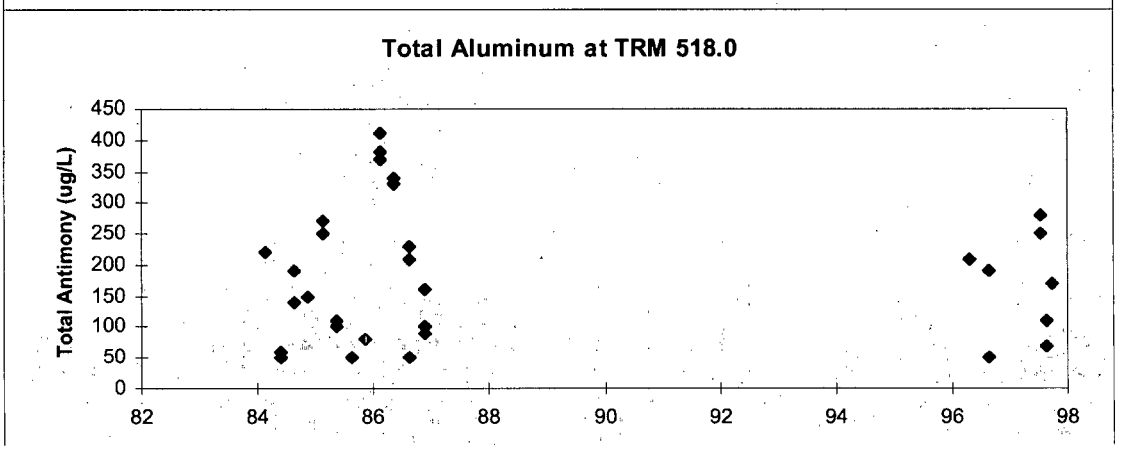

Total Copper at TRM 518.0
50
45
40
Total Boron at TRM 518.0
Total Boron (ug/L)
500
450
400
350
300
250
200
150
100
50
0
82
84
86
88
90
92
94
96
98
Year
1600
Total Cadmium at TRM 518.0
Total Cadmium (ug/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
82
84
86
88
90
92
94
96
98
Year
20
Total Chromium at TRM 518.0
Total Chromium (ug/L)
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 Aluminum at TRM 518.0
Total Antimony (ug/L)
450
400
350
300
250
200
150
100
50
0
82
84
86
88
90
92
94
96
98
Year

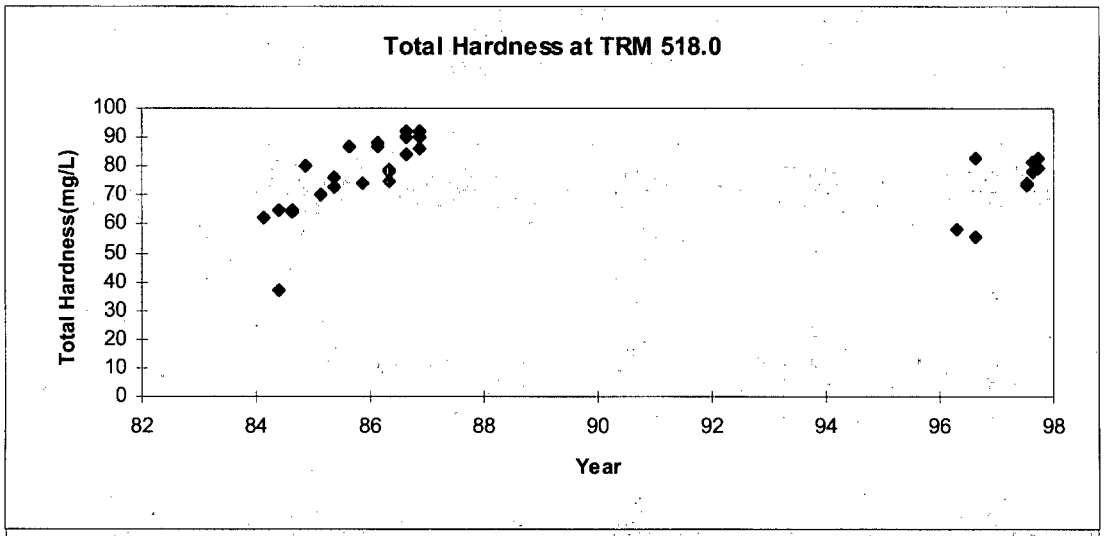

Total Selenium at TRM 518.0
Total Selenium (ug/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
82
84
86
88
90
92
94
96
98
Year

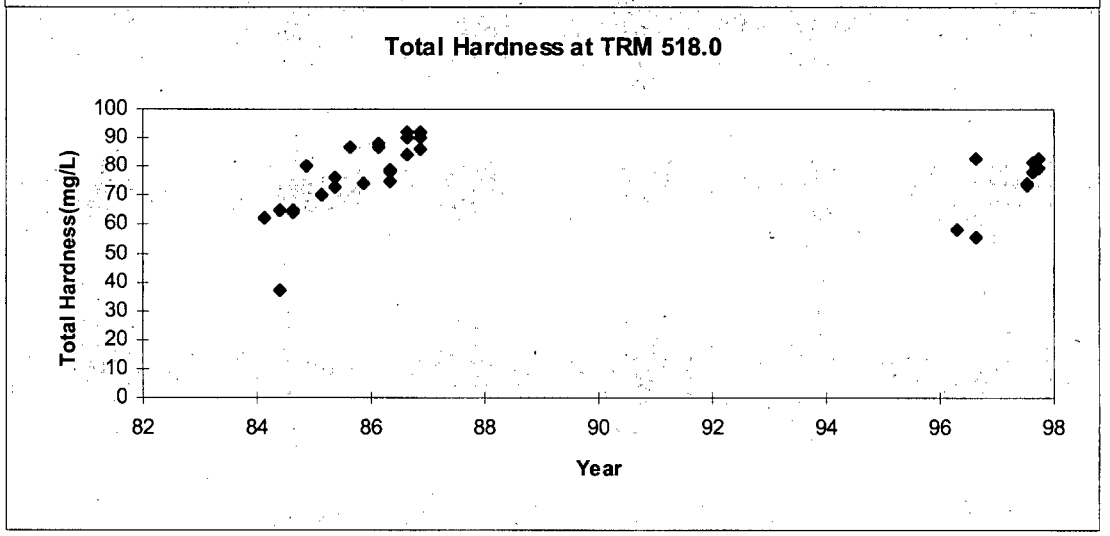

Total Mercury at TRM 518.0
Total Mercury (ug/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
82
84
86
88
90
92
94
96
98
Year


Total Aluminum at TRM 518.0
Total Antimony (ug/L)
450
400
350
300
250
200
150
100
50
0
82
84
86
88
90
92
94
96
98

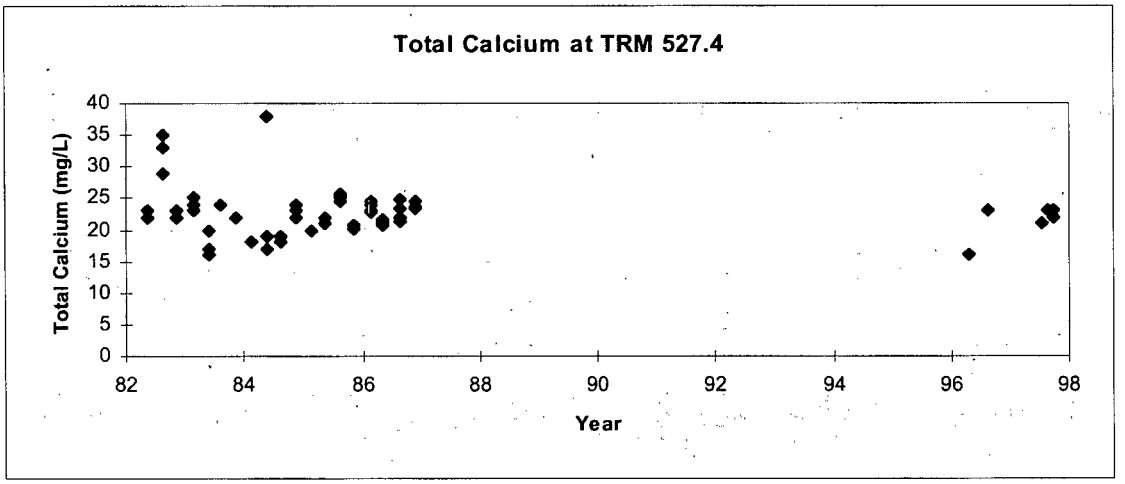
Appendix B-5 (Continued)

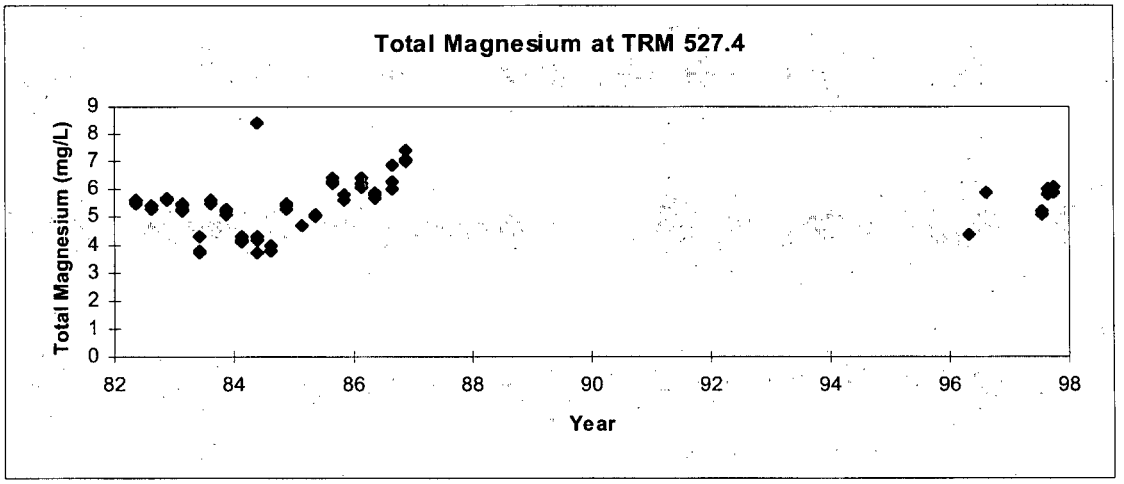
Appendix B-5 (Continued)

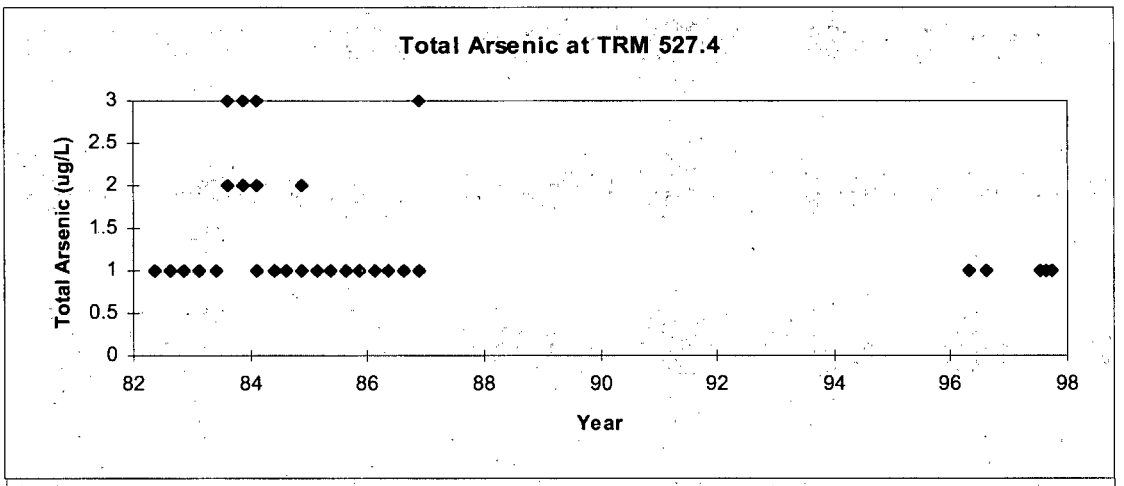


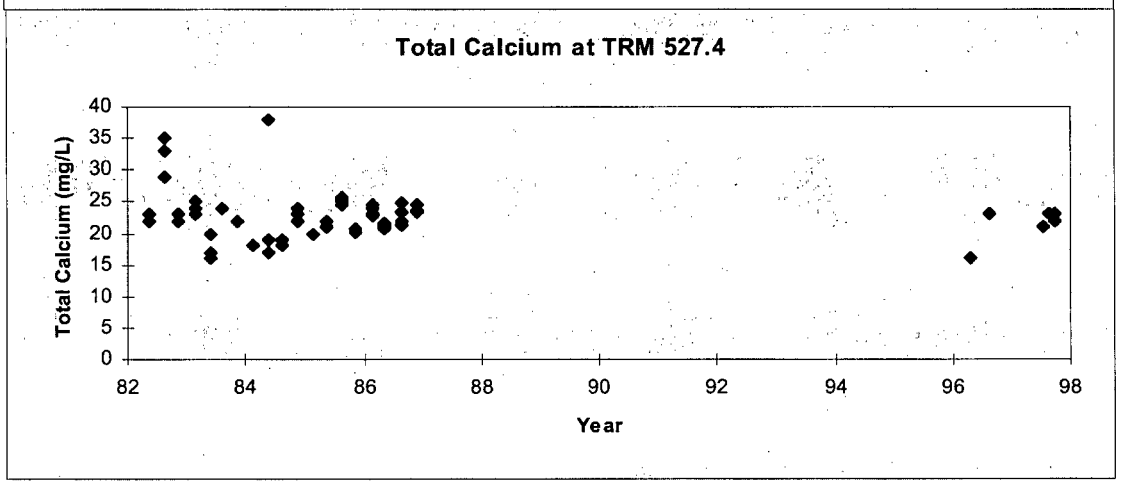


Appendix B-6. Concentrations of selected metals during preoperational (1982-1987) and operational (1996-1997) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 527.4



