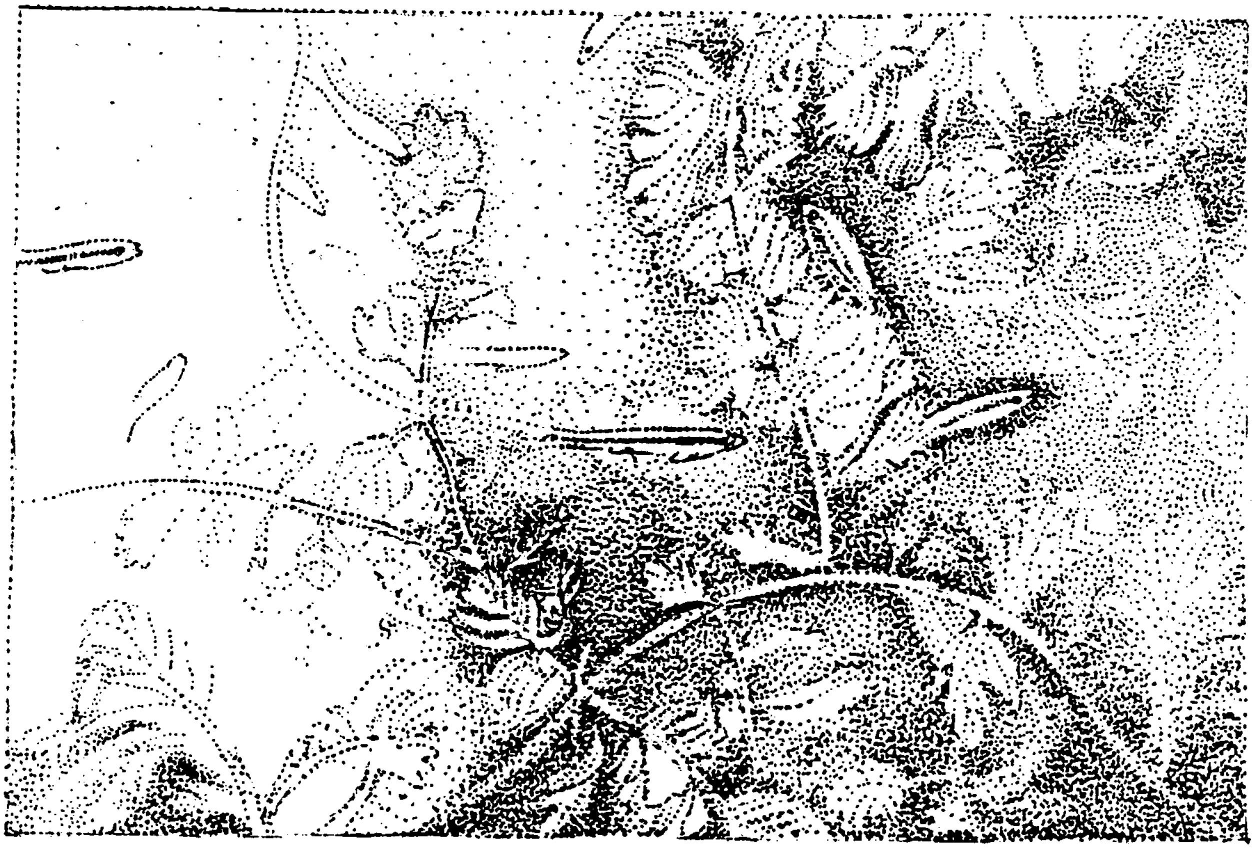
TENNESSEE VALLEY AUTHORITY
Water Management

The Effects of Aquatic Macrophytes on Fish Populations of Chickamauga Reservoir Coves, 1970-90



Water Management Services

Norris, Tennessee
September 1993

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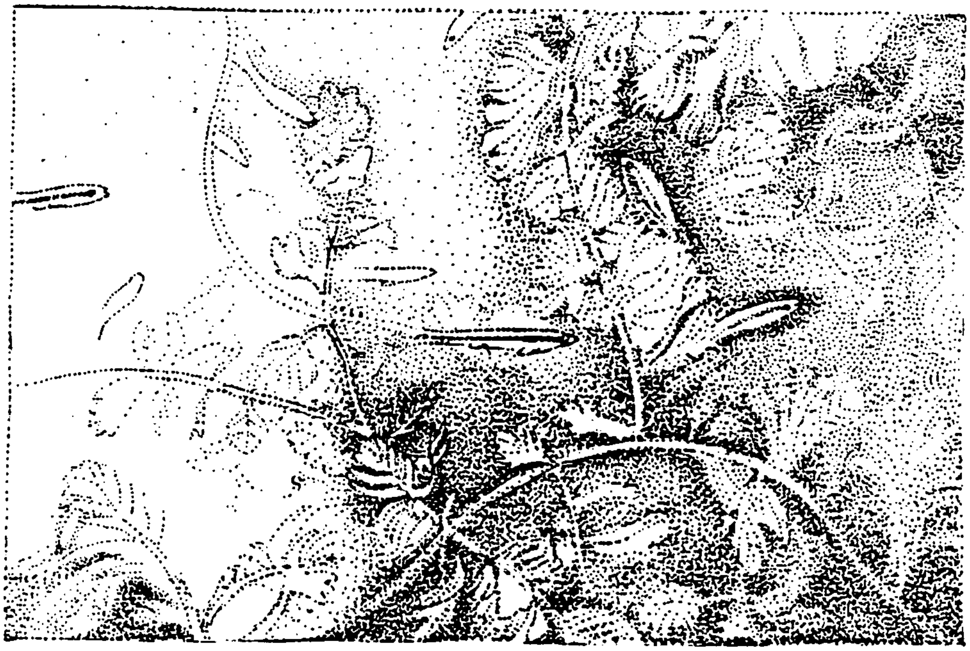

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EXECUTIVE SUMMARY

The expansion of submersed aquatic macrophytes in Chickamauga Reservoir had a dramatic effect on the resident fish community between 1970 and 1990. Although the original intent of studies upon which this report is based was to monitor the effects of a nuclear power plant on reservoir fish populations, an additional, unforeseen use of data arose when coverages of aquatic macrophytes expanded from less than 2 percent to 21 percent of the surface area of Chickamauga Reservoir during the study period. The primary purpose of this report is to investigate the relationship of submersed aquatic macrophyte coverage to the abundance of selected fish species in cove rotenone surveys. Species whose abundances significantly correlate with aquatic macrophyte coverage are discussed in detail according to the amount and dominant species of macrophyte present during four designated periods. A secondary purpose looks at the possibility of a relationship between the operation of Sequoyah Nuclear Plant (SQN) and the coverage of aquatic macrophytes in Chickamauga Reservoir.

During Period I (1970-75) aquatic macrophyte coverage in Chickamauga Reservoir was less than 100 hectares (ha). Macrophyte coverage increased greatly in Period II (1976-81) to nearly 2200 ha. Coverages of approximately 2800 ha existed during Period III (1982-88) which coincided with several drought years. Coverage of aquatic vegetation was negatively correlated to flows of the Tennessee River, and increased flows and associated factors (such as scouring and turbidity) during Period IV (1989-90) caused vegetation to decrease to approximately 1400 and 869 ha, respectively. This pattern continued in the 1991 and 1992 seasons when coverage dropped to 275 and 155 ha, respectively.

In the 1960s and 1970s the perennial Eurasian watermilfoil was the dominant species of submersed aquatic vegetation in Chickamauga Reservoir. Then annual species began to increase in abundance, especially spinyleaf naiad which became the most common submersed macrophyte in Chickamauga Reservoir during the 1980s.

Certain fish species became more abundant with increased vegetation coverage. Golden shiner, warmouth, bluegill, redear sunfish, brook silverside, yellow bass, black crappie, and yellow perch are mid-water insectivores which benefited from an increased invertebrate forage base and protective habitat provided by aquatic vegetation. As the forage base for piscivorous species shifted from shad to small sunfish during periods of heavy vegetation coverage, numbers of largemouth bass, an ambush predator, increased.

Other fish species declined in abundance as macrophytes increased. Most of them were open-water, benthic insectivores/omnivores whose feeding habitat in shallow, silted overbanks became colonized with vegetation. Species in this category are carp, smallmouth buffalo, spotted sucker, channel catfish, and freshwater drum. Decline of piscivorous adult white crappie has been attributed to several factors, most of which are directly related to the increase in macrophytes. Declining sauger populations, however, have been attributed to poor spawning success in the headwaters of Chickamauga Reservoir.

Based on preliminary analysis, milfoil appears more beneficial to several important gamefish species than spinyleaf naiad, possibly because of its different underwater growth form and structure.

The operation of SQN had no measurable effect on the coverage of macrophytes in Chickamauga Reservoir, and thus no indirect effects on resident fish populations.

INTRODUCTION

Macrophyte Effects on Chickamauga Reservoir Fish Populations

Monitoring studies of fish and aquatic macrophyte population trends in Chickamauga Reservoir, with respect to operation of SQN, found an overwhelming relationship of aquatic macrophytes and cove fish populations. This relationship developed over time, as aquatic macrophytes were relatively uncommon in the reservoir in the early years studied, became the purpose of this report. Temporal changes in the fish populations were evident in 1979 (TVA 1980), but were not attributed to aquatic vegetation until 1985 when significant (P>0.05) increases in abundance of certain species, particularly warmouth, redear sunfish, bluegill, and largemouth bass were detected (TVA 1985). At that time smallmouth buffalo, channel catfish, and freshwater drum showed significantly decreasing trends. A seven-fold increase in coverage of rooted aquatic macrophytes between 1976 and 1983 emerged as the overriding influence on the fish community of Chickamauga Reservoir (TVA 1985), and its alteration of the littoral zone habitat has continued to affect rotenone standing stock estimates of several fish species (McDonough and Buchanan 1991, Kerley 1989, 1990, and 1991). This report analyzes 21 consecutive years of fish sampling on Chickamauga Reservoir, spanning a broad range of aquatic macrophyte coverage.

Interpretations of fish community changes are more complex than simple correlations with amount of aquatic vegetation. Fish communities in reservoirs are not balanced (Noble 1986) and are subjected to highly variable water conditions (rate of spring warming, discharges, turbidity, water level fluctuation) which affect planktonic food chains, spawning times and success, and early survival of different fish species and interspecific competition between early life stages of fish species. Year class strength of some species depends on high spring discharges following gradual warming of water temperatures. Dissolved oxygen in deeper levels of reservoir such as Chickamauga Reservoir (TVA 1990b) may become limiting for coolwater species during years of low discharges. Aquatic vegetation provides foraging and protective habitat for young of many fish species, according to the size of individual fish.

Influence of Sequoyah Nuclear Plant (SQN) on Aquatic Macrophytes

SQN commenced operation in 1981, the first of eight consecutive years during which Chickamauga Reservoir aquatic macrophyte coverages exceeded 2,000 ha. The existence of SQN as a readily visible factor during these years of macrophyte expansion prompted an examination for any evidence of a connection between SQN operation and macrophyte coverage patterns.

History of Aquatic Macrophytes in Chickamauga Reservoir

Chickamauga Reservoir was created in 1940 with the completion of Chickamauga Dam at Tennessee River mile (TRM) 471. Rooted submersed aquatic macrophytic vegetation was not abundant until the establishment of Eurasian watermilfoil (Myriophyllum spicatum) in 1961 (Smith et al. 1967). Milfoil is an exotic plant that was introduced from an aquarium into Watts Bar Reservoir, the next reservoir upstream, about 1953. From its establishment in Chickamauga Reservoir until the mid-1970s milfoil was the only abundant submersed aquatic macrophyte within the reservoir. While milfoil coverage expanded in most mainstream Tennessee River reservoirs between 1970 and 1985, spinyleaf naiad (Najas minor), another exotic species, became the dominant species of vegetation in Chickamauga Reservoir in 1982 (Bates et al. 1985). It continued to be more abundant than milfoil until 1989 when there was a major decline in naiad coverage (Figure 1). Annual coverage of spinyleaf naiad (in combination with southern naiad, N. guadalupensis) and milfoil have fluctuated greatly over time. Hydrilla (Hydrilla verticillata) was found on Chickamauga Reservoir in 1988 (Burns et al. 1989), but has been rarely observed in recent years since treatment with herbicides (Lee Hill, TVA, personal communication).

As milfoil coverage expanded and colonized shallow water habitat along developed shorelines, the Tennessee Valley Authority (TVA) designated priority areas (Figure 2) for herbicide treatment. In addition to the application of herbicides such as 2,4-D to control milfoil and Aquathol K to control naiads, other management techniques currently in use include drawdowns and reservoir surcharge. Milfoil is vulnerable to winter drawdowns because it is a perennial, and its exposed root masses are subjected to lethal winter temperatures. The naiads, which are annuals have seeds which are less affected by dewatering. Winter drawdowns are particularly effective in controlling milfoil within the drawdown zone of Chickamauga Reservoir, relative to other TVA mainstream reservoirs, because the magnitude of the drawdown is greater, over 2.5 m, thereby exposing large areas with milfoil colonies.

Total macrophyte coverage (all species combined) in Chickamauga Reservoir has been dynamic over the past 15 years. Coverage increased from less than 20 ha in 1974 to about 300 ha in 1976. Between 1977 and

1983, total coverage of aquatic macrophytes increased seven fold (422 to 2,791 ha) and colonized 19 percent of the surface area of Chickamauga Reservoir. During this period, spinyleaf naiad became the dominant submersed species of aquatic vegetation. Submersed aquatic vegetation declined in 1984 (2,161 ha) due to record heavy rains in May, and high flows and increased turbidities, which suppressed growth of deep water colonies (TVA 1985). Aquatic macrophytes in Chickamauga Reservoir reached their greatest abundance during the drought years of 1985-88, averaging over 2,700 ha annually, as clearer water allowed naiads and other macrophytes to grow in deeper water. Peak abundance occurred in 1988, when over 3,000 ha or 21 percent of the total surface area of Chickamauga Reservoir, was colonized. As more normal rainfall patterns returned to the Tennessee Valley in 1989 and 1990, coupled with unusually high flows in June and July 1989, submersed aquatic vegetation dramatically decreased (Burns et al. 1991) to about 1,400 and 900 ha, respectively. High seasonal flows continued in 1991 and 1992, and submersed macrophytes declined to 275 ha in 1991 (Burns et al. 1992) and 155 ha in 1992 (Lee Hill, TVA, personal communication).

Macrophyte Management Plan for Chickamauga Reservoir

The TVA management plan for controlling aquatic macrophytes in Chickamauga Reservoir (Burns et al. 1992) does not attempt the total eradication of aquatic vegetation. Instead the intent is to control vegetation in priority areas: i.e., high-use recreation and public access areas, areas adjacent to residences, resorts, and marinas, small areas of exotic plant colonies in newly colonized reservoirs that could become major problems, and areas of dense vegetation that harbor mosquito populations. Approximately 3 percent of the surface area of Chickamauga Reservoir is designated for herbicide treatment if vegetation is excessive. During recent drought years (1985-88), when vegetation coverages exceeded 3,000 ha, about 650 ha-treatments were were made with herbicides annually. Although some of these areas during good growth periods received 2 or 3 treatments during the growing season, the physical areas treated did not exceed 3 percent of the total reservoir surface. Treatment has been reduced along with a natural decline of vegetation in 1989 and 1990, and only 130 ha (cumulative) were treated in 1990 (Burns et al. 1991). The downward trend in vegetation continued in 1991 and 1992, and treatment was reduced to 26 ha in 1992 (David Webb, TVA, personal communication).

Role of Macrophytes in the Aquatic Ecosystem

The literature is rich with information regarding the role of aquatic macrophytes in aquatic ecosystems. To quote John Muir, "When one tugs at a single thing in nature, he finds it attached to everything else in the world." So it seems with aquatic macrophytes. The complex morphology of aquatic macrophytes creates a diversity of microhabitats for colonizing organisms (from epiphytic algae and invertebrates to zooplankton to benthic macroinvertebrates to young and/or small fishes, as well as adult fish of some species) and provides refuge from predators (Miller et al. 1989). Macrophytes also modify the physical environment by directly or indirectly affecting the chemical composition, nutrient cycles, and biological features of the ecosystem. Published literature reporting importance and impacts of macrophytes have been reviewed by Gregg and Rose (1982), McDermid and Naiman (1983), Pandit (1984), Engel (1985, 1988), and Carpenter and Lodge (1986).

Aquatic macrophytes alter the velocity of waves and currents, modify sedimentation patterns and substrates, stabilize habitats, reduce erosion, affect temperature regimes, and influence available light. Macrophytes store nutrients during spring and early summer, thereby delaying blooms of blue-green algae until the macrophytes senesce in midsummer (Engel 1985). Macrophyte beds, by intercepting runoff, storing nutrients, and retarding algal blooms, can improve water quality (Goulder 1969, Modlin 1970, according to Engel 1985).

Diel variation in photosynthetic and respiration rates within macrophyte beds can cause depletion of oxygen and dissolved inorganic carbon and change pH. Oxygen depletion may be severe in morning hours following night respiration (Losee and Wetzel 1988). During summer when aquatic macrophyte biomass is greatest, diel ranges of dissolved oxygen and pH in a Missouri reservoir were as wide as 14 mg/l and 3 pH units, respectively (Wiley and Jones 1987). Daytime DO concentrations were 230 percent greater near macrophyte beds than no-plant zones (Sculthorpe 1967, according to Miller et al. 1989). Submersed macrophytes are important in maintaining chemical equilibria of the carbon dioxide-bicarbonate buffering system of the surrounding water mass.

Sediment-water interactions of aquatic macrophytes greatly influence the hydrochemistry and nutrient cycles in aquatic ecosystems. Nutrients are absorbed from the sediments by rooted species of plants and released back into the water during senescence, providing a nutrient resource for phytoplankton (Miller et al. 1989).

Aquatic macrophytes greatly increase habitat available to aquatic invertebrates. Submersed macrophytes provided nearly 10 times more surface area for invertebrate colonization than did the entire benthic area of Lawrence Lake, MI (Losee and Wetzel 1988). Macrophytes support complex interactions of invertebrate behavior, life cycles, and predator-prey relationships. The most common invertebrate organisms in macrophyte beds are crustaceans, chironomids, oligochaetes, and gastropods, with the majority being herbivores such as scrapers, shredders, filterers, and collectors. Less common are predators represented by Coleopterans (beetles), Odonates (dragonflies and damselflies), and Hemipterans (giant water bugs, backswimmers, water scorpions, and water boatmen) (Miller et al. 1989). Core samples indicated more benthic invertebrates below macrophytes than areas devoid of macrophytes.

Significant differences have been documented in the macroinvertebrate communities associated with Eurasian watermilfoil and open littoral habitats of the mainstream Tennessee River (Pardue and Webb 1985). Greater numbers of taxa and individual organisms occurred in dense beds of watermilfoil. Immature insects, amphipods, naidid worms, and leeches were more abundant in the milfoil than in open water areas. A non-burrowing mayfly, <u>Caenis</u>, an important fish food organism, was more abundant in the milfoil, probably due to the increased surface area provided by the highly dissected leaves of watermilfoil as well as the protection from predation afforded by the vegetation. However, a burrowing mayfly, *Hexagenia bilineata*, a highly important fish food organism, preferred the open littoral zone, presumably because the milfoil root system interferes with the ability of the mayfly nymphs to establish burrows.

Larval fishes are typically more abundant in submersed aquatic macrophyte beds than open water areas (Paller 1987), using them as a refuge from predators and feeding on associated zooplankton (Healey 1984). In Orange Lake, Florida, the greatest number of larval fish species was captured in floating-emergent vegetation, which was also important as a nursery area for juveniles of many species (Conrow et al. 1990). In Spirit Lake, Iowa, 17 of 21 YOY species studied were more abundant along vegetated shorelines than adjacent areas devoid of vegetation (Bryan 1989).

Macrophyte beds support higher densities of fish than areas without macrophytes (Borawa et al. 1979, Killgore 1979, Savitz 1981). Largemouth bass and bluegill behavior differs in lakes with and without aquatic macrophytes (Savitz et al. 1983). Small fishes (less than 120 mm long) find shelter in macrophyte beds denser than 200 g dry weight/m^2, while movement of larger fish is restricted (Hall and Werner 1977, Engel 1985, Mittlebach 1988). Small bass and bluegills avoid no-plant zones along shore, while larger individuals inhabit lower density macrophyte beds offshore (Engel 1985). Juvenile bluegill and longear sunfish numbers were positively correlated with the height of vegetation, and largemouth bass and other game species were more abundant in beds of hydrilla in shallow water than open water areas (Killgore 1979).

METHODS

Aquatic macrophyte coverage has been quantified annually since 1978 using aerial photography. Overflights were conducted in September or October. Aquatic macrophyte colonies were identified to species or dominant species combinations, delineated during photointerpretation, and area of coverage determined by planimetry (TVA 1985). Macrophyte coverages before 1977 were estimated from herbicide treatment records and by visual inspection (Leon Bates and David Webb, TVA, Water Management, Muscle Shoals, Alabama).

Relationships of vegetation coverage with average daily discharge from Chickamauga Reservoir, mean water temperature, percentage of possible sunshine, and the previous year's vegetation coverage were analyzed by linear regression (SAS Institute, 1985) for the period 1971-92. Daily discharges at Chickamauga Dam, water temperatures (1.5 m depth) at the SQN intake (TRM 484.7), phytoplankton densities and secchi readings near SQN, and sunlight availability at the Chattanooga airport (National Oceanic and Atmospheric Administration, Climatic Data Center, Asheville, North Carolina) were averaged for each year during the first four months of the growing season (March - June), which is the critical period for growth of submersed aquatic vegetation (David Webb and Leon Bates, TVA, personal communication).

Aquatic macrophyte coverage for Chickamauga Reservoir and management units 1, 3, 5, and 8 (Figure 3) was used to evaluate impacts of SQN operation on submersed aquatic vegetation. Coverage data were obtained from seasonal workplans of TVA's aquatic plant management program. Trends upstream of SQN were from units 5 and 8, and those downstream from units 1 and 3.

Fish community trend analysis was based on twenty-one consecutive years (1970-90) of cove rotenone surveys conducted in the lower and middle areas of Chickamauga Reservoir (Figure 2), following standardized methods (TVA 1980). The four coves sampled were Gold Point (TRM 476.2R), Chigger Point (TRM 478.0L), Sale Creek (TRM 495.0R/TRM 495.1R), and Gillespie Bend (TRM 508.0R). Log transformed standing stock estimates (number +1/ha) were analyzed by linear regression to determine correlations of submersed aquatic vegetation coverage with total and individual fish species abundances for three size groups. Significant trends, determined at the 0.05 alpha level, were discussed in the text. Trends in total fish biomass were also evaluated by regression analysis. Although the rotenone coves were sprayed with herbicides beginning in 1982 to facilitate the retrieval of fish, vegetation in areas adjacent to the coves was not treated.

Cove rotenone surveys are biased toward fish species inhabiting shallow shoreline areas. Common shoreline species in Chickamauga Reservoir (carp, golden shiner, several sunfish species, largemouth bass, yellow perch, brook silverside, and adult gizzard shad) are adequately sampled by cove rotenone surveys. However, during summer, when rotenone surveys are conducted, species such as black crappie, white crappie, sauger, freshwater drum, channel catfish, yellow bass, smallmouth buffalo, and spotted sucker prefer open-water and/or deeper, cooler water than that usually found in coves. Although open-water and deepwater species are not collected in their true abundance by cove rotenone methods, trends in their abundance may reasonably be discerned in TVA's long-standing database.

The twenty-one year time span was divided into four periods according to amount and dominant species of submersed aquatic macrophyte coverage (Figure 4). Standing stocks of fish species significantly correlated with macrophyte abundance were discussed for each period. During Period I, 1970-75, aquatic vegetation was sparse, covering less than 100 ha annually (ranged from 4 to 77 ha), and was primarily milfoil. Macrophyte coverage increased from 293 to 2,188 ha during Period II, 1976-81, and milfoil continued to be dominant. In Period III, 1982-88, vegetation on Chickamauga Reservoir reached its greatest coverage, ranging between 2,161 and 3,175 ha. Spinyleaf naiad, and to a lesser extent southern naiad, were the dominant species of aquatic vegetation during this time period, which included several drought years, especially 1985-88. During Period IV, 1989-90, vegetation decreased to 1,388 and 861 ha, respectively, and was primarily milfoil. The recent trend in macrophyte coverage in Chickamauga Reservoir is similar to trends observed in three other Tennessee River mainstream reservoirs (Figure 5).

Annual reservior-wide estimates of bluegill and largemouth bass harvest, 1977-91, were provided by TWRA creel surveys (TWRA 1992). Because creel surveys span the entire reservoir and year, their results are not directly comparable to shallow cove rotenone surveys conducted in midsummer. Data collected in 1986 were disregarded due to questionable validity (Todd St. John, TWRA, Nashville, personal communication).

RESULTS AND DISCUSSION

Overall Fish Community

Total fish standing stocks of each size class showed significant positive correlations with aquatic macrophyte coverage in Chickamauga Reservoir (Figure 6A). The trend was most evident for young-of-year (YOY) fish, whose average abundance increased from 8,097/ha during Period I to 26,000/ha and 37,150/ha during Periods II and III, respectively. But when vegetation sharply declined in Period IV, average standing stock of young fish fell to 20,000 fish/ha. Biomass of young fish was also significantly related to aquatic vegetation, ranging from 10.7 kg/ha in 1970 to 112 kg/ha in 1985 (Figure 6B). Average densities of intermediate fish increased from 571 fish/ha in Period I, to 1,212 and 1,206 for the next two time periods. Unlike young fish, intermediate sizes increased when vegetation plummeted in Period IV, averaging nearly 2,000 fish/ha. Biomass of intermediate fish was not significantly correlated with vegetation, and ranged from 12.6 kg/ha in 1980 to 91.2 kg/ha in 1971. Standing stocks of adults averaged 962 individuals/ha in Period I, and grew to averages of 1,407 and 2,035/ha during Periods II and III, respectively. Adult abundance dropped slightly in Period IV. The expansion began with a low of 537 fish/ha in 1970, peaked at 2,818 in 1983 during Period III, after which there has been a gradual, general decline. Biomass of adults was also significantly related to the amount of vegetation coverage, and was greatest during Period III when the average biomass was 269 kg/ha.

A hydroacoustic survey of Chickamauga Reservoir embayments in August, 1990, indicated fish numbers and biomass were positively related to surface coverage of aquatic macrophytes (Meinert et al. 1992). That study agrees with findings of the present study described above.

Species Increasing with Aquatic Vegetation

Abundance of several fish species increased with macrophyte abundance, most notably golden shiner, warmouth, bluegill, redear sunfish, largemouth bass, black crappie, and brook silverside. Yellow bass and yellow perch, relatively new inhabitants of Chickamauga Reservoir, also increased in abundance along with vegetation. All of these species are midwater insectivores with the exception of largemouth bass, which is an ambush predator on many of the other species. Gizzard shad also appeared to increase with vegetation; however, quantification of their abundance in Chickamauga Reservoir based on cove rotenone data following the initiation of herbicide treatment of rotenone coves in 1982 is somewhat unreliable. Increased abundance of YOY bluegill, redear sunfish, and warmouth shifted the forage base from shad to small sunfish, as also observed at Guntersville Reservoir during heavy macrophyte infestations (TVA 1989).

Golden Shiner

Golden shiner (Notemigonus crysoleucas) abundance (all sizes combined as YOY) was positively correlated with the amount of aquatic macrophyte coverage (Table 1). Average standing stock during Period I was only 3 fish/ha, but increased over a hundred-fold to 369/ha during Period II

(Figure 7). The peak year of abundance during Period II, 1980, occurred at 794/ha. Stocks of golden shiners declined to an average of 270/ha during Period III. Golden shiners reached their greatest abundance to date in Chickamauga Reservoir during Period IV. The two-year average was 547/ha, and the all-time annual peak abundance was 1,000/ha in 1990. The decline in golden shiner abundance during Period III implies that milfoil provides more favorable habitat for this species than spinyleaf naiad.

Preferred golden shiner habitat is moderate to very dense vegetation. Golden shiners consume a wide variety of food organisms, including protozoans, copepods, cladocerans, aquatic insects, and often filamentous algae and higher aquatic plants (Becker 1983). Being an omnivorous, phytophilic species, golden shiners benefit from aquatic vegetation by deriving habitat, invertebrate food sources, and even macrophytic food sources, explaining their recent upward population trends in Chickamauga Reservoir.

Warmouth

Warmouth (*Lepomis gulosus*) YOY standing stocks appeared to be highly correlated with aquatic macrophyte abundance (Figure 8). Averaging only 14/ha in Period I, their abundance increased dramatically to 818/ha (maximum 3,235/ha in 1981) in Period II. Average stock density continued high, 1,303/ha, during Period III, but declined with declining vegetation in Period IV, averaging 237/ha.

Standing stocks of intermediate warmouth significantly increased with vegetation, and their average abundances rose steadily during the four designated periods. Densities increased from 6/ha to 22/ha to 47/ha and 73/ha during Periods I-IV, respectively. Apparently intermediate warmouth were more able to survive; i.e., escape predation, in less vegetated cover than YOY because of their larger size.

Warmouth are considered food generalists due to the large variation in prey chosen by individual warmouth (Savitz 1981). They are in considerable competition for food with the other fish species present (bluegill, largemouth bass, and yellow perch). Due to their affinity for vegetation, warmouth are considered habitat specialists.

Bluegill

Standing stocks of young and intermediate bluegill (Lepomis macrochirus) significantly increased with aquatic macrophytes in Chickamauga Reservoir, 1970-90 (Table 1). In Period I standing stocks of young and intermediate bluegill averaged 1,484 and 261 fish/ha, respectively (Figure 9). Dramatic increases in abundance occurred during Period II when average standing stocks of young bluegill expanded over 10 times (to 16,620/ha), peaking in 1980 at nearly 27,000/ha, and numbers of intermediate sizes almost tripled (to 717/ha). The second-highest abundance of intermediate bluegill occurred in 1980 at 977/ha. But in Period III bluegill abundance fell. Young bluegill declined to about 70 percent (11,913/ha) of their density during Period II, while intermediate bluegill were less affected, dropping to 575/ha. During Period IV intermediate bluegill rebounded to an average of 973/ha, almost double their density during Period III. Peak abundance of intermediate bluegill, 1,096/ha, occurred in 1990. However, YOY bluegill continued to decline in Period IV, dropping to 6,071/ha. As was the case for warmouth, intermediate size bluegill are better able to escape predation in less dense vegetation than the smaller sizes.

Adults followed the same trend as intermediate bluegills, although their abundance did not significantly increase (P>0.05) with total vegetation coverage during the 21-year timespan. During Period III numbers of adults declined in rotenone samples, but rebounded in Period IV following the demise of spinyleaf naiad. Adult bluegill abundance in 1990 was similar to that of Period II, when milfoil was the dominant form of aquatic vegetation.

Annual harvest of bluegill fluctuated between 15,000 and 80,000 (Figure 10A), according to creel surveys conducted 1977-91 (TWRA 1992). Over 50,000 were taken in 1979 (Period II), 1987 and 1988 (Period III), and 1990 and 1991 (Period IV). The drop in 1989 harvest may have resulted from the four year drought which lasted until 1989. Increasing harvest in 1990 agrees with cove rotenone data, and the 1991 harvest is the largest recorded in the 15 year period.

Usual catch rates ranged from 1-2 fish/hr, but were highest in 1979 (Period II) when nearly 5 fish/hr were caught (Figure 10B). Lowest catch rates were in 1984 (Period III). Catch rates improved in 1990 and 1991 following the demise of spinyleaf naiad.

Certain aspects of bluegill life history favor their success, measured in increased abundance, in the presence of aquatic vegetation.

Hatched from nests in littoral areas, bluegill larvae migrate into open-water habitat before returning to littoral zones at a length of 12 mm (Conrow et al. 1990). Higher larval densities are found in dense, floating-emergent vegetation than littoral zones devoid of vegetation. Young bluegills find both shelter from predation and an abundant food supply in vegetated areas. Food consists of small invertebrates, including chironomids, mayflies, water mites, amphipods, cladocerans, caddisflies, and odonate larvae, supplemented with bryozoans, snails, and vegetation (Savitz 1981, Engel 1985). Bluegills frequently consume filamentous algae, pondweed leaves, and sprouting macrophytes, presumably for clumps of attached invertebrates (Savitz 1981). Lack of invertebrate food due to depletion of Daphnia and the emergence of chironomid larvae force bluegill to consume vegetation in July and August (Engel 1985). As bluegill grow to approximately 180 mm, their diet changes from microcrustaceans to larger insects, and competition with young largemouth bass sometimes occurs (see discussion below). Bluegills less than 100 mm standard length restrict their habitat to vegetated areas for protection from predation at the expense of higher foraging return available in open waters. Larger bluegills switch to open-water zooplankton as their risk of predation diminishes (Mittelbach 1981).

Bluegill in Lake Conroe, Texas, declined following removal of submersed aquatic vegetation by introduced grass carp (Ctenopharyngodon idella) (Bettoli et al. in press). This is the mirror effect of observations made during Period II in Chickamauga Reservoir when bluegill abundance increased dramatically with increases in aquatic macrophytes.

Redear sunfish

Standing stocks of redear sunfish (*Lepomis microlophus*) have followed a trend similar to that of bluegill in relation to aquatic macrophyte coverage (Figure 11). YOY redear have shown the strongest relationship (Table 1). Average standing stocks of YOY redear of 84/ha in Period I increased fifty-fold in Period II to 4,435/ha, peaking in 1981 at nearly 22,000/ha. Average densities rose slightly during Period III to 4,623/ha, reaching almost 8,000/ha in 1988 which was roughly a third of the peak abundance of Period II. When macrophytes declined in Period IV, standing stocks of YOY redear fell to an average of only 130/ha.

Intermediate redear sunfish abundance also corresponded positively to increased macrophyte coverage. There was a two-fold increase in average standing stocks between Period I and Period II, 21/ha vs. 41/ha. During Period III, standing stocks averaged 128/ha, nearly triple the previous average. Still greater abundances occurred in spite of vegetation declines in Period IV, peaking at over 700/ha in 1989, and averaged 413/ha. Increasing abundances of intermediate redear sunfish during Periods III and IV, while YOY abundances were declining, indicated the advantage of a larger size in being more able to escape predation in sparse vegetation than YOY.

Although overall correlation of adult redear sunfish and aquatic vegetation was not significant at the 0.05 level, useful information in the average standing stocks during the four designated periods was found. Adults were more abundant during the periods when milfoil was the predominant form of aquatic vegetation (Periods II and IV). Standing stocks averaged 74/ha and 101/ha, respectively for these periods, compared to averages of 42/ha during Period I and 54/ha during Period III. This is consistent with the pattern observed in adult bluegill standing stocks.

Largemouth Bass

Young and intermediate largemouth bass (*Micropterus salmoides*) standing stocks were significantly correlated with acreages of aquatic macrophytes (Table 1). Densities of young ranged from 18/ha in 1972 to 912 in 1980. Average densities in Period I, 66/ha, increased nearly nine-fold to 526/ha during Period II (Figure 12). In Period III average densities of young largemouth bass fell to 206/ha. Average abundance increased somewhat in Period IV to 285/ha.

Standing stocks of intermediate largemouth bass ranged between 3/ha in 1970 to 145/ha in 1981. Average densities were lowest, 28/ha, in Period I, and increased to 87 and 85/ha during Periods II and III, respectively. During Period IV average standing stocks of intermediate largemouth bass fell slightly to 58/ha.

Although the relationship between standing stocks of adult largemouth bass and aquatic vegetation was not statistically significant at the 0.05 level, their numbers generally increased over the 21-year period (Figure 12). The lowest abundance was 3/ha in 1970 (Period I), and the highest was 48/ha in 1985 (Period III). Cove populations of adult largemouth bass varied little since 1987 in spite of declining vegetation after 1988.

An increasing trend in largemouth bass abundance (all sizes combined) relative to aquatic macrophyte coverage is evident in Chickamauga Reservoir coves (Figure 12). The positive relationship between largemouth bass and aquatic vegetation was also evident in Lake Conroe, Texas, when numbers of age-1 and older bass declined after grass carp removed aquatic macrophytes (Bettoli et al. in press).

Fishing effort for largemouth bass in Chickamauga Reservoir increased tremendously between 1977 and 1991 (TWRA 1992). Creel surveys conducted by the State of Tennessee indicate black bass, predominantly largemouth bass, have been the most sought sportfish species in the reservoir since 1982. Estimated angler hours of fishermen seeking black bass increased from 35,000 in 1977 to nearly 600,000 in 1991 (Table 3). Expressed in trips, these figures represent about 8,250 in 1977 compared to nearly 190,000 in 1991. Harvest of largemouth bass increased nearly thirteen-fold between 1977 and 1991, as annual estimates increased from about 5,000 fish in 1977 to nearly 64,000 in 1991, peaking at over 125,000 fish in 1988 (Table 3, Figure 13A). Harvest estimates of largemouth bass numbers and weights were directly ($r=0.64$, $P=0.0100$ and $r=0.89$, $P=0.0001$, respectively) correlated to fishing pressure.

Annual catch rates for harvested fish over the past 16 years averaged about 0.20 fish/hr, ranging from 0.09 to 0.37 fish/hr (Figure 13B). Highest harvest rates occurred in 1983, 1984, and 1988, while lowest rates occurred in 1990 and 1991. Actual catch rates were higher than harvest rates, since many bass fishermen practiced catch and release fishing. Data from 1988 to 1991 indicate roughly 3 times more largemouth bass were caught than harvested in Chickamauga Reservoir (TWRA 1992). Declining harvest rates in recent years may be partly explained by catch and release fishing.

Harvest of largemouth bass by number and weight and fishing pressure were not significantly correlated ($P>0.05$) with the amount of aquatic macrophyte coverage during the study period. However, there was a positive relationship between catch rates for harvested fish and aquatic macrophytes ($r=0.58$, $P=0.0248$). Largemouth bass were harvested at higher rates during years of heavy aquatic vegetation, perhaps because they were more vulnerable to capture around patches of vegetation. Fishing pressure ($r=0.86$, $P=0.0001$) and harvest of largemouth bass numbers ($r=0.61$, $P=0.0158$) and weights ($r=0.83$, $P=0.0001$) were significantly correlated with year, indicating that all three parameters increased over time. However, harvest rates and average size of largemouth bass did not show a significant trend relative to year.

Comparison of data from 1988 and 1991, years of highly contrasting vegetation coverage, illustrates the effect of aquatic macrophytes on a largemouth bass sport fishery. During 1988, when vegetation was heavy, the number of bass harvested was greatest of the study period, but mean size was smallest, 0.56 pounds (Table 3). Total weight harvested was about 70,000 pounds. Bass were larger when vegetation coverage was sparse in 1991, averaging 1.32 pounds each. Total weight harvested in 1991 was highest of the study period, nearly 85,000 pounds, although the total number harvested was only half that of 1988 (TWRA 1992). Other studies have shown that usually there is an inverse relationship between mean size of largemouth bass and aquatic macrophyte coverage (Mike Maceina, Auburn University, personal communication).

From 1987 to 1991 over 50,000 pounds of largemouth bass were taken annually from Chickamauga Reservoir (TWRA 1992). The question arises as to the amount of fishing pressure and harvest Chickamauga Reservoir can sustain and still provide a quality sport fishery. Since 1987 the annual harvest rate averaged 1.71 pounds/acre. The greatest harvest rate, 2.39 pounds/acre, occurred in 1991, and was followed in 1992 by the lowest rate in recent years, 1.19 (Table 3). However, all harvest rates, are less than the national average of 2.67 pounds/acre (Jenkins 1982). At Guntersville Reservoir, another Tennessee River mainstem reservoir, 46 miles downstream, harvest rates were higher, but have decreased from 4.70 pounds/acre in 1990 to 3.66 and 1.59 in 1991 and 1992, respectively (Donny Lowery, TVA, personal communication). Fishing pressure and harvest at Chickamauga Reservoir declined in 1992 to 282,000 hours and 30,846 fish, respectively, but harvest rate, catch rate, and mean size improved from 1991 estimates (TWRA 1993).

Small bass and bluegill (39 to 119 mm) seek shelter in aquatic vegetation, but their access into extremely dense vegetation (greater than 300 g dry wt/m^2) is restricted. Medium-sized largemouth bass and bluegill (120 to 179 mm) select loose vegetation or disperse offshore. Bass larger than 180 mm stay offshore or in channels or open areas of the foliage, although during summer they may seek cooler water temperatures provided by overhanging plant canopies (Engel 1988). They frequently occupy small "holes" devoid of plants within dense vegetation, and become ambush predators, whereas in sparse vegetation they actively pursue prey (Killgore et al. 1989).

Principal food items of small largemouth bass inhabiting vegetation are chironomids, odonates, mayflies, fishes, and cladocerans (Engel 1985). The onset of piscivory by young largemouth in Lake Conroe, Texas, was delayed by abundant aquatic vegetation, as largemouth bass smaller than 100 mm rarely consumed fish (Bettoli et al. 1992). Most did not become piscivorous until reaching lengths of 140 mm. But when vegetation was very sparse, piscivory of young largemouth bass was common at smaller lengths, down to about 60 mm. Earlier piscivory translates into faster growth rates of young largemouth. In Wisconsin fish in the diet outnumber insects when bass lengths exceed 240 mm. (Engel 1985). In Oklahoma crayfish are the dominant food of bass in dense vegetation, followed by bluegill and YOY bass. In heavier vegetation YOY bass are more vulnerable to predation than bluegill, until they grow large enough to escape predation, about October (Summers 1980).

Largemouth bass production is enhanced by the presence of aquatic macrophytes; however, there is a point where increasing aquatic vegetation leads to decreased bass production, presumably due to foraging inefficiencies brought about by excessive plant growth. That point appears to be above 20 percent coverage in studies of 30 Texas reservoirs (Durocher et al. 1984). Optimal largemouth bass production in Illinois ponds dominated by <u>Potamogeton crispus</u> and <u>Najas flexilis</u> occurs at an aquatic macrophyte standing crop of 52 grams dry weight/m^3 (Wiley et al. 1984). Bass growth is also reduced in waters having dense vegetation (Engel 1985).

In experiments of various densities of simulated vegetation, largemouth bass switch foraging behavior from active searching to ambush tactics as plant density increases. Fathead minnows and golden shiners are more vulnerable to predation than bluegills (Savino and Stein 1982a). As simulated vegetation becomes extremely dense, bass predatory activity declines in response to reduced visual contact with bluegills and the ability of the bluegills to "hide" (Savino and Stein 1982b). Other laboratory experiments indicate that in sparsely vegetated environs largemouth bass are food specialists, whereas in dense vegetation they are food generalists (Anderson 1984).

Largemouth bass and bluegill are commonly found together in aquatic macrophyte beds, and the initial relationship observed is that of predator-prey. However, this is a function of size; i.e., the larger bass is the predator and the bluegill is the prey. Given the differences in size, both species have been designated as food specialists since there is very little or no competition for food (Savitz 1981). But when size is taken into account, and both species are smaller than 120 mm, diet overlap can be as high as 70 percent (Engel 1988). Diet overlap decreases to only 11 percent as the two species grow beyond 180 mm with bass consuming insects and small fish while bluegills graze zooplankton. Young of year bass and YOY yellow perch (25-49 mm) have a slightly overlapping diet for invertebrates in West Point Lake, Alabama-Georgia until midsummer at which time bass switch to small fishes (Timmons 1984).

Black crappie

Although black crappie (Pomoxis nigromaculatus) were present in cove rotenone samples as far back as 1972, they have only recently become common in Chickamauga Reservoir (Figure 14). Recent increases in YOY black crappie standing stocks were significantly correlated with increases in aquatic macrophyte coverages (Table 1). Increased water clarity during the drought years of 1985-88 may have favored black crappie over white crappie, which tend to do better in turbid water. Since increased water clarity also encourages aquatic macrophyte growth, it is not possible to say which had the larger effect on black crappie abundance. YOY black crappie were very rare in cove rotenone samples in Periods I and II, occurring in only three years and averaging only 1 fish/ha. During Period III average standing stocks improved greatly, to 16/ha, and the peak abundance occurred in 1988 when 102/ha were found. Following the decrease of naiads in Period IV, YOY black crappie abundance remained high, as standing stocks were 18 and 72/ha, respectively.

Increases in intermediate black crappie abundance were also correlated with aquatic macrophytes, but their numbers have not expanded greatly. None were found in rotenone surveys in Period I, and the average during Period II was only 1 fish/ha. Three fish/ha was the average density during Periods III and IV. Peak abundance of intermediate black crappie occurred in 1988 when standing stocks were 12/ha.

The shift in dominance to black crappie from white crappie in Chickamauga Reservoir has been recently attributed to increased aquatic macrophyte coverage (McDonough and Buchanan 1991). Young black crappie are thought to benefit more from vegetated areas for invertebrate feeding and shelter than white crappie which prefer deeper, more open-water habitats. This is particularly important in Chickamauga Reservoir where juvenile crappie survival is critical to harvestable-size recruitment. At lengths less than 200 mm both crappie species are zooplanktivorous and insectivorous (Ellison 1984). Adults of both species are mainly piscivorous, but black crappie are somewhat slower to convert to a fish diet, and are less adapted to capturing prey in turbid water than white crappie.

In a natural Wisconsin lake, crappie (presumably black crappie) occupied the pelagic region adjacent to macrophyte beds during summer and were spatially segregated from largemouth bass and bluegill (Engel 1985). They ate mainly zooplankton (Daphnia, Mesocyclops, and Leptodora) and relatively few insects, making their diet more specialized than largemouth bass or bluegill, and remained zooplanktivorous until about 200 mm. Small crappie consumed food under 2 mm long, while large crappie food measured 5 mm or more in length. The diets of medium bluegills and crappies overlapped by 90 percent, as both species shared Daphnia and Leptodora. This interspecific competition intensified with the collapse of Daphnia in July. Diets diverged as they grew to larger sizes, with overlaps of only 25 percent (Engel 1985). Fish are of primary importance to adult black crappie on a volume basis, although invertebrates are numerically more important (Becker 1983).

Brook silverside

Brook silverside (Labidesthes sicculus) also have benefited by increases in aquatic macrophytes (Table 1). Their average standing stocks (all sizes considered YOY) increased from 18/ha during Period I to 100/ha in Period II (Figure 15). Their greatest average abundance, 212/ha, occurred in Period III, peaking in 1986 at 490/ha. Average standing stocks of brook silverside fell to 92/ha in Period IV. Apparently this surface-dwelling species is more suited to abundant naiad growth than abundant milfoil growth.

Affinity of brook silverside for aquatic macrophytes was also reported from Lake Conroe, Texas (Bettoli et al. 1991, Bettoli et al. in press). Stocks of brook silverside collapsed following the removal of aquatic macrophytes by grass carp. However another atherinid species, the inland silverside (Menidia beryllina), increased in abundance, presumably because it was better adapted to open water conditions than brook silverside.

Young brook silverside are pelagic most of their first summer, feeding on cladocerans, copepods, and other small crustaceans. They migrate to shallow shoreline areas as summer ends, joining adult brook silverside. Diet shifts to aquatic and terrestrial insects along with move to shoreline habitat (Pflieger 1975). Their entire lifespan is 17 months (Becker 1983).

Yellow Bass

Standing stocks of all three sizes of yellow bass (Morone mississippiensis), a species not found in Chickamauga Reservoir before 1969 (Starnes et al. 1982), have shown significant positive correlations with aquatic macrophyte coverage in Chickamauga Reservoir (Table 1). Average YOY abundances have steadily increased over the four periods, although there were marked declines in 1978 and 1979 (Figure 16). Standing stocks increased from an average of 10/ha in Period I to 16/ha in Period II. During Period III, YOY yellow bass abundance averaged 28/ha, but the greatest abundance occurred in Period IV when average stocks were 190/ha. The all-time peak abundance of YOY occurred in 1990 (372/ha).

Intermediate and adult yellow bass also rose in average abundance in the first three periods, but, in contrast to YOY, fell in Period IV. Standing stocks of intermediate yellow bass were 3, 13, 13, and 5/ha, respectively, while adult stocks averaged 1, 4, 5, and 3/ha, respectively, over the four periods.

Young yellow bass feed primarily on small crustaceans (copepods and cladocerans), switching to aquatic insects as they grow (Pfleiger 1975). Based on the positive correlation of YOY yellow bass and aquatic macrophytes in Chickamauga Reservoir, and the enlarged insect fauna associated with aquatic macrophytes, it appears the macrophyte beds provide a desirable invertebrate food supply for YOY yellow bass.

Larger yellow bass also benefited from increased macrophyte coverage, presumably due to invertebrate fauna inhabiting submersed vegetation (Starnes et al. 1982), although fish become more important in their diet as they grow. Adults are mostly piscivorous, feeding on small fish, even young of their own species (Pfleiger 1975).

Yellow Perch

The young of yellow perch (Perca flavescens), a non-native species that invaded the Tennessee River system following introductions into headwater reservoirs of the Hiwassee River in North Carolina in the 1950's (Etnier and Starnes, in press), have increased in abundance along with aquatic vegetation in Chickamauga Reservoir (Table 1). Average standing stocks were 1/ha in Period I, 21/ha during Period II, 12/ha during Period III, and finally 32/ha in Period IV. Relatively high abundances were found in three years of Period II (1978 [36/ha], 1980 [41/ha], and 1981 [39/ha]) and one year of Period IV (1990 [48/ha]), when milfoil was the dominant macrophyte (Figure 17). YOY yellow perch abundance was also high in one year of Period III, 1988 (48/ha), but was less than 10/ha during the other six years of Period III.

Although trends in intermediate and adult abundance were not significantly correlated with coverage of total aquatic macrophytes, annual standing stock estimates imply yellow perch abundance is related to the type of aquatic vegetation Chickamauga Reservoir. Stocks rose from averages of 8 and 4/ha for intermediate and adult sizes, respectively, during Period I to 54 and 20/ha during Period II. But in Period III, average intermediate and adult stocks fell to 28 and 14/ha, respectively. When naiads declined and milfoil was once again the dominant macrophyte in Period IV, average standing stocks of intermediate and adult yellow perch rebounded to all-time highs of 118 and 83/ha, respectively. Thus, standing stocks of yellow perch appear to be more related to the species of aquatic macrophyte present than the amount of aquatic macrophyte present; i.e., they are more numerous during years of greater milfoil coverage than years when naiads are more abundant.

Yellow perch are termed food generalists due to large trophic diversity (Savitz 1981). They feed mostly on small invertebrates, along with some minnows and darters, putting them in competition with other fish species inhabiting littoral vegetation. They prefer habitats with cooler water than bluegill, warmouth, and largemouth bass (Timmons 1984), thus segregating them somewhat spatially.

Gizzard Shad

Standing stocks of YOY gizzard shad (*Dorosoma cepedianum*) have significantly increased with aquatic macrophytes in Chickamauga Reservoir (Table 1), but have been highly erratic over time, according to cove rotenone surveys (Figure 19). The average density in Period I was only 38 fish/ha, although they were considerably more abundant during 1970 and 1971. In Period II the average YOY gizzard shad density increased to 338/ha due to high densities of 1,905 and 115/ha during 1977 and 1978, respectively. Highest average standing stocks, 850/ha, occurred during Period III, and ranged from about 60/ha in 1984 to 2,800 in 1985. YOY gizzard shad dropped to about 8/ha but rebounded to 741/ha during Period IV.

There are several possible explanations for the variable abundance of gizzard shad in rotenone samples. YOY gizzard shad form pelagic, actively foraging schools in open-water areas during daylight hours, creating patchy distributions. When the block net is placed across the mouth of the rotenone cove late in the afternoon, schools of YOY shad may or may not be trapped in the cove. Increasing milfoil colonies between 1978 and 1981 reduced feeding zones inside the rotenone coves, resulting in apparent declining stocks of YOY shad. Beginning in 1982, coves were treated with herbicides to remove vegetation and facilitate collection of fish during rotenone surveys. However, this activity created open areas in the vegetation and may have attracted YOY shad into the "new" feeding zones. Standing stocks jumped in 1982 and remained high during the years of naiad dominance, but this is not believed to be a result of the increased vegetation, rather an attraction to the open areas following herbicide treatment.

Another factor complicating conclusions about YOY gizzard shad abundance drawn from rotenone surveys is species interactions with YOY threadfin shad. Evidence of competition between the two shad species followed the severe winters of 1976-77 and 1977-78, which caused high mortalities of temperature-sensitive threadfin shad. Coincident with greatly reduced stocks of YOY threadfin shad in cove rotenone samples, the following summers were very high stocks of YOY gizzard shad (Figure 19). Both species have extended, overlapping spawning seasons of approximately three months in the spring and early summer (Wallus and Kay 1990), and resultant young shad may be in frequent competition for planktonic food organisms during their first summer. (Inability to identify larval shad prevents research on interspecific competition in areas where they coexist.)

An obvious shortcoming of cove rotenone surveys to measure YOY gizzard shad abundance is the fact that standing stocks of adults are usually one or two orders of magnitude greater than the abundance of young (Figure 18). This amplifies the pelagic nature of YOY shad; i.e., the young are not sampled by cove rotenone in their "true" reservoir abundance. Hydroacoustic surveys provide better measurement of fish in the pelagic zone, which are primarily YOY shad during the summer.

Regression analysis indicated that adult gizzard shad standing stocks are significantly correlated to aquatic macrophyte coverage (Table 1). However, for the same reasons as YOY gizzard shad, adult shad should not be expected to increase in abundance with vegetation because their preferred habitat is open water (Wallus and Kay 1990). Declining abundance in 1979 and 1980 samples, before coves were treated with herbicides, may just indicate foraging habitat of adult shad was reduced by increased macrophyte coverage (Figure 18). There was little difference in average standing stocks between Periods I and II, 622 vs. 773 fish/ha, respectively. However, a major increase occurred during Period III, when average abundance doubled to 1,547 fish/ha. But since coves were treated with herbicides during this period, their observed abundance is not considered to be directly associated with the amount of aquatic vegetation, but instead due to the attraction of open-water foraging habitat within the macrophyte beds created by herbicide treatments. As the abundance of macrophytes plummeted in Period IV, gizzard shad abundance "fell" to an average of 933 fish/ha, which may be a more accurate measurement of their true abundance.

Aspects of gizzard shad early life history have a direct bearing on year classes of other species. Due to their sheer numbers and extended period of occurrence, larval and juvenile gizzard shad have an enormous effect on the planktonic food supply necessary to support young fish of spatially and temporally coincident species. Gizzard shad measuring between 6-25 mm in length feed exclusively on zooplankton (Kissick 1988) and later switch to phytoplankton. Selective predation on zooplankton populations by young gizzard shad is substantial (Cramer and Marzolf 1970), and can lead to zooplankton depletion (Kissick 1988). In one study gizzard shad less than 20 mm in length ate zooplankton (Cyclops, Bosmina, and Daphnia), but gradually switched to phytoplankton when they grew beyond 22 mm (Cramer and Marzolf 1970). Another study showed shad zooplanktivory continued to 30 mm, with small shad larvae less than 25 mm selecting larger zooplankton (Cyclops and Calanoida) and larger larvae feeding on smaller zooplankton (Bosmina and Keratella), while a 35 mm specimen had fed exclusively on the phytoplankter Pediastrum (Barger and Kilambi 1980). Young gizzard shad virtually cease feeding at night (Kissick 1988). In pond experiments gizzard shad suppressed bluegill growth and recruitment by removing planktonic food needed by small bluegill which indirectly affected growth of largemouth bass that preyed upon bluegill (Kirk and Davies 1985). In Ohio reservoirs peak densities of larval gizzard shad can drive zooplankton to temporal extinction, thereby limiting recruitment of other fish species and controlling fish community composition (DeVries and Stein 1992). Competition for planktonic food during larval stages to the detriment of other species has also been demonstrated with threadfin shad (Ziebell, et al. 1986, DeVries et al. 1991).

The timing of shad spawning, determined by water temperature, is a major factor in largemouth bass year class strength. Gradually rising temperatures in the spring delay shad spawning, separating them more temporally from the earlier-spawned largemouth bass. This favors YOY bass survival by allowing them to grow larger before the young shad become available as prey (Adams and DeAngeles 1987). If water temperature rises rapidly, young shad will grow too quickly to be utilized by YOY bass.

Species Decreasing with Aquatic Vegetation

Most of the fish species that have decreased over time are open-water benthic insectivores or omnivores, such as carp, smallmouth buffalo, spotted sucker, channel catfish, and freshwater drum. Their feeding habitat is predominantly broad mud flats. Piscivorous species that have declined, such as sauger and white crappie are also associated with open-water habitat.

Carp

Standing stocks of adult carp (*Cyprinus carpio*) have decreased relative to aquatic macrophyte abundance (Table 1). They were most numerous in Period I when average stocks were 10/ha (Figure 20). Peak abundance was measured in 1971 at 17/ha. As milfoil expanded during Period II average adult carp abundance dropped to 4/ha. During Period III average stocks were 2/ha, and remained at that level through Period IV.

A curious contrast to declining adult carp abundance relative to aquatic vegetation is increasing YOY abundance (Table 1). YOY carp were virtually absent in cove rotenone samples during Period I, averaging 0.06/ha. As milfoil invaded, average densities jumped to 5/ha, peaking at 24/ha in 1981. Average density fell to 3/ha in Period III. No YOY carp were found in Period IV.

Carp is a highly adaptive species, and tolerates considerable pollution. They are omnivorous, and consume a wide variety of animal and plant material (Pflieger 1975). Aquatic insects are the most important food category. Their decline in abundance in Chickamauga Reservoir cannot be explained solely in terms of vegetation dynamics.

Smallmouth Buffalo

Intermediate and adult smallmouth buffalo (*Ictiobus bubalus*) standing stocks were inversely related to aquatic macrophyte abundance (Table 1). Intermediate smallmouth buffalo abundance averaged highest (7/ha) during Period I (Figure 21). Peak abundance was 36/ha in 1971. This size has been virtually absent from cove rotenone samples since 1975, appearing during only three years.

Adult smallmouth buffalo also were most abundant during Period I, averaging 10/ha during 1970-75. Peak abundance of 25/ha occurred in 1972. As milfoil proliferated in Period II, adult smallmouth buffalo stocks fell to average 2/ha, and remained at that level during Period III. Stocks fell to 1/ha during Period III, following the collapse of naiads.

Smallmouth buffalo are opportunistic bottom-feeders, consuming aquatic insects, attached algae, crustaceans, and zooplankton (Tomelleri and Eberle 1990). Its feeding behavior is adapted for open, soft substrates, and is apparently hindered by rooted aquatic vegetation.

Spotted sucker

Another benthic invertivore significantly decreasing in abundance relative to aquatic macrophytes is spotted sucker (Minytrema melanops), specifically YOY and adults. Average YOY standing stocks were 19/ha in Period I (Figure 22). Peak YOY occurrence was in 1973 when 93/ha were observed. Average density fell to 4/ha during Period II, and further declined in Period III to 2/ha. Their abundance did not change in Period IV.

Standing stocks of adults averaged 13/ha in Period I, and increased slightly to 15/ha during Period II. Peak abundance was 31/ha in 1974. However, as total vegetation reached its greatest coverage in the 1980's, average abundance of adult spotted suckers dropped to 4/ha, and remained low (3/ha) in Period IV.

Food habits of spotted sucker have been little studied, but probable food organisms are molluscs and insect larvae (Forbes and Richardson 1920). A 150-mm specimen had ingested mostly ostracods and chironomid larvae, along with lesser amounts of mayfly larvae, amphipods, copepods, filamentous algae, and higher plant material (Becker 1983).

Channel Catfish

YOY and intermediate channel catfish (Ictalurus punctatus) abundance in Chickamauga Reservoir has decreased in relation to aquatic macrophytes (Table 1). Although YOY have never been particularly abundant in cove rotenone surveys in Chickamauga (all-time peak annual abundance was 9/ha), average standing stocks fell from 3/ha to 2/ha between Period I and Period II (Figure 23). YOY abundance further declined during Period III to an average of 0.4/ha, as none were sampled in five of the seven years of that period. Their numbers remained below 1/ha in Period IV.

Stocks of intermediate channel catfish were highest in Period I, averaging 8/ha. Their greatest abundance, 12/ha, occurred in 1971 and 1972. When milfoil coverage increased in Period II, intermediate stocks decreased to an average of only 2/ha. During Period III this size of channel catfish continued to decline in abundance, falling to an average of 1/ha. No rebound in abundance occurred during Period IV, and the average density of intermediate channel catfish remained at 1/ha.

Standing stocks of adult channel catfish were not significantly correlated at the 0.05 alpha level to aquatic macrophyte abundance, but were highly erratic over time. The peak abundance, 50/ha, occurred in 1981 when milfoil was very abundant; and were it not for this unusual observation, a significant negative relationship would have been found. Average standing stocks were 14/ha and 17/ha during the first two periods, respectively, and dropped to 6/ha in Period III. In Period IV adult channel catfish abundance still averaged only 5/ha.

Channel catfish feed on the bottom and detect food by touch and smell. Food is highly varied, both living and non-living (Becker 1983).

Insects, freshwater clams, snails, fish, and algae are common food items, with fish becoming more important numerically for adult catfish (Tomelleri and Eberle 1990).

White Crappie

The recent decline of white crappie (Pomoxis annularis) in Chickamauga Reservoir has been of great concern (Buchanan and McDonough 1990, McDonough and Buchanan 1991). Declining adult stocks have been attributed at least in part to increased aquatic vegetation. Other factors were obviously involved because average density during Period I, 8/ha, increased to 11/ha in Period II (Figure 24). The all-time annual peak density, 30/ha, occurred in 1979 following three years of rapidly climbing milfoil coverage (from 293 to 802 ha). Major declines in adult stocks occurred during Period III, as average abundance fell to 1/ha. In 1987 and 1988 no adult white crappie at all were found in any of the four Chickamauga coves sampled. White crappie did not recover following the naiad decline in Period IV, as average density was less than 1/ha. The peak abundance of YOY in 1987, 135/ha, did not survive to intermediate and/or adult size in succeeding years.

Although spawning success and survival through the first summer were found in Chickamauga Reservoir, year class strength declined during the second summer when mortality was correlated with increased aquatic vegetation, YOY and yearling sunfish and largemouth bass, and adult largemouth bass and gizzard shad (Buchanan and McDonough 1990). Larval sunfish abundance greatly increased during the years of heaviest macrophyte colonization, and the resultant competition for planktonic food may have reduced larval white crappie abundance in some years. Pelagic crappie also compete with preponderant numbers of larval gizzard and threadfin shad, which are capable of causing zooplankton depletion. Circumstantial evidence from Douglas Reservoir, Tennessee, indicates young, pelagic white crappie do very well in the absence of threadfin shad (Wilson 1991).

In recent years, white crappie have been replaced in dominance by black crappie in Chickamauga Reservoir due to differences in food habits and preferred habitats, especially during the drought period of 1985-88. YOY white crappie abundance was positively correlated with abundance of YOY gizzard shad, and inversely correlated with the abundance of adult threadfin shad. Adult white crappie abundance was positively correlated with dissolved oxygen, and negatively correlated with aquatic vegetation; fishing pressure; density of YOY black crappie, sunfish, gizzard shad, and threadfin shad; yearling stocks of sunfish; and adult density of gizzard shad (Buchanan and McDonough 1990).

Zooplankton food of young white crappie (11-100 mm) included *Daphnia*, *Cyclops*, *Diaptomus*, and *Leptodora*, with *Cyclops* being most strongly selected in crappie less than 30 mm. Bottom fauna organisms were unimportant food items. As the fish grew, the order of selection was *Daphnia*, *Diaptomus*, and *Leptodora* (Nelson et al. 1967). Small white crappie (8-17 cm) are pelagic in reservoirs (O'Brien et al. 1984). In Chickamauga Reservoir, juveniles of both crappie species (50-200 mm) had very similar feeding habits, consuming primarily copepods, with lesser amounts of cladocerans and chironomid larvae (Buchanan and McDonough

1990). As previously mentioned, competition with bluegills and other sunfish appears to have seriously impaired year class strengths of white crappie in Chickamauga Reservoir during the 1980's, coincident with heavy colonization of aquatic macrophytes.

In pond experiments the presence of gizzard and threadfin shad decreased the total number and biomass of YOY white crappie (Guest et al. 1990), due to overlapping zooplankton diets as larvae and juveniles. Threadfin shad continue to feed on zooplankton as adults by visual feeding, and suppressed densities of copepods and _Daphnia_. Adult threadfin shad compete with white crappie for zooplanktonic food, while adult gizzard shad do not. This is consistent with previous studies on Chickamauga Reservoir (Buchanan and McDonough 1990).

Sauger

All three sizes of sauger (_Stizostedion canadense_) declined coincident with increasing vegetation (Table 1). However the major factor for their decline is believed to be poor spawning success at Hunter Shoals (TRM 521) due to low discharges from Watts Bar Dam during April, especially during the drought years of the mid to late 1980s (Hickman et al. 1990).

YOY sauger abundance averaged 1.2/ha in Period I before aquatic macrophytes were common (Figure 25). Average abundance fell 0.6/ha during Period II, and sauger were only found one year of that 6-year period, 1977, which was also the all-time peak occurrence year, when 4/ha were measured. No YOY sauger were collected in cove rotenone surveys during Period III, but small numbers reappeared in 1990. These could have been naturally reproduced in Chickamauga Reservoir, but it is more likely they were from 191,000 fingerlings released by the Tennessee Wildlife Resources Agency (TWRA) into Chickamauga Reservoir during 1990 (Hevel and Hickman 1991).

Intermediate sauger declined from 1.0/ha in Period I 0.8/ha in Period II. No intermediate sauger were collected in cove rotenone surveys after 1979. Adult sauger average stocks fell successively during the four designated periods from 1.2/ha to 1.0, 0.4, and finally 0.0/ha, respectively.

Food of young saugers in the 12-50 mm size range includes *Daphnia*, *Cyclops*, chironomids, and YOY of other fishes, such as white bass and freshwater drum (Priegel 1969). Fish become more important in sauger diet as the young grow, but microcrustaceans are eaten when smaller fish are unavailable. Juvenile and adult sauger are highly piscivorous in Tennessee River reservoirs, preying heavily upon gizzard and threadfin shad, although *Hexagenia* nymphs occasionally occur in the diet.

Due to preference for coolwater habitats, sauger are not commonly found in the relatively shallow coves chosen for rotenone samples. Furthermore they are not directly affected by aquatic macrophytes due to their cooler, deeper habitat. But even though rotenone surveys do not provide accurate estimates of sauger abundance, the virtual absence of all three sizes from 1980 to 1990 indicates the species suffered considerable decline in Chickamauga Reservoir during that time period.

Estimates of the sauger spawning population fell from 18,000+ in 1986 to approximately 2,000 in 1991 (Hevel and Hickman 1991)

Sauger larvae do not compete for zooplankton with larval shad and sunfish due to temporal separation; i.e., sauger larvae hatch earlier in the spring than most other species. Instead of competition for food during the larval period, their decline in recent years is attributed to unfavorable conditions for spawning and/or egg survival on the spawning grounds at Hunter Shoals (TRM 521), primarily due to low river flows during drought years (Hickman et al. 1990). Increasing flows since 1989 coupled with a newly-instituted April minimum discharge of 4000 cfs in "dry" years or 8000 cfs during "wet" years for a three year test period at Watts Bar Dam (Yeager and Shiao 1992) should combine with the fingerling stocks by TWRA to improve the sauger fishery in Chickamauga Reservoir in the near future.

Freshwater drum

Decreases in YOY and intermediate freshwater drum (Aplodinotus grunniens) were significantly correlated with increasing aquatic macrophytes (Table 1). YOY drum, whose annual standing stocks were as high as 200/ha and 224/ha in 1972 and 1973, respectively, averaged 116/ha during Period I (Figure 26). In Period II standing stocks of YOY drum sharply decreased to only 4/ha. Their average abundance remained at 4/ha during Period III. In Period IV, following the decline of naiads, average density of YOY climbed to 69/ha, mostly due to a large increase in 1990 when 135/ha were found.

Intermediate drum also declined relative to aquatic plant abundance, with average standing stocks dropping from 135/ha in Period I to 39/ha in Period II. Their peak abundance was 275/ha in 1974 while vegetation was still relatively sparse. During Period III average intermediate drum abundance (surprisingly) rose to 64/ha, roughly half the Period I average. In Period IV stocks of intermediate drum rose to an average of 103/ha, and like YOY stocks, had the greater abundance in 1990, 138/ha.

The pelagic young of freshwater drum consume cladocerans and copepods, as do other larval fishes. Aquatic insects, such as chironomids and *Hexagenia*, become more important as the young grow and become bottom feeders (Becker 1983). Fish, crayfish, and immature aquatic insects provide the bulk of adult drum diet (Pflieger 1975), although Asiatic clams (*Corbicula* spp.) are frequently consumed by Tennessee River drum.

Milfoil and Spinyleaf Naiad Growth Forms

Many fish species whose numbers increased with aquatic macrophytes reached their greatest abundances during the period when milfoil was the dominant form of aquatic vegetation, 1976-81. Their numbers declined as spinyleaf naiad replaced milfoil as the dominant macrophyte, 1982-88. Abundance of these phytophilic species was not just related to the total amount of vegetation present, but also to the dominant species of macrophyte present.

Differences in leaf morphology and underwater growth form of Eurasian watermilfoil and spinyleaf naiad provide different habitats for invertebrates and fish. Broad, feathery leaves of milfoil provide abundant surface area for aquatic invertebrates and epiphytic algae (Figure 27A). Bunched stems of milfoil grow from the substrate to the water surface. Near the surface the stems branch to form dense canopies. From substrate level milfoil colonies have the appearance of a forest with distinct trunks (i.e. bunched stems) and an overhead canopy. Since the water column below the canopy remains somewhat open, movement of fish is not entirely restricted. Milfoil colonies usually are most abundant at depths between 1.5 and 3 m. Strands of milfoil persist into the winter, providing habitat for aquatic life well beyond the seasonal growth period.

In contrast, the growth form of the annual macrophyte spinyleaf naiad is dense, bushy, and brittle (Figure 27B). It usually grows in shallower areas than milfoil, often in backs of coves and along shorelines, and has a high density of slender, wire-like stems. During the drought years of the 1980s when the water was unusually clear, this plant expanded its coverage to deeper water (1-2 m) to areas once colonized by milfoil. In shallow water spinyleaf naiad may not form a distinct canopy near the surface. Instead its "Brillo pad" growth form may occupy a large portion of the water column. Fish are less able to move within this growth form than within milfoil. Although some foraging and protection benefit is afforded, spinyleaf naiad may actually decrease shoreline habitat for small fish due to its dense, bushy growth. Furthermore, spinyleaf naiad plants generally "break-up" by September, leaving shoreline areas devoid of vegetated cover for fish and aquatic invertebrates in the mid-fall, winter, and early spring months.

Factors Affecting Aquatic Macrophytes

Univariate regression analysis found that of the variables tested the amount of aquatic macrophyte coverage during the previous year had the greatest influence (r=0.90, P=0.0001) on coverage during the next year (Figure 28). In other words, propagules (milfoil root masses, fragments of milfoil stems, and seed banks of annual species) from the previous season are of prime importance to the magnitude of macrophyte coverage during the following season. Paucity of aquatic vegetation upstream from Chickamauga Reservoir also lessens the likelihood of recolonization by floating fragments. Favorable abiotic growing conditions alone will not produce abundant vegetation.

Sunlight availability was also highly correlated (r=0.68, P=0.0005) with aquatic macrophyte coverage (Figure 29). Sunlight availability in this model was the percentage of possible sunshine reaching the earth's surface. (Actual amounts of sunlight penetrating the reservoir's water surface in vegetated areas, measured with a secchi disc, would have been more appropriate, but were not available for the study period.) As with terrestrial plants, sunlight, the energy source for photosynthesis, has been documented as the most important environmental factor affecting submersed aquatic macrophyte abundance (Barko et al. 1986, Johnstone and Robinson 1987).

During the period 1971-92 aquatic macrophyte coverage was inversely related (r=0.54, P=0.0100) to discharges of the Tennessee River at Chickamauga Dam during the critical part of the growing season (March to June) (Figure 30). Factors associated with high discharges that negatively affect growth of aquatic macrophytes are increased scouring, siltation, and turbidity caused by suspended solids. Scouring action during high flows may uproot plants or cause fragmentation that results in reduced abundance of aquatic vegetation. Siltation can smother root masses, small plants, and bury seed banks with sediment. Turbidities due to suspended solids absorb sunlight penetrating the water's surface, thereby depriving submersed macrophytes of their photosynthetic energy source. A recent study of Chickamuga embayments also found aquatic vegetation negatively correlated to turbidity (Meinert et al. 1992).

A biogenic source of turbidity that may be important during some years is excessive growth of phytoplankton. Phytoplankton absorb sunlight, and like suspended solids may limit the amount of sunlight available for macrophytes. Although insufficient chlorophyll a and secchi depth data precluded regression analysis, it would be expected that reduced light availability caused by phytoplankton blooms would negatively affect aquatic macrophyte growth and coverage. An unusually large phytoplankton bloom in Chickamauga Reservoir during spring 1990 (Wayne Poppe, TVA, personal communication) may have suppressed aquatic macrophyte growth that year. Excessive phytoplankton blooms and epiphyton growth, associated with eutrophication, have led to reductions of submersed aquatic macrophytes in Chesapeake Bay (Orth and Moore 1983) and Europe (De Nie 1987).

As in other biological processes, temperature affects the growth rate of aquatic vegetation. However, when mean March-June water temperatures for years 1975-92 were regressed against macrophyte coverage, the relationship was not significant (P=0.4875). This was because two of the lowest mean water temperatures occurred during two of the highest vegetation years, 1983 and 1984 (Figure 31); and the effect of cooler water was overridden by the amount of previous years' vegetation coverage. Removing these two years from the regression yielded a significant relationship (r=0.55, P=0.0290).

Two multiple regression models explained large percentages of the variance in aquatic macrophyte coverage in Chickamauga Reservoir, 1975-92. The better model was:

Sumbersed aquatic macrophytes, hectares =

- 8347.71 + 0.67(Previous season's coverage, hectares)

+ 153.15(Sunlight availability, percentage)

where: $R^2 = 0.85$ F = 43.02 Prob>F = 0.0001; n = 18.

The second model was:

Sumbersed aquatic macrophytes, hectares =

2814.26 + 0.77(Previous season's coverage, hectares)

- 0.07(Average March-June daily discharge, cfs)

where: $R^2 = 0.83$ F = 36.6; Prob>F = 0.0001; n = 18.

Because sunlight and discharge were highly correlated (r = -0.84, P = 0.0001), it was inappropriate to include both in the same model.

Herbivorous animals, such as certain species of turtles, can affect the establishment and regrowth of some aquatic macrophytes. This may be especially important when vegetation is sparse. Turtles are trapped and removed from experimental vegetation plantings on Guntersville Reservoir to allow establishment of desirable plant species (Doug Murphy, TVA, personal communication).

Effects of SQN Operation on Aquatic Macrophytes

Because this report has identified populational levels of submersed aquatic macrophytes as having a dramatic effect on the resident fish community in Chickamauga Reservoir, a brief discussion and evaluation of the operational impacts of SQN on aquatic macrophyte communities is included to assess potential indirect impacts to the resident fish community. Macrophyte coverage data used in this analysis would detect only major changes rather than restricted or localized impacts associated with SQN operation.

Since initial operation in 1981, SQN has had no documented effect on growth or distribution of aquatic vegetation in Chickamauga Reservoir. After four years of operation, similarities in trends of vegetation coverage in littoral habitat along mainchannel areas upstream and downstream of SQN showed no significant effect on aquatic macrophyte communities (TVA 1985). During most years between 1977 and 1992, vegetation coverage fluctuated similarly in mainchannel habitat downstream of SQN and upstream of SQN, regardless of SQN operational status (Figure 32). During drought years from 1984 to 1988 aquatic macrophyte coverage remained relatively stable or increased in mainchannel habitat both upstream and downstream of SQN. Beginning in 1989 aquatic macrophyte coverage has declined dramatically on Chickamauga Reservoir (Figure 4) in mainchannel areas both upstream and downstream of SQN. In 1992 there was only about 155 ha of aquatic macrophytes in Chickamauga Reservoir (Table 2).

Significant changes that have occurred in aquatic macrophyte populations on Chickamauga Reservoir are considered to be primarily related to environmental factors associated with natural climatic events such as sunlight availability, water clarity, and flow and not the operational status of SQN. The increase in aquatic macrophyte coverage during the drought years from 1984 to 1988, followed by a dramatic decline in 1989 and 1990 is similar to that of other mainstream reservoirs such as Kentucky, Wheeler, and Guntersville (Figure 5). Because changes in aquatic macrophyte communities are related to factors other than the operational status of SQN, indirect effects of SQN to fish populations are minimal.

CONCLUSIONS

Aquatic macrophytes in the littoral zones of Chickamauga Reservoir have a profound effect on the fish community. Total numbers and biomass of all fish species combined increased with submersed aquatic vegetation coverage. Certain species (golden shiner, yellow bass, warmouth, bluegill, redbreast sunfish, largemouth bass, black crappie, yellow perch, and brook silverside) are favored by increasing vegetation, while others (carp, smallmouth buffalo, spotted sucker, channel catfish, white crappie, and freshwater drum) are hindered. The forage base for piscivorous predators is primarily shad when aquatic vegetation is sparse and small sunfish when vegetation is dense.

The dominant species of vegetation, i.e., milfoil and naiads, differ in leaf morphology and growth form and provide different habitats for invertebrates and fish. This is believed to affect the abundance of many fish species in Chickamauga Reservoir. Based on preliminary analysis, milfoil appears more beneficial to most of the important gamefish species than spinyleaf naiad because of its growth form.

Black crappie and white crappie abundances are oppositely affected by dense growth of aquatic macrophytes. Young black crappie benefit from an increased invertebrate food source and protective habitat within macrophyte colonies, while white crappie prefer deeper, open-water habitats and do not benefit from shoreline vegetation. Both species are in competition for zooplanktonic food with enormous numbers of young gizzard and threadfin shad and, in seasons of abundant aquatic macrophytes, young of three sunfish species. Clear water in Chickamauga Reservoir during the drought years of the 1980s also contributed to the shift in dominance from white crappie to black crappie.

Decreases in aquatic macrophyte coverage since 1989 should result in a restructuring of the fish community that would reverse some of the trends presented in this report. Species that increased with heavy infestations of aquatic macrophytes are expected to decrease in abundance, while open-water species should increase. White crappie are expected to return as the dominant crappie species in Chickamauga Reservoir.

Factors identified as affecting submersed aquatic macrophyte coverage were macrophyte coverages from the previous year, sunlight availability, and discharges of the Tennessee River. Water temperature was an important factor in most years. Two factors affecting water clarity, suspended solids and phytoplankton, could not be identified as important factors given the limited amount of available data.

There is no evidence that SQN operation affected the coverage of submersed aquatic macrophytes in Chickamauga Reservoir; thus, there were no indirect effects to the resident fish community.

RECOMMENDATIONS

Further studies of fish communities within milfoil and spinyleaf naiad colonies are needed to verify that differences in community structure of fishes are related to the growth forms of the dominant vegetation species. The present study compared fish densities on an annual basis, and in many years the habitat of the coves was altered by herbicide treatment to facilitate rotenone sampling. Recommended future studies would involve taking rotenone samples in two milfoil-dominated coves and in two similar coves where spinyleaf naiad is the dominant macrophyte. Herbicides would not be used in any of the four coves. All four coves would be sampled during the same summer, and would not be the coves routinely sampled for SQN monitoring.

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Table 1. Fish species showing significant correlation in numerical abundance (numbers/hectare) or weight (kg/hectare) and aquatic macrophyte coverage in Chickamauga Reservoir, 1970-90 by size group*.

Species	Size Group	Slope	F-Value	PR > F
<u>Increasing species</u>				
Total species	YNG_NO	0.00009	52.953	0.0001
Total species	YNG_WT	0.00005	16.842	0.0001
Total species	INT_NO	0.00004	12.612	0.0006
Total species	ADT_NO	0.00004	9.701	0.0025
Total species	ADT_WT	0.00002	5.533	0.0211
Gizzard shad	YNG_NO	0.00021	15.052	0.0002
Gizzard shad	ADT_NO	0.00005	5.495	0.0215
Golden shiner	YNG_NO	0.00020	31.766	0.0001
Carp	YNG_NO	0.00007	17.213	0.0001
Brook silverside	YNG_NO	0.00003	18.379	0.0001
Yellow bass	YNG_NO	0.00008	5.608	0.0203
Yellow bass	INT_NO	0.00010	15.958	0.0001
Yellow bass	ADT_NO	0.00007	17.929	0.0001
Warmouth	YNG_NO	0.00029	101.323	0.0001
Warmouth	INT_NO	0.00012	43.691	0.0001
Warmouth	ADT_NO	0.00008	16.719	0.0001
Bluegill	YNG_NO	0.00011	28.029	0.0001
Bluegill	INT_NO	0.00004	8.434	0.0047
Redear sunfish	YNG_NO	0.00029	90.765	0.0001
Redear sunfish	INT_NO	0.00009	16.591	0.0001
Largemouth bass	YNG_NO	0.00008	13.553	0.0004
Largemouth bass	INT_NO	0.00007	16.721	0.0001
Black crappie	YNG_NO	0.00007	7.933	0.0061
Black crappie	INT_NO	0.00005	12.125	0.0008
Yellow perch	YNG_NO	0.00011	10.140	0.0021
<u>Decreasing species</u>				
Carp	ADT_NO	-0.00007	13.856	0.0004
Smallmouth buffalo	INT_NO	-0.00004	8.922	0.0037
Smallmouth buffalo	ADT_NO	-0.00005	6.777	0.0110
Spotted sucker	YNG_NO	-0.00009	10.875	0.0014
Spotted sucker	ADT_NO	-0.00008	13.301	0.0005
Channel catfish	YNG_NO	-0.00004	8.474	0.0047
Channel catfish	INT_NO	-0.00009	28.297	0.0001
White crappie	ADT_NO	-0.00011	30.338	0.0001
Sauger	YNG_NO	-0.00003	8.439	0.0047
Sauger	INT_NO	-0.00002	6.717	0.0113
Sauger	ADT_NO	-0.00002	5.928	0.0171
Freshwater drum	YNG_NO	-0.00017	26.305	0.0001
Freshwater drum	INT_NO	-0.00005	5.398	0.0227

* YNG_NO = YOY/ha, INT_NO = intermediates/ha, ADT_NO = adults/ha, YNG_WT + YOY kg/ha, ADT_WT = adult kg/ha.

Table 2. Aquatic macrophytes (hectares) in Chickamauga Reservoir, 1970-92.*

Year	Total	Milfoil	Naiads	Pondweeds	Mixed	Algae
1970	11	-	-	-	-	-
1971	13	-	-	-	-	-
1972	20	-	-	-	-	-
1973	4	-	-	-	-	-
1974	13	-	-	-	-	-
1975	77	-	-	-	-	-
1976	293	-	-	-	-	-
1977	422	-	-	-	-	-
1978	802	190	612	0	tr	0
1979	635	-	-	-	-	-
1980	1,328	482	844	1	0	0
1981	2,188	1,225	879	79	4	0
1982	2,626	701	1,827	85	13	0
1983	2,791	759	1,921	2	48	60
1984	2,161	292	1,788	0	116	3
1985	2,275	341	1,799	13	114	8
1986	2,778	477	1,853	3	438	7
1987	2,770	465	1,994	23	267	21
1988	3,017	849	1,901	8	251	8
1989	1,388	869	312	11	221	tr
1990	861	638	69	17	134	4
1991	275	100	8	11	149	tr
1992	155	71	27	9	24	6

tr--less than 0.5

* Coverages for 1970-77 and 1979 are estimates from surveys and herbicide treatment records; coverages for 1978 and 1980-92 were determined by aerial photography.

Table 3. Angling summary for black bass in Chickamauga Reservoir, 1977-92.*

Year	Estimated Hours	Estimated Trips	Estimated Number Harvested	Estimated Weight Harvested	Harvest Rate (No./Hr)	Mean Weight (Lbs.)	Estimated Weight Per Acre
1977	35,331	8,251	5,014	6,736	0.141	1.34	0.19
1978	28,418	6,675	5,931	6,792	0.208	1.15	0.19
1979	44,171	9,830	11,930	14,010	0.270	1.17	0.39
1980	123,020	28,829	17,760	25,989	0.144	1.46	0.73
1981	123,304	26,909	22,730	28,027	0.184	1.23	0.79
1982	163,736	36,088	31,332	41,000	0.191	1.31	1.15
1983	132,551	27,022	39,983	48,765	0.301	1.22	1.37
1984	113,106	23,310	36,654	41,720	0.324	1.14	1.17
1985	135,017	29,840	23,006	27,943	0.170	1.21	0.78
1986	-	-	-	-	-	-	-
1987	291,517	58,733	46,355	57,996	0.159	1.25	1.63
1988	336,764	114,336	125,686	70,233	0.373	0.56	1.98
1989	273,732	53,399	43,477	54,795	0.158	1.26	1.54
1990	449,698	86,198	42,030	54,314	0.093	1.29	1.53
1991	598,039	189,486	63,971	84,542	0.106	1.32	2.39
1992	281,895	104,793	30,846	41,951	0.120	1.36	1.19

* TWRA 1992, 1993.