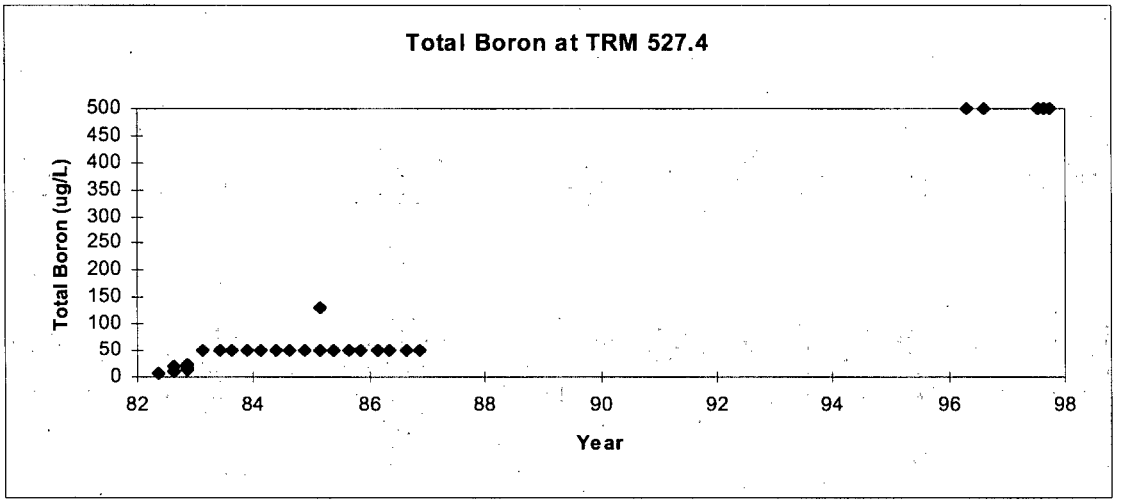


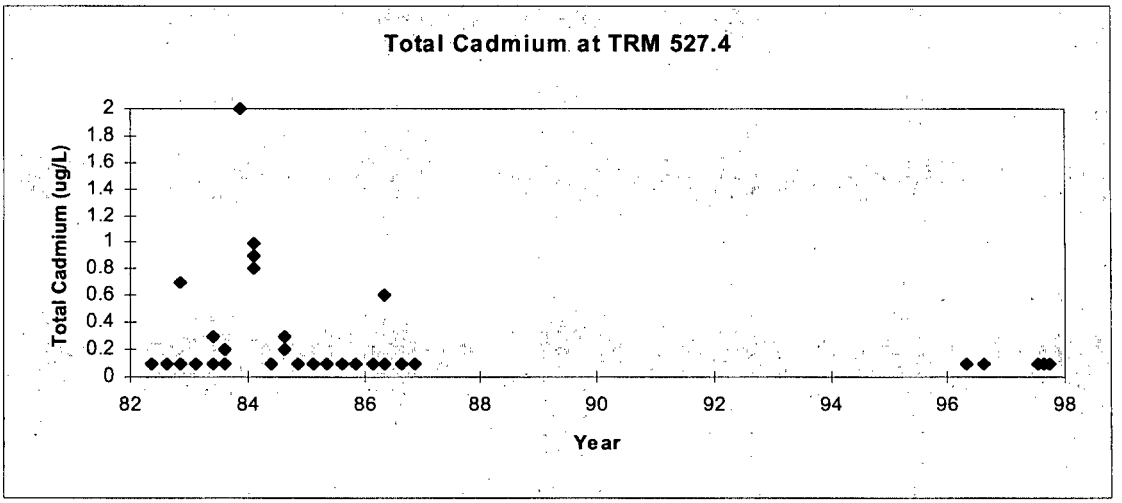


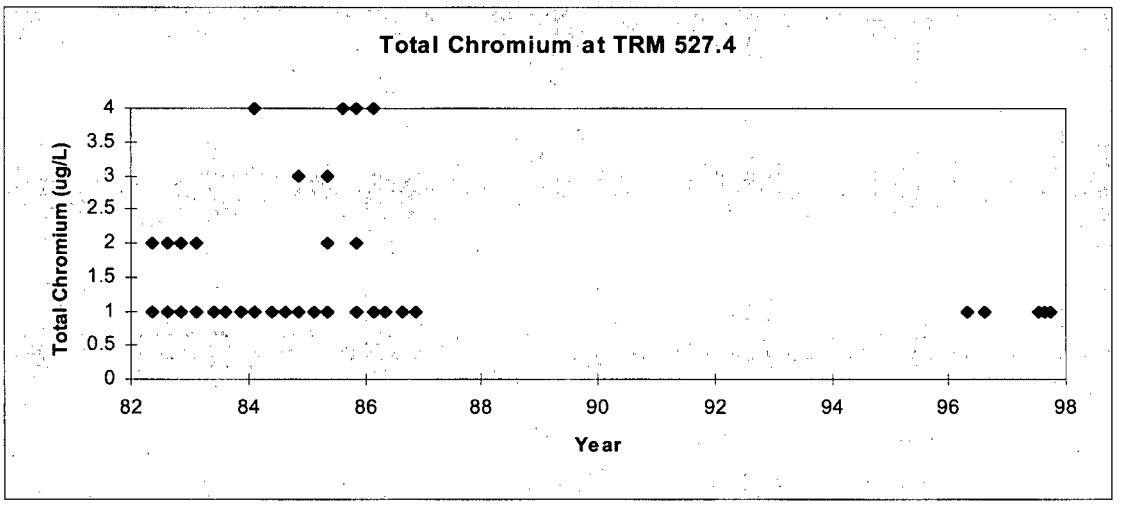


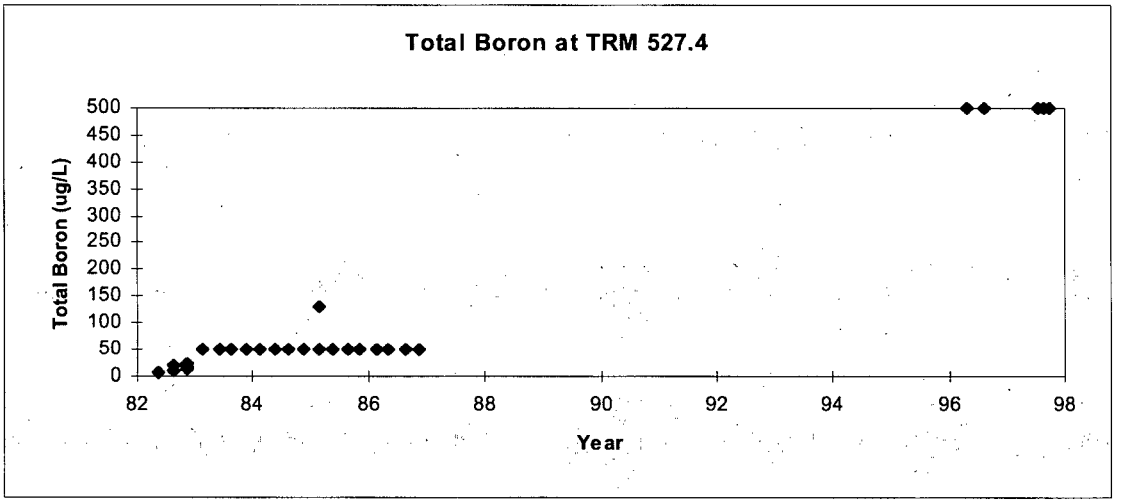
Total Magnesium at TRM 527.4

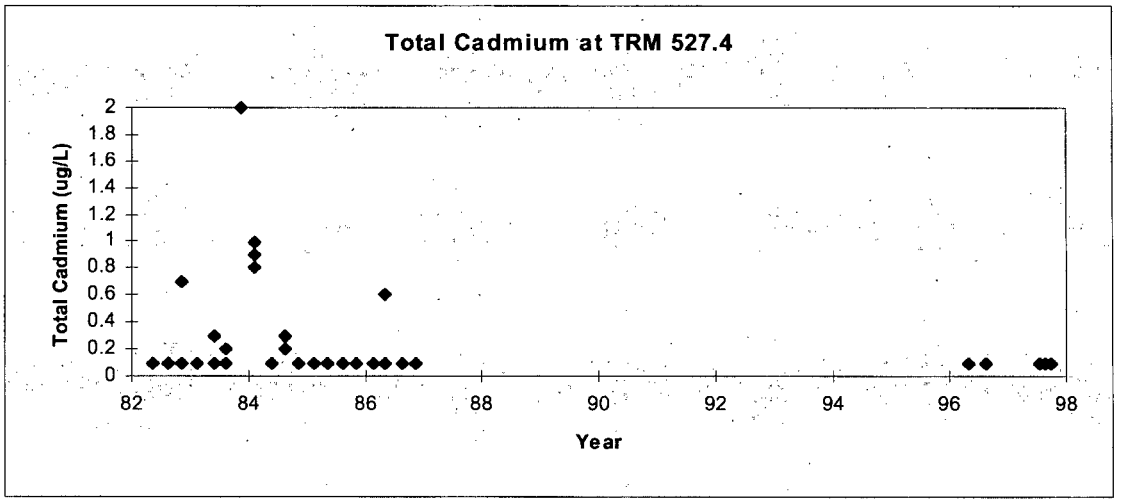
Appendix B-6 (Continued)

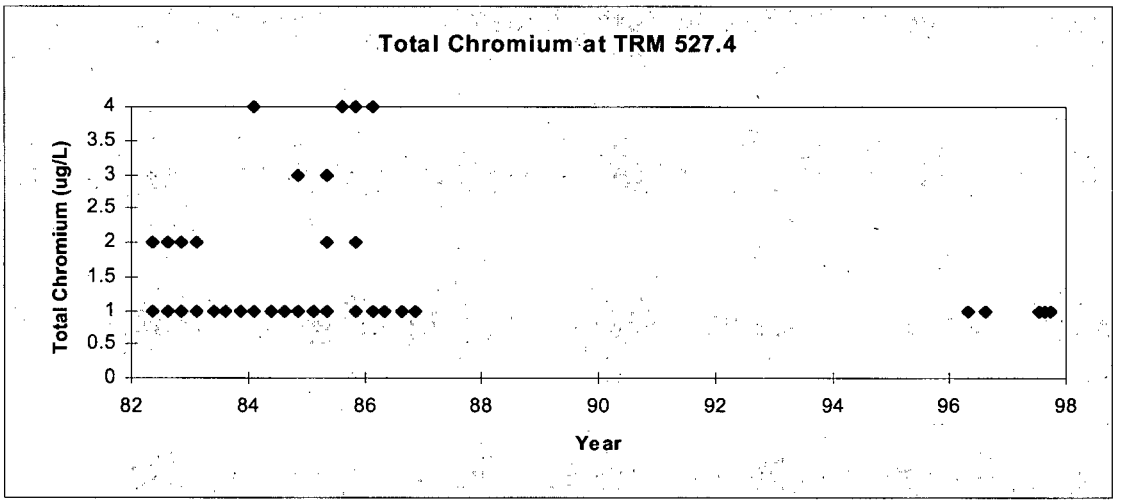

Total Boron at TRM 527.4
Total Boron (ug/L)
500
450
400
350
300
250
200
150
100
50
0
82
84
86
88
90
92
94
96
98
Year


Total Cadmium at TRM 527.4
Total Cadmium (ug/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
82
84
86
88
90
92
94
96
98
Year

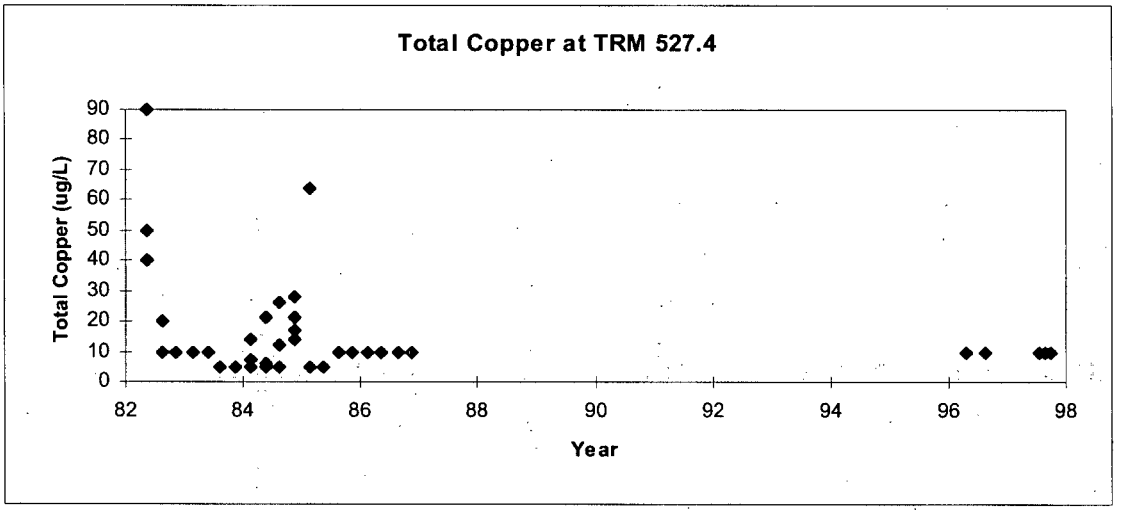

Total Chromium at TRM 527.4
Total Chromium (ug/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
82
84
86
88
90
92
94
96
98
Year

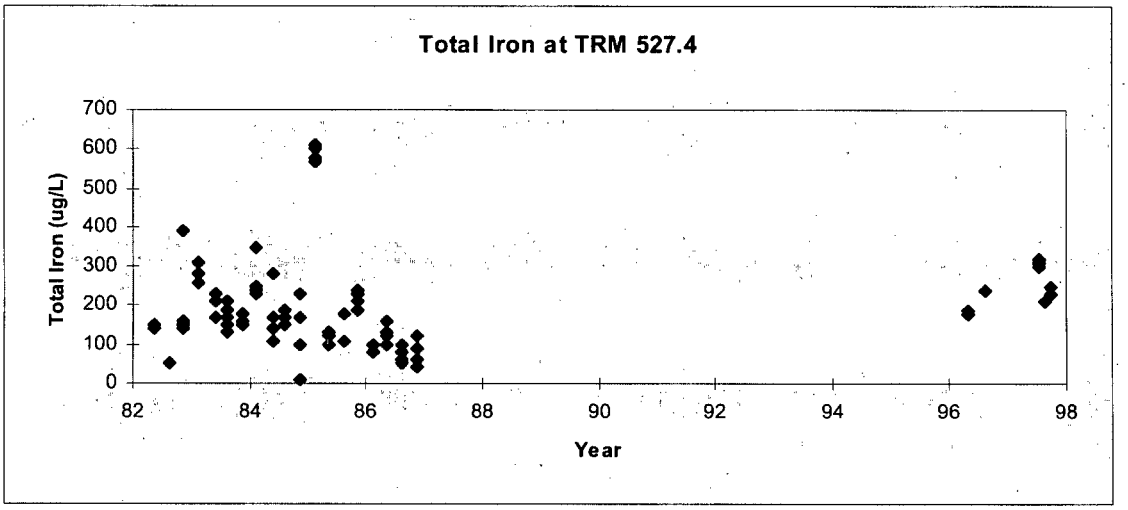

Total Boron at TRM 527.4
Total Boron (ug/L)
500
450
400
350
300
250
200
150
100
50
0
82
84
86
88
90
92
94
96
98
Year

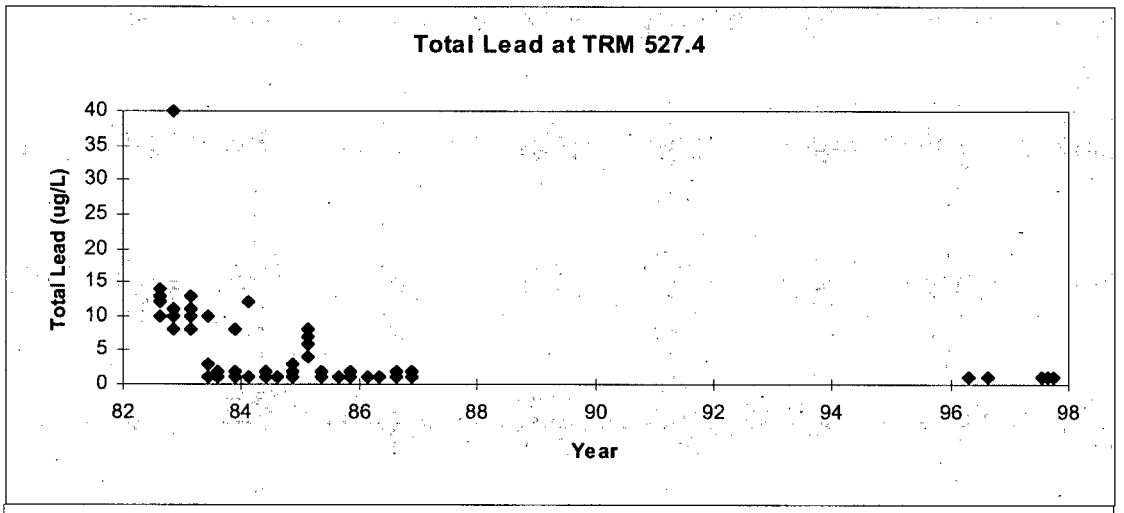

Total Cadmium at TRM 527.4
Total Cadmium (ug/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
82
84
86
88
90
92
94
96
98
Year

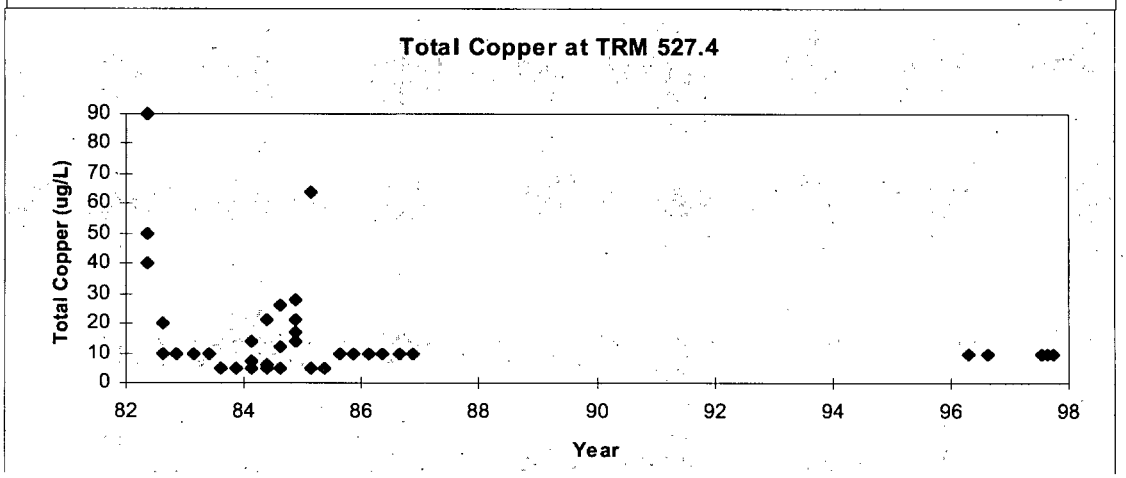

Total Chromium at TRM 527.4
Total Chromium (ug/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
82
84
86
88
90
92
94
96
98
Year

Appendix B-6 (Continued)

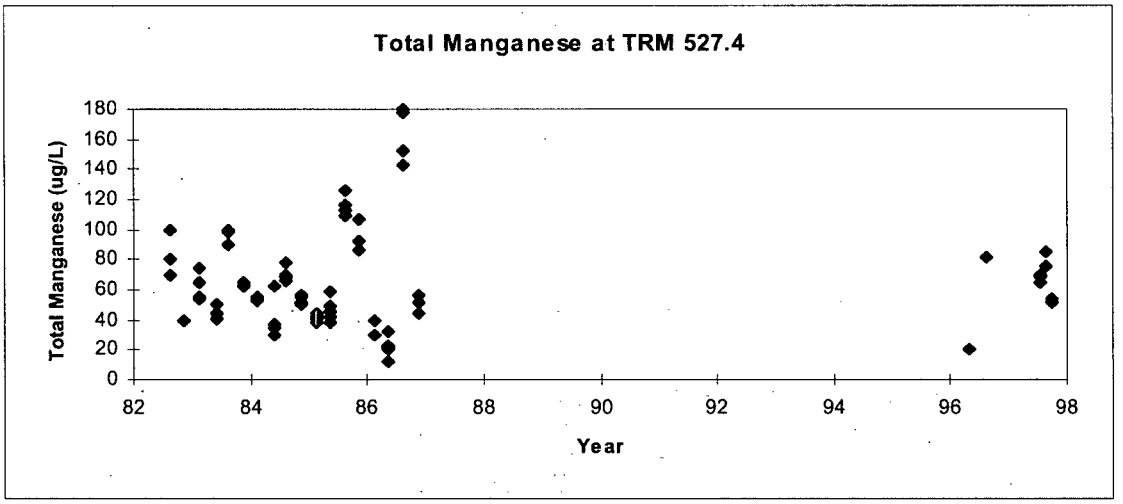

Total Copper at TRM 527.4
Total Copper (ug/L)
90
80
70
60
50
40
30
20
10
0
82
84
86
88
90
92
94
96
98
Year

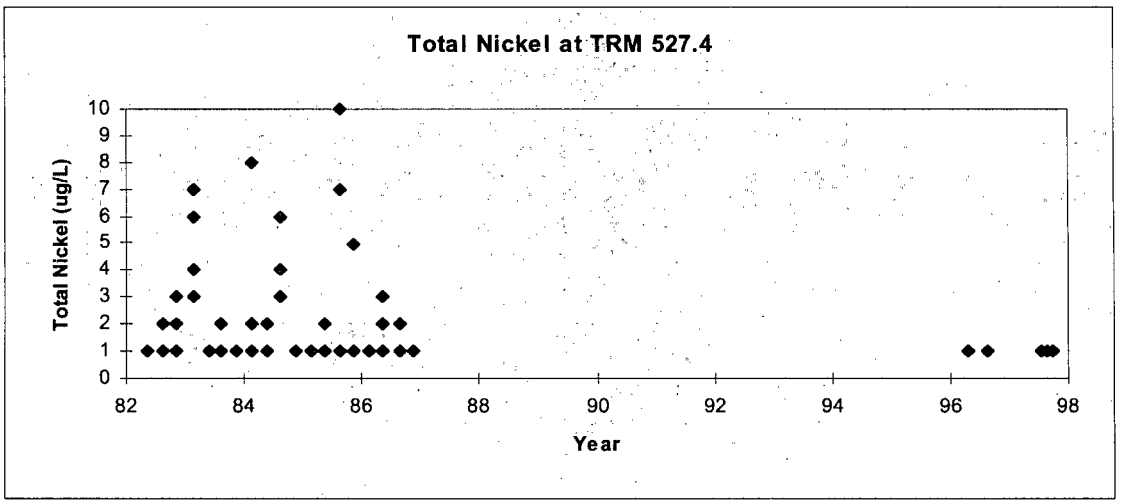

Total Iron at TRM 527.4
Total Iron (ug/L)
700
600
500
400
300
200
100
0
82
84
86
88
90
92
94
96
98
Year

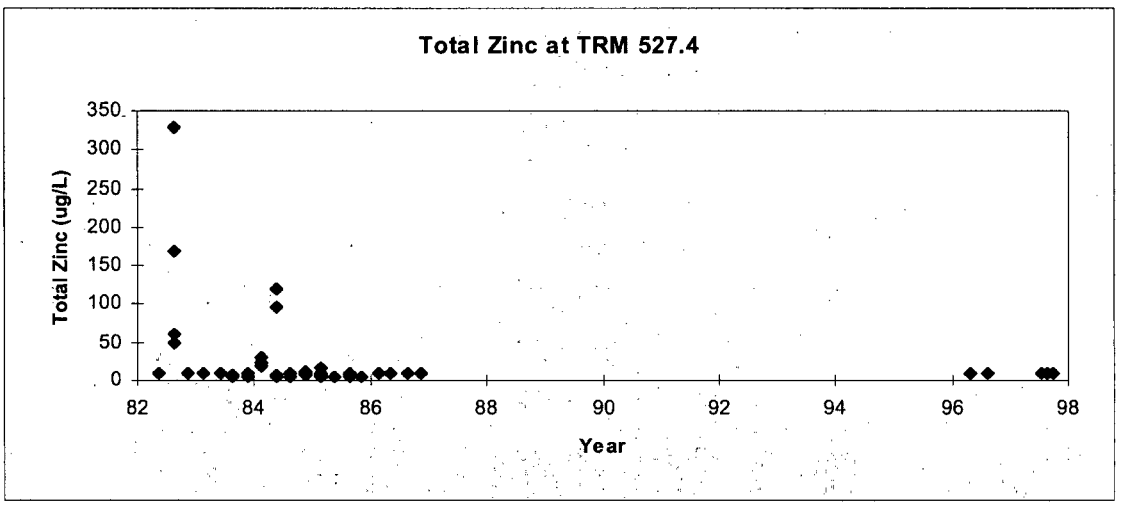

Total Lead at TRM 527.4
Total Lead (ug/L)
40
35
30
25
20
15
10
5
0
82
84
86
88
90
92
94
96
98
Year