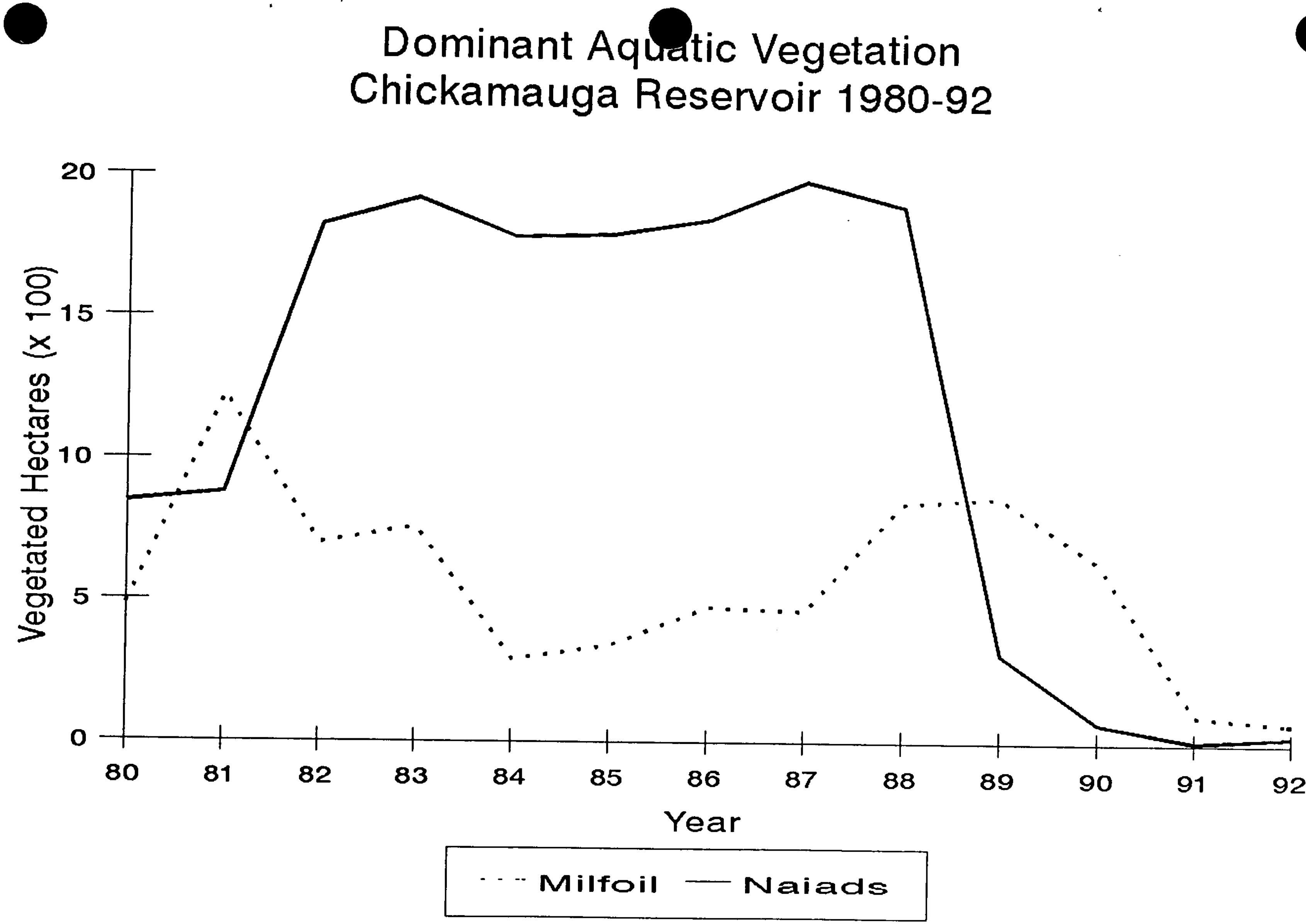


Figure 1. Coverages (hectares) of Eurasian watermilfoil and spinyleaf naiad in Chickamauga Reservoir, 1980-92.

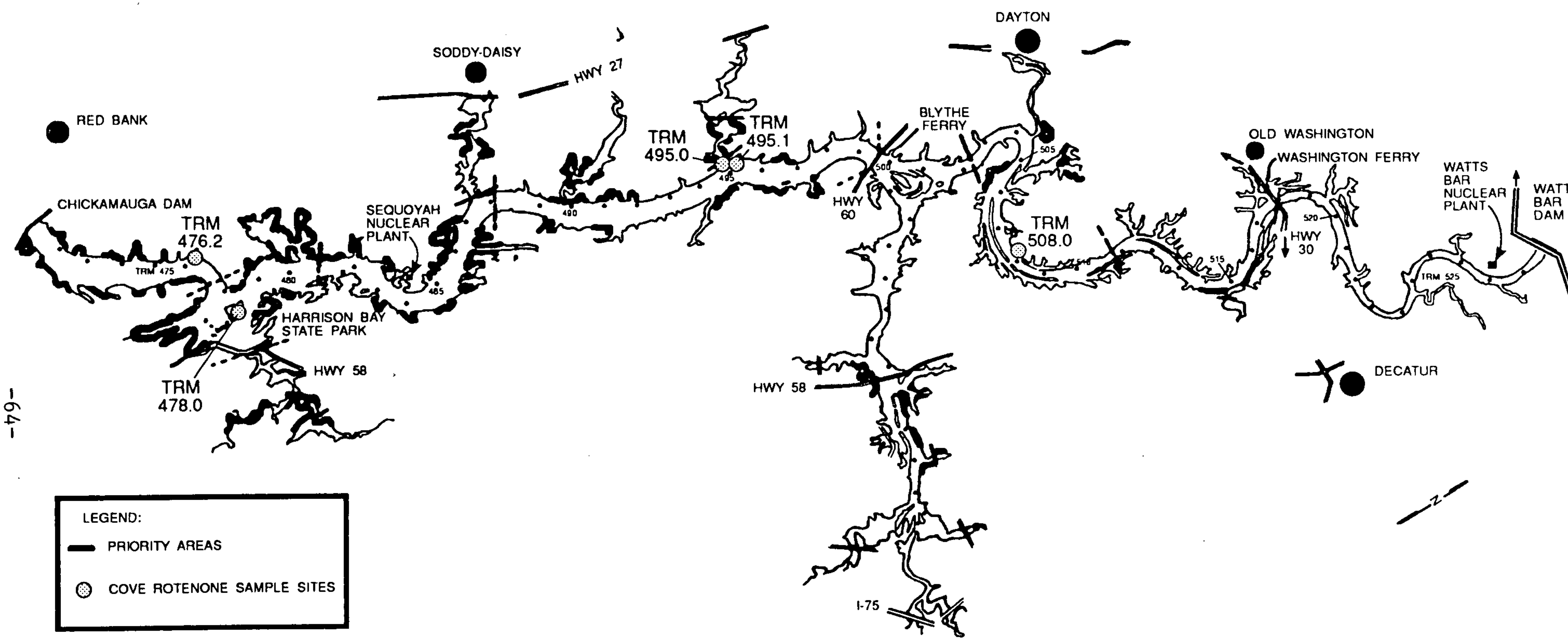


Figure 2. Locations of cove rotenone sample sites and priority areas treated with herbicides in Chickamauga Reservoir, 1970-90.

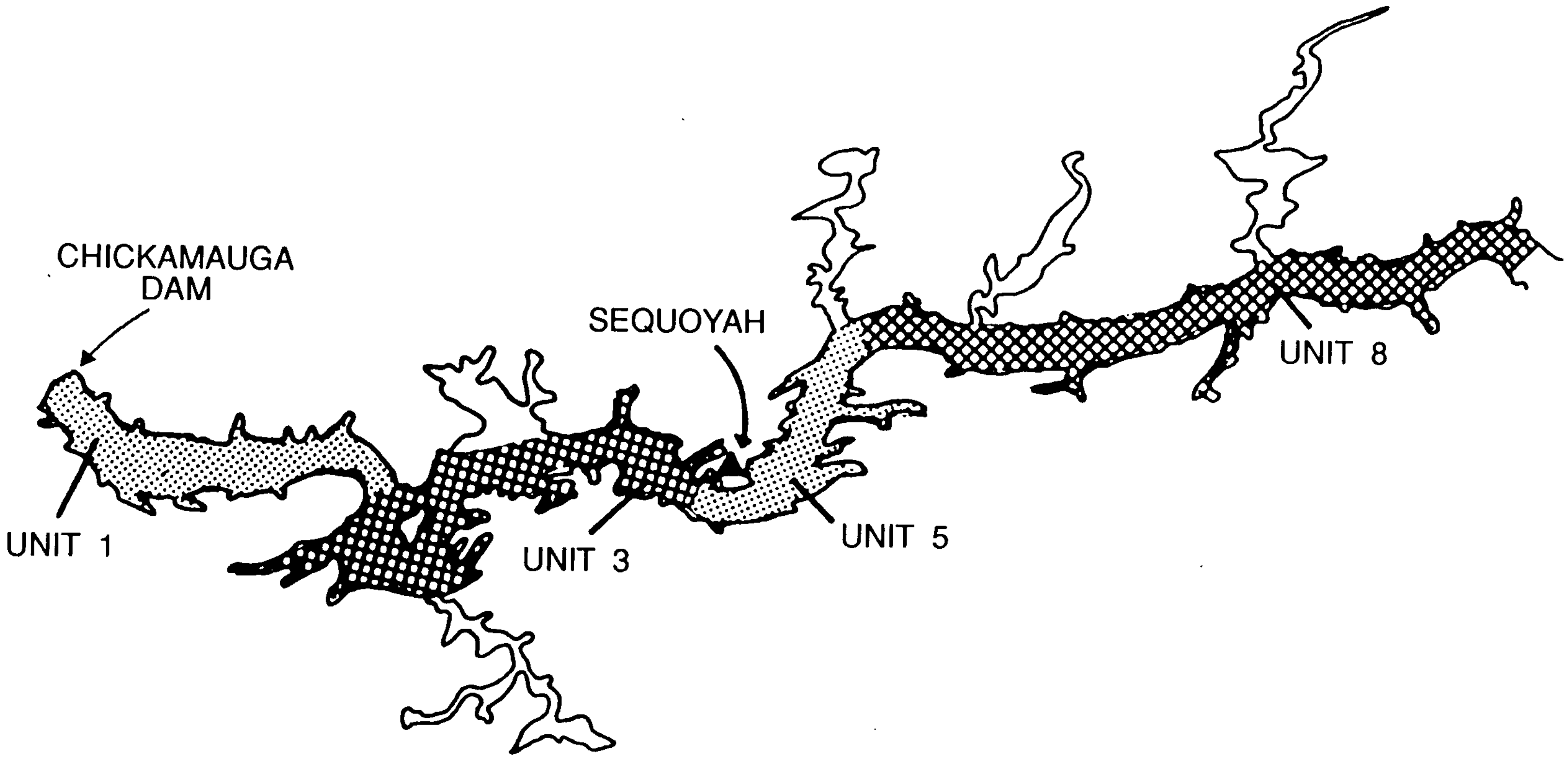


Figure 3. Mainchannel aquatic plant management units on Chickamauga Reservoir in the vicinity of SQN.

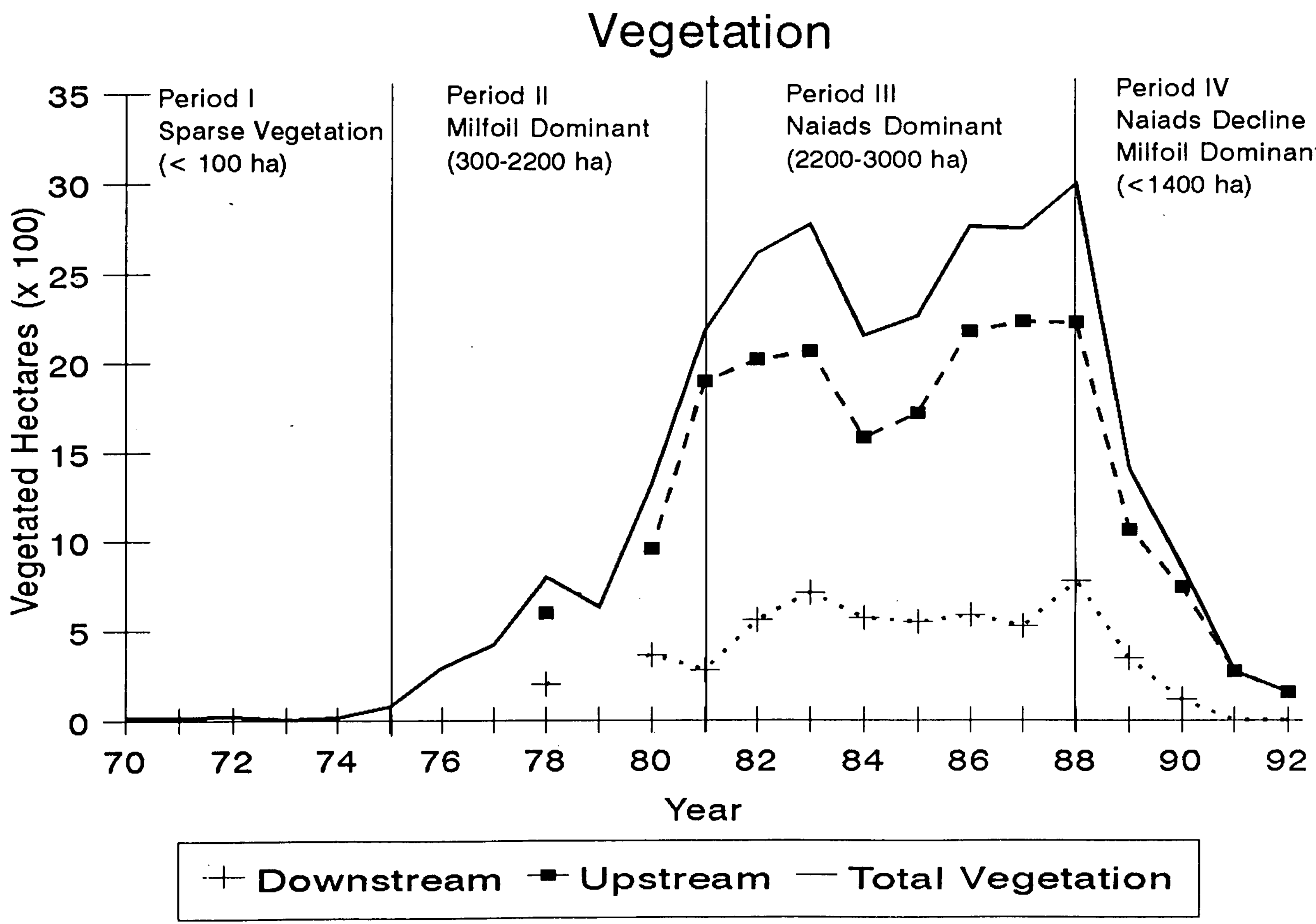


Figure 4. Total coverage of aquatic macrophytes in Chickamauga Reservoir (solid line), upstream and downstream from SQN (dashed lines), and four time periods based on extent of macrophyte coverage and dominant species present, 1970-92.

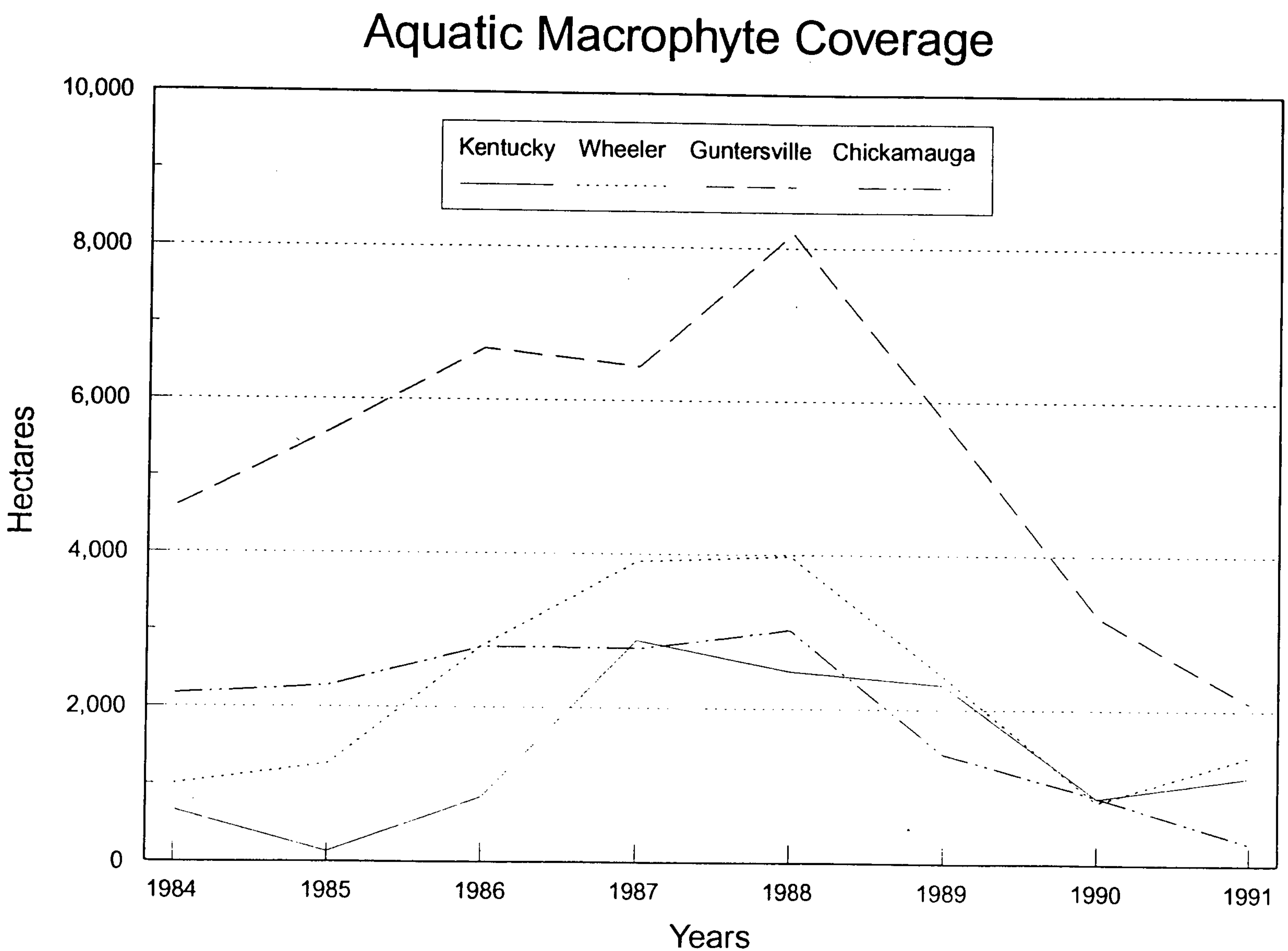


Figure 5. Total macrophyte coverages of four TVA mainstream reservoirs, 1984-91.

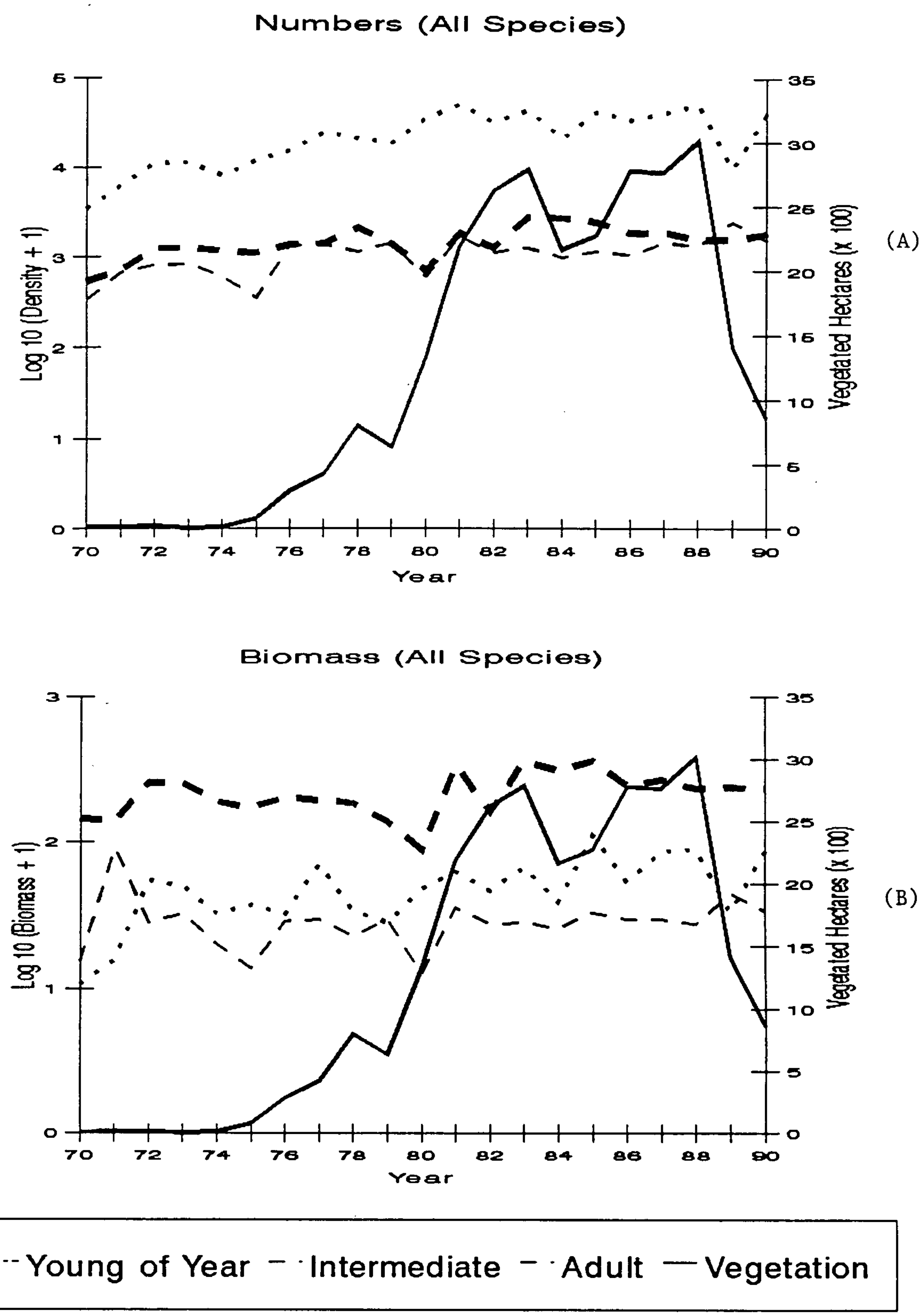


Figure 6. Annual standing stock densities (A, numbers/hectare) of all species combined and biomass (B, kg/hectare) as determined by cove rotenone sampling, 1970-90.

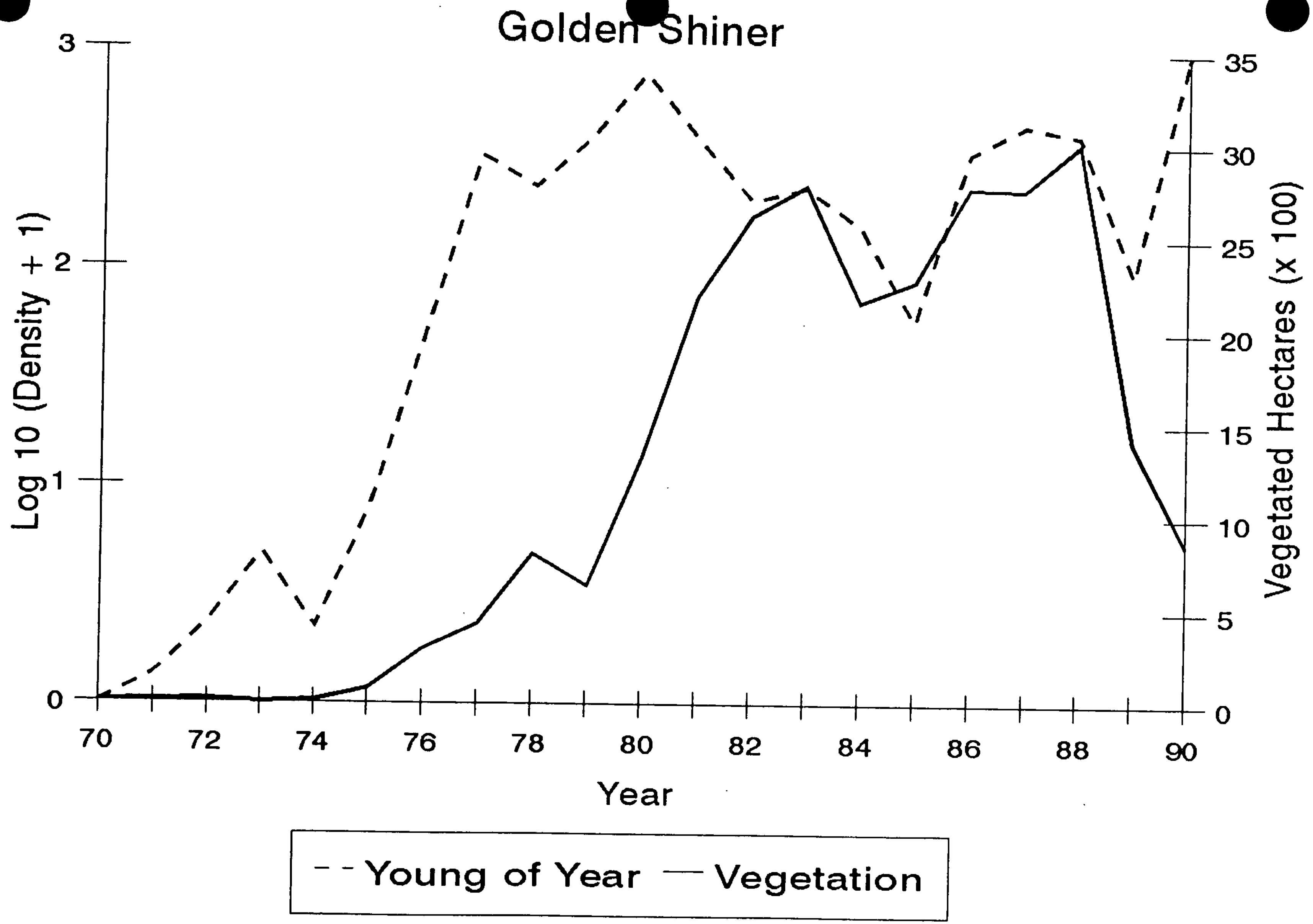


Figure 7. Annual standing stock densities (numbers/hectare) of golden shiner, as determined by cove rotenone sampling, 1970-90.

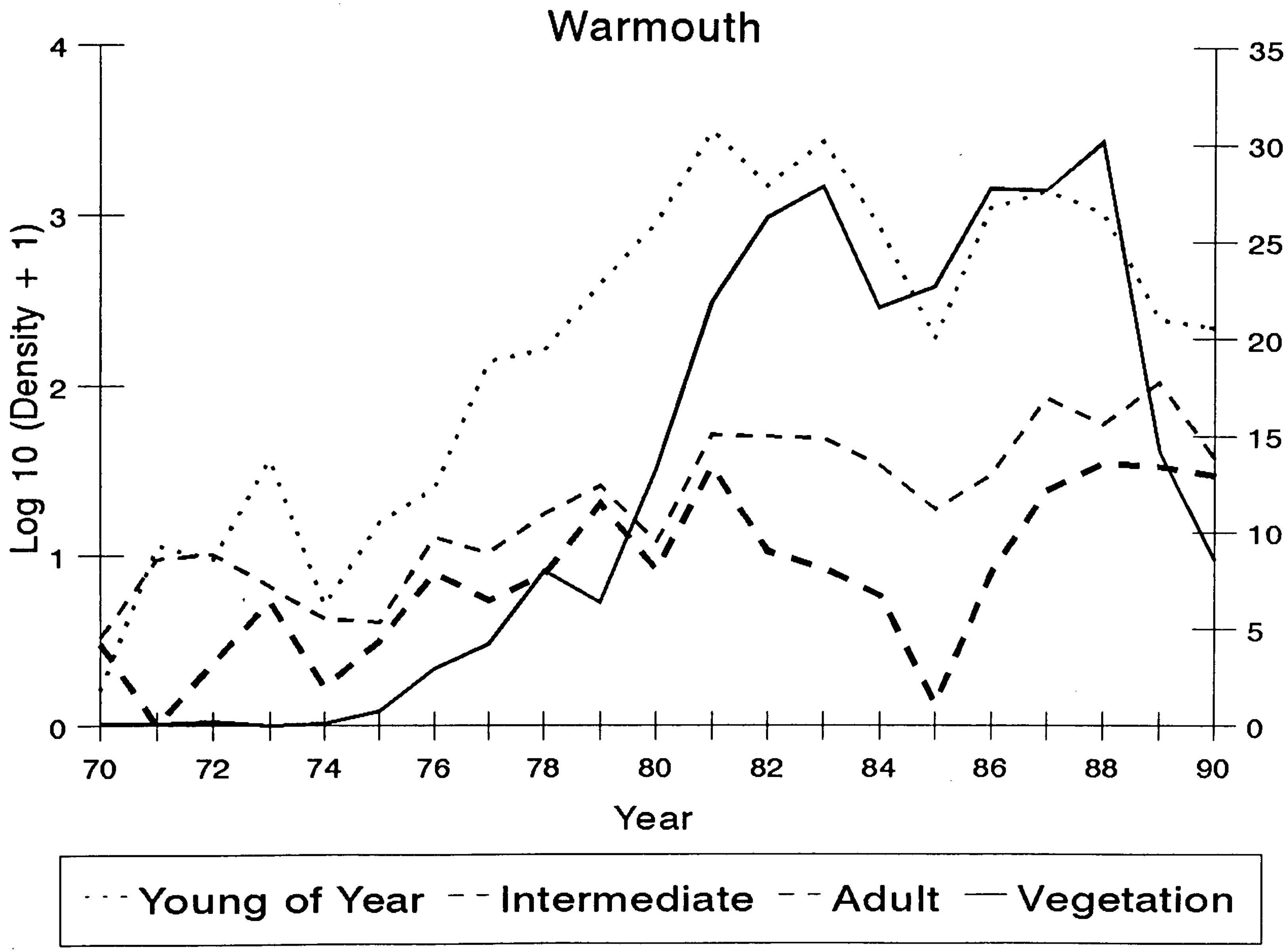


Figure 8. Annual standing stock densities (numbers/hectare) of warmouth, as determined by cove rotenone sampling, 1970-90.

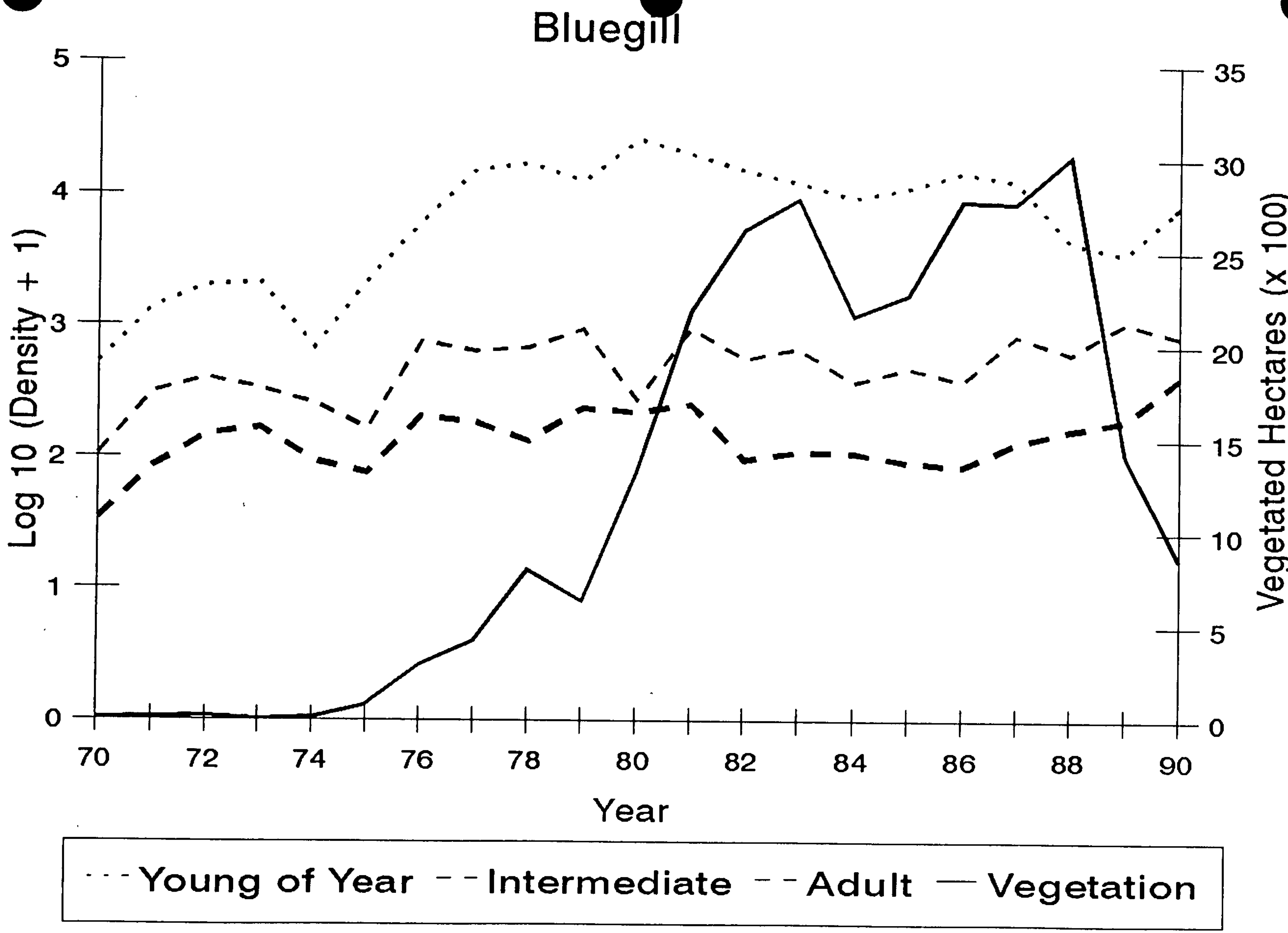
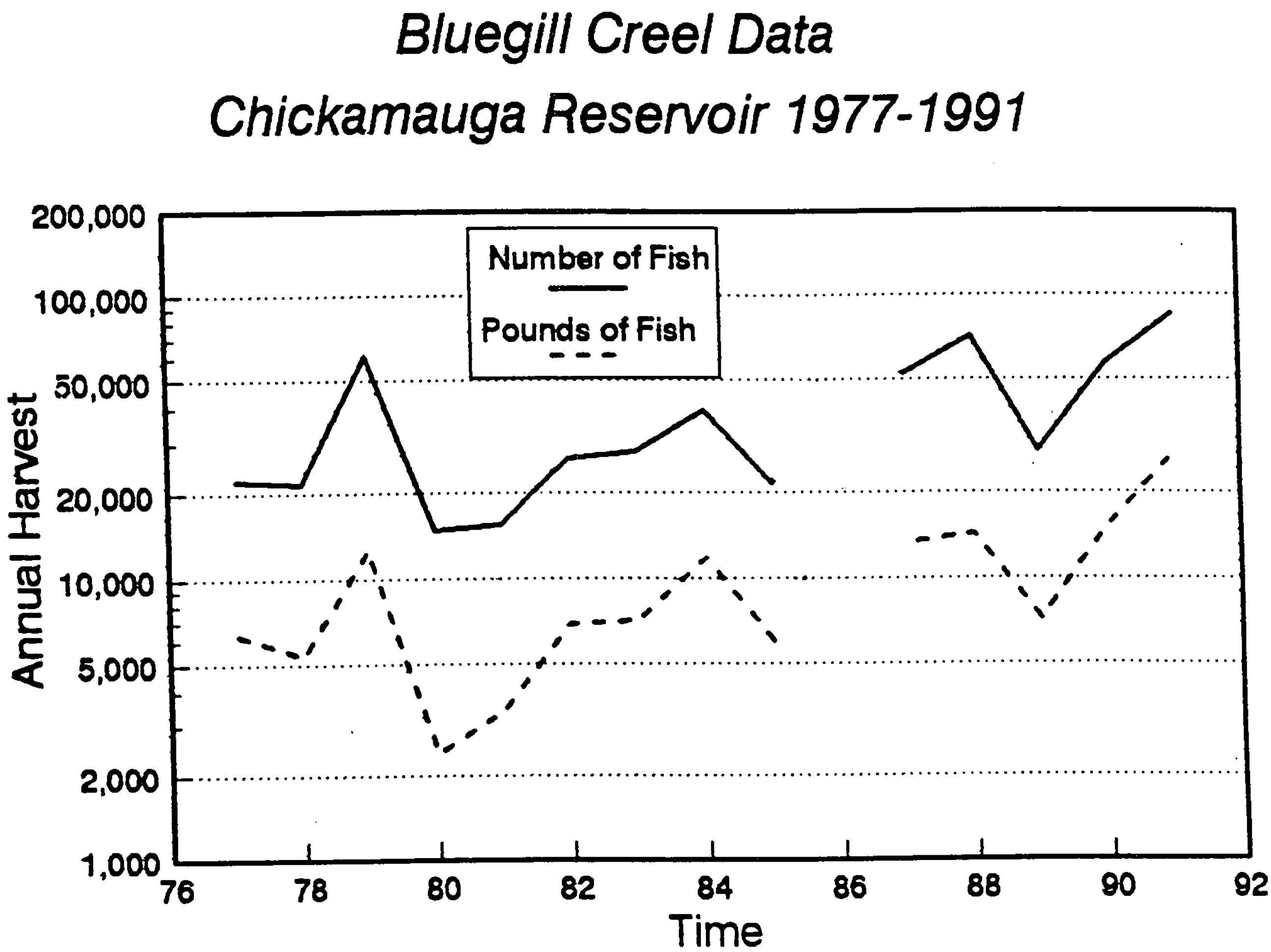
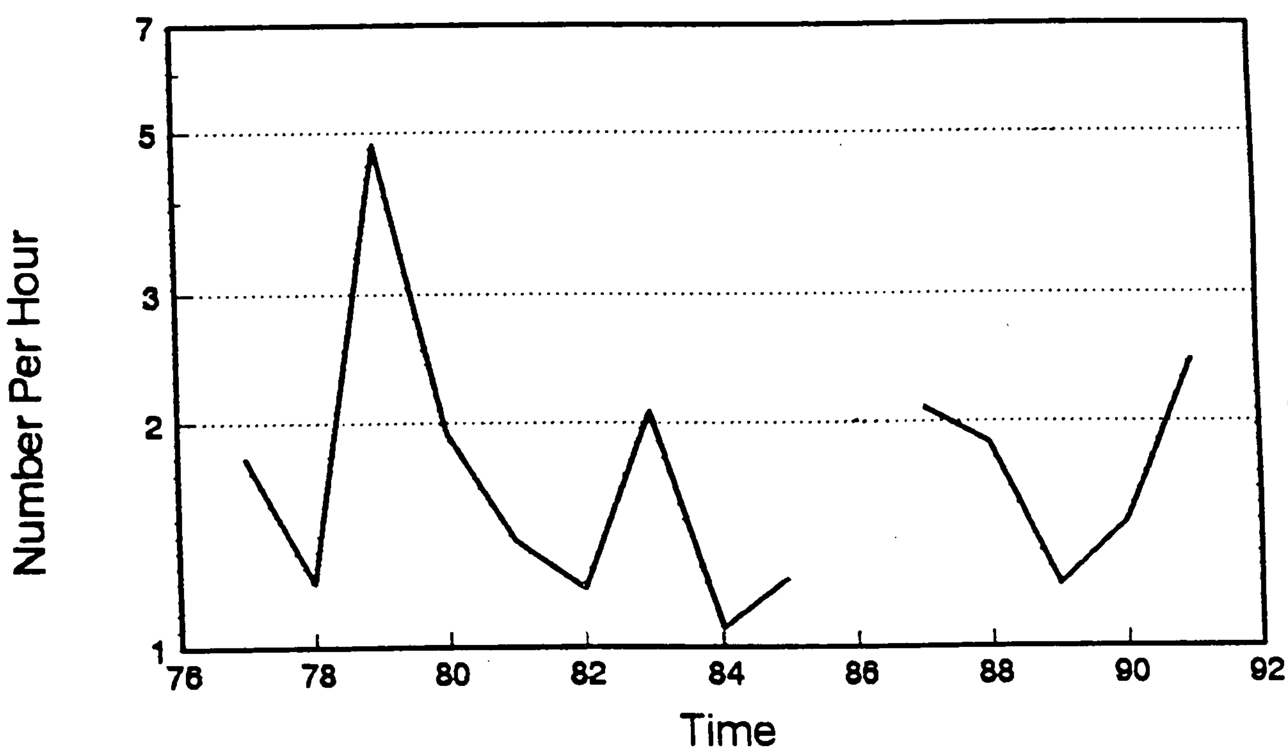


Figure 9. Annual standing stock densities (numbers/hectare) of bluegill, as determined by cove rotenone sampling, 1970-90.



(A)



(B)

Figure 10. Estimates of creel harvest (numbers and pounds) of bluegill (A) and catch per hour, (B) 1977-91 (TWRA data).

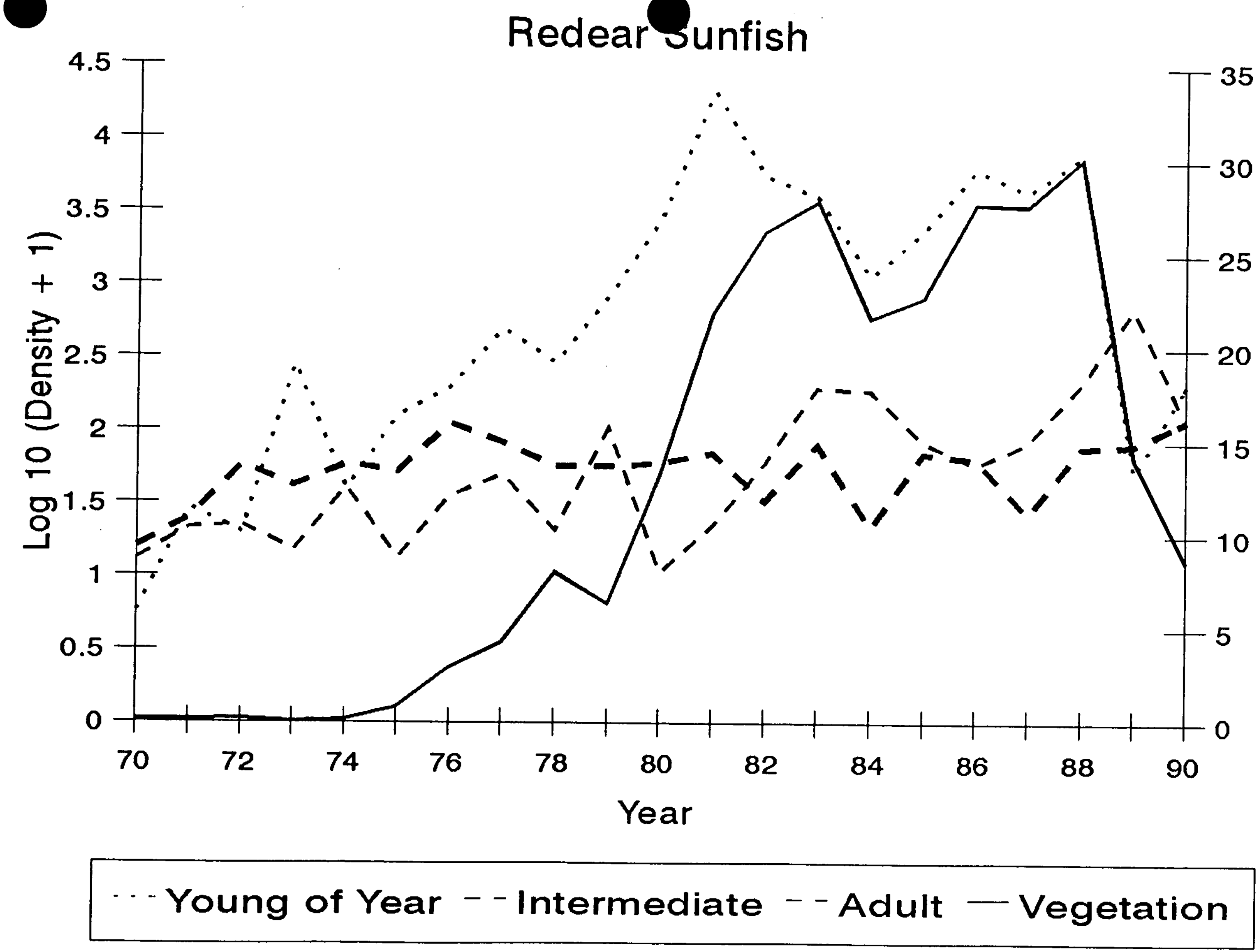


Figure 11. Annual standing stock densities (numbers/hectare) of redear sunfish, as determined by cove rotenone sampling, 1970-90.

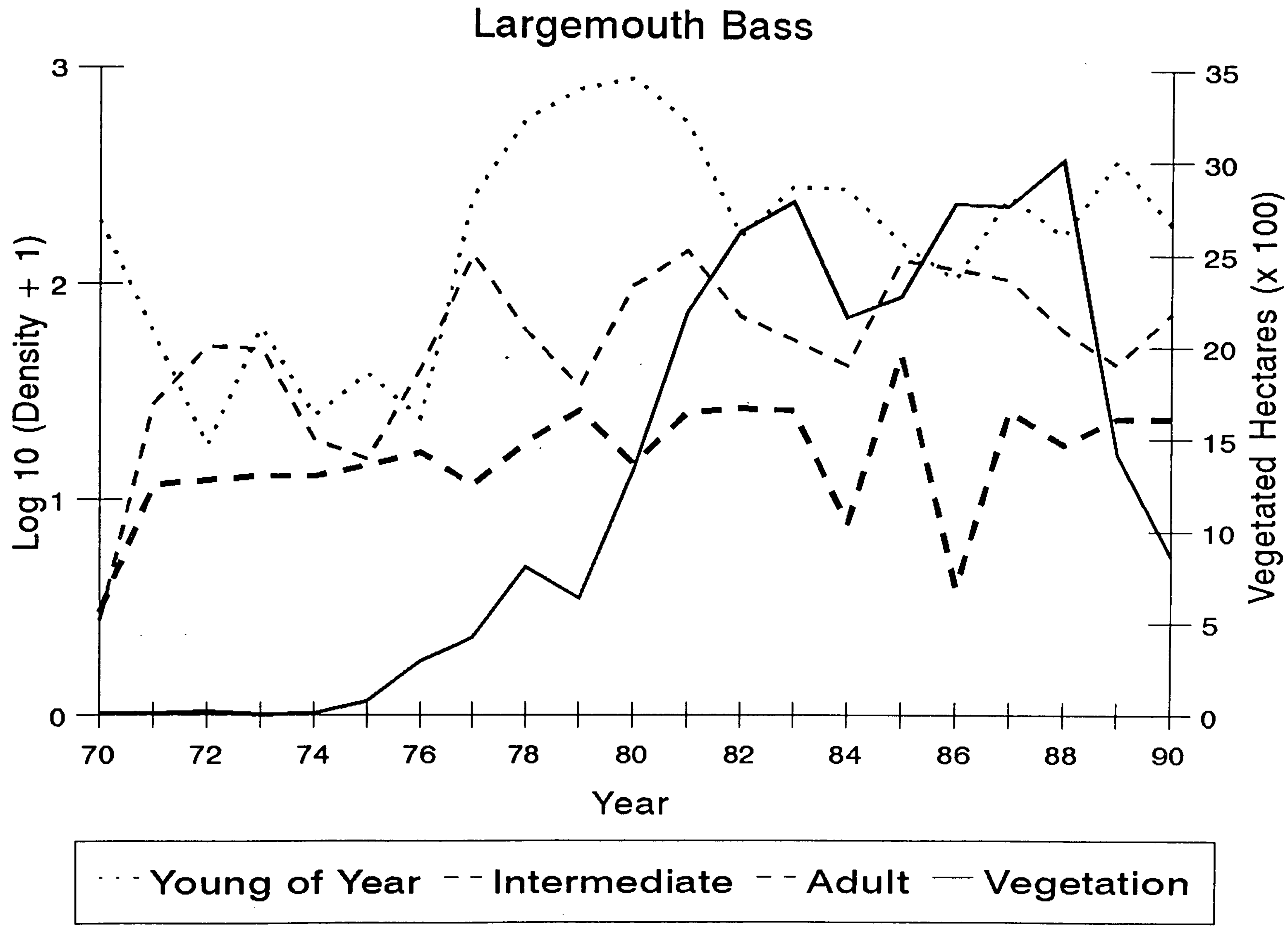


Figure 12. Annual standing stock densities (numbers/hectare) of largemouth bass, as determined by cove rotenone sampling, 1970-90.

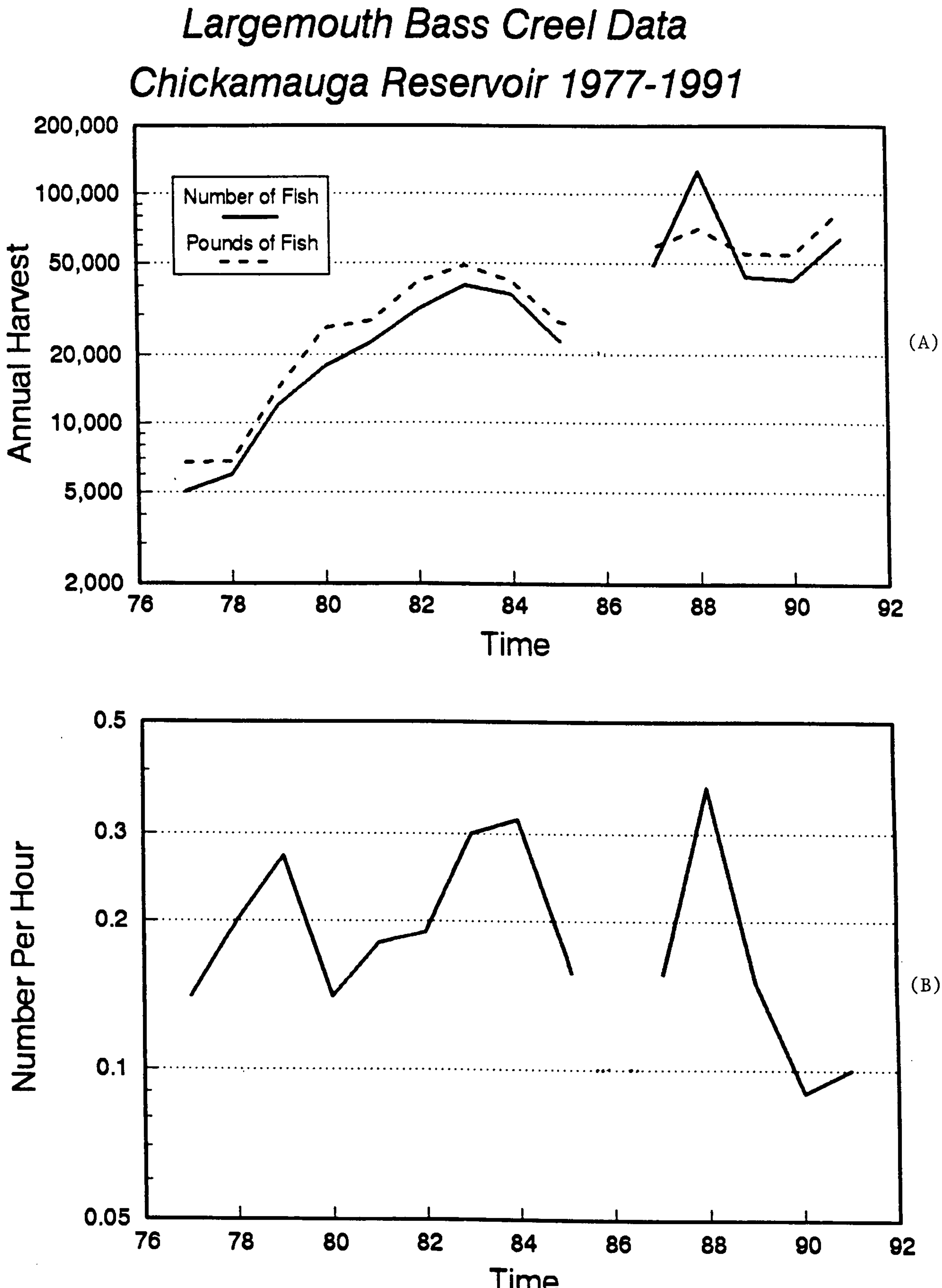


Figure 13. Estimates of creel harvest (numbers and pounds) of largemouth bass (A) and catch per hour, (B) 1977-91 (TWRA data).

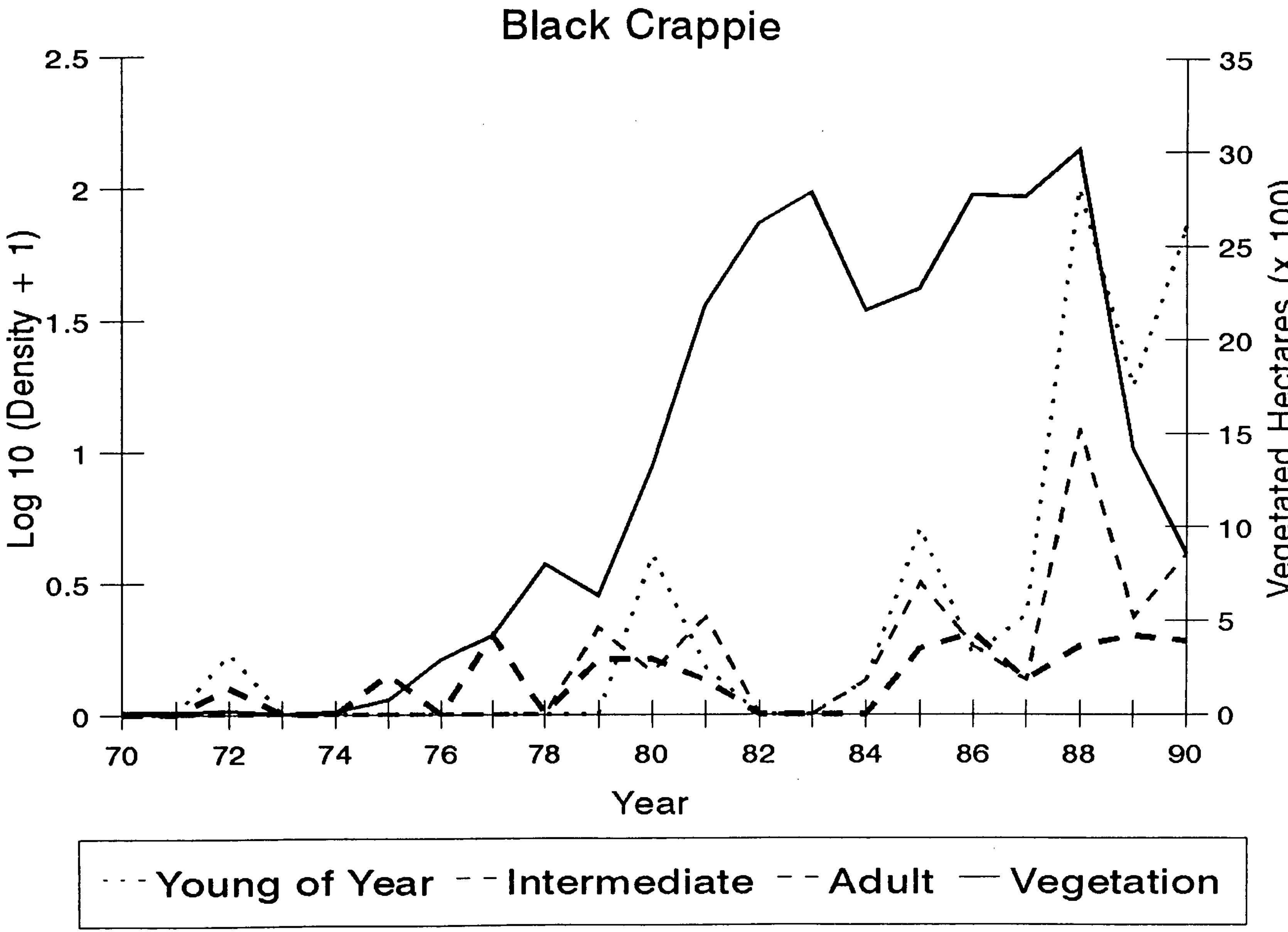


Figure 14. Annual standing stock densities (numbers/hectare) of black crappie, as determined by cove rotenone sampling, 1970-90.

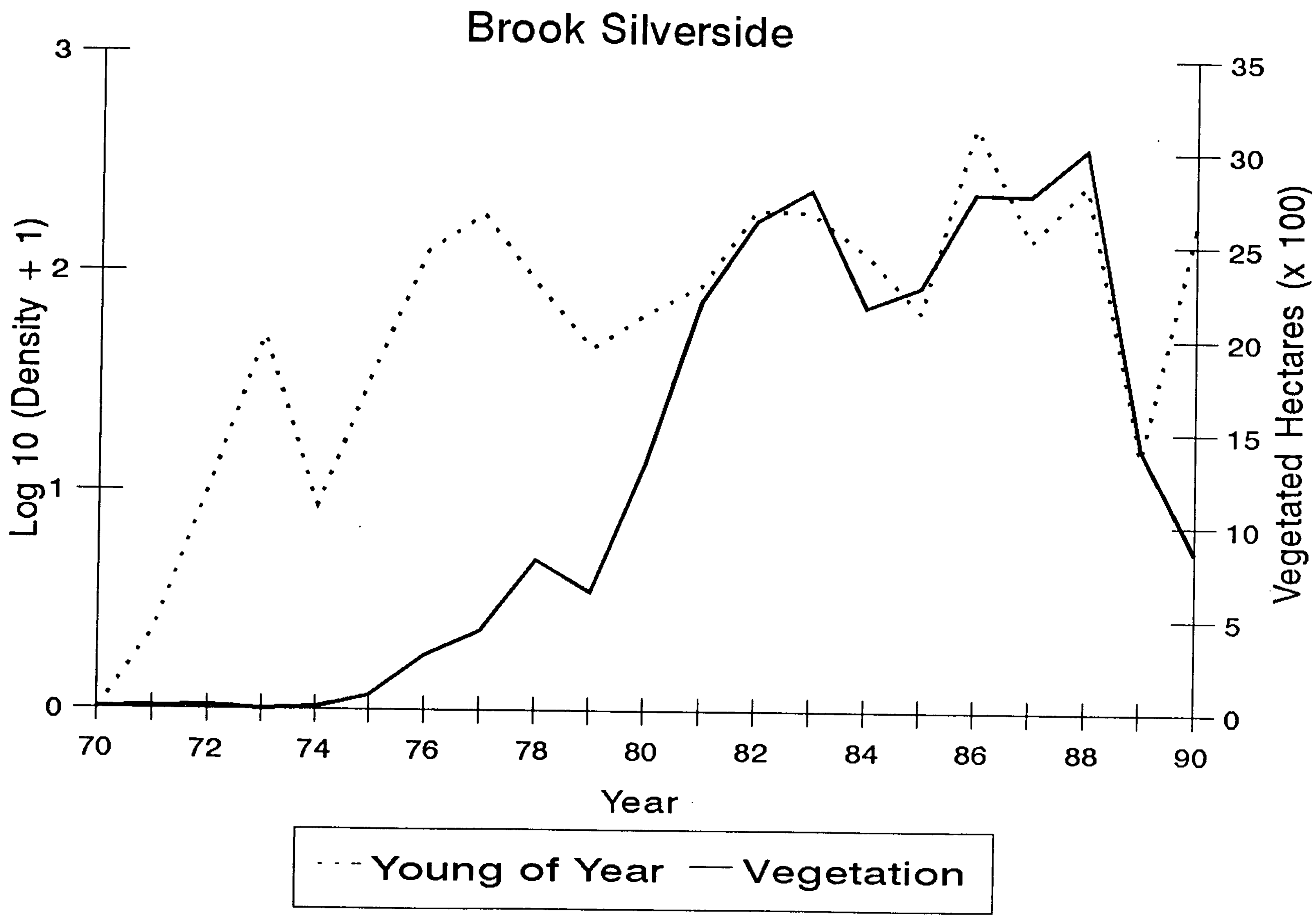


Figure 15. Annual standing stock densities (numbers/hectare) of black crappie, as determined by cove rotenone sampling, 1970-90.

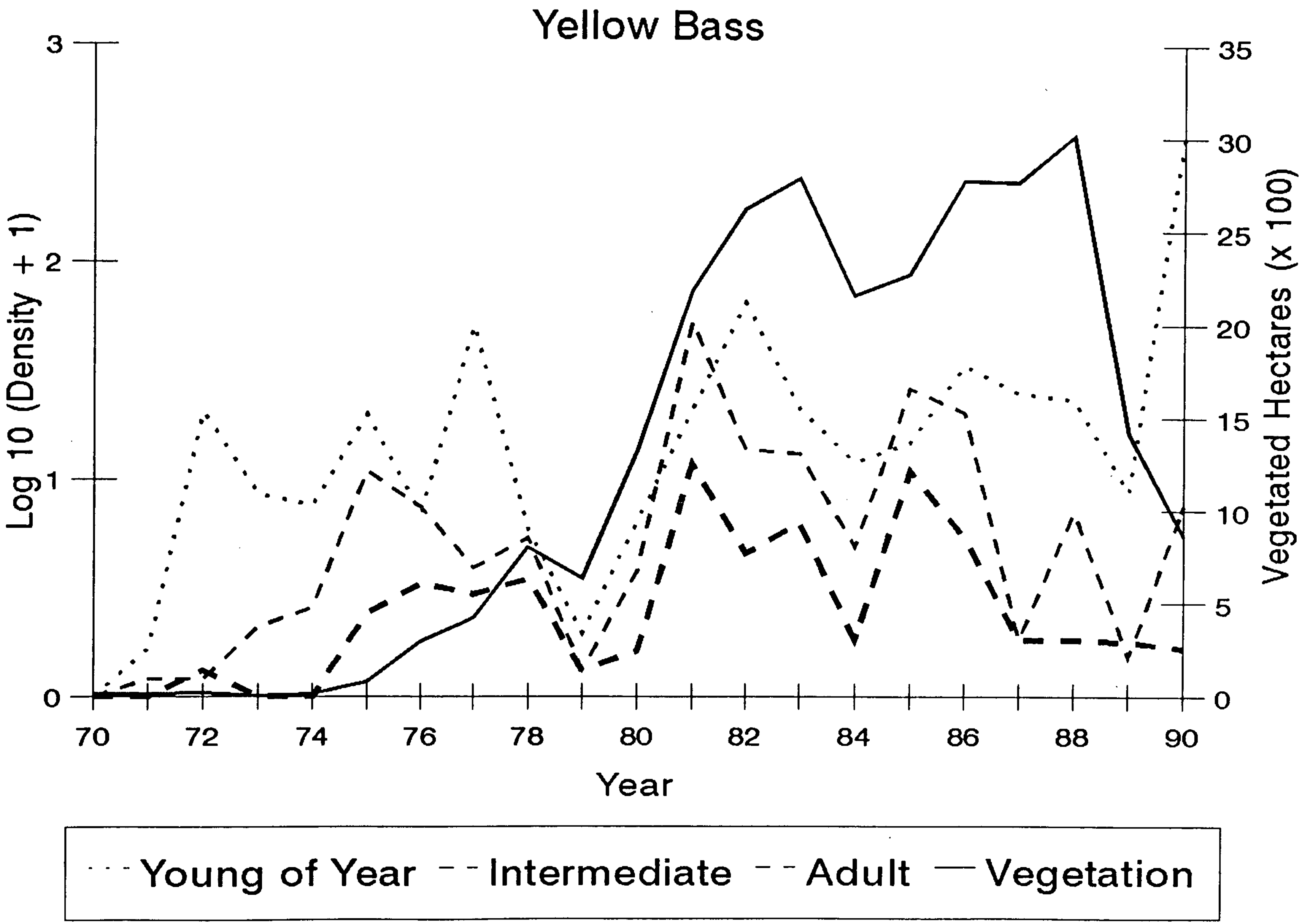


Figure 16. Annual standing stock densities (numbers/hectare) of yellow bass, as determined by cove rotenone sampling, 1970-90.

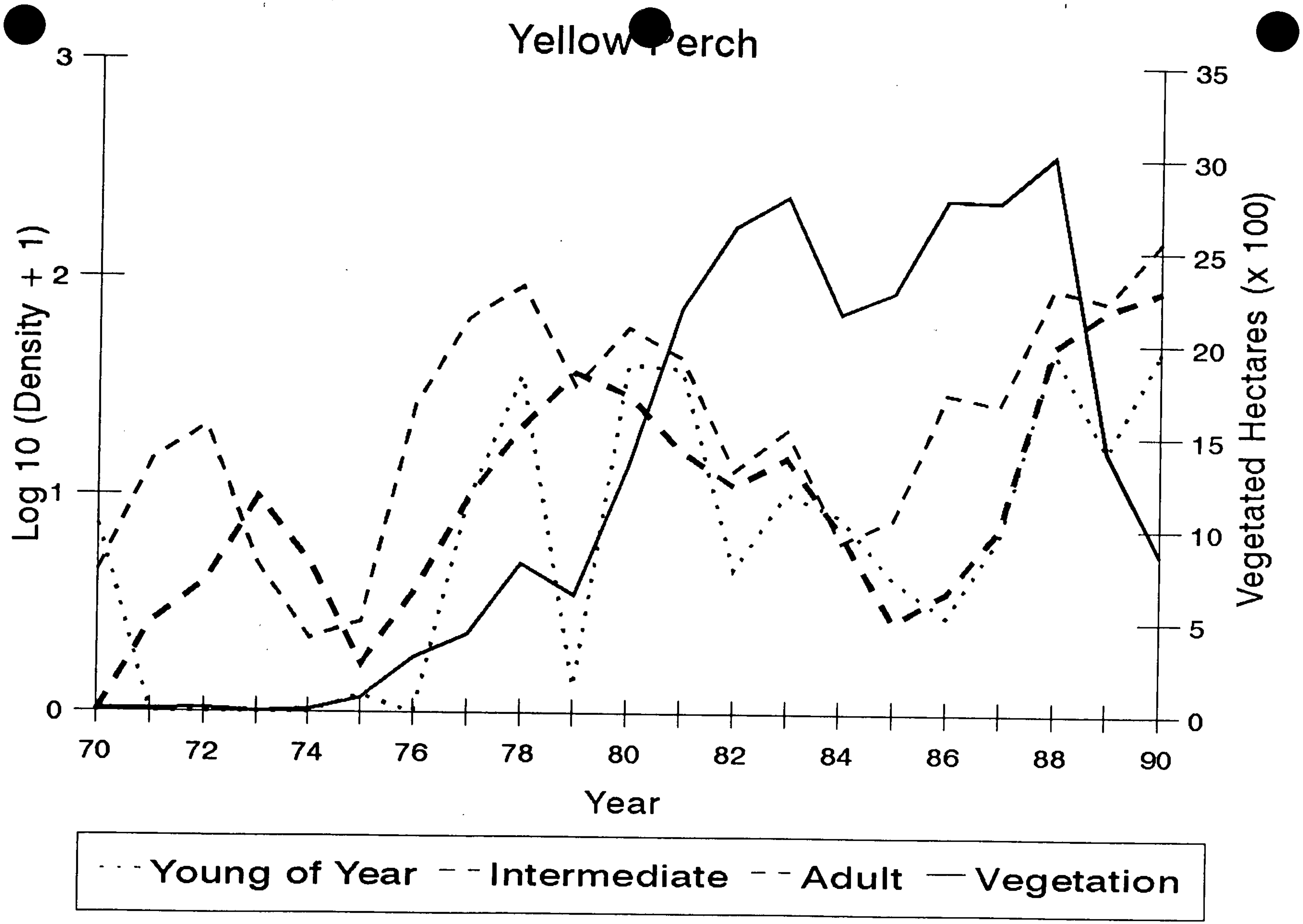


Figure 17. Annual standing stock densities (numbers/hectare) of yellow perch, as determined by cove rotenone sampling, 1970-90.

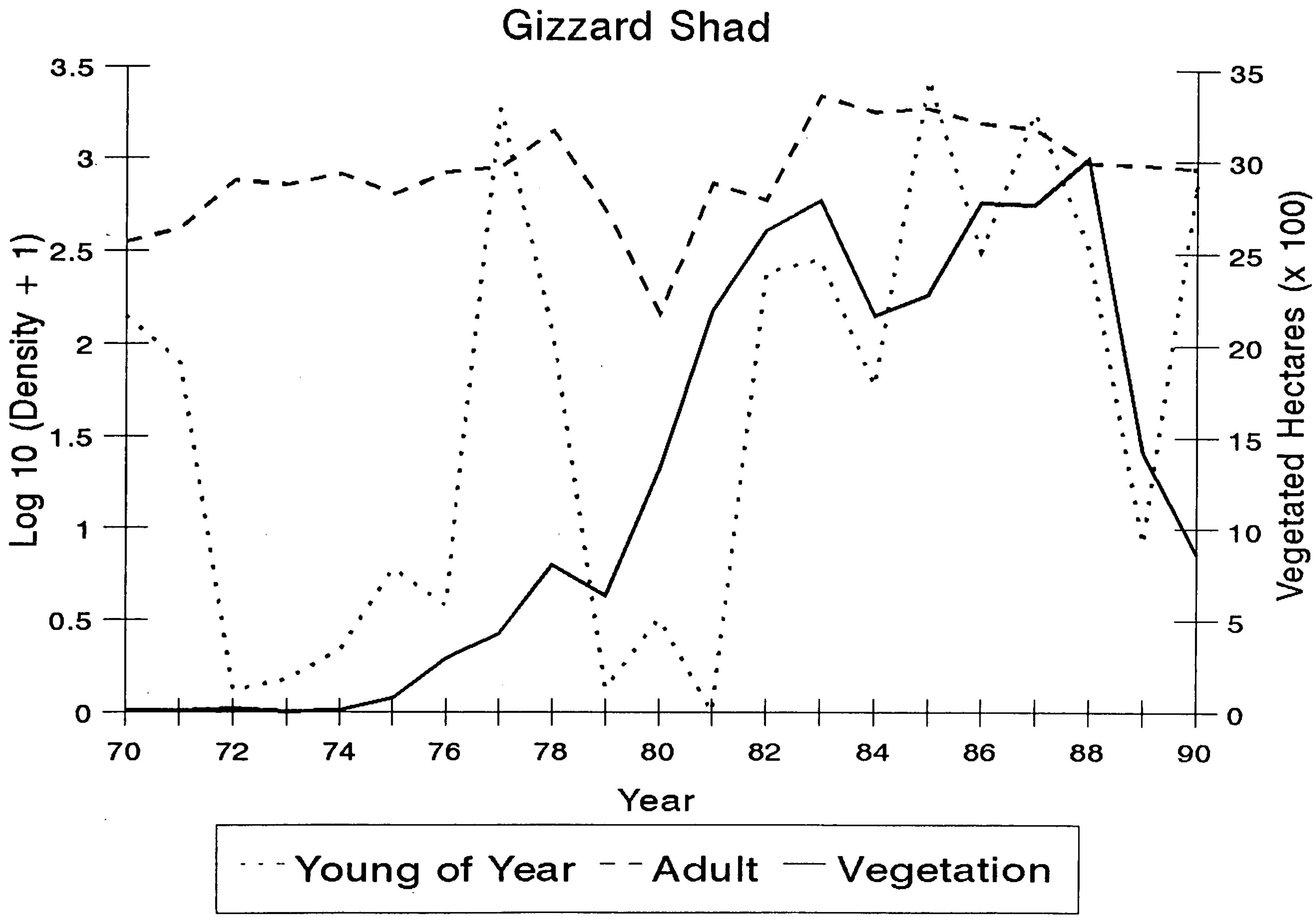


Figure 18. Annual standing stock densities (numbers/hectare) of gizzard shad, as determined by cove rotenone sampling, 1970-90.

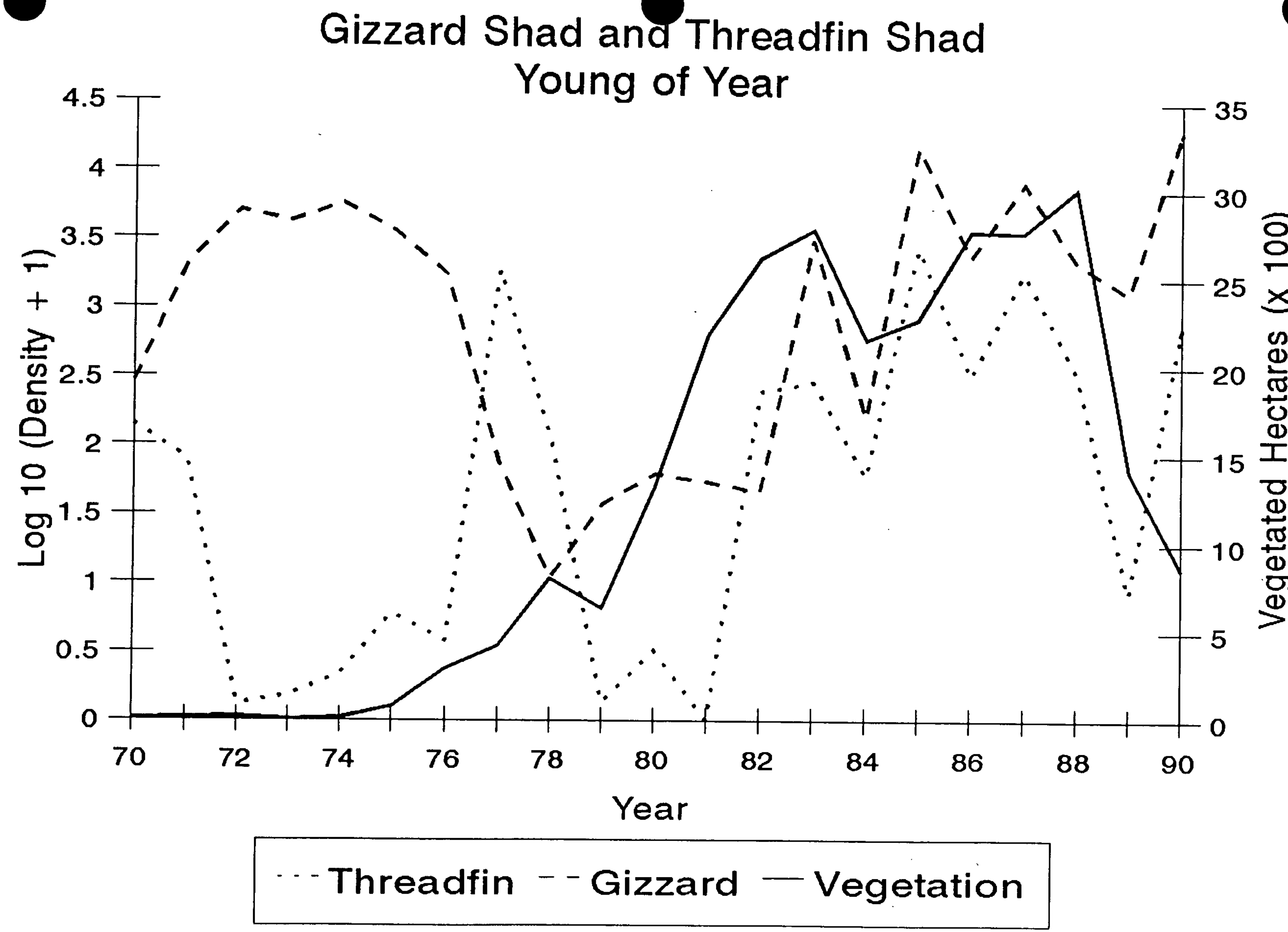


Figure 19. Annual standing stock densities (numbers/hectare) of YOY gizzard shad and threadfin shad, as determined by cove rotenone sampling, 1970-90.

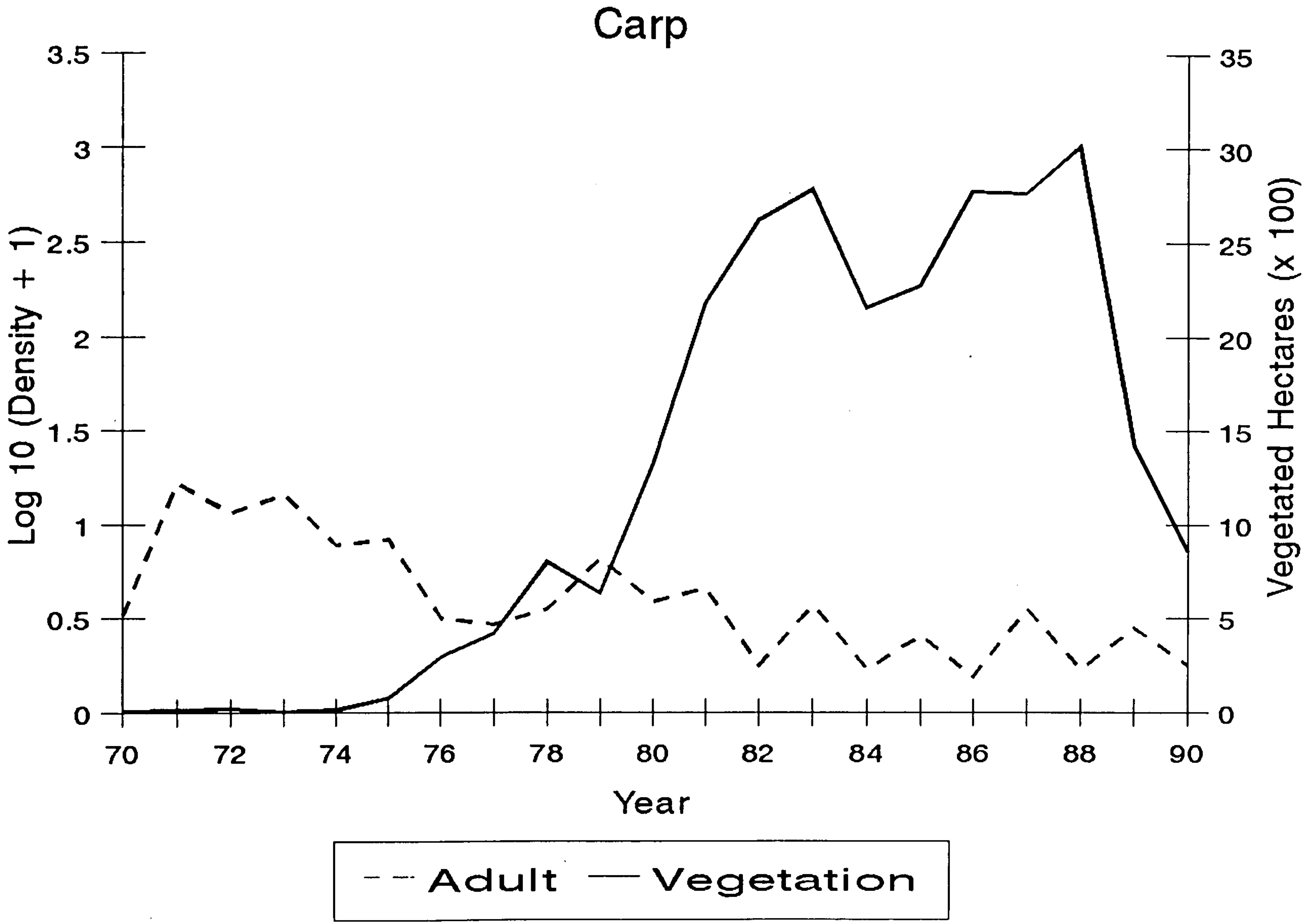


Figure 20. Annual standing stock densities (numbers/hectare) of carp, as determined by cove rotenone sampling, 1970-90.

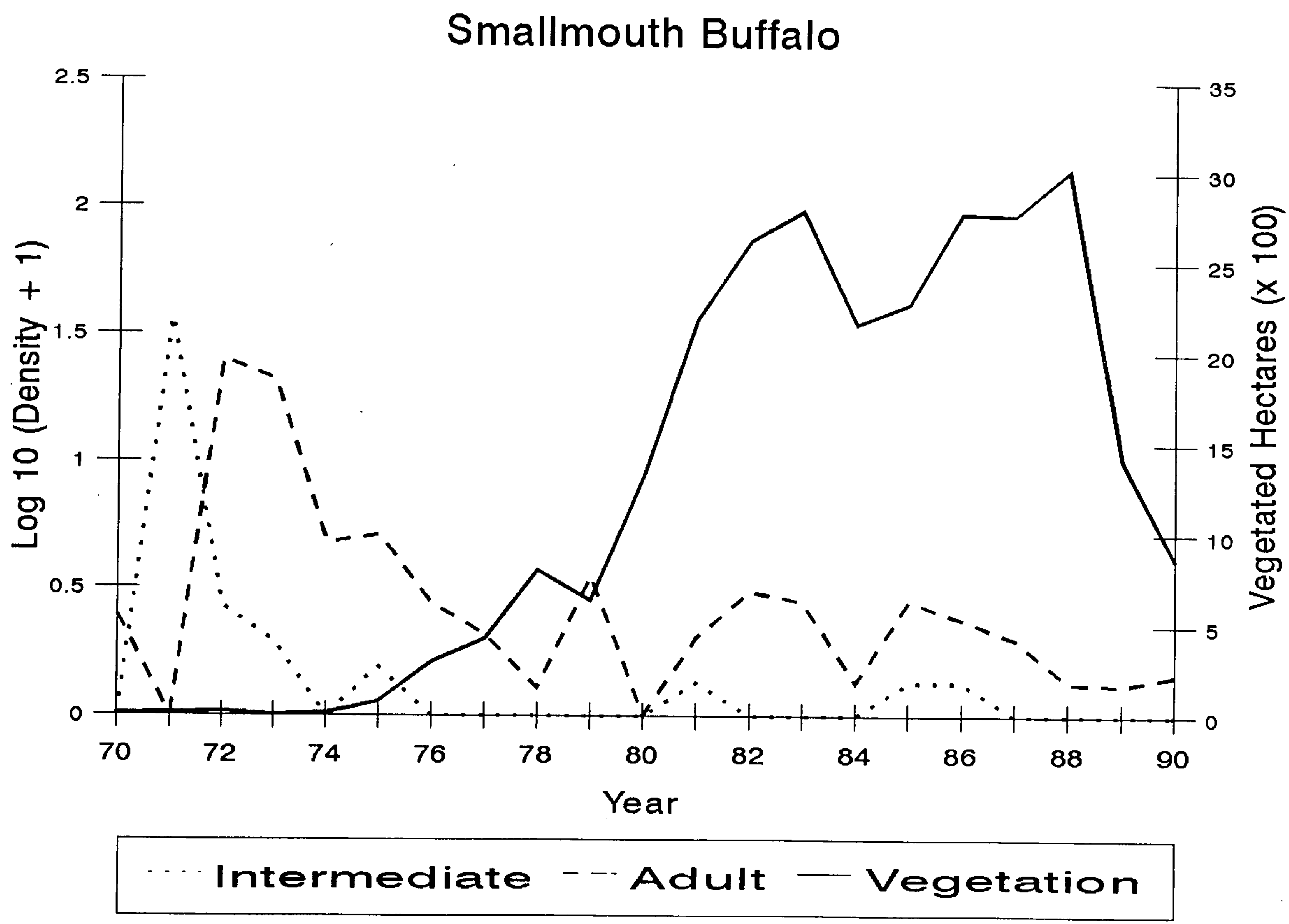


Figure 21. Annual standing stock densities (numbers/hectare) of smallmouth buffalo, as determined by cove rotenone sampling, 1970-90.

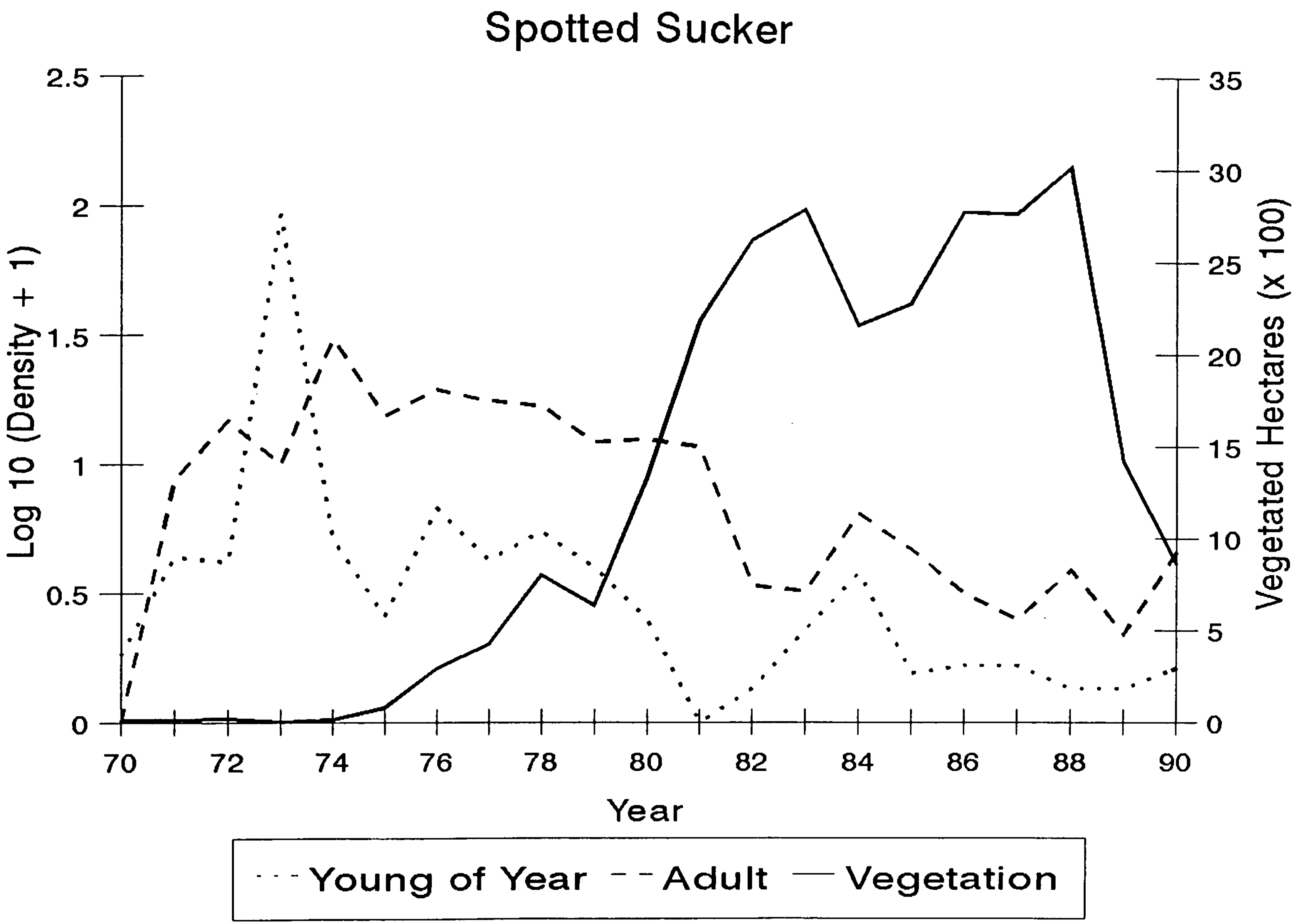


Figure 22. Annual standing stock densities (numbers/hectare) of spotted sucker, as determined by cove rotenone sampling, 1970-90.