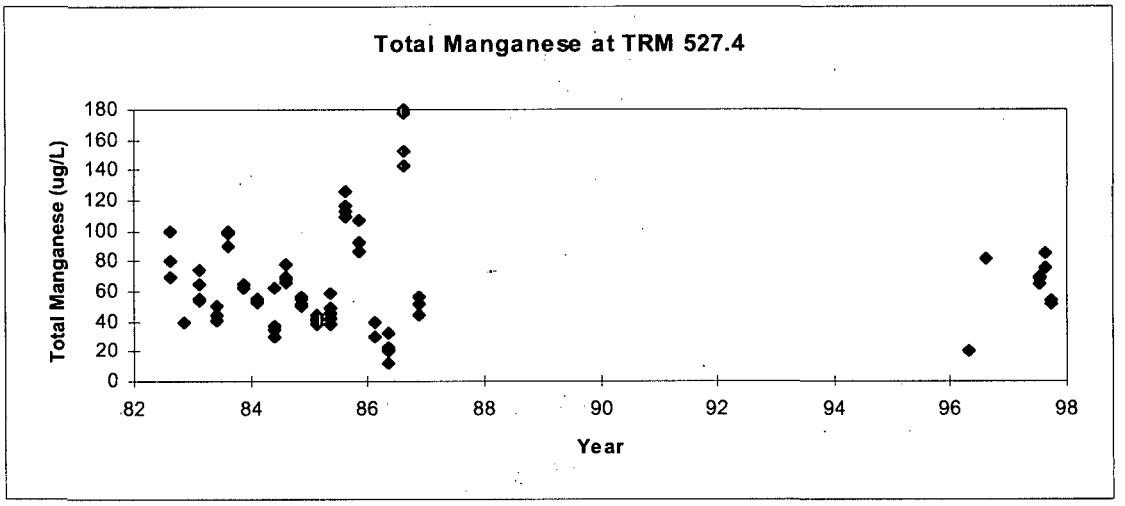

Total Copper at TRM 527.4
Total Copper (ug/L)
90
80
70
60
50
40
30
20
10
0
82
84
86
88
90
92
94
96
98
Year

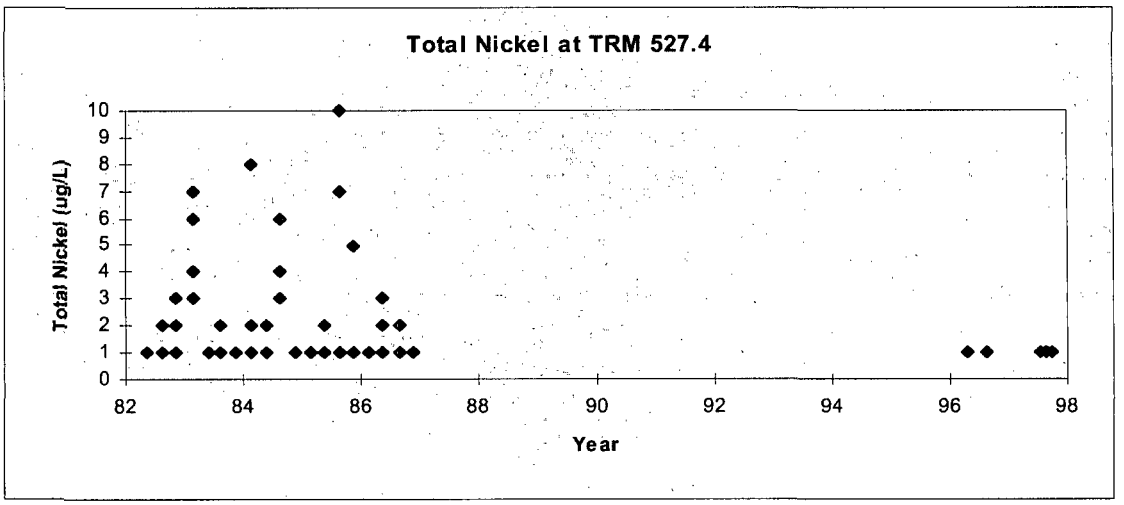
Appendix B-6 (Continued)

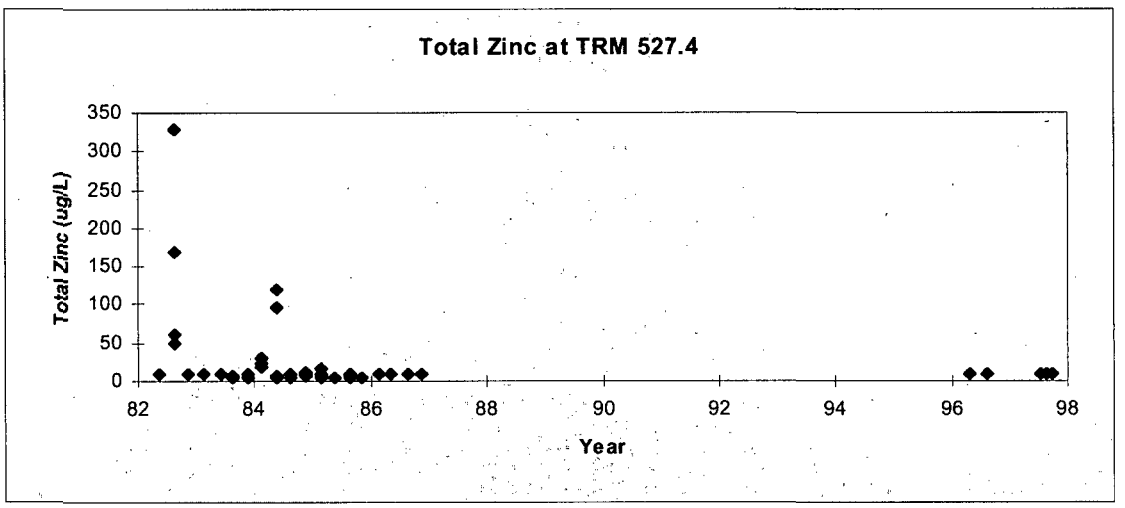

Total Manganese at TRM 527.4
Total Manganese (ug/L)
180
160
140
120
100
80
60
40
20
0
82
84
86
88
90
92
94
96
98
Year


Total Nickel at TRM 527.4
Total Nickel (ug/L)
10
9
8
7
6
5
4
3
2
1
0
82
84
86
88
90
92
94
96
98
Year

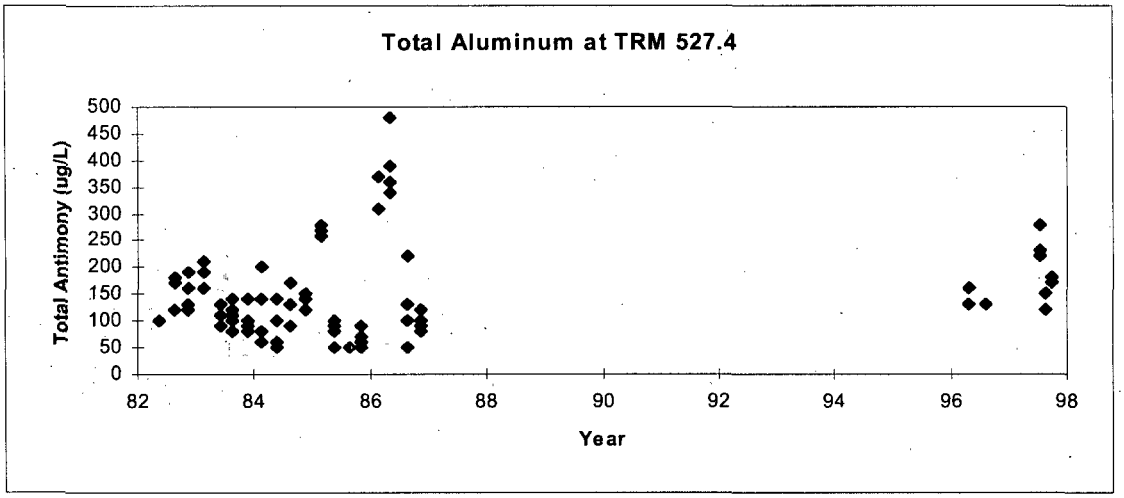

Total Zinc at TRM 527.4
Total Zinc (ug/L)
350
300
250
200
150
100
50
0
82
84
86
88
90
92
94
96
98
Year

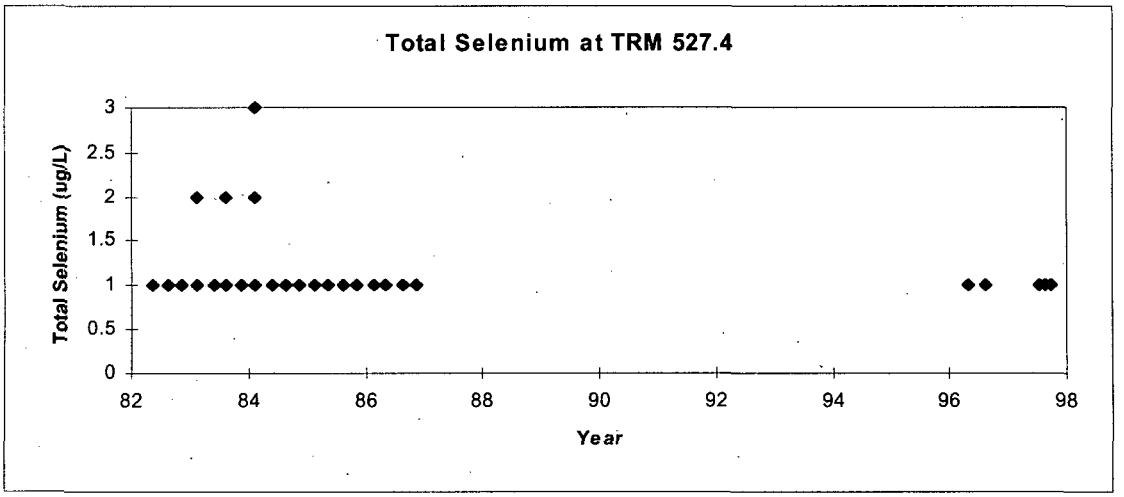


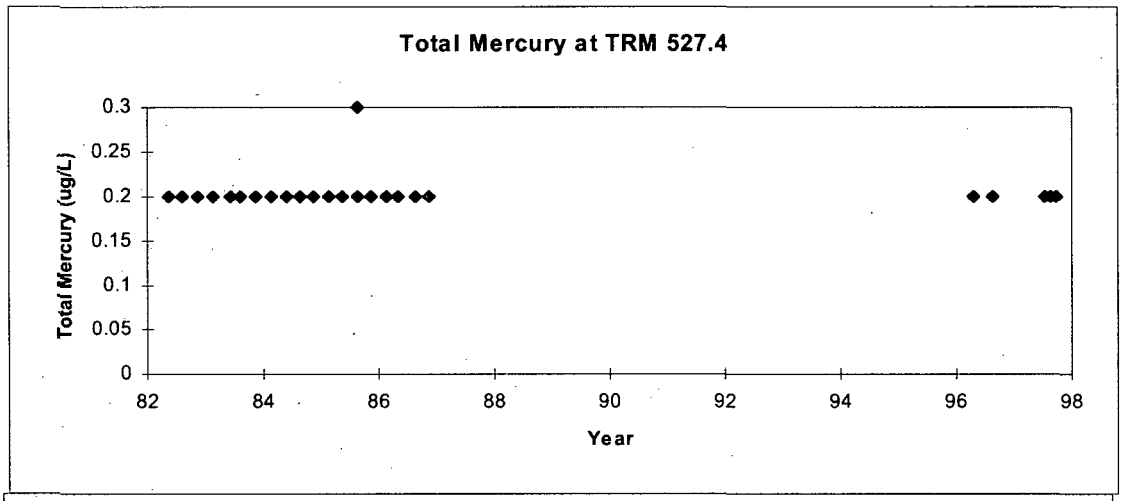


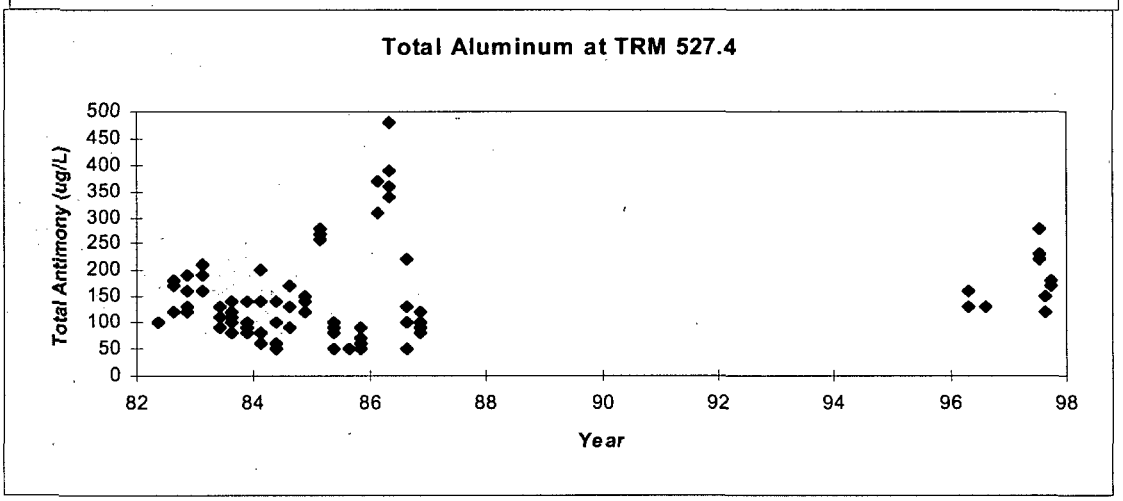


Appendix B-6 (Continued)

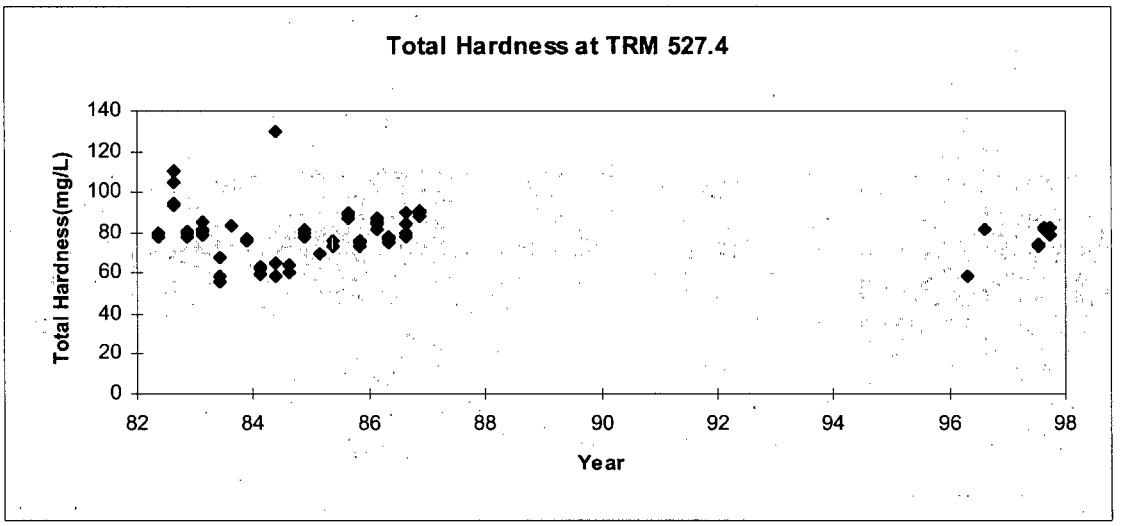

Total Aluminum at TRM 527.4
Total Antimony (ug/L)
500
450
400
350
300
250
200
150
100
50
0
82
84
86
88
90
92
94
96
98
Year


Total Selenium at TRM 527.4
Total Selenium (ug/L)
3
2.5
2
1.5
1
0.5
0
82
84
86
88
90
92
94
96
98
Year

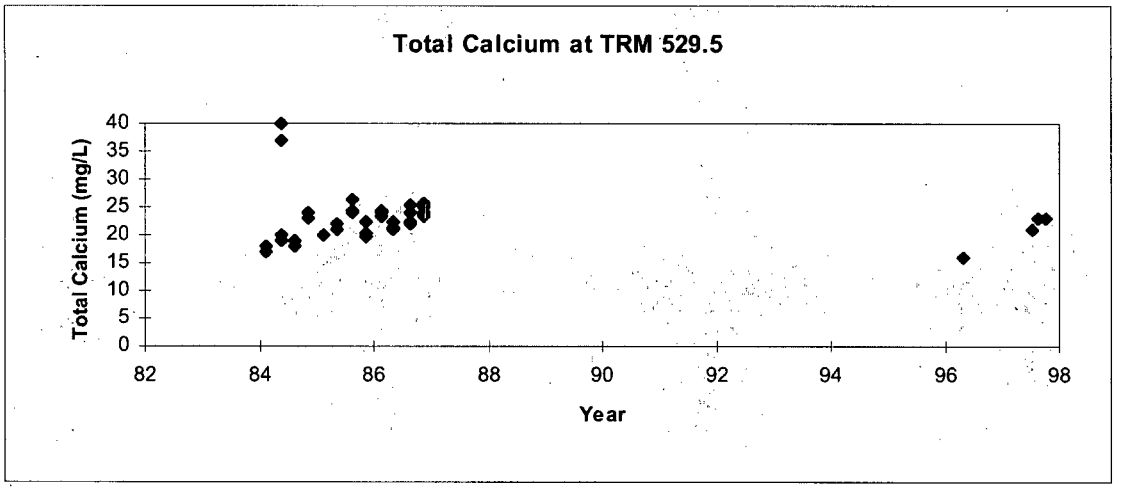

Total Mercury at TRM 527.4
Total Mercury (ug/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
82
84
86
88
90
92
94
96
98
Year

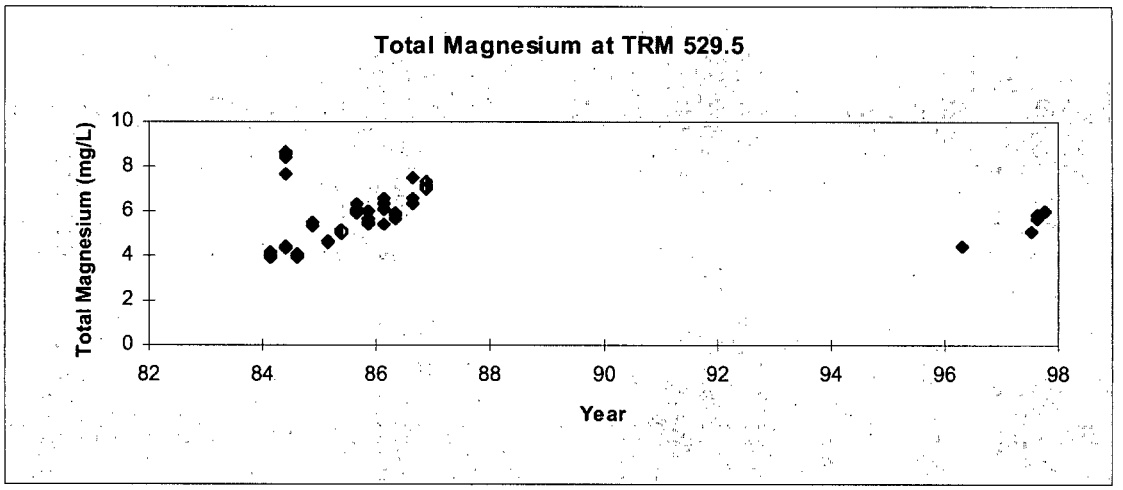

Total Aluminum at TRM 527.4
Total Antimony (ug/L)
500
450
400
350
300
250
200
150
100
50
0
82
84
86
88
90
92
94
96
98
Year

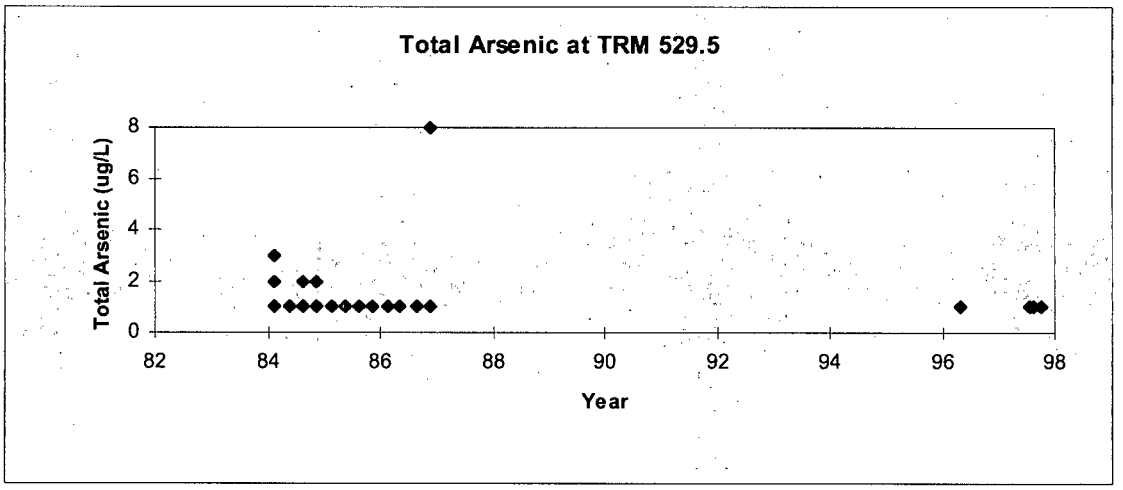
Appendix B-6 (Continued)

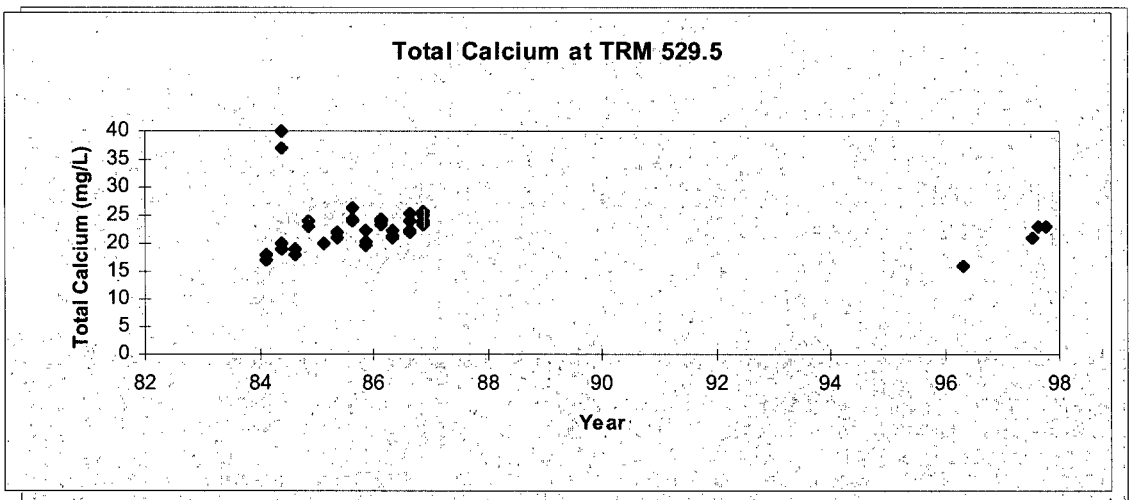


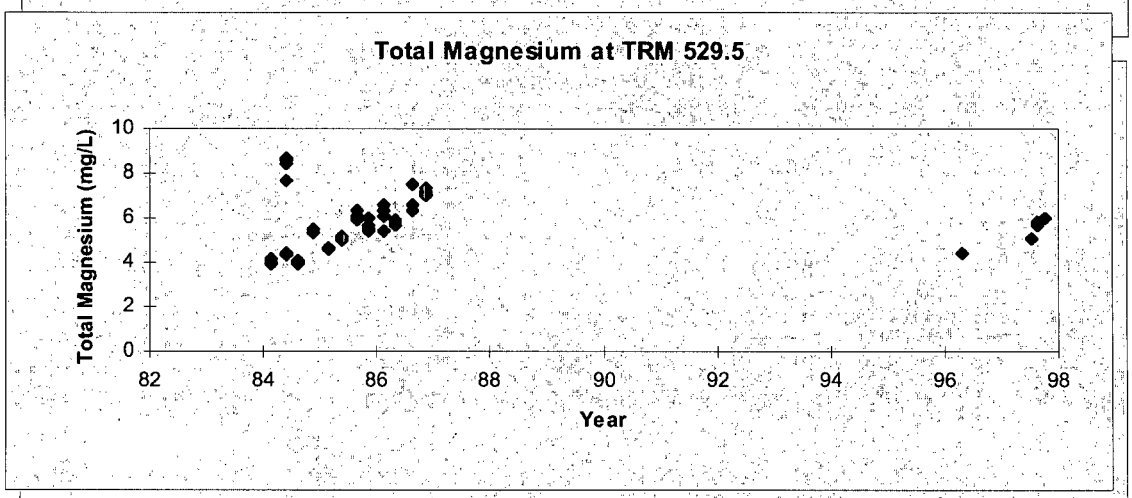
Appendix B-7. Concentrations of selected metals during preoperational (1984-1987) and operational (1996-1997) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 529.5