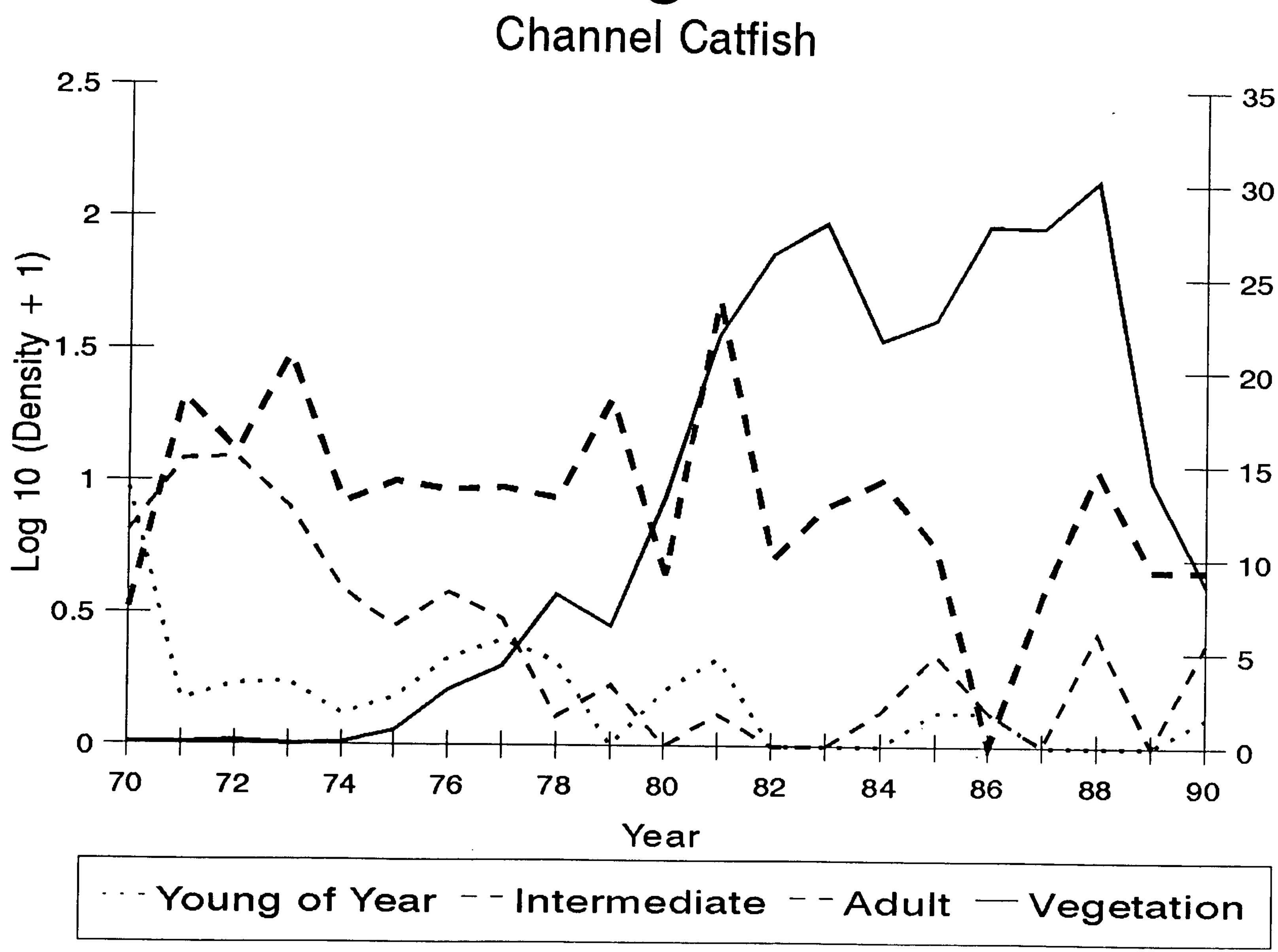


Figure 23. Annual standing stock densities (numbers/hectare) of channel catfish, as determined by cove rotenone sampling, 1970-90.

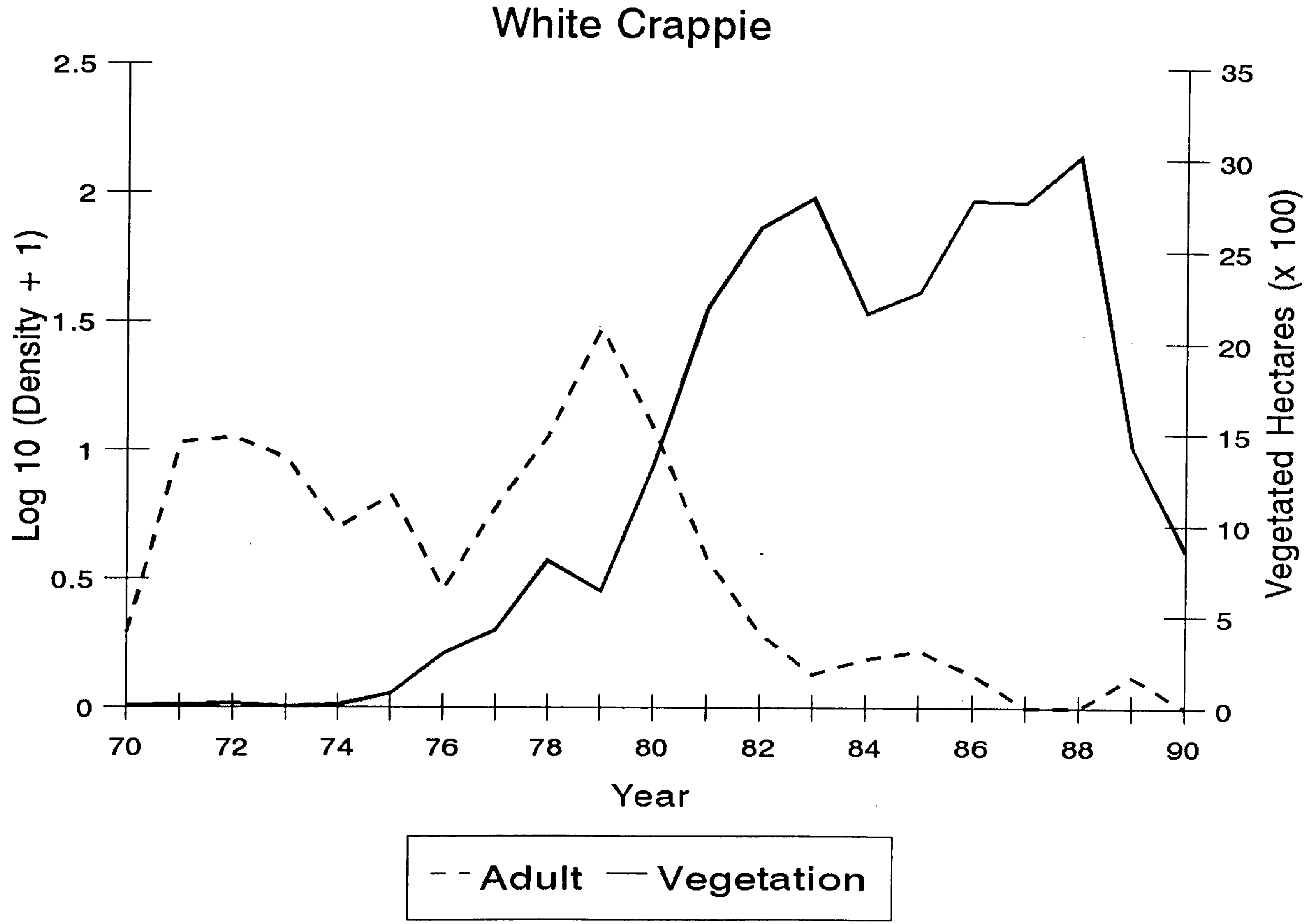


Figure 24. Annual standing stock densities (numbers/hectare) of white crappie, as determined by cove rotenone sampling, 1970-90.

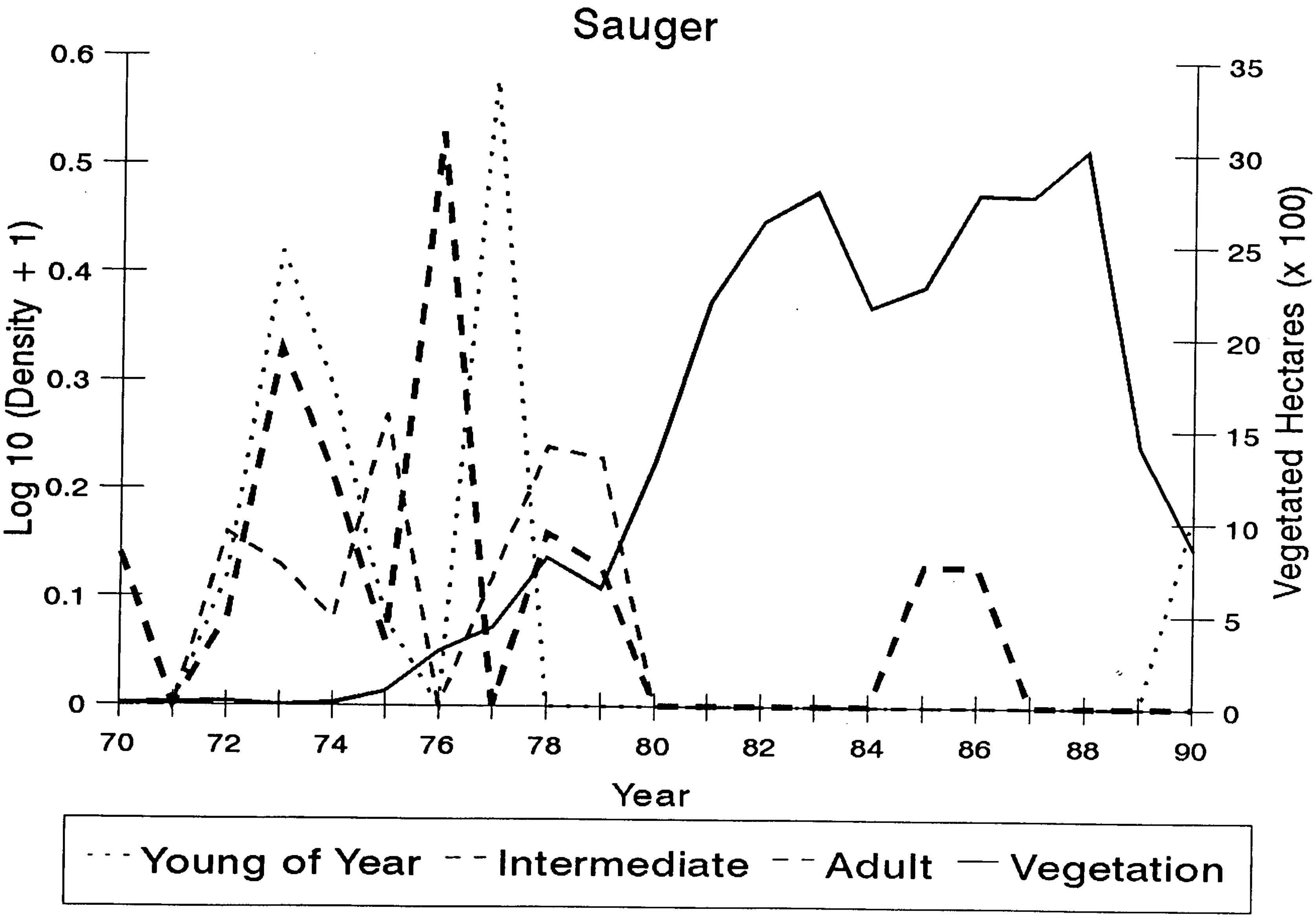


Figure 25. Annual standing stock densities (numbers/hectare) of sauger, as determined by cove rotenone sampling, 1970-90.

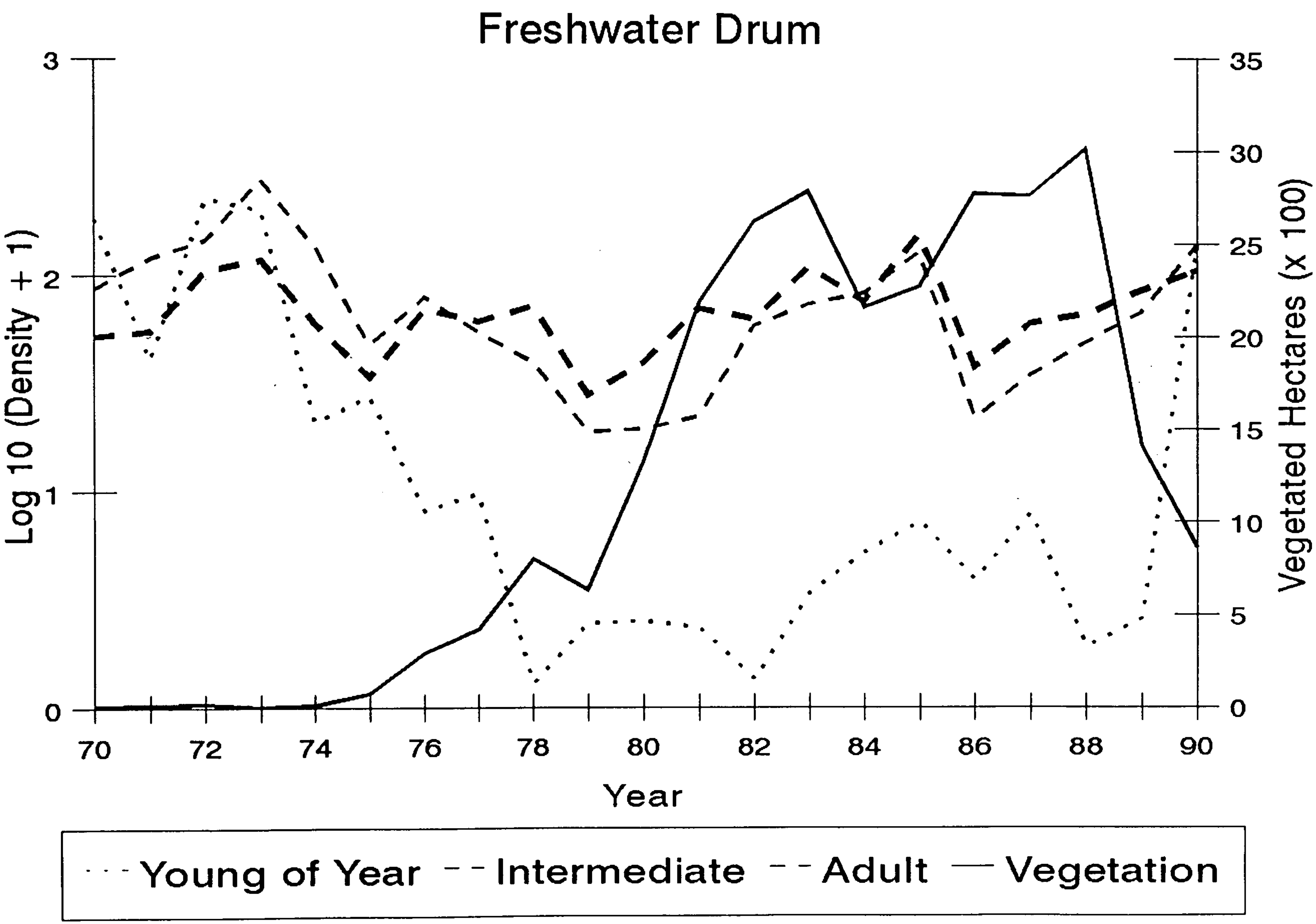
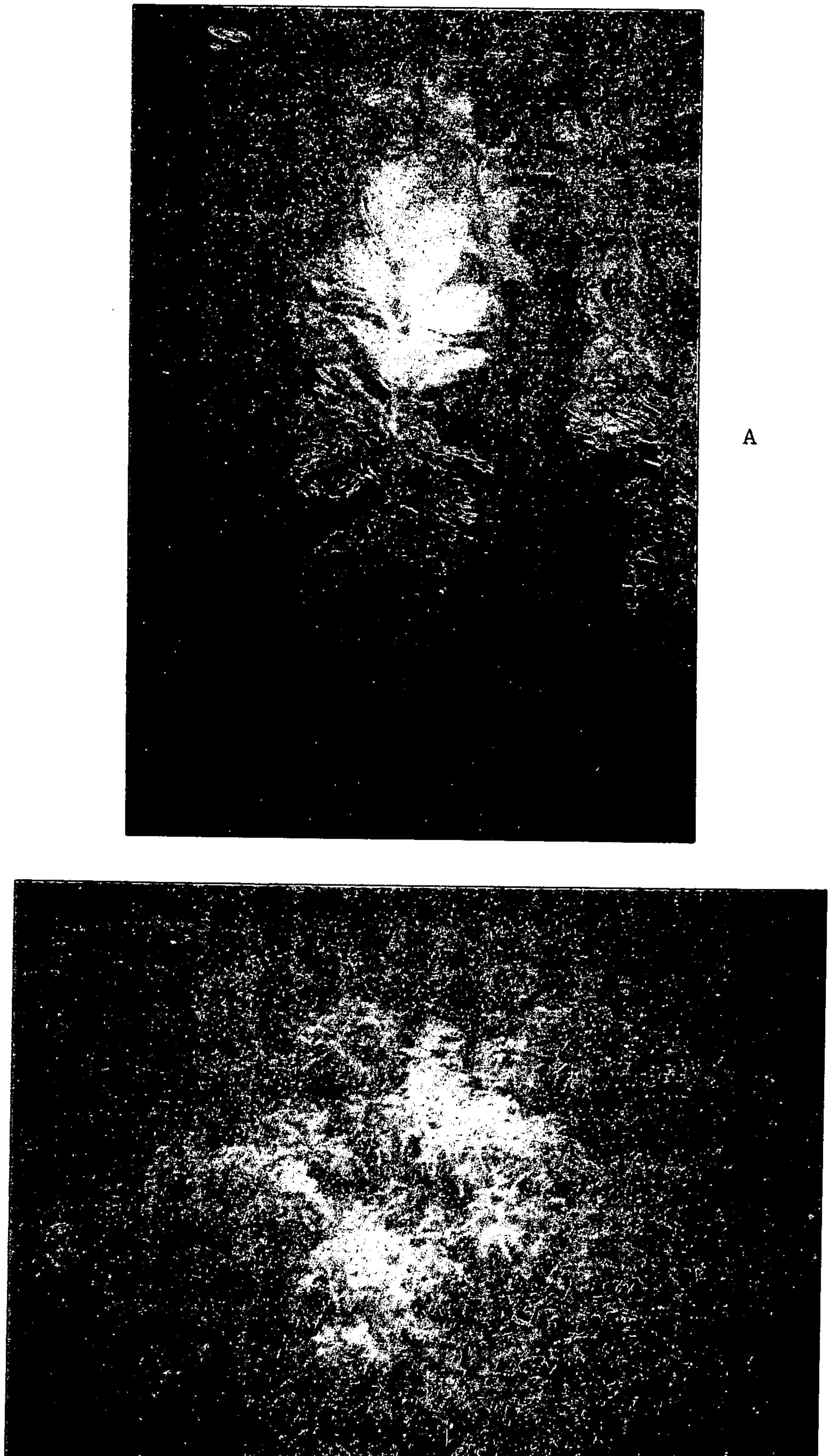


Figure 26. Annual standing stock densities (numbers/hectare) of freshwater drum, as determined by cove rotenone sampling, 1970-90.



A

B

Figure 27. Underwater photographs of Eurasian watermilfoil (A) and spinyleaf naiad (B) illustrating differences in growth forms.

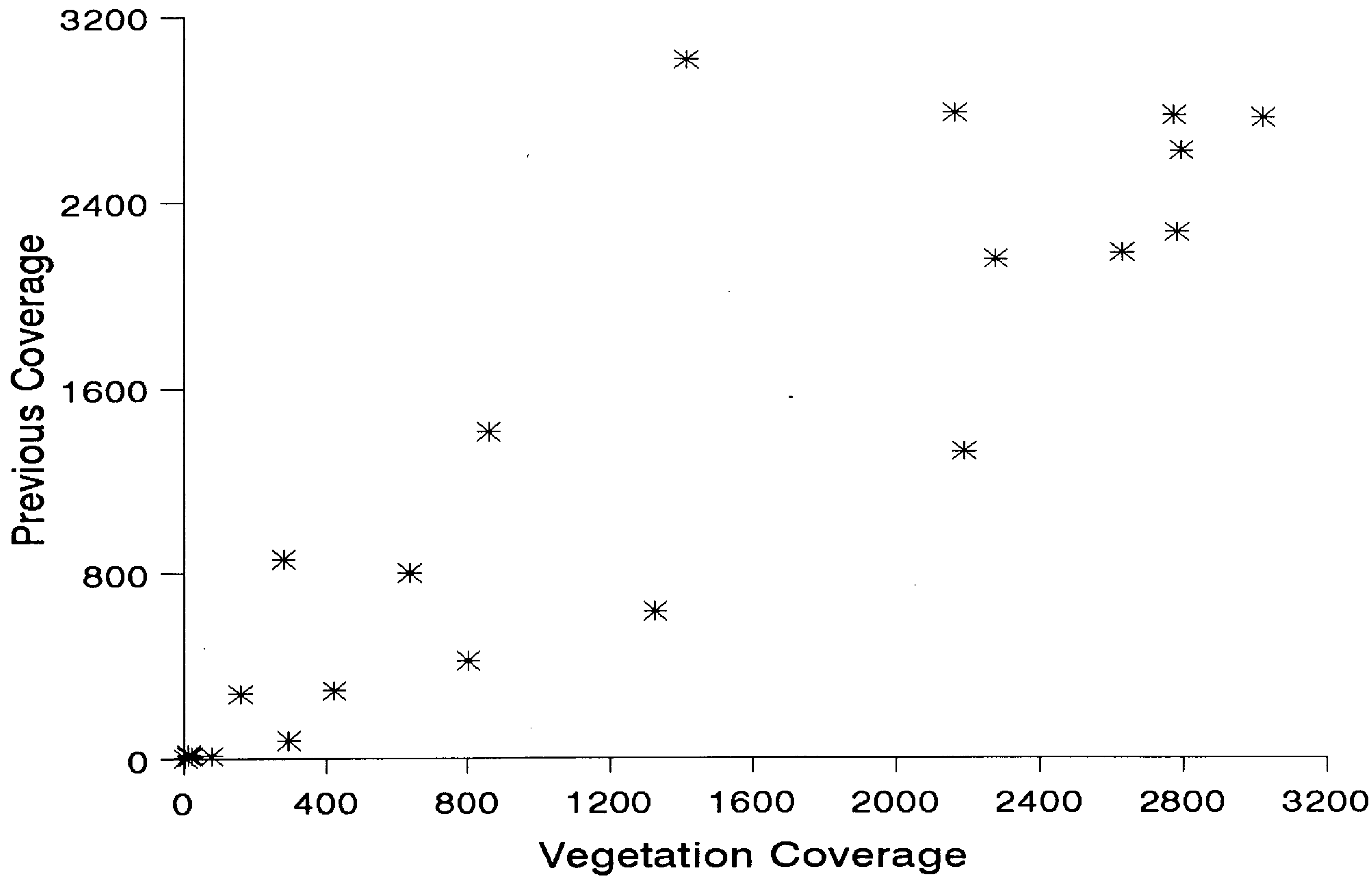


Figure 28. Previous year's aquatic macrophyte coverage (hectares) versus current year's coverage in Chickamauga Reservoir, 1971-92.

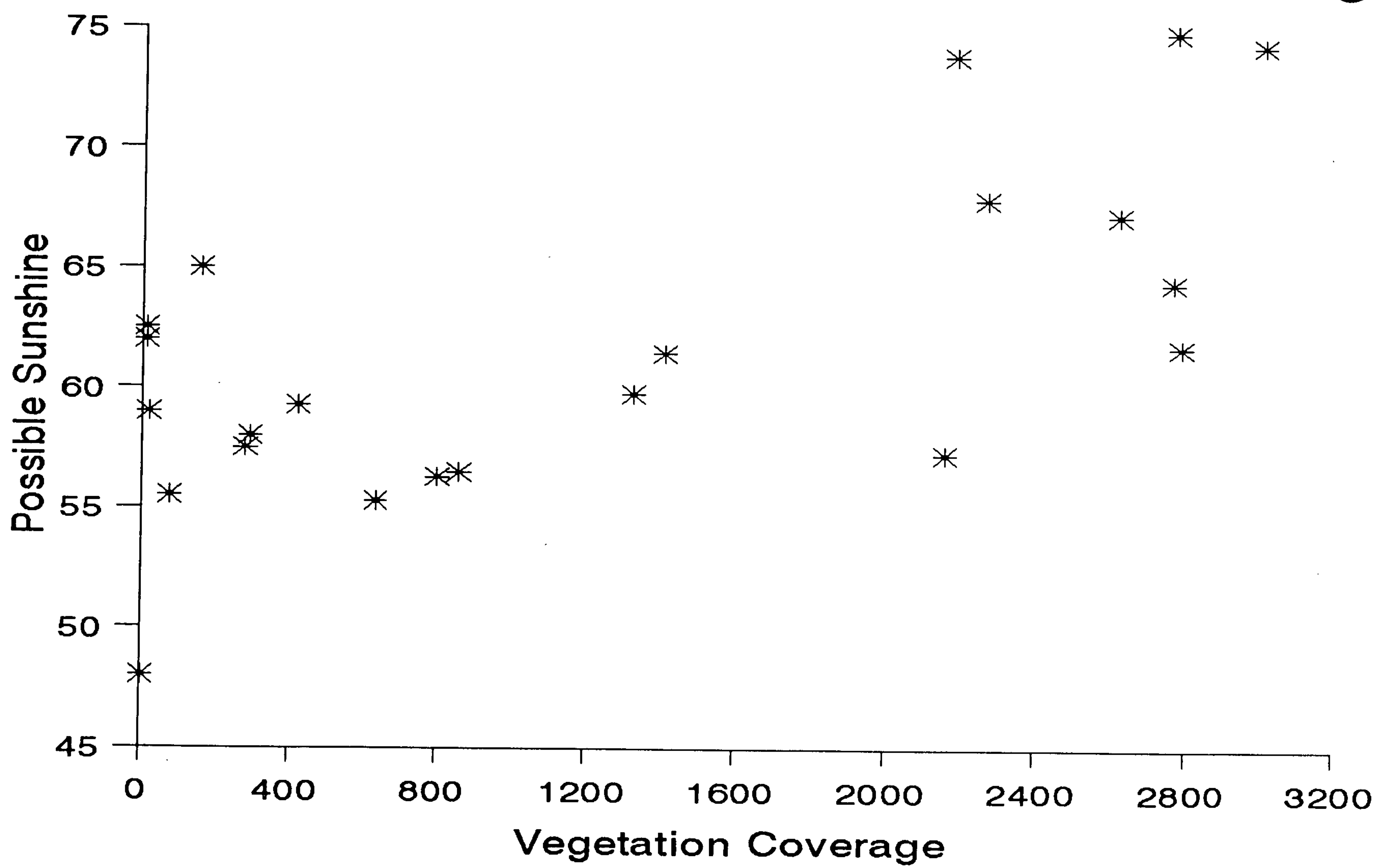


Figure 29. Average March-June sunshine (percent of possible) at Chattanooga, TN, versus aquatic macrophyte coverage (hectares) in Chickamauga Reservoir, 1971-92.

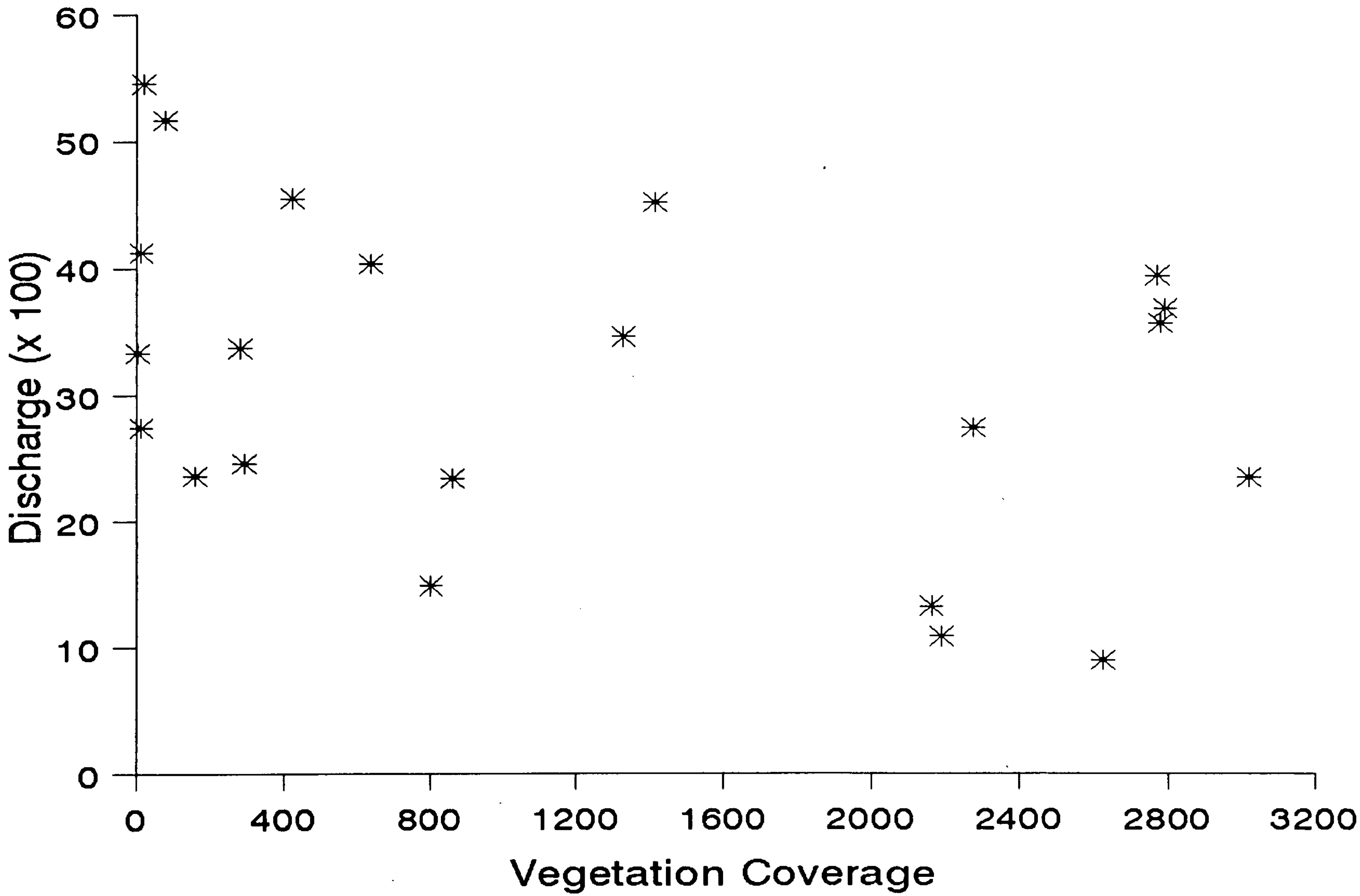


Figure 30. Average March-June daily discharge (cfs) at Chickamauga Dam versus current year's aquatic macrophyte coverage in Chickamauga Reservoir, 1971-92.

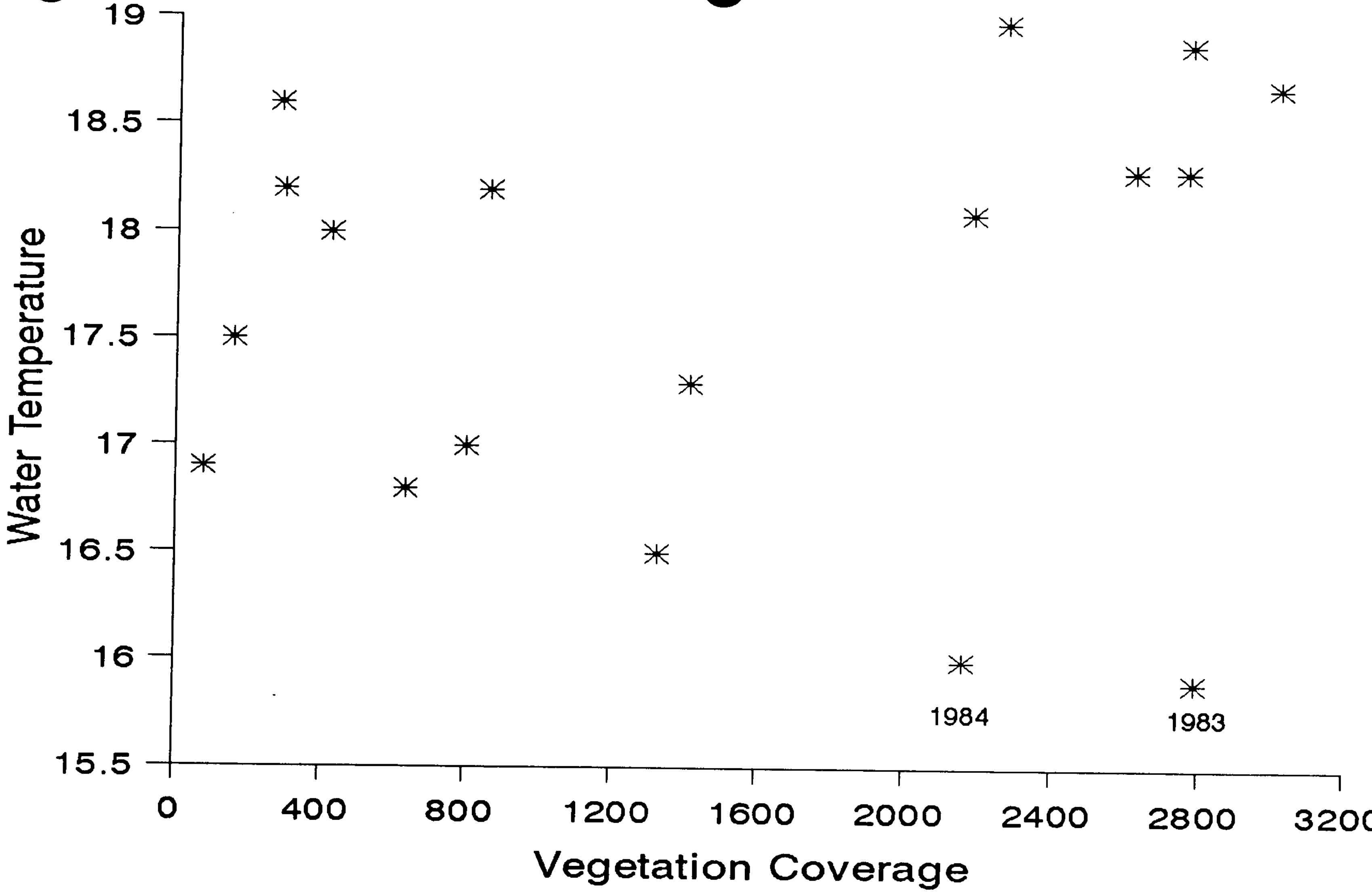


Figure 31. Average March-June water temperatures (^{o}C, 1.5 m depth) at TRM 484.7 versus aquatic macrophyte coverage (hectares) in Chickamauga Reservoir, 1975-92.

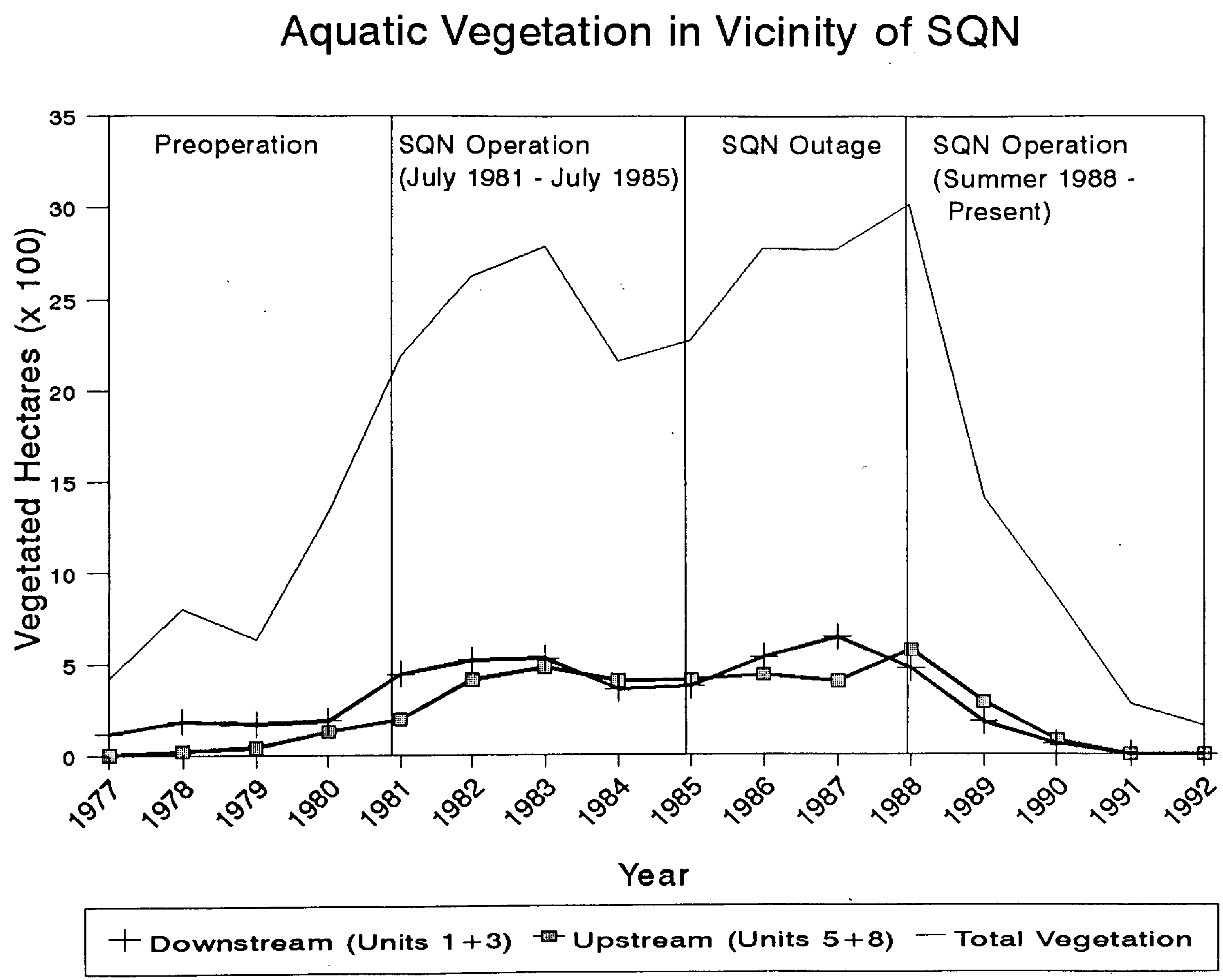


Figure 32. Aquatic macrophyte coverage (hectares) in mainchannel areas downstream and upstream from SQN and total coverage in Chickamauga Reservoir, 1977-92.

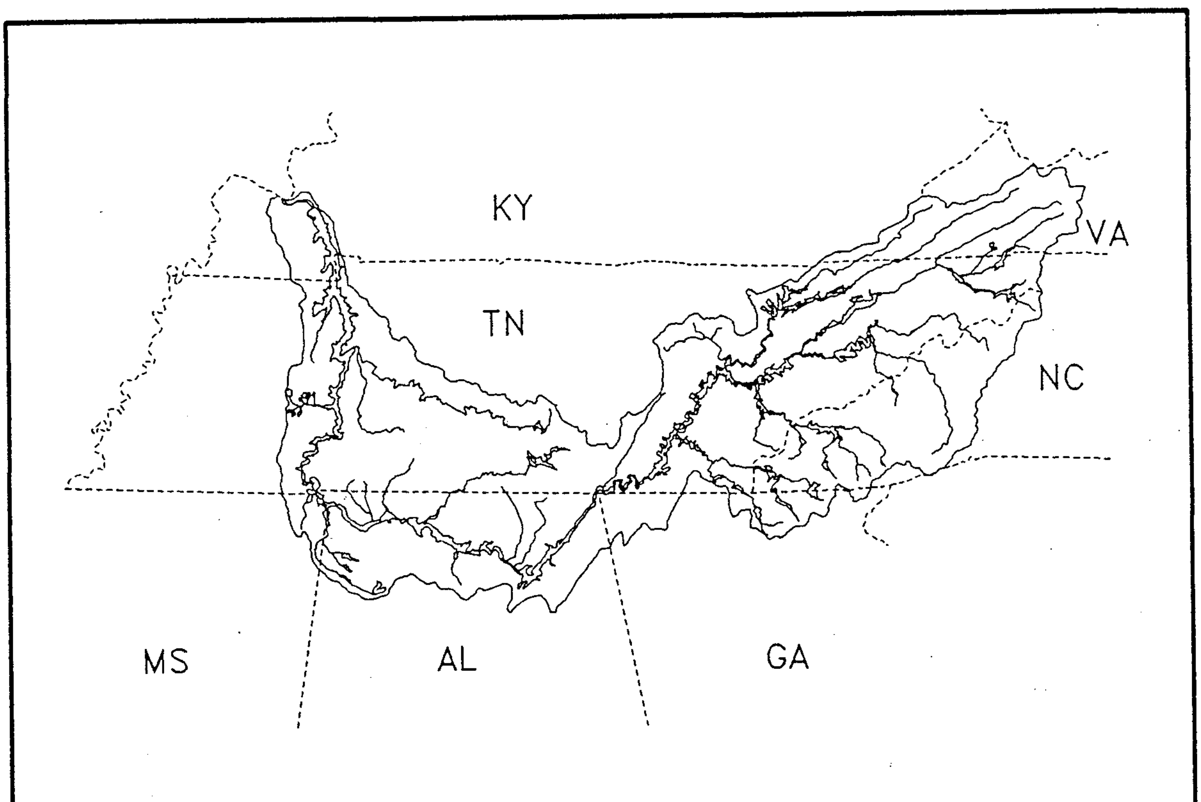
Tennessee
Valley
Authority

Water Resources Division
Chattanooga, Tennessee

TVA/WR/WQ--91/10
May 1991

RESERVOIR VITAL SIGNS MONITORING - 1990

PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER AND SEDIMENT



WATER RESOURCES &
ECOLOGICAL MONITORING
WATER RESOURCES MANAGEMENT

INTRODUCTION

In FY 1990, the Tennessee Valley Authority (TVA) initiated a Reservoir "Vital Signs" Monitoring program on 12 TVA reservoirs (the nine main stem Tennessee river reservoirs - Kentucky through Fort Loudoun and three major tributary reservoirs - Cherokee, Douglas and Norris) as part of its Water Resources and Ecological Monitoring Program (TVA, 1989). The objective of the Vital Signs program is to provide basic information on the "health" or integrity of the aquatic ecosystem in each TVA reservoir and to provide screening level information for describing how well each reservoir meets the "fishable and swimmable" goals of the Clean Water Act. This is the first time in the history of the Agency that a long term, systematic sampling of all major TVA reservoirs has been conducted. The basis of the Vital Signs monitoring is examination of appropriate physical, chemical and biological indicators in three areas of each reservoir. These three areas are the forebay (the lacustrine region of the reservoir, immediately upstream of the dam), the transition zone (the mid-reservoir region where the water changes from free flowing to more quiescent, impounded water), and the inflow or headwater region of the reservoir. The information gathered is used to make seasonal and spatial assessments of each reservoir's health and the overall health of the reservoir system, and to implement more detailed short-term studies where problems seem to exist. In addition, this information establishes a baseline for comparing with future water quality conditions and monitoring water quality trends for TVA reservoirs.

The Vital Signs program employs several activities to assess reservoir health. They include physical and chemical characteristics of water and sediment, acute toxicity screening of water and sediment, benthic macroinvertebrate population assessments, and fish abundance, composition and health.

This report presents information on the physical and chemical characteristics of water and sediment for water year

(WY) 1990. Water samples were collected and water quality measurements made at two locations (forebay and transition zone) on each of twelve TVA reservoirs (the nine main stem Tennessee River Reservoirs and three tributary reservoirs - Norris, Cherokee, and Douglas). Water samples were not collected at inflow locations for two reasons: (1) the ambient stream monitoring program includes inflow locations for Norris, Douglas and Cherokee; (2) "inflow" water samples at the other inflow locations would be dominated by the effects of the impoundment immediately upstream, rather than the process occurring in the reservoir being sampled. Sediment samples were also collected at these same locations. The twenty four Reservoir Vital Signs Monitoring locations sampled in WY 1990 are shown on Figure 1 and listed in Table 1.

FIGURE 1

RESERVOIR VITAL SIGNS - WY 1990

WATER QUALITY MONITORING LOCATIONS

PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER AND SEDIMENT

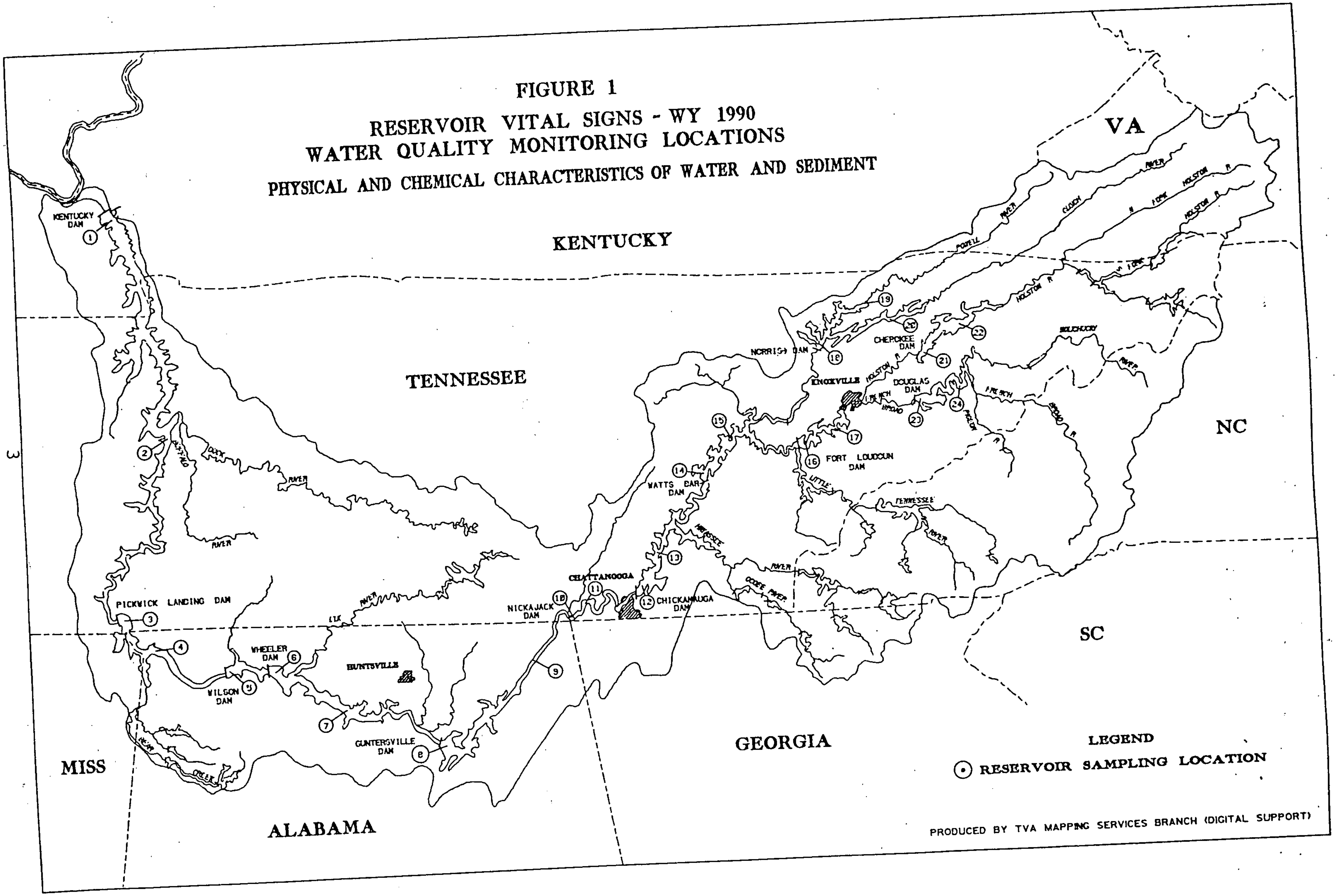


Table 1

WATER QUALITY MONITORING LOCATIONS
RESERVOIR VITAL SIGNS MONITORING, WY 1990

Reservoir	Forebay Locations River Mile (Tennessee)	Forebay Locations Map ID Number	Forebay Locations Storet Station #	Transition Zone Locations River Mile (Tennessee)	Transition Zone Locations Map ID Number	Transition Zone Locations Storet Station #
Main Stream						
Kentucky	23.0	1.	202832	112.0	2.	475015
Pickwick	207.3	3.	476799	230.0	4.	016923
Wilson	260.8	5.	016912	--	--	
Wheeler	277.0	6.	016900	307.5	7.	017012
Guntersville	350.0	8.	017261	396.8	9.	017101
Nickajack	425.5	10.	476344	433.0	11.	476239
Chickamauga	472.3	12.	475358	490.5	13.	475265
Watts Bar	531.0	14.	475317	560.8	15.	476041
Fort Loudoun	603.2	16.	475602	624.6	17.	475603

Reservoir	Forebay Locations River Mile	Forebay Locations Map ID Number	Forebay Locations Storet Station #	Transition Zone Locations River Mile	Transition Zone Locations Map ID Number	Transition Zone Locations Storet Station #
Tributary						
Cherokee	HRM 53.0	21.	475025	HRM 76.0	22.	475028
Douglas	FBRM 33.0	23.	475081	FBRM 60.7	24.	475993
Norris	CRM 80.0	18.	476009	PRM 30.0	19.	477187
				CRM 125.0	20.	477186

WRC 0336M-1

Table 13
Chickamauga Reservoir - Water Quality Summary
Reservoir Vital Signs Monitoring, WY 1990

Variable	Forebay N	Forebay Mean	Forebay Min	Forebay Max	Transition Zone N	Transition Zone Mean	Transition Zone Min	Transition Zone Max
Temperature (° C)	85	22.1	8.3	28.0	51	20.4	7.2	26.5
Dissolved Oxygen, (mg/l)	85	7.3	3.1	11.4	51	7.4	4.2	11.9
pH (s.u.)	85	7.5	6.8	8.7	51	7.6	7.1	8.5
Conductivity, (μmhos/cm)	85	163.1	123.0	192.0	51	163.3	129.0	190.0
Organic - N (mg/l)	18	0.24	0.12	0.48	18	0.23	0.10	0.38
Ammonia - N (mg/l)	18	0.03	0.01	0.08	18	0.04	0.01	0.11
Nitrate+Nitrite - N (mg/l)	18	0.23	0.13	0.41	18	0.26	0.18	0.43
Total Nitrogen (mg/l)	18	0.5	0.4	0.7	18	0.5	0.4	0.7
Total Phosphorous (mg/l)	18	0.03	0.02	0.04	18	0.03	0.02	0.04
TN/TP Ratio	18	20.1	14.8	27.5	18	19.9	11.0	28.5
Dissolved Ortho - P (mg/l)	18	0.007	0.003	0.010	18	0.009	0.004	0.020
Total Organic Carbon (mg/l)	18	1.9	0.9	2.4	18	2.0	0.8	2.4
Soluble Organic Carbon (mg/l)	18	1.7	0.6	2.1	18	1.8	0.7	2.2
Chlorophyll-a (μg/l)	14	8.9	2.0	24.0	13	7.0	2.0	17.0
Secchi depth (m)	7	1.2	0.9	1.6	7	1.2	1.1	1.4
Turbidity (NTU)	18	6.2	3.0	16.0	18	7.1	3.0	18.0
Suspended Solids (mg/l)	18	4.9	3.0	8.0	18	5.8	3.0	10.0
True Color (PCU)	18	18.2	2.0	30.0	18	17.4	2.0	35.0
Apparent Color (PCU)	18	23.6	5.0	35.0	18	24.4	5.0	43.0
Fecal Coliform (#/100 ml)	9	57.8	10.0	440.0	9	25.6	10.0	150.0

depth in April were at super saturation levels of 116% and 120%, respectively, at the forebay and transition zones. Contour plots of temperature and DO versus depth for the period January through the end of September for both the forebay (figure 23) and the transition zone (figure 24) depict the seasonal variation and rather weak stratification of Chickamauga reservoir in WY1990.

Values of pH ranged from 6.8 to 8.7 on Chickamauga reservoir. Values of pH approaching 8.5 and higher and supersaturation DO levels were observed during algal blooms in April and May at both the forebay and transition zones.

Conductivities ranged from 123 to 192 umhos/cm, with highest conductivities coinciding with low streamflows in July, and averaged about 165 umhos/cm.

Biochemical Measurements - In Chickamauga reservoir, during WY 1990, concentrations of organic nitrogen, ammonia nitrogen, nitrite plus nitrate nitrogen, and total phosphorus averaged 0.24, 0.03, 0.23 and 0.026 mg/l, respectively at the forebay; and 0.22, 0.04, 0.26 and 0.028 mg/l, respectively, at the transition zone. The total phosphorus concentrations measured in Chickamauga reservoir were among the lowest observed at any of the Vital Signs monitoring locations, with the exception of those sampling locations on Norris reservoir.

TN/TP ratios ranged from 11 to 28 in Chickamauga reservoir, indicating periods of phosphorus limiting conditions. The highest chlorophyll-a concentrations were measured in May (12-19 ug/l and 13-17 ug/l, respectively, at the forebay and transition zones) and in June (24 ug/l at the forebay). Values of pH up to 8.7 were measured during this May bloom. Surface concentrations of chlorophyll-a averaged 12 ug/l at the Chickamauga reservoir forebay, and 9.5 ug/l at the transition zone. Organic carbon concentrations (both total and soluble) in Chickamauga reservoir are quite low, averaging 1.9 and 1.7 mg/l, respectively, at the forebay; and averaging 2.0 and 1.8 mg/l, respectively, at the transition location.

FIGURE 23.
CHICKAMAUGA RESERVOIR – TRM 472.3

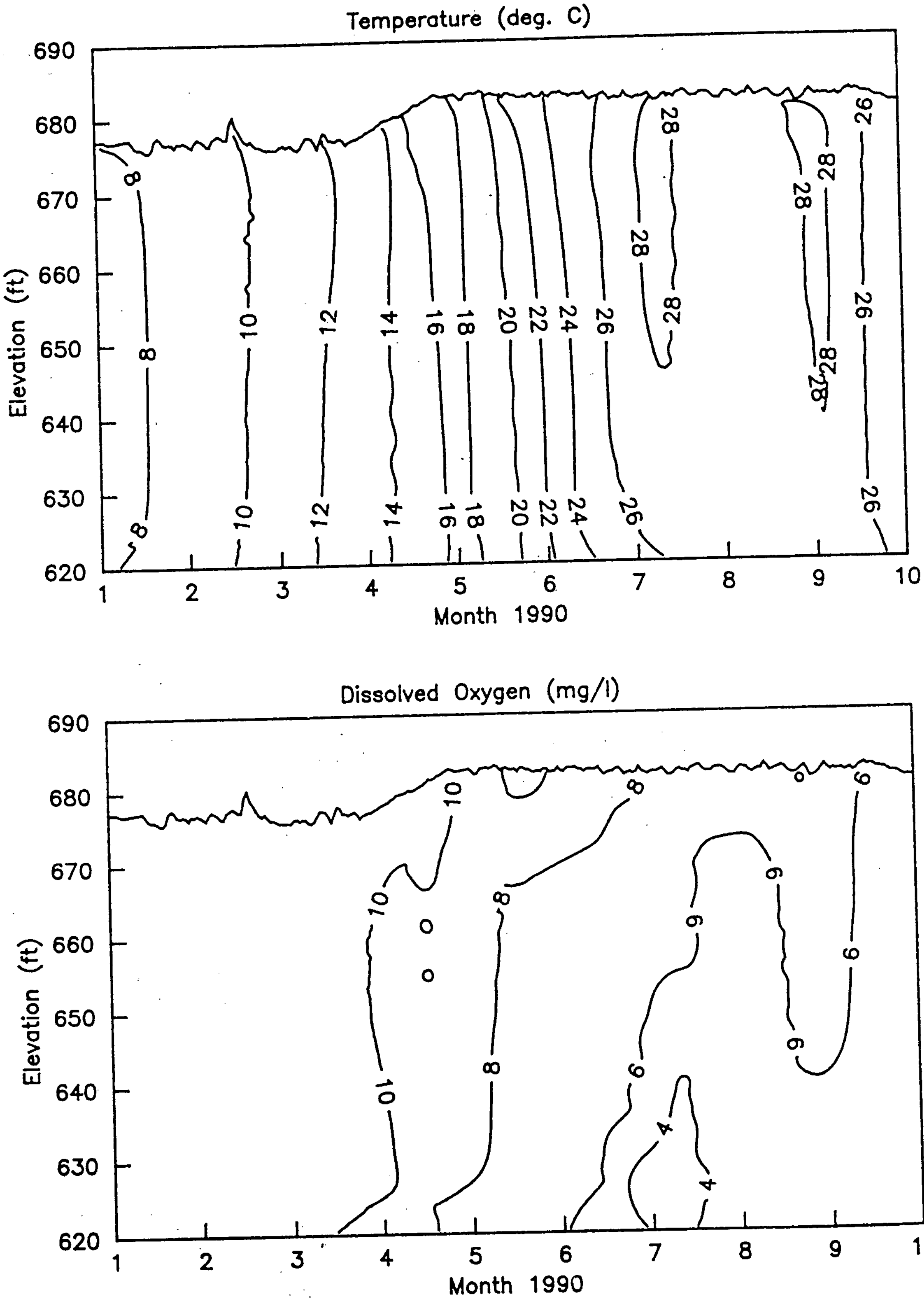
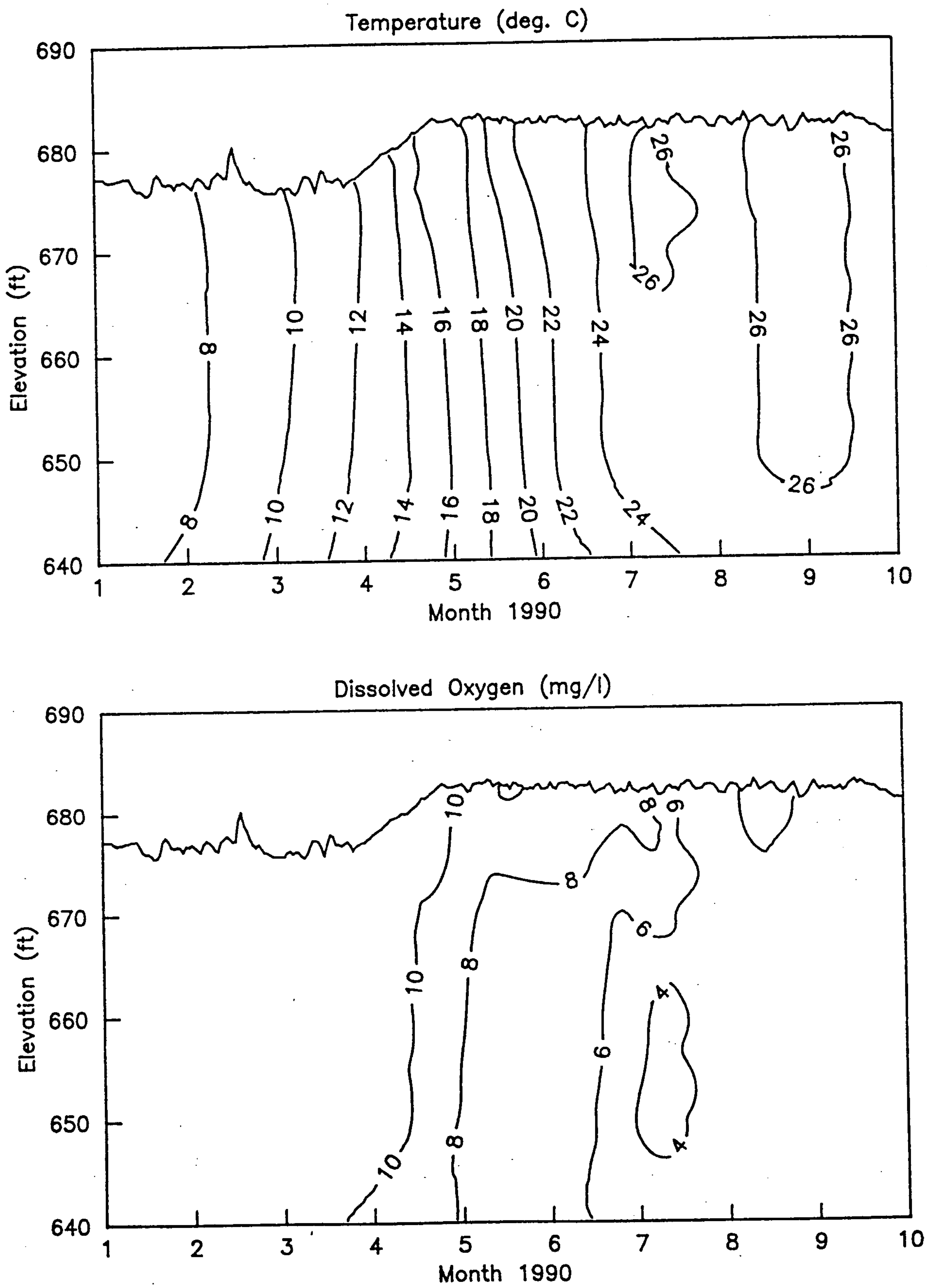


FIGURE 24.
CHICKAMAUGA RESERVOIR – TRM 490.5



Physical/Bacteriological Measurements - Figure 25 illustrates the average daily discharge from Chickamauga reservoir in WY 1990 with water quality sampling dates superimposed. Periods of high flow in January and February are reflected in the water quality data with low Secchi depth measurements and high concentrations of turbidity and suspended solids. Secchi depth measurements of 0.88 meters, turbidity values in excess of 15 NTU's and suspended solids concentrations of 8 mg/l at the forebay were observed in January. Forebay Secchi depth, turbidity, and suspended solids measurements averaged 1.19 meters, 6.2 NTU's, and 4.9 mg/l, respectively. Transition zone Secchi depths, turbidity, and suspended solids averaged 1.22 meters, 7.1 NTU's, and 5.8 mg/l, respectively. These values indicate the light transparency of Chickamauga reservoir to be high when compared with the other mainstem Tennessee River reservoirs. True color values, averaging 18 and 17 PCU's, at the forebay and transition zones, respectively, were higher than the next upstream monitoring location (Watts Bar forebay), indicating the effects of a colored waste outfall upstream of the transition zone. A large paper company discharges to the Hiwassee River which joins the Tennessee River at mile 499.4, about nine miles upstream of the transition zone monitoring location. Two of eighteen samples collected for fecal coliform organisms were positive; with one of these positive occurrences (440/100 ml at the forebay in January) exceeding a water-contact recreation guideline of 200/100 ml.

Water Quality Indices -The results for the TVA RWQI (Figure 26) show that except for samples collected in January, both the forebay and transition zone evidenced similar water quality index values. In January, a high fecal coliform concentration of 440/100 ml at the forebay resulted in the lower RWQI value when compared with the transition zone. Overall, RWQI values were high, averaging over 91 at the forebay and 92 at the transition zone and indicating very good reservoir water quality.

FIGURE 25.

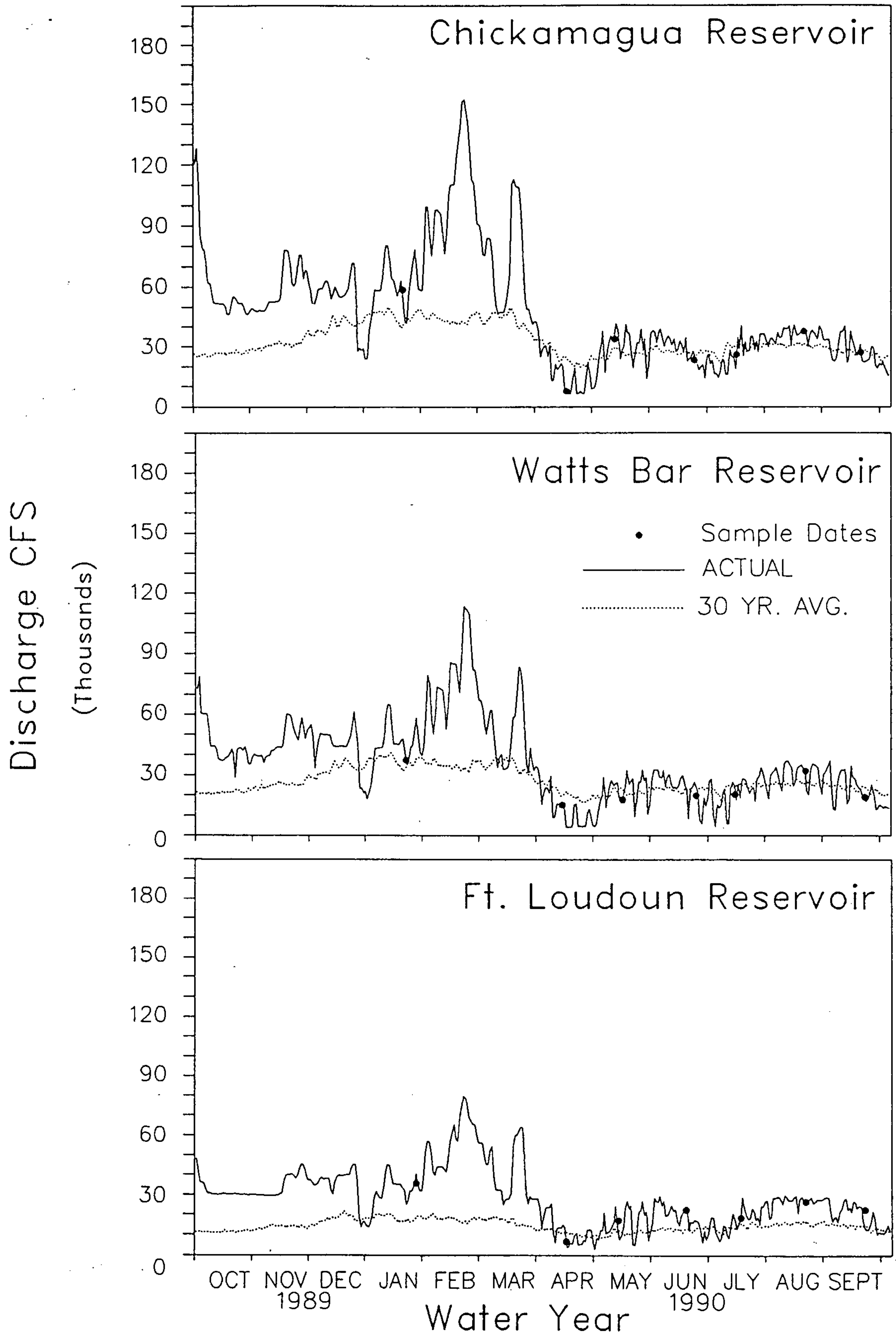
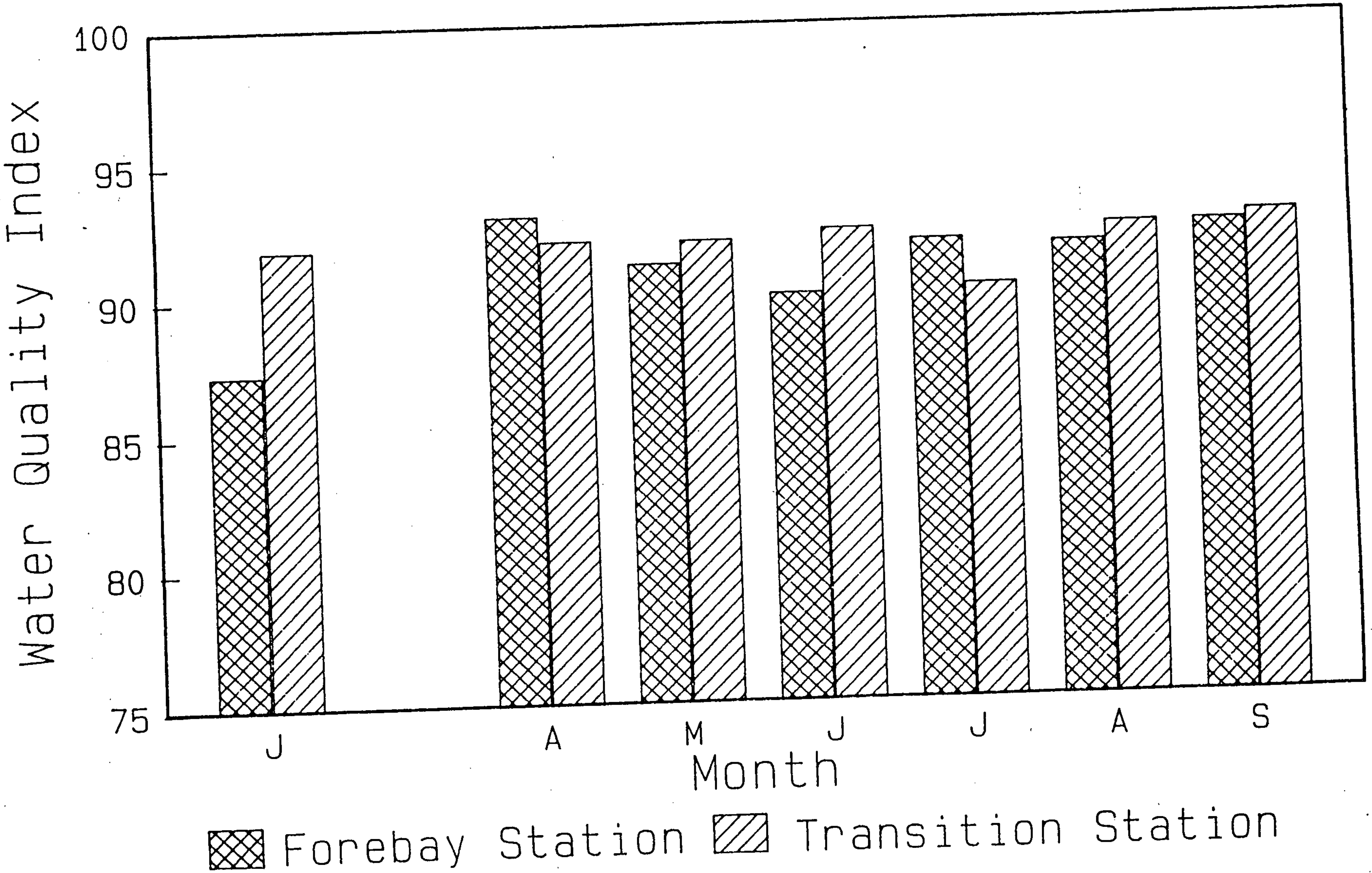

Chickamagua Reservoir
Watts Bar Reservoir
Ft. Loudoun Reservoir
Sample Dates
ACTUAL
30 YR. AVG.
Discharge CFS
(Thousands)
0
30
60
90
120
150
180
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JLY
AUG
SEPT
1989
1990
Water Year

FIGURE 26.
Chickamauga Reservoir



Watts Bar Reservoir

In situ Measurements -In situ measurements of temperature, dissolved oxygen (DO), pH and conductivity show the reservoir to be well mixed early in the year but developing a moderate degree of thermal stratification in July and August (Appendix A-8, Table 14). Surface water temperatures ranged from 7.0 °C in January to 28.3 °C in July in the forebay, and from 7.8 °C in January to 26.2 °C in June at the transition zone. Temperatures at the transition zone are influenced by the inflow of cool water from the Clinch River which joins the Tennessee River about seven miles upstream of the transition zone at river mile 567.7. In July, a warming in surface temperature of almost 3 °C was noted between the transition zone (25.4 °C) and the forebay (28.3 °C).

Values for DO at the 1.5 meter depth ranged from 11.5 mg/l in June to 6.1 mg/l in September at the forebay, and from 11.5 mg/l to 6.2 mg/l for the same months at the transition zone. Contour plots of temperature and DO versus depth for the period January through the end of September for both the forebay (figure 27) and the transition zone (figure 28) depict the seasonal variation with a weak summer time thermal stratification and a rather strong oxycline in the forebay of Watts Bar reservoir. In late June, at the forebay, the data show a 6 °C decrease in temperature and nearly an 11 mg/l decrease in DO from the surface to the bottom of the reservoir. This stratified condition persisted through mid-August. In June and July DO concentrations were less than 1 mg/l in the hypolimnion of Watts Bar forebay.

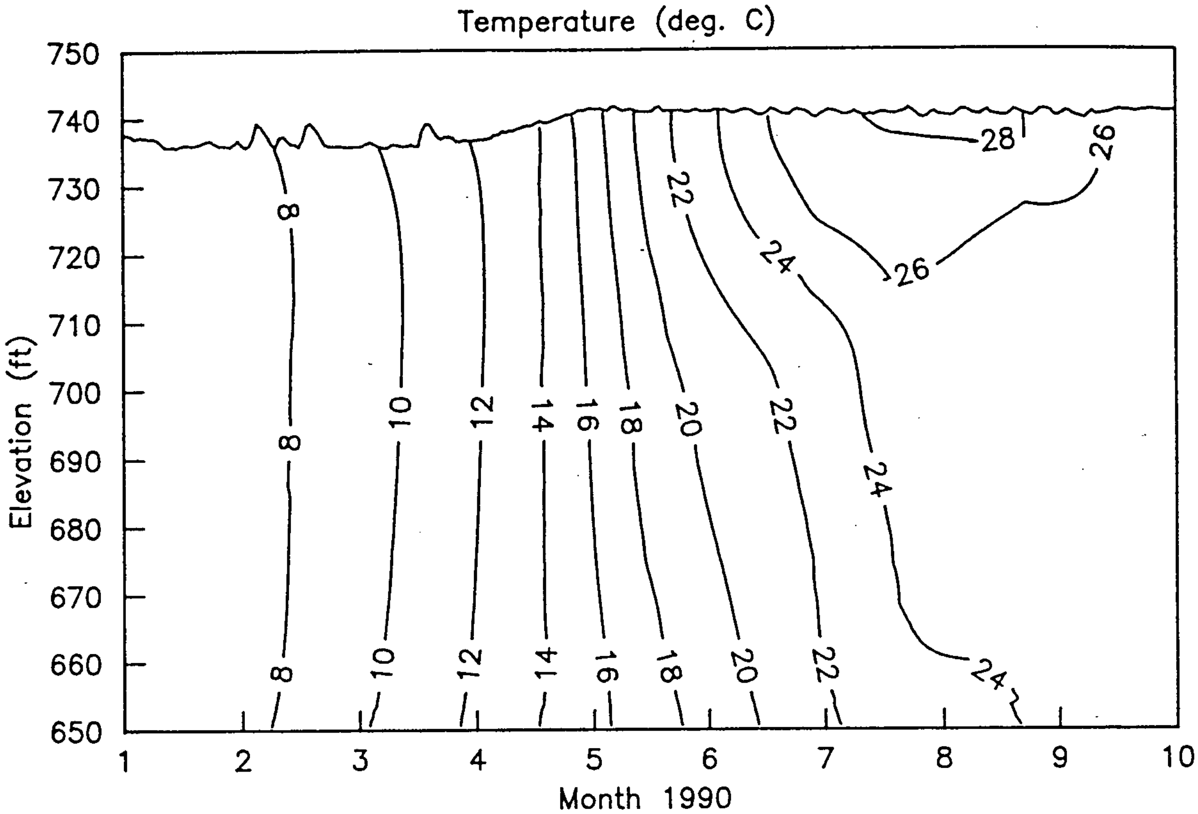
Values of pH ranged form 6.6 to 9.2 on Watts Bar reservoir. In late June, values of pH exceeding 9.0 and DO saturation values approaching 150% were measured, giving evidence of a large algal bloom which existed at both the forebay and transition zone locations. In addition, at the forebay, pH's greater than 8.5 and supersaturation DO values were also observed in May, July and August.

Table 14
Watts Bar Reservoir - Water Quality Summary
Reservoir Vital Signs Monitoring, WY 1990

Variable	Forebay N	Forebay Mean	Forebay Min	Forebay Max	Transition Zone N	Transition Zone Mean	Transition Zone Min	Transition Zone Max
Temperature (° C)	112	20.8	7.0	28.3	55	21.2	7.8	26.2
Dissolved Oxygen, (mg/l)	112	7.0	0.2	11.5	55	8.2	5.8	12.0
pH (s.u.)	112	7.8	6.8	9.2	55	7.8	7.3	9.1
Conductivity, (μmhos/cm)	112	170.6	114.0	208.0	55	174.7	126.0	209.0
Organic - N (mg/l)	18	0.28	0.15	0.50	17	0.24	0.11	0.52
Ammonia - N (mg/l)	18	0.04	0.01	0.09	17	0.03	0.01	0.07
Nitrate+Nitrite - N (mg/l)	18	0.23	0.01	0.47	17	0.27	0.19	0.52
Total Nitrogen (mg/l)	18	0.6	0.4	0.8	17	0.5	0.4	0.8
Total Phosphorous (mg/l)	18	0.03	0.01	0.05	17	0.03	0.02	0.04
TN/TP Ratio	18	22.9	9.0	51.0	17	19.1	14.0	31.5
Dissolved Ortho - P (mg/l)	18	0.007	0.002	0.010	17	0.006	0.003	0.020
Total Organic Carbon (mg/l)	18	1.8	0.9	2.7	17	1.8	1.0	2.4
Soluble Organic Carbon (mg/l)	18	1.7	0.7	2.5	17	1.6	0.9	2.2
Chlorophyll-a (μg/l)	14	9.6	2.0	20.0	13	9.5	5.0	14.0
Secchi depth (m)	5	1.4	1.3	1.8	7	1.1	0.8	1.3
Turbidity (NTU)	17	6.5	2.0	11.0	17	9.3	3.0	20.0
Suspended Solids (mg/l)	17	5.7	1.0	18.0	17	8.6	4.0	21.0
True Color (PCU)	18	15.5	5.0	30.0	17	14.5	5.0	25.0
Apparent Color (PCU)	18	19.6	10.0	33.0	17	18.7	7.0	30.0
Fecal Coliform (#/100 ml)	7	11.4	10.0	20.0	7	18.6	10.0	70.0

FIGURE 27.

WATTS BAR RESERVOIR - TRM 531.0



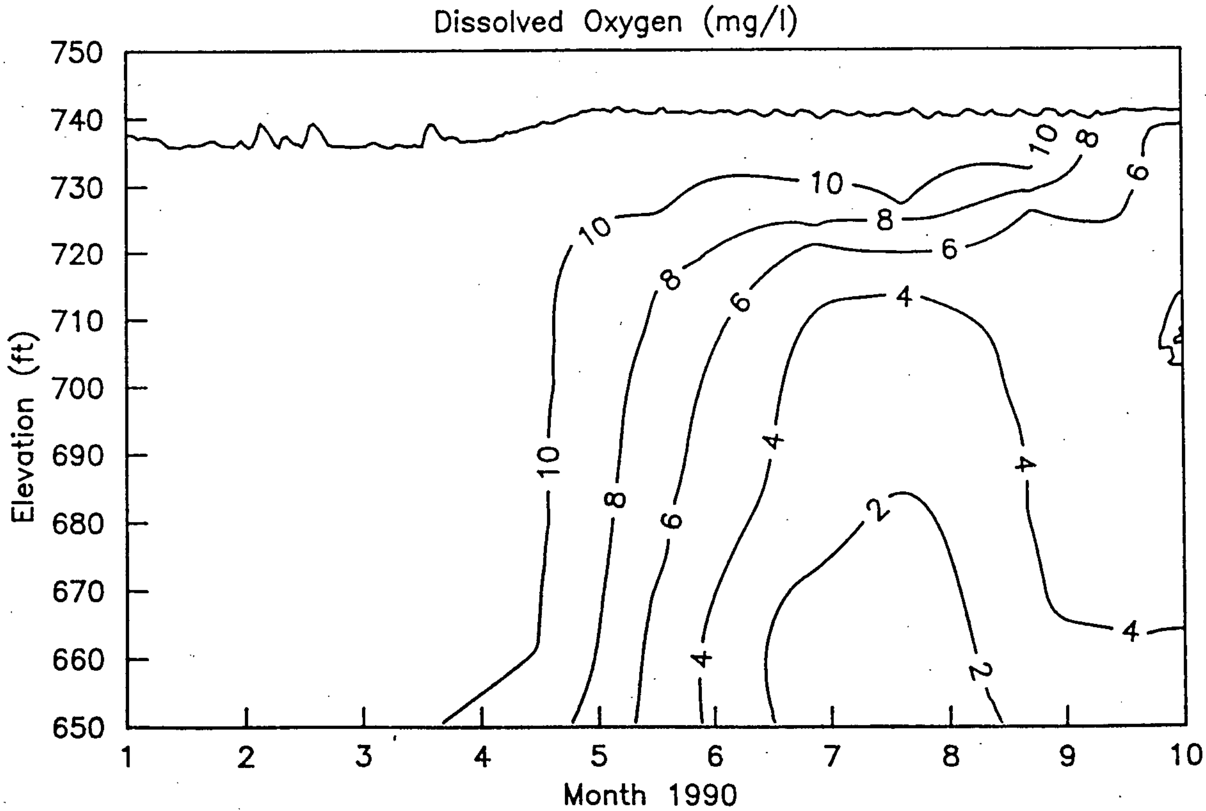
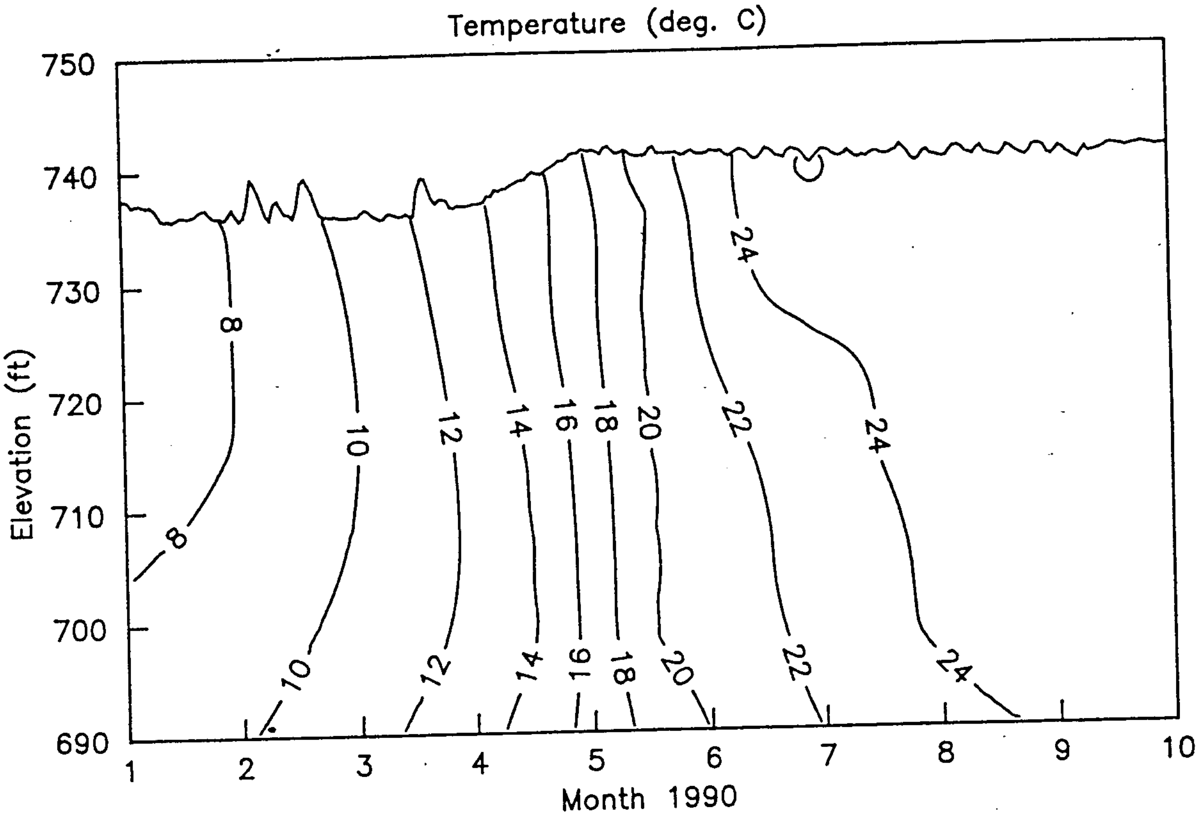
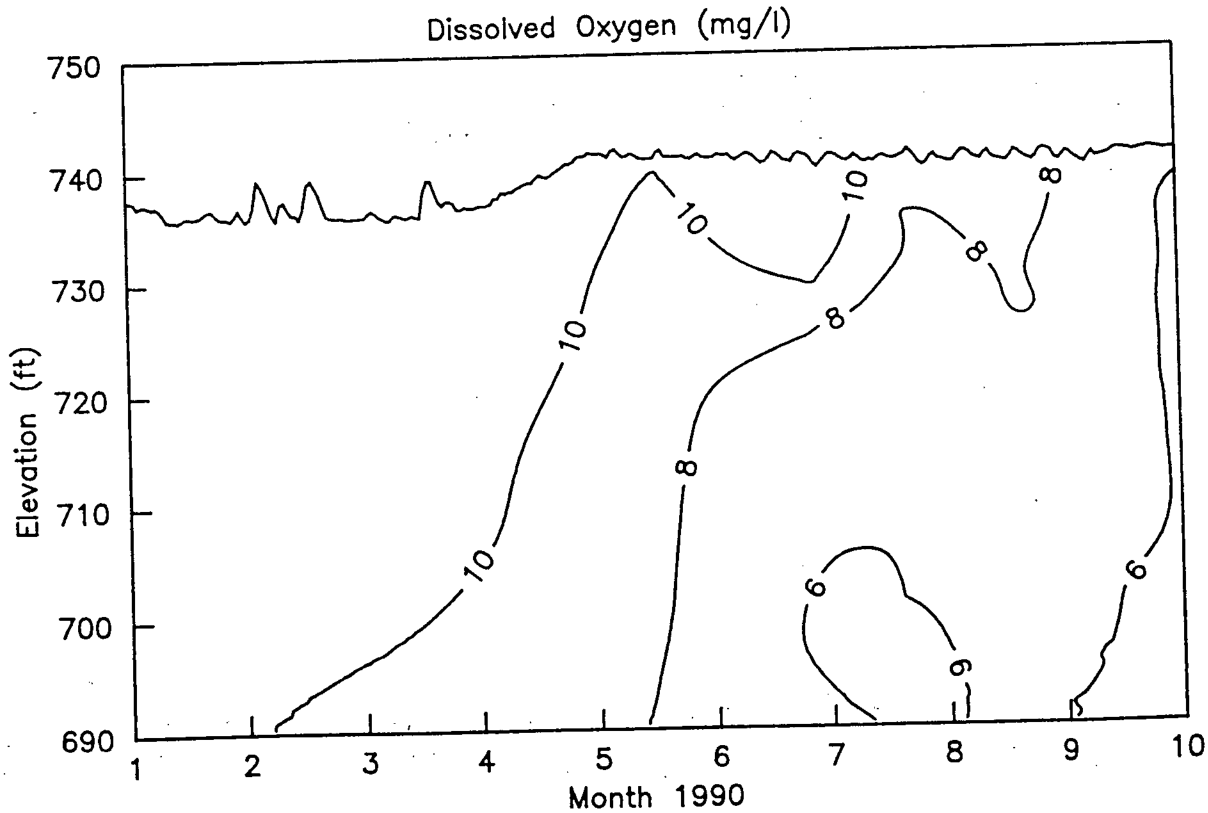


FIGURE 28.

WATTS BAR RESERVOIR – TRM 560.8





Conductivities ranged from 114 to 209 umhos/cm and averaged about 175 umhos/cm, with highest conductivities coinciding with low streamflows in June and July.

Biochemical Measurements - In Watts Bar reservoir during WY 1990, concentrations of organic nitrogen, ammonia nitrogen, nitrite plus nitrate nitrogen, and total phosphorus averaged 0.28, 0.04, 0.23 and 0.028 mg/l, respectively at the forebay; and 0.24, 0.03, 0.27 and 0.029 mg/l, respectively, at the transition zone. The total phosphorus concentrations observed at the forebay and transition zones on Watts Bar reservoir were quite low. The dissolved orthophosphorus concentrations of 0.007 and 0.006 mg/l, respectively, at the forebay and transition zones were the lowest observed at any of the twenty four Vital Signs monitoring locations.

TN/TP ratios ranged from 9 to 51 in Watts Bar reservoir, indicating periods of phosphorus limiting conditions, particularly at Watts Bar forebay. The highest chlorophyll-a concentrations were measured in May, 20 ug/l and 14 ug/l, respectively, at the forebay and transition zones. Surface concentrations of chlorophyll-a pigment averaged about 13 ug/l at the Watts Bar reservoir forebay, and about 11 ug/l at the transition zone. Organic carbon concentrations (both total and soluble) in Watts Bar reservoir were low, averaging 1.8 and 1.6 mg/l, respectively, at both the forebay and transition zones. These organic carbon concentrations were the lowest measured at any of the mainstem Tennessee river Vital Signs monitoring locations.

Physical/Bacteriological Measurements - Figure 25 illustrates the average daily discharge from Watts Bar reservoir in WY 1990 with sampling dates superimposed. Forebay Secchi depth, turbidity, and suspended solids measurements averaged 1.44 meters, 6.5 NTU's, and 5.7 mg/l, respectively. Transition zone Secchi depths, turbidity, and suspended solids averaged 1.05 meters, 9.3 NTU's, and 8.6 mg/l, respectively. These values indicate the light transparency of Watts Bar reservoir forebay to be among the highest of the mainstem Tennessee River reservoirs, in WY 1990. True color values, averaged 16 and 15 PCU's, at the forebay and transition zones, respectively, falling about in the mid-range of values measured at mainstem Tennessee river Vital Signs monitoring locations. Two of fourteen samples collected for fecal coliform organisms were positive; however, neither of these positive occurrences exceeded a water-contact recreation guideline of 200/100 ml.

Water Quality Indices -The results for the TVA RWQI (Figure 29) show that at the forebay, the very high surface pH's, ranging from 8.8 to 9.2, and coincident high chlorophyll-a concentrations during the May through August period, had the greatest effect in lowering the computed RWQI values. Overall, RWQI values were high, averaging 91 at the forebay and over 92 at the transition zone and indicating very good reservoir water quality.

Fort Loudoun Reservoir

In situ Measurements -*In situ* measurements of temperature, dissolved oxygen (DO), pH and conductivity show the reservoir is well mixed early in the year but develops a fairly strong thermal stratification from July through September (Appendix A-9, Table 15). Surface water temperatures ranged from 7.3 °C in January to 28.8 °C in July in the forebay, and from 7.0 °C to 27.4 °C for the same months at the transition zone. In June, a warming in surface temperature of almost 3.5 °C was noted between the transition zone (23.4 °C) and the forebay (26.8 °C).

Values for DO at the 1.5 meter depth ranged from 12.7 mg/l in July to 6.0 mg/l in September at the forebay, and from 11.6 mg/l in April to 5.7 mg/l in September at the transition zone. Contour plots of temperature and DO versus depth for the period January through the end of September for both the forebay (figure 30) and the transition zone (figure 31) depict the seasonal variation and summer time stratification of Fort Loudoun reservoir. In July, at the forebay, the temperature decreased

FIGURE 29.

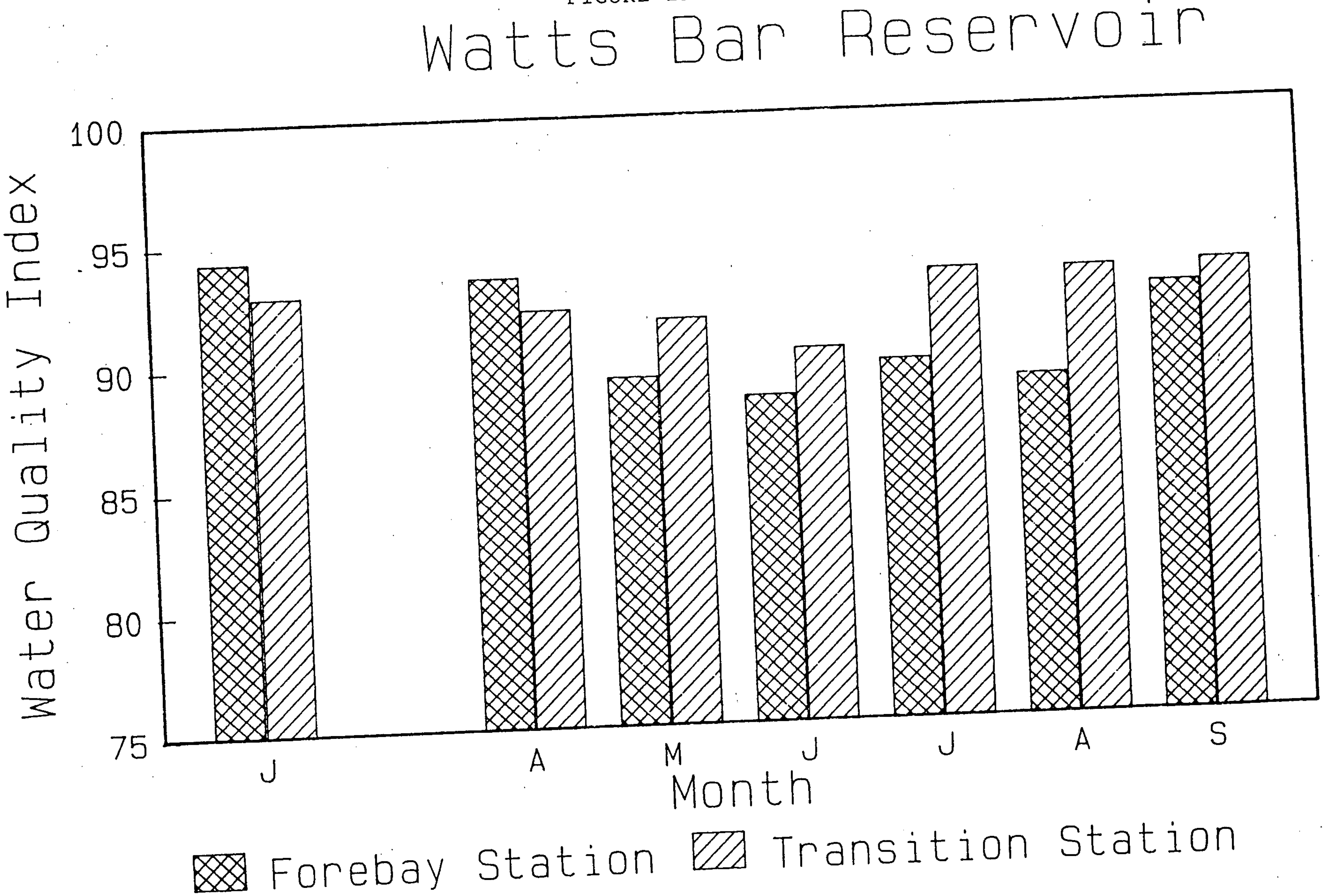

Watts Bar Reservoir
Water Quality Index
100
95
90
85
80
75
J
A
M
J
J
A
S
Month
Forebay Station
Transition Station

Table 15
Fort Loudoun Reservoir – Water Quality Summary
Reservoir Vital Signs Monitoring, WY 1990

Variable	Forebay N	Forebay Mean	Forebay Min	Forebay Max	Transition Zone N	Transition Zone Mean	Transition Zone Min	Transition Zone Max
Temperature (° C)	100	19.5	6.8	28.8	75	19.7	6.9	27.4
Dissolved Oxygen, (mg/l)	100	7.1	0.5	12.8	75	7.7	4.2	12.6
pH (s.u.)	100	7.6	6.6	9.0	75	7.6	6.9	8.7
Conductivity, (µmhos/cm)	100	181.7	70.0	230.0	75	199.2	150.0	240.0
Organic – N (mg/l)	18	0.27	0.09	0.46	18	0.32	0.11	0.66
Ammonia – N (mg/l)	18	0.05	0.01	0.19	18	0.05	0.01	0.09
Nitrate+Nitrite – N (mg/l)	18	0.37	0.05	0.70	18	0.50	0.22	0.65
Total Nitrogen (mg/l)	18	0.7	0.3	1.1	18	0.9	0.4	1.2
Total Phosphorous (mg/l)	18	0.04	0.02	0.09	18	0.05	0.03	0.08
TN/TP Ratio	18	19.1	6.1	46.0	18	16.7	8.4	21.3
Dissolved Ortho – P (mg/l)	18	0.015	0.002	0.030	18	0.019	0.009	0.040
Total Organic Carbon (mg/l)	18	2.1	0.9	3.0	18	2.3	1.1	3.9
Soluble Organic Carbon (mg/l)	18	1.9	0.8	2.7	18	2.1	0.9	3.9
Chlorophyll-a (µg/l)	9	11.9	1.0	20.0	8	11.5	3.0	20.0
Secchi depth (m)	7	1.2	0.5	2.0	7	0.8	0.3	1.0
Turbidity (NTU)	18	10.9	2.0	25.0	18	16.8	4.0	46.0
Suspended Solids (mg/l)	18	10.4	3.0	42.0	18	16.1	6.0	34.0
True Color (PCU)	18	18.1	5.0	35.0	18	21.1	5.0	45.0
Apparent Color (PCU)	18	23.5	7.0	43.0	18	27.0	10.0	50.0
Fecal Coliform (#/100 ml)	8	25.0	10.0	130.0	8	11.3	10.0	20.0

STORET RETRIEVAL DATE 91/03/06 PGM=RET
VITAL SIGNS RESERVOIR MONITORING
WY90

475358 1017
35 06 26.0 085 12 20.0 2
CHICKAMAUGA RES. AT LIGHTED BUOY
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 472.3
131TVAC 06020001021 0000.710 ON
0000 METERS DEPTH

/TYPA/AMBNT/STREAM/SOLIDS

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00078 TRANSP SECCHI METERS	00010 WATER TEMP CENT	00300 DO MG/L	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
90/01/24	1119	WATER	0.3	.88	8.3	11.1	7.70	148.0
90/01/24	1122	WATER	1.5		8.3	10.9	7.70	146.0
90/01/24	1125	WATER	4		8.3	10.8	7.70	149.0
90/01/24	1128	WATER	6		8.3	10.9	7.70	149.0
90/01/24	1131	WATER	8		8.3	10.8	7.70	151.0
90/01/24	1134	WATER	10		8.3	10.8	7.70	151.0
90/01/24	1137	WATER	12		8.3	10.8	7.70	151.0
90/01/24	1140	WATER	14		8.3	10.8	7.70	150.0
90/01/24	1143	WATER	16		8.3	10.8	7.70	151.0
90/04/17	1100	WATER	0.3	1.00	16.8	11.4	8.60	128.0
90/04/17	1101	WATER	1.5		16.4	11.3	8.50	128.0
90/04/17	1102	WATER	3		15.6	10.3	8.00	128.0
90/04/17	1104	WATER	3.5		15.2	10.2	7.90	127.0
90/04/17	1106	WATER	4		15.2	10.2	7.90	127.0
90/04/17	1110	WATER	6		15.0	10.1	7.90	126.0
90/04/17	1114	WATER	8		14.9	10.1	7.90	125.0
90/04/17	1118	WATER	10		14.5	10.0	7.80	124.0
90/04/17	1120	WATER	12		14.4	9.9	7.80	123.0
90/04/17	1122	WATER	14		14.1	9.4	7.70	124.0
90/04/17	1124	WATER	16		14.1	8.9	7.60	124.0
90/04/17	1127	WATER	17.5		14.0	7.9	7.40	123.0
90/05/15	1058	WATER	0.3	.92	21.8	11.0	8.70	134.0
90/05/15	1100	WATER	1		20.6	10.2	8.50	134.0
90/05/15	1100	WATER	1.5		20.3	9.2	8.00	134.0
90/05/15	1102	WATER	4		19.8	8.3	7.70	133.0
90/05/15	1108	WATER	6		19.6	8.0	7.50	133.0
90/05/15	1110	WATER	8		19.5	7.8	7.40	132.0
90/05/15	1115	WATER	10		19.2	7.6	7.40	132.0
90/05/15	1120	WATER	12		19.1	7.3	7.30	133.0
90/05/15	1125	WATER	14		19.0	7.2	7.30	133.0
90/05/15	1130	WATER	16		18.9	7.0	7.20	132.0
90/05/15	1135	WATER	17.5		18.9	6.9	7.20	133.0
90/06/26	1028	WATER	0.3	1.30	26.5	8.4	7.70	173.0
90/06/26	1030	WATER	1		26.6	8.1	7.60	172.0
90/06/26	1031	WATER	1.5		26.6	7.8	7.60	172.0
90/06/26	1032	WATER	4		26.6	7.6	7.50	172.0
90/06/26	1035	WATER	6		26.6	7.3	7.40	172.0
90/06/26	1036	WATER	8		26.6	6.7	7.30	173.0
90/06/26	1037	WATER	10		26.6	6.5	7.20	173.0
90/06/26	1038	WATER	12		26.6	6.3	7.20	173.0
90/06/26	1040	WATER	14		26.5	5.9	7.10	171.0
90/06/26	1042	WATER	15		26.2	5.4	7.00	171.0
90/06/26	1045	WATER	15.5		26.2	4.7	7.00	172.0
90/06/26	1048	WATER	16		26.0	4.1	6.90	171.0
90/06/26	1052	WATER	17		25.7	3.1	6.80	171.0
90/07/17	1059	WATER	0.3	1.25	27.2	7.2	7.60	191.0
90/07/17	1102	WATER	1.5		27.1	7.1	7.60	191.0
90/07/17	1103	WATER	2.5		26.9	6.2	7.50	191.0
90/07/17	1104	WATER	4		26.8	5.9	7.50	192.0
90/07/17	1107	WATER	6		26.8	5.8	7.50	192.0
90/07/17	1108	WATER	8		26.8	5.9	7.50	191.0
90/07/17	1109	WATER	10		26.8	5.9	7.50	191.0
90/07/17	1110	WATER	12		26.8	5.7	7.50	191.0
90/07/17	1111	WATER	14		26.7	4.9	7.40	190.0
90/07/17	1114	WATER	16		26.5	4.7	7.40	191.0
90/07/17	1116	WATER	18		26.5	4.0	7.30	188.0
90/08/21	1116	WATER	0.3	1.36	28.0	8.2	7.90	175.0
90/08/21	1118	WATER	1.5		27.9	7.5	7.70	176.0
90/08/21	1119	WATER	4		27.7	7.2	7.50	176.0
90/08/21	1122	WATER	6		27.7	7.0	7.50	175.0
90/08/21	1123	WATER	8		27.7	6.9	7.50	175.0
90/08/21	1124	WATER	10		27.6	6.6	7.40	175.0
90/08/21	1125	WATER	12		27.6	6.2	7.30	175.0
90/08/21	1126	WATER	14		27.5	5.7	7.20	174.0
90/08/21	1129	WATER	16		27.5	5.5	7.10	174.0
90/08/21	1130	WATER	17.5		27.5	5.3	7.10	174.0
90/09/18	1228	WATER	0.3	1.60	26.1	5.7	7.50	181.0
90/09/18	1230	WATER	1		26.1	5.7	7.40	181.0
90/09/18	1231	WATER	1.5		26.0	5.5	7.40	181.0
90/09/18	1232	WATER	2		26.0	5.4	7.40	181.0
90/09/18	1232	WATER	3		25.9	5.4	7.40	182.0
90/09/18	1232	WATER	4		25.9	5.3	7.40	182.0
90/09/18	1234	WATER	5		25.9	5.2	7.40	182.0
90/09/18	1234	WATER	6		25.8	5.2	7.30	182.0
90/09/18	1235	WATER	7		25.8	5.2	7.30	182.0
90/09/18	1235	WATER	8		25.8	5.2	7.30	182.0
90/09/18	1236	WATER	9		25.8	5.2	7.30	183.0
90/09/18	1236	WATER	10		25.8	5.2	7.30	183.0
90/09/18	1237	WATER	11		25.8	5.2	7.30	183.0
90/09/18	1237	WATER	12		25.8	5.2	7.30	183.0
90/09/18	1238	WATER	13		25.8	5.2	7.30	183.0
90/09/18	1238	WATER	14		25.8	5.3	7.40	182.0

STORET RETRIEVAL DATE 91/03/06 PGM=RET
VITAL SIGNS RESERVOIR MONITORING
WY90

475358 1017
35 06 26.0 085 12 20.0 2
CHICKAMAUGA RES. AT LIGHTED BUOY
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 472.3
131TVAC 06020001021 0000.710 ON
0000 METERS DEPTH

/TYPA/AMBNT/STREAM/SOLIDS

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00078 TRANSP SECCHI METERS	00010 WATER TEMP CENT	00300 DO MG/L	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
90/09/18	1240	WATER	15		25.8	5.4	7.40	182.0
90/09/18	1240	WATER	16		25.8	5.4	7.40	184.0
90/09/18	1241	WATER	17		25.7	5.4	7.40	183.0

STORET RETRIEVAL DATE 91/03/06 PGM=RET
VITAL SIGNS RESERVOIR MONITORING
HY90

/TYPA/AMBNT/STREAM/SOLIDS

475358 1017
35 06 26.0 085 12 20.0 2
CHICKAMAUGA RES. AT LIGHTED BUOY
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 472.3
131TVAC 06020001021 0000.710 ON
0000 METERS DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00080 COLOR PT-CO UNITS	00081 AP COLOR PT-CO UNITS	82079 TURBIDTY LAB NTU	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P
90/01/24	1125	VERT	4		15	25	16.0	8	.210	.050	.41	.040	.010
90/01/24	1138	WATER	13.5		10	15	11.0	6	.190	.050	.41	.030	.009
90/04/17	1106	VERT	4		10	15	5.8	5	.160	.010K	.24	.020	.005
90/04/17	1123	WATER	14.5		10	20	7.9	5	.140	.020	.29	.020	.006
90/05/15	1058	WATER	0.3	D1									
90/05/15	1059	WATER	0.3	D2									
90/05/15	1100	WATER	0.3	D3									
90/05/15	1102	VERT	4	D1	25	28	3.0	3	.370	.010	.13	.020	.003
90/05/15	1103	VERT	4	D2	30	35	4.0	4	.410	.010	.13	.030	.004
90/05/15	1104	VERT	4	D3	30	32	5.0	5	.450	.010	.13	.040	.004
90/05/15	1126	WATER	14.5	D1	30	33	8.0	8	.130	.070	.26	.030	.010
90/05/15	1127	WATER	14.5	D2	25	33	8.0	7	.130	.070	.26	.030	.010
90/05/15	1128	WATER	14.5	D3	25	33	8.0	7	.160	.060	.25	.030	.010
90/06/26	1032	VERT	4		20	25	6.0	4	.480	.010K	.20	.030	.004
90/06/26	1041	WATER	14.5		25	30	6.0	4	.250	.030	.23	.020	.007
90/07/17	1104	VERT	4		20	25	5.0	3	.180	.010K	.21	.020	.003
90/07/17	1112	WATER	15		20	25	5.0	4	.290	.010	.25	.020	.007
90/08/21	1119	VERT	4		10	15	3.0	3	.280	.010K	.16	.020	.004
90/08/21	1127	WATER	14.6		10	15	3.0	4	.150	.030	.19	.020	.006
90/09/18	1232	VERT	4		10	15	3.0	3	.160	.040	.19	.020	.010
90/09/18	1239	WATER	14.4		2	5	4.0	6	.120	.080	.18	.020	.010

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00680 T ORG C C MG/L	00681 D ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L	31616 FEC COLI MFM-FCBR /100ML
90/01/24	1119	WATER	0.3								440
90/01/24	1125	VERT	4		.9	.6	5	1	1	1	
90/01/24	1138	WATER	13.5		.9	.7	4	1	1	2	
90/04/17	1100	WATER	0.3								10K
90/04/17	1106	VERT	4		1.8	1.7	5	1	2	5	
90/04/17	1123	WATER	14.5		1.6	1.5	4	1K	1K	1	
90/05/15	1058	WATER	0.3	D1							10K
90/05/15	1059	WATER	0.3	D2							10K
90/05/15	1100	WATER	0.3	D3							10K
90/05/15	1102	VERT	4	D1	2.1	2.0	12	2	2	1K	
90/05/15	1103	VERT	4	D2	2.2	1.9	16	1	3	1K	
90/05/15	1104	VERT	4	D3	2.4	2.0	19	4	5	6	
90/05/15	1126	WATER	14.5	D1	2.1	1.9	2	1	2	4	
90/05/15	1127	WATER	14.5	D2	2.0	2.1	2	2	2	3	
90/05/15	1128	WATER	14.5	D3	2.0	1.9	2	1K	1K	1	
90/06/26	1028	WATER	0.3								10K
90/06/26	1032	VERT	4		2.4	2.1	24	2	3	5	
90/06/26	1041	WATER	14.5		2.0	1.9					
90/07/17	1059	WATER	0.3								10K
90/07/17	1104	VERT	4		2.1	1.9	11	1K	1	2	
90/07/17	1112	WATER	15		1.9	1.7					
90/08/21	1116	WATER	0.3								10K
90/08/21	1119	VERT	4		2.2	2.1	13	1	1	2	
90/08/21	1127	WATER	14.6		1.9	1.9					
90/09/18	1228	WATER	0.3								10K
90/09/18	1232	VERT	4		2.0	1.8	5	1K	1K	1	
90/09/18	1239	WATER	14.4		1.9	1.8					

STORET RETRIEVAL DATE 91/03/06 PGM=RET
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HY90

/TYPA/AMBNT/STREAM/SOLIDS

475265 1053
35 18 00.0 085 04 33.0 2
CHICKAMAUGA RESERVOIR
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 490.47
131TVAC 06020001025 0005.740 ON
0000 METERS DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00078 TRANSP SECCHI METERS	00010 WATER TEMP CENT	00300 DO MG/L	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
90/01/24	0935	WATER	0.3	1.38	7.3	11.2	7.80	158.0
90/01/24	0936	WATER	1.5		7.3	11.1	7.70	158.0
90/01/24	0937	WATER	4		7.2	11.1	7.70	160.0
90/01/24	0940	WATER	6		7.2	11.1	7.80	162.0
90/01/24	0943	WATER	8		7.2	11.1	7.80	162.0
90/01/24	0946	WATER	9		7.2	11.1	7.80	161.0
90/04/17	0946	WATER	0.3	1.10	15.8	11.9	8.50	134.0
90/04/17	0947	WATER	1.5		15.8	11.8	8.50	134.0
90/04/17	0948	WATER	2.5		15.3	10.9	8.10	134.0
90/04/17	0949	WATER	3		14.8	10.0	7.70	136.0
90/04/17	0950	WATER	4		14.7	9.7	7.70	136.0
90/04/17	0955	WATER	6		14.3	9.4	7.60	134.0
90/04/17	1000	WATER	8		14.2	9.0	7.60	133.0
90/04/17	1005	WATER	10		14.1	8.7	7.50	134.0
90/05/15	0930	WATER	0.3	1.07	21.0	10.2	8.40	134.0
90/05/15	0932	WATER	1		20.8	9.4	8.20	136.0
90/05/15	0934	WATER	1.5		20.4	8.9	7.90	135.0
90/05/15	0936	WATER	2		20.0	8.5	7.70	136.0
90/05/15	0938	WATER	4		19.2	7.5	7.40	134.0
90/05/15	0945	WATER	6		18.8	7.4	7.40	133.0
90/05/15	0950	WATER	8		18.6	7.2	7.30	131.0
90/05/15	1000	WATER	10		18.4	7.0	7.30	130.0
90/05/15	1012	WATER	10.5		18.4	7.0	7.30	129.0
90/06/26	0920	WATER	0.3	1.25	24.6	8.9	7.90	175.0
90/06/26	0922	WATER	1		24.5	8.0	7.80	176.0
90/06/26	0923	WATER	1.5		24.7	7.8	7.80	175.0
90/06/26	0925	WATER	2.5		24.6	7.1	7.50	176.0
90/06/26	0928	WATER	3		24.5	6.0	7.30	175.0
90/06/26	0931	WATER	4		24.4	5.7	7.20	175.0
90/06/26	0935	WATER	6		24.3	5.3	7.20	176.0
90/06/26	0940	WATER	8		24.3	5.2	7.20	175.0
90/06/26	0948	WATER	10		24.2	4.4	7.10	175.0
90/07/17	0933	WATER	0.3	1.25	25.1	4.9	7.50	188.0
90/07/17	0935	WATER	1.5		25.1	4.7	7.50	188.0
90/07/17	0936	WATER	4		25.1	4.5	7.50	188.0
90/07/17	0938	WATER	6		25.0	4.5	7.50	189.0
90/07/17	0938	WATER	8		25.0	4.4	7.50	189.0
90/07/17	0940	WATER	10		24.9	4.2	7.50	190.0
90/07/17	0942	WATER	10.5		24.9	4.2	7.50	190.0
90/08/21	1032	WATER	0.3	1.24	26.5	6.1	7.50	178.0
90/08/21	1035	WATER	1.5		26.3	5.7	7.40	178.0
90/08/21	1036	WATER	4		26.2	5.5	7.30	179.0
90/08/21	1039	WATER	6		26.2	5.4	7.30	179.0
90/08/21	1040	WATER	8		26.2	5.3	7.20	179.0
90/08/21	1043	WATER	10		26.2	5.3	7.20	179.0
90/09/18	1001	WATER	0.3	1.25	25.0	5.5	7.40	187.0
90/09/18	1003	WATER	1.5		25.1	5.4	7.40	187.0
90/09/18	1004	WATER	4		25.1	5.3	7.40	186.0
90/09/18	1006	WATER	6		25.1	5.3	7.40	186.0
90/09/18	1007	WATER	8		25.1	5.2	7.40	187.0
90/09/18	1009	WATER	10		25.1	5.2	7.30	187.0

STORET RETRIEVAL DATE 91/03/06 PGM=RET
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HY90

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475265 1053
35 18 00.0 085 04 33.0 2
CHICKAMAUGA RESERVOIR
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 490.47
131TVAC 06020001025 0005.740 ON
0000 METERS DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00080 COLOR PT-CO UNITS	00081 AP COLOR PT-CO UNITS	82079 TURBIDTY LAB NTU	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P
90/01/24	0937	VERT	4		10	20	12.0	8	.210	.050	.43	.030	.010
90/01/24	0941	WATER	6.2		10	20	18.0	10	.150	.050	.43	.030	.010
90/04/17	0950	VERT	4		10	20	5.2	4	.200	.010K	.24	.020	.005
90/04/17	1002	WATER	9.2000		10	20	10.3	7	.100	.040	.30	.030	.010
90/05/15	0930	WATER	0.3	D1									
90/05/15	0931	WATER	0.3	D2									
90/05/15	0932	WATER	0.3	D3									
90/05/15	0938	VERT	4	D1	20	31	4.0	3	.330	.010	.19	.030	.006
90/05/15	0939	VERT	4	D2	20	27	4.0	3	.360	.020	.19	.020	.005
90/05/15	0940	VERT	4	D3	25	32	4.0	3	.350	.030	.19	.020	.005
90/05/15	0955	WATER	9.8	D1	30	38	11.0	8	.160	.080	.26	.030	.010
90/05/15	0956	WATER	9.8	D2	35	43	10.0	9	.190	.070	.26	.030	.010
90/05/15	0957	WATER	9.8	D3	30	38	11.0	9	.270	.070	.25	.030	.010
90/06/26	0931	VERT	4		25	30	6.0	5	.380	.010K	.22	.030	.004
90/06/26	0942	WATER	9.5		30	35	9.0	6	.260	.020	.29	.030	.005
90/07/17	0936	VERT	4		20	25	5.0	4	.210	.010	.28	.020	.010
90/07/17	0939	WATER	9.6000		15	20	6.0	5	.250	.010	.28	.020	.010
90/08/21	1036	VERT	4		10	15	3.0	5	.190	.030	.23	.040	.010
90/08/21	1041	WATER	9.3		10	15	4.0	5	.170	.030	.24	.040	.010
90/09/18	1004	VERT	4		2	5	3.0	6	.160	.080	.18	.020	.010
90/09/18	1008	WATER	9.4		2	5	3.0	4	.110	.110	.18	.030	.020

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00680 T ORG C C MG/L	00681 D ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L	31616 FEC COLI MFM-FCBR /100ML
90/01/24	0935	WATER	0.3								150
90/01/24	0937	VERT	4		.9	.7	5	1	2	2	
90/01/24	0941	WATER	6.2		.8	.7	4	1	1	2	
90/04/17	0946	WATER	0.3								10K
90/04/17	0950	VERT	4		1.9	1.9	11	1K	1	1	
90/04/17	1002	WATER	9.2000		1.8	1.8	4	1	1	1	
90/05/15	0930	WATER	0.3	D1							10K
90/05/15	0931	WATER	0.3	D2							10
90/05/15	0932	WATER	0.3	D3							10
90/05/15	0938	VERT	4	D1	2.2	2.0	17	3	3	3	
90/05/15	0939	VERT	4	D2	2.3	2.0	13	4	3	2	
90/05/15	0940	VERT	4	D3	2.4	2.1	16	2	3	1K	
90/05/15	0955	WATER	9.8	D1	2.3	2.0	2	1	1	2	
90/05/15	0956	WATER	9.8	D2	2.1	1.9	3	1	1	1K	
90/05/15	0957	WATER	9.8	D3	2.1	2.0	2	1K	1K	2	
90/06/26	0920	WATER	0.3								10K
90/06/26	0931	VERT	4		2.4	2.2					
90/06/26	0942	WATER	9.5		2.1	2.0					
90/07/17	0933	WATER	0.3								10K
90/07/17	0936	VERT	4		2.1	1.9	5	1K	1K	1K	
90/07/17	0939	WATER	9.6000		1.9	1.7					
90/08/21	1032	WATER	0.3								10K
90/08/21	1036	VERT	4		2.1	2.0	5	1K	1	1	
90/08/21	1041	WATER	9.3		1.9	1.9					
90/09/18	1001	WATER	0.3								10K
90/09/18	1004	VERT	4		2.0	2.0	4	1K	1K	1	
90/09/18	1008	WATER	9.4		2.0	1.9					

STORET RETRIEVAL DATE 91/03/06 PGM=RET
VITAL SIGNS RESERVOIR MONITORING
HY90

/TYPA/AMBNT/STREAM/SOLIDS

475317 1089
35 38 10.0 084 47 06.0 2
OPP. LOWE BR. WATTS BAR RES.
47121 TENNESSEE MEIGS
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 531.0
131TVAC HQ 06010201002 0002.040 OFF
0000 METERS DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00078 TRANSP SECCHI METERS	00010 WATER TEMP CENT	00300 DO MG/L	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
90/01/25	1542	WATER	0.3	1.38	7.0	11.4	7.80	155.0
90/01/25	1543	WATER	1.5		7.0	11.3	7.90	154.0
90/01/25	1544	WATER	4		7.0	11.3	7.80	156.0
90/01/25	1547	WATER	6		7.0	11.3	7.80	158.0
90/01/25	1549	WATER	8		7.0	11.2	7.80	158.0
90/01/25	1551	WATER	10		7.0	11.2	7.80	158.0
90/01/25	1553	WATER	12		7.0	11.2	7.80	157.0
90/01/25	1555	WATER	14		7.0	11.2	7.90	157.0
90/01/25	1557	WATER	16		7.0	11.2	7.80	159.0
90/01/25	1559	WATER	18		7.0	11.2	7.90	159.0
90/01/25	1601	WATER	20		7.0	11.2	7.90	158.0
90/01/25	1603	WATER	22		7.0	11.2	7.90	158.0
90/01/25	1605	WATER	24		7.0	11.1	7.90	158.0
90/01/25	1607	WATER	25		7.0	11.1	7.90	157.0
90/04/18	1234	WATER	0.3	1.36	14.1	10.5	8.10	124.0
90/04/18	1235	WATER	1.5		14.1	10.4	8.10	124.0
90/04/18	1236	WATER	4		14.1	10.3	8.10	124.0
90/04/18	1239	WATER	6		14.1	10.2	8.10	123.0
90/04/18	1240	WATER	8		14.0	10.1	8.10	123.0
90/04/18	1241	WATER	10		14.0	10.1	8.10	123.0
90/04/18	1242	WATER	12		14.1	10.1	8.10	123.0
90/04/18	1243	WATER	14		14.0	10.0	8.00	122.0
90/04/18	1244	WATER	16		14.0	10.0	8.00	122.0
90/04/18	1245	WATER	18		14.0	10.0	8.00	124.0
90/04/18	1246	WATER	20		14.0	9.9	8.00	122.0
90/04/18	1247	WATER	22		14.0	9.8	8.00	123.0
90/04/18	1248	WATER	24		13.9	9.8	8.00	123.0
90/05/16	1213	WATER	0.3		21.1	10.7	8.80	153.0
90/05/16	1216	WATER	1.5		21.0	10.6	8.80	153.0
90/05/16	1217	WATER	4		20.6	10.3	8.70	154.0
90/05/16	1220	WATER	5		20.4	9.7	8.50	154.0
90/05/16	1223	WATER	6		20.2	8.9	8.20	156.0
90/05/16	1226	WATER	8		19.7	8.0	7.70	156.0
90/05/16	1229	WATER	10		19.5	7.7	7.60	156.0
90/05/16	1232	WATER	12		19.1	7.2	7.50	154.0
90/05/16	1235	WATER	14		18.8	6.9	7.40	149.0
90/05/16	1238	WATER	16		18.8	6.8	7.40	152.0
90/05/16	1241	WATER	18		18.5	6.4	7.40	152.0
90/05/16	1244	WATER	20		18.3	6.3	7.30	144.0
90/05/16	1247	WATER	22		17.9	5.7	7.20	146.0
90/05/16	1250	WATER	24		17.7	5.4	7.20	143.0

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00078 TRANSP SECCHI METERS	00010 WATER TEMP CENT	00300 DO MG/L	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
90/05/16	1254	WATER	25		17.5	5.3	7.10	114.0
90/06/27	1144	WATER	0.3	1.75	27.6	11.4	9.20	167.0
90/06/27	1146	WATER	1.5		26.9	11.5	9.20	166.0
90/06/27	1147	WATER	2.5		26.5	10.7	9.00	168.0
90/06/27	1148	WATER	3		26.4	10.0	8.90	169.0
90/06/27	1149	WATER	4		26.1	9.0	8.70	170.0
90/06/27	1151	WATER	5		25.8	8.2	8.60	171.0
90/06/27	1152	WATER	5.5		25.5	6.7	8.20	174.0
90/06/27	1153	WATER	6		25.2	5.9	7.90	177.0
90/06/27	1154	WATER	6.5		24.4	5.2	7.40	181.0
90/06/27	1155	WATER	8		24.0	4.4	7.20	184.0
90/06/27	1156	WATER	10		22.8	3.7	7.00	187.0
90/06/27	1157	WATER	12		22.6	3.4	7.00	186.0
90/06/27	1158	WATER	14		22.5	3.3	6.90	186.0
90/06/27	1159	WATER	16		22.3	3.2	6.90	185.0
90/06/27	1200	WATER	18		22.1	3.2	6.90	185.0
90/06/27	1201	WATER	20		21.9	2.3	6.90	177.0
90/06/27	1201	WATER	21		21.9	1.8	6.80	173.0
90/06/27	1202	WATER	22		21.8	1.1	6.80	168.0
90/06/27	1205	WATER	24		21.7	.7	6.80	168.0
90/06/27	1206	WATER	25		21.6	.6	6.80	165.0
90/07/19	1147	WATER	0.3	1.45	28.3	11.0	8.90	185.0
90/07/19	1147	WATER	1.5		27.7	11.0	8.90	185.0
90/07/19	1148	WATER	4		27.1	10.1	8.90	188.0
90/07/19	1150	WATER	4.5		27.0	9.4	8.70	188.0
90/07/19	1151	WATER	5		26.6	6.5	8.40	193.0
90/07/19	1152	WATER	6		26.4	6.2	8.20	194.0
90/07/19	1153	WATER	7.5		26.1	5.3	7.90	196.0
90/07/19	1154	WATER	8		25.9	4.4	7.80	199.0
90/07/19	1155	WATER	8.5		25.2	3.2	7.50	200.0
90/07/19	1156	WATER	10		25.0	3.0	7.30	202.0
90/07/19	1157	WATER	12		24.9	3.0	7.40	203.0
90/07/19	1158	WATER	14		24.7	3.0	7.40	202.0
90/07/19	1159	WATER	16		24.4	2.3	7.40	205.0
90/07/19	1200	WATER	18		24.2	1.7	7.30	206.0
90/07/19	1201	WATER	20		24.1	1.2	7.30	206.0
90/07/19	1202	WATER	22		24.0	.9	7.30	205.0
90/07/19	1202	WATER	24		23.8	.2	7.30	197.0
90/07/19	1204	WATER	25.5		23.6	.2	7.30	208.0
90/08/22	1130	WATER	0.3		28.0	11.1	8.90	178.0
90/08/22	1133	WATER	1.5		28.0	10.7	8.80	178.0

A32

STORET RETRIEVAL DATE 91/03/06 PGM=RET
VITAL SIGNS RESERVOIR MONITORING
WY90

/TYPA/AMBNT/STREAM/SOLIDS

475317 1089
35 38 10.0 084 47 06.0 2
OPP. LOWE BR. WATTS BAR RES.
47121 TENNESSEE MEIGS
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 531.0
131TVAC HQ 06010201002 0002.040 OFF
0000 METERS DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00078 TRANSP SECCHI METERS	00010 WATER TEMP CENT	00300 DO MG/L	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
90/08/22	1134	WATER	2		27.8	10.4	8.70	178.0
90/08/22	1135	WATER	2.5		27.7	10.0	8.70	179.0
90/08/22	1136	WATER	3		27.6	8.7	8.50	181.0
90/08/22	1137	WATER	3.5		26.8	8.0	8.10	183.0
90/08/22	1138	WATER	4		26.0	6.2	7.50	185.0
90/08/22	1141	WATER	6		25.0	5.0	7.10	185.0
90/08/22	1142	WATER	8		24.7	4.7	7.00	184.0
90/08/22	1142	WATER	10		24.5	4.5	7.00	183.0
90/08/22	1143	WATER	12		24.4	4.5	7.00	184.0
90/08/22	1143	WATER	14		24.3	4.2	7.00	183.0
90/08/22	1144	WATER	16		24.3	4.1	7.00	182.0
90/08/22	1145	WATER	18		24.2	4.1	6.90	182.0
90/08/22	1147	WATER	20		24.2	3.9	6.90	181.0
90/08/22	1149	WATER	22		24.1	3.8	6.90	183.0
90/08/22	1151	WATER	24		24.1	3.7	6.90	182.0
90/08/22	1153	WATER	24.5		24.1	3.5	7.00	182.0
90/09/19	1146	WATER	0.3	1.25	25.5	6.2	7.70	194.0
90/09/19	1148	WATER	1.5		25.5	6.1	7.70	194.0
90/09/19	1149	WATER	4		25.5	5.9	7.60	194.0
90/09/19	1151	WATER	6		25.6	6.0	7.70	195.0
90/09/19	1151	WATER	8		25.6	5.9	7.70	194.0
90/09/19	1151	WATER	10		25.6	5.9	7.60	195.0
90/09/19	1152	WATER	12		25.6	5.9	7.70	194.0
90/09/19	1152	WATER	14		25.6	5.8	7.70	195.0
90/09/19	1152	WATER	16		25.6	5.7	7.60	194.0
90/09/19	1153	WATER	18		25.5	5.3	7.60	195.0
90/09/19	1153	WATER	20		25.4	4.8	7.50	195.0
90/09/19	1155	WATER	22		25.4	4.8	7.50	196.0
90/09/19	1155	WATER	23.5		25.5	4.7	7.50	195.0
90/09/19	1155	WATER	24		25.4	2.6	7.50	199.0

STORET RETRIEVAL DATE 91/03/06 PGM=RET
VITAL SIGNS RESERVOIR MONITORING
MY90

/TYPA/AMBNT/STREAM/SOLIDS

475 [illegible] 1089
35 38 [illegible].0 084 47 06.0 2
OPP. LOWE BR. WATTS BAR RES.
47121 TENNESSEE MEIGS
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 531.0
131TVAC HQ 06010201002 0002.040 OFF
0000 METERS DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00080 COLOR PT-CO UNITS	00081 AP COLOR PT-CO UNITS	82079 TURBIDTY LAB NTU	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P
90/01/25	1544	VERT	4		10	15	9.0	5	.190	.070	.47	.040	.010
90/01/25	1604	WATER	22.3		10	20	8.8	4	.170	.050	.47	.030	.010
90/04/18	1236	VERT	4		15	15	5.1	4	.180	.020	.30	.020	.006
90/04/18	1246	WATER	21.3		15	15	6.0	6	.170	.030	.31	.010	.005
90/05/16	1213	WATER	0.3	D1									
90/05/16	1214	WATER	0.3	D2									
90/05/16	1215	WATER	0.3	D3									
90/05/16	1217	VERT	4	D1	20	25	2.0	1K	.320	.020	.16	.020	.003
90/05/16	1218	VERT	4	D2	20	23	3.0	1K	.400	.020	.16	.020	.003
90/05/16	1219	VERT	4	D3	25	30	2.0	2	.420	.020	.17	.020	.003
90/05/16	1248	WATER	22.2	D1	30	33	10.0	7	.210	.090	.30	.030	.010
90/05/16	1249	WATER	22.2	D2	30	33	10.0	7	.230	.070	.23	.020	.008
90/05/16	1250	WATER	22.2	D3	30	33	9.0	6	.270	.070	.25	.030	.008
90/06/27	1149	VERT	4		10	15	3.0	5	.500	.010K	.01	.030	.002
90/06/27	1203	WATER	22.3		7	10	9.0	8	.440	.080	.27	.030	.007
90/07/19	1148	VERT	4		15	20	4.0	3	.500	.010K	.01K	.020	.003
90/07/19	1202	WATER	22.7		7	10	9.0	7	.200	.040	.29	.040	.010
90/08/22	1138	VERT	4		10	15	3.0	3	.310	.010	.05	.020	.003
90/08/22	1148	WATER	21.8		10	15	7.0	10	.150	.010	.33	.020	.010
90/09/19	1149	VERT	4		10	15			.180	.060	.21	.050	.008
90/09/19	1154	WATER	21.1		5	10	11.0	18	.210	.070	.21	.050	.010

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00680 T ORG C C MG/L	00681 D ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L	31616 FEC COLI MFM-FCBR /100ML
90/01/25	1542	WATER	0.3								20
90/01/25	1544	VERT	4		.9	.7	4	1K	1K	1	
90/01/25	1604	WATER	22.3		.9	.7	6	1K	1	1	
90/04/18	1236	VERT	4		1.7	1.5	7	1K	1	1	
90/04/18	1246	WATER	21.3		1.5	1.5	6	1K	1K	2	
90/05/16	1213	WATER	0.3	D1							10K
90/05/16	1214	WATER	0.3	D2							10K
90/05/16	1215	WATER	0.3	D3							10K
90/05/16	1217	VERT	4	D1	1.9	1.7	15	1K	2	1K	
90/05/16	1218	VERT	4	D2	2.1	1.8	20	1K	2	1K	
90/05/16	1219	VERT	4	D3	2.1	1.7	19	1K	2	1K	
90/05/16	1248	WATER	22.2	D1	1.7	1.5	3	1	1	2	
90/05/16	1249	WATER	22.2	D2	1.6	1.5	2	1K	1K	2	
90/05/16	1250	WATER	22.2	D3	1.5	1.5	2	1K	1	2	
90/06/27	1149	VERT	4		2.7	2.4	14	1	2	2	
90/06/27	1203	WATER	22.3		1.8	1.6					
90/07/19	1147	WATER	0.3								10K
90/07/19	1148	VERT	4		2.6	2.5	10	1K	1	1	
90/07/19	1202	WATER	22.7		1.8	1.6					
90/08/22	1130	WATER	0.3								10K
90/08/22	1138	VERT	4		2.4	2.1	17	1	2	2	
90/08/22	1148	WATER	21.8		1.9	1.8					
90/09/19	1146	WATER	0.3								10K
90/09/19	1149	VERT	4		1.9	1.8	9	1	1K	2	
90/09/19	1154	WATER	21.1		1.8	1.8					

A33

STORET RETRIEVAL DATE 91/03/06
VITAL SIGNS RESERVOIR MONITORING
WY90

PGM=RET

476041 1114C
35 49 50.0 084 36 33.0 2
WATTS BAR RESERVOIR
47145 TENNESSEE
TENNESSEE RIVER BASIN
TENNESSEE RIVER 560.80
131TVAC
0000 METERS DEPTH

ROANE
040801

HQ 06010201002 0043.170 OFF

/TYPA/AMBNT/STREAM/SOLIDS

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00078 TRANSP SECCHI METERS	00010 WATER TEMP CENT	00300 DO MG/L	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
90/01/25	1159	WATER	0.3	1.12	7.8	11.1	7.90	162.0
90/01/25	1200	WATER	1.5		7.8	11.0	7.90	162.0
90/01/25	1202	WATER	4		7.8	11.0	7.90	165.0
90/01/25	1205	WATER	6		7.8	11.0	7.90	167.0
90/04/18	1107	WATER	0.3	.98	15.5	11.2	8.30	146.0
90/04/18	1108	WATER	1.5		15.5	10.9	8.30	146.0
90/04/18	1109	WATER	4		15.4	10.6	8.20	143.0
90/04/18	1112	WATER	6		14.8	10.0	7.90	133.0
90/04/18	1115	WATER	8		14.5	9.7	7.80	130.0
90/04/18	1118	WATER	10		14.3	9.7	7.80	127.0
90/04/18	1121	WATER	12		14.2	9.4	7.70	127.0
90/04/18	1124	WATER	13		14.3	9.3	7.70	126.0
90/05/16	1038	WATER	0.3	.92	21.1	10.0	8.30	144.0
90/05/16	1040	WATER	1.5		20.0	9.7	8.20	144.0
90/05/16	1042	WATER	4		20.3	8.8	7.80	144.0
90/05/16	1050	WATER	6		20.2	8.5	7.80	144.0
90/05/16	1055	WATER	8		20.0	8.4	7.80	142.0
90/05/16	1100	WATER	10		19.9	8.3	7.70	143.0
90/05/16	1110	WATER	12		19.9	8.2	7.70	142.0
90/05/16	1123	WATER	13		19.9	8.1	7.70	142.0
90/06/27	1032	WATER	0.3	1.33	26.2	12.0	9.10	192.0
90/06/27	1034	WATER	1.5		25.7	11.5	8.90	197.0
90/06/27	1035	WATER	2.5		25.5	10.7	8.60	200.0
90/06/27	1036	WATER	3.5		25.2	10.0	8.40	202.0
90/06/27	1037	WATER	4		24.3	8.4	7.90	202.0
90/06/27	1039	WATER	5		23.8	7.9	7.70	201.0
90/06/27	1040	WATER	6		23.1	7.1	7.50	201.0
90/06/27	1041	WATER	8		22.6	6.7	7.40	205.0
90/06/27	1042	WATER	10		22.4	6.2	7.30	208.0
90/06/27	1043	WATER	12		22.4	5.9	7.30	209.0
90/06/27	1045	WATER	13		22.3	5.8	7.30	209.0
90/07/19	1036	WATER	0.3	.80	25.4	8.7	8.00	170.0
90/07/19	1038	WATER	1.5		24.7	8.0	7.90	168.0
90/07/19	1039	WATER	4		24.4	7.3	7.80	167.0
90/07/19	1041	WATER	6		24.3	7.0	7.70	168.0
90/07/19	1041	WATER	8		24.3	6.9	7.70	168.0
90/07/19	1041	WATER	10		23.9	6.1	7.60	173.0
90/07/19	1042	WATER	12		23.8	6.0	7.70	174.0
90/07/19	1043	WATER	13		23.8	5.8	7.50	174.0
90/08/22	1037	WATER	0.3	1.22	25.4	8.6	7.90	186.0
90/08/22	1040	WATER	1.5		25.4	8.3	7.80	186.0
90/08/22	1041	WATER	4		25.4	8.1	7.60	186.0
90/08/22	1044	WATER	6		25.3	7.7	7.50	184.0
90/08/22	1046	WATER	8		24.9	7.0	7.40	183.0
90/08/22	1049	WATER	10		24.7	6.7	7.30	183.0
90/08/22	1053	WATER	12		24.7	6.5	7.30	182.0
90/08/22	1058	WATER	12.5		24.7	6.4	7.30	183.0
90/09/19	1044	WATER	0.3	1.00	24.8	6.3	7.60	208.0
90/09/19	1046	WATER	1.5		24.8	6.2	7.60	208.0
90/09/19	1047	WATER	4		24.8	6.2	7.60	208.0
90/09/19	1049	WATER	6		24.8	6.2	7.60	208.0
90/09/19	1049	WATER	8		24.8	6.2	7.60	208.0
90/09/19	1050	WATER	10		24.8	6.2	7.60	208.0
90/09/19	1050	WATER	12		24.7	5.9	7.60	209.0
90/09/19	1052	WATER	13		24.9	5.9	7.60	209.0

STORET RETRIEVAL DATE 91/03/06 PGM=RET
VITAL SIGNS RESERVOIR MONITORING
WY90

/TYPA/AMBNT/STREAM/SOLIDS

476041 1114C
35 49 50. 36 33.0 2
WATTS BAR RESERVOIR
47145 TENNESSEE ROANE
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 560.80
131TVAC HQ 06010201002 0043.170 OFF
0000 METERS DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00080 COLOR PT-CO UNITS	00081 AP COLOR PT-CO UNITS	82079 TURBIDTY LAB NTU	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P
90/01/25	1201	WATER	3.4		10	15	12.0	8	.160	.060	.53	.030	.020
90/01/25	1202	VERT	4		10	15	12.0	9	.200	.060	.52	.040	.020
90/04/18	1109	VERT	4		15	15	8.8	8	.300	.020	.31	.020	.006
90/04/18	1122	WATER	12.2		20	25	13.0	10	.210	.030	.39	.030	.007
90/05/16	1038	WATER	0.3	D1									
90/05/16	1039	WATER	0.3	D2									
90/05/16	1040	WATER	0.3	D3									
90/05/16	1042	VERT	4	D1	25	30	6.0	5	.310	.030	.21	.030	.004
90/05/16	1043	VERT	4	D2	20	25	7.0	5	.340	.020	.21	.030	.004
90/05/16	1044	VERT	4	D3	20	23	7.0	5	.240	.020	.21	.030	.004
90/05/16	1111	WATER	12.3	D1	25	30	12.0	10	.110	.050	.26	.030	.004
90/05/16	1112	WATER	12.3	D2	20	23	15.0	12	.150	.050	.26	.030	.004
90/05/16	1113	WATER	12.3	D3	20	25	14.0	12	.180	.040	.25	.030	.004
90/06/27	1037	VERT	4		10	15	5.0	4	.520	.010K	.19	.040	.004
90/06/27	1044	WATER	12.5		10	15	20.0	16	.250	.030	.40	.040	.007
90/07/19	1039	VERT	4		7	15	6.0	4	.340	.010K	.19	.020	.004
90/07/19	1042	WATER	12.2		15	20	9.0	7	.180	.020	.26	.020	.005
90/08/22	1041	VERT	4		10	15	3.0	5	.180	.010K	.19	.020	.003
90/08/22	1050	WATER	11.7		10	7	10.0	21	.210	.030	.20	.030	.006
90/09/19	1047	VERT	4		5	10	4.0	5	.130	.070	.21	.020	.009
90/09/19	1051	WATER	12.2		5	10	6.0	8	.150	.070	.25	.030	.010

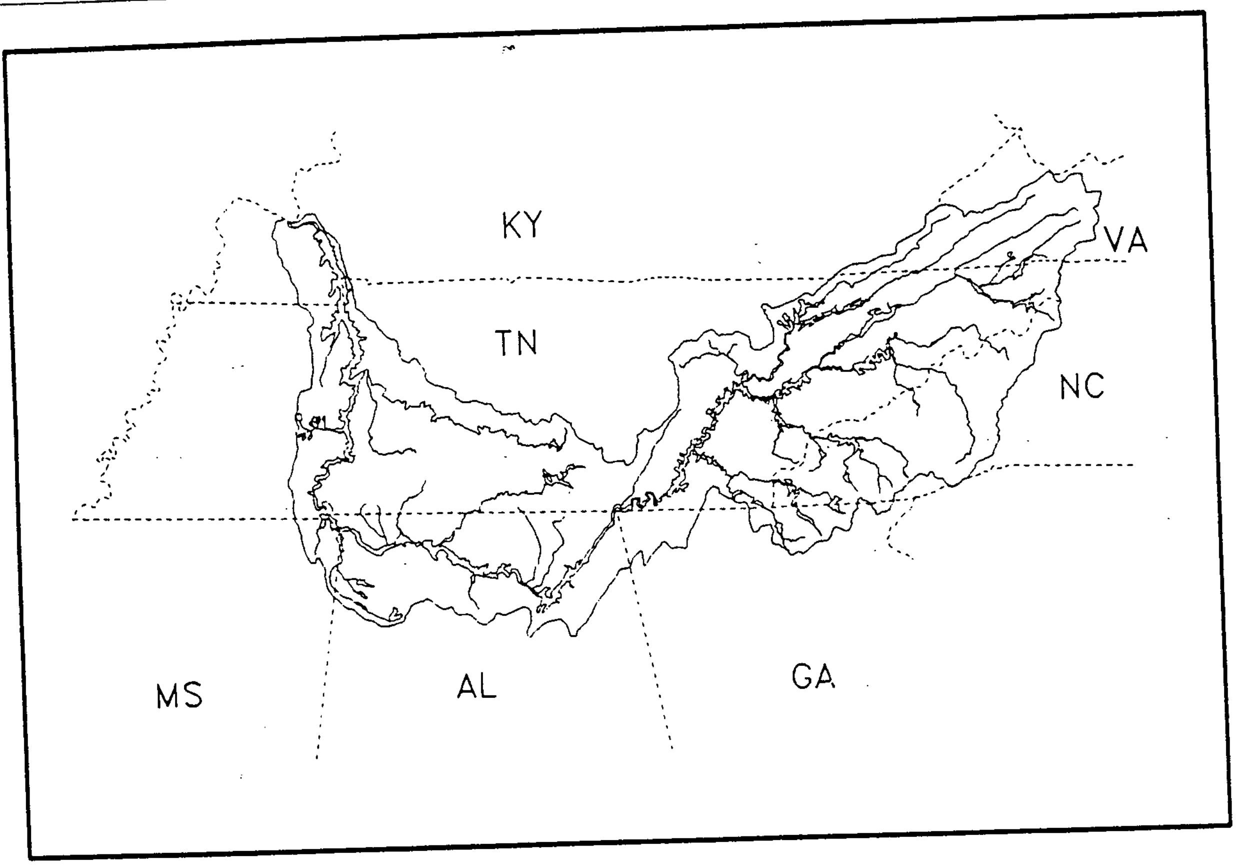
DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00680 T ORG C C MG/L	00681 D ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L	31616 FEC COLI MFM-FCBR /100ML
90/01/25	1159	WATER	0.3								70
90/01/25	1201	WATER	3.4		.9	.7	5	1K	1	1	
90/01/25	1202	VERT	4		1.0	.9	5	1	1	1	
90/04/18	1109	VERT	4		1.7	1.6	10	1K	1	1K	
90/04/18	1122	WATER	12.2		1.6	1.5	7	1K	1	2	
90/05/16	1038	WATER	0.3	D1							10
90/05/16	1039	WATER	0.3	D2							10K
90/05/16	1040	WATER	0.3	D3							10
90/05/16	1042	VERT	4	D1	1.8	1.6	14	1	1	1	
90/05/16	1043	VERT	4	D2	1.8	1.6	14	1	2	1	
90/05/16	1044	VERT	4	D3	1.9	1.7	14	1	1	2	
90/05/16	1111	WATER	12.3	D1	1.7	1.5	6	1	1	4	
90/05/16	1112	WATER	12.3	D2	1.6	1.5	6	1	1	3	
90/05/16	1113	WATER	12.3	D3	1.6	1.5	5	1	1	3	
90/06/27	1037	VERT	4		2.4	2.2	14	1	1	3	
90/06/27	1044	WATER	12.5		1.8	1.7					
90/07/19	1036	WATER	0.3								10K
90/07/19	1039	VERT	4		2.0	1.8	10	1K	1	2	
90/07/19	1042	WATER	12.2		1.6	1.4					
90/08/22	1037	WATER	0.3								10K
90/08/22	1041	VERT	4		2.0	1.9	12	1	1	3	
90/08/22	1050	WATER	11.7		1.9	1.8					
90/09/19	1044	WATER	0.3								10K
90/09/19	1047	VERT	4		1.9	1.9	6	1K	1K	3	
90/09/19	1051	WATER	12.2		1.8	1.9					

Tennessee
Valley
Authority

Water Resources Division
Chattanooga, Tennessee

TVA/WR--92/1
July 1992

RESERVOIR VITAL SIGNS MONITORING - 1991
PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER AND SEDIMENT



WATER RESOURCES &
ECOLOGICAL MONITORING
WATER RESOURCES MANAGEMENT

INTRODUCTION

In FY 1990, the Tennessee Valley Authority (TVA) initiated a Vital Signs Monitoring program on 12 TVA reservoirs (the nine mainstem Tennessee river reservoirs - Kentucky through Fort Loudoun, and three major tributary reservoirs - Cherokee, Douglas and Norris) as part of its Water Resources and Ecological Monitoring Program (TVA, 1989). In FY 1991, the Vital Signs Monitoring program was expanded to include Melton Hill and Tellico reservoirs to comprise TVA's Basic Vital Signs monitoring strategy, Table 1a, (TVA, 1991). In addition, ten non-navigable tributary impoundments were also added to the program in 1991 which received less intensive monitoring, called TVA's Limited Vital Signs monitoring strategy, Table 1b, (TVA, 1991b).

The objective of the Vital Signs program is to provide basic information on the health or integrity of the aquatic ecosystem in each TVA reservoir and to provide screening level information for describing how well each reservoir meets the "fishable and swimmable" goals of the Clean Water Act. This is the first time in the history of the Agency that a commitment to a long term, systematic sampling of all major TVA reservoirs has been made.

The basis of the Vital Signs monitoring is examination of appropriate physical, chemical and biological indicators in three areas of each reservoir. These three areas are the forebay (the lacustrine region of the reservoir, immediately upstream of the dam), the transition zone (the mid-reservoir region where the water changes from free flowing to more quiescent, impounded water), and the inflow or headwater region of the reservoir. The information gathered is used to make seasonal and spatial assessments of each reservoir's health and the overall health of the reservoir system, and to provide guidance on the need to design and implement more detailed short-term studies where problems seem to exist. In addition, this information establishes a baseline for comparing with future water quality conditions and monitoring water quality trends for TVA reservoirs.

The Vital Signs program employs several activities to assess reservoir health. They include physical and chemical characteristics of water and sediment, acute toxicity screening of water and sediment, benthic macroinvertebrate population assessments, and fish abundance, composition and health.

This report presents 1991 information on the physical and chemical characteristics of water and sediment collected on the present twenty four Vital Signs reservoirs. Sampling was conducted at the forebay and transition zone locations on the largest eighteen reservoirs. Only the forebay location was sampled on the remaining six, smaller reservoirs. Water and sediment samples were not collected at reservoir inflow locations because: (1) for several tributary reservoirs, TVA's ambient stream monitoring program (Parr, 1991) incorporates sampling at inflow locations; (2) for mainstem or run-of-the-river reservoirs, inflow water sampling locations are tailrace locations and are dominated by the effects of the impoundment immediately upstream, rather than the processes occurring in the downstream reservoir being sampled; and (3) the lack of suitable substrate often precluded the collection of sediment samples at reservoir inflow tailrace locations.

The Reservoir Vital Signs Monitoring locations sampled in 1991 are shown on Figure 1 and listed in Table 1.

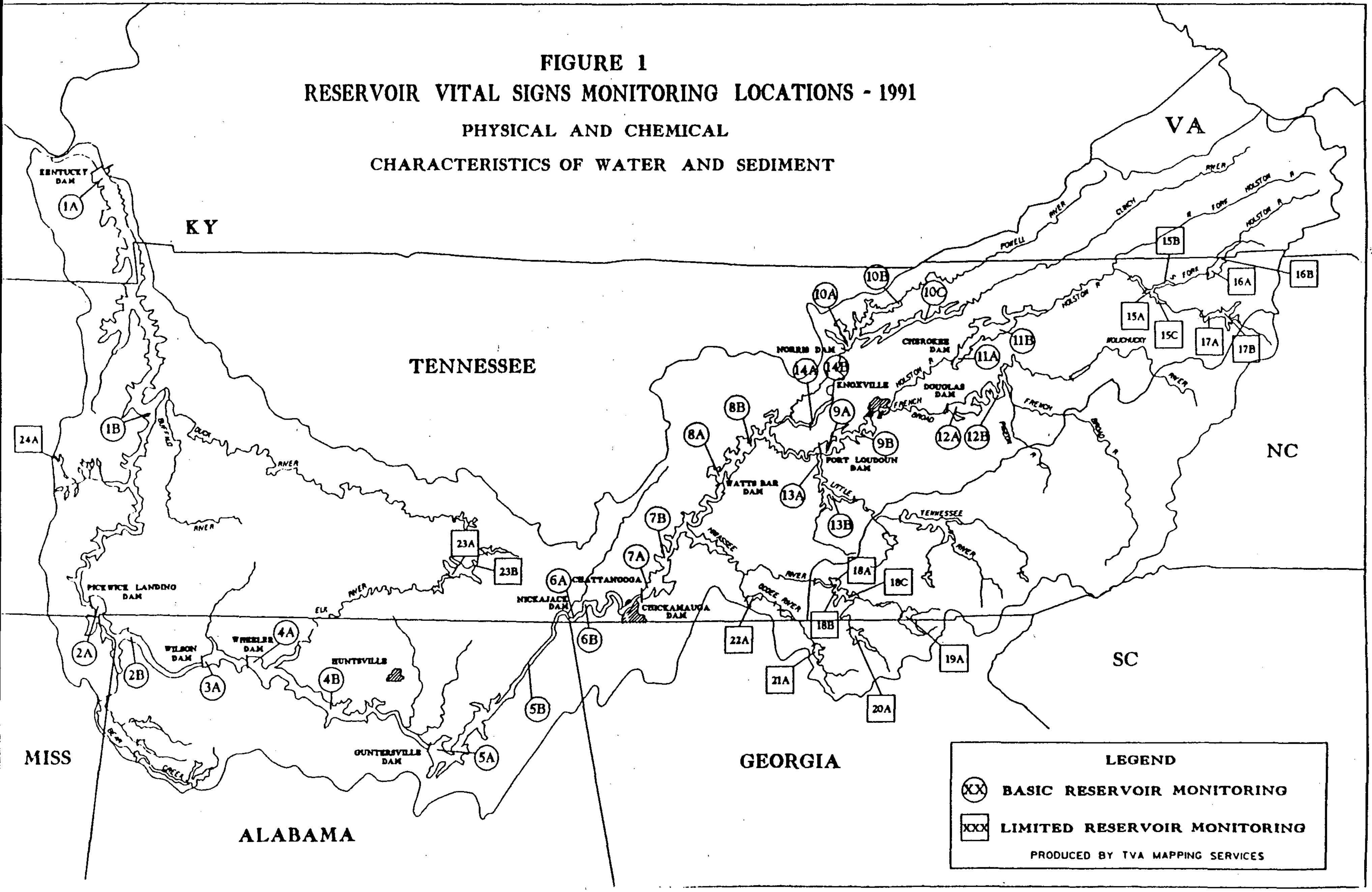


FIGURE 1

RESERVOIR VITAL SIGNS MONITORING LOCATIONS - 1991

PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER AND SEDIMENT

Table 1a

WATER QUALITY MONITORING LOCATIONS
RESERVOIR VITAL SIGNS MONITORING, 1991

Basic Water Quality Monitoring Locations

Reservoir	Forebay Locations River Mile (Tennessee)	Forebay Locations Map ID Number	Forebay Locations Storet Station #	Transition Zone Locations River Mile (Tennessee)	Transition Zone Locations Map ID Number	Transition Zone Locations Storet Station #
Main Stream						
Kentucky	23.0	1A.	202832	112.0	1B.	475015
Pickwick	207.3	2A.	476799	230.0	2B.	016923
Wilson	260.8	3A.	016912	--	--	
Wheeler	277.0	4A.	016900	307.5	4B.	017012
Guntersville	350.0	5A.	017261	396.8	5B.	017101
Nickajack	425.5	6A.	476344	433.0	6B.	476239
Chickamauga	472.3	7A.	475358	490.5	7B.	475265
Watts Bar	531.0	8A.	475317	560.8	8B.	476041
Fort Loudoun	603.2	9A.	475602	624.6	9B.	475603
Tributary						
Norris	CRM 80.0	10A.	476009	PRM 30.0	10B.	477187
				CRM 125.0	10C.	477186
Cherokee	HRM 53.0	11A.	475025	HRM 76.0	11B.	475028
Douglas	FBRM 33.0	12A.	475081	FBRM 60.7	12B.	475993
Tellico	LTRM 1.0	13A.	476260	LTRM 21.0	13B.	476295
Melton Hill	CRM 24.0	14A.	477064	CRM 45.0	14B.	476194

HYDROLOGIC OVERVIEW OF WATER YEAR 1991

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

Atmospheric Temperature - The average annual temperature in the TVA Region is approximately 60 degrees Fahrenheit (°F), with January usually being the coldest month and July the hottest. During WY 1991, atmospheric temperatures in the TVA Region averaged about 2.4 degrees Fahrenheit (°F) warmer than for the normal period, 1951-1980, (USDOC, 1990 and 1991). All twelve months of WY 1991 experiencing above normal temperatures. The greatest monthly departures (about 4 °F above normal) were in November and December 1990 and May 1991, Figure 2a. January through April also had departures about three degrees Fahrenheit above normal. The result was that the seven month period

FIGURE 2. Temperature, Precipitation, and Runoff – Tennessee River Basin, WY-91

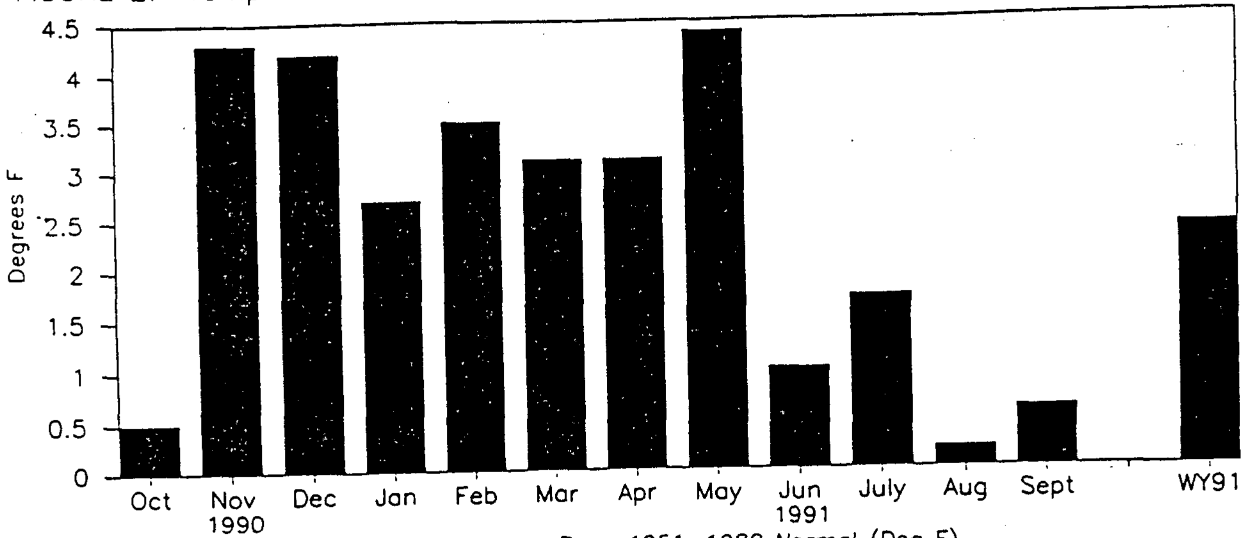


FIGURE 2a. Temperature Departures From 1951–1980 Normal (Deg F)
in The TVA Region.

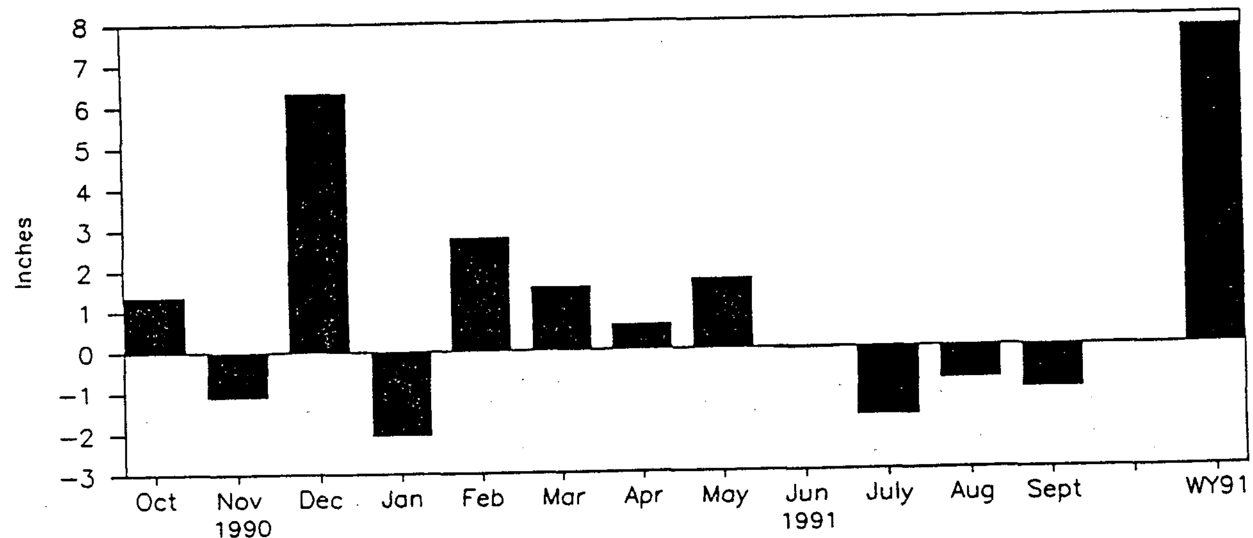


FIGURE 2b. Precipitation Departures From 1890–1990 Average (Inches)
For The Tennessee River Basin.

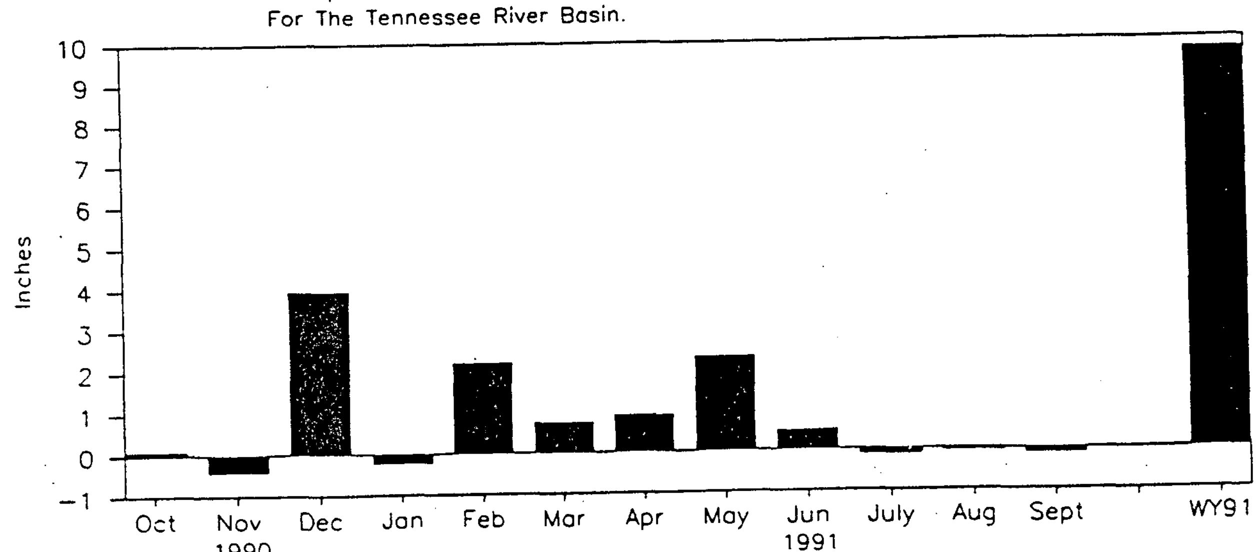


FIGURE 2c. Runoff Departures From 1890–1990 Average (Inches)
For Tennessee River Basin, Above Kentucky Dam.

(November 1990-May 1991) was unusually warm - averaging over 3.5 degrees above normal. Although August was near normal, spells of hot, dry weather occurred in the summer, with conditions somewhat worse to the west and south of Chattanooga. This pattern persisted through September.

Rainfall - The Tennessee River basin averages about 52 inches of precipitation annually. However, there are large variations in the spatial distribution of precipitation. The range is from a high of about 93 inches in the mountains of southwestern North Carolina near Highlands to a low of about 37 inches in the shielded valleys of these same mountains near Asheville, North Carolina. Elsewhere in the Valley, precipitation usually ranges within five to ten inches of the basin average. March is usually the wettest month and October the driest. WY 1991 was wetter than the previous year, but resembled the pattern of a wetter than average cool season and a dryer than average warm season, Figure 2b. The precipitation in WY 1991 for the Tennessee River basin was slightly in excess of 59 inches, a departure of 15 percent above the 101-year long term average, with that portion of the basin downstream of Chattanooga generally wetter than the portion of the basin upstream of Chattanooga. Precipitation in November 1990 and January 1991 was below average, but the other months in the October 1990 through May 1991 period were wet enough to exceed the long term average for this eight month period by 11 inches. For the Tennessee River basin, December 1990 was the wettest December on record averaging 11.1 inches of precipitation, which was 6.3 inches above the long term average for December. The period of June through September was about 3.5 inches drier than average for the Tennessee River basin (TVA 1991c).

Streamflow - Streamflow varies seasonally with rainfall, although during the spring and summer evapotranspiration reduces the amount of runoff somewhat. Watersheds that receive 50 to 60 inches of precipitation annually average about 20 to 30 inches of runoff. In a normal year, the discharge of the Tennessee River (approximately 64,000 cfs) corresponds to about 22 inches of runoff distributed over the 40,900 square mile drainage basin. A larger amount of runoff occurs during the wet winter and spring months when precipitation events are frequent, temperatures are low, and there are no leaves on deciduous vegetation. Consequently soil absorption, evaporation and transpiration losses are low at that time of year, and both runoff and streamflow are higher than during the summer and fall months. In WY 1991 there was an unusually high amount of precipitation and runoff, particularly in December and during the period February through May. Much of this runoff was held in storage in tributary reservoirs and later released such that during the subsequent dry period of June through September, even though rainfall was substantially below normal, streamflow of the Tennessee River at Kentucky Dam was near normal (Figures 2b and 2c). The net result for WY 1991 was an annual 15% excess in precipitation with resultant total runoff that was approximately ten inches above the long term mean of 22.4 inches. Mean flows during 1991 for each of the Vital Signs reservoirs reflect the higher-than-average annual runoff (Table 2).

1.3 meters, 5.2 NTU's, and 4.4 mg/l, respectively; transition zone Secchi depths, turbidity, and suspended solids averaged 1.4 meters, 5.4 NTU's, and 5.4 mg/l, respectively. True color values averaged about 11-12 PCU's at the forebay and transition zones. These data show the light transparency of Nickajack Reservoir to fall within the mid-range of observations at the Vital Signs monitoring locations.

Additional Comments - Water quality data collected as part of the Vital Signs monitoring program for Nickajack Reservoir in 1990 and 1991 have shown the physical/chemical water quality characteristics of the forebay and the transition zone to be very similar. Because of the well mixed hydrologic conditions of Nickajack Reservoir and the relatively short distance between the forebay (TRM 425.5) and the transition zone (TRM 433.0), future Vital Signs monitoring will be conducted only at the forebay.

Chickamauga Reservoir

In situ Measurements - Measurements of temperature, dissolved oxygen (DO), pH and conductivity show Chickamauga Reservoir to be generally well mixed and lacking any strong thermal stratification (Appendix A-7, Table 13). Surface temperatures ranged from 8.3°C in January to 29.9°C in July in the forebay; and from 7.1°C to 27.6°C for the same months at the transition zone.

Values for DO at the 1.5 meter depth ranged from 10.4 mg/l in April to 6.0 mg/l in August at the forebay; and from 10.1 mg/l in January to 5.5 mg/l in August at the transition zone. Contour plots of temperature and DO versus depth for the period January through the end of September for both the forebay (Figure 17) and the transition zone (Figure 18) depict the seasonal variation and rather weak stratification of Chickamauga Reservoir in 1991.