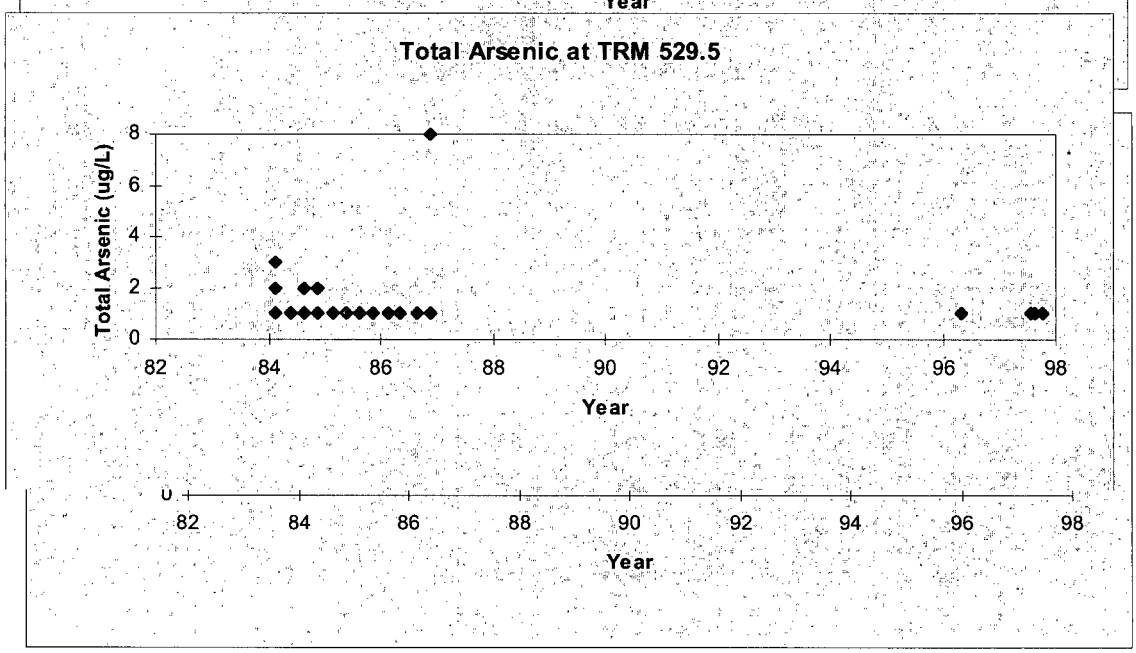




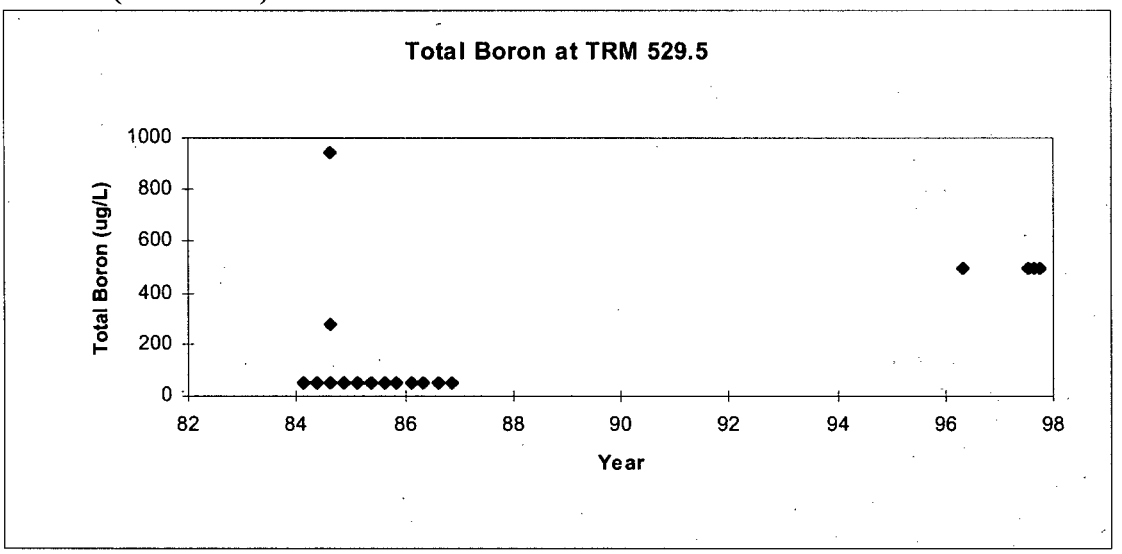

Total Calcium at TRM 529.5
Total Calcium (mg/L)
40
35
30
25
20
15
10
5
0
82
84
86
88
90
92
94
96
98
Year

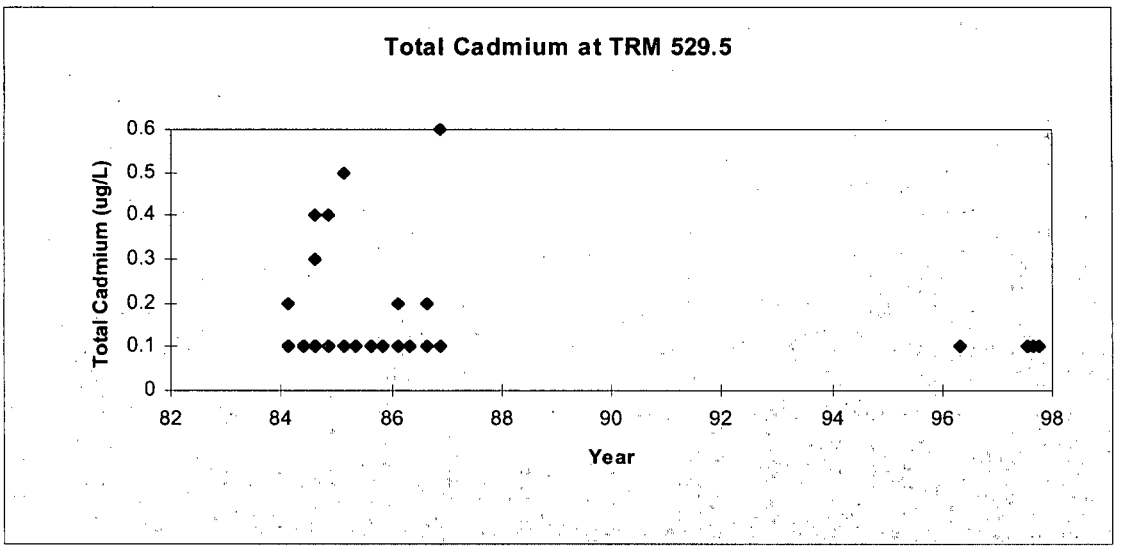

Total Magnesium at TRM 529.5
Total Magnesium (mg/L)
10
8
6
4
2
0
82
84
86
88
90
92
94
96
98
Year

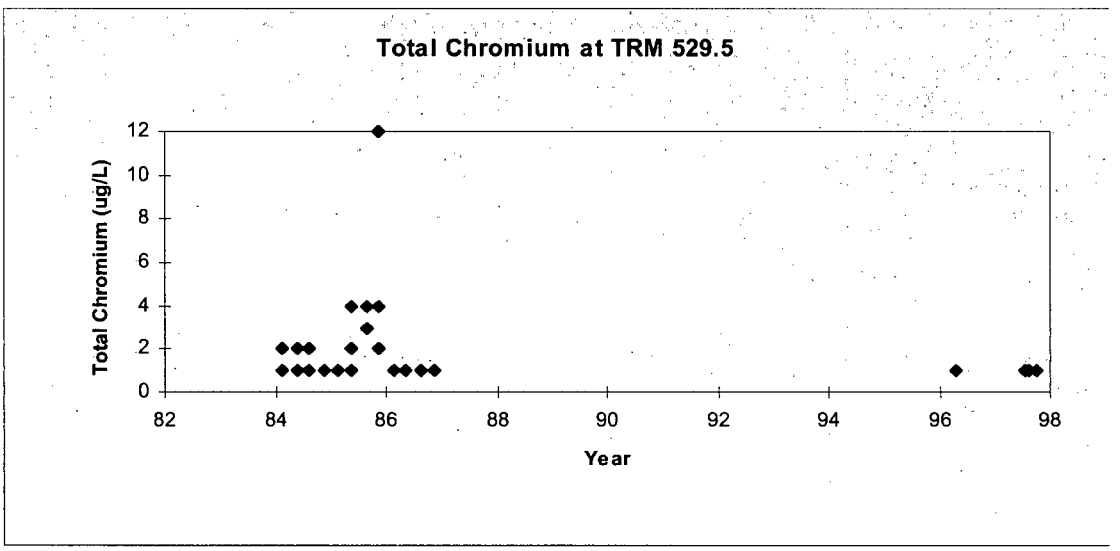
Year


Total Arsenic at TRM 529.5
Total Arsenic (ug/L)
8
6
4
2
0
82
84
86
88
90
92
94
96
98
Year

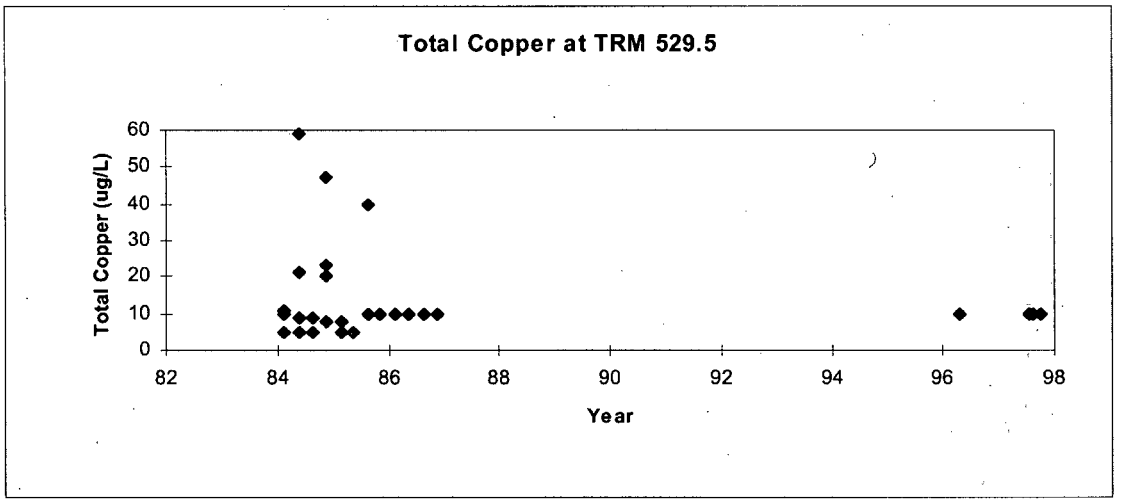
Appendix B-7 (Continued)