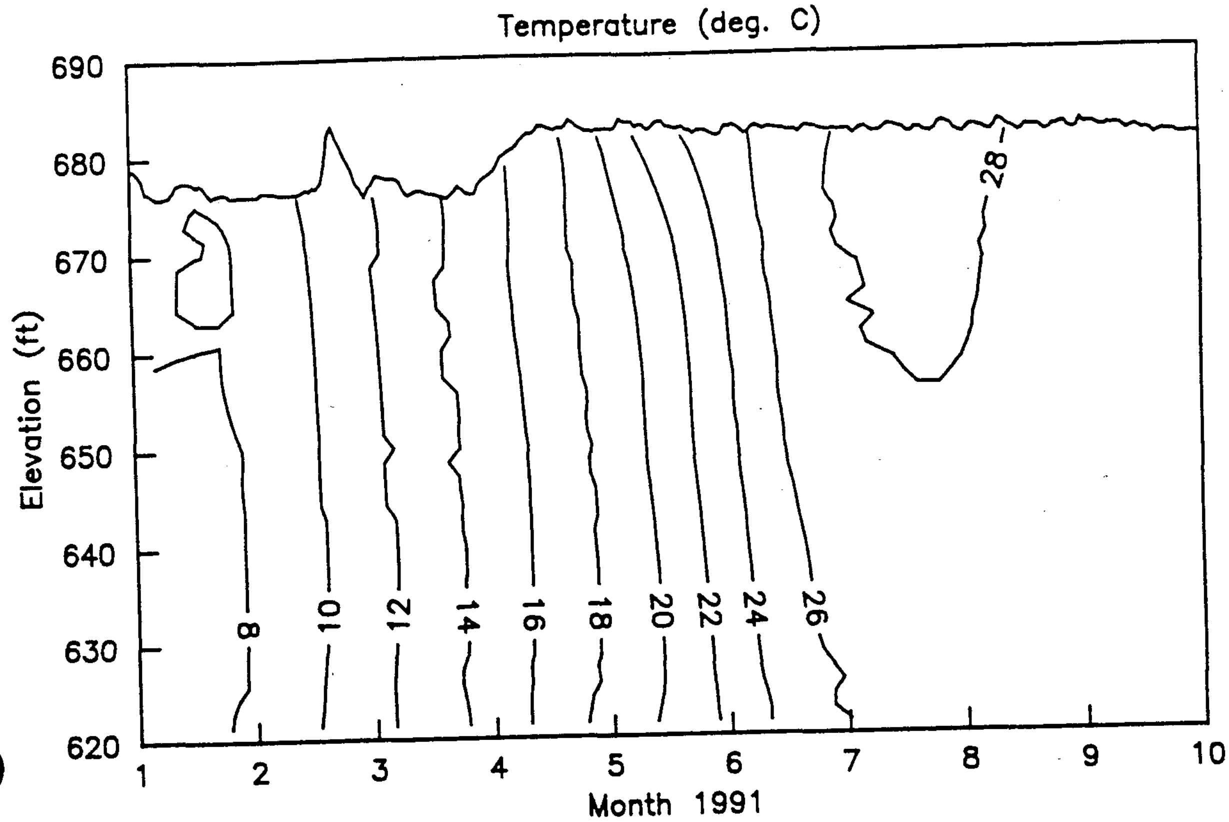
Values of pH ranged from 7.0 to 8.2 on Chickamauga Reservoir. Conductivities ranged from 117 to 182 μmhos/cm, and averaged about 160 μmhos/cm. Comparison of pH and conductivity at the transition zone with upstream pH and conductivity at Watts

Table 13
Chickamauga Reservoir - Water Quality Summary
Reservoir Vital Signs Monitoring, WY 1991

Variable	Forebay (TRM 472.3) N	Mean	Min	Max	Transition Zone (TRM 490.47) N	Mean	Min	Max
Temperature (°C)	78	22.52	7.90	29.90	55	21.18	7.10	27.60
Dissolved Oxygen (mg/l)	78	6.93	3.00	11.10	55	7.14	3.40	10.30
pH (s.u.)	77	7.46	7.00	8.20	55	7.52	7.00	8.10
Conductivity (umhos/cm)	78	159.06	137.00	182.00	55	156.93	117.00	177.00
Organic - N (mg/l)	18	0.21	0.03	0.37	18	0.19	0.06	0.38
Ammonia - N (mg/l)	18	0.05	0.01	0.09	18	0.05	0.01	0.08
Nitrate+Nitrite - N (mg/l)	18	0.24	0.11	0.50	18	0.25	0.14	0.47
Total Nitrogen (mg/l)	18	0.50	0.30	0.60	18	0.49	0.35	0.59
Total Phosphorus (mg/l)	18	0.025	0.020	0.030	18	0.024	0.020	0.030
TN/TP Ratio	18	20.5	15.0	26.5	18	20.8	11.7	29.5
Dissolved Ortho - P (mg/l)	18	0.008	0.002	0.020	18	0.009	0.004	0.020
Total Organic Carbon (mg/l)	18	1.84	1.70	2.00	18	1.88	1.70	2.20
Soluble Organic Carbon (mg/l)	18	1.76	1.60	1.90	17	1.78	1.60	2.00
Chlorophyll-a (ug/l)	9	6.78	2.00	10.00	9	7.22	1.00	13.00
Secchi depth (m)	6	1.45	1.16	1.75	7	1.40	1.13	1.78
Turbidity (NTU)	18	5.72	3.00	12.00	18	4.56	3.00	7.00
Suspended Solids (mg/l)	18	4.78	1.00	11.00	18	4.17	1.00	7.00
True Color (PCU)	12	10.42	5.00	15.00	12	10.00	5.00	15.00
Apparent Color (PCU)	12	17.92	10.00	30.00	12	17.50	10.00	25.00
Fecal Coliform (#/100 ml)	8	11.25	10.00	20.00	8	11.25	10.00	20.00

FIGURE 17

CHICKAMAUGA RESERVOIR — TRM 472.3



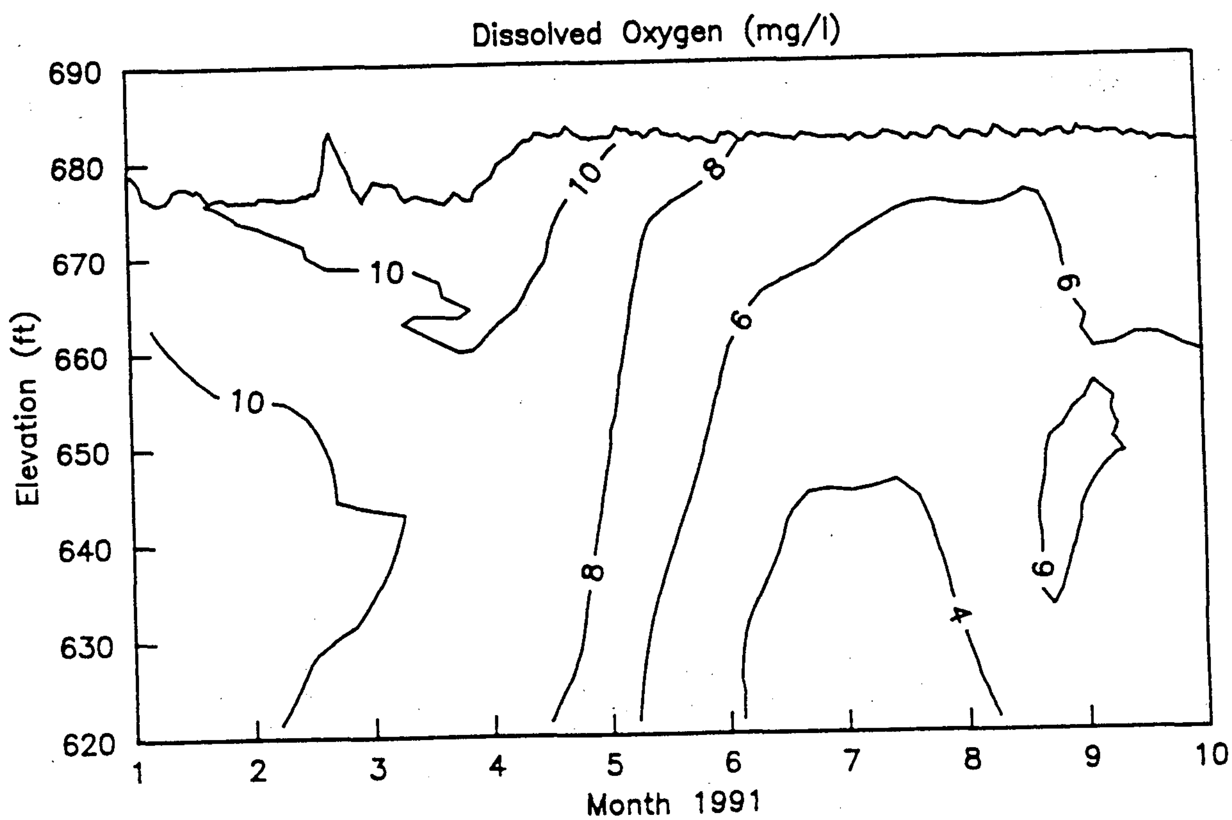
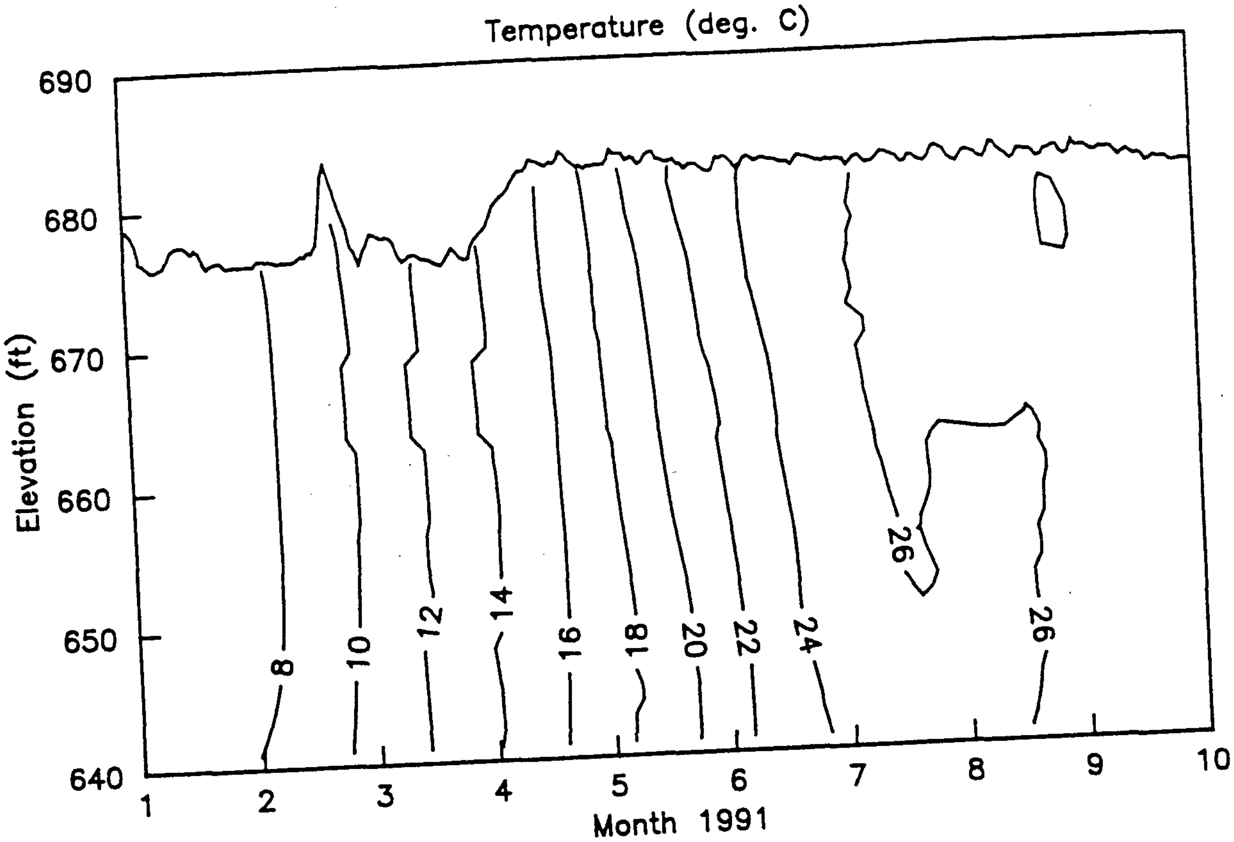
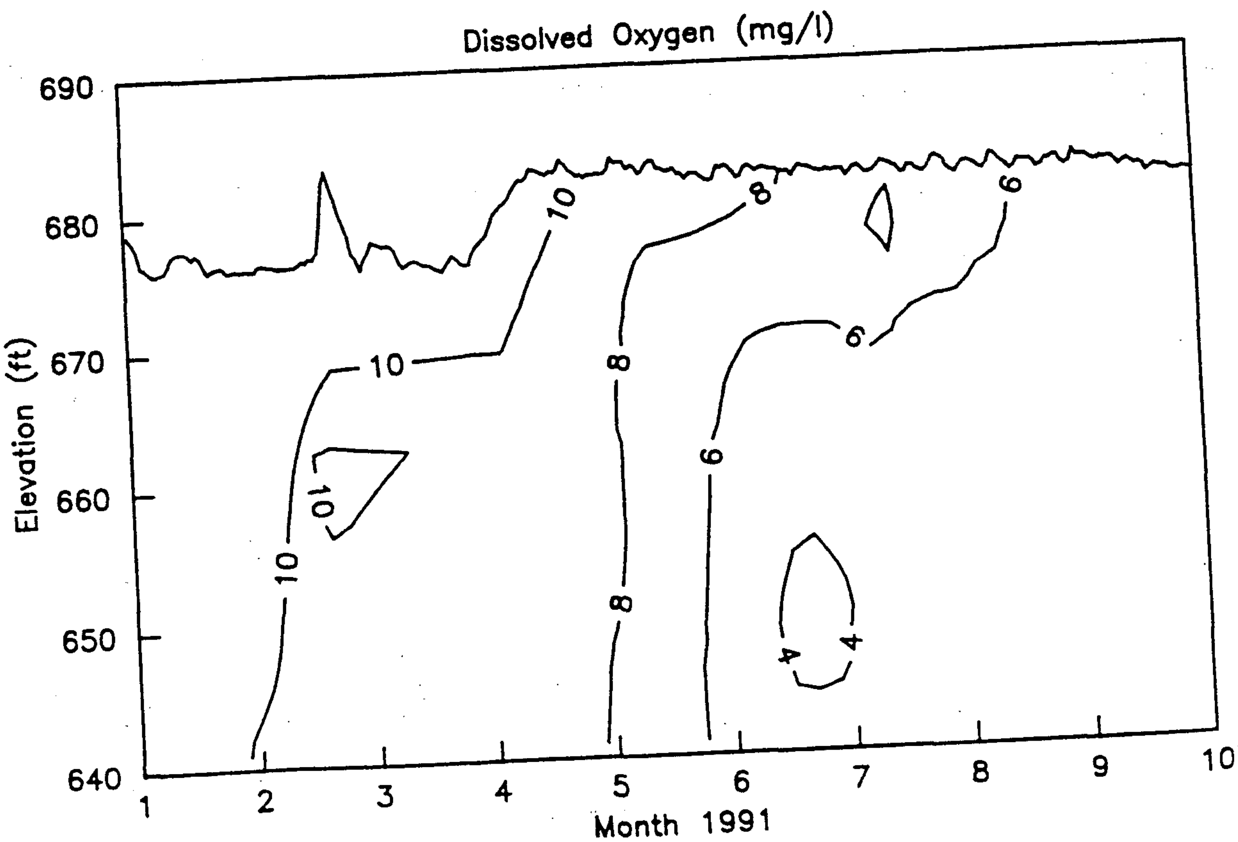


FIGURE 18

CHICKAMAUGA RESERVOIR – TRM 490.5





Bar Dam forebay shows that pH and conductivity are lowered by the effect of the Hiwassee River inflows to Chickamauga Reservoir about 9 miles upstream of the transition zone.

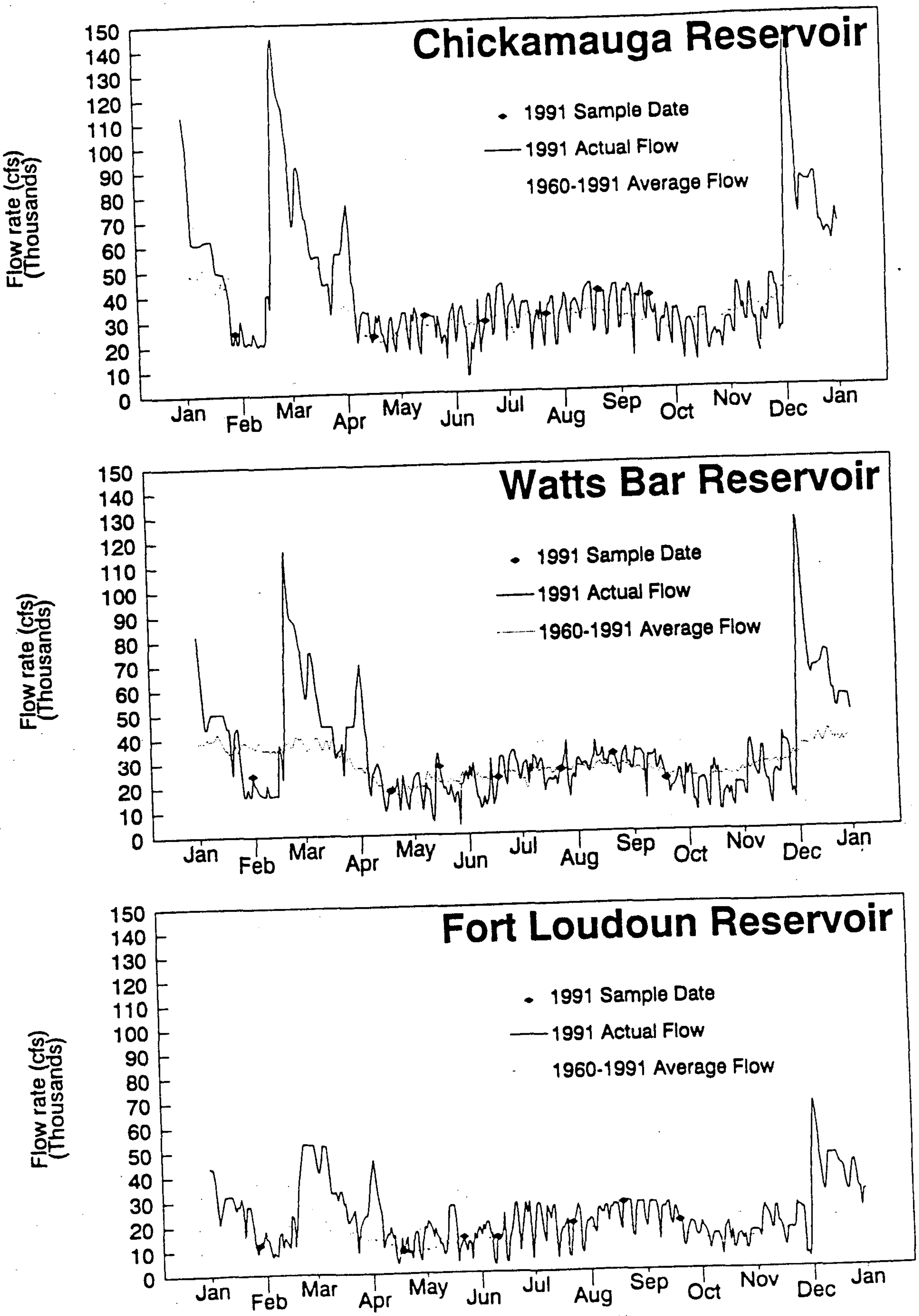
Biochemical Measurements - In Chickamauga Reservoir, during 1991, concentrations of organic nitrogen, ammonia nitrogen, nitrite plus nitrate nitrogen, and total phosphorus averaged 0.21, 0.05, 0.24 and 0.025 mg/l, respectively at the forebay; and 0.19, 0.05, 0.25 and 0.024 mg/l, respectively, at the transition zone. Average total nitrogen concentrations were the lowest measured among Vital Signs monitoring locations on the Tennessee River in 1991. In addition, both total phosphorus and dissolved ortho phosphorus concentrations were also among the lowest observed at any of the Vital Signs monitoring locations on the Tennessee River.

TN/TP ratios ranged from 12 to 30 in Chickamauga Reservoir, indicating extended periods of phosphorus limiting conditions. The highest chlorophyll-a concentrations were measured in May ranging from 8-10 μg/l at the forebay and 11-13 μg/l at the transition zone. The surface concentrations of chlorophyll-a averaged approximately 7 μg/l at both the Chickamauga Reservoir forebay and the transition zone in 1991.

Organic carbon concentrations, total and soluble, in Chickamauga Reservoir were quite low, averaging between 1.9 and 1.8 mg/l, at both the forebay and the transition zone.

Physical Measurements - Figure 19 illustrates the average daily discharge from Chickamauga Reservoir in 1991 with water quality sampling dates superimposed. None of the water quality surveys conducted in 1991 on Chickamauga Reservoir occurred on days with unusually high or low flows. Consequently the variation in those measures of water clarity (Secchi depth, turbidity, suspended solids) is quite small. Forebay Secchi depth, turbidity, and suspended solids measurements averaged 1.4 meters, 5.7 NTU's, and 4.8 mg/l, respectively. Transition zone Secchi depths, turbidity, and suspended solids averaged 1.4 meters, 4.6 NTU's, and 4.2 mg/l, respectively. In addition, true

FIGURE 19



Chickamauga Reservoir
1991 Sample Date
1991 Actual Flow
1960-1991 Average Flow
Flow rate (cfs) (Thousands)
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Watts Bar Reservoir
1991 Sample Date
1991 Actual Flow
1960-1991 Average Flow
Flow rate (cfs) (Thousands)
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Fort Loudoun Reservoir
1991 Sample Date
1991 Actual Flow
1960-1991 Average Flow
Flow rate (cfs) (Thousands)
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

color values, averaged about 10 PCU's, at the forebay and transition zones, respectively. Together, these values indicate the light transparency of Chickamauga Reservoir to be high compared with the other mainstem Tennessee River reservoirs.

Watts Bar Reservoir

In situ Measurements - Temperature, dissolved oxygen (DO), pH and conductivity measurements show the reservoir to be well mixed early in the year and developing just a moderate degree of thermal stratification at the forebay in July and August (Appendix A-8, Table 14). Surface water temperatures ranged from 7.2°C in January to 30.2°C in July in the forebay, and from 7.7°C to 28.4°C for these same months at the transition zone.

Values for DO at the 1.5 meter depth ranged from 12.8 mg/l in April (due to high photosynthetic activity) to 8.1 mg/l in September at the forebay, and from 11.2 mg/l in January to 6.6 mg/l in September at the transition zone. Contour plots of temperature and DO versus depth for the period January through the end of September for both the forebay (Figure 20) and the transition zone (Figure 21) depict the seasonal variation with a weak summer time thermal stratification and a rather strong oxycline in the forebay of Watts Bar Reservoir. From the surface to the bottom of the reservoir, at the forebay, the data show an 8°C decrease in temperature in May, and about a 10 mg/l decrease in DO in June and July; with near bottom DO concentrations in the hypolimnion of Watts Bar forebay less than 1 mg/l.

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

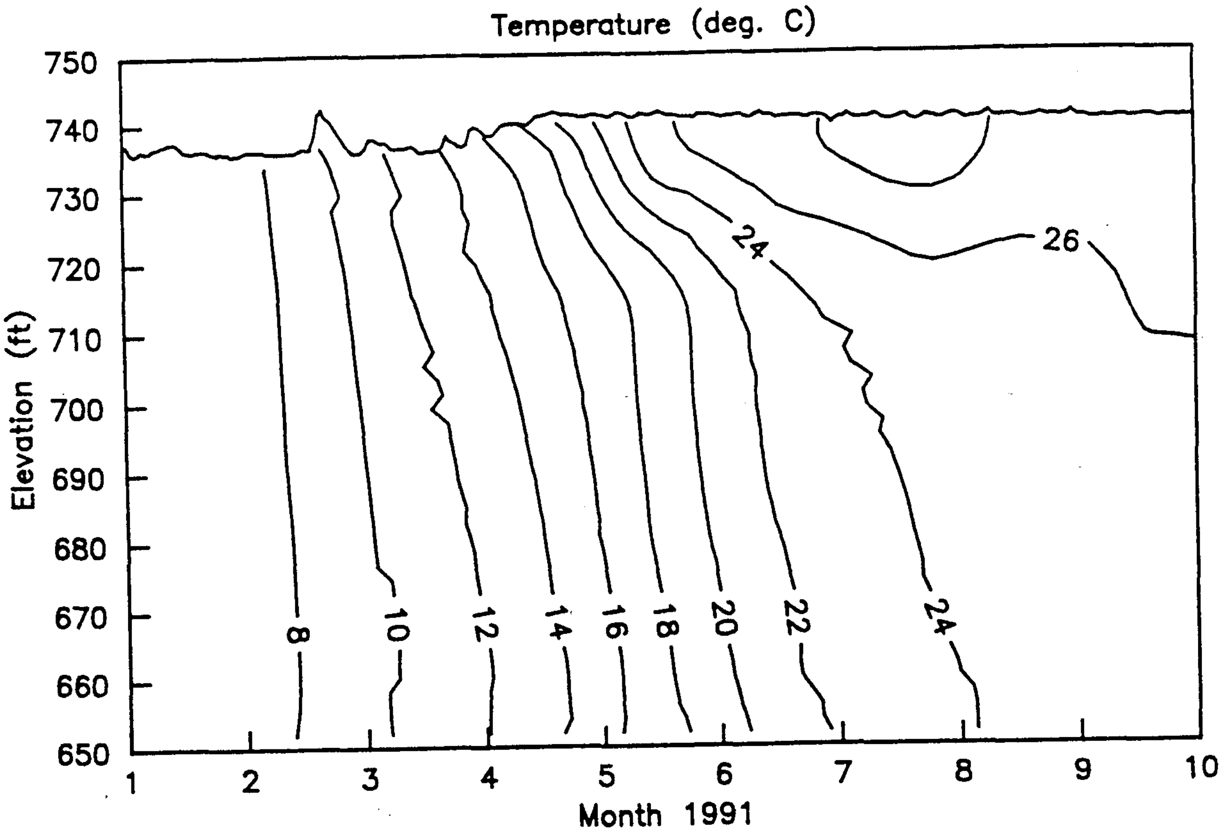
Conductivities ranged from 126 to 208 µmhos/cm and averaged about 175 µmhos/cm, with highest conductivities coinciding with lower streamflows in January.

Table 14
Watts Bar Reservoir - Water Quality Summary
Reservoir Vital Signs Monitoring, WY 1991

Variable	Forebay (TRM 531.0)				Transition Zone (TRM 560.8)			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (°C)	124	21.32	7.00	30.20	66	20.93	7.60	28.40
Dissolved Oxygen (mg/l)	124	6.80	0.30	13.40	66	8.11	4.40	11.70
pH (s.u.)	124	7.79	7.00	9.20	66	7.76	7.20	8.80
Conductivity (umhos/cm)	124	169.78	126.00	188.00	66	175.58	126.00	208.00
Organic - N (mg/l)	18	0.20	0.03	0.44	18	0.22	0.03	0.78
Ammonia - N (mg/l)	18	0.04	0.01	0.12	18	0.03	0.01	0.07
Nitrate+Nitrite - N (mg/l)	18	0.28	0.01	0.51	18	0.34	0.17	0.61
Total Nitrogen (mg/l)	18	0.52	0.22	0.61	18	0.60	0.45	0.99
Total Phosphorus (mg/l)	18	0.021	0.009	0.030	18	0.027	0.020	0.040
TN/TP Ratio	18	29.0	16.3	57.0	18	23.2	11.5	49.5
Dissolved Ortho - P (mg/l)	18	0.008	0.002	0.020	18	0.009	0.002	0.020
Total Organic Carbon (mg/l)	18	1.97	1.70	2.40	18	1.87	1.40	2.30
Soluble Organic Carbon (mg/l)	18	1.77	1.50	2.00	18	1.71	1.30	2.00
Chlorophyll-a (ug/l)	9	11.78	6.00	19.00	9	7.78	5.00	13.00
Secchi depth (m)	7	1.51	1.26	1.73	6	1.10	0.75	1.46
Turbidity (NTU)	18	4.39	1.00	10.00	18	6.00	3.00	13.00
Suspended Solids (mg/l)	18	5.67	2.00	15.00	18	7.56	3.00	15.00
True Color (PCU)	16	9.19	2.00	25.00	16	11.06	2.00	35.00
Apparent Color (PCU)	16	18.44	5.00	60.00	16	16.25	5.00	35.00
Fecal Coliform (#/100 ml)	9	10.00	10.00	10.00	9	10.00	10.00	10.00

FIGURE 20

WATTS BAR RESERVOIR – TRM 531.0



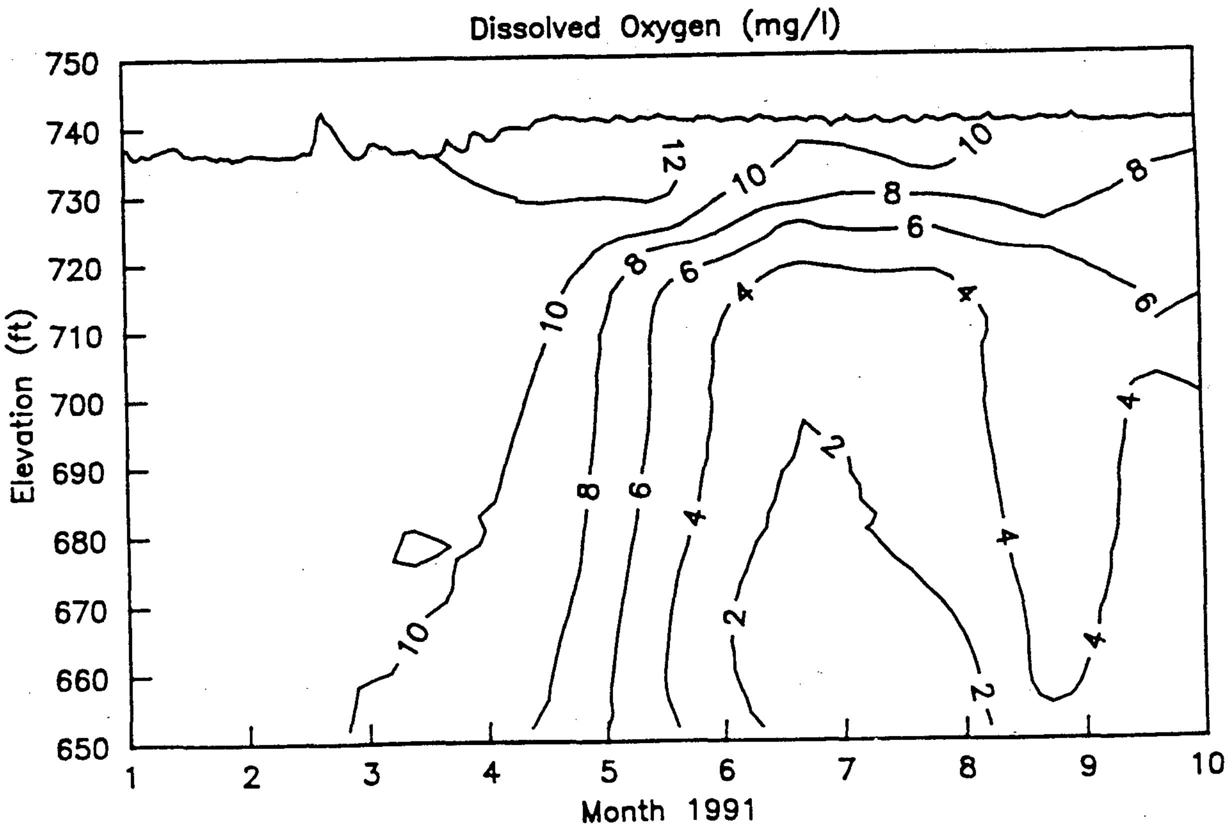
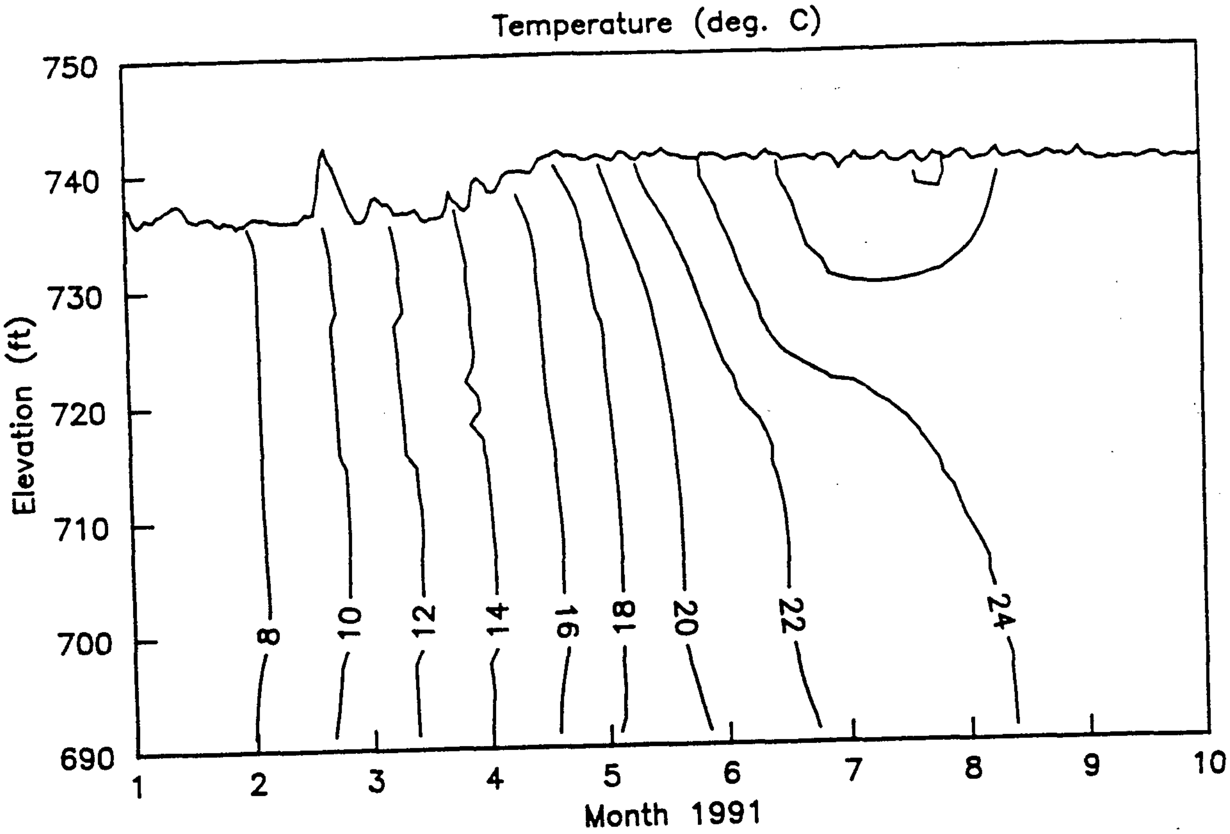
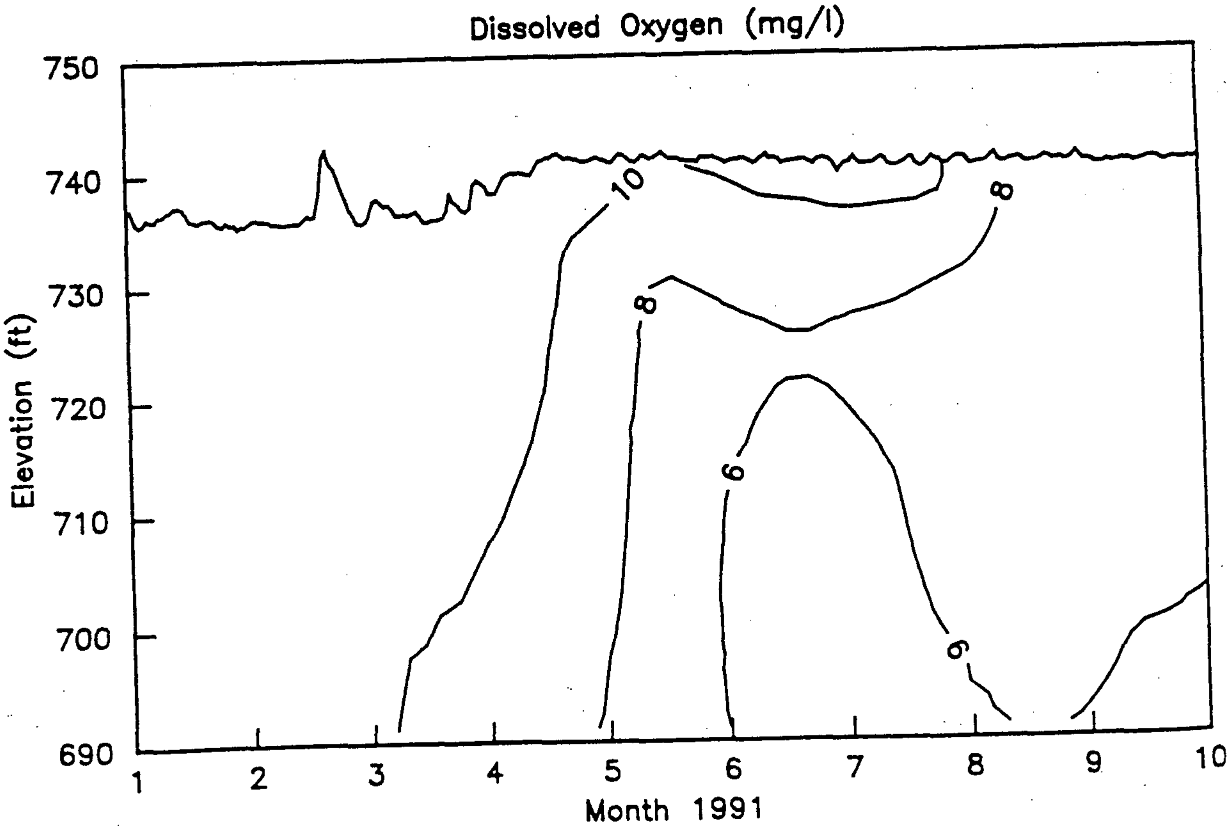


FIGURE 21

WATTS BAR RESERVOIR – TRM 560.8





Biochemical Measurements - In Watts Bar Reservoir during 1991, concentrations of organic nitrogen, ammonia nitrogen, nitrite plus nitrate nitrogen, and total phosphorus averaged 0.20, 0.04, 0.28 and 0.021 mg/l, respectively at the forebay; and 0.22, 0.03, 0.34 and 0.027 mg/l, respectively, at the transition zone. The average total phosphorus concentrations observed at the forebay on Watts Bar Reservoir were lower than any of the other Tennessee River Vital Signs monitoring locations. The average dissolved ortho phosphorus concentrations of 0.008 and 0.009 mg/l, respectively, at the forebay and transition zones were essentially identical to the average concentrations of dissolved ortho phosphorus in Chickamauga Reservoir, and were among the lowest observed at any of the Tennessee River Vital Signs monitoring locations in 1991.

TN/TP ratios ranged from 12 to 57 in Watts Bar Reservoir, indicating (at least) intermittent periods of phosphorus limiting conditions. Watts Bar forebay's lowest observed TN/TP ratios were 16; however, high chlorophyll-a concentrations were measured in the forebay of Watts Bar Reservoir. The highest chlorophyll-a concentrations were measured in August, 19 μg/l at the forebay, and in July, 13 μg/l at the transition zone. Surface concentrations of chlorophyll-a pigment averaged about 12 μg/l at the Watts Bar Reservoir forebay, and about 8 μg/l at the transition zone in 1991.

Organic carbon concentrations (both total and soluble) in Watts Bar Reservoir were low, averaging 2.0 and 1.8 mg/l, at the forebay and 1.9 and 1.7 mg/l at the transition zone.

Physical Measurements - Figure 19 illustrates the average daily discharge from Watts Bar Reservoir in 1991 with sampling dates superimposed. Forebay Secchi depth, turbidity, and suspended solids measurements averaged 1.5 meters, 4.4 NTU's, and 5.7 mg/l, respectively. Transition zone Secchi depths, turbidity, and suspended solids averaged 1.1 meters, 6.0 NTU's, and 7.6 mg/l, respectively. These values indicate the light transparency of Watts Bar Reservoir forebay to be among the highest of the mainstem Tennessee River reservoirs, in 1991. True color values, averaged 9 and 11 PCU's, at the forebay and transition zones, respectively, also falling among the lower values measured at mainstem Tennessee river Vital Signs monitoring locations.

Fort Loudoun Reservoir

In situ Measurements - Measurements of temperature, dissolved oxygen (DO), pH and conductivity show the reservoir is well mixed early in the year but develops a fairly strong thermal stratification from June through September (Appendix A-9, Table 15). Surface water temperatures ranged from 7.5°C in January to 28.2°C in July at the forebay, and from 6.8°C to 29.6°C for the same months at the transition zone. In July, at the forebay, the temperature decreased over 8°C from water surface to bottom. The reservoir remained stratified through September.

Values for DO at the 1.5 meter depth ranged from 12.3 mg/l in April (algal bloom) to 8.9 mg/l in August at the forebay, and from 14.6 mg/l in July (algal bloom) to 5.7 mg/l in August at the transition zone. Contour plots of temperature and DO versus depth for the period January through the end of September for both the forebay (Figure 22) and the transition zone (Figure 23) depict the seasonal variation and summer time stratification of Fort Loudoun Reservoir. Hypolimnetic DO concentrations measured in the forebay of Fort Loudoun Reservoir in 1991 were higher than in 1990. For example, in the hypolimnion in 1990, DO's were measured below 2 mg/l in July and August; but, in 1991 no DO's were measured below 3 mg/l.

Values of pH ranged from 6.7 to 9.1 on Fort Loudoun Reservoir. At the forebay, values of pH exceeding 8.5 and DO saturation values exceeding 120% were measured each month, April through September, giving evidence of much photosynthetic activity. During these same months, the same pattern of high pH and high DO saturation was observed, although to a lesser extent, at the transition zone.

STORET RETRIEVAL DATE 92/05/16 PGM=RET
475358 1017
35 06 26.0 085 12 20.0 2
CHICKAMAUGA RES. AT LIGHTED BUOY
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 472.3
131TVAC 06020001021 0000.710 ON /TYPA/AMBNT/STREAM/SOLIDS
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 472.30

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
91/01/28	1038	WATER	0.3	609000	8.3	10.0	84.0%	7.80	182
91/01/28	1039	WATER	1		8.1	10.0	84.0%	7.80	181
91/01/28	1040	WATER	1.5		8.0	9.9	83.2%	7.80	182
91/01/28	1042	WATER	4		8.0	9.9	83.2%	7.80	182
91/01/28	1045	WATER	6		8.0	9.9	83.2%	7.80	181
91/01/28	1050	WATER	8		7.9	10.4	87.4%	7.80	182
91/01/28	1055	WATER	10		7.9	10.5	88.2%	7.70	182
91/01/28	1100	WATER	12		7.9	10.4	87.4%	7.70	181
91/01/28	1105	WATER	14		7.9	10.4	87.4%	7.70	182
91/01/28	1111	WATER	15.5		7.9	10.2	85.7%		181
91/04/16	0954	WATER	0.3	23188	17.5	11.1	114.4%	7.70	153
91/04/16	0956	WATER	1		17.4	10.7	110.3%	7.60	153
91/04/16	0957	WATER	1.5		17.4	10.4	107.2%	7.50	153
91/04/16	0958	WATER	4		17.3	10.0	103.1%	7.40	154
91/04/16	1000	WATER	6		17.2	9.7	100.0%	7.20	154
91/04/16	1002	WATER	8		17.0	9.4	96.9%	7.10	153
91/04/16	1004	WATER	10		16.8	9.2	94.8%	7.00	155
91/04/16	1006	WATER	12		16.7	9.1	93.8%	7.00	154
91/04/16	1010	WATER	14		16.7	8.9	91.8%	7.00	154
91/04/16	1013	WATER	16		16.7	8.8	90.7%	7.00	154
91/04/16	1016	WATER	16.5		16.7	8.7	89.7%	7.00	154
91/05/15	1018	WATER	0.3	30908	23.6	9.8	115.3%	7.90	142
91/05/15	1020	WATER	1		22.8	9.3	106.9%	7.90	139
91/05/15	1021	WATER	1.5		22.5	8.6	97.7%	7.70	139
91/05/15	1022	WATER	3.1		21.7	7.7	87.5%	7.40	138
91/05/15	1023	WATER	4		21.4	7.6	84.4%	7.40	137
91/05/15	1026	WATER	6		21.0	7.3	81.1%	7.30	138
91/05/15	1026	WATER	8		20.8	7.1	78.9%	7.30	138
91/05/15	1026	WATER	10		20.8	6.9	76.7%	7.20	138
91/05/15	1027	WATER	12		20.5	6.5	70.7%	7.20	139
91/05/15	1027	WATER	14		20.3	6.0	65.2%	7.20	141
91/05/15	1030	WATER	16		20.2	5.5	59.8%	7.10	143
91/05/15	1031	WATER	17.5		20.1	5.3	57.6%	7.10	143
91/06/18	0924	WATER	0.3	28250	27.2	7.2	88.9%	7.80	139
91/06/18	0925	WATER	1		27.3	7.1	87.7%	7.80	139
91/06/18	0926	WATER	1.5		27.3	7.0	86.4%	7.80	139
91/06/18	0927	WATER	4		27.2	6.4	79.0%	7.60	140
91/06/18	0930	WATER	5.1		27.0	5.4	66.7%	7.40	141
91/06/18	0931	WATER	6		26.8	5.0	61.7%	7.30	141

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	000[illegible] CNDUC[illegible] FIELD MICRO[illegible]
91/06/18	0932	WATER	8		26.7	4.9	60.5%	7.30	[illegible]
91/06/18	0933	WATER	10		26.4	4.4	53.7%	7.30	1[illegible]
91/06/18	0933	WATER	12		26.0	3.9	47.6%	7.20	1[illegible]
91/06/18	0934	WATER	14		25.7	3.7	45.1%	7.20	1[illegible]
91/06/18	0936	WATER	16		25.6	3.2	39.0%	7.10	1[illegible]
91/06/18	0936	WATER	16.5		25.6	3.0	36.6%	7.10	1[illegible]
91/07/23	1045	WATER	0.5	34188	29.9	7.7	101.3%	8.20	1[illegible]
91/07/23	1047	WATER	1		29.5	7.3	93.6%	8.00	1[illegible]
91/07/23	1048	WATER	1.5		29.2	6.7	85.9%	7.80	1[illegible]
91/07/23	1049	WATER	2		29.0	5.8	74.4%	7.50	1[illegible]
91/07/23	1050	WATER	3		28.8	5.3	67.9%	7.40	1[illegible]
91/07/23	1051	WATER	4		28.7	5.2	66.7%	7.40	1[illegible]
91/07/23	1054	WATER	6		28.6	4.8	61.5%	7.30	1[illegible]
91/07/23	1055	WATER	8		28.0	4.5	57.0%	7.30	1[illegible]
91/07/23	1057	WATER	10		27.8	4.2	53.2%	7.30	1[illegible]
91/07/23	1059	WATER	12		27.6	4.0	50.6%	7.30	1[illegible]
91/07/23	1105	WATER	14		27.3	3.7	45.7%	7.20	1[illegible]
91/07/23	1107	WATER	16		27.2	3.4	42.0%	7.20	1[illegible]
91/07/23	1110	WATER	16.5		27.1	3.1	38.3%	7.10	1[illegible]
91/08/20	1055	WATER	0.5	39554	27.3	6.1	75.3%	7.50	1[illegible]
91/08/20	1057	WATER	1		27.3	6.0	74.1%	7.50	1[illegible]
91/08/20	1059	WATER	1.5		27.2	6.0	74.1%	7.50	1[illegible]
91/08/20	1100	WATER	4		27.1	5.9	72.8%	7.50	1[illegible]
91/08/20	1102	WATER	6		27.1	5.9	72.8%	7.50	1[illegible]
91/08/20	1104	WATER	8		27.1	5.8	71.6%	7.50	1[illegible]
91/08/20	1106	WATER	10		27.1	6.0	74.1%	7.50	1[illegible]
91/08/20	1108	WATER	12		27.1	6.1	75.3%	7.50	1[illegible]
91/08/20	1112	WATER	14		27.1	6.1	75.3%	7.50	1[illegible]
91/08/20	1115	WATER	15		27.1	6.1	75.3%	7.50	1[illegible]
91/09/17	1035	WATER	0.5	37175	27.7	6.8	86.1%	7.70	1[illegible]
91/09/17	1038	WATER	1		27.6	6.4	81.0%	7.60	1[illegible]
91/09/17	1039	WATER	1.5		27.6	6.3	79.7%	7.60	1[illegible]
91/09/17	1040	WATER	4		27.5	6.2	76.5%	7.50	1[illegible]
91/09/17	1043	WATER	6		27.5	6.0	74.1%	7.50	1[illegible]
91/09/17	1044	WATER	8		27.4	5.9	72.8%	7.50	1[illegible]
91/09/17	1045	WATER	10		27.4	6.0	74.1%	7.60	1[illegible]
91/09/17	1046	WATER	12		27.4	5.4	66.7%	7.60	1[illegible]
91/09/17	1050	WATER	14		27.2	4.9	60.5%	7.40	1[illegible]
91/09/17	1051	WATER	16		27.2	4.7	58.0%	7.40	1[illegible]

STORET RETRIEVAL DATE 92/05/16 PGM=RET
475358 1017
35 06 26.0 085 12 20.0 2
CHICKAMAUGA RES. AT LIGHTED BUOY
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 472.3
131TVAC 06020001021 0000.710 ON /TYPA/AMBNT/STREAM/SOLIDS
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 472.30

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00081 AP COLOR PT-CO UNITS	82079 TURBIDTY LAB NTU	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
91/01/28	1038	WATER	0.3		1.64								
91/01/28	1042	VERT	4				5	10	4.0	1K	.030	.070	.50
91/01/28	1107	WATER	12.8				5	10	4.0	1K	.050	.050	.49
91/04/16	0954	WATER	0.3		1.16	10K							
91/04/16	0958	VERT	4				5	10	5.0	3	.110	.010	.39
91/04/16	1008	WATER	13.8				5	10	6.0	3	.100	.080	.40
91/05/15	1018	WATER	0.3	D1	1.38	10K							
91/05/15	1019	WATER	0.3	D2		10K							
91/05/15	1020	WATER	0.3	D3		20							
91/05/15	1023	VERT	4	D1					4.0	3	.250	.030	.19
91/05/15	1024	VERT	4	D2					4.0	2	.290	.010	.19
91/05/15	1025	VERT	4	D3					4.0	4	.310	.010	.19
91/05/15	1027	WATER	14.6	D1					12.0	10	.200	.080	.26
91/05/15	1028	WATER	14.6	D2					12.0	11	.240	.080	.26
91/05/15	1029	WATER	14.6	D3					12.0	9	.240	.080	.26
91/06/18	0924	WATER	0.3		1.45	10K							
91/06/18	0927	VERT	4				10	20	5.0	5	.310	.010	.14
91/06/18	0934	WATER	14				15	30	9.0	5	.240	.080	.19
91/07/23	1045	WATER	0.5			10K							
91/07/23	1051	VERT	4				10	20	3.0	3	.370	.030	.13
91/07/23	1100	WATER	13.9				10	20	4.0	3	.150	.090	.21
91/08/20	1055	WATER	0.5		1.75	10K							
91/08/20	1100	VERT	4				15	20	3.0	4	.310	.020	.18
91/08/20	1110	WATER	12.4				15	20	4.0	7	.270	.020	.16
91/09/17	1035	WATER	0.5		1.30	10K							
91/09/17	1040	VERT	4				15	25	3.0	5	.170	.020	.11
91/09/17	1047	WATER	13				15	20	5.0	7	.180	.050	.14

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	00681 D ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
91/01/28	1042	VERT	4		.030	.020	1.9	1.9	2.00	1.00	1.00	1.00
91/01/28	1107	WATER	12.8		.030	.020	1.8	1.8				
91/04/16	0958	VERT	4		.020	.005	1.8	1.7	5.00	1.00	1.00	1.00
91/04/16	1008	WATER	13.8		.030	.009	1.7	1.6				
91/05/15	1018	WATER	0.3	D1								
91/05/15	1019	WATER	0.3	D2								
91/05/15	1020	WATER	0.3	D3								
91/05/15	1023	VERT	4	D1	.020	.004	1.7	1.7	8.00	1.00K	1.00	2.00
91/05/15	1024	VERT	4	D2	.020	.010	1.8	1.7	10.00	1.00K	1.00	3.00
91/05/15	1025	VERT	4	D3	.020	.004	1.9	1.8	9.00	1.00K	1.00	2.00
91/05/15	1027	WATER	14.6	D1	.030	.010	1.8	1.7				
91/05/15	1028	WATER	14.6	D2	.030	.010	1.8	1.7				
91/05/15	1029	WATER	14.6	D3	.030	.004	1.8	1.7				
91/06/18	0927	VERT	4		.030	.002K	2.0	1.8	9.00	1.00	1.00	1.00
91/06/18	0934	WATER	14		.030	.010	1.9	1.8				
91/07/22	1200	WATER	0.3						8.00	1.00K	1.00	1.00K
91/07/23	1051	VERT	4		.020	.004	1.9	1.9	7.00	1.00	1.00	1.00
91/07/23	1100	WATER	13.9		.020	.007	1.8	1.7				
91/08/20	1100	VERT	4		.030	.006	1.8	1.7	4.00	1.00K	1.00	2.00
91/08/20	1110	WATER	12.4		.020	.006	1.8	1.7				
91/09/17	1040	VERT	4		.020	.005	2.0	1.9	7.00	1.00K	1.00	2.00
91/09/17	1047	WATER	13		.020	.010	1.9	1.8				

STORET RETRIEVAL DATE 92/05/16 PGM=RET
475265 1053
35 18 00.0 085 04 33.0 2
CHICKAMAUGA RESERVOIR
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801 /TYPA/AMBNT/STREAM/SOLIDS
TENNESSEE RIVER 490.47
131TVAC 0602000102S 0005.740 ON
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 490.47

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
91/01/28	0940	WATER	0.3		7.1	10.2	83.6$	7.70	174
91/01/28	0942	WATER	1		7.1	10.1	82.8$	7.70	173
91/01/28	0944	WATER	1.5		7.1	10.1	82.8$	7.70	173
91/01/28	0947	WATER	4		7.1	10.1	82.8$	7.70	175
91/01/28	0950	WATER	6		7.1	10.1	82.8$	7.70	175
91/01/28	0955	WATER	8		7.1	10.1	82.8$	7.70	175
91/01/28	1001	WATER	8.5		7.1	10.1	82.8$	7.70	174
91/04/16	0858	WATER	0.3		16.2	10.3	103.0$	7.50	139
91/04/16	0900	WATER	1		16.2	10.2	102.0$	7.40	138
91/04/16	0902	WATER	1.5		16.2	10.1	101.0$	7.40	138
91/04/16	0904	WATER	4		15.8	9.6	96.0$	7.20	144
91/04/16	0906	WATER	6		15.7	9.4	94.0$	7.10	145
91/04/16	0909	WATER	8		15.6	9.3	93.0$	7.00	148
91/04/16	0914	WATER	10		15.6	9.1	91.0$	7.00	150
91/04/16	0917	WATER	10.5		15.6	9.0	90.0$	7.00	149
91/05/15	0908	WATER	0.3		21.6	9.7	110.2$	7.90	142
91/05/15	0910	WATER	1		21.4	9.0	100.0$	7.90	143
91/05/15	0911	WATER	1.5		21.2	8.9	98.9$	7.80	145
91/05/15	0919	WATER	1.9		20.8	7.4	82.2$	7.50	144
91/05/15	0920	WATER	4		20.4	7.1	77.2$	7.40	141
91/05/15	0923	WATER	6		20.1	7.1	77.2$	7.40	138
91/05/15	0923	WATER	8		19.7	7.2	78.3$	7.40	132
91/05/15	0927	WATER	10		19.0	7.0	74.5$	7.30	117
91/05/15	0928	WATER	10.5		19.0	6.8	72.3$	7.30	117
91/06/18	0817	WATER	0.3		25.3	7.9	94.0$	8.00	147
91/06/18	0818	WATER	1		25.3	7.8	92.9$	8.00	147
91/06/18	0819	WATER	1.5		25.3	7.2	85.7$	7.90	147
91/06/18	0820	WATER	3.1		25.2	6.7	79.8$	7.70	147
91/06/18	0821	WATER	4		24.7	4.8	57.1$	7.50	148
91/06/18	0824	WATER	6		24.5	4.5	52.9$	7.40	149
91/06/18	0824	WATER	8		24.1	4.0	47.1$	7.30	149
91/06/18	0826	WATER	10		24.0	3.4	40.0$	7.20	148
91/07/23	0855	WATER	0.5		27.6	7.7	97.5$	8.10	166
91/07/23	0857	WATER	1		27.6	7.5	94.9$	8.10	166
91/07/23	0858	WATER	1.5		27.5	7.3	90.1$	8.00	166
91/07/23	0859	WATER	2		27.5	6.8	84.0$	7.80	166
91/07/23	0900	WATER	3		27.2	5.9	72.8$	7.70	166
91/07/23	0901	WATER	4		26.5	4.7	57.3$	7.50	166
91/07/23	0905	WATER	6		25.9	4.0	48.8$	7.40	163

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 490.47

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
91/07/23	0910	WATER	8		25.9	3.9	47.6$	7.30	163
91/07/23	0916	WATER	10		25.9	3.8	46.3$	7.30	163
91/08/20	0950	WATER	0.5		26.0	5.8	70.7$	7.50	177
91/08/20	0952	WATER	1		26.0	5.6	68.3$	7.50	177
91/08/20	0954	WATER	1.5		26.0	5.5	67.1$	7.50	177
91/08/20	0956	WATER	4		26.0	5.4	65.9$	7.40	176
91/08/20	0958	WATER	6		26.0	5.4	65.9$	7.40	176
91/08/20	1000	WATER	8		26.0	5.4	65.9$	7.40	177
91/08/20	1010	WATER	10		26.0	5.3	64.6$	7.40	177
91/09/17	0935	WATER	0.5		26.3	6.0	73.2$	7.60	163
91/09/17	0938	WATER	1		26.3	5.9	72.0$	7.50	163
91/09/17	0939	WATER	1.5		26.2	5.8	70.7$	7.50	162
91/09/17	0940	WATER	4		26.2	5.3	64.6$	7.40	163
91/09/17	0943	WATER	6		26.1	5.1	62.2$	7.40	162
91/09/17	0944	WATER	8		26.1	5.1	62.2$	7.30	163
91/09/17	0948	WATER	10		26.1	5.0	61.0$	7.30	162

STORET RETRIEVAL DATE 92/05/16 PGM=RET
475265 1053
35 18 00.0 085 04 33.0 2
CHICKAMAUGA RESERVOIR
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801 /TYPA/AMBNT/STREAM/SOLIDS
TENNESSEE RIVER 490.47
131TVAC 06020001025 0005.740 ON
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 490.47

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00081 AP COLOR PT-CO UNITS	82079 TURBIDTY LAB NTU	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
91/01/28	0940	WATER	0.3		1.68								
91/01/28	0947	VERT	4				10	15	4.0	1K	.060	.060	.46
91/01/28	0952	WATER	7.8				10	15	3.0	1K	.070	.050	.47
91/04/16	0858	WATER	0.3		1.13	20							
91/04/16	0904	VERT	4				5	10	5.0	3	.150	.070	.34
91/04/16	0911	WATER	9.8				5	10	6.0	6	.100	.080	.36
91/05/15	0908	WATER	0.3	D1	1.38	10K							
91/05/15	0909	WATER	0.3	D2		10K							
91/05/15	0910	WATER	0.3	D3		10K							
91/05/15	0920	VERT	4	D1					4.0	4	.330	.030	.23
91/05/15	0921	VERT	4	D2					4.0	4	.280	.020	.22
91/05/15	0922	VERT	4	D3					4.0	3	.150	.050	.22
91/05/15	0924	WATER	9.6000	D1					6.0	6	.180	.040	.23
91/05/15	0925	WATER	9.6000	D2					6.0	5	.180	.060	.24
91/05/15	0926	WATER	9.6000	D3					6.0	4	.140	.040	.23
91/06/18	0817	WATER	0.3		1.25	10K							
91/06/18	0821	VERT	4				10	20	4.0	5	.220	.010K	.17
91/06/18	0825	WATER	9				15	25	7.0	7	.200	.040	.25
91/07/23	0855	WATER	0.5		1.26	10K							
91/07/23	0901	VERT	4				10	20	3.0	3	.380	.020	.17
91/07/23	0912	WATER	9.4				10	20	4.0	4	.180	.060	.26
91/08/20	0950	WATER	0.5		1.78	10K							
91/08/20	0956	VERT	4				15	20	4.0	4	.240	.030	.21
91/08/20	1005	WATER	9.4				10	25	5.0	7	.240	.030	.22
91/09/17	0935	WATER	0.5		1.30	10							
91/09/17	0940	VERT	4				15	20	3.0	3	.180	.050	.16
91/09/17	0945	WATER	9.2000				5	10	4.0	5	.130	.080	.14

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	00681 D ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
91/01/28	0947	VERT	4		.030	.020	2.1		1.00	1.00	1.00	1.00
91/01/28	0952	WATER	7.8		.030	.020	1.8	1.8				
91/04/16	0904	VERT	4		.030	.006	1.8	1.8	4.00	2.00	3.00	3.00
91/04/16	0911	WATER	9.8		.030	.009	1.8	1.8				
91/05/15	0908	WATER	0.3	D1								
91/05/15	0909	WATER	0.3	D2								
91/05/15	0910	WATER	0.3	D3								
91/05/15	0920	VERT	4	D1	.020	.004	1.9	1.8	13.00	1.00K	1.00	1.00K
91/05/15	0921	VERT	4	D2	.020	.004	1.9	1.8	10.00	1.00K	1.00	1.00
91/05/15	0922	VERT	4	D3	.020	.004	1.8	1.8	11.00	1.00K	1.00	1.00
91/05/15	0924	WATER	9.6000	D1	.020	.007	1.7	1.6				
91/05/15	0925	WATER	9.6000	D2	.020	.006	1.7	1.6				
91/05/15	0926	WATER	9.6000	D3	.020	.006	1.7	1.6				
91/06/18	0821	VERT	4		.020	.004	2.2	2.0	11.00	1.00K	1.00	3.00
91/06/18	0825	WATER	9		.020	.010	1.9	1.7				
91/07/22	1200	WATER	0.3						14.00	1.00	1.00	1.00
91/07/23	0901	VERT	4		.020	.006	2.0	1.8	9.00	1.00K	1.00	2.00
91/07/23	0912	WATER	9.4		.020	.010	1.8	1.7				
91/08/20	0956	VERT	4		.030	.010	1.9	1.8	3.00	1.00K	1.00K	1.00
91/08/20	1005	WATER	9.4		.030	.010	1.8	1.7				

STORET RETRIEVAL DATE 92/05/16 PGM=RET
475317 1089
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OPP. LOWE BR. WATTS BAR RES.
47121 TENNESSEE MEIGS
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 531.0 /TYPA/AMBNT/FISH/STREAM/SOLIDS
131TVAC 06010201002 0002.040 ON
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 531.00

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
91/01/31	1254	WATER	0.3	593200	7.2	11.1	91.0$	7.80	184
91/01/31	1255	WATER	1		7.2	11.1	91.0$	7.80	184
91/01/31	1256	WATER	1.5		7.2	11.1	91.0$	7.80	184
91/01/31	1257	WATER	4		7.2	11.1	91.0$	7.80	185
91/01/31	1300	WATER	6		7.1	11.1	91.0$	7.80	185
91/01/31	1301	WATER	8		7.1	11.1	91.0$	7.80	184
91/01/31	1302	WATER	10		7.1	11.1	91.0$	7.80	184
91/01/31	1303	WATER	12		7.1	11.1	91.0$	7.80	184
91/01/31	1304	WATER	14		7.1	11.1	91.0$	7.70	184
91/01/31	1305	WATER	16		7.0	11.1	91.0$	7.70	182
91/01/31	1306	WATER	18		7.0	11.1	91.0$	7.70	182
91/01/31	1307	WATER	20		7.0	11.1	91.0$	7.70	181
91/01/31	1308	WATER	22		7.0	11.0	90.2$	7.70	181
91/01/31	1312	WATER	24		7.0	11.0	90.2$	7.60	180
91/01/31	1317	WATER	25		7.0	11.0	90.2$	7.60	181
91/04/18	1238	WATER	0.3	17779	19.9	12.8	139.1$	9.00	156
91/04/18	1241	WATER	1		18.5	13.4	141.1$	9.00	158
91/04/18	1242	WATER	1.5		17.7	12.8	134.7$	8.90	162
91/04/18	1243	WATER	4		16.7	11.9	122.7$	8.40	170
91/04/18	1246	WATER	6		16.4	11.3	113.0$	8.10	168
91/04/18	1246	WATER	8		15.7	10.3	103.0$	7.70	171
91/04/18	1247	WATER	10		15.4	9.9	97.1$	7.60	172
91/04/18	1247	WATER	12		15.0	9.6	94.1$	7.40	171
91/04/18	1248	WATER	14		14.8	9.4	92.2$	7.40	169
91/04/18	1248	WATER	16		14.5	9.2	88.5$	7.30	169
91/04/18	1249	WATER	18		14.3	9.1	87.5$	7.30	165
91/04/18	1249	WATER	20		14.1	8.9	85.6$	7.30	164
91/04/18	1249	WATER	22		13.9	8.4	80.8$	7.20	145
91/04/18	1252	WATER	24		13.6	8.0	76.9$	7.20	131
91/04/18	1253	WATER	26		13.5	7.8	73.6$	7.10	126
91/05/16	1503	WATER	0.3	27621	25.7	12.2	148.8$	8.80	147
91/05/16	1504	WATER	1		25.5	12.3	146.4$	8.90	148
91/05/16	1505	WATER	1.5		25.4	12.3	146.4$	9.00	148
91/05/16	1506	WATER	3		24.3	12.7	149.4$	9.00	148
91/05/16	1507	WATER	4		22.5	11.7	133.0$	8.80	149
91/05/16	1510	WATER	5		21.8	10.7	121.6$	8.60	149
91/05/16	1510	WATER	5.5		20.6	8.4	93.3$	7.80	149
91/05/16	1511	WATER	6		20.3	7.3	79.3$	7.80	149
91/05/16	1512	WATER	8		18.9	5.8	61.7$	7.40	149

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 531.00

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
91/05/16	1513	WATER	10		18.9	5.6	59.6$	7.30	150
91/05/16	1514	WATER	12		18.9	5.6	59.6$	7.30	149
91/05/16	1515	WATER	14		18.8	5.5	58.5$	7.30	149
91/05/16	1517	WATER	16		18.6	5.2	55.3$	7.20	149
91/05/16	1519	WATER	18		18.5	5.0	52.6$	7.20	149
91/05/16	1520	WATER	20		18.2	4.5	47.4$	7.20	149
91/05/16	1522	WATER	22		17.9	4.2	44.2$	7.10	149
91/05/16	1524	WATER	24		17.7	4.0	42.1$	7.10	143
91/05/16	1526	WATER	25		17.6	3.9	41.1$	7.10	143
91/06/19	0959	WATER	0.3	30892	27.4	10.1	124.7$	9.10	148
91/06/19	0959	WATER	1		27.4	10.0	123.5$	9.20	148
91/06/19	1000	WATER	1.5		27.4	10.0	123.5$	9.20	148
91/06/19	1000	WATER	3.7		26.7	9.1	112.3$	9.00	149
91/06/19	1001	WATER	4		26.1	6.4	78.0$	8.60	151
91/06/19	1004	WATER	4.5		25.6	5.7	69.5$	7.90	154
91/06/19	1005	WATER	6		24.8	4.8	57.1$	7.60	160
91/06/19	1006	WATER	6.5		24.4	3.7	43.5$	7.40	159
91/06/19	1007	WATER	8		23.6	2.6	30.6$	7.30	162
91/06/19	1008	WATER	10		23.2	2.2	25.3$	7.20	161
91/06/19	1009	WATER	12		23.0	2.0	23.0$	7.20	161
91/06/19	1010	WATER	14		22.8	2.0	23.0$	7.10	161
91/06/19	1011	WATER	16		22.7	1.8	20.7$	7.10	160
91/06/19	1012	WATER	18		22.4	1.5	17.0$	7.10	158
91/06/19	1013	WATER	20		22.1	1.0	11.4$	7.10	154
91/06/19	1014	WATER	22		21.9	.5	5.7$	7.00	152
91/06/19	1017	WATER	24		21.9	.5	5.7$	7.00	153
91/06/19	1017	WATER	24.5		21.9	.5	5.7$	7.00	152
91/07/24	1120	WATER	0.5	26725	30.2	10.9	143.4$	9.10	164
91/07/24	1121	WATER	1		29.8	10.8	142.1$	9.10	164
91/07/24	1122	WATER	1.5		29.6	10.8	142.1$	9.10	165
91/07/24	1123	WATER	2		29.5	10.4	133.3$	9.10	165
91/07/24	1124	WATER	3		28.3	8.7	110.1$	8.00	171
91/07/24	1125	WATER	3.5		27.6	7.4	93.7$	8.50	174
91/07/24	1126	WATER	4		27.3	7.0	86.4$	8.30	175
91/07/24	1129	WATER	4.5		26.9	6.0	74.1$	7.90	176
91/07/24	1130	WATER	5		26.7	5.7	70.4$	7.90	177
91/07/24	1131	WATER	5.5		26.6	5.4	66.7$	7.80	177
91/07/24	1132	WATER	6		26.3	4.6	56.1$	7.70	177
91/07/24	1133	WATER	7		25.5	3.6	42.9$	7.40	177

STORET RETRIEVAL DATE 92/05/16 PGM=RET
475317 1089
35 38 10.0 084 47 06.0 2
OPP. LOWE BR. WATTS BAR RES.
47121 TENNESSEE MEIGS
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 531.0
131TVAC 06010201002 0002.040 ON /TYPA/AMBNT/FISH/STREAM/SOLIDS
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 531.00

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
91/07/24	1134	WATER	8		24.9	3.4	40.5$	7.30	181
91/07/24	1135	WATER	10		24.8	3.3	39.3$	7.30	182
91/07/24	1136	WATER	12		24.6	3.3	39.3$	7.30	184
91/07/24	1137	WATER	14		24.5	3.2	37.6$	7.30	184
91/07/24	1138	WATER	16		24.3	2.9	34.1$	7.20	181
91/07/24	1139	WATER	18		24.2	2.7	31.8$	7.20	181
91/07/24	1140	WATER	20		24.1	2.5	29.4$	7.20	181
91/07/24	1141	WATER	22		23.9	1.5	17.6$	7.10	178
91/07/24	1145	WATER	23.5		23.8	.9	10.6$	7.10	176
91/07/24	1147	WATER	24		23.7	.4	4.7$	7.00	171
91/07/24	1149	WATER	26		23.6	.3	3.5$	7.00	173
91/08/21	1127	WATER	0.5	31525	26.5	9.5	115.9$	8.70	180
91/08/21	1129	WATER	1		26.5	9.3	113.4$	8.70	180
91/08/21	1131	WATER	1.5		26.4	9.1	111.0$	8.70	181
91/08/21	1133	WATER	4		26.3	8.2	100.0$	8.50	181
91/08/21	1135	WATER	5		26.2	7.8	95.1$	8.40	182
91/08/21	1136	WATER	5.5		26.0	6.4	78.0$	8.00	185
91/08/21	1137	WATER	6		25.5	5.1	60.7$	7.70	184
91/08/21	1138	WATER	8		25.1	4.7	56.0$	7.50	183
91/08/21	1139	WATER	10		25.0	4.7	56.0$	7.50	182
91/08/21	1140	WATER	12		24.9	4.6	54.8$	7.40	181
91/08/21	1142	WATER	14		24.8	4.6	54.8$	7.40	181
91/08/21	1144	WATER	16		24.8	4.6	54.8$	7.40	181
91/08/21	1146	WATER	18		24.7	4.5	53.6$	7.40	179
91/08/21	1148	WATER	20		24.7	4.5	53.6$	7.40	179
91/08/21	1150	WATER	22		24.7	4.4	52.4$	7.40	178
91/08/21	1154	WATER	24		24.7	4.4	52.4$	7.40	181
91/08/21	1156	WATER	25.5		24.6	4.4	52.4$	7.40	181
91/09/19	1213	WATER	0.5	20779	26.7	8.6	106.2$	8.70	183
91/09/19	1216	WATER	1		26.7	8.6	106.2$	8.60	183
91/09/19	1217	WATER	1.5		26.7	8.1	100.0$	8.60	183
91/09/19	1218	WATER	4		26.5	7.6	92.7$	8.40	184
91/09/19	1219	WATER	5		26.4	7.6	92.7$	8.10	183
91/09/19	1220	WATER	5.5		26.4	6.5	79.3$	8.10	185
91/09/19	1221	WATER	6		26.3	6.5	79.3$	8.10	185
91/09/19	1222	WATER	8		26.2	6.1	74.4$	7.90	185
91/09/19	1223	WATER	9.5		26.1	6.0	73.2$	7.80	185
91/09/19	1224	WATER	10		25.8	4.5	54.9$	7.70	186
91/09/19	1225	WATER	12		25.5	3.8	45.2$	7.60	186

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 531.00

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
91/09/19	1227	WATER	14		25.5	3.8	45.2$	7.50	187
91/09/19	1229	WATER	16		25.3	3.6	42.9$	7.40	187
91/09/19	1231	WATER	18		25.2	3.6	42.9$	7.40	187
91/09/19	1233	WATER	20		25.1	3.4	40.5$	7.30	188
91/09/19	1235	WATER	22		25.0	3.3	39.3$	7.40	188
91/09/19	1240	WATER	24		25.0	2.6	31.0$	7.30	188
91/09/19	1242	WATER	26		25.0	2.2	26.2$	7.40	188

STORET RETRIEVAL DATE 92/05/16 PGM=RET
475317 1089
35 38 10.0 084 47 06.0 2
OPP. LOWE BR. WATTS BAR RES.
47121 TENNESSEE MEIGS
TENNESSEE RIVER BASIN 040801 /TYPA/AMBNT/FISH/STREAM/SOLIDS
TENNESSEE RIVER 531.0
131TVAC 06010201002 0002.040 ON
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 531.00

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00081 AP COLOR PT-CO UNITS	82079 TURBIDTY LAB NTU	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
91/01/31	1254	WATER	0.3		1.32	10K	10	15	4.0	4	.080	.020	.51
91/01/31	1257	VERT	4				15	20	4.0	4	.030	.030	.49
91/01/31	1309	WATER	22.1										
91/04/18	1238	WATER	0.3	D1	1.26	10							
91/04/18	1239	WATER	0.3	D2		10K							
91/04/18	1240	WATER	0.3	D3		10							
91/04/18	1243	VERT	4	D1			2	5	2.0	4	.110	.030	.31
91/04/18	1244	VERT	4	D2			2	5	1.0	3	.240	.020	.31
91/04/18	1245	VERT	4	D3			2	5	2.0	4	.200	.040	.31
91/04/18	1250	WATER	23	D1			2	5	6.0	10	.110	.090	.38
91/04/18	1251	WATER	23	D2			2	5	6.0	9	.110	.090	.37
91/04/18	1252	WATER	23	D3			2	5	6.0	5	.100	.120	.39
91/05/16	1503	WATER	0.3		1.70	10K			4.0	2	.280	.010K	.14
91/05/16	1507	VERT	4						9.0	9	.220	.060	.33
91/05/16	1523	WATER	22.7										
91/06/19	0959	WATER	0.3		1.65	10K	15	15	2.0	4	.200	.010K	.01
91/06/19	1001	VERT	4				25	40	10.0	15	.110	.050	.41
91/06/19	1014	WATER	22										
91/07/24	1120	WATER	0.5		1.73	10K	5	20	2.0	2	.360	.010K	.03
91/07/24	1126	VERT	4				15	60	7.0	9	.170	.050	.34
91/07/24	1142	WATER	23.1										
91/08/21	1127	WATER	0.5		1.30	10K	5	20	2.0	3	.440	.020	.03
91/08/21	1133	VERT	4				20	25	5.0	7	.250	.070	.25
91/08/21	1152	WATER	23										
91/09/19	1213	WATER	0.5		1.60	10K	15	20	2.0	3	.420	.020	.08
91/09/19	1218	VERT	4				10	30	5.0	5	.220	.040	.32
91/09/19	1237	WATER	23.5										

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	00681 D ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
91/01/31	1257	VERT	4		.020	.010	1.9	2.0	6.00	1.00K	1.00	2.00
91/01/31	1309	WATER	22.1		.020	.010	1.8	1.8				
91/04/18	1238	WATER	0.3	D1								
91/04/18	1239	WATER	0.3	D2								
91/04/18	1240	WATER	0.3	D3								
91/04/18	1243	VERT	4	D1	.010	.004	2.1	1.7	10.00	1.00	2.00	1.00K
91/04/18	1244	VERT	4	D2	.010	.004	2.1	1.8	9.00	1.00	1.00	1.00
91/04/18	1245	VERT	4	D3	.010	.004	2.1	1.7	9.00	1.00K	1.00	1.00K
91/04/18	1250	WATER	23	D1	.020	.007	1.8	1.6				
91/04/18	1251	WATER	23	D2	.030	.007	1.7	1.5				
91/04/18	1252	WATER	23	D3	.030	.008	1.7	1.5				
91/05/16	1507	VERT	4		.009	.002	2.0	1.8	10.00	1.00K	1.00K	1.00
91/05/16	1523	WATER	22.7		.020	.009	1.7	1.6				
91/06/19	1001	VERT	4		.010	.002K	2.2	2.0	17.00	2.00	1.00	2.00
91/06/19	1014	WATER	22		.030	.010	1.9	1.6				
91/07/24	1126	VERT	4		.020	.004	2.4	2.0	14.00	1.00	2.00	1.00
91/07/24	1142	WATER	23.1		.020	.010	1.9	1.7				
91/08/21	1133	VERT	4		.030	.007	2.1	1.9	19.00	1.00	2.00	1.00
91/08/21	1152	WATER	23		.030	.010	1.8	1.7				
91/09/19	1218	VERT	4		.030	.009	2.3	2.0	12.00	1.00	1.00	2.00
91/09/19	1237	WATER	23.5		.030	.020	2.0	1.9				

A33

STORET RETRIEVAL DATE 92/05/16 PGM=RET
476041 1114C
35 49 50.0 084 36 33.0 2
WATTS BAR RESERVOIR
47145 TENNESSEE ROANE
TENNESSEE RIVER BASIN 040801 /TYPA/AMBNT/STREAM/SOLIDS
TENNESSEE RIVER 560.80
131TVAC HQ 06010201002 0043.170 OFF
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 560.80

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
91/01/31	1145	WATER	0.5		7.7	11.4	95.8$	7.70	206
91/01/31	1146	WATER	1		7.7	11.3	95.0$	7.70	207
91/01/31	1147	WATER	1.5		7.7	11.2	94.1$	7.80	207
91/01/31	1148	WATER	4		7.7	11.2	94.1$	7.80	207
91/01/31	1151	WATER	6		7.7	11.2	94.1$	7.80	208
91/01/31	1155	WATER	8		7.7	11.1	93.3$	7.70	206
91/01/31	1200	WATER	10		7.6	11.1	93.3$	7.70	206
91/01/31	1213	WATER	11		7.6	11.1	93.3$	7.70	206
91/04/18	1049	WATER	0.3		17.9	11.7	123.2$	8.20	126
91/04/18	1052	WATER	1		17.3	10.8	111.3$	7.90	130
91/04/18	1052	WATER	1.5		16.6	10.3	106.2$	7.70	135
91/04/18	1053	WATER	4		16.4	10.1	101.0$	7.50	139
91/04/18	1056	WATER	6		16.3	9.9	99.0$	7.40	143
91/04/18	1057	WATER	8		16.0	9.7	97.0$	7.30	163
91/04/18	1058	WATER	10		15.8	9.4	94.0$	7.20	168
91/04/18	1059	WATER	12		15.8	9.2	92.0$	7.20	169
91/04/18	1103	WATER	13		15.7	8.8	88.0$	7.20	169
91/05/16	1342	WATER	0.3		23.4	9.8	112.6$	8.20	152
91/05/16	1343	WATER	1		22.6	9.9	113.8$	8.20	151
91/05/16	1345	WATER	1.5		22.0	9.6	109.1$	8.00	148
91/05/16	1347	WATER	3.1		20.8	8.0	88.9$	7.60	142
91/05/16	1349	WATER	4		20.4	7.6	82.6$	7.50	142
91/05/16	1351	WATER	6		19.9	7.4	80.4$	7.40	140
91/05/16	1353	WATER	8		19.7	7.2	78.3$	7.40	139
91/05/16	1356	WATER	10		19.6	7.1	77.2$	7.40	140
91/05/16	1400	WATER	12		19.6	7.0	76.1$	7.40	140
91/05/16	1405	WATER	13		19.6	7.0	76.1$	7.40	140
91/06/19	0848	WATER	0.3		26.5	11.1	135.4$	8.80	177
91/06/19	0849	WATER	1		26.1	9.8	119.5$	8.60	176
91/06/19	0850	WATER	1.5		26.0	9.6	117.1$	8.60	175
91/06/19	0851	WATER	4		25.5	8.8	104.8$	8.30	172
91/06/19	0854	WATER	4.8		24.7	7.9	94.0$	8.00	168
91/06/19	0855	WATER	6		23.1	5.4	62.1$	7.60	164
91/06/19	0855	WATER	8		22.4	5.2	59.1$	7.40	161
91/06/19	0855	WATER	10		22.2	5.0	56.8$	7.40	161
91/06/19	0856	WATER	12		22.2	4.9	55.7$	7.40	161
91/06/19	0859	WATER	12.5		22.2	4.4	50.0$	7.30	163
91/07/24	1015	WATER	0.5		28.4	10.4	131.6$	8.80	185
91/07/24	1017	WATER	1		27.9	9.9	125.3$	8.60	189

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 560.80

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
91/07/24	1018	WATER	1.5		27.3	9.4	116.1$	8.50	191
91/07/24	1019	WATER	2.5		26.5	8.6	104.9$	8.30	193
91/07/24	1020	WATER	3		26.0	8.1	98.8$	8.10	194
91/07/24	1021	WATER	4		25.2	7.5	89.3$	7.90	194
91/07/24	1025	WATER	6		24.4	6.7	78.8$	7.70	194
91/07/24	1027	WATER	8		24.0	6.5	76.5$	7.70	192
91/07/24	1029	WATER	10		23.8	6.4	75.3$	7.70	194
91/07/24	1033	WATER	12		23.5	6.1	70.1$	7.60	194
91/07/24	1035	WATER	13		23.5	5.9	67.8$	7.60	195
91/08/21	1010	WATER	0.5		24.5	7.2	84.7$	7.70	180
91/08/21	1012	WATER	1		24.4	7.0	82.4$	7.70	179
91/08/21	1014	WATER	1.5		24.4	6.9	81.2$	7.70	180
91/08/21	1016	WATER	4		24.4	6.8	80.0$	7.70	181
91/08/21	1018	WATER	6		24.3	6.6	77.6$	7.70	181
91/08/21	1020	WATER	8		24.3	6.6	77.6$	7.60	181
91/08/21	1022	WATER	10		24.3	6.5	76.5$	7.60	181
91/08/21	1030	WATER	12		24.3	6.5	76.5$	7.60	181
91/08/21	1035	WATER	12.5		24.3	6.4	75.3$	7.60	179
91/09/19	1110	WATER	0.5		24.9	6.6	78.6$	7.80	193
91/09/19	1113	WATER	1		24.9	6.6	78.6$	7.70	193
91/09/19	1114	WATER	1.5		24.9	6.6	78.6$	7.70	192
91/09/19	1116	WATER	4		24.9	6.5	77.4$	7.80	193
91/09/19	1120	WATER	6		24.9	6.5	77.4$	7.60	193
91/09/19	1122	WATER	8		24.9	6.3	75.0$	7.60	194
91/09/19	1124	WATER	10		24.9	6.2	73.8$	7.70	193
91/09/19	1126	WATER	12		24.8	6.1	72.6$	7.60	195
91/09/19	1132	WATER	13		24.7	5.7	67.9$	7.70	197

STORET RETRIEVAL DATE 92/05/16 PGM=RET
47[illegible] 1114C
35 4[illegible]0.0 084 36 33.0 2
WATTS BAR RESERVOIR
47145 TENNESSEE ROANE
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 560.80 /TYPA/AMBNT/STREAM/SOLIDS
131TVAC HQ 06010201002 0043.170 OFF
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 560.80

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00081 AP COLOR PT-CO UNITS	82079 TURBIDTY LAB NTU	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
91/01/31	1145	WATER	0.5		1.00	10							
91/01/31	1148	VERT	4				10	15	6.0	7	.060	.060	.61
91/01/31	1205	WATER	10.6				10	15	5.0	8	.060	.040	.60
91/04/18	1049	WATER	0.3	D1	.75	10K							
91/04/18	1050	WATER	0.3	D2		10K							
91/04/18	1051	WATER	0.3	D3		10							
91/04/18	1053	VERT	4	D1			2	5	5.0	7	.120	.040	.30
91/04/18	1054	VERT	4	D2			2	5	5.0	7	.110	.030	.31
91/04/18	1055	VERT	4	D3			2	5	7.0	7	.120	.020	.31
91/04/18	1100	WATER	12.1	D1			2	5	6.0	8	.030	.050	.40
91/04/18	1101	WATER	12.1	D2			2	5	6.0	9	.090	.070	.41
91/04/18	1102	WATER	12.1	D3			2	5	6.0	8	.080	.060	.42
91/05/16	1342	WATER	0.3		1.22	10K							
91/05/16	1349	VERT	4						6.0	5	.290	.010	.28
91/05/16	1401	WATER	12.2						10.0	10	.230	.050	.41
91/06/19	0848	WATER	0.3		1.00	10K							
91/06/19	0851	VERT	4				20	20	4.0	6	.400	.010K	.17
91/06/19	0856	WATER	12				35	35	13.0	15	.220	.020	.41
91/07/24	1015	WATER	0.5		1.46	10K							
91/07/24	1021	VERT	4				5	20	3.0	3	.780	.010K	.20
91/07/24	1034	WATER	12.1				10	25	6.0	7	.160	.060	.34
91/08/21	1010	WATER	0.5			10K							
91/08/21	1016	VERT	4				15	20	4.0	5	.330	.010	.22
91/08/21	1025	WATER	11.9				20	35	7.0	12	.210	.020	.23
91/09/19	1110	WATER	0.5		1.20	10K							
91/09/19	1116	VERT	4				20	20	4.0	5	.320	.020	.28
91/09/19	1128	WATER	12.3				20	25	5.0	7	.320	.040	.27

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	00681 D ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
91/01/31	1148	VERT	4		.030	.020	2.0	1.9	5.00	1.00	1.00	2.00
91/01/31	1205	WATER	10.6		.040	.020	1.9	1.9				
91/04/18	1049	WATER	0.3	D1								
91/04/18	1050	WATER	0.3	D2								
91/04/18	1051	WATER	0.3	D3								
91/04/18	1053	VERT	4	D1	.020	.005	1.9	1.6	6.00	1.00K	1.00	1.00K
91/04/18	1054	VERT	4	D2	.020	.006	1.7	1.5	6.00	1.00K	1.00	1.00
91/04/18	1055	VERT	4	D3	.020	.006	1.6	1.5	5.00	1.00K	1.00	1.00
91/04/18	1100	WATER	12.1	D1	.020	.009	1.5	1.4				
91/04/18	1101	WATER	12.1	D2	.020	.009	1.4	1.3				
91/04/18	1102	WATER	12.1	D3	.020	.010	1.5	1.4				
91/05/16	1349	VERT	4		.030	.004	2.1	1.8	9.00	1.00K	1.00	1.00K
91/05/16	1401	WATER	12.2		.030	.009	1.9	1.8				
91/06/19	0851	VERT	4		.030	.002	2.3	1.9	9.00	1.00	1.00	1.00K
91/06/19	0856	WATER	12		.040	.007	2.1	1.8				
91/07/24	1021	VERT	4		.020	.006	2.2	1.8	13.00	1.00K	1.00	2.00
91/07/24	1034	WATER	12.1		.020	.007	1.8	1.7				
91/08/21	1016	VERT	4		.030	.009	1.9	1.8	9.00	1.00	1.00	3.00
91/08/21	1025	WATER	11.9		.040	.010	1.8	1.8				
91/09/19	1116	VERT	4		.030	.010	2.2	2.0	8.00	1.00	1.00	2.00
91/09/19	1128	WATER	12.3		.030	.010	1.9	1.8				

TENNESSEE VALLEY AUTHORITY

Resource Group
River Basin Operations
Water Resources

RESERVOIR VITAL SIGNS MONITORING - 1992
PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER AND SEDIMENT

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Chattanooga, Tennessee
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INTRODUCTION

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

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

The basis of Vital Signs Monitoring is examination of appropriate physical, chemical, and biological indicators - monitoring tools - at one or more strategic locations in each reservoir, i.e. the forebay immediately upstream of the dam; the transition zone (the mid-reservoir region where the water changes from free flowing to more quiescent, impounded water; and the inflow or headwater region of the reservoir. The monitoring tools comprised: basic physical/chemical water quality sampling; sediment quality and toxicity testing; benthic macroinvertebrate community evaluations; and fish community evaluations. A summary report (Meinert and Dycus, 1993) presents results of TVA's 1992 Reservoir Monitoring Program, to include all Vital Signs (physical/chemical, sediment, benthic and fish communities) and

Use Sutiability Monitoring.

This technical data summary presents the 1992 Vital Signs physical/chemical water quality sampling information only. The basic group of 24 reservoirs were again monitored, however, several sampling location changes were made prior to commencement of 1992 sampling activities. Transition zone sampling locations were relocated further downstream to less riverine environs on Kentucky, Wheeler, and Guntersville reservoirs. Due to the similarities in water quality between forebay and transition zone the transition zone sampling was dropped on Nickajack reservoir. Forebay sampling locations on Chatuge and Nottely reservoirs were relocated slightly downstream and mid-reservoir sampling locations were added to better define ecological conditions on these two reservoirs.

MATERIALS AND METHODS

Reservoir Characteristics - The physical characteristics of a reservoir (volume, surface area, depth, hydraulic residence time, etc.) have a great effect on its intrinsic physical and chemical processes and water quality characteristics. The Vital Signs reservoirs are very broadly categorized as either run-of-the-river or tributary reservoirs, with generally large differences in their morphologic and hydraulic characteristics (Table 1). Primary differences include the greater depths and longer hydraulic residence times of tributary reservoirs, resulting in the development of strong thermal stratification and its associated physical/chemical processes. Short average residence times found on most of the main stream, run-of-the-river reservoirs (usually less than 30 days) results in well-mixed riverine conditions. Thermal stratification of the run-of-the-river reservoirs rarely exists and then for only short periods of time under conditions of low flow and intense solar heating. However, tributary reservoirs with their longer residence times (typically greater than 100 days) develop strong thermal stratification that begins in the spring and ends with seasonal cooling and mixing in the late autumn. During this summer stratification, inflowing water may be cooler than the epilimnetic surface water and may enter the reservoir as a cold underflow to the hypolimnion rather than mixing with the epilimnion. This results in an even longer residence time of the epilimnetic water than is indicated by the calculated average reservoir volume/flow quotient, particularly if the turbine power intakes draw water exclusively from below the thermocline.

A major effect of this thermal stratification in tributary reservoirs is the depletion of hypolimnetic dissolved oxygen. The pattern of hypolimnetic dissolved oxygen depletion is variable both spatially and temporally for any one reservoir and among reservoirs. The general pattern, however, is that after the onset of thermal stratification, an anoxic zone first begins

Table 1

CHARACTERISTICS OF VITAL SIGNS RESERVOIRS

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

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

b. Major/minor arms of reservoir.

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

d. Estimated

to develop in the transition zone of the reservoir. The large input and settling out of allochthonous organic matter (leaves and detritus washed in by the tributary streams) causes high rates of oxygen uptake in the transition zone and results in the initial depletion of dissolved oxygen in this area of the reservoir. The zone of anoxic water gradually extends both upstream and downstream, until it reaches the free-flowing river upstream and the dam downstream. At the same time the anoxic zone develops vertically and laterally. In the worst case, the entire hypolimnion may become anoxic and remain so until reaeration during autumn overturn. The hypolimnetic anoxia promotes the dissolution and release of metals, minerals, and nutrients from the reservoir sediment and bottom water, resulting in elevated concentrations of reduced forms of iron, manganese, sulfate, nitrate, and phosphate. When reservoir destratification occurs in autumn, the hypolimnion is mixed with surface water and replenished with oxygen.

Epilimnetic processes are also affected by thermal stratification, particularly in deeper tributary reservoirs. With the onset of spring stratification, primary production can be quite high, particularily in the transition zone. The phytoplankton community frequently receives amples supplies of nutrients from periodic spring rainfall/runoff events, and with lower water velocities and increased rates of sedimentation, improved water clarity and light penetration often results in episodes of high algal productivity as evidenced by high chlorophyll-a concentrations, high pH values and supersaturation of dissolved oxygen. The longer residence times of tributary reservoirs results in water clarity usually being more a function of algal cell abundance and chlorophyll pigment and less a function of inorganic suspended material as is the case in mainstream reservoirs with shorter residence times and higher velocities. In mainstream reservoirs, the shorter detention times and higher velocities inhibit the deposition of suspended material, resulting in generally lower water clarity and light availability and often limiting algal productivity.

Epilimnetic water clarity often increases moving downstream into the forebay area of the reservoir and into the late summer as rainfall/runoff events occur less frequently. Even though water clarity increases, nutrients become depleted and primary production often is reduced as much of the organic matter produced during photosynthesis decomposes and settles below the photic zone. Bacterial decomposition consumes available dissolved oxygen (respiration) and releases carbon dioxide, thereby lowering the pH. Unlike mainstream reservoirs, this decomposition process in tributary reservoirs often results in two oxygen minima in the water column - one in the epilimnion at or near the thermocline and one in the hypolimnion.

Consequently, physical/chemical differences in water quality between run-of-the-river and tributary reservoirs are expected in examining the 1992 Vital Signs data. In the Results and Discussion section of this report, water quality characteristics are discussed and comparisons are made among the Vital Signs reservoirs to point out these differences. Because physical/chemical water quality conditions are different, this does not imply that one reservoir is good and another is poor, it merely is a reflection of the unique physical and chemical differences between each. For example, one particular reservoir, Fort Loudoun, exhibits both run-of-the-river and tributary reservoir characteristics. Although it is located on the main stream of the Tennessee River, it is the most upstream reservoir and is formed by the confluence of the French Broad and Holston Rivers. Major tributary reservoir impoundments on both these river systems, Douglas Dam at mile 32.3 of the French Broad and Cherokee Dam at mile 52.3 on the Holston, release cool, hypolimnetic water low in dissolved oxygen during the summer. Depending upon the quantity and duration of water released from Douglas and Cherokee dams and the temperature of the impounded Fort Loudoun water, this cool water may flow under the warmer water impounded in Fort Loudoun Reservoir resulting in thermally stratified conditions. Consequently, Fort Loudoun can intermittently exhibit the characteristics of either a run-of-the-river reservoir or a tributary reservoir.

Overview - Physical/chemical variables were measured at a total of forty seven locations on the twenty four Vital Signs reservoirs (Figure 1, Table 2). The Vital Signs water quality monitoring activities on these reservoirs, followed either a "basic" or "limited" sampling strategy (Tables 2 and 3). The basic sampling strategy included monthly water quality surveys (January and April through September) at the forebay and transition zone locations on fourteen TVA reservoirs: the nine mainstem Tennessee River reservoirs; and Cherokee, Douglas, Norris, Melton Hill and Tellico reservoirs. The limited sampling strategy included monthly water sampling (April through October) for a smaller list of parameters at the forebay locations (and at mid-reservoir locations on larger reservoirs) on ten non-navigable tributary impoundments.

Water quality measurements, sample collections and sample handling followed standard practices accepted by the Environmental Protection Agency (EPA, 1979 and 40 CFR 136), US Geological Survey (USGS, 1977), and American Public Health Association (AWWA, WPCF, APHA, 1989) as specified in TVA quality assurance/quality control (QA/QC) procedures (TVA, 1990 and TVA, 1987). TVA laboratory analyses conformed to established EPA, USGS, and APHA QA/QC procedures (TVA, 1989b).

Details on the physical/chemical analyses and measurements on the water samples are summarized in Tables 3 and 4. The 1992 data are tabulated in the Appendix A - Physical/Chemical Characteristics of Water. All the data are stored and are available on EPA's water quality data storage and retrieval (STORET) computer system.

FIGURE 1

RESERVOIR VITAL SIGNS MONITORING LOCATIONS - 1992

PHYSICAL AND CHEMICAL

CHARACTERISTICS OF WATER AND SEDIMENT

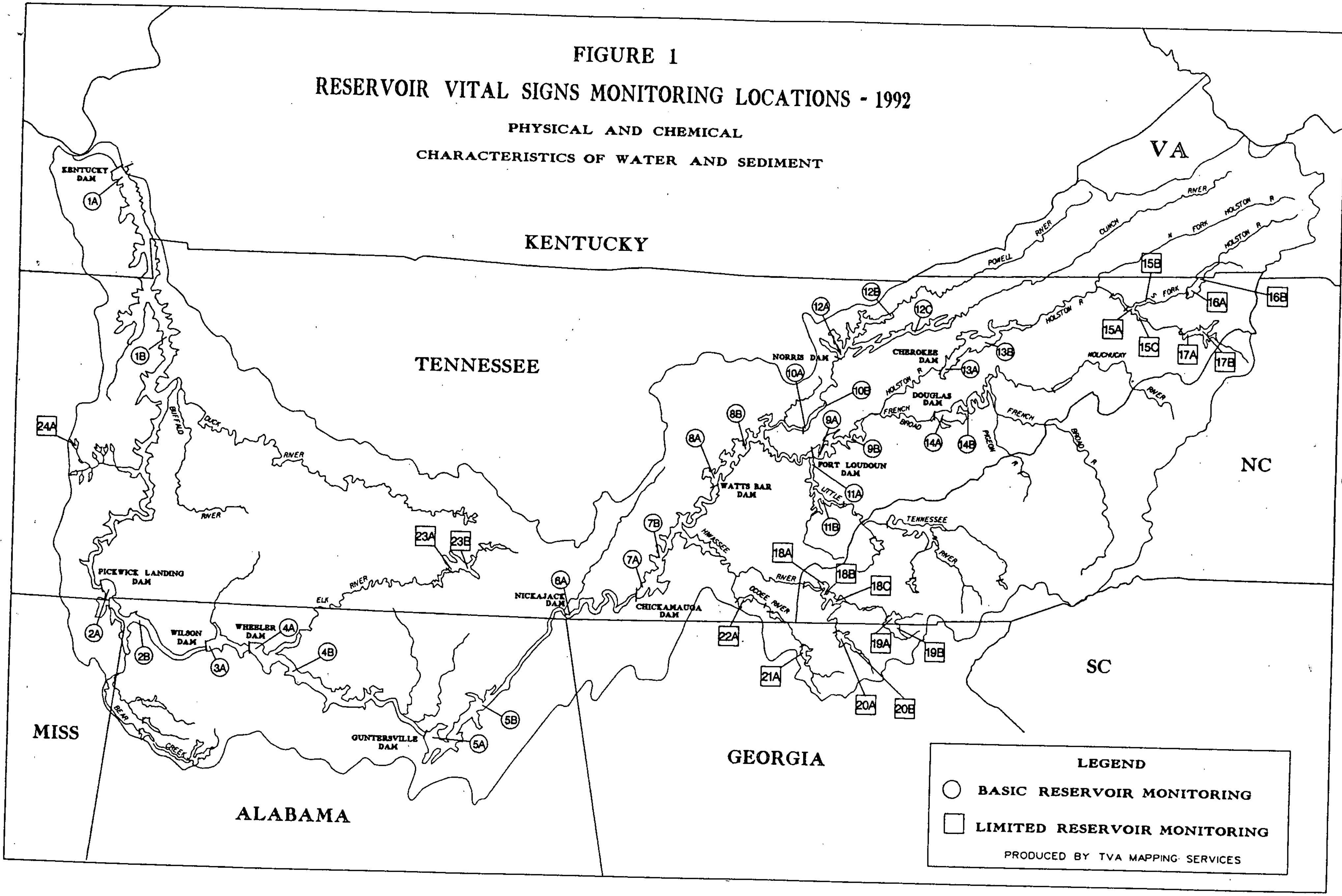

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Table 2

WATER QUALITY MONITORING LOCATIONS
RESERVOIR VITAL SIGNS MONITORING, 1992

Basic Water Quality Monitoring Locations

	Forebay Locations			Transition Zone Locations		
Reservoir	River Mile (Tennessee)	Map ID Number	Storet Station #	River Mile (Tennessee)	Map ID Number	Storet Station #
Run-of-the-River Reservoirs						
Kentucky	23.0	1A.	202832	85.0	1B.	477403
Pickwick	207.3	2A.	476799	230.0	2B.	016923
Wilson	260.8	3A.	016912	--	--	
Wheeler	277.0	4A.	016900	295.9	4B.	017009
Guntersville	350.0	5A.	017261	375.2	5B.	017522
Nickajack	425.5	6A.	476344	--	--	
Chickamauga	472.3	7A.	475358	490.5	7B.	475265
Watts Bar	531.0	8A.	475317	560.8	8B.	476041
Fort Loudoun	605.5	9A.	475602	624.6	9B.	475603
	(603.2		477404)			
Melton Hill	CRM 24.0	10A.	477064	CRM 45.0	10B.	476194
Tellico	LTRM 1.0	11A.	476260	LTRM 21.0	11B.	476295
Tributary Reservoirs						
Norris	CRM 80.0	12A.	476009	PRM 30.0	12B.	477187
				CRM 125.0	12C.	477186
Cherokee	HRM 53.0	13A.	475025	HRM 76.0	13B.	475028
Douglas	FBRM 33.0	14A.	475081	FBRM 60.7	14B.	475993

Table 2 (continued)

WATER QUALITY MONITORING LOCATIONS
RESERVOIR VITAL SIGNS MONITORING, 1992

Limited Water Quality Monitoring Locations

Reservoir	Forebay Locations			Mid-Reservoir Locations		
	River Mile	Map ID Number	Storet Station #	River Mile	Map ID Number	Storet Station #
-Tributary-						
Boone	SFHR 19.0	15A.	475858	SFHR 27.0	15B.	476221
				WRM 8.3	15C.	475997
South Holston	SFHR 51.0	16A.	475859	SFHR 62.5	16B.	475573
Watauga	WRM 37.4	17A.	475576	WRM 44.0	17B.	475577
Hiwassee	HiRM 77.0	18A.	370001	HiRM 85.0	18B.	370154
				HiRM 90.0	18C.	370163
Chatuge	HiRM 121.1	19A.	370059	HiRM 125.6	19B.	130071
Nottely	NRM 21.5	20A.	130073	NRM 31.0	20B.	120806
Blue Ridge	ToRM 54.1	21A.	130032			
Ocoee #1	ORM 12.5	22A.	475684			
Tims Ford	ERM 135.0	23A.	477072	ERM 150.0	23B.	475768
Beech	BRM 36.0	24A.	475876			

Abbreviations:
BRM - Beech River Mile
CRM - Clinch River Mile
ERM - Elk River Mile
FBRM - French Broad River Mile
HiRM - Hiwassee River Mile
HRM - Holston River Mile
LTRM - Little Tennessee River Mile
NRM - Nottely River Mile
ORM - Ocoee River Mile
PRM - Powell River Mile
SFHR - South Fork Holston River Mile
ToRM - Toccoa River Mile
WRM - Watauga River Mile

Table 3

RESERVOIR VITAL SIGNS - 1992
WATER QUALITY MONITORING STRATEGY

Description	Sample Collection Depths	Monitoring Strategy[b] Basic	Limited
Field Measurements			
Hydrolab® (temperature, pH, dissolved oxygen, and conductivity)	0.3,1.5,4,6,8[a] etc.	monthly	monthly
Secchi Depth	--	monthly	monthly
Fecal Coliform	0.3 (surface grab)	monthly	NA
Laboratory Measurements			
Chlorophyll-a	composite[c]	monthly	monthly
Nutrients			
Organic Nitrogen	composite (& bottom)[d]	monthly	April & August
Ammonia Nitrogen	composite (& bottom)	monthly	April & August
Nitrite & Nitrate Nitrogen	composite (& bottom)	monthly	April & August
Total Phosphorus	composite (& bottom)	monthly	April & August
Dissolved Ortho phosphorus	composite (& bottom)	monthly	April & August
Organic Carbon			
Total Organic Carbon	composite (& bottom)	monthly	April & August
Color and Solids			
Color	composite (& bottom)	monthly	NA
Suspended Solids	composite (& bottom)	monthly	NA

[a] *In situ* Hydrolab measurements were made at the depths indicated and at regularly spaced intervals (2-4 meters) from the water surface to the bottom of the water column. These measurements were also made at intermediate depths any time the temperature changed by more than 2°C or the dissolved oxygen changed by more than 1 mg/l.

[b] Basic monthly is January and April through September. Limited monthly is April through October.

[c] Composite indicates a photic zone composite sample with the photic zone defined as four meters or twice the Secchi depth, whichever is greater.

[d] Bottom grab samples were only collected as part of the basic sampling strategy. Bottom indicates a grab sample collected three meters above the bottom at forebay locations and one meter above the bottom at transition zone locations.

Table 4

RESERVOIR VITAL SIGNS MONITORING - WATER
PHYSICAL/CHEMICAL MEASUREMENTS, 1992

EPA Storet Code	Description	Units	Detection Limits
	Field Measurements		
	Hydrolab		
00010	Temperature	°C	--
00300	Dissolved Oxygen	mg/l	--
00400	pH	Std. units	--
00094	Conductivity	micromhos	--
00078	Secchi Depth	meters	0.1 meters
31616	Fecal Coliform	colonies/100mL	1/100 mL
	Laboratory Measurements		
32211	Chlorophyll-a	µg/l	1 µg/l
	Nutrients		
00605	Organic Nitrogen	mg/l	0.02 mg/l
00610	Ammonia Nitrogen	mg/l	0.01 mg/l
00630	Nitrite & Nitrate Nitrogen	mg/l	0.01 mg/l
00665	Total Phosphorus	mg/l	0.002 mg/l
00671	Dissolved Ortho phosphorus	mg/l	0.002 mg/l
	Organic Carbon		
00680	Total Organic Carbon	mg/l	0.2 mg/l
	Color and Solids		
00080	Color	PCU	1 PCU
00530	Suspended Solids	mg/l	1 mg/l

Quality Assurance/Quality Control - The Reservoir Vital Signs Monitoring program includes three unique QA/QC measures. These are: (1.) collection of triplicate sets of samples at each reservoir sampling location; (2.) preparation of sample container (and/or field) blanks (defined below) each collection day; and, (3.) preparation of sample filtration blanks (defined below) with each set of filtered samples. These data in tabular form are given in the appendix.

•Triplicates - On one occasion during the year, water samples from each reservoir were collected and analyzed in triplicate to assess sample collection, analysis, and natural variability. Triplicate data shown in Appendix A are identified by the remarks codes "D1", "D2", and "D3", respectively, for each individual measurement in a set of triplicates. Each individual water quality parameter has its own inherent naturally occurring variability, and different methods of analysis have varing degrees of precision and accuracy which are reflected in these data.

•Container Blanks - A container blank is defined as a sample container which has been filled with water taken directly from a Reagent Grade I water system without transference to any intermediary container. A field blank is defined as a sample container which has been filled with Reagent Grade I water which has been temporally stored in a transport carboy or large container for use in the field. A set of container (or field) blanks was collected by each survey party on each monthly survey. Container blanks sample bottles are filled and handled in the same manner and analyzed for the same variables as actual reservoir water quality samples. This assesses the degree of contamination associated with the sample bottles and/or the sample handling processes. The container blank information for the last three years (Table 5) show that true color and suspended solids have a very low frequency of detection, less than 3%. However, the results also indicate that contamination of samples due to ammonia nitrogen is quite frequent. Approximately 16% of the "blank" ammonia nitrogen containers show detectable concentrations greater than or equal to twice the laboratory detection limit of 0.01 mg/l. An acceptable level of sample bottle contamination would be less than 10%.

Table 5 shows that total organic carbon also is frequently detected in blank samples, with approximately two-thirds of the container blanks showing possible evidence of contamination, in 1992. However, because of instrument variability (±0.1 mg/l) at or near the instrument's operational detection limit of 0.2 mg/l, and the variable quality of reagent grade water used in the field, carbon values equal to or less than 0.4 mg/l (twice the detection limit) have been judged to be indicative of contaminate-free containers. Considering only total organic carbon values greater than 0.4 mg/l (twice the detection limit), about 10% of the organic carbon blank containers showed contamination in 1992.

The quality of sample containers, chemical preservatives, Reagent Grade I water, and field and laboratory handling all need to be examined to minimize and eliminate possible sources of contamination.

•Filtration Blanks - Filtration blanks were prepared with each set of water samples whenever dissolved phosphorus samples were collected. Filtration blanks were prepared in the field by filtering and handling Reagent Grade I water in exactly the same manner as the ambient reservoir water was handled and filtered. The filtration blank samples were analyzed in the same manner as ambient water quality samples to assess variability due to field sample filtration techniques. The data are summarized in Table 5 and show that approximately 32% of the dissolved ortho phosphorus filtration blank samples had detectable concentrations of phosphorus greater than the laboratory detection limit of 2 μg/l. This was about twice the percentage of contamination for (unfiltered) dissolved phosphorus container blanks (15.6%), indicating contamination due to sample filtration and handling.

Recommendations - Because of the low frequency of contamination of container blanks for true color and suspended solids, collection of container blanks for these parameters should be discontinued in the 1993 Vital Signs Reservoir Monitoring Program. Continued attention needs to be given to elimination sources of ammonia nitrogen contamination and contamination introduced by the handling and filtration of dissolved phosphorus samples.

TABLE 5

QUALITY ASSURANCE/QUALITY CONTROL DATA SUMMARY
RESERVOIR VITAL SIGNS MONITORING 1990-1992

	Organic-N (mg/l)	Ammonia-N (mg/l)	Nitrite + Nitrate-N (mg/l)	Total Phosphorus (µg/l)	Dissolved Ortho-P (µg/l)	Total Organic Carbon (mg/l)	True Color (PCU)	Suspended Solids (mg/l)
Detection Limit (DL)	0.02	0.01	0.01	2	2	0.2	1	1
CONTAINER BLANK SAMPLES								
1990								
Number of Samples	70	70	70	70	30	73	70	70
% ≥ DL	27.1	34.3	8.6	38.6	3.3	72.4	1.4	0.0
% ≥ 2xDL	5.7	15.7	7.1	4.3	0.0	21.9	1.4	0.0
1991								
Number of Samples	100	101	101	101	65	100	69	81
% ≥ DL%	29.0	30.7	7.9	61.4	30.8	72.0	2.9	0.0
% ≥ 2xDL	11.0	20.8	5.9	23.8	7.7	32.0	2.9	0.0
1992								
Number of Samples	92	94	94	92	90	93	9	9
% Exceeding DL	30.4	48.9	6.4	32.6	15.6	66.7	0.0	0.0
% ≥ 2xDL	3.3	16.0	3.3	7.6	4.4	10.8	0.0	0.0
FILTRATION BLANK SAMPLES								
1990								
Number of Samples					118			
% ≥ DL					20.3			
% ≥ 2xDL					5.1			
1991								
Number of Samples					153			
% ≥ DL%					26.8			
% ≥ 2xDL					9.2			
1992								
Number of Samples					129			
% Exceeding DL					31.8			
% ≥ 2xDL					8.5			

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HYDROLOGIC OVERVIEW OF WATER YEAR 1992

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

Atmospheric Temperature

Average annual temperature in the TVA region is approximately 60 degrees Fahrenheit,°F (15.6 degrees Celsius,°C) with January usually being the coldest month and July the hottest. According to U.S. Department of Commerce climatic data, atmospheric temperatures in the TVA region averaged about 0.3°F (0.2°C) cooler than normal in 1992 (USDOC, 1992). January and February were unusually warm with 2.6°F (1.4°C) and 4.9°F (2.7°C) above normal, respectively, Figure 2-a. However, the rest of the months were near or below normal. May, June, August, and October had departures greater than -1.0°F (-0.6°C). This resulted in a cooler than normal growing season.

Rainfall

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

Rainfall in the Tennessee Valley in 1992 averaged 43.4 inches (1102 mm), about 8 inches (204 mm) less than the long term 100-year average, (a departure of about minus 15 percent) and about 12.7 inches (323 mm) less rainfall than 1991 (TVA 1992). Following a wet October-December 1991, each of the first five months of 1992 was more than an inch (25 mm) below the long term average, with the greatest departure being -2.4 inches (-61 mm) in April, as shown in Figure 2-b. Consequently, the period January-May 1992 ranked as one of the ten driest on record in the Tennessee Valley. In spite of this rainfall deficit, all TVA reservoirs were at summer pool levels by the end of May. Rainfall during the summer (June through October) was slightly below normal (0.1 inches). Rainfall was rather evenly distributed in the Tennessee Valley in 1992 with that portion east of Chattanooga receiving about 43.5 inches (1105 mm) and that portion west of Chattanooga receiving about 43.3 inches (1100 mm).

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

Streamflow

Streamflow varies seasonally with rainfall, although during the spring and summer evaporation, transpiration, and infiltration reduce the amount of runoff. Watersheds that receive 50 to 60 inches of precipitation annually average about 20 to 30 inches of runoff. In a normal year, the discharge of the Tennessee River (approximately 64,000 cfs) corresponds to about 22 inches of runoff distributed over the 40,900 square mile drainage basin. A larger amount of runoff occurs during the wet winter and spring months (January-April) when precipitation events are frequent, temperatures are low, and there are no leaves on deciduous vegetation. Consequently, soil absorption, evaporation, and plant transpiration losses are low at that time of year, and both runoff and streamflow are higher than during the summer and fall months. In 1992, runoff was about an inch

(25 mm) below normal, with the first six months of the year having below normal runoff and the last six months having above average runoff, Figure 2-c. The abnormally dry spring and low runoff (January-May) of 1992, combined with the spring filling of the tributary reservoirs (resulting in the release of little water from the tributary reservoirs) resulted in low flows in the mainstem Tennessee River reservoirs, particularly in April. Consequently, an unusual episode of early spring thermal stratification on the tributary and many of the mainstem reservoirs was observed in April 1992. Higher, more normal flows in May and June (after the filling of the tributary reservoirs and higher amounts of rain) resulted in the destratification of the mainstem reservoirs and a return to more normal reservoir conditions. The impacts of the early spring stratification on the water quality of several reservoirs is discussed in the following chapter.

The net result for the Tennessee Valley in 1992 was an annual 15 percent deficit in precipitation with resultant total runoff that was approximately 0.9 inches below the long-term mean of 22.5 inches. Mean streamflows during 1992 for each of the Vital Signs reservoirs reflect the lower than average annual runoff (table 1).

FIGURE 2. Temperature, Precipitation, and Runoff – Tennessee River Basin, 1992

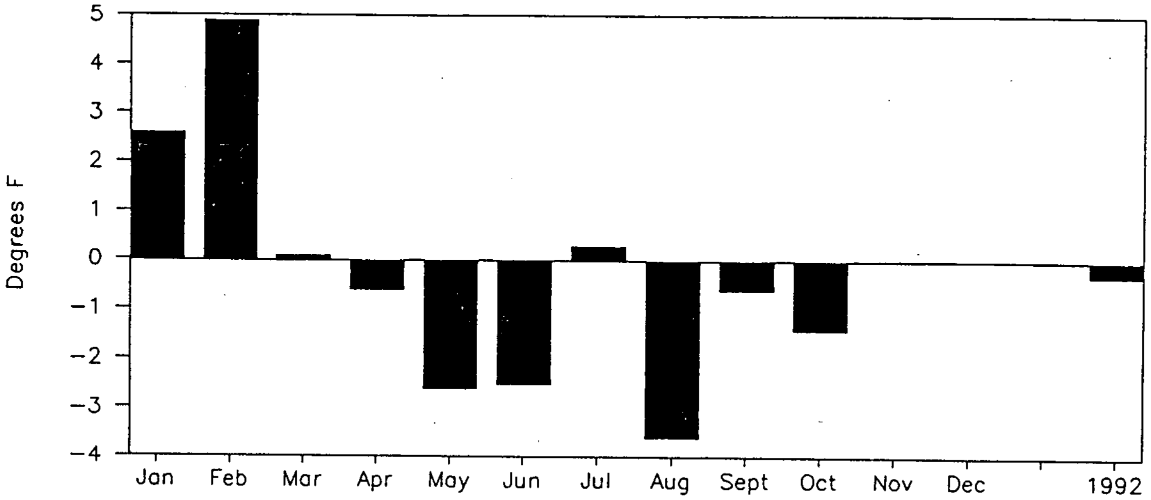

FIGURE 2a. Temperature Departures From 1951–1980 Normal (Deg F) in the TVA Region.

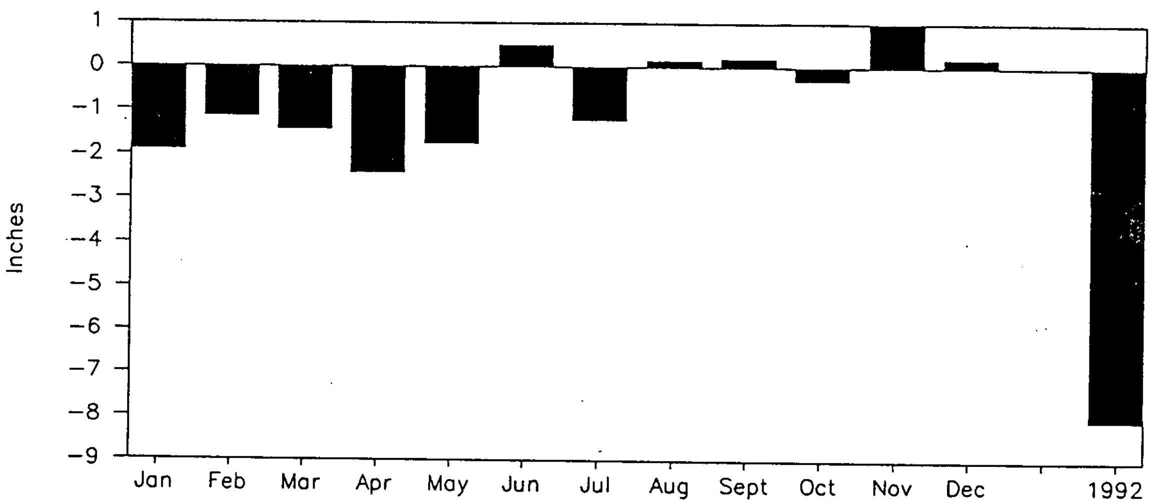

FIGURE 2b. Precipitation Departures From 1890–1990 Average (Inches) For The Tennessee River Basin.

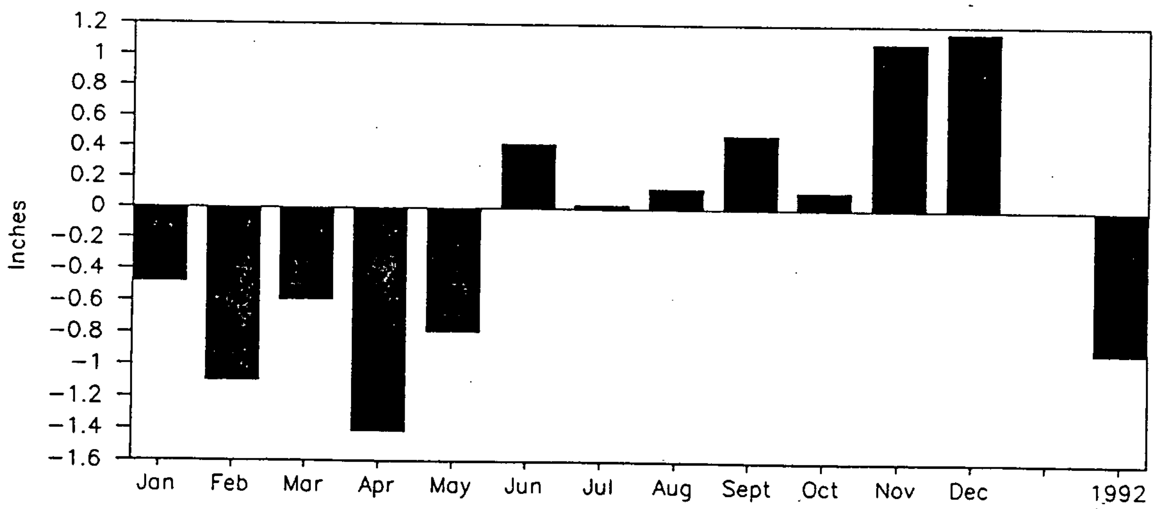

FIGURE 2c. Runoff Departures From 1890–1990 Average (Inches) For Tennessee River Basin, Above Kentucky Dam.

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forebay, but pHs did not exceed 7.8 at the transition zone. There was about a 23 percent decrease in average nitrite plus nitrate concentrations from 0.31 mg/l at the transition zone to 0.24 mg/l at the forebay (along with corresponding increases in organic nitrogen and organic carbon) suggesting the photosynthetic uptake of nutrients and primary production processes occurring in the lower end of Guntersville Reservoir.

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

Nickajack Reservoir

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

The riverine character of Nickajack Reservoir, with an average hydraulic residence time of only three to four days (table 3.1), results in it being the best mixed of any of the Vital Signs reservoirs. Temperature and DO data reflect a lack of stratification in Nickajack reservoir in 1992, with the exception that in April, during low flow conditions on the Tennessee River, a maximum temperature differential (surface to bottom) of 3.8°C was measured at the forebay. During the same month, the maximum DO differential was 2.8 mg/l. In all other months the reservoir was well mixed. The minimum DO measured in Nickajack Reservoir in 1992 was 5.0 mg/l, at the bottom of the forebay, in July. DOs of 2.7, 3.8, and 4.5 mg/l were measured in the releases of water from Chickamauga Dam in July and August.

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

Chickamauga Reservoir

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

Like many other mainstem Tennessee River reservoirs, Chickamauga is generally well mixed and lacks any strong thermal stratification. However, the low flows of the Tennessee River system in April and early May facilitated the development of a weak thermocline and oxycline in these months at both the forebay and transition zone sampling locations, in 1992. Maximum temperature differentials (surface to bottom) of 4.5°C and 3.0°C were observed at the forebay, in April and May, respectively. At the transition zone, in April and May, maximum temperature differentials of 2.4°C and 3.0°C, respectively, were measured. During these same two months, oxygen differentials of 3.2 mg/l and 5.8 mg/l, respectively, were measured at the forebay; and, 3.3 mg/l and 4.7 mg/l, respectively, were measured at the transition zone. (The larger oxygen differentials measured in May were a result high DOs at the water surface during a period of high photosynthetic activity.) Minimum DOs measured in Chickamauga Reservoir in 1992 were 2.8 mg/l and 3.5 mg/l, at the bottom of the forebay and the transition zone, respectively, in July.

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

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

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

Watts Bar Reservoir

Surface water temperatures ranged from 6.0°C in January to 27.3°C in July in the forebay and from 6.2°C to 26.3°C for these same months at the transition zone. Values for DO at the 1.5-meter depth ranged from 11.6 mg/l in January (as well as 11.6 mg/l in April due to high photosynthetic activity) to 6.3 mg/l in September at the forebay; and, from 11.4 mg/l in January to 5.8 mg/l in September at the transition zone. The minimum observed DO concentration in Watts Bar Reservoir in 1992 was 0.6 mg/l at the bottom of the forebay in July.

Temperature and dissolved oxygen data show that during the summer of 1992, Watts Bar Reservoir developed a moderate degree of both thermal and oxygen stratification in the forebay. Surface to bottom temperature differentials (ΔT's) were 7.0°C in April (during the period of low flows) and exceeded 6°C in May and June. DO versus depth data showed a rather strong oxycline to develop in the forebay of Watts Bar Reservoir from May through August. During these four months surface to bottom differences in DO were consistently greater than 7.0 mg/l, and near bottom DO concentrations in the hypolimnion were less than 1 mg/l in July. The transition zone was much more well mixed during the summer of 1992. Maximum ΔT's were 4.1°C (in April) and the minimum bottom DO measured was 5.5 mg/l (in September).

Values of pH ranged from 6.7 to 9.1 on Watts Bar Reservoir. Through out the summer (April-August) near surface values of pH in the forebay were often high, exceeding 8.5, with DO saturation values commonly exceeding 100 percent, indicating high rates of photosynthesis.

The average total phosphorus concentrations observed in Watts Bar Reservoir (0.029 mg/l at the forebay and 0.033 mg/l at the transition zone) were among the lowest of the Tennessee River Vital Signs Monitoring locations. In addition, the average dissolved ortho phosphorus concentrations of 0.008 mg/l and 0.010 mg/l, respectively, at the forebay and transition zones were also among the lowest observed at any of the Tennessee River Vital Signs Monitoring locations in 1992.

The highest chlorophyll-a concentrations were measured in June at the forebay (14 ug/l) and in May at the transition zone (14 ug/l). Surface concentrations of chlorophyll-a averaged about 7 ug/l at the forebay and about 8 ug/l at the transition zone in 1992. The high TN/TP ratios observed at the transition zone indicate the possibility of phosphorus limitation on primary productivity.

Forebay Secchi depth and suspended solids measurements averaged 1.4 meters and 4.9 mg/l, respectively. These values indicate the light transparency of Watts Bar Reservoir forebay to be relatively high compared with other mainstem Tennessee River reservoirs in 1992.

Fort Loudoun Reservoir

Temperature and dissolved oxygen (DO) data show the establishment of stratification (both a thermocline and oxycline) in the forebay portion of the reservoir which persisted throughout most of the summer (April through August) of 1992. Surface water temperatures ranged from 6.6°C in January to 28.7°C in July at the forebay and from 6.1°C to 29.6°C for the same months at the transition zone. Maximum thermal stratification occurred in the forebay in June when surface to bottom temperature differentials (ΔT's) were 8.2°C, and in the transition zone in April when ΔT's of 9.9°C were observed.

In Fort Loudoun Reservoir in 1992, DO at the 1.5-meter depth ranged from 11.5 mg/l in August (algal bloom) to 5.3 mg/l in September at the forebay; and from 14.0 mg/l in January to 5.4 mg/l in September at the transition zone. The minimum DO observed in Fort Loudoun Reservoir in 1992 was 1.8 mg/l at the bottom of the forebay during August. Maximum surface to bottom dissolved oxygen differentials (ΔDO's) exceeded 7 mg/l each month, May through August, at the forebay. The transition zone was better mixed with ΔDO's exceeding 3 mg/l observed only in July, and a minimum bottom DO of 5.1 in August.

Values of pH ranged from 6.5 to 9.1. At the forebay, pH values exceeding 8.5, and DO saturation values exceeding 110 percent were measured from April through August giving evidence of substantial photosynthetic activity. During April, May, and July, a similar pattern of high pHs and high DO saturations was observed, although to a lesser extent, at the transition zone.

Conductivity ranged from 90 to 255 umhos/cm, averaging about

195 umhos/cm at the forebay and 215 umhos/cm at the transition zone. The slightly lower conductivities measured at the forebay area were caused by the mixing of the inflows from the Little Tennessee River, via the Tellico Reservoir canal with the higher conductivity water of the Tennessee River. For example, during summer, water from Tellico Reservoir is usually colder than the surface water of Fort Loudoun Reservoir causing it to flow under the warmer water of Fort Loudoun Reservoir. This was the case in September, 1992, when water surface conductivity was greater than 200 umhos/cm and near bottom conductivity was about 110 umhos/cm in the forebay of Fort Loudoun Reservoir. In the spring, the water from Tellico Reservoir may be warmer than the water of Fort Loudoun Reservoir and often flow across the top and "float" on the surface of the Fort Loudoun Reservoir. Such was the case in April 1992, when the Fort Loudoun forebay had surface conductivity less than 100 umhos/cm and near bottom conductivity near 200 umhos/cm. Other months (e.g., May, June, July, etc.) give evidence of partially mixed "lenses" of low conductivity water from Tellico Reservoir merging with the higher conductivity water from Fort Loudoun Reservoir forebay at one or more depths.

Nutrient concentrations (total nitrogen and total phosphorus) were high at both the forebay and the transition zone. The average nitrite plus nitrate nitrogen concentrations of 0.55 mg/l (forebay) and 0.41 mg/l (transition zone) were the highest average concentrations of this nutrient measured in 1992 at any of the Tennessee River Vital Signs Monitoring locations. These high concentrations of nitrogen are due to a combined effect of the wastewater discharges in the Knoxville metropolitan area and the inflows to Fort Loudoun Reservoir from the Holston and French Broad rivers, which also have relatively high nitrogen concentrations.

The highest chlorophyll-a concentrations in the forebay occurred in May (17 ug/l) and June (18 ug/l) and in the transition zone in April (18 ug/l). Surface concentrations of chlorophyll-a averaged about 11 ug/l and 8 ug/l, at the forebay

TABLE 8

Guntersville Forebay

Variable	N	Mean	Min	Max
Temperature (C)	73	21.589	6.930	28.300
Dissolved Oxygen (mg/l)	73	7.371	2.930	10.710
Percent Saturation	73	80.718	37.089	115.976
pH (s.u.)	73	7.509	6.840	8.350
Conductivity (umhos/cm)	73	165.194	147.000	186.000
Organic - N (mg/l)	18	0.304	0.110	0.620
Ammonia - N (mg/l)	18	0.051	0.020	0.090
Nitrate+Nitrite - N (mg/l)	18	0.243	0.090	0.540
Total Nitrogen (mg/l)	18	0.598	0.330	0.880
Total Phosphorus (mg/l)	18	0.032	0.030	0.040
Dissoved Ortho - P (mg/l)	18	0.015	0.003	0.030
TN/TP Ratio	18	19.196	8.250	29.333
Total Organic Carbon (mg/l)	18	2.629	1.900	4.300
Chlorophyll-a (ug/l)	9	5.714	1.000	12.000
Secchi depth (m)	7	1.843	1.500	2.250
Suspended Solids (mg/l)	18	3.571	1.000	7.000
True Color (PCU)	18	10.000	5.000	15.000
Fecal Coliform (#/100 ml)	7	10.000	10.000	10.000

Guntersville Transition

Variable	N	Mean	Min	Max
Temperature (C)	53	22.603	7.260	28.530
Dissolved Oxygen (mg/l)	53	7.120	5.410	10.660
Percent Saturation	53	79.321	67.500	101.111
pH (s.u.)	45	7.548	7.200	7.830
Conductivity (umhos/cm)	53	176.865	157.000	194.000
Organic - N (mg/l)	14	0.238	0.080	0.370
Ammonia - N (mg/l)	14	0.050	0.020	0.130
Nitrate+Nitrite - N (mg/l)	13	0.312	0.170	0.540
Total Nitrogen (mg/l)	13	0.595	0.360	0.920
Total Phosphorus (mg/l)	14	0.033	0.020	0.040
Dissoved Ortho - P (mg/l)	14	0.019	0.005	0.030
TN/TP Ratio	13	18.570	9.000	26.300
Total Organic Carbon (mg/l)	14	2.507	1.900	3.500
Chlorophyll-a (ug/l)	7	3.571	1.000	9.000
Secchi depth (m)	7	1.571	1.000	2.000
Suspended Solids (mg/l)	14	4.214	1.000	8.000
True Color (PCU)	14	10.000	5.000	15.000
Fecal Coliform (#/100 ml)	7	10.000	10.000	10.000

Nickajack Forebay (TRM 425.5)

Variable	N	Mean	Min	Max
Temperature (C)	85	20.618	6.700	27.700
Dissolved Oxygen (mg/l)	85	7.169	5.000	11.500
Percent Saturation	85	76.312	62.069	108.421
pH (s.u.)	85	7.436	7.100	8.200
Conductivity (umhos/cm)	85	174.303	158.000	191.000
Organic - N (mg/l)	36	0.200	0.070	0.490
Ammonia - N (mg/l)	36	0.060	0.010	0.140
Nitrate+Nitrite - N (mg/l)	36	0.312	0.150	0.520
Total Nitrogen (mg/l)	36	0.573	0.360	0.850
Total Phosphorus (mg/l)	36	0.033	0.020	0.050
Dissoved Ortho - P (mg/l)	36	0.020	0.006	0.040
TN/TP Ratio	36	17.928	11.750	25.667
Total Organic Carbon (mg/l)	36	2.104	1.800	2.300
Chlorophyll-a (ug/l)	18	4.071	1.000	11.000
Secchi depth (m)	7	1.383	1.210	1.600
Suspended Solids (mg/l)	36	4.143	2.000	7.000
True Color (PCU)	36	10.893	5.000	15.000
Fecal Coliform (#/100 ml)	7	10.000	10.000	10.000

TABLE 9

Chickamauga Forebay (472.3)

Variable	N	Mean	Min	Max
Temperature (C)	81	20.680	6.800	28.000
Dissolved Oxygen (mg/l)	81	7.057	2.800	11.500
Percent Saturation	81	75.224	34.146	126.667
pH (s.u.)	81	7.470	7.000	8.600
Conductivity (umhos/cm)	81	171.148	155.000	194.000
Organic - N (mg/l)	18	0.225	0.080	0.520
Ammonia - N (mg/l)	18	0.053	0.010	0.100
Nitrate+Nitrite - N (mg/l)	18	0.251	0.100	0.520
Total Nitrogen (mg/l)	18	0.529	0.230	0.740
Total Phosphorus (mg/l)	18	0.028	0.020	0.060
Dissoved Ortho - P (mg/l)	18	0.009	0.002	0.020
TN/TP Ratio	18	20.904	7.000	33.000
Total Organic Carbon (mg/l)	18	2.121	1.800	2.300
Chlorophyll-a (ug/l)	7	5.167	1.000	12.000
Secchi depth (m)	6	1.348	1.130	1.500
Suspended Solids (mg/l)	18	4.429	2.000	7.000
True Color (PCU)	18	11.071	10.000	15.000
Fecal Coliform (#/100 ml)	7	10.000	10.000	10.000

Chickamauga Transition (TRM 490.47)

Variable	N	Mean	Min	Max
Temperature (C)	51	19.071	6.100	25.300
Dissolved Oxygen (mg/l)	51	7.474	4.500	11.700
Percent Saturation	51	77.881	52.941	117.021
pH (s.u.)	51	7.566	7.300	8.400
Conductivity (umhos/cm)	51	166.890	155.000	190.000
Organic - N (mg/l)	12	0.265	0.100	0.430
Ammonia - N (mg/l)	12	0.060	0.020	0.090
Nitrate+Nitrite - N (mg/l)	12	0.285	0.150	0.520
Total Nitrogen (mg/l)	12	0.610	0.330	0.760
Total Phosphorus (mg/l)	12	0.035	0.020	0.050
Dissoved Ortho - P (mg/l)	12	0.011	0.002	0.020
TN/TP Ratio	12	18.704	8.250	28.500
Total Organic Carbon (mg/l)	12	2.133	1.800	2.500
Chlorophyll-a (ug/l)	5	4.000	2.000	7.000
Secchi depth (m)	6	1.283	1.210	1.470
Suspended Solids (mg/l)	12	5.250	3.000	8.000
True Color (PCU)	12	10.417	5.000	15.000
Fecal Coliform (#/100 ml)	6	10.000	10.000	10.000

Watts Bar Forebay (TRM 531)

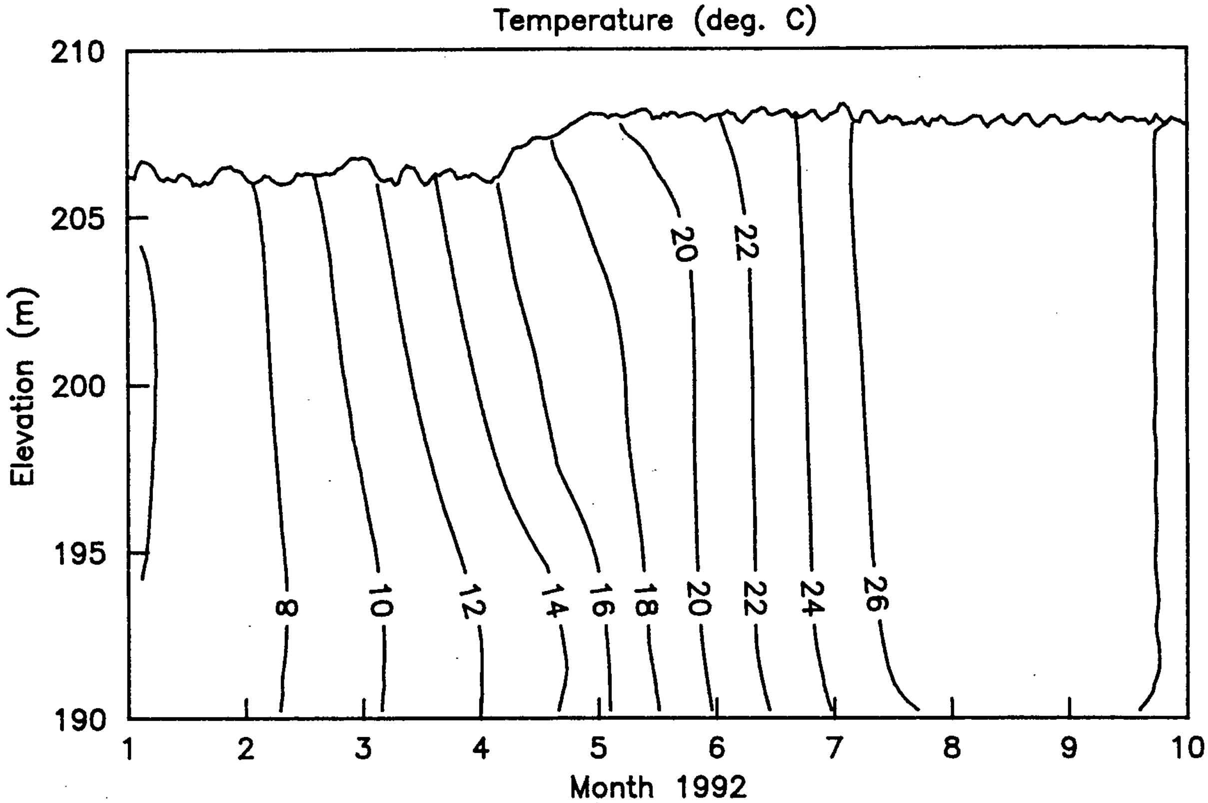
Variable	N	Mean	Min	Max
Temperature (C)	124	19.307	6.000	27.300
Dissolved Oxygen (mg/l)	124	6.856	0.600	11.800
Percent Saturation	124	71.527	6.897	142.683
pH (s.u.)	124	7.685	6.700	9.100
Conductivity (umhos/cm)	124	172.769	137.000	200.000
Organic - N (mg/l)	18	0.307	0.100	0.630
Ammonia - N (mg/l)	18	0.025	0.010	0.060
Nitrate+Nitrite - N (mg/l)	18	0.281	0.100	0.570
Total Nitrogen (mg/l)	18	0.613	0.370	0.780
Total Phosphorus (mg/l)	18	0.029	0.020	0.040
Dissoved Ortho - P (mg/l)	18	0.008	0.002	0.030
TN/TP Ratio	18	21.440	14.666	38.000
Total Organic Carbon (mg/l)	18	2.100	1.700	2.800
Chlorophyll-a (ug/l)	9	7.286	4.000	14.000
Secchi depth (m)	7	1.393	1.100	1.770
Suspended Solids (mg/l)	16	4.917	3.000	10.000
True Color (PCU)	16	11.250	5.000	15.000
Fecal Coliform (#/100 ml)	7	10.000	10.000	10.000

Watts Bar Transition (TRM 560.8)

Variable	N	Mean	Min	Max
Temperature (C)	68	19.478	6.100	26.300
Dissolved Oxygen (mg/l)	68	8.354	5.500	11.500
Percent Saturation	68	88.222	63.218	125.000
pH (s.u.)	68	7.810	7.400	8.700
Conductivity (umhos/cm)	68	187.276	150.000	213.000
Organic - N (mg/l)	14	0.312	0.170	0.600
Ammonia - N (mg/l)	14	0.033	0.010	0.090
Nitrate+Nitrite - N (mg/l)	14	0.354	0.180	0.720
Total Nitrogen (mg/l)	14	0.699	0.540	0.940
Total Phosphorus (mg/l)	14	0.033	0.002	0.050
Dissoved Ortho - P (mg/l)	14	0.010	0.002	0.020
TN/TP Ratio	14	43.198	12.600	325.000
Total Organic Carbon (mg/l)	14	2.114	1.900	2.300
Chlorophyll-a (ug/l)	7	7.857	4.000	14.000
Secchi depth (m)	7	1.103	0.800	1.270
Suspended Solids (mg/l)	12	9.083	4.000	17.000
True Color (PCU)	12	10.833	5.000	15.000
Fecal Coliform (#/100 ml)	7	10.000	10.000	10.000

FIGURE 13

CHICKAMAUGA RESERVOIR – TRM 472.3



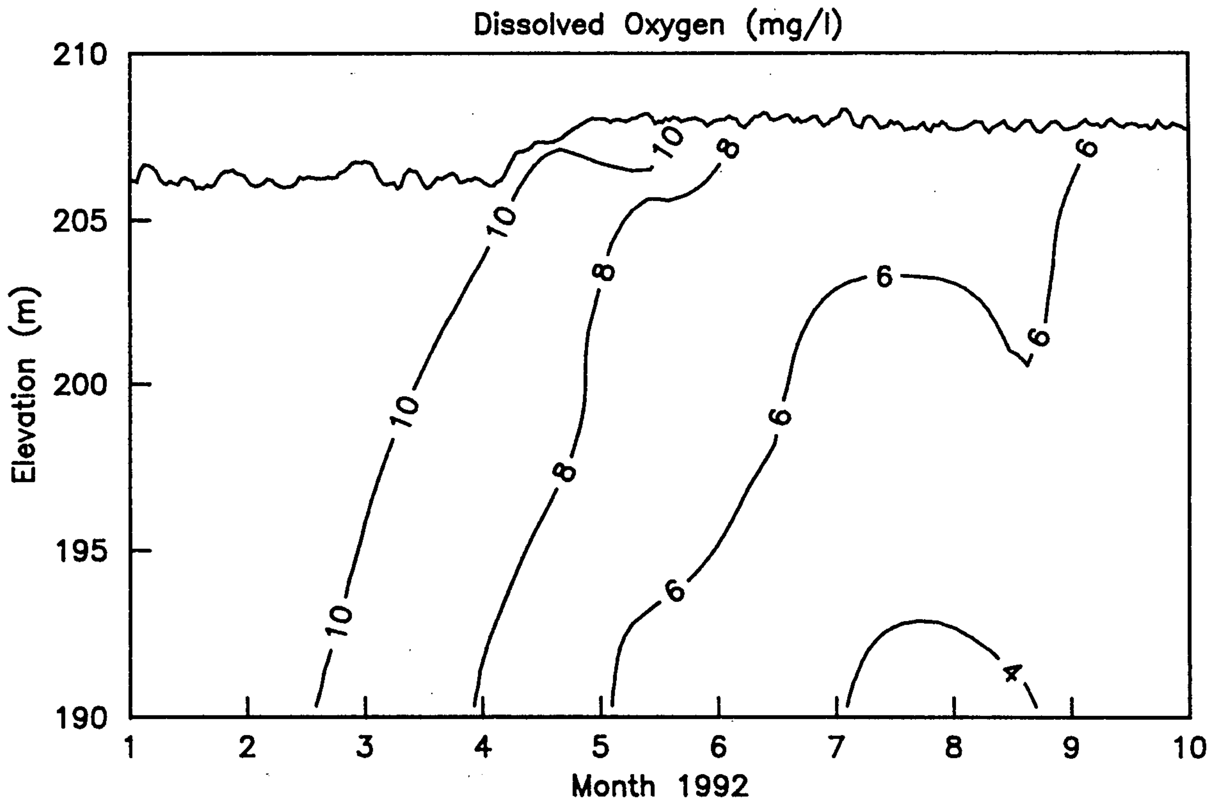


FIGURE 14

CHICKAMAUGA RESERVOIR – TRM 490.5

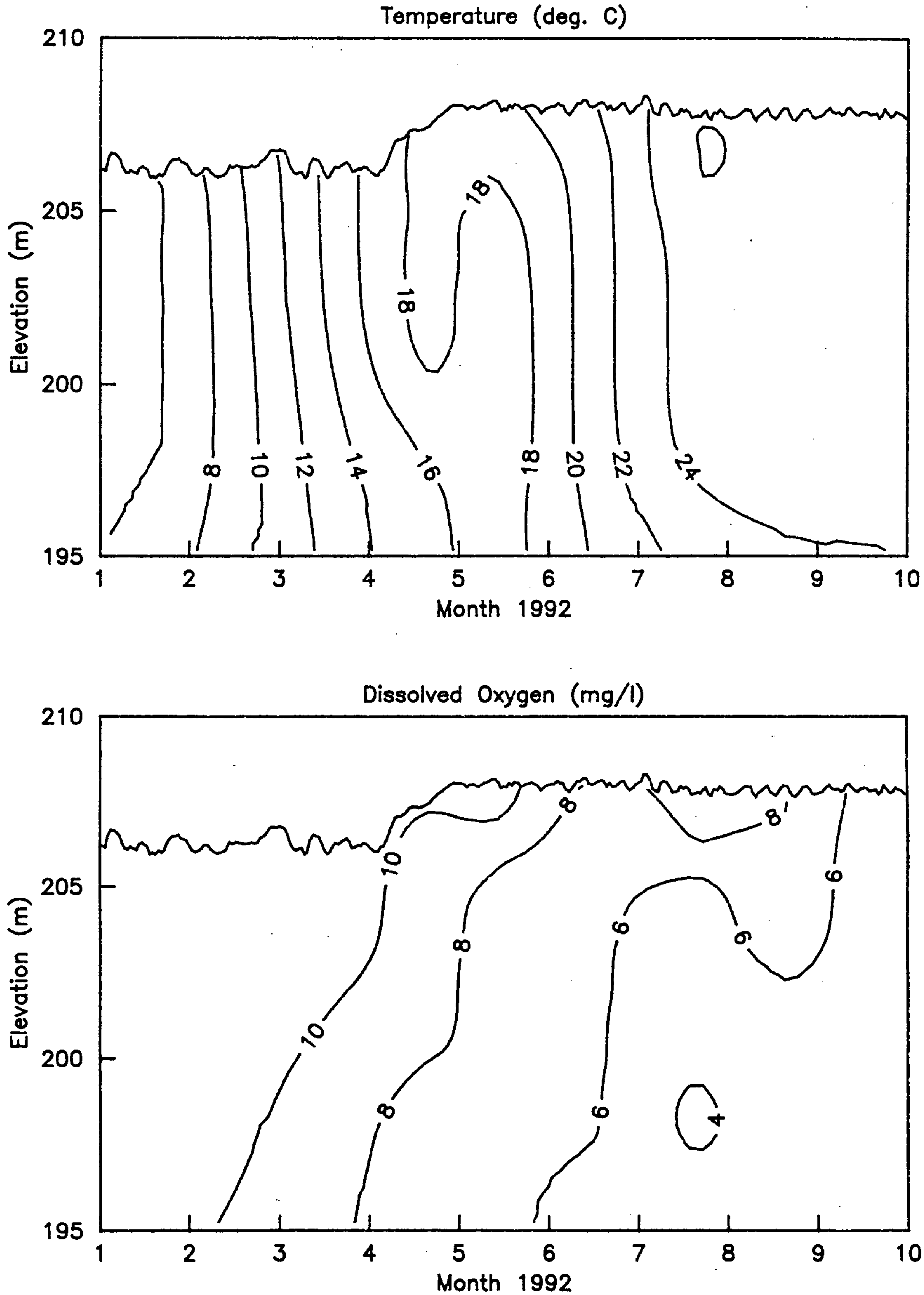
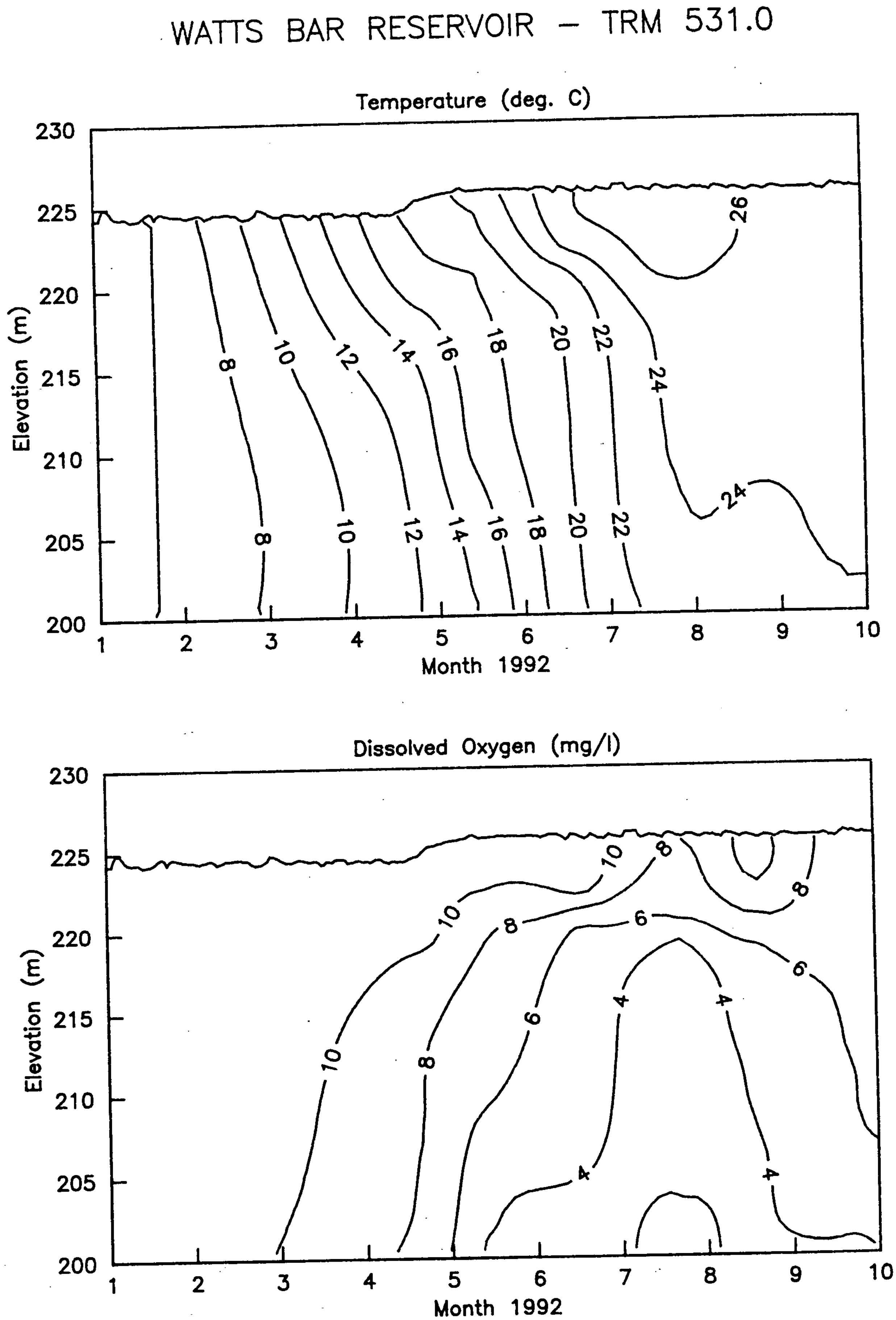


FIGURE 15



WATTS BAR RESERVOIR – TRM 531.0
Temperature (deg. C)
Elevation (m)
Month 1992
Dissolved Oxygen (mg/l)
Elevation (m)
Month 1992

FIGURE 16

WATTS BAR RESERVOIR – TRM 560.8

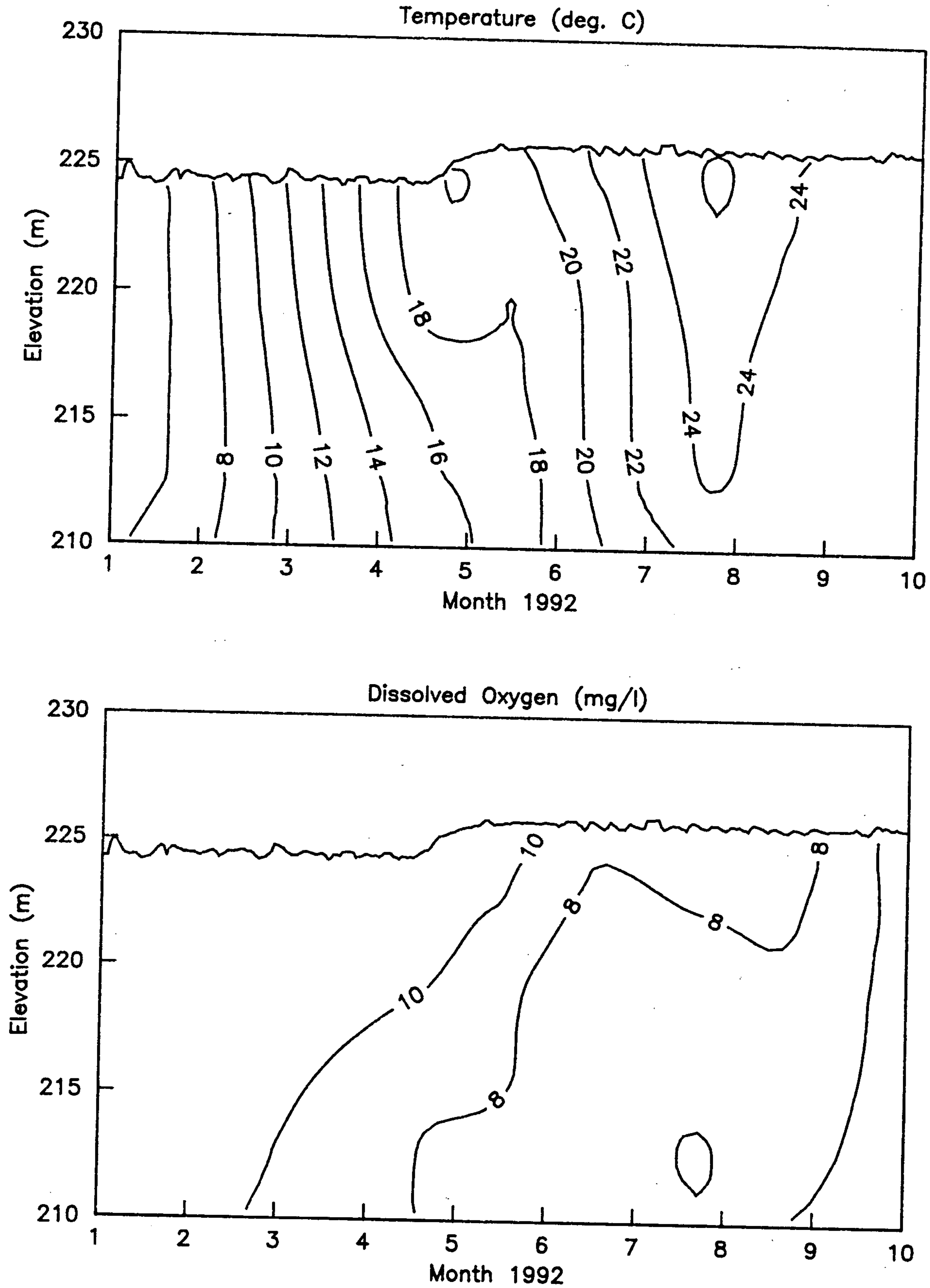
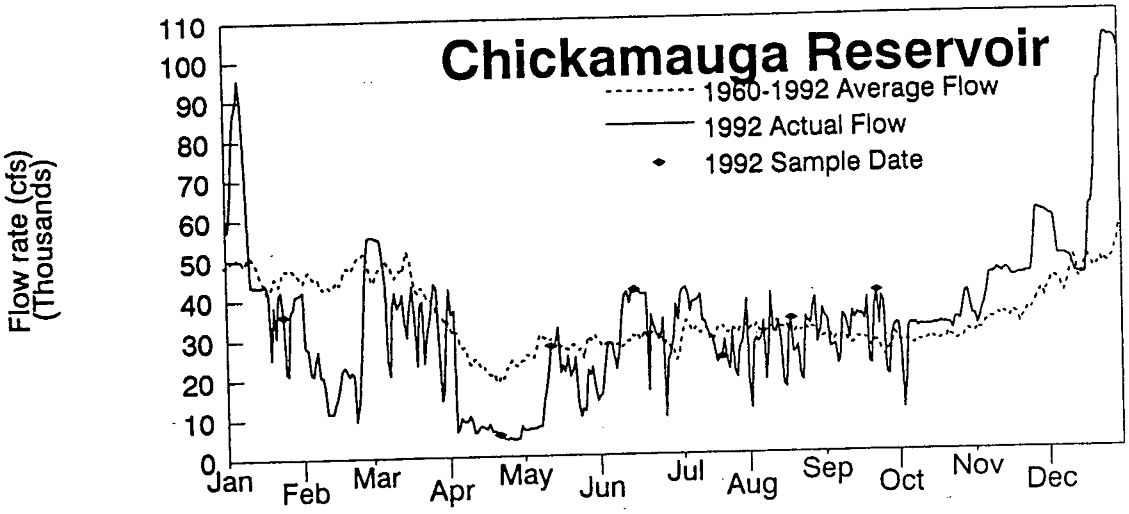
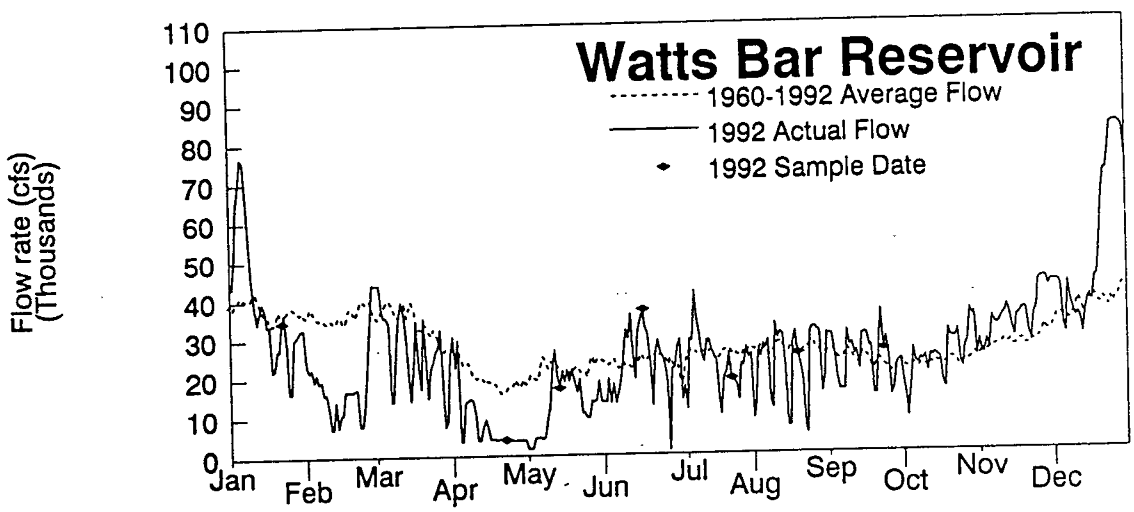


FIGURE 51


Chickamauga Reservoir
1960-1992 Average Flow
1992 Actual Flow
1992 Sample Date
Flow rate (cfs) (Thousands)
110
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Watts Bar Reservoir
1960-1992 Average Flow
1992 Actual Flow
1992 Sample Date
Flow rate (cfs) (Thousands)
110
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

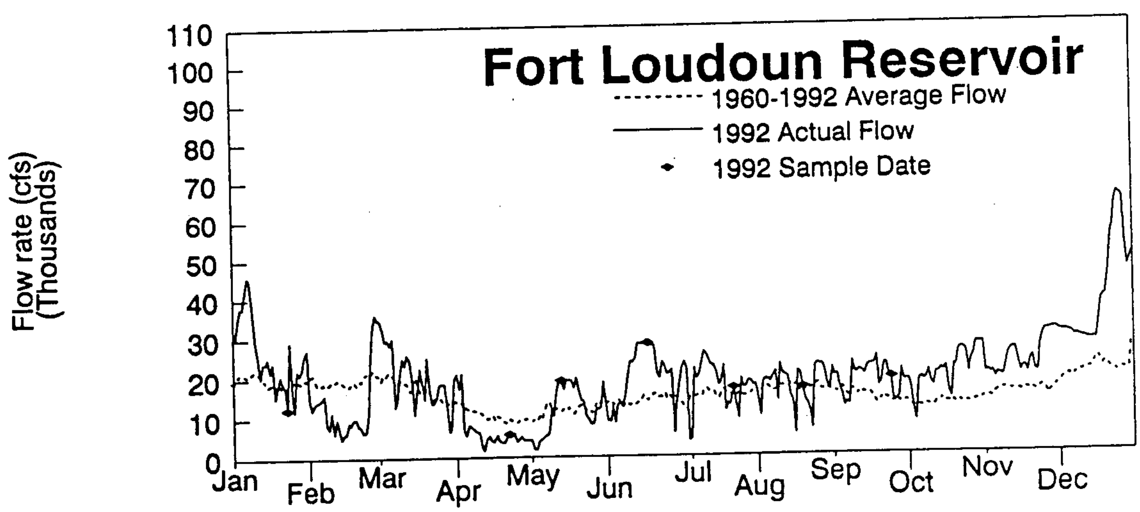
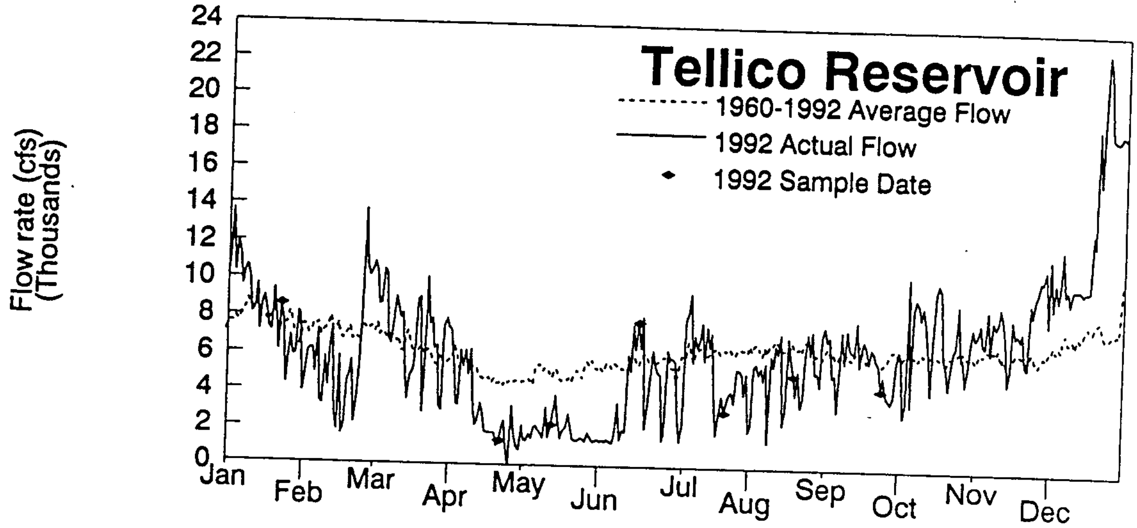
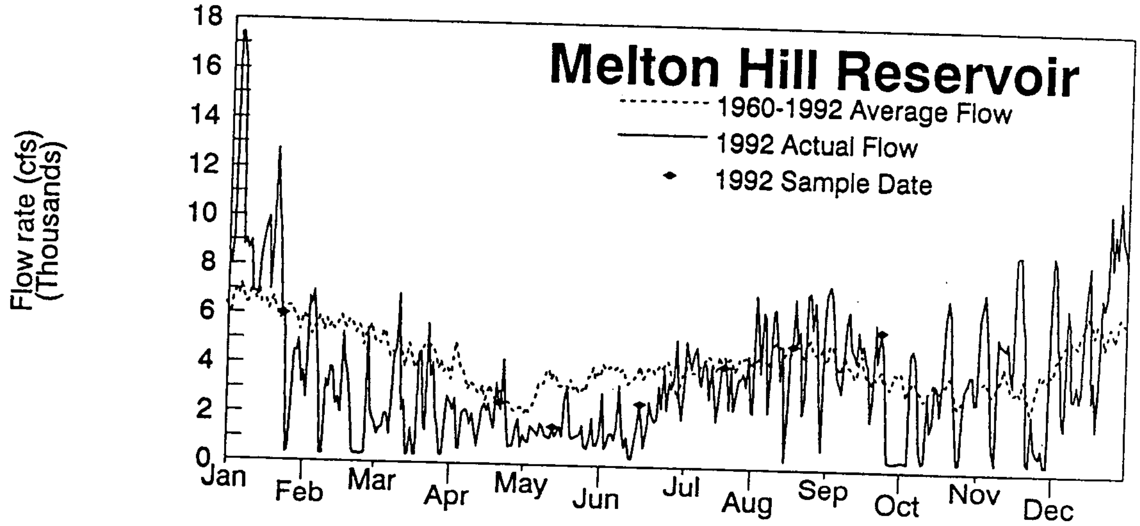

Fort Loudoun Reservoir
1960-1992 Average Flow
1992 Actual Flow
1992 Sample Date
Flow rate (cfs) (Thousands)
110
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

FIGURE 52


Tellico Reservoir
1960-1992 Average Flow
1992 Actual Flow
1992 Sample Date
Flow rate (cfs) (Thousands)
0
2
4
6
8
10
12
14
16
18
20
22
24
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Melton Hill Reservoir
1960-1992 Average Flow
1992 Actual Flow
1992 Sample Date
Flow rate (cfs) (Thousands)
0
2
4
6
8
10
12
14
16
18
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

STORET RETRIEVAL DATE 93/01/12 PGM=RET

475358 1017
35 06 26.0 085 12 20.0 2
CHICKAMAUGA RES. AT LIGHTED BUOY
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 472.3
131TVAC 06020001021 0000.710 ON
0000 METERS DEPTH

/TYPA/AMBNT/STREAM/SOLIDS

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
92/01/24	0959	WATER	0.5	36108	6.8	11.5	94.3$	7.50	168
92/01/24	1000	WATER	1		6.8	11.5	94.3$	7.50	168
92/01/24	1001	WATER	1.5		6.8	11.4	93.4$	7.50	169
92/01/24	1002	WATER	4		6.8	11.4	93.4$	7.50	168
92/01/24	1004	WATER	6		6.8	11.3	92.6$	7.50	169
92/01/24	1005	WATER	8		6.8	11.3	92.6$	7.50	167
92/01/24	1006	WATER	10		6.8	11.3	92.6$	7.40	168
92/01/24	1007	WATER	12		6.8	11.3	92.6$	7.40	168
92/01/24	1008	WATER	13		6.8	11.2	91.8$	7.40	167
92/01/24	1009	WATER	14		6.8	11.3	92.6$	7.40	168
92/01/24	1010	WATER	15		6.8	11.2	91.8$	7.40	168
92/04/21	1035	WATER	0.5	5421	18.2	9.9	104.2$	7.90	160
92/04/21	1037	WATER	1		18.0	9.7	102.1$	7.90	160
92/04/21	1039	WATER	1.5		17.7	9.6	101.1$	7.80	160
92/04/21	1041	WATER	4		17.5	9.3	95.9$	7.80	160
92/04/21	1045	WATER	6		16.8	8.5	87.6$	7.70	160
92/04/21	1047	WATER	8		16.5	8.5	85.0$	7.60	158
92/04/21	1049	WATER	10		16.1	8.1	81.0$	7.50	159
92/04/21	1051	WATER	12		15.0	7.6	74.5$	7.40	159
92/04/21	1053	WATER	13		14.3	7.3	70.2$	7.30	158
92/04/21	1055	WATER	14		14.1	7.3	70.2$	7.40	156
92/04/21	1057	WATER	16		13.7	6.7	64.4$	7.30	155
92/05/12	1058	WATER	0.5	21454	20.8	11.4	126.7$	8.60	166
92/05/12	1102	WATER	1		20.0	10.5	114.1$	8.40	167
92/05/12	1104	WATER	1.5		19.8	10.3	112.0$	8.30	167
92/05/12	1106	WATER	2		19.7	9.9	107.6$	8.20	167
92/05/12	1108	WATER	2.5		19.2	7.9	84.0$	7.80	165
92/05/12	1110	WATER	4		18.6	7.0	74.5$	7.60	166
92/05/12	1118	WATER	6		18.5	6.7	70.5$	7.50	166
92/05/12	1120	WATER	8		18.4	6.8	71.6$	7.50	167
92/05/12	1122	WATER	10		18.4	6.7	70.5$	7.40	166
92/05/12	1124	WATER	12		18.2	6.5	68.4$	7.40	166
92/05/12	1126	WATER	13.6		18.0	6.4	67.4$	7.30	166
92/05/12	1132	WATER	14		18.0	6.4	67.4$	7.40	165
92/05/12	1134	WATER	16		17.8	5.6	58.9$	7.30	165
92/06/15	1131	WATER	0.3	41238	23.2	7.0	80.5$	7.60	174
92/06/15	1133	WATER	1		23.0	6.9	79.3$	7.50	174
92/06/15	1135	WATER	1.5		23.0	6.7	77.0$	7.50	174
92/06/15	1137	WATER	4		22.8	6.4	73.6$	7.50	173
92/06/15	1141	WATER	6		22.8	6.2	71.3$	7.40	174
92/06/15	1143	WATER	8		22.7	6.1	70.1$	7.40	173
92/06/15	1145	WATER	10		22.7	6.0	69.0$	7.40	173
92/06/15	1147	WATER	12		22.6	5.8	66.7$	7.40	173
92/06/15	1149	WATER	14		22.6	5.7	65.5$	7.40	174
92/06/15	1151	WATER	14.2		22.6	5.6	64.4$	7.30	174
92/06/15	1153	WATER	16		22.6	5.6	64.4$	7.30	174
92/07/21	1108	WATER	0.5	24342	28.0	7.6	96.2$	7.90	165
92/07/21	1110	WATER	1		27.9	7.3	92.4$	7.80	165
92/07/21	1112	WATER	1.5		27.8	7.0	88.6$	7.70	165
92/07/21	1114	WATER	4		27.7	6.3	79.7$	7.50	165
92/07/21	1118	WATER	5.5		27.4	5.4	66.7$	7.30	166
92/07/21	1120	WATER	6		27.3	5.3	65.4$	7.30	165
92/07/21	1122	WATER	8		27.3	5.3	65.4$	7.30	165
92/07/21	1124	WATER	10		27.1	4.9	60.5$	7.20	166
92/07/21	1126	WATER	12		27.0	4.8	59.3$	7.20	165
92/07/21	1128	WATER	14		26.8	4.5	55.6$	7.10	165
92/07/21	1130	WATER	15.5		26.6	3.6	44.4$	7.00	166
92/07/21	1132	WATER	16		26.6	3.3	40.7$	7.00	166
92/07/21	1134	WATER	16.5		26.5	2.8	34.1$	7.00	167
92/08/18	1107	WATER	0.5	33592	27.2	6.7	82.7$	7.60	193
92/08/18	1110	WATER	1		27.1	6.5	80.2$	7.60	194
92/08/18	1113	WATER	1.5		27.1	6.3	77.8$	7.60	194
92/08/18	1116	WATER	4		27.1	6.2	76.5$	7.50	193
92/08/18	1122	WATER	6		27.1	6.1	75.3$	7.50	193
92/08/18	1125	WATER	8		27.1	6.0	74.1$	7.50	193
92/08/18	1128	WATER	10		27.1	5.7	70.4$	7.40	193
92/08/18	1131	WATER	12		27.0	5.5	67.9$	7.40	192
92/08/18	1134	WATER	13.5		26.7	5.1	63.0$	7.30	191
92/08/18	1137	WATER	14		26.7	5.1	63.0$	7.30	190
92/08/18	1140	WATER	16		26.5	4.1	50.0$	7.20	190
92/09/22	1034	WATER	0.5	40142	26.0	5.4	65.9$	7.50	176
92/09/22	1035	WATER	1		26.0	5.4	65.9$	7.50	176
92/09/22	1036	WATER	1.5		26.0	5.4	65.9$	7.50	177
92/09/22	1037	WATER	3		26.0	5.3	64.6$	7.50	176
92/09/22	1039	WATER	5		26.0	5.3	64.6$	7.40	176
92/09/22	1040	WATER	7		26.0	5.2	63.4$	7.40	175
92/09/22	1041	WATER	9		26.0	5.1	62.2$	7.40	173
92/09/22	1042	WATER	11		26.0	5.1	62.2$	7.40	174
92/09/22	1043	WATER	13		26.0	5.1	62.2$	7.40	177
92/09/22	1044	WATER	15		26.0	5.0	61.0$	7.30	177
92/09/22	1045	WATER	17		26.0	4.9	59.8$	7.30	177

STORET RETRIEVAL DATE 93/01/12 PGM=RET

/TYPA/AMBNT/STREAM/SOLIDS

475358 1017
35 06 26.0 085 12 20.0 2
CHICKAMAUGA RES. AT LIGHTED BUOY
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 472.3
131TVAC 06020001021 0000.710 ON
0000 METERS DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
92/01/24	0959	WATER	0.5		1.50	10K					
92/01/24	1003	VERT	4				10	3	.180	.040	.51
92/01/24	1008	WATER	13				10	2	.180	.040	.52
92/04/21	1035	WATER	0.5			10K					
92/04/21	1043	VERT	4				10	4	.180	.040	.28
92/04/21	1053	WATER	13				10	4	.190	.090	.34
92/05/12	1058	WATER	0.5		1.47	10K					
92/05/12	1112	VERT	4	D1			15	5	.100	.030	.10
92/05/12	1114	VERT	4	D2			15	5	.370	.020	.11
92/05/12	1116	VERT	4	D3			10	5	.520	.030	.11
92/05/12	1126	WATER	13.6	D1			10	3	.170	.090	.15
92/05/12	1128	WATER	13.6	D2			10	4	.230	.090	.14
92/05/12	1130	WATER	13.6	D3			10	4	.180	.100	.15
92/06/15	1131	WATER	0.3		1.13	10					
92/06/15	1139	VERT	4				10	4	.080	.060	.27
92/06/15	1151	WATER	14.2				10	4	.360	.070	.27
92/07/21	1108	WATER	0.5		1.37	10K					
92/07/21	1116	VERT	4				10	6	.330	.030	.20
92/07/21	1128	WATER	14				10	6	.250	.060	.24
92/08/18	1107	WATER	0.5		1.36	10K					
92/08/18	1119	VERT	4				10	5	.280	.010	.19
92/08/18	1134	WATER	13.5				10	3	.150	.050	.22
92/09/22	1034	WATER	0.5		1.26	10K					
92/09/22	1038	VERT	4				15	5	.180	.060	.11
92/09/22	1044	WATER	15				15	7	.240	.070	.11

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
92/01/24	1003	VERT	4		.030	.020	1.8	1.00	1.00K	1.00K	1.00
92/01/24	1008	WATER	13		.030	.020	1.8				
92/04/21	1043	VERT	4		.020	.009	2.0				
92/04/21	1053	WATER	13		.020	.010	2.0				
92/05/12	1112	VERT	4	D1	.020	.003	2.3	10.00	1.00K	1.00	1.00K
92/05/12	1114	VERT	4	D2	.020	.003	2.3	12.00	1.00	1.00	1.00K
92/05/12	1116	VERT	4	D3	.020	.003	2.3				
92/05/12	1126	WATER	13.6	D1	.020	.005	2.2				
92/05/12	1128	WATER	13.6	D2	.020	.005	2.1				
92/05/12	1130	WATER	13.6	D3	.020	.005	2.1				
92/06/15	1139	VERT	4		.030	.010	2.3	5.00	1.00K	1.00K	1.00K
92/06/15	1151	WATER	14.2		.030	.010	2.2				
92/07/21	1116	VERT	4		.020	.005	2.2	6.00	1.00	1.00	3.00
92/07/21	1128	WATER	14		.020	.009	2.1				
92/08/18	1119	VERT	4		.030	.002	2.3	4.00	1.00K	1.00K	1.00
92/08/18	1134	WATER	13.5		.030	.006	2.2				
92/09/22	1038	VERT	4		.030	.009	2.1	4.00	1.00	1.00	2.00
92/09/22	1044	WATER	15		.060	.010	2.3				