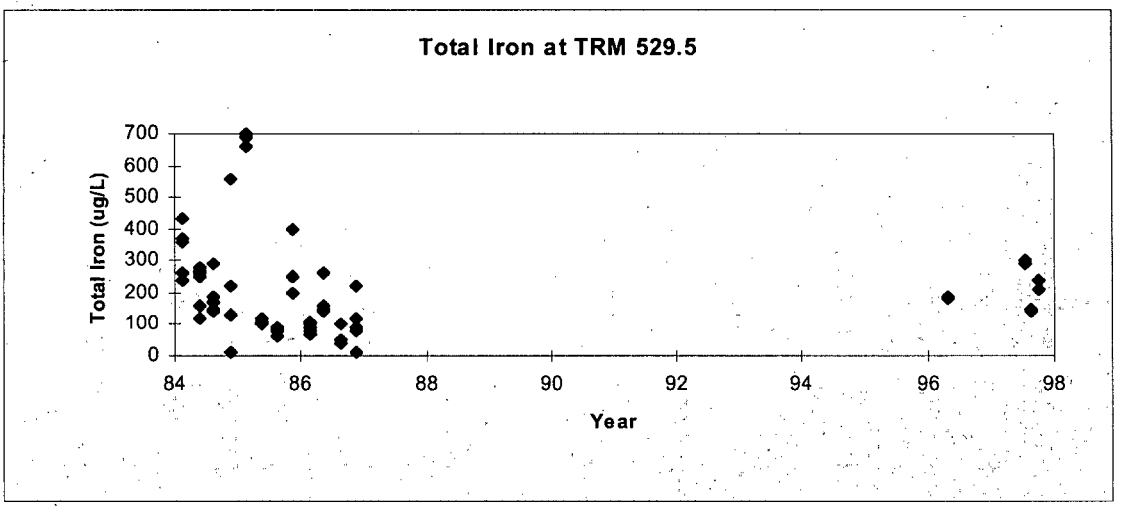


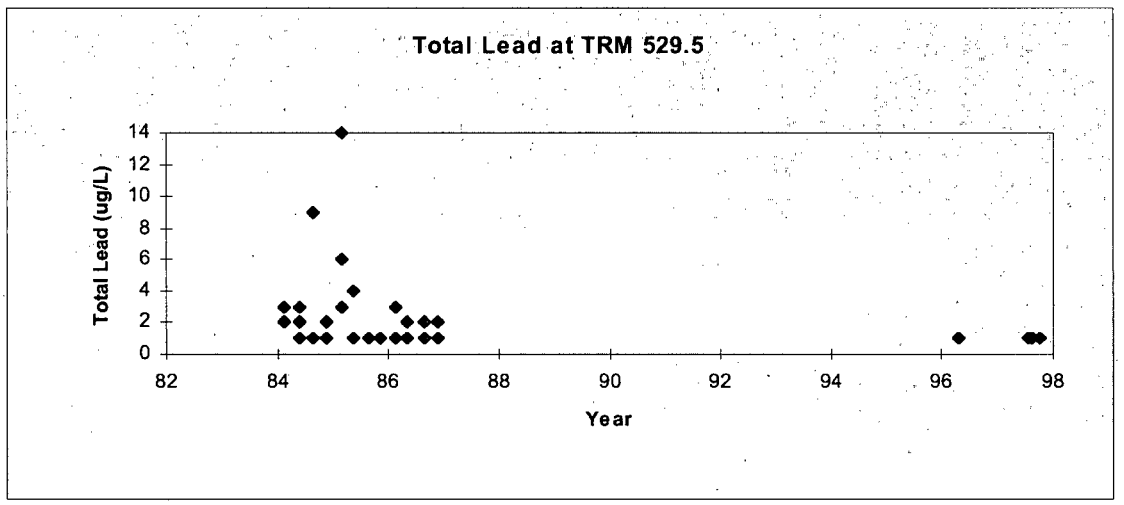


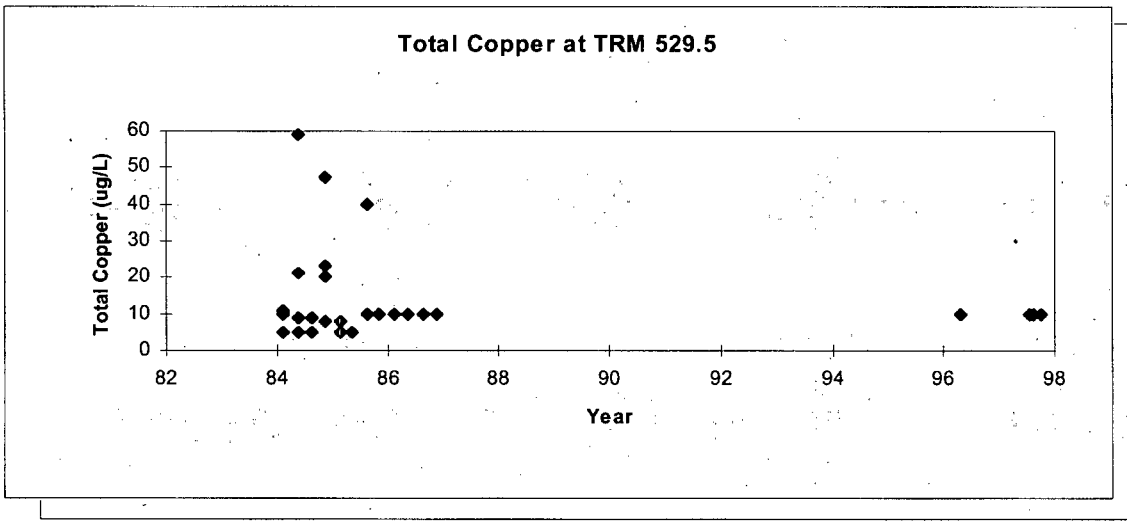


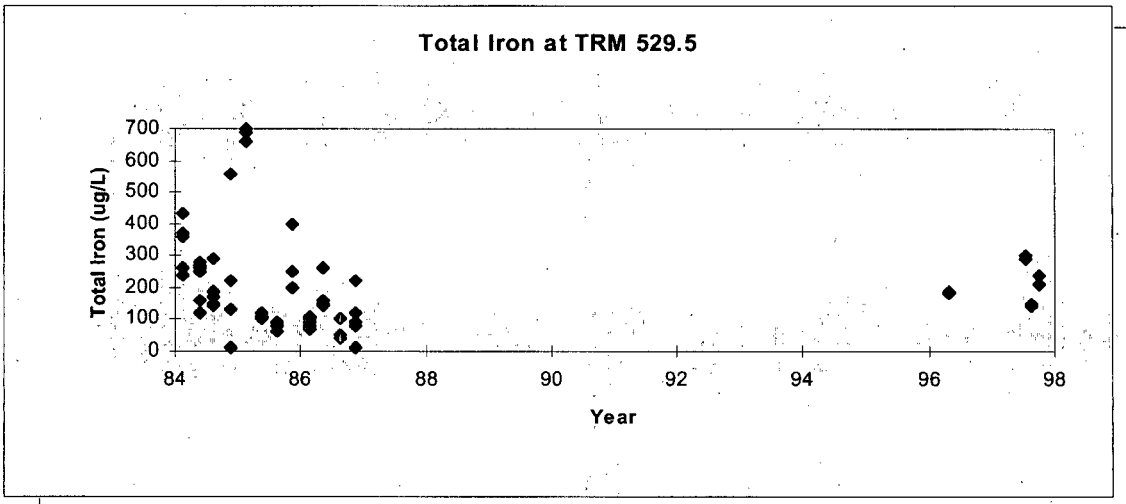
Appendix B-7 (Continued)

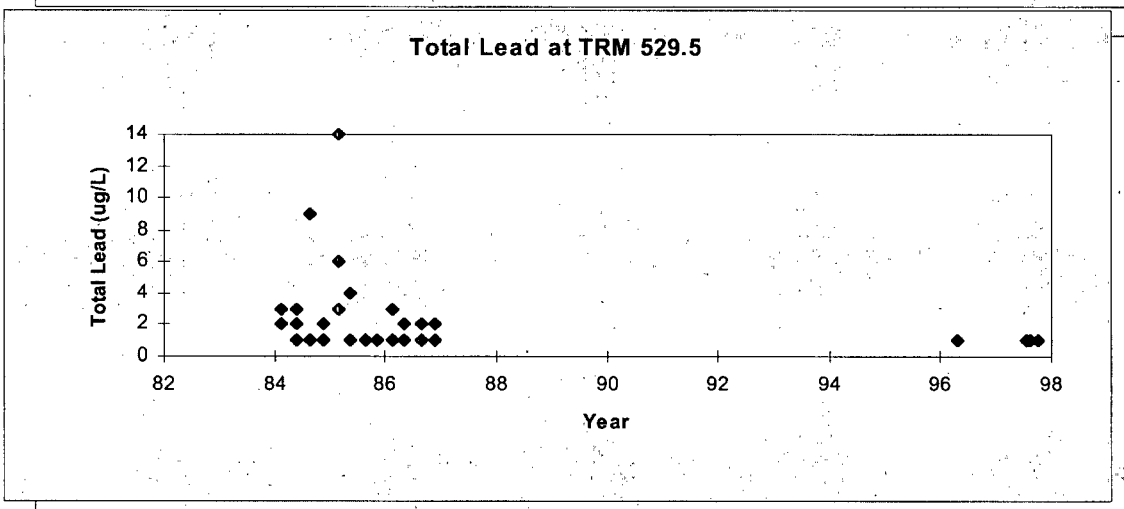




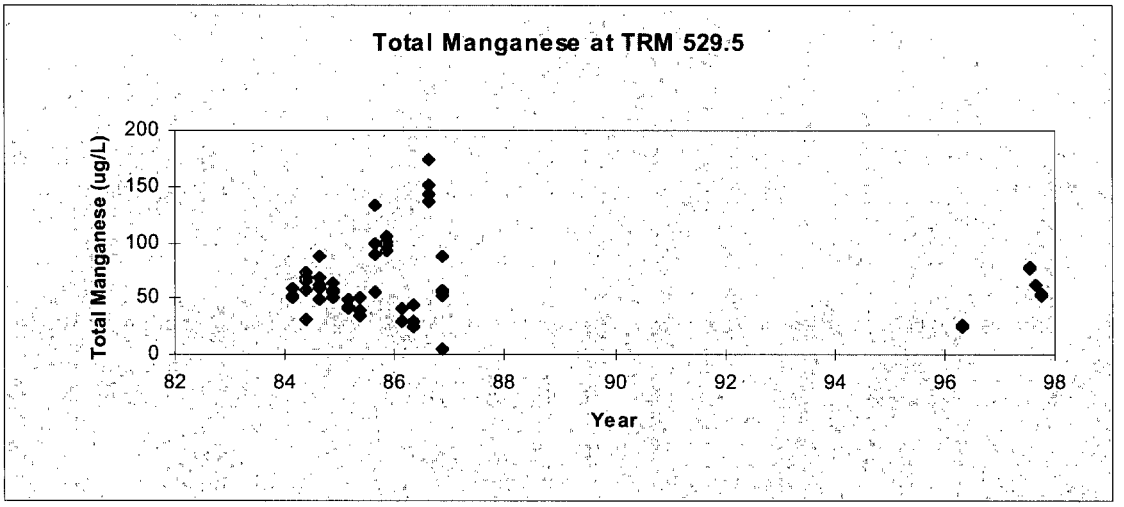


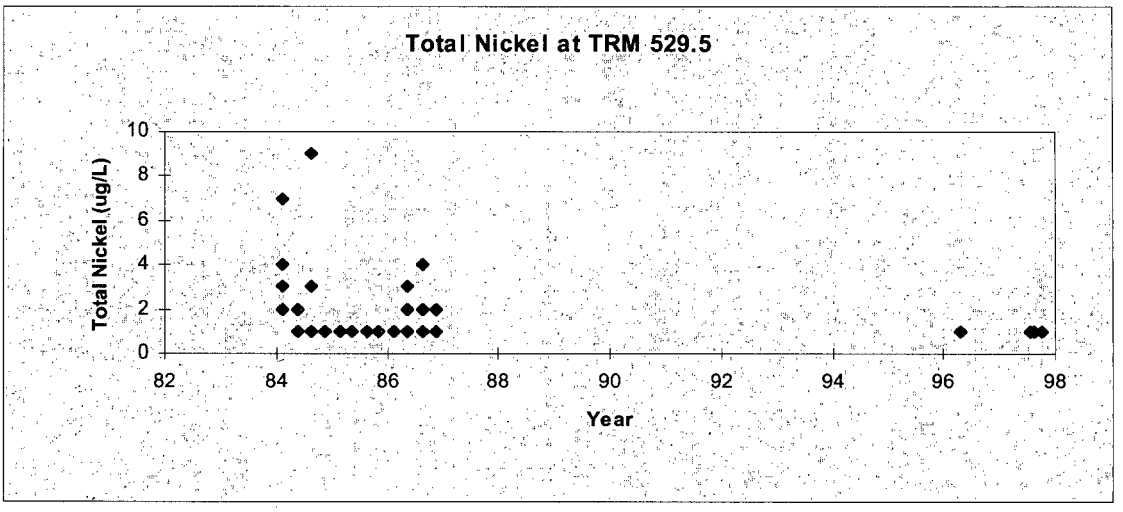

Total Copper at TRM 529.5
Total Copper (ug/L)
60
50
40
30
20
10
0
82
84
86
88
90
92
94
96
98
Year

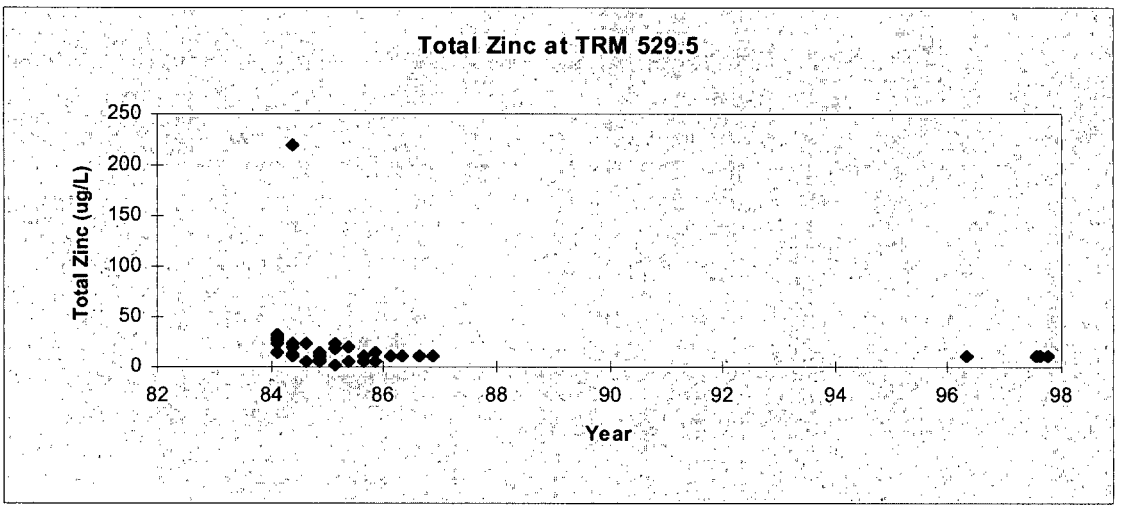

Total Iron at TRM 529.5
Total Iron (ug/L)
700
600
500
400
300
200
100
0
84
86
88
90
92
94
96
98
Year