STORET RETRIEVAL DATE 93/01/12 PGM=RET

/TYPA/AMBNT/STREAM/SOLIDS

475265 1053
35 18 00.0 085 04 33.0 2
CHICKAMAUGA RESERVOIR
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 490.47
131TVAC 06020001025 0005.740 ON
0000 METERS DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
92/01/24	0856	WATER	0.5		6.1	11.7	93.6$	7.60	170
92/01/24	0857	WATER	1		6.1	11.6	92.8$	7.60	170
92/01/24	0858	WATER	1.5		6.1	11.5	92.0$	7.60	170
92/01/24	0859	WATER	4		6.1	11.5	92.0$	7.50	170
92/01/24	0901	WATER	6		6.1	11.4	91.2$	7.50	170
92/01/24	0902	WATER	8		6.1	11.4	91.2$	7.50	170
92/04/22	0925	WATER	0.5		18.7	9.9	105.3$	8.00	166
92/04/22	0926	WATER	1		18.8	9.6	102.1$	8.00	165
92/04/22	0927	WATER	1.5		18.8	9.4	100.0$	8.00	166
92/04/22	0928	WATER	4		18.8	9.3	98.9$	7.90	165
92/04/22	0930	WATER	6		18.7	9.0	95.7$	7.90	165
92/04/22	0931	WATER	7		18.2	8.9	93.7$	7.70	164
92/04/22	0932	WATER	7.5		17.9	8.1	85.3$	7.70	164
92/04/22	0933	WATER	8		17.0	7.5	77.3$	7.60	162
92/04/22	0934	WATER	9		16.4	6.9	69.0$	7.40	162
92/04/22	0935	WATER	9.5		16.3	6.6	66.0$	7.50	161
92/05/12	0930	WATER	0.5		19.5	11.0	117.0$	8.40	163
92/05/12	0935	WATER	1		19.3	10.5	111.7$	8.30	163
92/05/12	0940	WATER	1.5		18.8	9.6	102.1$	8.00	160
92/05/12	0945	WATER	2		18.0	8.5	89.5$	7.70	157
92/05/12	0950	WATER	3		17.7	7.9	83.2$	7.60	157
92/05/12	0955	WATER	4		17.0	6.9	71.1$	7.50	156
92/05/12	1005	WATER	6		16.7	6.5	67.0$	7.50	155
92/05/12	1010	WATER	8		16.5	6.4	64.0$	7.40	158
92/05/12	1020	WATER	9.5		16.5	6.3	63.0$	7.40	158
92/05/12	1025	WATER	10		16.5	6.3	63.0$	7.40	158
92/06/15	1020	WATER	0.3		21.7	7.5	85.2$	7.60	161
92/06/15	1022	WATER	1		21.3	7.5	83.3$	7.50	160
92/06/15	1024	WATER	1.5		21.0	6.7	74.4$	7.50	159
92/06/15	1026	WATER	4		21.0	6.5	72.2$	7.40	159
92/06/15	1028	WATER	6		21.0	6.4	71.1$	7.40	158
92/06/15	1030	WATER	8		21.0	6.3	70.0$	7.40	159
92/06/15	1032	WATER	9.4		20.9	6.2	68.9$	7.40	159
92/06/15	1034	WATER	10		20.9	6.2	68.9$	7.40	158
92/07/21	0937	WATER	0.5		26.1	8.5	103.7$	8.30	165
92/07/21	0939	WATER	1		26.0	8.3	101.2$	8.20	165
92/07/21	0941	WATER	1.5		26.0	8.0	97.6$	8.10	164
92/07/21	0943	WATER	2		25.9	7.4	90.2$	7.90	164
92/07/21	0945	WATER	2.5		25.5	5.9	70.2$	7.40	164
92/07/21	0947	WATER	3		24.9	4.9	58.3$	7.20	163
92/07/21	0949	WATER	4		24.9	4.9	58.3$	7.20	163
92/07/21	0953	WATER	6		24.8	4.6	54.8$	7.20	164
92/07/21	0955	WATER	8		24.8	4.2	50.0$	7.20	163
92/07/21	0957	WATER	9		24.7	3.7	44.0$	7.10	163
92/07/21	0959	WATER	9.5		24.7	3.5	41.7$	7.10	163
92/08/18	1015	WATER	0.5		25.3	8.3	98.8$	8.00	189
92/08/18	1017	WATER	1		25.3	7.7	91.7$	7.80	190
92/08/18	1019	WATER	1.5		25.2	7.3	86.9$	7.70	189
92/08/18	1021	WATER	4		25.1	7.6	90.5$	7.70	186
92/08/18	1025	WATER	4.5		24.9	6.4	76.2$	7.50	183
92/08/18	1027	WATER	6		24.7	5.9	70.2$	7.40	179
92/08/18	1029	WATER	8		24.7	5.9	70.2$	7.40	178
92/08/18	1031	WATER	8.5		24.7	5.8	69.0$	7.40	178
92/08/18	1033	WATER	9		24.7	5.8	69.0$	7.40	178
92/09/22	0930	WATER	0.5		24.4	4.7	55.3$	7.40	174
92/09/22	0931	WATER	1		24.4	4.7	55.3$	7.40	174
92/09/22	0932	WATER	1.5		24.3	4.6	54.1$	7.30	173
92/09/22	0933	WATER	3		24.3	4.6	54.1$	7.30	173
92/09/22	0935	WATER	5		24.3	4.6	54.1$	7.30	173
92/09/22	0936	WATER	7		24.3	4.5	52.9$	7.30	172
92/09/22	0937	WATER	9		24.3	4.5	52.9$	7.30	172
92/09/22	0938	WATER	10		24.3	4.5	52.9$	7.30	171

STORET RETRIEVAL DATE 93/01/12 PGM=RET

/TYPA/AMBNT/STREAM/SOLIDS

475265 1053
35 18 00.0 085 04 33.0 2
CHICKAMAUGA RESERVOIR
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 490.47
131TVAC 06020001025 0005.740 ON
0000 METERS DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
92/01/24	0856	WATER	0.5		1.25	10K					
92/01/24	0900	VERT	4				10	3	.180	.040	.51
92/01/24	0902	WATER	8				5	3	.190	.030	.52
92/04/22	0925	WATER	0.5		1.27	10K					
92/04/22	0929	VERT	4				10	5	.210	.050	.26
92/04/22	0934	WATER	9				10	6	.210	.090	.35
92/05/12	0930	WATER	0.5		1.23	10K					
92/05/12	1000	VERT	4				10	5	.210	.040	.26
92/05/12	1020	WATER	9.5				5	5	.220	.080	.27
92/06/15	1020	WATER	0.3		1.21	10					
92/06/15	1030	VERT	4				15	7	.430	.060	.27
92/06/15	1032	WATER	9.4				10	5	.400	.070	.28
92/07/21	0937	WATER	0.5		1.80	10K					
92/07/21	0951	VERT	4				10	4	.260	.030	.28
92/07/21	0957	WATER	9				10	4	.170	.060	.30
92/08/18	1015	WATER	0.5		1.27	10K					
92/08/18	1023	VERT	4				10	4	.400	.020	.20
92/08/18	1031	WATER	8.5				10	7	.380	.080	.20
92/09/22	0930	WATER	0.5		1.47	10K					
92/09/22	0934	VERT	4				15	5	.250	.080	.15
92/09/22	0938	WATER	10				15	8	.100	.080	.15

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
92/01/24	0900	VERT	4		.030	.010	1.9	2.00	1.00K	1.00K	1.00
92/01/24	0902	WATER	8		.030	.010	1.8				
92/04/22	0929	VERT	4		.030	.010	2.2				
92/04/22	0934	WATER	9		.030	.020	2.0				
92/05/12	1000	VERT	4		.020	.008	2.1	7.00	1.00	1.00	1.00K
92/05/12	1020	WATER	9.5		.020	.010	2.1				
92/06/15	1030	VERT	4		.050	.010	2.5	4.00	1.00	1.00K	1.00
92/06/15	1032	WATER	9.4		.050	.020	2.3				
92/07/21	0951	VERT	4		.020	.007	2.1	5.00	1.00	1.00K	1.00
92/07/21	0957	WATER	9		.020	.010	2.0				
92/08/18	1023	VERT	4		.040	.002	2.2	5.00	1.00K	1.00K	1.00K
92/08/18	1031	WATER	8.5		.040	.006	2.2				
92/09/22	0934	VERT	4		.040	.020	2.2	2.00	1.00K	1.00	2.00
92/09/22	0938	WATER	10		.040	.010	2.1				

STORET RETRIEVAL DATE 93/01/12   PGM=RET

475317   1089
35 38 10.0 084 47 06.0 2
OPP. LOWE BR. WATTS BAR RES.
47121   TENNESSEE   MEIGS
TENNESSEE RIVER BASIN   040801
TENNESSEE RIVER 531.0
1311VAC
0000 METERS DEPTH

/TYPA/AMBNT/FISH/STREAM/SOLIDS   06010201002 0002.040 ON

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
92/01/22	1211	WATER	0.5	34538	6.0	11.8	94.4$	7.60	174
92/01/22	1212	WATER	1		6.0	11.6	92.8$	7.60	176
92/01/22	1213	WATER	1.5		6.0	11.6	92.8$	7.60	176
92/01/22	1214	WATER	4		6.0	11.6	92.8$	7.50	174
92/01/22	1216	WATER	6		6.0	11.6	92.8$	7.50	175
92/01/22	1217	WATER	8		6.0	11.6	92.8$	7.50	176
92/01/22	1218	WATER	10		6.0	11.6	92.8$	7.50	176
92/01/22	1219	WATER	12		6.0	11.6	92.8$	7.50	175
92/01/22	1220	WATER	14		6.0	11.5	92.0$	7.50	174
92/01/22	1221	WATER	16		6.0	11.5	92.0$	7.50	176
92/01/22	1222	WATER	18		6.0	11.4	91.2$	7.50	176
92/01/22	1223	WATER	20		6.0	11.5	92.0$	7.50	175
92/01/22	1224	WATER	22		6.0	11.4	91.2$	7.50	175
92/01/22	1225	WATER	22.4		6.0	11.3	90.4$	7.50	174
92/01/22	1226	WATER	24		6.0	11.4	91.2$	7.50	175
92/04/23	1210	WATER	0.5	4067	18.9	11.4	121.3$	8.70	141
92/04/23	1212	WATER	1		18.4	10.9	114.7$	8.80	140
92/04/23	1214	WATER	1.5		18.2	10.9	114.7$	8.80	141
92/04/23	1216	WATER	4		17.5	10.9	112.4$	8.70	142
92/04/23	1220	WATER	6		16.2	10.2	102.0$	8.50	146
92/04/23	1222	WATER	7		15.2	9.3	91.2$	8.10	146
92/04/23	1224	WATER	8		14.8	8.8	86.3$	7.90	146
92/04/23	1226	WATER	10		13.8	8.4	80.8$	7.80	147
92/04/23	1228	WATER	12		13.2	8.0	75.5$	7.40	145
92/04/23	1230	WATER	14		12.9	7.9	74.5$	7.80	144
92/04/23	1232	WATER	16		12.6	7.9	74.5$	7.60	143
92/04/23	1234	WATER	18		12.4	7.8	72.2$	7.60	139
92/04/23	1236	WATER	20		12.1	7.6	70.4$	7.60	137
92/04/23	1238	WATER	22		12.0	7.5	69.4$	7.50	137
92/04/23	1240	WATER	24		11.9	7.3	67.6$	7.50	142
92/05/14	1225	WATER	0.5	17154	20.6	10.6	117.8$	8.70	161
92/05/14	1227	WATER	1		20.2	10.6	115.2$	8.70	161
92/05/14	1230	WATER	1.5		19.8	10.7	116.3$	8.70	161
92/05/14	1233	WATER	3		19.5	10.2	108.5$	8.60	160
92/05/14	1235	WATER	4		18.8	9.2	97.9$	8.40	161
92/05/14	1242	WATER	5		17.9	8.3	87.4$	8.10	161
92/05/14	1245	WATER	6		17.8	8.1	85.3$	8.00	159
92/05/14	1248	WATER	8		17.3	7.5	77.3$	7.90	168
92/05/14	1249	WATER	10		17.1	7.2	74.2$	7.80	171
92/05/14	1252	WATER	12		16.8	6.8	70.1$	7.70	173
92/05/14	1255	WATER	14		16.7	6.6	68.0$	7.70	175
92/05/14	1258	WATER	16		16.4	6.2	62.0$	7.60	172
92/05/14	1301	WATER	18		15.6	5.3	53.0$	7.50	166
92/05/14	1304	WATER	20		15.0	4.8	47.1$	7.40	162
92/05/14	1307	WATER	22		14.6	4.4	43.1$	7.40	159
92/05/14	1310	WATER	24		14.3	4.1	39.4$	7.40	156
92/05/14	1313	WATER	25		14.0	3.6	34.6$	7.30	155
92/06/17	1402	WATER	0.5	37046	25.8	11.7	142.7$	9.10	174
92/06/17	1405	WATER	1		25.8	11.6	141.5$	9.10	173
92/06/17	1408	WATER	1.5		25.7	11.6	141.5$	9.10	173
92/06/17	1411	WATER	3.1		24.9	11.1	132.1$	9.00	172
92/06/17	1414	WATER	3.4		24.8	10.5	125.0$	8.90	172
92/06/17	1417	WATER	4		22.9	8.5	97.7$	8.30	172
92/06/17	1423	WATER	4.3		22.6	8.1	93.1$	8.20	172
92/06/17	1426	WATER	5.7		21.2	5.6	62.2$	7.60	172
92/06/17	1429	WATER	6		20.8	5.3	58.9$	7.90	171
92/06/17	1432	WATER	8		20.3	5.2	56.5$	7.40	170
92/06/17	1435	WATER	10		20.2	5.1	55.4$	7.30	170
92/06/17	1438	WATER	12		20.1	5.0	54.3$	7.30	169
92/06/17	1441	WATER	14		20.0	4.9	53.3$	7.30	170
92/06/17	1444	WATER	16		20.0	4.8	52.2$	7.20	170
92/06/17	1447	WATER	18		19.9	4.7	51.1$	7.20	172
92/06/17	1450	WATER	20		19.8	4.3	46.7$	7.20	170
92/06/17	1453	WATER	22		19.6	3.6	39.1$	7.10	157
92/06/17	1456	WATER	22.4		19.6	3.6	39.1$	7.10	156
92/06/17	1459	WATER	24		19.5	3.4	36.2$	7.10	151
92/06/17	1502	WATER	25		19.5	3.3	35.1$	7.10	146
92/07/23	1410	WATER	0.5	19229	27.3	7.7	95.1$	8.70	173
92/07/23	1411	WATER	1		27.3	7.7	95.1$	8.70	173
92/07/23	1412	WATER	1.5		27.2	7.1	87.7$	8.60	174
92/07/23	1413	WATER	4		27.0	7.0	86.4$	8.50	173
92/07/23	1415	WATER	4.5		27.1	6.7	82.7$	8.60	172
92/07/23	1416	WATER	5		26.3	6.1	74.4$	8.10	174
92/07/23	1417	WATER	5.5		25.9	5.1	62.2$	7.50	176
92/07/23	1418	WATER	6		25.6	4.2	51.2$	7.40	177
92/07/23	1419	WATER	7		24.9	3.6	42.9$	7.10	178
92/07/23	1420	WATER	8		24.5	3.1	36.5$	7.00	179
92/07/23	1421	WATER	10		24.4	3.0	35.3$	7.00	179
92/07/23	1422	WATER	12		24.3	2.9	34.1$	7.00	179
92/07/23	1423	WATER	14		24.2	2.8	32.9$	7.00	179
92/07/23	1424	WATER	16		24.1	2.5	29.4$	6.90	177
92/07/23	1425	WATER	18		23.9	2.4	28.2$	6.90	176
92/07/23	1426	WATER	20		23.8	2.2	25.9$	6.90	175
92/07/23	1427	WATER	22		23.7	2.1	24.7$	6.90	176
92/07/23	1428	WATER	23		23.5	1.4	16.1$	6.80	166
92/07/23	1429	WATER	23.5		23.4	1.1	12.6$	6.80	162
92/07/23	1430	WATER	24		23.3	.7	8.0$	6.70	157
92/07/23	1431	WATER	24.5		23.2	.6	6.9$	6.70	155
92/08/19	1130	WATER	0.5	25233	26.0	10.7	130.5$	8.90	192
92/08/19	1132	WATER	1		26.0	10.7	130.5$	8.90	192
92/08/19	1134	WATER	1.5		26.0	10.6	129.3$	8.90	192
92/08/19	1136	WATER	3		25.9	9.9	120.7$	8.80	192
92/08/19	1138	WATER	4		25.8	9.4	114.6$	8.70	193
92/08/19	1142	WATER	4.5		25.4	7.9	94.0$	8.30	196
92/08/19	1144	WATER	5.5		25.4	7.7	91.7$	8.20	195
92/08/19	1146	WATER	6		25.2	6.8	81.0$	8.00	196
92/08/19	1148	WATER	6.5		24.9	5.9	70.2$	7.70	197
92/08/19	1150	WATER	8		24.6	5.1	60.7$	7.40	198
92/08/19	1152	WATER	10		24.5	5.1	60.0$	7.40	199
92/08/19	1154	WATER	12		24.4	4.8	56.5$	7.30	199
92/08/19	1156	WATER	14		24.1	4.4	51.8$	7.30	200
92/08/19	1158	WATER	16		24.1	4.3	50.6$	7.30	200
92/08/19	1200	WATER	18		24.0	4.0	47.1$	7.20	200
92/08/19	1202	WATER	20		23.8	3.7	43.5$	7.20	200
92/08/19	1204	WATER	22		23.8	3.7	43.5$	7.20	200
92/08/19	1206	WATER	22.5		23.8	3.7	43.5$	7.10	200
92/08/19	1208	WATER	24		23.8	3.7	43.5$	7.20	199
92/08/19	1210	WATER	25		23.8	3.6	42.4$	7.20	200
92/09/23	1143	WATER	0.5	26163	24.2	6.3	74.1$	7.80	186
92/09/23	1144	WATER	1		24.2	6.3	74.1$	7.80	186
92/09/23	1145	WATER	1.5		24.2	6.3	74.1$	7.80	186
92/09/23	1146	WATER	3		24.2	6.3	74.1$	7.80	186
92/09/23	1148	WATER	5		24.2	6.2	72.9$	7.80	187
92/09/23	1149	WATER	7		24.2	6.2	72.9$	7.80	186
92/09/23	1150	WATER	9		24.1	6.1	71.8$	7.80	186
92/09/23	1151	WATER	11		24.1	6.1	71.8$	7.70	187
92/09/23	1152	WATER	13		24.1	6.1	71.8$	7.70	185
92/09/23	1153	WATER	15		24.1	6.0	70.6$	7.70	186
92/09/23	1154	WATER	17		24.1	6.0	70.6$	7.70	185
92/09/23	1155	WATER	19		24.1	5.9	69.4$	7.70	185
92/09/23	1156	WATER	21		24.1	5.8	68.2$	7.60	187
92/09/23	1157	WATER	23		24.0	5.2	61.2$	7.40	188
92/09/23	1158	WATER	24		24.0	4.8	56.5$	7.40	189
92/09/23	1159	WATER	25		23.9	3.7	43.5$	7.30	188

STORET RETRIEVAL DATE 93/01/12

PGM=RET

/TYPA/AMBNT/FISH/STREAM/SOLIDS

475317 1089
35 38 10.0 084 47 06.0 2
OPP. LOWE BR. WATTS BAR RES.
47121 TENNESSEE MEIGS
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 531.0
131TVAC
0000 METERS DEPTH 06010201002 0002.040 ON

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
92/01/22	1211	WATER	0.5		1.20	10K					
92/01/22	1215	VERT	4						.120	.020	.56
92/01/22	1225	WATER	22.4						.100	.040	.57
92/04/23	1210	WATER	0.5		1.77	10K					
92/04/23	1218	VERT	4				10	4	.410	.010K	.21
92/04/23	1238	WATER	22				10	5	.240	.060	.31
92/05/14	1225	WATER	0.5		1.40	10K					
92/05/14	1239	VERT	4				5	3	.230	.010	.13
92/05/14	1307	WATER	22				10	5	.180	.010K	.41
92/06/17	1402	WATER	0.5		1.10	10K					
92/06/17	1420	VERT	4	D1			15	3	.630	.010	.12
92/06/17	1421	VERT	4	D2			15	4	.490	.020	.13
92/06/17	1422	VERT	4	D3			15	4	.450	.020	.12
92/06/17	1456	WATER	22.4	D1			10	10	.300	.040	.36
92/06/17	1457	WATER	22.4	D2			10	10	.240	.030	.43
92/06/17	1458	WATER	22.4	D3			15	10	.300	.040	.38
92/07/23	1410	WATER	0.5		1.38	10K					
92/07/23	1414	VERT	4				15	3	.610	.010K	.10
92/07/23	1427	WATER	22				10	6	.250	.020	.40
92/08/19	1130	WATER	0.5		1.43	10K					
92/08/19	1140	VERT	4				10	3	.400	.020	.11
92/08/19	1206	WATER	22.5				10	9	.390	.010	.38
92/09/23	1143	WATER	0.5		1.47	10K					
92/09/23	1147	VERT	4				15	3	.310	.040	.12
92/09/23	1157	WATER	23				15	4	.270	.040	.13

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
92/01/22	1215	VERT	4		.030	.010	1.9	6.00	1.00K	1.00	1.00K
92/01/22	1225	WATER	22.4		.030	.010	1.8				
92/04/23	1218	VERT	4		.020	.002K	2.0	6.00	1.00	1.00	3.00
92/04/23	1238	WATER	22		.030	.004	1.7				
92/05/14	1239	VERT	4		.020	.002K	2.1	8.00	1.00	1.00	1.00
92/05/14	1307	WATER	22		.020	.002K	1.7				
92/06/17	1420	VERT	4	D1	.020	.010	2.5	4.00	1.00K	1.00	1.00K
92/06/17	1421	VERT	4	D2	.030	.020	2.7	14.00	1.00	1.00	1.00K
92/06/17	1422	VERT	4	D3	.030	.010	2.8	5.00	1.00K	1.00	1.00K
92/06/17	1456	WATER	22.4	D1	.040	.010	2.2				
92/06/17	1457	WATER	22.4	D2	.040	.020	2.1				
92/06/17	1458	WATER	22.4	D3	.040	.030	2.1				
92/07/23	1414	VERT	4		.030	.006	1.9	9.00	1.00K	1.00	1.00
92/07/23	1427	WATER	22		.030	.020	2.5				
92/08/19	1140	VERT	4		.030	.002K	2.4	5.00	1.00	1.00	1.00
92/08/19	1206	WATER	22.5		.040	.010	2.2				
92/09/23	1147	VERT	4		.030	.003	2.2	12.00	1.00	2.00	1.00
92/09/23	1157	WATER	23		.030	.005	2.2				

STORET RETRIEVAL DATE 93/01/12 PGM=RET

476041 1114C
35 49 50.0 084 36 33.0 2
WATTS BAR RESERVOIR
47145 TENNESSEE ROANE
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TENNESSEE RIVER 560.80
131TVAC HQ 06010201002 0043.170 OFF
0000 METERS DEPTH

/TYPA/AMBNT/STREAM/SOLIDS

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
92/01/22	1104	WATER	0.5		6.2	11.5	92.0$	7.50	213
92/01/22	1105	WATER	1		6.2	11.4	91.2$	7.60	213
92/01/22	1106	WATER	1.5		6.2	11.4	91.2$	7.60	213
92/01/22	1107	WATER	4		6.2	11.4	91.2$	7.60	213
92/01/22	1109	WATER	6		6.1	11.3	90.4$	7.50	213
92/01/22	1110	WATER	8		6.1	11.3	90.4$	7.50	212
92/01/22	1111	WATER	10		6.1	11.3	90.4$	7.50	212
92/01/22	1112	WATER	11.3		6.1	11.3	90.4$	7.50	212
92/01/22	1113	WATER	12		6.1	11.3	90.4$	7.50	212
92/04/23	1105	WATER	0.5		20.2	11.5	125.0$	8.60	185
92/04/23	1107	WATER	1		20.1	11.5	125.0$	8.70	185
92/04/23	1109	WATER	1.5		20.0	11.4	123.9$	8.70	185
92/04/23	1111	WATER	4		19.6	10.7	116.3$	8.60	186
92/04/23	1115	WATER	6		19.3	9.9	105.3$	8.40	197
92/04/23	1117	WATER	7		17.8	9.4	98.9$	8.10	204
92/04/23	1119	WATER	8		17.0	9.1	93.8$	8.00	203
92/04/23	1121	WATER	10		16.4	8.5	85.0$	7.90	190
92/04/23	1123	WATER	11		16.1	8.1	81.0$	7.70	183
92/04/23	1125	WATER	12		16.1	7.8	78.0$	7.70	182
92/05/14	1049	WATER	13		16.7	7.5	77.3$	7.70	158
92/05/14	1050	WATER	12		16.8	7.8	80.4$	7.80	158
92/05/14	1051	WATER	10		17.5	8.3	85.6$	7.90	157
92/05/14	1052	WATER	8		17.7	8.3	87.4$	8.00	158
92/05/14	1053	WATER	6		17.9	8.5	89.5$	8.10	160
92/05/14	1055	WATER	4		18.7	9.3	98.9$	8.20	164
92/05/14	1056	WATER	3		19.2	10.2	108.5$	8.50	166
92/05/14	1057	WATER	1.5		19.4	10.5	111.7$	8.60	166
92/05/14	1058	WATER	1		19.4	10.7	113.8$	8.60	167
92/05/14	1059	WATER	0.5		19.6	11.0	119.6$	8.70	164
92/06/17	1101	WATER	0.5		23.0	8.8	101.2$	7.90	150
92/06/17	1104	WATER	1		22.8	8.5	97.7$	7.90	151
92/06/17	1107	WATER	1.5		22.3	7.9	89.8$	7.70	152
92/06/17	1110	WATER	4		21.4	7.3	81.1$	7.60	156
92/06/17	1116	WATER	6		21.1	7.1	78.9$	7.50	159
92/06/17	1119	WATER	8		21.1	7.0	77.8$	7.50	159
92/06/17	1122	WATER	10		21.0	6.9	76.7$	7.50	158
92/06/17	1126	WATER	12		21.0	6.8	75.6$	7.50	157
92/06/17	1129	WATER	12.3		21.0	6.8	75.6$	7.50	158
92/07/23	1240	WATER	0.5		26.3	9.1	111.0$	8.40	201
92/07/23	1242	WATER	1		26.3	9.1	111.0$	8.40	202
92/07/23	1244	WATER	1.5		26.2	8.9	108.5$	8.40	201
92/07/23	1246	WATER	2.5		26.0	8.7	106.1$	8.30	202
92/07/23	1248	WATER	4		25.5	7.6	90.5$	7.90	203
92/07/23	1252	WATER	5		25.1	6.9	82.1$	7.60	204
92/07/23	1254	WATER	6		24.9	6.6	78.6$	7.60	204
92/07/23	1256	WATER	8		24.5	6.4	75.3$	7.50	208
92/07/23	1258	WATER	10		24.4	6.3	74.1$	7.50	208
92/07/23	1300	WATER	12		24.3	6.0	70.6$	7.40	207
92/07/23	1302	WATER	12.4		24.2	5.9	69.4$	7.40	206
92/07/23	1304	WATER	13		24.2	5.9	69.4$	7.40	206
92/08/19	1025	WATER	0.5		24.1	9.3	109.4$	8.10	187
92/08/19	1027	WATER	1		24.0	9.3	109.4$	8.10	187
92/08/19	1029	WATER	1.5		24.0	8.9	104.7$	8.10	186
92/08/19	1031	WATER	4		23.7	8.3	97.6$	7.90	187
92/08/19	1035	WATER	6		23.4	7.7	88.5$	7.70	188
92/08/19	1037	WATER	8		23.1	7.4	85.1$	7.70	186
92/08/19	1039	WATER	10		23.0	7.0	80.5$	7.60	190
92/08/19	1041	WATER	12		22.9	6.7	77.0$	7.50	192
92/08/19	1043	WATER	12.5		22.9	6.6	75.9$	7.50	192
92/09/23	1015	WATER	0.5		23.5	5.8	66.7$	7.50	192
92/09/23	1017	WATER	1		23.5	5.8	66.7$	7.50	191
92/09/23	1019	WATER	1.5		23.5	5.8	66.7$	7.50	191
92/09/23	1021	WATER	3		23.5	5.9	67.8$	7.50	193
92/09/23	1025	WATER	5		23.5	5.8	66.7$	7.50	192
92/09/23	1027	WATER	7		23.5	5.7	65.5$	7.50	192
92/09/23	1029	WATER	9		23.5	5.7	65.5$	7.40	192
92/09/23	1030	WATER	11		23.4	5.6	64.4$	7.40	196
92/09/23	1031	WATER	13		23.4	5.5	63.2$	7.40	196

STORET RETRIEVAL DATE 93/01/12

PGM=RET

/TYPA/AMBNT/STREAM/SOLIDS

476041 1114C
35 49 50.0 084 36 33.0 2
WATTS BAR RESERVOIR
47145 TENNESSEE
TENNESSEE RIVER BASIN ROANE
TENNESSEE RIVER 560.80 040801
131TVAC
0000 METERS DEPTH HQ 06010201002 0043.170 OFF

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
92/01/22	1104	WATER	0.5		1.10	10K					
92/01/22	1108	VERT	4						.170	.040	.72
92/01/22	1112	WATER	11.3						.190	.040	.71
92/04/23	1105	WATER	0.5		1.23	10K					
92/04/23	1113	VERT	4				10	6	.430	.010K	.21
92/04/23	1123	WATER	11				10	10	.250	.090	.37
92/05/14	1050	WATER	12				5	12	.290	.050	.27
92/05/14	1054	VERT	4				10	6	.360	.020	.18
92/05/14	1059	WATER	0.5		1.20	10K					
92/06/17	1101	WATER	0.5		.80	10K					
92/06/17	1113	VERT	4				10	9	.250	.020	.38
92/06/17	1129	WATER	12.3				10	17	.180	.050	.40
92/07/23	1240	WATER	0.5		.98	10					
92/07/23	1250	VERT	4				15	7	.600	.010	.27
92/07/23	1302	WATER	12.4				10	14	.250	.040	.34
92/08/19	1025	WATER	0.5		1.27	10K					
92/08/19	1033	VERT	4				10	4	.310	.040	.27
92/08/19	1041	WATER	12				10	14	.300	.010	.23
92/09/23	1015	WATER	0.5		1.14	10K					
92/09/23	1023	VERT	4				15	4	.240	.020	.30
92/09/23	1030	WATER	11				15	6	.550	.020	.31

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
92/01/22	1108	VERT	4		.040	.020	1.9	4.00	1.00K	1.00	1.00
92/01/22	1112	WATER	11.3		.040	.020	1.9				
92/04/23	1113	VERT	4		.002	.002	2.1	11.00	1.00	2.00	5.00
92/04/23	1123	WATER	11		.040	.008	2.0				
92/05/14	1050	WATER	12		.040	.002K	1.9				
92/05/14	1054	VERT	4		.030	.002K	2.1	14.00	1.00	2.00	1.00
92/06/17	1113	VERT	4		.040	.020	2.3	9.00	1.00	1.00	1.00K
92/06/17	1129	WATER	12.3		.050	.020	2.3				
92/07/23	1250	VERT	4		.020	.007	2.3	8.00	1.00	1.00	2.00
92/07/23	1302	WATER	12.4		.020	.008	2.0				
92/08/19	1033	VERT	4		.040	.003	2.2	5.00	1.00	1.00	1.00
92/08/19	1041	WATER	12		.040	.004	2.2				
92/09/23	1023	VERT	4		.030	.007	2.2	4.00	2.00	1.00	2.00
92/09/23	1030	WATER	11		.030	.010	2.2				

TENNESSEE VALLEY AUTHORITY

Resource Group
Water Management
Clean Water Initiative

TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY, 1993
PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER
RESERVOIR VITAL SIGNS MONITORING

Prepared by

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Joseph P. Fehring,
and
Dennis L. Meinert

Chattanooga, Tennessee
June 1994

INTRODUCTION

The Tennessee Valley Authority (TVA) initiated a Reservoir Monitoring Program in 1990 as part of its Water Resources and Ecological Monitoring Activities. In these first four years (1990-1993), the Reservoir Monitoring Program has undergone continual change and improvement. Initially, in 1990, only 12 TVA reservoirs were examined, the nine mainstream Tennessee River reservoirs (Kentucky through Fort Loudoun), and three major tributary storage reservoirs: Cherokee, Douglas, and Norris (Dycus and Meinert, 1991). In 1991, the Reservoir Monitoring Program was expanded to 24 reservoirs, to include the system's only two tributary reservoirs with navigation locks (Tellico and Melton Hill) and ten other smaller tributary reservoirs (Dycus and Meinert, 1992). In 1993, six additional tributary reservoirs were added (Dycus and Meinert, 1994). No further expansion of reservoir monitoring is planned.

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

The basis of Vital Signs Monitoring is examination of appropriate physical, chemical, and biological indicators - monitoring tools - at one or more strategic locations in each reservoir, i.e. the forebay immediately upstream of the dam; the transition zone (the mid-reservoir region where the water changes from free flowing to more quiescent, impounded water; and the inflow or headwater region of the reservoir. The monitoring tools comprised: basic physical/chemical water quality sampling; sediment quality and toxicity testing; benthic macroinvertebrate community evaluations; and fish community evaluations. A summary report (Dycus and Meinert, 1994) presents results of TVA's 1993 Reservoir Monitoring Program, to include all Vital Signs (physical/chemical, sediment, benthic and fish communities) and Use Suitability Monitoring.

This technical data summary presents the 1993 Vital Signs physical/chemical water quality sampling information only. The basic group of 30 reservoirs were monitored. Embayment monitoring sites were added in 1993 on four reservoirs: the Big Sandy River embayment of Kentucky Reservoir; the Bear Creek embayment of Pickwick Reservoir; the Elk River embayment of Wheeler Reservoir; and the Hiwassee River embayment of Chickamauga Reservoir. Transition zone sites were moved somewhat downstream on Tellico and Douglas Reservoirs, to capture a less riverine environment; and the transition zone site was moved slightly upstream on Watauga Reservoir, to differentiate that site more from the forebay site. Further, the forebay site on Nottely Reservoir was moved upstream; and on Chatuge, a site was added on Shooting Creek.

MATERIALS AND METHODS

Reservoir Characteristics - The physical characteristics of a reservoir (volume, surface area, depth, hydraulic residence time, etc.) have a great effect on its intrinsic physical and chemical processes and water quality characteristics. The Vital Signs reservoirs are very broadly categorized as either run-of-the-river or tributary reservoirs, with generally large differences in their morphologic and hydraulic characteristics (Table 1). Primary differences include the greater depths and longer hydraulic residence times of tributary reservoirs, resulting in the development of strong thermal stratification and its associated physical/chemical processes. Short average residence times found on most of the main stream, run-of-the-river reservoirs (usually less than 30 days) results in well-mixed riverine conditions. Thermal stratification of the run-of-the-river reservoirs rarely exists and then for only short periods of time under conditions of low flow and intense solar heating. However, tributary reservoirs with their longer residence times (typically greater than 100 days) develop strong thermal stratification that begins in the spring and ends with seasonal cooling and mixing in the late autumn. During this summer stratification, inflowing water may be cooler than the epilimnetic surface water and may enter the reservoir as a cold underflow to the hypolimnion rather than mixing with the epilimnion. This results in an even longer residence time of the epilimnetic water than is indicated by the calculated average

Table 1

CHARACTERISTICS OF VITAL SIGNS RESERVOIRS

Reservoir Name	Drainage Area (sq. miles)	Reservoir Length[a] (miles)	Surface Area[a] (acres) 1000's	Depth at Dam[a] (ft)	Volume[a] (ac-ft) 1000's	Average Annual Drawdown[b] (ft)	Average Reservoir Flow-POR (cfs)	Average Hydraulic Residence Time-1993[a] (days)	CY 1993 Reservoir Flow (cfs)
Run-of-the-River Reservoirs									
Kentucky	40,200	184.3	160.3	88	2,839	5	66,600	27.5	52,097
Pickwick	32,820	52.7	43.1	84	924	6	54,900	9.6	48,566
Wilson	30,750	15.5	15.5	108	634	3	51,500	6.8	47,236
Wheeler	29,590	74.1	67.1	66	1,050	6	49,400	11.4	46,264
Guntersville	24,450	75.7	67.9	65	1,018	2	40,700	12.9	39,691
Nickajack	21,870	46.3	10.4	60	241	0	35,900	3.6	34,092
Chickamauga	20,790	58.9	35.4	83	628	7	34,200	9.6	32,887
Watts Bar	17,300	72.0/24.0[c]	39.0	105	1,010	6	27,100	19.5	26,145
Fort Loudoun	9,550	50.0	14.6	94	363	6	18,400	9.7	18,897
Melton Hill	3,343	44.0	5.7	69	120	0	4,920	12.7	4,764
Tellico	2,627	33.2	16.5	80	415	6	6,300[d]	34.0	6,159[d]
Tributary, Storage Reservoirs									
Norris	2,912	73.0/53.0[c]	34.2	202	2,040	32	4,190	249.4	4,124
Cherokee	3,428	54.0	30.3	163	1,481	28	4,460	162.2	4,604
Douglas	4,541	43.1	30.4	127	1,408	48	6,780	109.4	6,490
Ft Patrick Henry	1,903	10.4	0.9	81	27	0	2,650	5.6	2,423
Boone	1,840	17.4/15.3[c]	4.3	129	189	25	2,550	38.5	2,477
South Holston	703	23.7	7.6	239	658	33	976	341.3	972
Watauga	468	16.3	6.4	274	569	26	714	403.5	711
Fontana	1,571	29.0	10.6	460	1,420	64	3,840	173.5	4,126
Hiwassee	968	22.2	6.1	255	422	45	2,020	98.8	2,154
Chatuge	189	13.0	7.0	124	234	10	459	291.3	405
Nottely	214	20.2	4.2	167	170	24	416	228.0	376
Ocoee #1 (Parksville)	595	7.5	1.9	115	85	7	1,420	33.1	1,296
Blue Ridge	232	11.0	3.3	156	193	36	614	156.2	623
Tims Ford	529	34.2	10.6	143	530	12	940	328.7	813
Bear Creek	232	16.0	0.7	74	10	11[e]	380	14.4	337
Cedar Creek	179	9.0	4.2	79	94	14[e]	282	185.7	255
Little Bear Creek	61	7.1	1.6	82	45	12[e]	101	253.9	90
Beech	16	5.3	0.9	32	11	1[e]	14	616.2	9
Normandy	195	17.0	3.2	83	110	11	320	201.7	275

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

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

reservoir volume/flow quotient, particularly if the turbine power intakes draw water exclusively from below the thermocline.

A major effect of this thermal stratification in tributary reservoirs is the depletion of hypolimnetic dissolved oxygen. The pattern of hypolimnetic dissolved oxygen depletion is variable both spatially and temporally for any one reservoir and among reservoirs. The general pattern, however, is that after the onset of thermal stratification, an anoxic zone first begins to develop in the transition zone of the reservoir. The large input and settling out of allochthonous organic matter (leaves and detritus washed in by the tributary streams) causes high rates of oxygen uptake in the transition zone and results in the initial depletion of dissolved oxygen in this area of the reservoir. The zone of anoxic water gradually extends both upstream and downstream, until it reaches the free-flowing river upstream and the dam downstream. At the same time the anoxic zone develops vertically and laterally. In the worst case, the entire hypolimnion may become anoxic and remain so until reaeration during autumn overturn. The hypolimnetic anoxia promotes the dissolution and release of metals, minerals, and nutrients from the reservoir sediment and bottom water, resulting in elevated concentrations of reduced forms of iron, manganese, sulfate, nitrate, and phosphate. When reservoir destratification occurs in autumn, the hypolimnion is mixed with surface water and replenished with oxygen.

Epilimnetic processes are also affected by thermal stratification, particularly in deeper tributary reservoirs. With the onset of spring stratification, primary production can be quite high, particularly in the transition zone. The phytoplankton community frequently receives ample supplies of nutrients from periodic spring rainfall/runoff events, and with lower water velocities and increased rates of sedimentation, improved water clarity and light penetration often results in episodes of high algal productivity as evidenced by high chlorophyll-a concentrations, high pH values and supersaturation of dissolved oxygen. The longer residence times of tributary reservoirs results in water clarity usually being more a function of algal cell abundance and chlorophyll pigment and less a function of inorganic suspended material as is the case in mainstream reservoirs with shorter residence times and higher velocities. In mainstream reservoirs, the shorter detention times and higher velocities inhibit the deposition of suspended material, resulting in generally lower water clarity and light availability and often limiting algal productivity.

Epilimnetic water clarity often increases moving downstream into the forebay area of the reservoir and into the late summer as rainfall/runoff events occur less frequently. Even though water clarity increases, nutrients become depleted and primary production often is reduced as much of the organic matter produced during photosynthesis decomposes and settles below the photic zone. Bacterial decomposition consumes available dissolved oxygen (respiration) and releases carbon dioxide, thereby lowering the pH. Unlike mainstream reservoirs, this decomposition process in tributary reservoirs often results in two oxygen minima in the water column - one in the epilimnion at or near the thermocline and one in the hypolimnion.

Consequently, physical/chemical differences in water quality between run-of-the-river and tributary reservoirs are expected in examining the 1993 Vital Signs data. In the Results and Discussion section of this report, water quality characteristics are discussed and comparisons are made among the Vital Signs reservoirs to point out these differences. Because physical/chemical water quality conditions are different, this does not imply that one reservoir is good and another is poor, it merely is a reflection of the unique physical and chemical differences between each. For example, one particular reservoir, Fort Loudoun, exhibits both run-of-the-river and tributary reservoir characteristics. Although it is located on the main stream of the Tennessee River, it is the most upstream reservoir and is formed by the confluence of the French Broad and Holston Rivers. Major tributary reservoir impoundments on both these river systems, Douglas Dam at mile 32.3 of the French Broad and Cherokee Dam at mile 52.3 on the Holston, release cool, hypolimnetic water low in dissolved oxygen during the summer. Depending upon the quantity and duration of water released from Douglas and Cherokee dams and the temperature of the impounded Fort Loudoun water, this cool water may flow under the warmer water impounded in Fort Loudoun Reservoir resulting in thermally stratified conditions. Consequently, Fort Loudoun can intermittently exhibit the characteristics of either a run-of-the-river reservoir or a tributary reservoir.

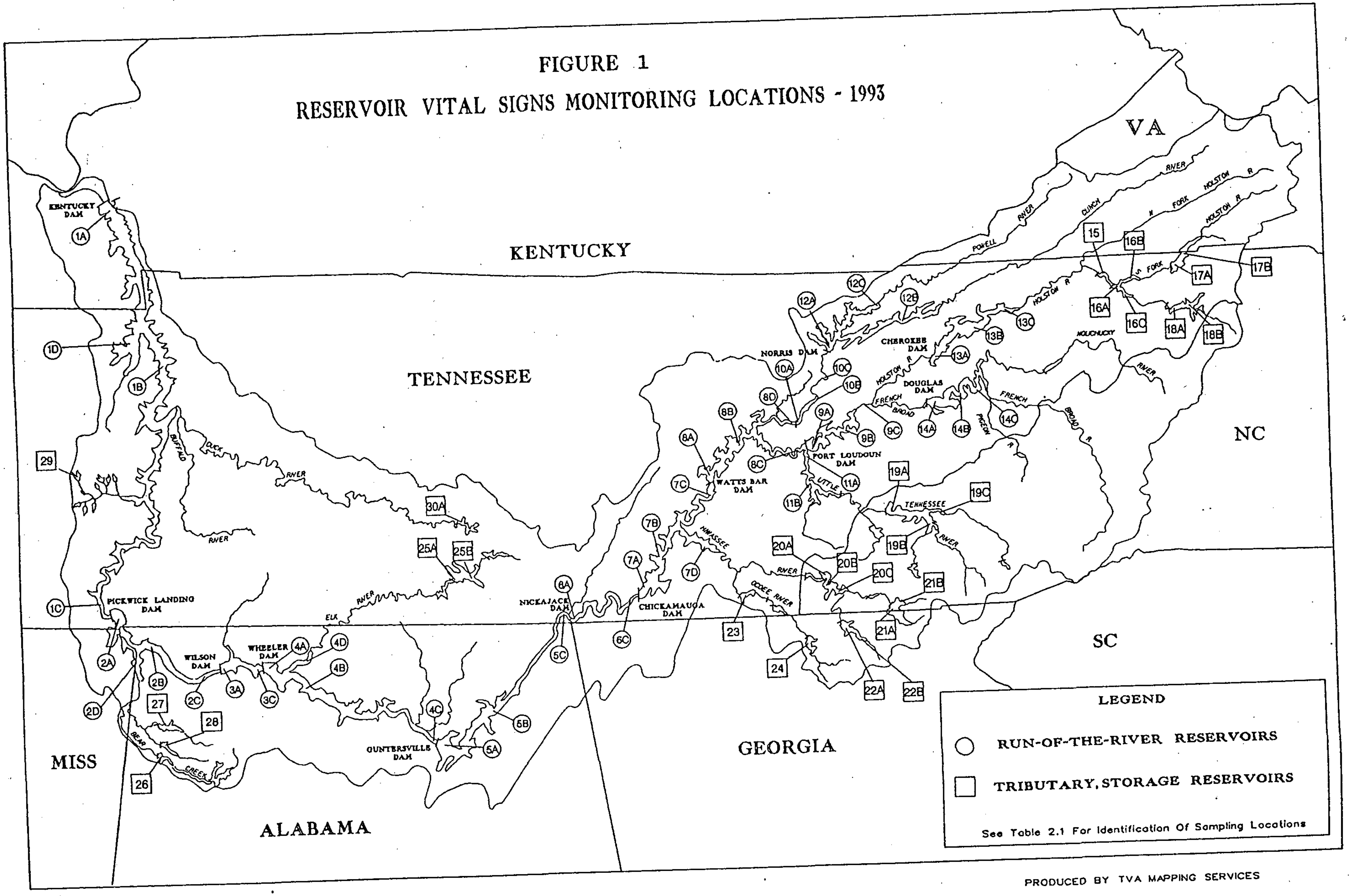
Overview - Physical/chemical variables were measured at a total of fifty seven locations on the thirty Vital Signs reservoirs (Figure 1, Table 2). The Vital Signs water quality monitoring activities on these reservoirs, followed either a "basic" or "limited" sampling strategy (Tables 2 and 3). The basic sampling strategy included monthly water quality surveys (April through September) at the forebay and transition zone (and on four reservoirs, an embayment--see Table 2) locations on eleven TVA reservoirs: the nine mainstem Tennessee River reservoirs; and Melton Hill and Tellico reservoirs. The limited sampling strategy included monthly water sampling (April through October) for a smaller list of parameters at the forebay locations (and at mid-reservoir locations on larger reservoirs) on nineteen tributary impoundments.

Water quality measurements, sample collections and sample handling followed standard practices accepted by the Environmental Protection Agency (EPA, 1979 and 40 CFR 136), US Geological Survey (USGS, 1977), and American Public Health Association (AWWA, WPCF, APHA, 1989) as specified in TVA quality assurance/quality control (QA/QC) procedures (TVA, 1990 and TVA, 1987). TVA laboratory analyses conformed to established EPA, USGS, and APHA QA/QC procedures (TVA, 1989b).

Details on the physical/chemical analyses and measurements on the water samples are summarized in Tables 3 and 4. The 1993 data are tabulated in the Appendix A - Physical/Chemical Characteristics of Water. All the data are stored and are available on EPA's water quality data storage and retrieval (STORET) computer system.

FIGURE 1

RESERVOIR VITAL SIGNS MONITORING LOCATIONS - 1993



PRODUCED BY TVA MAPPING SERVICES

Table 2

WATER QUALITY MONITORING LOCATIONS
RESERVOIR VITAL SIGNS MONITORING, 1993

Basic Water Quality Monitoring Locations

Reservoir	Sampling Locations[a]	STORET ID No.	Description[b]
Kentucky	TRM 23.0	202832	1A-FB
	TRM 85.0	477403	1B-TZ
	TRM 200-206	--	1C-I
	Big Sandy 7.4	477210	1D-E
Pickwick	TRM 207.3	476799	2A-FB
	TRM 230.0	016923	2B-TZ
	TRM 253-259	--	2C-I
	Bear Cr. 8.4	017849	2D-E
Wilson	TRM 260.8	016912	3A-FB
	TRM 273-274	--	3C-I
Wheeler	TRM 277.0	016900	4A-FB
	TRM 295.9	017009	4B-TZ
	TRM 347-348	--	4C-I
	Elk River 6.0	017850	4D-E
Guntersville	TRM 350.0	017261	5A-FB
	TRM 375.2	017522	5B-TZ
	TRM 420-424	--	5C-I
Nickajack	TRM 425.5	476344	6A-FB
	TRM 469-470	--	6C-I
Chickamauga	TRM 472.3	475358	7A-FB
	TRM 490.5	475265	7B-TZ
	TRM 518-529	--	7C-I
	Hiwassee 8.5	477512	7D-E
Watts Bar	TRM 531.0	475317	8A-FB
	TRM 560.8	476041	8B-TZ
	TRM 600-601	--	8C-I
	CRM 19-22	--	8D-I
Fort Loudoun	TRM 605.5	477404	9A-FB
	TRM 624.6	475603	9B-TZ
	TRM 652	--	9C-I
Melton Hill	CRM 24.0	477064	10A-FB
	CRM 45.0	476194	10B-TZ
	CRM 59-66	--	10C-I
Tellico	LTRM 1.0	476260	11A-FB
	LTRM 15.0	476456	11B-TZ
	LTRM 21.0	476295	--

Limited Water Quality Monitoring Locations

Reservoir	Sampling Locations[a]	STORET ID No.	Description[b]
Norris	CRM 80.0	476009	12A-FB
	CRM 125.0	477186	12B-MR
	PRM 30.0	477187	12C-MR
Cherokee	HRM 53.0	475025	13A-FB
	HRM 76.0	475028	13B-MR
	HRM 91	--	13C-I
Douglas	FBRM 33.0	475081	14A-FB
	FBRM 51.0	477510	14B-MR
	FBRM 61	--	14C-I

Table 2 (Continued)

WATER QUALITY MONITORING LOCATIONS
RESERVOIR VITAL SIGNS MONITORING, 1993

Limited Water Quality Monitoring Locations

Reservoir	Sampling Locations[a]	STORET ID No.	Description[b]
Ft. Patrick Henry	SFHR 8.7	477509	15-FB
Boone	SFHR 19.0	475858	16A-FB
	SFHR 27.0	476221	16B-MR
	WRM 6.5	477511	16C-MR
South Holston	SFHR 51.0	475859	17A-FB
	SFHR 62.5	475573	17B-MR/I
Watauga	WRM 37.4	475576	18A-FB
	WRM 45.5	477513	18B-MR
Fontana	LTRM 62.0	370004	19A-FB
	LTRM 81.5	370177	19B-MR
	TkRM 3.0	370162	19C-MR
Hiwassee	HiRM 77.0	370001	20A-FB
	HiRM 85.0	370154	20B-MR
	HiRM 90	--	20C-I
Chatuge	HiRM 122.0	370003	21A-FB
	Shooting Cr. 1.5	370178	21B-FB
Nottely	NRM 23.5	120883	22A-FB
	NRM 31.0	120806	22B-MR
Ocoee No. 1	ORM 12.5	475684	23-FB
	ORM 16.5	--	--
Blue Ridge	ToRM 54.1	130032	24-FB
Tims Ford	ERM 135.0	477072	25A-FB
	ERM 150.0	475768	25B-MR
Bear Creek	BCM 75.0	017041	26-FB
Cedar Creek	CCM 25.2	017233	27-FB
Little Bear Creek	LBCM 12.5	017474	28-FB
Beech	BRM 36.0	475876	29-FB
Normandy	DRM 249.5	477453	30-FB

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

b. Numbers are keyed to Figure 1. FB - forebay; TZ - transitic zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR means that sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations), and as a mid-reservoir location in the evaluation of the water qualit data (sampling done in summer at higher water level elevations).

Table 3
RESERVOIR VITAL SIGNS - 1993
WATER QUALITY MONITORING STRATEGY

Description	Sample Collection Depths	Monitoring Strategy[a] Basic	Limited
Field Measurements			
Hydrolab/ (temperature, pH, dissolved oxygen, and conductivity)	0.3,1.5,4,6,8[b] etc.	monthly	monthly
Secchi Depth	--	monthly	monthly
Fecal Coliform	0.3 (surface grab)	monthly	NA
Turbidity	composite (& bottom)[c]	monthly	monthly
Hydrogen Sulfide	bottom[c]	as needed[d]	
Laboratory Measurements			
Chlorophyll-a	composite[e]	monthly	monthly
Nutrients			
Organic Nitrogen	composite (& bottom)[c]	monthly	April & August
Ammonia Nitrogen	composite (& bottom)	monthly	April & August
Nitrite & Nitrate Nitrogen	composite (& bottom)	monthly	April & August
Total Phosphorus	composite (& bottom)	monthly	April & August
Dissolved Ortho phosphorus	composite (& bottom)	monthly	April & August
Organic Carbon			
Total Organic Carbon	composite (& bottom)	monthly	April & August
Color and Solids			
Color	composite (& bottom)	monthly	NA
Suspended Solids	composite (& bottom)	monthly	NA

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[a] Basic monthly and April through September. Limited monthly is April through October, with some variables measured only in April and August.

[b] In situ Hydrolab measurements were made at the depths indicated and at regularly spaced intervals (2-4 meters) from the water surface to the bottom of the water column. These measurements were also made at intermediate depths any time the temperature changed by more than 2°C or the dissolved oxygen changed by more than 1 mg/l.

[c] Bottom grab samples were only collected as part of the basic sampling strategy, except for hydrogen sulfide. Bottom indicates a grab sample collected three meters above the bottom at forebay locations and one meter above the bottom at transition zone locations.

[d] When low dissolved oxygen was measured near the bottom of the reservoir (i.e., less than 1 mg/l), the bottom water grab sample was smelled to check for the presence of hydrogen sulfide (rotten egg odor). If detected, the concentration was measured.

[e] Composite indicates a photic zone composite sample with the photic zone defined as four meters or twice the Secchi depth, whichever is greater.

Table 4

RESERVOIR VITAL SIGNS MONITORING - WATER PHYSICAL/CHEMICAL MEASUREMENTS, 1993

EPA Storet Code	Description	Units	Detection Limits
	Field Measurements		
	Hydrolab		
00010	Temperature	°C	--
00300	Dissolved Oxygen	mg/l	--
00400	pH	Std. units	--
00094	Conductivity	micromhos	--
00078	Secchi Depth	meters	0.1 meters
31616	Fecal Coliform	colonies/100mL	1/100 mL
82078	Turbidity	NTU	1 NTU
00745	Hydrogen Sulfide	mg/l	0.00025
	Laboratory Measurements		
32211	Chlorophyll-a	ug/l	1 ug/l
	Nutrients		
00605	Organic Nitrogen	mg/l	0.02 mg/l
00610	Ammonia Nitrogen	mg/l	0.01 mg/l
00630	Nitrite & Nitrate Nitrogen	mg/l	0.01 mg/l
00665	Total Phosphorus	mg/l	0.002 mg/l
00671	Dissolved Ortho phosphorus	mg/l	0.002 mg/l
	Organic Carbon		
00680	Total Organic Carbon	mg/l	0.2 mg/l
	Color and Solids		
00080	Color	PCU	1 PCU
00530	Suspended Solids	mg/l	1 mg/l

HYDROLOGIC OVERVIEW OF WATER YEAR 1993

Many water quality characteristics (e.g., temperature, dissolved oxygen conductivity, water clarity, suspended solids, etc.) exhibit changes due to seasonal variations in atmospheric temperature and rainfall. During those times of year when runoff is minimal (normally August-October), streamflow is largely derived from the base flow of groundwater. Because of greater contact between the water and the soil/rock and the longer groundwater residence times, groundwater contains more dissolved minerals (i.e., higher concentrations of hardness and alkalinity, higher pHs and conductivities, etc.) than does surface water. During those times of the year when runoff is higher (normally January-March), streamflow is principally derived from rapid overland runoff that allows little time for mineral dissolution.

Consequently, during those times of the year with higher rainfall and subsequent higher flows, base flow accounts for a smaller proportion of the total streamflow, resulting in lower concentrations of most dissolved constituents. In addition, periods of intense rainfall and high overland flows wash off or "flush" a watershed and transport soil particles to streams, often carrying large loads of nonpoint source pollutants (nutrients, suspended solids, fecal bacteria, etc.) to streams and rivers.

In addition to flood control, electric power generation, and navigation, an important benefit of the TVA's system of dams and reservoirs is its ability to maintain adequate streamflow during extended periods of low rainfall and low runoff by the controlled release of water from tributary storage impoundments. However, this alteration of natural streamflow (diminishing high flows during floods and augmenting low flows during droughts) by storing and then slowly releasing water from tributary storage impoundments creates conditions of strong thermal stratification and low dissolved oxygen in the bottom waters of these tributary storage impoundments.

From a water quality perspective, the lower streamflows occurring during the warmer summer months, combined with naturally occurring higher water temperatures and lower dissolved oxygen concentrations, result not only in lakes becoming thermally stratified but also having less water and less oxygen available to dilute and assimilate the wastes discharged to them. In addition, the warmer water temperatures increase aquatic biological processes (respiration, bacteriological decomposition, etc.). This results in oxygen being used at a faster rate, which can further lower oxygen concentrations. In combination, these factors (low streamflows and diminished assimilative capacity, warmer temperatures and higher biological oxygen consumption rates, and the inhibition of mixing and reaeration caused by thermal stratification) result in low dissolved oxygen concentrations and adversely impact the health of aquatic life. The summer of 1993 was a case in point. July 1993 was the hottest month on record (since 1890s) in the Tennessee Valley. Valley-wide temperatures averaged almost 83°F (28.3°C), about 5°F (2.8°C) above normal for July. For example, in Chattanooga, all 31 days in July had temperatures above 90°F (32.2°C), with temperatures up to 104°F

(40.0°C) and 15 days with temperatures 98°F (36.7°C) or higher. This record-breaking heat (and low streamflows) resulted in high water temperatures in the Tennessee River. In fact, all nine mainstem Tennessee River reservoirs had surface water temperatures that exceeded 86°F (30.0°C), some with highs up to 90°F (32.2°C).

In addition, Tennessee Valley rainfall and runoff were well below normal in the summer of 1993. In July, Valley-wide rainfall averaged only 1.76 inches (45mm), a deficit of 3 inches (76mm) below the long-term July mean of 4.77 inches (121mm). As a result, rainfall runoff was only 0.66 inches (17mm), compared to the long-term July mean of 1.03 inches (26mm). Further, runoff was significantly lower in the western half of the Tennessee Valley than in the eastern half. In July, runoff above Chattanooga was 90 percent of the long-term mean, while runoff was only 64 percent of the long-term mean above Kentucky Dam. For the period of January through July, runoff above Chattanooga was 80 percent of the long-term mean, while runoff was 72 percent of the long-term mean above Kentucky Dam. Consequently, flows in the Tennessee River in 1993 increasingly fell below the long-term average as the river flowed downstream from Fort Loudoun Dam to Kentucky Dam.

The high temperatures and low flows of July 1993 adversely impacted dissolved oxygen concentrations in the Tennessee River, particularly in the downstream reservoirs. In mid-July, hypolimnetic anoxia (DOs equal to 0 mg/L) was found in the forebays of Kentucky, Pickwick, Wilson, Wheeler, and Chickamauga Reservoirs. All-time low concentrations of DO were recorded in the releases from Chickamauga Dam on July 16 (2.2 mg/L) and Nickajack Dam on July 19 (1.8 mg/L) when flows from both dams were only 9000 cfs. During the first two weeks of July (July 1 to 15), daily flows averaged only about 17,250-17,500 cfs at Chickamauga and Nickajack Dams, or about 55 percent of the normal flow for this period of time. Once the effects of the high temperatures and low flows on DOs in the Tennessee River were recognized, flows were immediately increased (by drawing water from tributary storage reservoirs) and DO concentrations improved. For example, at Chickamauga Dam, from July 16-31, average daily flows were increased to an average of about 24,500 cfs (about 80 percent of the normal flow for July) and DOs in the releases increased to an average of about 4.3 mg/L, ranging from 3.2 to 6.3 mg/L. Compounding this whole situation were the record-setting rains and flooding occurring in the mid-West along the Mississippi and Missouri Rivers during the "flood of the century." During this period, TVA minimized discharge from the Tennessee River through Kentucky Dam so as to not increase flood crests on the lower Ohio and Mississippi Rivers and worsen the already catastrophic flooding in those areas.

Obviously, examining atmospheric temperature, rainfall, and runoff patterns during 1993 aids in interpretation of the Vital Signs monitoring data and the ecological health assessments of the streams and reservoirs.

Atmospheric Temperature

Average annual temperature in the TVA region is approximately 60 degrees Fahrenheit, °F (15.6 degrees Celsius, °C), with January usually being the coldest month and July the hottest. According to U.S. Department of Commerce (USDOC) climatic data, atmospheric temperatures in the TVA region averaged only about 0.3°F (0.2°C) warmer than normal in 1993; however, 1993 was a year of extremes (USDOC, 1993). January and July were unusually warm with 5.0°F (2.8°C) and 4.7°F (2.6°C) above normal, respectively; while, March and April were below normal with departures greater than -2.0°F (-1.1°C) (Figure 2a).

In review, 1993 began with an unusually warm January but cooled to below normal in February. As has often occurred in the last 15 years, another cold spring with late freezes was experienced. A record-breaking late season blizzard struck the Valley in mid-March and hit hardest in the eastern half. Summer was hotter than normal, with Tennessee, Alabama, Georgia, North Carolina, and Virginia all having the hottest July on record since the 1890s. The persistent heat and high humidity created great stress on livestock and people. The daily records for Chattanooga Airport provide an indication of the unusual conditions. All 31 days had maximums above 90°F (32.2°C), with the observed maximums ranging from 92°F (33.3°C) to 104°F (40°C) and 15 days of 98°F (36.7°C) or higher. The last four months had near or below normal temperatures, and the annual average temperature was only slightly above normal.

Rainfall

The Tennessee River basin averages about 51-52 inches (1295-1320 millimeters (mm) of precipitation annually. However, there are large variations in the spatial distribution of precipitation. The range is from a high of about 93 inches (2360mm) in the mountains of southwestern North Carolina near Highlands, North Carolina, to a low of about 37 inches (940mm) in the shielded valleys of these same mountains near Asheville, North Carolina. Elsewhere in the Valley, precipitation usually ranges within five to ten inches (127mm to 254mm) of the basin average. March is usually the wettest month and October the driest.

Rainfall across the Tennessee Valley in 1993 averaged only 39.8 inches (1011mm), almost 12 inches (about 300mm) or 23 percent less than the long-term 100-year average. The diminished rainfall in 1993 followed another dry year, 1992, when annual rainfall was about 8 inches (204mm) or about 15 percent below the long-term average. The period January-May 1992 ranked as one of the ten driest on record in the Tennessee Valley. During 1993, only the month of December had rainfall greater than normal (6.1 inches [155mm]) compared to normal December rainfall of 4.8 inches (122mm); the greatest rainfall deficit occurred in July (1.8 inches [45mm] compared to the normal July rainfall of 4.8 inches [122mm]). In addition to the extremes of December and July, March and September precipitation was close to average while February, April, June, and October were more than an inch (254mm) below average (figure 2b). During March 1993, the Tennessee Valley received the equivalent of 5.4 inches (137mm) of rain, much of this during the "Winter Snow Storm of the Century" when many areas received record amounts (greater than 20 inches [about 500mm]) of snowfall.

The unusually persistent hot weather and below average rainfall in the summer was related to an unusual upper air pattern, which kept the storm track well west and north of the region and allowed very few cold fronts to reach the Tennessee Valley. This nearly stationary position of a strong upper air trough over the Rocky Mountains was associated with the record flooding in the middle of the country and kept the Southeast hot and dry. This general pattern was most persistent in the summer, but frequently alternated with a pattern having an upper trough over or to the east of the Valley in the other seasons. This latter trough kept most storms associated with it to the south of the TVA region. These two upper air patterns dominated the weather during 1993, so significant rainfall events tended to occur only when there was a transition period between one and the other.

Streamflow

Streamflow varies seasonally with rainfall, although during the spring and summer evaporation and transpiration also significantly reduce the amount of runoff. Watersheds that receive 50 to 60 inches (1270 to 1524mm) of precipitation annually average about 20 to 30 inches (508 to 762mm) of runoff. In a normal year, the discharge of the Tennessee River (approximately 66,000 cfs [1868 meters^3/second]) corresponds to about 22 inches (about 560 mm) of runoff distributed over the 40,900 square mile (105,930 square kilometer drainage basin. A larger amount of runoff occurs during the wet winter and spring months (January-April) when precipitation events are frequent, temperatures are low, and there are no leaves or deciduous vegetation. Consequently, soil absorption, evaporation, and plant transpiration losses are low at that time of year, and both runoff and streamflow are higher than during the summer and autumn months. Average rainfall in the eastern and western portions of the Tennessee Valley (above and below Chattanooga) is about equal. However, topographic differences (viz. the largely steep and mountainous terrain in the eastern portion of the Valley, compared with the mostly flat and rolling terrain in the western portion of the Valley) and generally shallow soils result in higher amounts of runoff above Chattanooga.

In 1993, runoff for the Tennessee River basin was well below normal, particularly from February through July and particularly in the western half of the Valley. Runoff above Chattanooga was only slightly below normal in 1993, 21.4 inches, or 92 percent of the long-term mean of 23.4 inches. However, runoff above Kentucky Dam was only 17.6 inches, a deficit of almost 5 inches and only 78 percent of the long-term mean of 22.5 inches (figure 2c). The 1993 releases from tributary reservoirs in the western part of the Valley (e.g., Normandy, Tims Ford, etc.) were below their long-term means, while the releases from the tributary reservoirs in the eastern part of the Valley (e.g., South Holston, Watauga, etc.) were close to normal. Consequently, flows in the Tennessee River in 1993 increasingly fell below the long-term average as the river flowed downstream from Fort Loudoun Dam to Kentucky Dam.

FIGURE 2. Temperature, Precipitation, and Runoff – Tennessee River Basin, 1993

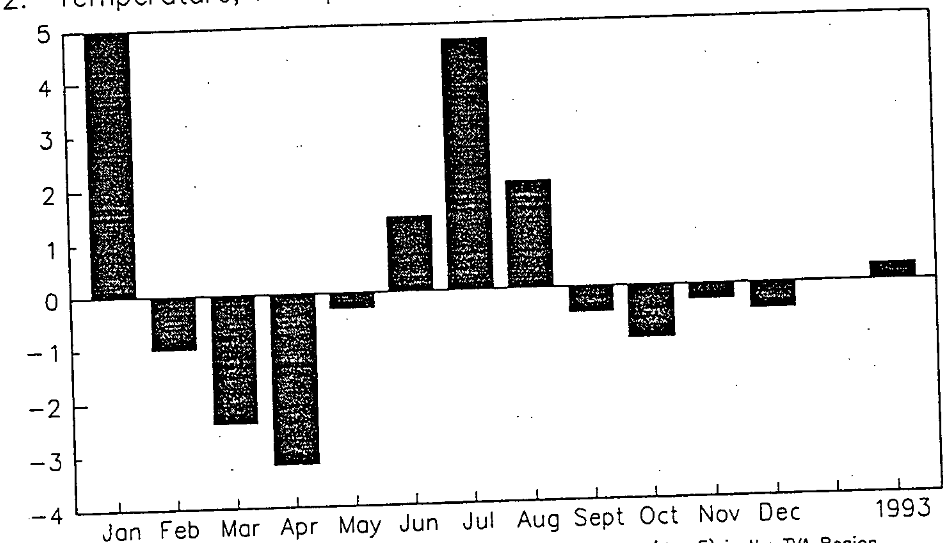


FIGURE 2a. Temperature Departures From Long–Term Mean (deg F) in the TVA Region

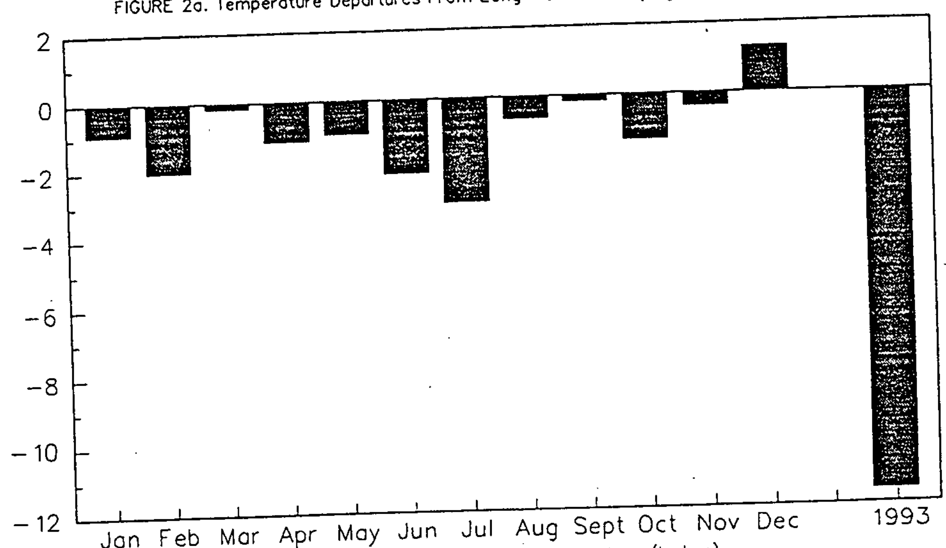


FIGURE 2b. Precipitation Departures From Long–Term Mean (Inches)
For The Tennessee River Basin

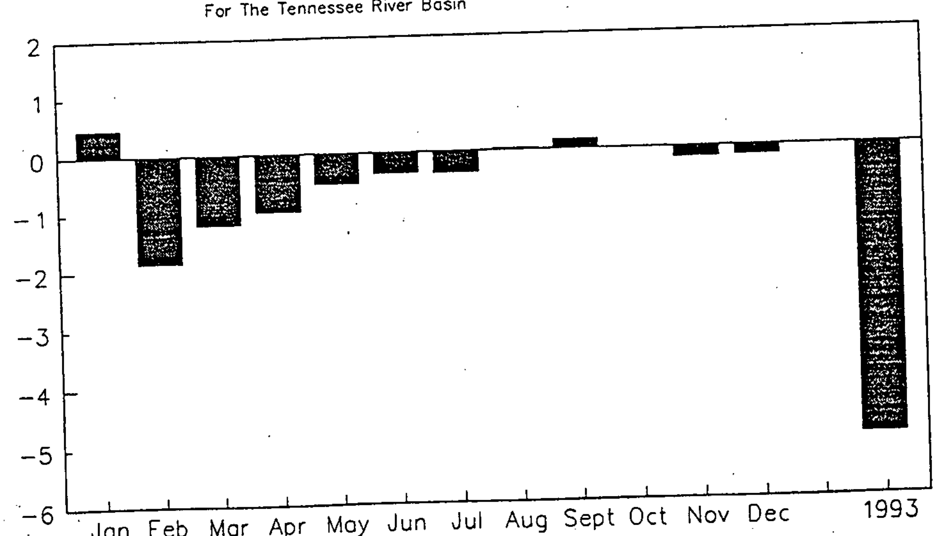


FIGURE 2c. Runoff Departures From Long–Term Mean (Inches)
For Tennessee River Basin, Above Kentucky Dam

aquatic life in the tailrace of Chickamauga dam (i.e. inflow sampling site on Nickajack Reservoir), the inflow sampling site's DO rating used in the overall ecological health evaluation of Nickajack Reservoir was "poor." Based on no DO's actually being measured in the hypolimnion of the forebay of Nickajack Reservoir below 2 mg/l, the forebay sampling site's DO rating was "excellent".

Values of pH varied over a rather narrow range, from 7.0-8.0 during the summer of 1993. At the forebay, the highest chlorophyll-a concentration of about 10 ug/l was measured in May and averaged about 6 ug/l in the summer of 1993. Consequently, the chlorophyll-a rating used in the 1993 ecological health evaluation for Nickajack Reservoir was "good" (i.e. average concentration between 3 and 10 ug/l).

<u>Chickamauga Reservoir</u>

<u>Water</u>--During the summer of 1993 (April-September), coolest surface water temperatures in Chickamauga Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 17.0°C to a maximum of 31.7°C at the forebay; from 16.2°C to 30.1°C at the transition zone; and from 19.1°C to 28.8°C in the Hiwassee River embayment. The State of Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Dissolved oxygen (DO) concentrations at the 1.5-meter depth ranged from a low of 6.9 mg/l in September to a high of 11.4 mg/l in April at the forebay; from 5.7 mg/l in September to 10.3 mg/l in April at the transition zone; and from 7.3 mg/l in August to

9.9 mg/l in April at the sampling location in the Hiwassee River embayment. At the inflow sampling site (i.e. the tailrace of Watts Bar dam) a minimum DQ of 3.7 mg/l was recorded in August. The State of Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature data depict seasonal warming and weak thermal stratification in Chickamauga Reservoir from May through July. The maximum observed surface to bottom temperature differentials occurred in July. Temperature differentials were 5.5°C at the forebay, 3.2°C at the transition zone, and 4.1°C in the Hiwassee River embayment. There was also an oxycline at the forebay and transition zone in June and July when differences between surface and bottom DO's were about 6 to 9 mg/l at the forebay and transition zone. In July 1993, a minimum DO of less than 0.1 mg/l was measured on the bottom at the forebay and a minimum of 1.6 mg/l was measured on the bottom at the transition zone. Better DO conditions were observed in the Hiwassee River embayment portion of Chickamauga Reservoir, where maximum DO differentials were only 1.7 mg/l and near-bottom DO's only slightly below 6 mg/l.

DO ratings used in the overall reservoir ecological health evaluation for Chickamauga Reservoir were "good" at the forebay; "good to excellent" at the transition zone; "excellent" in Hiwassee River embayment; and "fair" at the inflow. The forebay would have rated higher had it not been for the low near-bottom oxygen concentrations which existed in July. The fair rating at the inflow sampling site on Chickamauga Reservoir was a result of oxygen levels being measured about 1.5 mg/l below the Tennessee criteria (5 mg/l, at the 1.5 meter depth) in the releases from Watts Bar dam.

Values of pH ranged from 6.8 to 8.8 on Chickamauga Reservoir in 1993. Near-surface pH values exceeding 8.5 (and DO saturation values exceeding 100 percent) were observed on only two occasions (April and July), both at the forebay. Both of these periods of high pH and high oxygen saturations were also coincident with high chlorophyll-a concentrations, indicative of periods of high photosynthetic activity. The State of Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Total nitrogen (TN), total phosphorus (TP), and dissolved ortho phosphorus (DOP) were low in the Tennessee River portion of Chickamauga Reservoir in 1993. TN averaged only 0.37 mg/l at the forebay, the lowest TN concentration measured at any of the Tennessee River sampling sites in 1993. At both the forebay and the transition zone, TP and DOP concentrations averaged only about 0.026 mg/l and 0.005 mg/l, respectively, and were among the lowest TP and DOP concentrations measured at any of the Tennessee River sampling sites in 1993. Because of these low concentrations (and because TN/TP ratios often exceeded 20), periods of phosphorus limitation on algal productivity were likely to have occurred.

In 1993, Chickamauga Reservoir chlorophyll-a concentrations averaged 8.5 ug/l, 7.8 ug/l, and 5.5 ug/l, respectively, at the forebay, transition zone, and Hiwassee River embayment. Consequently, the chlorophyll-a ratings used in the 1993 ecological health evaluation for Chickamauga Reservoir were "good" (i.e. falling in the 3 to 10 ug/l range) at all three locations.

HIWASSEE RIVER WATERSHED

Hiwassee Reservoir

Water--The average flow through Hiwassee Reservoir was about 107 percent of normal; the average residence time was about 99 days. The reservoir is strongly stratified, with a maximum temperature difference in the water column at the forebay of 20.9°C in July. The maximum surface temperature was 28.7°C in July, both at the forebay and mid-reservoir. North Carolina's standard for maximum temperature of Class C waters is 29°C. Low DO water (DO <5.0 mg/l) first appeared at mid-reservoir in June and at the forebay in July, at the bottom of the water column at both locations. Depleted DO water (DO <2.0 mg/l) occurred at both locations at the bottom of the water column in August and September. The limited area of DO depletion provided ratings for the reservoir ecological health index of fair at the forebay and good at mid-reservoir.

Conductivities averaged about 30 umhos/cm in April, and increased slightly in the DO-depleted area to a maximum of 40 and 38 umhos/cm at the forebay and mid-reservoir, respectively. The average conductivity in Hiwassee Reservoir was the fourth-lowest of the 19 tributary reservoirs. Only in June, July, and August did pH reach or exceed 8.4 SU, and only in the four- to eight-meter depth. Summer DO concentrations were normally higher at these depths.

the 33 tributary reservoir stations. Organic and nitrate nitrogen concentrations were 0.03 and 0.09 mg/l in April, and 0.06 and 0.04 mg/l in August. Total and dissolved ortho phosphorus concentrations were 0.005 and 0.003 mg/l in April, and 0.002 and <0.002 in August. Total organic carbon concentrations were very low--0.8 and 1.4 mg/l in April and August, respectively. Chlorophyll-a concentrations averaged 2.5 ug/l. This chlorophyll concentration is considered fair in the reservoir ecological health index. Secchi depths varied from 1.6 meters in April to 3.6 meters in July, September, and October.

WATTS BAR RESERVOIR, FORT LOUDOUN RESERVOIR, AND MELTON HILL RESERVOIR WATERSHED

Watts Bar Reservoir

Water--During the summer of 1993 (April-September), surface water temperatures ranged from a minimum of 18.3°C in April to a maximum of 30.2°C in July in the forebay; and from 16.7°C to 29.8°C (for the same months) at the transition zone. The State of Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Values for DO at the 1.5-meter depth ranged from a low of 6.5 mg/l in September to a high of 12.6 mg/l in April at the forebay; and from 7.1 mg/l to 11.3 mg/l (for the same months) at the transition zone. At the inflow sampling site on the Tennessee River arm of Watts Bar Reservoir (i.e. the tailrace of Fort Loudoun dam) a minimum DO of 3.9 mg/l was recorded in September.

At the inflow sampling site on the Clinch River arm of Watts Bar Reservoir (i.e. the tailrace of Melton Hill dam) a minimum DO of 6.3 mg/l was recorded in March. The State of Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature and dissolved oxygen data show that Watts Bar Reservoir developed a moderate degree of both thermal and oxygen stratification throughout most of the summer of 1993. For the period April through August, monthly surface to bottom temperatur differentials were: 5.2°C, 5.5°C, 7.4°C, 7.3°C, and 4.0°C at the forebay; and 2.3°C, 2.6°C, 3.9°C, 6.2°C, and 2.2°C at the transition zone.

DO versus depth data show that a rather strong oxycline also developed in Watts Bar Reservoir, particularly from June through August. During these three months, surface to bottom differences in DO were: 9.2 mg/l, 9.2 mg/l, and 5.8 mg/l at the forebay; and 7.2 mg/l, 5.8 mg/l, and 3.1 mg/l at the transition zone. At the forebay, near-bottom DO concentrations in the hypolimnion were less than 2 mg/l in June and July. In addition, the proportion c the hypolimnion with low DO's (i.e., less than 2 mg/l) averaged about 13% of the total cross sectional area, higher than in any other Tennessee River reservoir. The minimum observed DO concentration in Watts Bar Reservoir in 1993 was 0.6 mg/l at the bottom of the forebay in July; but DO's were never less than 4 mg/l at the transition zone.

DO ratings used in the overall reservoir ecological health evaluation for Watts Bar Reservoir were "poor" at the forebay;

"excellent" at the transition zone and at the inflow sampling site on the Clinch River; and "fair" at the inflow site on the Tennessee River. The low forebay rating was due to the large proportion of the forebay hypolimnion with low DO's (i.e. less than 2 mg/l). The fair rating at the inflow sampling site on the Tennessee River arm of Watts Bar Reservoir was a result of oxygen levels being measured about 1 mg/l below the Tennessee criteria (5 mg/l, at the 1.5 meter depth) in the releases from Fort Loudoun dam.

Historically, pH's measured in Watts Bar Reservoir have been higher than other Tennessee River sampling sites. This is due to the addition of the cool, clear, well-oxygenated, nitrate rich, and hard water of the Clinch River which combines with the Tennessee River (and Watts Bar Reservoir) at Tennessee River Mile (TRM) 567.9, about 7 miles upstream from the transition zone sampling site. In the summer of 1993, values of pH ranged from 6.8 to 9.0 on Watts Bar Reservoir. Throughout the summer (April-September), near-surface values of pH frequently exceeded 8.5 at both the forebay and the transition zone, with DO saturation values commonly exceeding 100 percent, indicating high rates of photosynthesis. The State of Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

The average total phosphorus concentrations observed in Watts Bar Reservoir (0.029 mg/l at the forebay and 0.035 mg/l at the transition zone) were among the lowest of the Tennessee River Vital Signs Monitoring locations in 1993. In addition, the average dissolved ortho phosphorus concentrations of 0.007 mg/l and 0.004 mg/l, respectively, at the forebay and transition zones were also among the lowest observed at any of the Tennessee River Vital Signs Monitoring locations in 1993. TN/TP ratios on Watts Bar Reservoir are higher than on any other Tennessee River reservoir . The low phosphorus concentrations in combination with the relatively high nitrogen concentrations (supplied by both the Clinch and Tennessee River inflows) results in the high TN/TP ratios in Watts Bar (particularly at the transition zone) and suggest periods of phosphorus limitation on primary productivity.

The highest chlorophyll-a concentrations were measured in August at the forebay (10 ug/l) and in May at the transition zone (11 ug/l). Surface concentrations of chlorophyll-a averaged about 7 ug/l at the forebay and about 8 ug/l at the transition zone in 1993. Consequently, the chlorophyll-a ratings used in the 1993 ecological health evaluation for Watts Bar Reservoir were "good" (i.e., falling in the 3 to 10 ug/l range) at both locations.

Forebay Secchi depth and suspended solids measurements averaged 1.5 meters and 6.3 mg/l, respectively. These values indicate the light transparency of Watts Bar Reservoir forebay to be relatively high compared with other main stem Tennessee River reservoirs in 1993.