Total Lead at TRM 529.5
Total Lead (ug/L)
14
12
10
8
6
4
2
0
82
84
86
88
90
92
94
96
98
Year

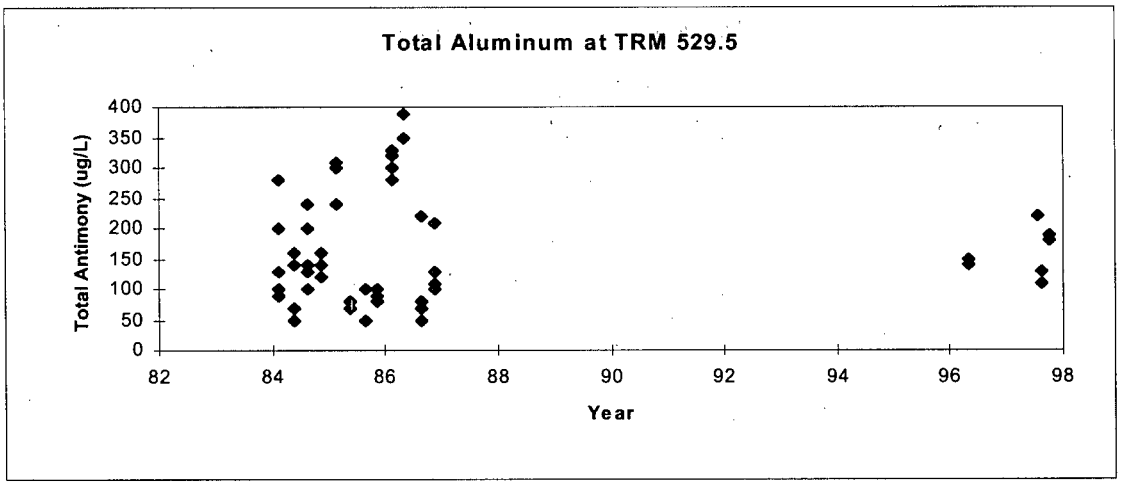
Appendix B-7 (Continued)

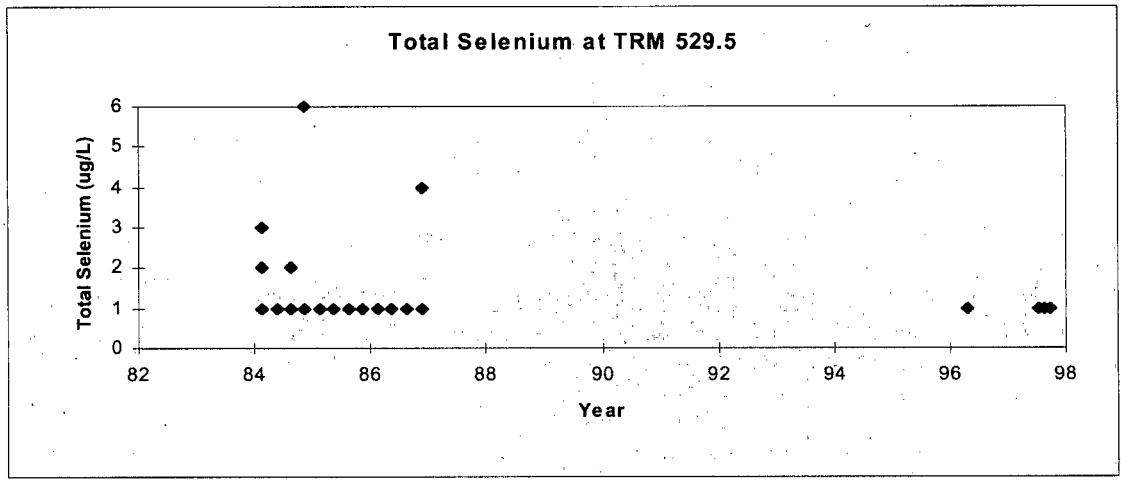


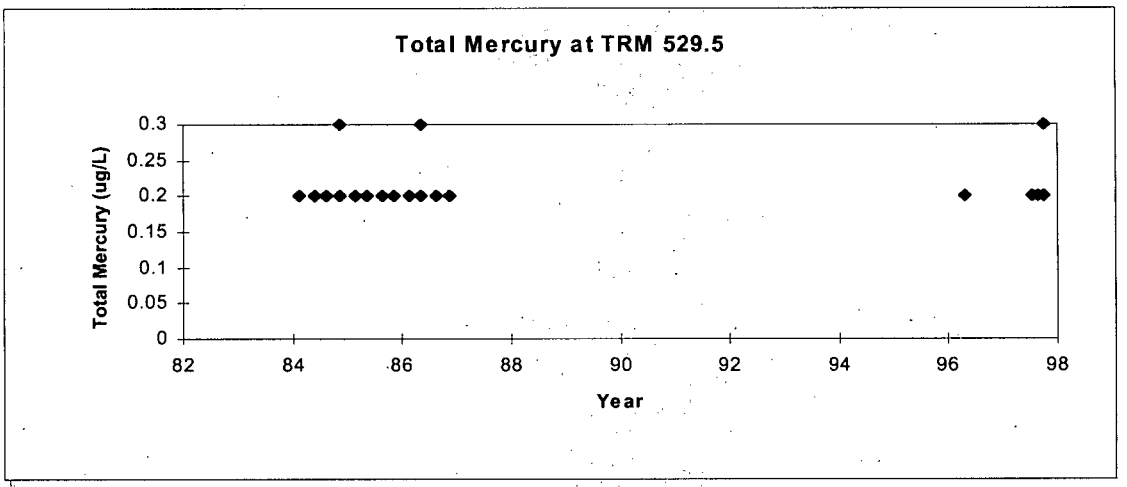


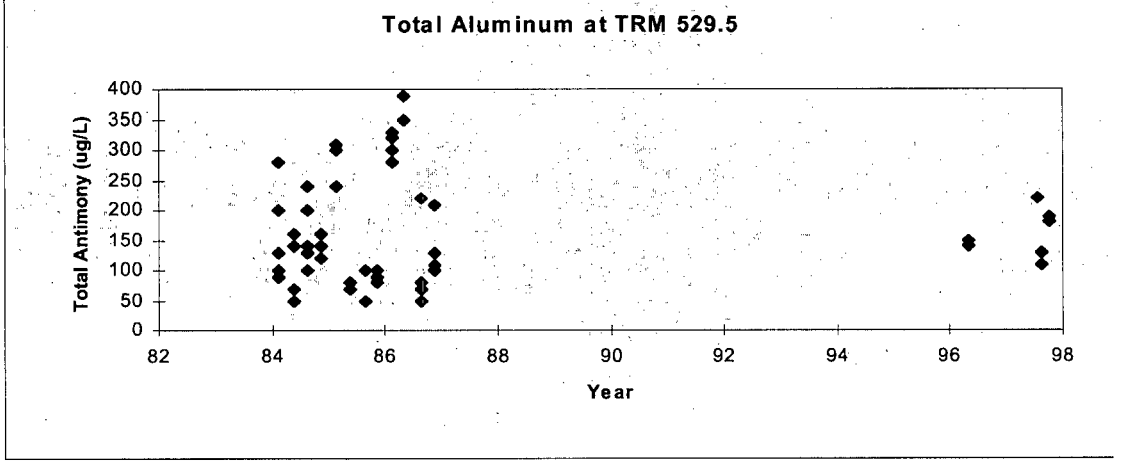


Appendix B-7 (Continued)



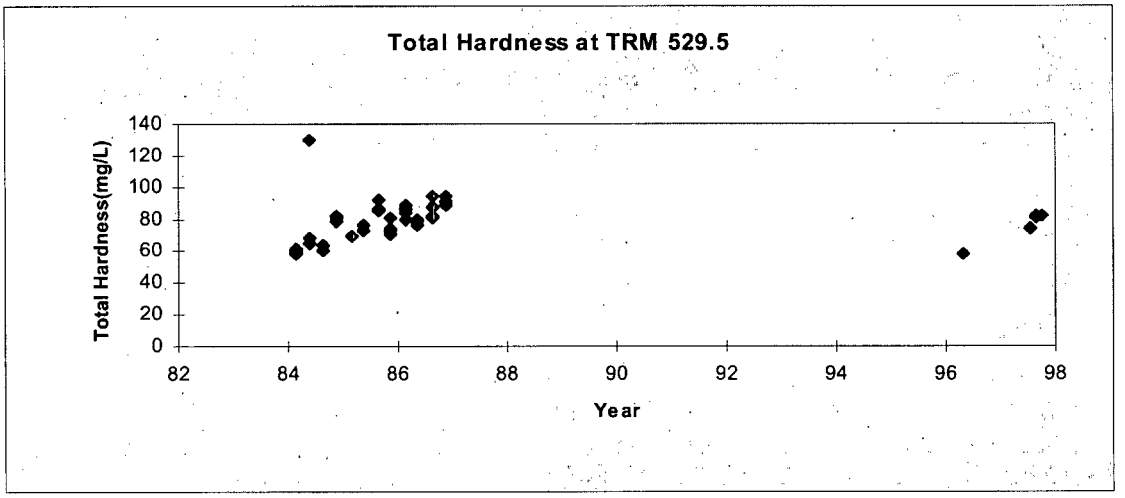


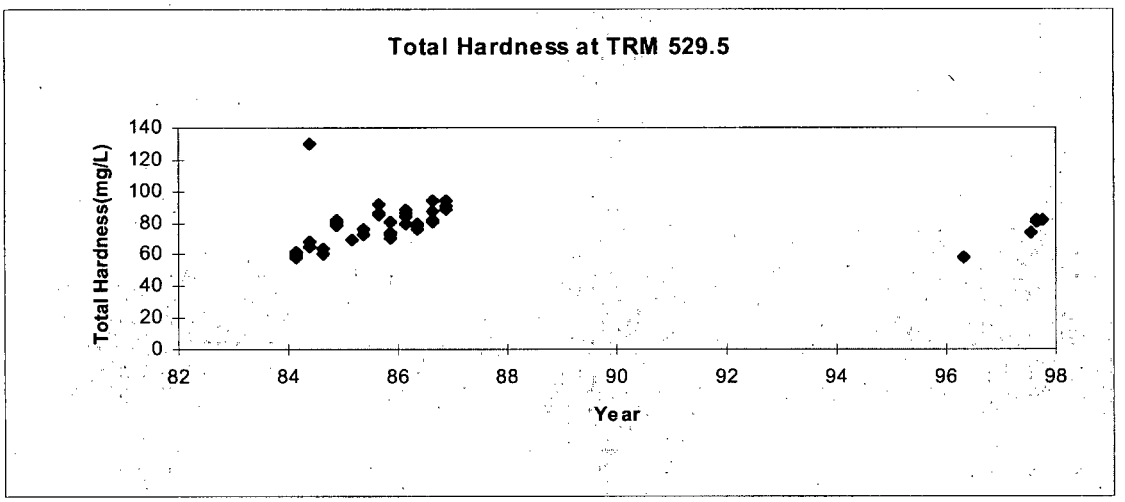




Total Selenium at TRM 529.5

Appendix B-7 (Continued)





Attachment 4

(Paper Copy and on Enclosed OSM)

Summary of Revised Computation for RAI H-11

WBN_U2_RAI_H-11_Intake_Pumping_Station_Velocity_Rev2.pdf

		PLANT WITHDRAWAL IMPACTS									
		Water Supplied by Intake Pumping Station (IPS)									
		ERCW			RCW			Approx Combined IPS inflow for all systems		Approx Average Velocity Through Net Open Area of Traveling Screens	
Number of Operating Units	Flow Condition	Number of Operating Pumps	Approx Combined Flow of Pumps		Number of Operating Pumps	Approx Combined Flow of Pumps					
Two	Normal Mode Operation	2	47.9 21,500 31.0	cfs gpm mgd	6	68.2 30,600 44.1	cfs gpm mgd	116.10 52,100 75.10	cfs gpm mgd	0.8	fps

Pump station total no. intake openings	4	
Pump station total no. ERCW pumps	8	
Pump station total no. RCW pumps	7	
Height of each intake opening	17.5	(ft)
Width of traveling screen panels for each intake opening	4	(ft)
Percent open area for screen panels (conveyance area efficiency)	50.3%	(%)
Approx open area of traveling screen for each intake opening	**35.21**	**(ft^2)**