Fort Loudoun Reservoir

Water--Temperature and dissolved oxygen (DO) data show the establishment of stratification (both a thermocline and oxycline) in Fort Loudoun reservoir which persisted throughout most of the summer (April through September) of 1993. Summer surface water temperatures were warmest in July and coolest in April. They

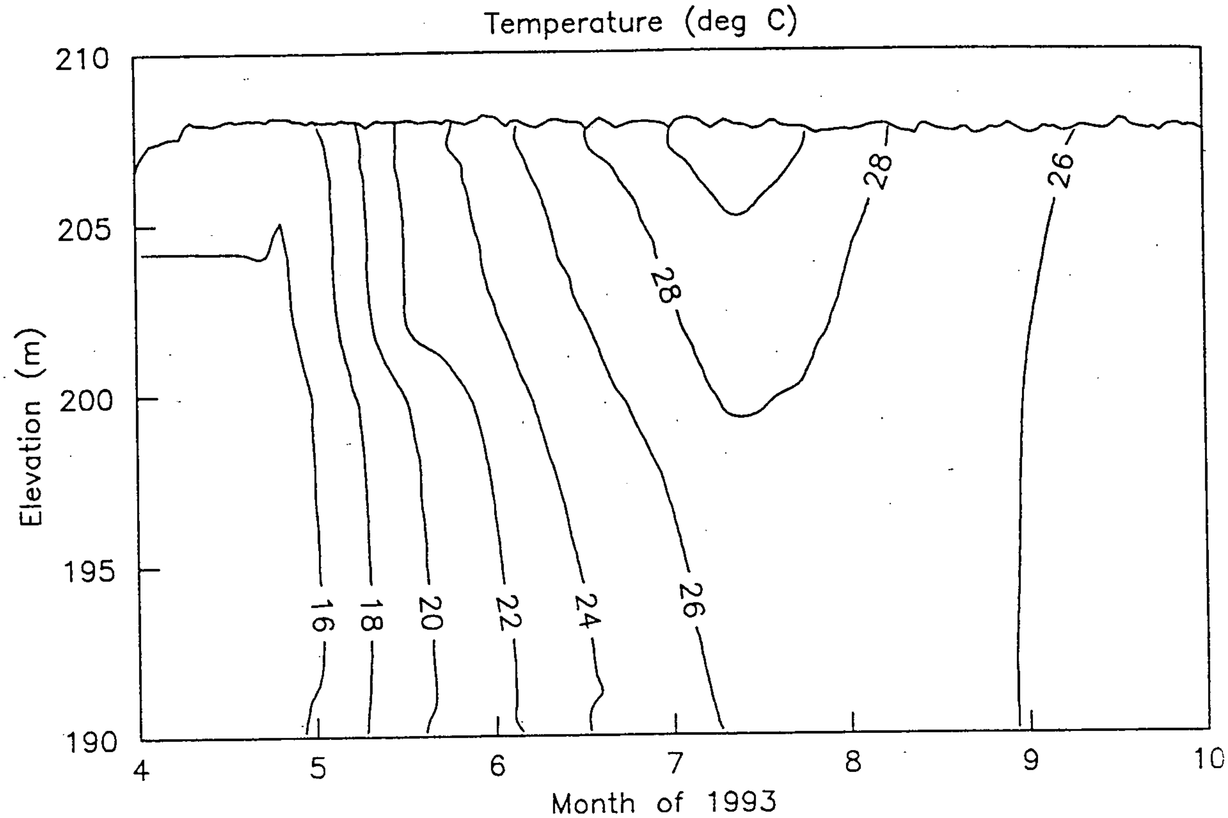
Table 9

	Chickamauga Forebay (TRM 472.3)				Chickamauga Transition (TRM 490.5)				Chickamauga Embayment (HiRM 8.5)			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	88	24.539	15.100	31.700	60	23.973	15.300	30.100	53	21.928	16.700	28.800
Dissolved Oxygen (mg/l)	88	6.502	0.020	11.500	60	6.678	1.200	10.700	53	7.868	5.800	10.200
Percent Saturation (%)	88	76.069	0.200	129.300	60	77.172	14.800	126.800	53	88.640	69.000	110.300
pH (s.u.)	88	7.598	6.800	8.800	60	7.575	6.900	8.600	53	7.200	6.800	7.600
Conductivity (umhos/cm)	88	177.602	162.000	192.000	60	177.567	161.000	190.000	53	139.585	100.000	169.000
Organic N (mg/l)	16	0.144	0.020	0.310	12	0.197	0.030	0.900	12	0.172	0.040	0.430
Ammonia - N (mg/l)	16	0.043	0.010	0.110	12	0.046	0.010	0.090	12	0.079	0.010	0.130
Nitrate+nitrite - N (mg/l)	16	0.183	0.010	0.320	12	0.219	0.110	0.340	12	0.157	0.110	0.210
Total Nitrogen (mg/l)	16	0.370	0.230	0.540	12	0.462	0.310	1.140	12	0.409	0.260	0.620
Total Phosphorus (mg/l)	16	0.026	0.020	0.040	12	0.026	0.010	0.050	12	0.043	0.030	0.060
Dissolved Ortho - P (mg/l)	16	0.005	0.002	0.010	12	0.006	0.002	0.010	12	0.007	0.003	0.020
TN/TP Ratio	16	15.097	8.000	22.000	12	20.393	7.750	50.000	12	9.829	6.500	14.000
Total Organic Carbon (mg/l)	16	1.908	1.700	2.300	12	1.933	1.800	2.200	12	2.342	1.800	2.700
Chlorophyll-a (ug/l)	8	8.500	7.000	10.000	6	7.833	3.000	13.000	6	5.500	3.000	12.000
Secchi Depth (m)	4	1.167	1.000	1.300	5	1.196	1.000	1.300	6	0.933	0.770	1.250
Suspended Solids (mg/l)	16	6.167	3.000	17.000	12	7.000	2.000	21.000	12	11.833	7.000	20.000
True Color (PCU)	16	6.333	1.000	10.000	12	7.917	5.000	10.000	12	14.583	10.000	20.000
Fecal Coliform (#/100ml)	8	10.000	10.000	10.000	6	10.000	10.000	10.000	5	68.000	10.000	300.000

	Watts Bar Forebay (TRM 531.0)				Watts Bar Transition (TRM 560.8)			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	118	22.981	13.100	30.200	69	23.067	14.400	29.800
Dissolved Oxygen (mg/l)	118	6.458	0.400	12.600	69	7.933	4.000	11.500
Percent Saturation (%)	118	73.773	4.600	139.700	69	91.233	46.000	139.500
pH (s.u.)	118	7.787	6.800	9.000	69	7.832	6.900	8.900
Conductivity (umhos/cm)	118	184.975	146.000	211.000	69	191.768	162.000	218.000
Organic N (mg/l)	17	0.187	0.020	0.490	12	0.218	0.040	0.470
Ammonia - N (mg/l)	16	0.024	0.010	0.080	12	0.033	0.010	0.060
Nitrate+nitrite - N (mg/l)	17	0.244	0.020	0.450	12	0.277	0.130	0.420
Total Nitrogen (mg/l)	16	0.461	0.220	0.650	12	0.527	0.300	0.750
Total Phosphorus (mg/l)	17	0.029	0.020	0.050	12	0.035	0.020	0.050
Dissolved Ortho - P (mg/l)	17	0.007	0.002	0.020	12	0.004	0.002	0.008
TN/TP Ratio	16	15.990	11.000	26.500	12	16.531	7.500	37.500
Total Organic Carbon (mg/l)	17	2.008	1.600	2.500	12	1.892	1.700	2.200
Chlorophyll-a (ug/l)	8	7.167	4.000	10.000	6	7.833	3.000	11.000
Secchi Depth (m)	6	1.545	1.200	2.000	6	1.233	1.000	1.520
Suspended Solids (mg/l)	17	6.308	3.000	11.000	12	8.667	4.000	15.000
True Color (PCU)	17	7.308	5.000	10.000	12	7.167	1.000	10.000
Fecal Coliform (#/100ml)	8	10.000	10.000	10.000	6	10.000	10.000	10.000

Figure 16

Chickamauga Reservoir – TRM 472.3



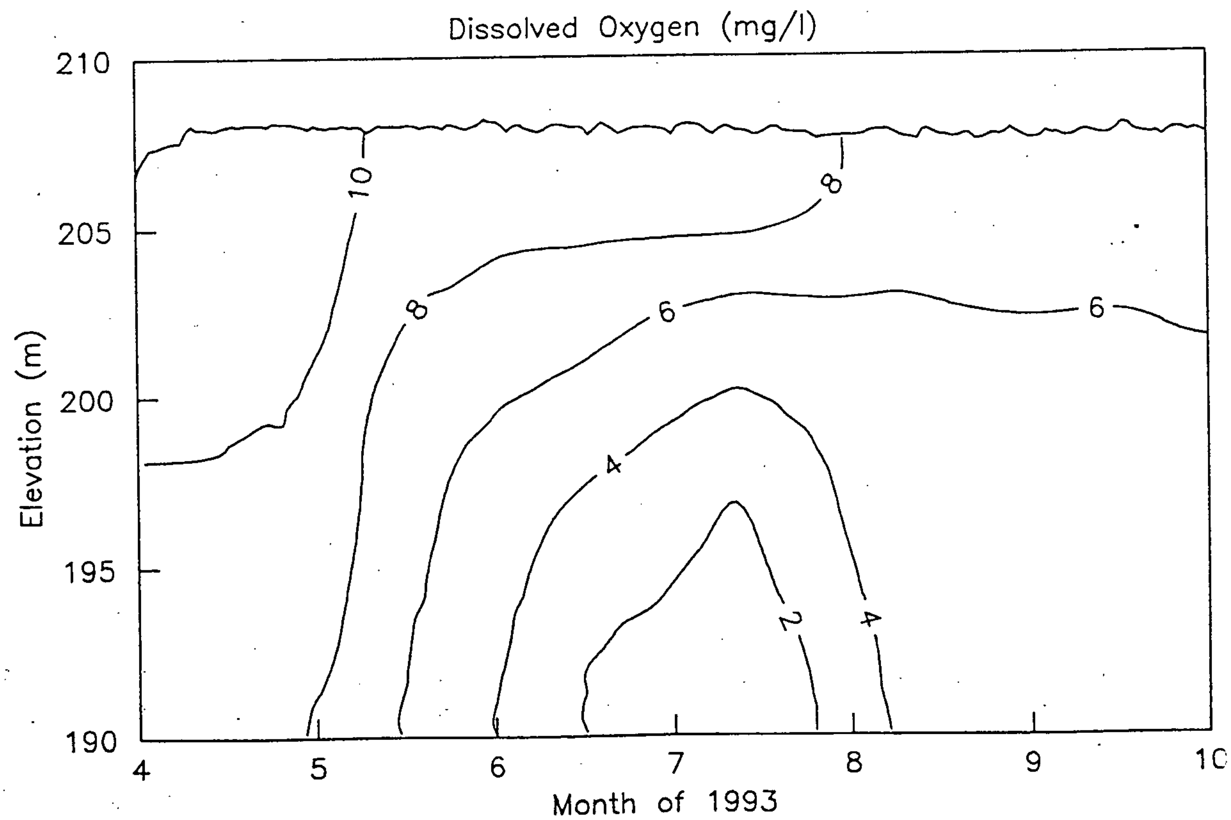


Figure 17

Chickamauga Reservoir – TRM 490.5

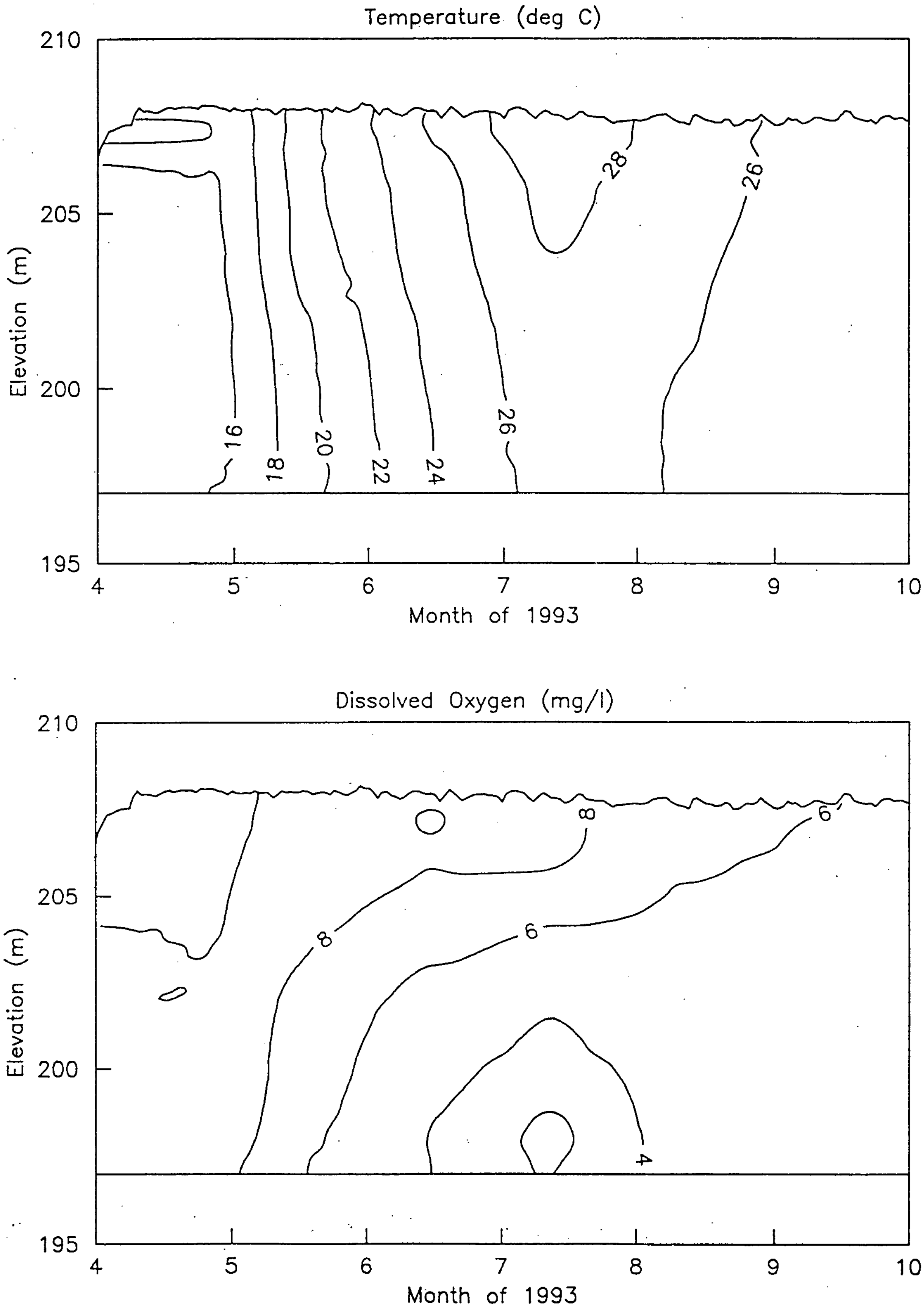
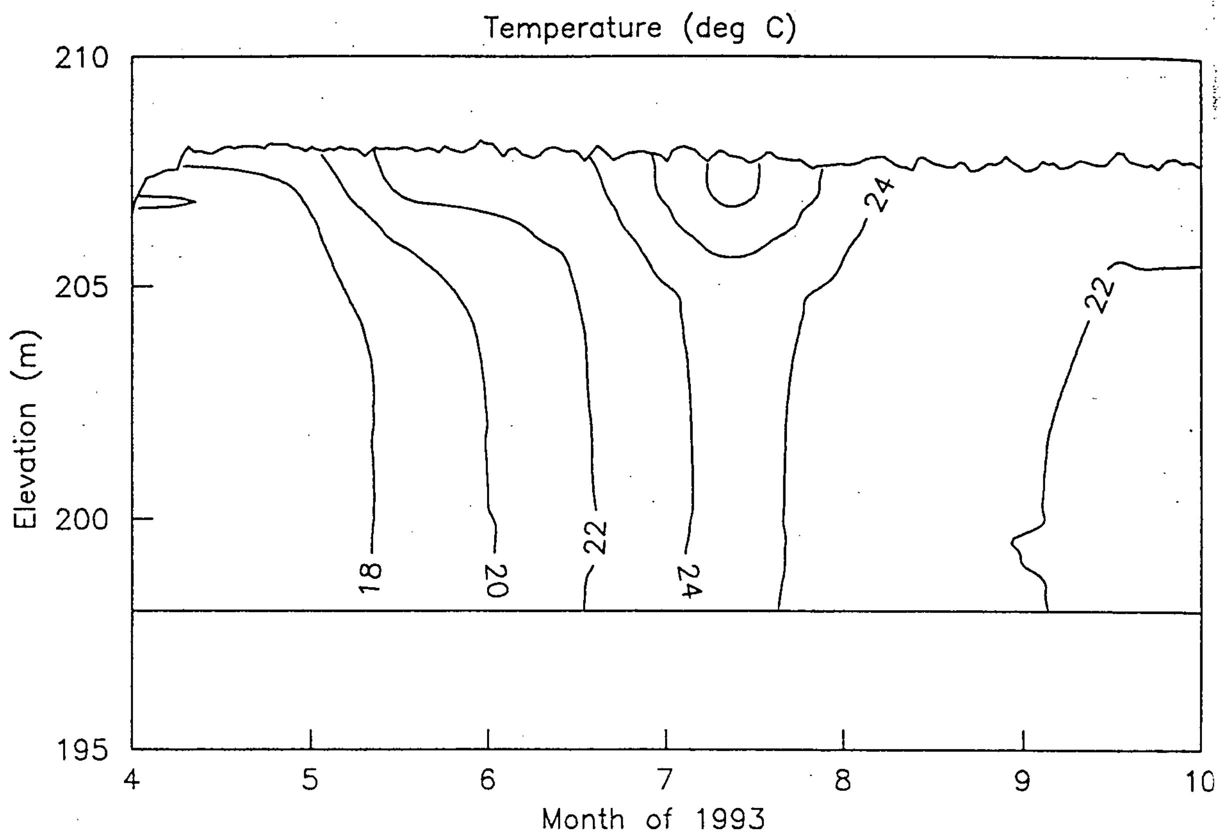


Figure 18

Chickamauga Reservoir – Hiwassee River Mile 8.5



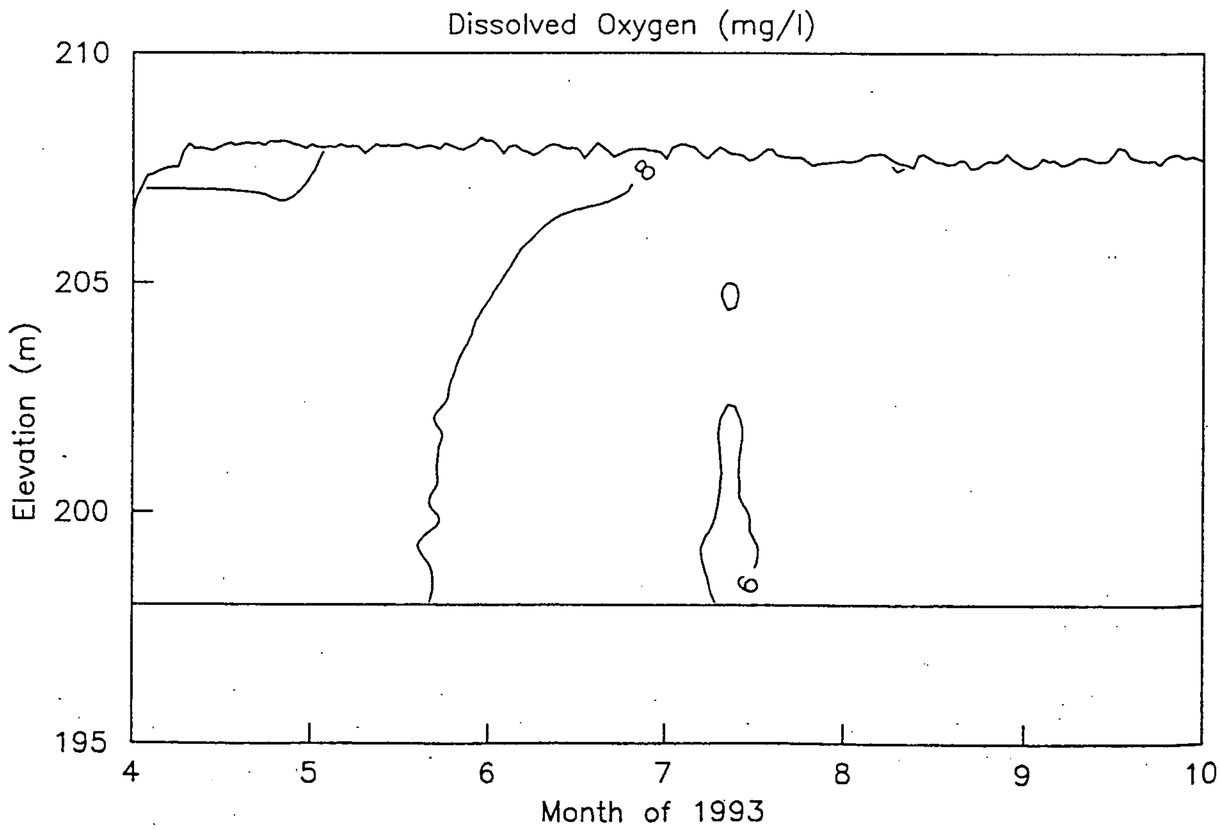


Figure 19

Watts Bar Reservoir – TRM 531.0

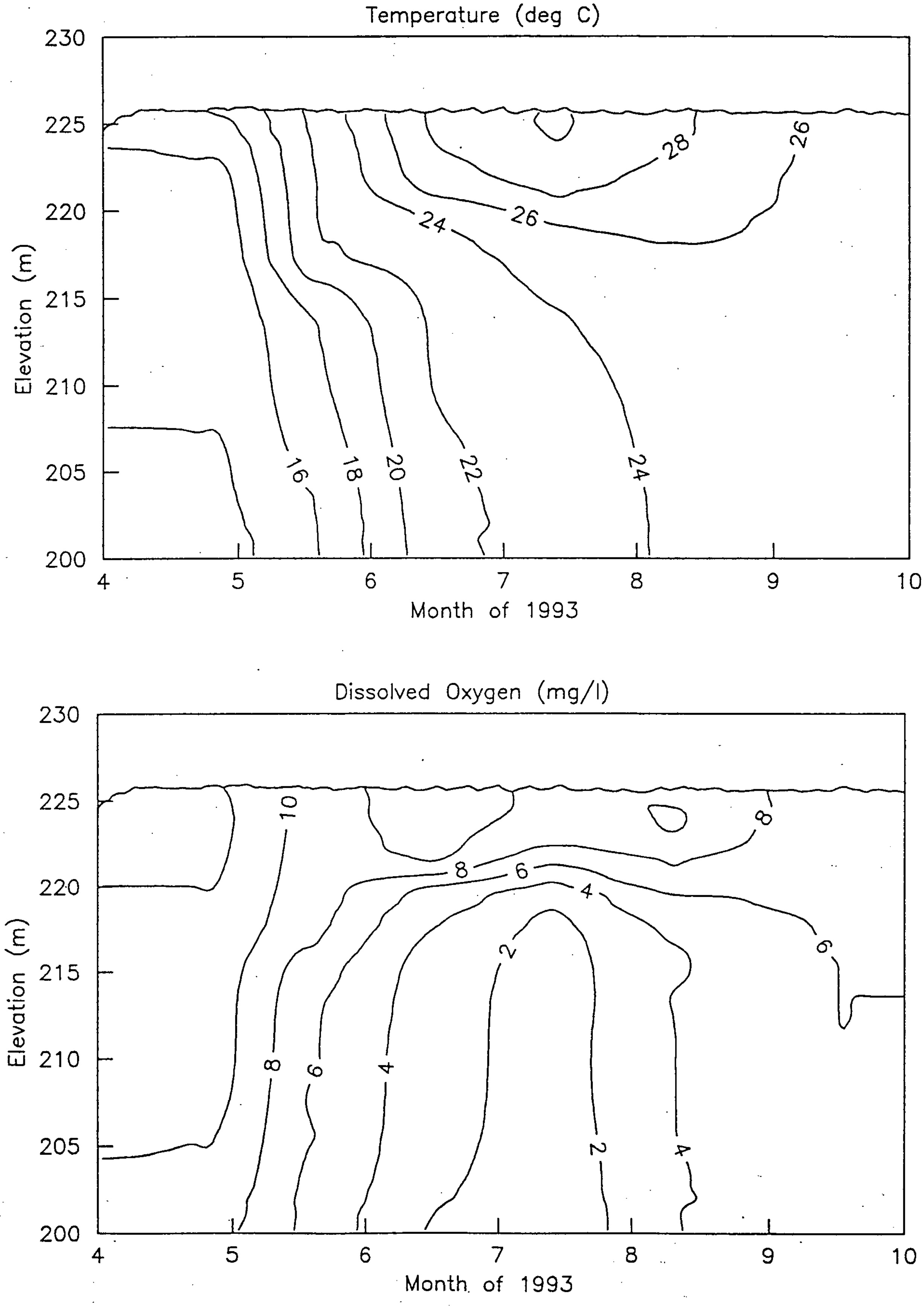


Figure 20

Watts Bar Reservoir – TRM 560.8

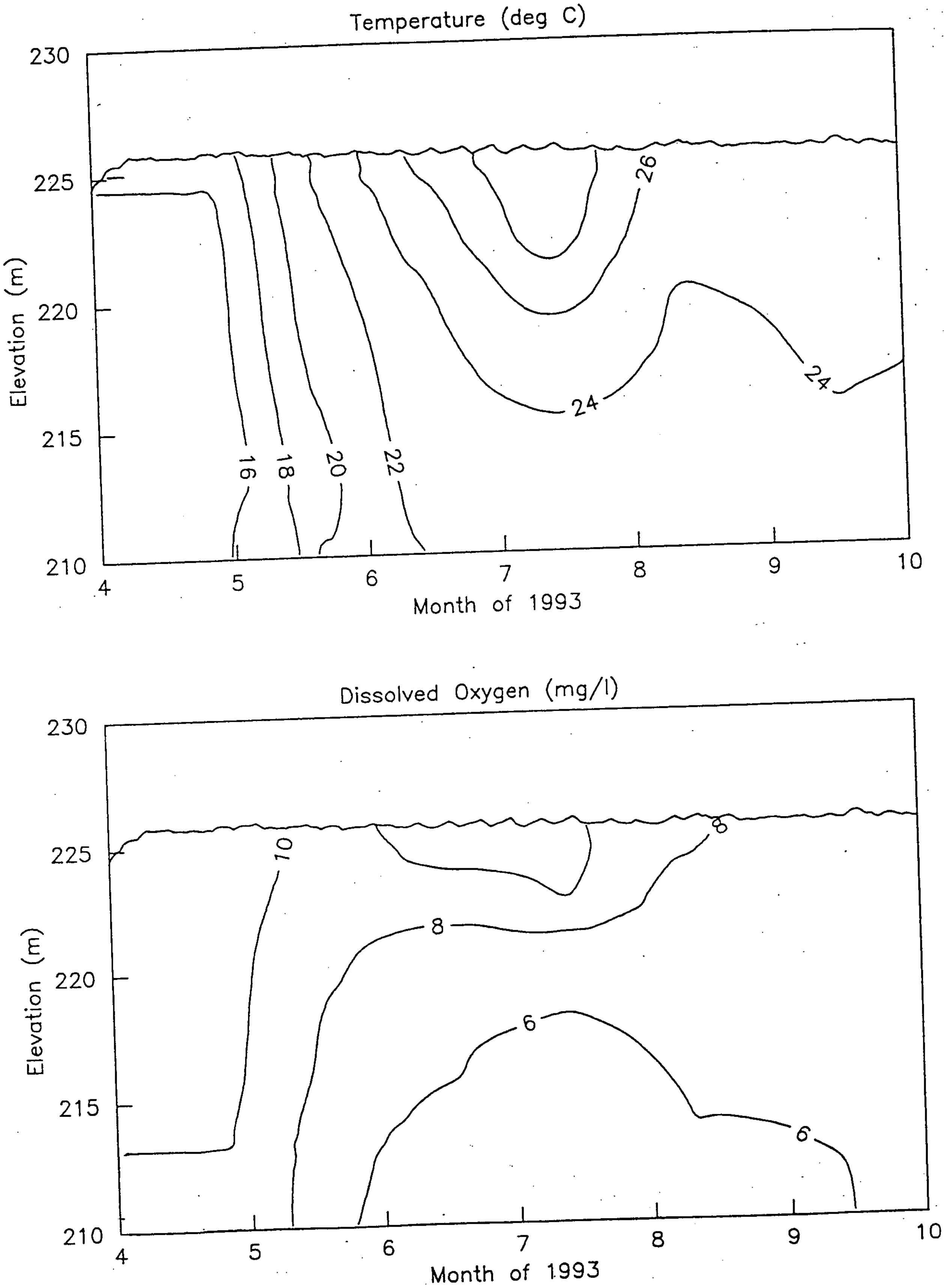
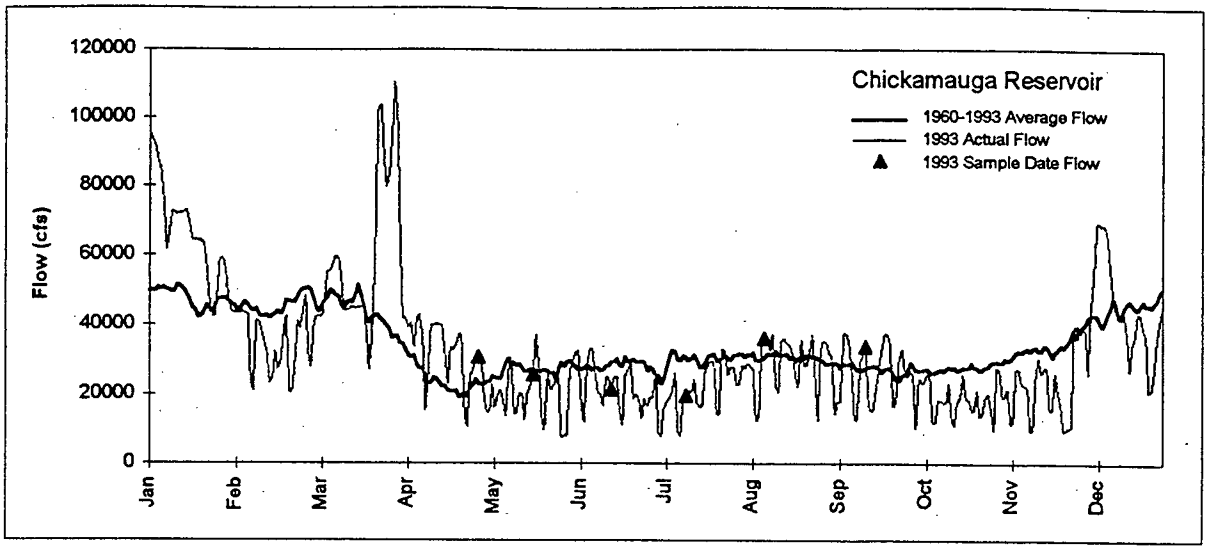
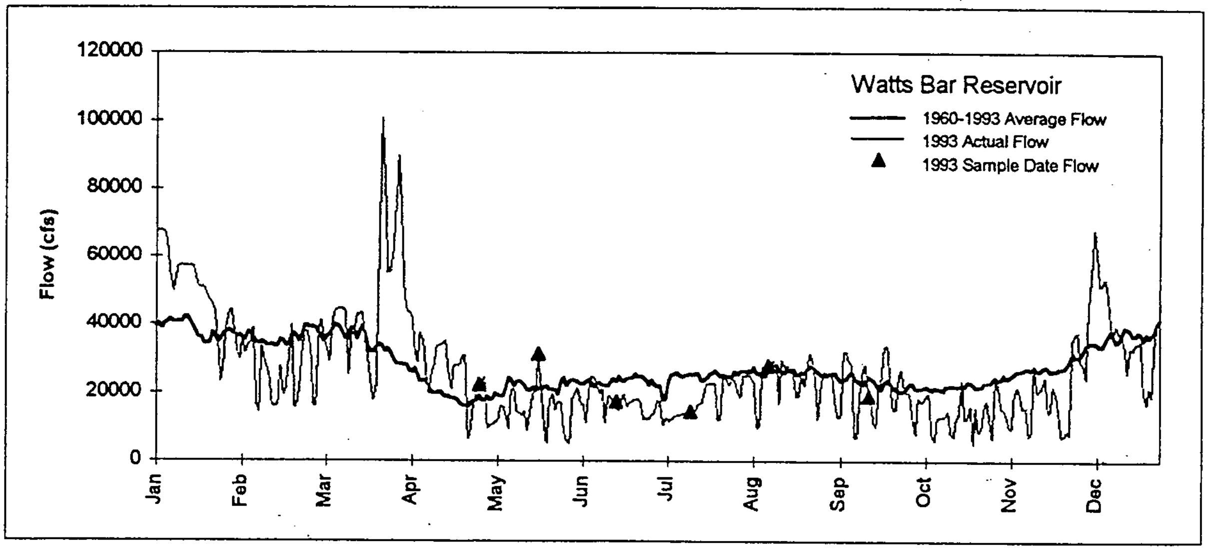


Figure 62



120000
100000
80000
60000
40000
20000
0
Flow (cfs)
Chickamauga Reservoir
1960-1993 Average Flow
1993 Actual Flow
1993 Sample Date Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



120000
100000
80000
60000
40000
20000
0
Flow (cfs)
Watts Bar Reservoir
1960-1993 Average Flow
1993 Actual Flow
1993 Sample Date Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
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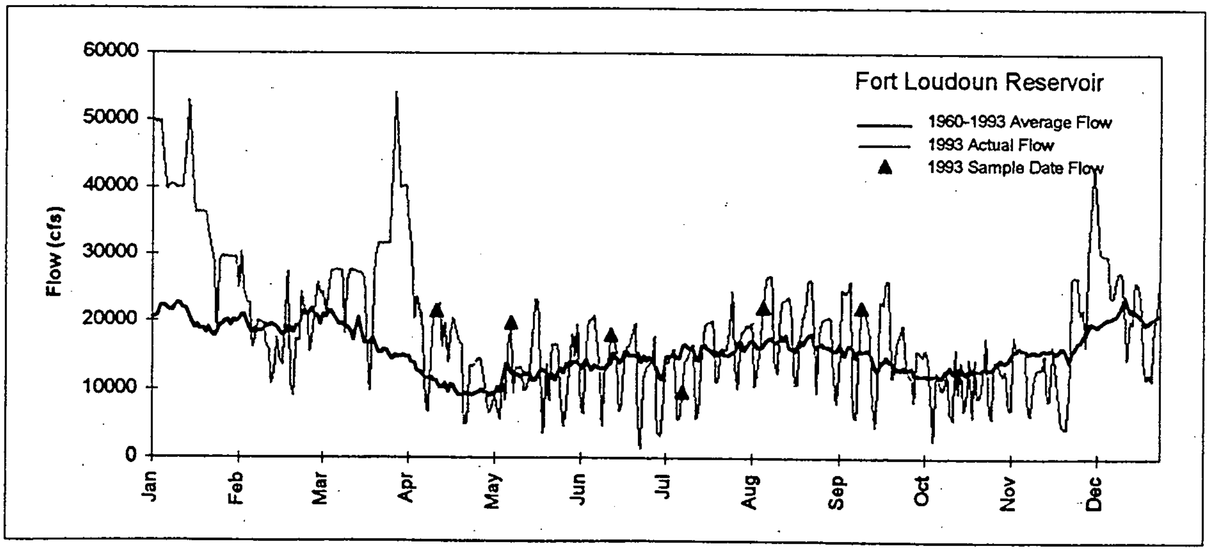
Sep
Oct
Nov
Dec



60000
50000
40000
30000
20000
10000
0
Flow (cfs)
Fort Loudoun Reservoir
1960-1993 Average Flow
1993 Actual Flow
1993 Sample Date Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

STORET RETRIEVAL DATE 94/05/26
475358 1017
35 06 26.0 085 12 20.0 2
CHICKAMAUGA RES. AT LIGHTED BUOY
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 472.3
131TVAC
0000 METERS DEPTH 06020001021 0000.710 ON /TYPA/AMBNT/STREAM/SOLIDS

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 472.30

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
93/04/29	1050	WATER	0.3	30642	17.0	11.4	117.5$	8.50	171
93/04/29	1052	WATER	1		16.4	11.5	115.0$	8.50	170
93/04/29	1054	WATER	1.5		16.2	11.4	114.0$	8.40	170
93/04/29	1056	WATER	2		16.1	11.2	112.0$	8.40	170
93/04/29	1058	WATER	4		16.0	11.0	110.0$	8.30	169
93/04/29	1102	WATER	6		15.9	10.8	108.0$	8.30	169
93/04/29	1104	WATER	8		15.4	10.0	98.0$	7.90	173
93/04/29	1106	WATER	10		15.4	9.9	97.1$	7.90	175
93/04/29	1108	WATER	12		15.3	9.7	95.1$	7.80	173
93/04/29	1110	WATER	14		15.2	9.1	89.2$	7.70	169
93/04/29	1115	WATER	16		15.1	8.7	85.3$	7.60	172
93/04/29	1120	WATER	14.6		15.2	9.2	90.2$	7.70	163
93/05/19	1350	WATER	0.3	25463	22.9	9.0	103.4$	7.60	177
93/05/19	1351	WATER	1		22.9	9.0	103.4$	7.70	177
93/05/19	1352	WATER	1.5		22.8	9.0	103.4$	7.70	178
93/05/19	1353	WATER	4		22.5	8.5	96.6$	7.50	178
93/05/19	1355	WATER	6		22.5	7.7	87.5$	7.20	180
93/05/19	1356	WATER	7.4		20.8	7.1	78.9$	7.00	180
93/05/19	1357	WATER	8		20.3	6.7	72.8$	7.00	181
93/05/19	1358	WATER	10		19.9	6.4	69.6$	7.00	182
93/05/19	1359	WATER	12		19.8	6.3	68.5$	6.90	182
93/05/19	1400	WATER	14		19.7	6.1	66.3$	6.90	183
93/05/19	1401	WATER	14.5		19.7	5.9	64.1$	6.80	183
93/05/19	1402	WATER	16		19.7	5.8	63.0$	6.90	183
93/05/19	1403	WATER	17		19.6	5.6	60.9$	6.80	183
93/06/16	1402	WATER	0.3	21188	27.8	9.1	115.2$	8.40	166
93/06/16	1406	WATER	1		27.6	9.1	115.2$	8.40	166
93/06/16	1408	WATER	1.5		27.3	9.1	112.3$	8.40	166
93/06/16	1410	WATER	2		26.7	9.1	112.3$	8.40	167
93/06/16	1412	WATER	3		26.5	8.3	101.2$	8.10	167
93/06/16	1414	WATER	3.5		26.5	8.0	97.6$	8.10	167
93/06/16	1416	WATER	4		26.4	7.8	95.1$	8.00	166
93/06/16	1422	WATER	4.5		26.1	6.8	82.9$	7.60	167
93/06/16	1424	WATER	5		26.1	6.7	81.7$	7.60	168
93/06/16	1426	WATER	6		25.8	6.4	78.0$	7.50	171
93/06/16	1428	WATER	8		25.3	5.6	66.7$	7.30	166
93/06/16	1430	WATER	9		25.0	5.0	59.5$	7.20	162
93/06/16	1432	WATER	10		24.6	4.3	51.2$	7.10	169
93/06/16	1434	WATER	12		24.2	3.4	40.0$	7.00	171
93/06/16	1436	WATER	14		23.9	2.8	32.9$	7.00	169
93/06/16	1438	WATER	14.5		23.8	2.7	31.8$	7.00	165
93/06/16	1442	WATER	16		23.7	2.0	23.5$	6.90	172
93/07/13	1402	WATER	0.3	19467	31.7	9.3	125.7$	8.80	172
93/07/13	1403	WATER	1		31.3	9.4	125.3$	8.80	171
93/07/13	1404	WATER	1.5		30.6	9.7	129.3$	8.80	172
93/07/13	1405	WATER	2		30.4	9.6	126.3$	8.80	172
93/07/13	1406	WATER	2.5		30.2	9.1	119.7$	8.70	171
93/07/13	1407	WATER	3		29.9	8.1	106.6$	8.50	174
93/07/13	1408	WATER	3.5		29.8	7.2	94.7$	8.30	173
93/07/13	1409	WATER	4		29.6	6.5	85.5$	8.10	173
93/07/13	1411	WATER	5.5		29.2	5.6	71.8$	7.60	178
93/07/13	1412	WATER	6		29.0	5.0	64.1$	7.50	175
93/07/13	1413	WATER	7.5		28.5	4.0	50.6$	7.20	177
93/07/13	1414	WATER	8		28.3	3.8	48.1$	7.20	180
93/07/13	1415	WATER	8.5		28.2	3.6	45.6$	7.10	182
93/07/13	1416	WATER	9		27.6	2.6	32.9$	7.00	187
93/07/13	1417	WATER	10		27.3	2.1	25.9$	6.90	179
93/07/13	1418	WATER	12		27.0	1.7	21.0$	6.90	181
93/07/13	1419	WATER	14		26.7	1.2	14.8$	6.80	182
93/07/13	1420	WATER	14.7		26.6	.7	8.6$	6.80	180
93/07/13	1421	WATER	16		26.4	.03	.4$	6.80	183
93/07/13	1422	WATER	16.7		26.4	.02	.2$	6.80	186
93/07/13	1423	WATER	17.5		26.2	.02	.2$	6.80	191
93/08/10	1347	WATER	0.3	35983	27.8	7.3	92.4$	7.90	187
93/08/10	1349	WATER	1		27.7	7.3	92.4$	7.90	187
93/08/10	1351	WATER	1.5		27.7	7.2	91.1$	7.90	187
93/08/10	1353	WATER	2		27.6	6.9	87.3$	7.80	188
93/08/10	1355	WATER	4		27.3	6.1	75.3$	7.60	189
93/08/10	1357	WATER	6		27.2	5.8	71.6$	7.60	189
93/08/10	1359	WATER	8		27.1	5.6	69.1$	7.50	187
93/08/10	1401	WATER	10		27.1	5.5	67.9$	7.50	188
93/08/10	1403	WATER	12		27.1	5.1	63.0$	7.40	188
93/08/10	1405	WATER	14		27.0	4.7	58.0$	7.40	187
93/08/10	1407	WATER	16		27.0	4.5	55.6$	7.30	188
93/08/10	1409	WATER	16.5		27.0	4.5	55.6$	7.30	187
93/08/10	1411	WATER	17		27.0	4.4	54.3$	7.30	188
93/09/15	1306	WATER	0.3	33892	25.7	7.2	87.8$	7.70	182
93/09/15	1307	WATER	1		25.6	7.1	86.6$	7.70	183
93/09/15	1308	WATER	1.5		25.6	6.9	84.1$	7.70	184
93/09/15	1309	WATER	2		25.5	6.7	79.8$	7.60	182
93/09/15	1310	WATER	4		25.4	6.3	75.0$	7.50	181
93/09/15	1312	WATER	6		25.3	5.8	69.0$	7.40	185
93/09/15	1313	WATER	8		25.2	5.8	69.0$	7.40	187
93/09/15	1314	WATER	10		25.2	5.8	69.0$	7.40	185
93/09/15	1315	WATER	12		25.2	5.8	69.0$	7.40	183
93/09/15	1316	WATER	14		25.2	5.8	69.0$	7.40	181
93/09/15	1317	WATER	16		25.2	5.8	69.0$	7.40	192
93/09/15	1318	WATER	17		25.2	5.8	69.0$	7.40	189

STORET RETRIEVAL DATE 94/05/26
475338 1017
35 06 26.0 085 12 20.0 2
CHICKAMAUGA RES. AT LIGHTED BUOY
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 472.3
131TVAC 06020001021 0000.710 ON /TYPA/AMBNT/STREAM/SOLIDS
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 472.30

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
93/04/29	1050	WATER	0.3		1.30	10K	5Q	6	.130	.020	.29
93/04/29	1100	VERT	4				5Q	4	.020	.060	.32
93/04/29	1120	WATER	14.6								
93/05/19	1350	WATER	0.3		1.00	10K	5	3	.090	.020	.16
93/05/19	1354	VERT	4				10	6	.070	.080	.25
93/05/19	1401	WATER	14.5								
93/06/16	1402	WATER	0.3	D1		10K					
93/06/16	1403	WATER	0.3	D2		10K					
93/06/16	1404	WATER	0.3	D3		10K	5	4	.120	.010	.08
93/06/16	1418	VERT	4	D1			5	4	.160	.010	.07
93/06/16	1419	VERT	4	D2			5	4	.170	.010K	.08
93/06/16	1420	VERT	4	D3			5	7	.130	.110	.22
93/06/16	1438	WATER	14.5	D1			5	8	.130	.110	.22
93/06/16	1439	WATER	14.5	D2			5	7	.090	.110	.22
93/06/16	1440	WATER	14.5	D3							
93/07/13	1402	WATER	0.3		1.27	10K	10	4	.310	.030	.01
93/07/13	1410	VERT	4				5	3	.120	.060	.24
93/07/13	1420	WATER	14.7								
93/08/10	1347	WATER	0.3		1.10	10K	5	4	.260	.010K	.15
93/08/10	1356	VERT	4				10	17	.290	.050	.20
93/08/10	1409	WATER	18.5								
93/09/15	1306	WATER	0.3			10K	10	5	.060	.030	.14
93/09/15	1311	VERT	4				1K	11	.090	.040	.14
93/09/15	1316	WATER	14								

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
93/04/29	1100	VERT	4		.020	.002K	1.9	9.00	1.00	2.00	2.00
93/04/29	1120	WATER	14.6		.020	.007	1.7				
93/05/19	1354	VERT	4		.030	.002	2.0	9.00	1.00K	1.00	1.00
93/05/19	1401	WATER	14.5		.030	.006	1.7				
93/06/16	1402	WATER	0.3	D1							
93/06/16	1403	WATER	0.3	D2							
93/06/16	1404	WATER	0.3	D3							
93/06/16	1418	VERT	4	D1	.030	.002	2.3	7.00	1.00K	1.00	2.00
93/06/16	1419	VERT	4	D2	.030	.002K	2.3	5.00	1.00K	1.00	1.00
93/06/16	1420	VERT	4	D3	.030	.002	2.3	7.00	1.00K	1.00	2.00
93/06/16	1438	WATER	14.5	D1	.030	.020	1.9				
93/06/16	1439	WATER	14.5	D2	.030	.010	1.8				
93/06/16	1440	WATER	14.5	D3	.030	.010	1.8				
93/07/13	1410	VERT	4		.020	.003	2.2	10.00	1.00	1.00	2.00
93/07/13	1420	WATER	14.7		.020	.005	1.8				
93/08/10	1356	VERT	4		.020	.002K	2.0	9.00	1.00K	1.00	2.00
93/08/10	1409	WATER	18.5		.040	.006	1.9				
93/09/15	1311	VERT	4		.020	.007	1.8	7.00	1.00K	1.00	1.00
93/09/15	1316	WATER	14		.030	.009	1.8				

STORET RETRIEVAL DATE 94/05/26
475265 1053
35 18 00.0 085 04 33.0 2
CHICKAMAUGA RESERVOIR
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 490.47 /TYPA/AMBNT/STREAM/SOLIDS
131TVAC 06020001025 0005.740 ON
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 490.47

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
93/04/29	0915	WATER	0.3		16.2	10.7	107.0$	8.22	174
93/04/29	0920	WATER	1		16.2	10.6	106.0$	8.20	174
93/04/29	0925	WATER	1.5		16.2	10.3	103.0$	8.20	175
93/04/29	0930	WATER	2		15.9	10.3	103.0$	8.10	175
93/04/29	0935	WATER	4		15.7	10.1	101.0$	8.00	175
93/04/29	0945	WATER	6		15.4	9.6	94.1$	7.90	176
93/04/29	0950	WATER	8		15.4	9.5	93.1$	7.80	178
93/04/29	0955	WATER	9.6000		15.3	9.4	92.2$	7.80	175
93/05/19	1038	WATER	0.3		21.5	9.1	101.1$	7.60	175
93/05/19	1039	WATER	1		21.6	9.1	103.4$	7.60	175
93/05/19	1040	WATER	1.5		21.6	8.9	101.1$	7.50	176
93/05/19	1041	WATER	4		21.3	8.3	92.2$	7.30	175
93/05/19	1043	WATER	5.4		20.6	7.6	84.4$	7.10	176
93/05/19	1044	WATER	6		20.0	7.1	77.2$	7.10	176
93/05/19	1045	WATER	8		19.7	6.8	73.9$	7.00	178
93/05/19	1046	WATER	10		19.5	6.4	68.1$	6.90	178
93/05/19	1047	WATER	10.5		19.4	6.0	63.8$	6.90	179
93/06/16	1247	WATER	0.3		26.4	9.9	120.7$	8.50	166
93/06/16	1250	WATER	1		26.0	10.4	126.8$	8.60	165
93/06/16	1253	WATER	1.5		25.4	9.2	109.5$	8.30	165
93/06/16	1256	WATER	2		25.2	8.0	95.2$	7.90	164
93/06/16	1259	WATER	4		25.1	7.2	85.7$	7.20	162
93/06/16	1305	WATER	4.5		25.0	6.7	79.8$	7.50	164
93/06/16	1308	WATER	5		24.9	5.9	70.2$	7.40	167
93/06/16	1311	WATER	6		24.4	5.1	60.0$	7.30	167
93/06/16	1314	WATER	7		24.4	4.9	57.6$	7.20	162
93/06/16	1317	WATER	8		24.2	4.7	55.3$	7.20	164
93/06/16	1320	WATER	9.5		24.0	4.0	47.1$	7.10	165
93/06/16	1323	WATER	10		24.0	3.9	45.9$	7.10	161
93/07/13	1337	WATER	0.3		30.1	8.5	111.8$	8.40	181
93/07/13	1338	WATER	1		29.3	8.9	114.1$	8.50	181
93/07/13	1339	WATER	1.5		28.8	8.5	109.0$	8.40	182
93/07/13	1340	WATER	2		28.7	8.0	102.6$	8.30	181
93/07/13	1341	WATER	3		28.5	7.4	93.7$	8.10	182
93/07/13	1342	WATER	3.5		28.4	6.4	81.0$	8.00	184
93/07/13	1343	WATER	4		28.0	5.3	67.1$	7.60	185
93/07/13	1345	WATER	5.5		27.6	4.5	57.0$	7.30	188
93/07/13	1346	WATER	6		27.5	4.1	50.6$	7.30	190
93/07/13	1347	WATER	7.5		27.2	3.5	43.2$	7.10	184
93/07/13	1348	WATER	8		27.2	3.3	40.7$	7.10	190
93/07/13	1349	WATER	9.6000		26.9	1.2	14.8$	7.00	189
93/07/13	1350	WATER	10		26.9	1.6	19.8$	7.00	190
93/08/10	1234	WATER	0.3		27.0	6.6	81.5$	7.70	188
93/08/10	1236	WATER	1		27.0	6.5	80.2$	7.70	188
93/08/10	1238	WATER	1.5		26.9	6.4	79.0$	7.70	189
93/08/10	1240	WATER	2		26.8	6.1	75.3$	7.60	188
93/08/10	1242	WATER	4		26.3	5.5	67.1$	7.50	184
93/08/10	1244	WATER	6		26.2	5.1	62.2$	7.40	182
93/08/10	1246	WATER	8		25.9	4.8	58.5$	7.30	174
93/08/10	1248	WATER	9.6000		25.9	4.7	57.3$	7.30	177
93/08/10	1250	WATER	10		25.9	4.8	58.5$	7.30	177
93/09/15	1205	WATER	0.3		25.1	6.0	71.4$	7.50	182
93/09/15	1206	WATER	1		25.1	5.8	69.0$	7.40	182
93/09/15	1207	WATER	1.5		25.1	5.7	67.9$	7.40	183
93/09/15	1208	WATER	2		25.1	5.6	66.7$	7.40	182
93/09/15	1209	WATER	4		24.9	5.3	63.1$	7.40	184
93/09/15	1211	WATER	6		24.9	5.3	63.1$	7.40	179
93/09/15	1212	WATER	8		24.9	5.2	61.9$	7.30	182
93/09/15	1213	WATER	9		24.9	5.2	61.9$	7.30	181
93/09/15	1214	WATER	10		24.9	5.2	61.9$	7.30	183

STORET RETRIEVAL DATE 94/05/26
475265 1053
35 18 00.0 085 04 33.0 2
CHICKAMAUGA RESERVOIR
47065 TENNESSEE HAMILTON
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 490.47
131TVAC 06020001025 0005.740 ON
0000 METERS DEPTH

/TYPA/AMBNT/STREAM/SOLIDS

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 490.47

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
93/04/29	0915	WATER	0.3		1.25	10K	5Q	5	.030	.020	.33
93/04/29	0940	VERT	4				5Q	6	.040	.040	.34
93/04/29	0955	WATER	9.6000								
93/05/19	1038	WATER	0.3		1.00	10K	5	6	.130	.010K	.17
93/05/19	1042	VERT	4				5	5	.080	.070	.26
93/05/19	1046	WATER	10								
93/06/16	1247	WATER	0.3			10K	10	6	.140	.010	.16
93/06/16	1302	VERT	4				5	9	.040	.090	.25
93/06/16	1320	WATER	9.5								
93/07/13	1337	WATER	0.3		1.18	10K	10	4	.210	.030	.11
93/07/13	1344	VERT	4				10	7	.170	.090	.25
93/07/13	1349	WATER	9.6000								
93/08/10	1234	WATER	0.3		1.30	10K	10	2	.280	.010K	.21
93/08/10	1243	VERT	4				10	7	.220	.040	.20
93/08/10	1248	WATER	9.6000								
93/09/15	1205	WATER	0.3		1.25	10K	10	6	.130	.070	.18
93/09/15	1210	VERT	4				10	21	.900	.070	.17
93/09/15	1213	WATER	9								

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
93/04/29	0940	VERT	4		.020	.002	1.8	7.00	1.00	1.00	2.00
93/04/29	0955	WATER	9.6000		.020	.004	1.8				
93/05/19	1042	VERT	4		.040	.003	2.2	13.00	1.00K	2.00	2.00
93/05/19	1046	WATER	10		.020	.007	1.8				
93/06/16	1302	VERT	4		.020	.010	2.1	10.00	1.00	1.00	3.00
93/06/16	1320	WATER	9.5		.040	.003	1.9				
93/07/13	1344	VERT	4		.020	.004	2.1	9.00	1.00	1.00	3.00
93/07/13	1349	WATER	9.6000		.020	.010	1.9				
93/08/10	1243	VERT	4		.010	.002	2.0	5.00	1.00K	1.00	1.00
93/08/10	1248	WATER	9.6000		.020	.008	1.9				
93/09/15	1210	VERT	4		.030	.010	1.9	3.00	1.00K	1.00	1.00
93/09/15	1213	WATER	9		.050	.010	1.8				

S[illegible] RETRIEVAL DATE 94/05/26
HRM 008.50
3[illegible]8.0 084 53 30.0 2
C[illegible]HAUGA RESERVOIR - 2 MILES ABOVE HIGHWAY 58
47121 TENNESSEE MEIGS
TENNESSEE RIVER BASIN 040501
HIWASSEE RIVER 8.5
131TVAC 930501 06020002 /TYPA/AMBNT/STREAM
0000 METERS DEPTH

INDEX 1021500 007720 00920 6824
MILES 0953.80 0046.50 499.70 008.50

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
93/04/28	1605	WATER	0.3		19.1	10.2	108.5$	7.50	160
93/04/28	1607	WATER	1		17.7	10.1	106.3$	7.60	162
93/04/28	1609	WATER	1.5		17.3	9.9	102.1$	7.60	164
93/04/28	1611	WATER	2		17.1	9.6	99.0$	7.50	163
93/04/28	1613	WATER	4		16.7	9.1	93.8$	7.40	161
93/04/28	1617	WATER	6		16.7	9.0	92.8$	7.40	162
93/04/28	1619	WATER	8		16.7	8.9	91.8$	7.40	161
93/04/28	1621	WATER	8.4		16.7	8.9	91.8$	7.40	163
93/05/19	1530	WATER	0.3		23.4	9.6	110.3$	7.60	152
93/05/19	1531	WATER	1		22.6	9.1	104.6$	7.50	151
93/05/19	1532	WATER	1.2		21.7	8.9	101.1$	7.30	148
93/05/19	1533	WATER	1.5		21.3	8.9	98.9$	7.30	147
93/05/19	1534	WATER	2.2		20.0	8.5	92.4$	7.10	145
93/05/19	1535	WATER	4		18.6	8.2	87.2$	7.00	137
93/05/19	1537	WATER	6		18.6	8.1	86.2$	6.90	137
93/05/19	1538	WATER	8		18.5	8.1	85.3$	6.90	137
93/05/19	1539	WATER	8.8		18.5	8.0	84.2$	6.80	137
93/05/19	1540	WATER	9.3		18.5	8.1	85.3$	6.80	137
93/06/16	1000	WATER	0.3		23.5	8.7	100.0$	7.50	137
93/06/16	1005	WATER	1		23.0	8.2	94.3$	7.40	135
93/06/16	1010	WATER	1.5		22.6	7.9	90.8$	7.30	134
93/06/16	1015	WATER	2		22.2	7.7	87.5$	7.20	134
93/06/16	1020	WATER	4		21.8	7.6	86.4$	7.20	134
93/06/16	1030	WATER	6		21.7	7.5	85.2$	7.10	135
93/06/16	1035	WATER	8		21.6	7.4	84.1$	7.10	134
93/06/16	1040	WATER	8.5		21.6	7.4	84.1$	7.10	134
93/07/13	0935	WATER	0.3		28.8	7.5	96.2$	7.50	167
93/07/13	0940	WATER	1		28.3	7.5	94.9$	7.50	169
93/07/13	0945	WATER	1.5		27.6	7.5	94.9$	7.50	169
93/07/13	0950	WATER	2		26.8	6.7	82.7$	7.30	169
93/07/13	0955	WATER	2.5		25.1	6.0	71.4$	7.00	165
93/07/13	1000	WATER	3		24.9	5.9	70.2$	7.00	167
93/07/13	1005	WATER	4		24.8	6.0	71.4$	7.00	165
93/07/13	1015	WATER	6		24.7	5.9	70.2$	6.90	165
93/07/13	1020	WATER	8		24.7	5.9	70.2$	6.90	165
93/07/13	1025	WATER	8.5		24.7	5.8	69.0$	6.90	162
93/07/13	1030	WATER	9		24.7	5.8	69.0$	6.90	166
93/08/10	1017	WATER	0.3		23.9	8.0	94.1$	7.40	119
93/08/10	1019	WATER	1		23.3	7.6	87.4$	7.30	114
93/08/10	1021	WATER	1.5		23.2	7.6	87.4$	7.30	117
93/08/10	1023	WATER	2		23.2	7.7	88.5$	7.20	122
93/08/10	1025	WATER	4		22.6	7.4	85.1$	7.10	123
93/08/10	1027	WATER	6		22.5	7.4	84.1$	7.10	122
93/08/10	1029	WATER	8		22.5	7.4	84.1$	7.10	122
93/08/10	1031	WATER	9		22.5	7.3	83.0$	7.10	122
93/09/15	0947	WATER	0.3		22.2	7.9	89.8$	7.20	100
93/09/15	0948	WATER	1		22.1	7.9	89.8$	7.10	100
93/09/15	0949	WATER	1.5		22.1	7.8	88.6$	7.10	100
93/09/15	0950	WATER	2		22.0	7.8	88.6$	7.10	100
93/09/15	0951	WATER	4		21.9	7.8	88.6$	7.10	103
93/09/15	0953	WATER	6		21.8	7.8	88.6$	7.10	103
93/09/15	0954	WATER	8		21.8	7.8	88.6$	7.00	101
93/09/15	0955	WATER	9		21.8	7.7	87.5$	7.00	100

STORET RETRIEVAL DATE 94/05/26
477512 HRM 008.50
35 21 38.0 084 53 30.0 2
CHICKAMAUGA RESERVOIR - 2 MILES ABOVE HIGHWAY 58
47121 TENNESSEE MEIGS
TENNESSEE RIVER BASIN 040501
HIWASSEE RIVER 8.5
131TVAC 930501 06020002 /TYPA/AMBNT/STREAM
0000 METERS DEPTH

INDEX 1021500 007720 00920 6824
MILES 0953.80 0046.50 499.70 008.50

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
93/04/28	1605	WATER	0.3		1.25	300					
93/04/28	1615	VERT	4				10Q	7	.170	.090	.18
93/04/28	1621	WATER	8.4				15Q	12	.110	.100	.18
93/05/19	1530	WATER	0.3		1.13	10K					
93/05/19	1536	VERT	4				15	8	.120	.030	.11
93/05/19	1539	WATER	8.8				15	10	.040	.130	.21
93/06/16	1000	WATER	0.3		.85						
93/06/16	1025	VERT	4				10	10	.070	.100	.18
93/06/16	1035	WATER	8				15	20	.100	.100	.20
93/07/13	0935	WATER	0.3		.77	10K					
93/07/13	1010	VERT	4				15	10	.190	.090	.14
93/07/13	1025	WATER	8.5				20	18	.230	.110	.17
93/08/10	1017	WATER	0.3		.80	10K					
93/08/10	1026	VERT	4				15	8	.420	.010	.12
93/08/10	1029	WATER	8				15	16	.430	.040	.15
93/09/15	0947	WATER	0.3		.80	10K					
93/09/15	0952	VERT	4				15	9	.110	.070	.12
93/09/15	0954	WATER	8				15	14	.080	.080	.13

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
93/04/28	1615	VERT	4		.050	.005	2.5	5.00	1.00K	1.00K	1.00K
93/04/28	1621	WATER	8.4		.050	.006	2.6				
93/05/19	1536	VERT	4		.040	.003	2.5	12.00	1.00K	1.00	1.00
93/05/19	1539	WATER	8.8		.050	.010	2.5				
93/06/16	1025	VERT	4		.040	.006	1.9	3.00	1.00K	1.00K	1.00
93/06/16	1035	WATER	8		.050	.010	1.9				
93/07/13	1010	VERT	4		.030	.003	2.6	5.00	1.00K	1.00	2.00
93/07/13	1025	WATER	8.5		.040	.005	2.6				
93/08/10	1026	VERT	4		.040	.010	2.6	4.00	1.00K	1.00	1.00
93/08/10	1029	WATER	8		.060	.020	2.7				
93/09/15	0952	VERT	4		.030	.004	1.9	4.00	1.00K	1.00	1.00K
93/09/15	0954	WATER	8		.030	.005	1.8				

STORET RETRIEVAL DA… 94/05/26
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35 38 10.0 084 …0 2 OPPOSITE LOWER BRIDGE
WATTS BAR RESERV… MEIGS
47121 TENNESSEE 040801
TENNESSEE RIVER BASIN
TENNESSEE RIVER 531.0 06010201002 0002.040 ON /TYPA/AMBNT/FISH/STREAM/SOLIDS
131TVAC
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 531.00

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
93/04/28	1405	WATER	0.3	22346	18.3	12.2	128.4$	8.80	175
93/04/28	1407	WATER	1		17.0	12.6	129.9$	8.80	175
93/04/28	1409	WATER	1.5		16.7	12.6	129.9$	8.80	175
93/04/28	1411	WATER	2		16.6	12.6	129.9$	8.80	176
93/04/28	1413	WATER	4		15.3	12.4	121.6$	8.70	180
93/04/28	1417	WATER	6		15.0	12.0	117.6$	8.60	183
93/04/28	1419	WATER	8		14.6	11.5	112.7$	8.50	183
93/04/28	1421	WATER	10		14.4	11.2	107.7$	8.40	184
93/04/28	1423	WATER	12		14.3	10.9	104.8$	8.30	182
93/04/28	1425	WATER	14		14.3	10.9	104.8$	8.30	185
93/04/28	1427	WATER	16		14.2	10.9	104.8$	8.30	184
93/04/28	1429	WATER	18		14.1	10.7	102.9$	8.30	184
93/04/28	1431	WATER	20		13.8	10.1	97.1$	8.00	183
93/04/28	1433	WATER	22		13.7	9.8	94.2$	8.00	180
93/04/28	1435	WATER	24		13.4	9.3	87.7$	7.90	181
93/04/28	1437	WATER	26		13.1	8.5	80.2$	7.60	146
93/04/28	1439	WATER	23.4		13.5	9.5	89.6$	7.80	176
93/05/20	1313	WATER	0.3	31154	22.7	9.3	106.9$	8.10	160
93/05/20	1314	WATER	1		22.4	9.3	105.7$	8.10	161
93/05/20	1315	WATER	1.5		22.3	9.2	104.5$	8.10	162
93/05/20	1316	WATER	4		22.0	9.0	102.3$	8.00	163
93/05/20	1318	WATER	6		22.0	8.9	101.1$	8.00	163
93/05/20	1319	WATER	8		21.8	8.6	97.7$	7.90	164
93/05/20	1320	WATER	9.1000		21.4	8.1	90.0$	7.80	164
93/05/20	1321	WATER	9.3		21.2	7.4	82.2$	7.60	166
93/05/20	1322	WATER	10		19.2	7.0	74.5$	7.10	168
93/05/20	1323	WATER	12		18.0	6.3	66.3$	7.00	170
93/05/20	1324	WATER	14		17.8	6.2	65.3$	7.00	172
93/05/20	1325	WATER	16		17.6	6.2	65.3$	6.90	172
93/05/20	1326	WATER	18		17.2	5.7	58.8$	6.90	175
93/05/20	1327	WATER	20		16.8	6.1	62.9$	6.90	154
93/05/20	1328	WATER	22		16.1	5.6	56.0$	6.80	156
93/05/20	1329	WATER	23.6		16.0	5.4	54.0$	6.80	166
93/05/20	1330	WATER	24		16.0	5.4	54.0$	6.80	165
93/05/20	1331	WATER	26		15.9	5.3	53.0$	6.80	166
93/06/17	1255	WATER	0.3	17263	28.6	10.9	139.7$	9.00	172
93/06/17	1257	WATER	1		28.4	10.9	138.0$	9.00	172
93/06/17	1259	WATER	1.5		28.3	10.9	138.0$	9.00	171
93/06/17	1301	WATER	2		28.1	11.0	139.2$	9.00	171
93/06/17	1303	WATER	4		27.2	10.7	132.1$	8.90	173
93/06/17	1307	WATER	4.5		26.9	9.9	122.2$	8.80	172
93/06/17	1309	WATER	5		25.9	8.2	100.0$	8.50	173
93/06/17	1311	WATER	5.5		25.1	6.5	77.4$	7.80	175
93/06/17	1313	WATER	6		24.2	5.2	61.2$	7.50	174
93/06/17	1315	WATER	7		23.7	4.5	52.9$	7.30	167
93/06/17	1317	WATER	8		23.3	4.1	47.1$	7.20	172
93/06/17	1319	WATER	10		22.5	3.1	35.2$	7.10	169
93/06/17	1321	WATER	12		22.3	2.9	33.0$	7.10	167
93/06/17	1323	WATER	14		22.3	3.0	34.1$	7.10	169
93/06/17	1325	WATER	16		22.2	2.6	29.5$	7.00	164
93/06/17	1327	WATER	18		21.9	2.9	33.0$	7.00	160
93/06/17	1329	WATER	20		21.6	2.8	31.8$	7.00	158
93/06/17	1331	WATER	22		21.5	2.6	28.9$	7.00	157
93/06/17	1333	WATER	24		21.3	2.2	24.4$	7.00	164
93/06/17	1335	WATER	26		21.2	1.7	18.9$	7.00	161
93/06/17	1340	WATER	23		21.4	2.4	26.7$	7.00	164
93/07/14	1325	WATER	0.3	14567	30.2	9.6	126.3$	9.00	170
93/07/14	1331	WATER	1		30.2	9.5	125.0$	9.00	171
93/07/14	1333	WATER	1.5		30.2	9.6	126.3$	9.00	171
93/07/14	1335	WATER	2		29.9	9.5	125.0$	8.90	171
93/07/14	1337	WATER	3		29.4	8.7	111.5$	8.90	170
93/07/14	1339	WATER	3.5		28.9	7.5	96.2$	8.60	178
93/07/14	1341	WATER	4		28.4	6.2	78.5$	8.30	183
93/07/14	1349	WATER	4.5		28.3	6.0	75.9$	8.10	182
93/07/14	1351	WATER	5		28.2	5.2	65.8$	8.10	185
93/07/14	1353	WATER	5.5		27.0	3.6	44.4$	7.50	196
93/07/14	1355	WATER	6		26.5	2.9	35.4$	7.40	195
93/07/14	1357	WATER	7		25.6	1.9	23.2$	7.20	200
93/07/14	1359	WATER	8		25.0	1.3	15.5$	7.10	204
93/07/14	1401	WATER	10		24.4	1.0	11.8$	7.00	203
93/07/14	1403	WATER	12		23.8	.9	10.6$	7.00	192
93/07/14	1405	WATER	14		23.7	1.1	12.9$	7.00	206
93/07/14	1407	WATER	16		23.4	1.1	12.6$	6.90	201
93/07/14	1409	WATER	18		23.3	1.1	12.6$	6.90	201
93/07/14	1411	WATER	20		23.1	.9	10.3$	6.90	205
93/07/14	1413	WATER	22		23.0	.7	8.0$	6.90	203
93/07/14	1415	WATER	23.5		22.9	.5	5.7$	6.90	192
93/07/14	1421	WATER	24		22.9	.5	5.7$	6.90	194
93/07/14	1423	WATER	26		22.9	.4	4.6$	6.90	194
93/08/11	1306	WATER	0.3	27733	28.3	9.7	122.8$	8.90	193
93/08/11	1307	WATER	1		28.3	9.9	125.3$	8.90	193
93/08/11	1308	WATER	1.5		28.1	10.4	131.6$	8.90	193
93/08/11	1309	WATER	2		28.1	10.5	132.9$	8.90	194
93/08/11	1310	WATER	3		27.6	9.5	120.3$	9.00	197
93/08/11	1311	WATER	3.5		27.4	8.4	103.7$	8.60	201
93/08/11	1312	WATER	4		27.3	8.2	101.2$	8.60	201
93/08/11	1314	WATER	5		27.1	7.8	96.3$	8.60	201
93/08/11	1315	WATER	5.5		27.1	7.3	90.1$	8.50	200
93/08/11	1316	WATER	6		26.8	6.2	76.5$	8.20	203
93/08/11	1317	WATER	7		26.6	5.0	61.7$	8.10	206
93/08/11	1318	WATER	7.5		25.9	4.5	54.9$	7.60	207
93/08/11	1319	WATER	8		25.8	4.5	54.9$	7.60	207
93/08/11	1320	WATER	10		25.3	3.6	42.9$	7.50	208
93/08/11	1321	WATER	12		25.0	4.1	48.8$	7.40	207
93/08/11	1322	WATER	14		24.6	4.0	47.6$	7.40	207
93/08/11	1323	WATER	16		24.5	4.0	47.1$	7.40	208
93/08/11	1324	WATER	18		24.5	4.0	47.1$	7.40	208
93/08/11	1325	WATER	20		24.4	4.0	47.1$	7.30	208
93/08/11	1326	WATER	22		24.3	3.9	45.9$	7.30	208
93/08/11	1327	WATER	24		24.3	3.9	45.9$	7.30	206
93/08/11	1328	WATER	26		24.3	3.9	45.9$	7.30	211
93/09/16	1147	WATER	0.3	18975	25.4	6.7	79.8$	7.80	203
93/09/16	1148	WATER	1		25.4	6.6	78.6$	7.80	203
93/09/16	1149	WATER	1.5		25.4	6.5	77.4$	7.70	201
93/09/16	1150	WATER	2		25.4	6.5	77.4$	7.70	203
93/09/16	1151	WATER	4		25.3	6.3	75.0$	7.70	205
93/09/16	1153	WATER	6		25.3	6.3	75.0$	7.70	200
93/09/16	1154	WATER	8		25.3	6.3	75.0$	7.70	203
93/09/16	1155	WATER	10		25.3	6.0	71.4$	7.60	205
93/09/16	1156	WATER	12		25.2	6.0	71.4$	7.60	205
93/09/16	1157	WATER	14		25.2	6.0	71.4$	7.60	209
93/09/16	1158	WATER	16		25.1	5.9	70.2$	7.60	205
93/09/16	1159	WATER	18		25.0	5.5	65.5$	7.50	208
93/09/16	1200	WATER	20		25.0	5.3	63.1$	7.40	203
93/09/16	1201	WATER	22		25.0	5.0	59.5$	7.40	201
93/09/16	1202	WATER	23.5		25.0	4.9	58.3$	7.40	206
93/09/16	1203	WATER	24		25.0	4.9	58.3$	7.40	204
93/09/16	1204	WATER	26		25.0	4.7	56.0$	7.40	205

STORET RETRIEVAL DATE 94/05/26
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WATTS BAR RESERVOIR - OPPOSITE LOWER BRIDGE
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TENNESSEE RIVER BASIN 040801
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0000 METERS DEPTH 06010201002 0002.040 ON /TYPA/AMBNT/FISH/STREAM/SOLIDS

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MILES 0953.80 0046.50 531.00

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
93/04/28	1405	WATER	0.3		2.00	10K					
93/04/28	1415	VERT	4				10Q	6	.200	.010	.32
93/04/28	1439	WATER	23.4				5Q	8	.160	.040	.36
93/05/20	1313	WATER	0.3		1.50	10K					
93/05/20	1317	VERT	4				5	3	.030	.010	.18
93/05/20	1329	WATER	23.6				5	7	.030	.080	.30
93/06/17	1255	WATER	0.3		1.60	10K					
93/06/17	1305	VERT	4				10	5	.020K	.020	.21
93/06/17	1340	WATER	23				10	8	.060	.030	.41
93/07/14	1325	WATER	0.3	D1	1.67	10K					
93/07/14	1327	WATER	0.3	D2		10K					
93/07/14	1329	WATER	0.3	D3		10K					
93/07/14	1343	VERT	4	D1			10	4	.290	.010K	.02
93/07/14	1345	VERT	4	D2			5	3	.290	.010K	.02
93/07/14	1347	VERT	4	D3			10	3	.310	.010K	.02
93/07/14	1415	WATER	23.5	D1			5	12	.230	.010	.46
93/07/14	1417	WATER	23.5	D2			5	9	.190	.010	.45
93/07/14	1419	WATER	23.5	D3			10	10	.160	.020	.44
93/08/11	1306	WATER	0.3		1.30	10K					
93/08/11	1313	VERT	4				10	4	.490	.010K	..10
93/08/11	1327	WATER	24				10	11	.250	.010K	.38
93/09/15	1152	VERT	4				5	3	.230		.13
93/09/16	1147	WATER	0.3		1.20	10K					
93/09/16	1151	VERT	4				5	3	.230	.020	.13
93/09/16	1202	WATER	23.5				5	11	.250	.040	.18

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
93/04/28	1415	VERT	4		.020	.004	1.9	10.00	1.00	2.00	1.00
93/04/28	1439	WATER	23.4		.030	.004	1.8				
93/05/20	1317	VERT	4		.020	.003	2.2	5.00	1.00K	1.00	1.00K
93/05/20	1329	WATER	23.6		.030	.005	1.6				
93/06/17	1305	VERT	4		.020	.002K	2.2	4.00	1.00	1.00	2.00
93/06/17	1340	WATER	23		.040	.020	1.7				
93/07/14	1325	WATER	0.3	D1							
93/07/14	1327	WATER	0.3	D2							
93/07/14	1329	WATER	0.3	D3							
93/07/14	1343	VERT	4	D1	.020	.002K	2.3	8.00	1.00K	1.00	1.00
93/07/14	1345	VERT	4	D2	.020	.002	2.4	9.00	1.00K	1.00	1.00
93/07/14	1347	VERT	4	D3	.010	.002	2.5	9.00	1.00K	1.00	1.00
93/07/14	1415	WATER	23.5	D1	.040	.020	1.7				
93/07/14	1417	WATER	23.5	D2	.040	.020	1.7				
93/07/14	1419	WATER	23.5	D3	.030	.020	1:7				
93/08/11	1313	VERT	4		.030	.003	2.5	10.00	1.00K	1.00	3.00
93/08/11	1327	WATER	24		.050	.010	1.6				
93/09/15	1152	VERT	4		.020	.004	2.2				
93/09/16	1151	VERT	4		.020	.004	2.2				
93/09/16	1152	VERT	4					5.00	1.00	1.00	4.00
93/09/16	1202	WATER	23.5		.040	.010	2.1				

STORET RETRIEVAL DATE 94/05/26
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TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 560.80 /TYPA/AMBNT/STREAM/SOLIDS
131TVAC HQ 06010201002 0043.170 OFF
0000 METERS DEPTH

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MILES 0953.80 0046.50 560.80

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	00060 STREAM FLOW CFS	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00400 PH SU	00094 CNDUCTVY FIELD MICROMHO
93/04/28	1210	WATER	0.3		16.7	11.5	118.6$	8.40	165
93/04/28	1215	WATER	1		16.3	11.4	114.0$	8.40	165
93/04/28	1220	WATER	1.5		16.0	11.3	113.0$	8.30	164
93/04/28	1225	WATER	2		15.7	11.2	112.0$	8.30	164
93/04/28	1230	WATER	4		15.3	10.7	104.9$	8.20	171
93/04/28	1240	WATER	6		15.2	10.5	102.9$	8.10	177
93/04/28	1245	WATER	8		15.1	10.4	102.0$	8.10	179
93/04/28	1250	WATER	10		14.8	10.3	101.0$	8.10	186
93/04/28	1255	WATER	12		14.4	10.0	96.2$	8.00	206
93/04/28	1300	WATER	12.5		14.4	10.0	96.2$	8.00	195
93/05/20	1142	WATER	0.3		21.7	9.2	104.5$	7.70	179
93/05/20	1143	WATER	1		21.7	9.1	103.4$	7.70	179
93/05/20	1144	WATER	1.5		21.7	9.1	103.4$	7.70	180
93/05/20	1145	WATER	4		21.0	8.3	92.2$	7.40	179
93/05/20	1147	WATER	6		20.7	8.2	91.1$	7.40	174
93/05/20	1148	WATER	8		20.2	7.8	84.8$	7.20	181
93/05/20	1149	WATER	10		19.7	7.6	82.6$	7.20	183
93/05/20	1150	WATER	12		19.3	6.9	73.4$	7.10	183
93/05/20	1151	WATER	12.6		19.2	7.0	74.5$	6.90	183
93/05/20	1152	WATER	13.1		19.1	6.9	73.4$	7.00	185
93/06/17	1047	WATER	0.3		27.1	11.1	137.0$	8.70	195
93/06/17	1050	WATER	1		26.2	10.9	132.9$	8.60	195
93/06/17	1055	WATER	1.5		25.9	10.3	125.6$	8.60	194
93/06/17	1100	WATER	2		25.7	9.9	120.7$	8.50	192
93/06/17	1105	WATER	2.5		25.4	8.9	106.0$	8.20	185
93/06/17	1110	WATER	4		25.0	8.3	98.8$	8.00	181
93/06/17	1120	WATER	4.5		24.3	7.1	83.5$	7.60	175
93/06/17	1125	WATER	6		23.9	6.7	78.8$	7.50	172
93/06/17	1130	WATER	8		23.6	6.1	71.8$	7.40	174
93/06/17	1135	WATER	10		23.6	6.1	71.8$	7.40	170
93/06/17	1140	WATER	12		23.3	5.1	58.6$	7.30	163
93/06/17	1145	WATER	12.5		23.2	4.6	52.9$	7.20	166
93/06/17	1150	WATER	13		23.2	4.0	46.0$	7.20	162
93/07/14	1125	WATER	0.3		29.8	10.3	135.5$	8.80	205
93/07/14	1129	WATER	1		29.7	10.6	139.5$	8.90	206
93/07/14	1133	WATER	1.5		29.5	10.5	134.6$	8.90	204
93/07/14	1137	WATER	2		29.5	10.4	133.3$	8.70	205
93/07/14	1141	WATER	3		29.4	10.1	129.5$	8.80	205
93/07/14	1145	WATER	3.5		29.2	9.5	121.8$	8.70	207
93/07/14	1149	WATER	4		28.6	9.2	117.9$	8.60	208
93/07/14	1157	WATER	4.5		27.7	7.3	92.4$	8.00	214
93/07/14	1201	WATER	6		27.0	7.1	87.7$	7.90	210
93/07/14	1205	WATER	6.5		25.8	6.5	79.3$	7.60	201
93/07/14	1209	WATER	8		25.0	5.8	69.0$	7.40	200
93/07/14	1213	WATER	10		24.1	5.2	61.2$	7.30	192
93/07/14	1217	WATER	12		23.6	4.6	54.1$	7.20	194
93/07/14	1221	WATER	12.5		23.6	4.5	52.9$	7.20	191
93/08/11	1118	WATER	0.3		25.5	8.3	98.8$	8.10	202
93/08/11	1119	WATER	1		25.2	8.1	96.4$	8.10	201
93/08/11	1120	WATER	1.5		25.1	8.0	95.2$	8.00	200
93/08/11	1121	WATER	2		24.9	7.4	88.1$	7.90	200
93/08/11	1122	WATER	4		24.2	6.7	78.8$	7.70	199
93/08/11	1124	WATER	6		23.9	6.5	76.5$	7.60	199
93/08/11	1125	WATER	8		23.8	6.5	76.5$	7.60	200
93/08/11	1126	WATER	10		23.6	6.2	72.9$	7.60	200
93/08/11	1127	WATER	12		23.6	6.0	70.6$	7.60	203
93/08/11	1128	WATER	12.5		23.5	5.7	65.5$	7.50	205
93/08/11	1129	WATER	13		23.3	5.2	59.8$	7.50	206
93/09/16	1050	WATER	0.3		24.2	7.3	85.9$	7.70	203
93/09/16	1051	WATER	1		24.1	7.1	83.5$	7.70	203
93/09/16	1052	WATER	1.5		24.1	7.1	83.5$	7.70	203
93/09/16	1053	WATER	2		24.1	7.1	83.5$	7.70	203
93/09/16	1054	WATER	4		24.1	6.9	81.2$	7.70	203
93/09/16	1056	WATER	6		24.1	6.9	81.2$	7.60	201
93/09/16	1057	WATER	8		24.1	6.9	81.2$	7.60	209
93/09/16	1058	WATER	10		24.0	6.8	80.0$	7.60	207
93/09/16	1059	WATER	12		23.7	6.3	74.1$	7.50	218
93/09/16	1100	WATER	12.4		23.7	6.2	72.9$	7.50	209
93/09/16	1101	WATER	13		23.7	6.1	71.8$	7.50	214

STORET RETRIEVAL DATE 94/05/26
476041 1114C
35 49 50.0 084 36 33.0 2
WATTS BAR RESERVOIR
47145 TENNESSEE ROANE
TENNESSEE RIVER BASIN 040801
TENNESSEE RIVER 560.80
131TVAC HQ 06010201002 0043.170 OFF /TYPA/AMBNT/STREAM/SOLIDS
0000 METERS DEPTH

INDEX 1021500 007720 00920
MILES 0953.80 0046.50 560.80

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00078 TRANSP SECCHI METERS	31616 FEC COLI MFM-FCBR /100ML	00080 COLOR PT-CO UNITS	00530 RESIDUE TOT NFLT MG/L	00605 ORG N N MG/L	00610 NH3+NH4- N TOTAL MG/L	00630 NO2&NO3 N-TOTAL MG/L
93/04/28	1210	WATER	0.3		1.52	10K					
93/04/28	1235	VERT	4				5Q	8	.150	.010	.34
93/04/28	1300	WATER	12.5				5Q	9	.090	.040	.42
93/05/20	1142	WATER	0.3		1.00	10K					
93/05/20	1146	VERT	4				10	8	.040	.020	.28
93/05/20	1151	WATER	12.6				5	10	.180	.060	.35
93/06/17	1047	WATER	0.3		1.15	10K					
93/06/17	1115	VERT	4				10	6	.090	.020	.19
93/06/17	1145	WATER	12.5				10	15	.040	.050	.29
93/07/14	1125	WATER	0.3		1.33	10K					
93/07/14	1153	VERT	4				10	5	.320	.030	.13
93/07/14	1217	WATER	12				5	14	.200	.040	.39
93/08/11	1118	WATER	0.3		1.20	10K					
93/08/11	1123	VERT	4				10	5	.470	.010K	.27
93/08/11	1129	WATER	13				1K	6	.330	.020	.30
93/09/16	1050	WATER	0.3		1.20	10K					
93/09/16	1055	VERT	4				10	4	.460	.030	.16
93/09/16	1100	WATER	12.4				5	14	.250	.060	.20

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (M)	84002 CODE GENERAL REMARKS	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00680 T ORG C C MG/L	32211 CHLRPHYL A UG/L CORRECTD	32212 CHLRPHYL B UG/L	32214 CHLRPHYL C UG/L	32218 PHEOPHTN A UG/L
93/04/28	1235	VERT	4		.030	.002	1.9	9.00	1.00	1.00	2.00
93/04/28	1300	WATER	12.5		.030	.003	1.8				
93/05/20	1146	VERT	4		.030	.003	2.0	11.00	1.00K	2.00	2.00
93/05/20	1151	WATER	12.6		.040	.004	1.8				
93/06/17	1115	VERT	4		.040	.002K	2.0	10.00	2.00	2.00	5.00
93/06/17	1145	WATER	12.5		.050	.004	1.7				
93/07/14	1153	VERT	4		.030	.003	2.2	9.00	1.00K	1.00	2.00
93/07/14	1217	WATER	12		.050	.007	1.8				
93/08/11	1123	VERT	4		.020	.002K	2.0	3.00	1.00	1.00	3.00
93/08/11	1129	WATER	13		.030	.005	1.7				
93/09/16	1055	VERT	4		.030	.005	2.0	5.00	1.00	1.00K	4.00
93/09/16	1100	WATER	12.4		.040	.008	1.8				

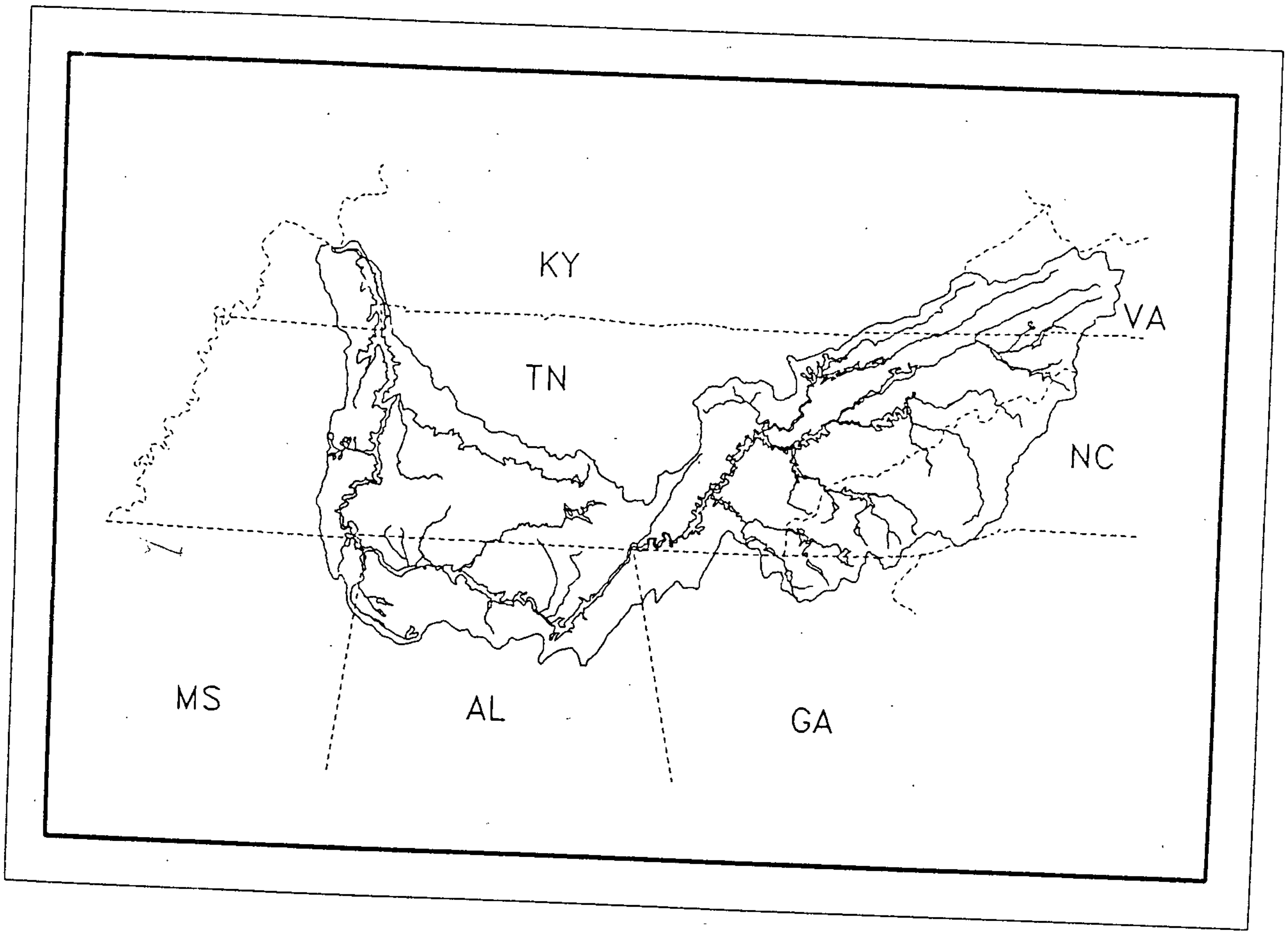
Tennessee
Valley
Authority

Water Resources Division
Chattanooga, Tennessee

TVA/WR/AB--91/4
May 1991

RESERVOIR VITAL SIGNS MONITORING - 1990

FISH COMMUNITY RESULTS



WATER RESOURCES &
ECOLOGICAL MONITORING

WATER RESOURCES MANAGEMENT

Introduction

The Tennessee Valley Authority (TVA) operates 9 reservoirs on the Tennessee River and 37 reservoirs on its tributaries. TVA is committed to maintaining the health of aquatic resources created when the reservoir system was built. To that end, TVA in cooperation with Valley states, operates a water resource monitoring program that includes physical, chemical, and biological data collection components. Biological monitoring will target the following selected elements within three zones of the reservoir (inflow, transition, and forebay):

- Sediment/Water-column Acute Toxicity Screening
- Benthic macroinvertebrates
- Fish

Reservoir fisheries monitoring is divided into the following activities:

- Fish Biomass
- Fish Tissue Contamination
- Fish Community Monitoring
- Fish Health Assessment

This report presents the results of fish community monitoring and fish health assessments. Reports on other components and activities are published in companion reports, and a summary report on the results of the monitoring program also is available.

Fish Community Monitoring

The basic ecological principle underlying the community monitoring program is that characteristics of fish populations, because of their trophic status, will reflect changes in the entire aquatic ecosystem. The program's objective is to provide the minimum information necessary to evaluate the status of the fish community at inflow, transition zone, and forebay areas of reservoirs throughout the Tennessee Valley. The information gathered is used to:

- Screen for significant differences from average conditions
- Detect long-term trends

- Aid in establishing project priorities
- Trigger intensive sampling to determine causes and solutions where problems are identified

Fish Health Assessment Index

The general health of aquatic communities is a reflection of the quality of the water and habitat. The primary objective of fish health assessment was to develop baseline information on the health of populations of a top predator species represented in fish communities in reservoirs throughout the Tennessee Valley. Future samples will allow detection of year-to-year variations and long-term trends. The survey utilized a method developed by Goede (1991), to assess the general health and condition of a fish population. To better reflect existing conditions the method was modified by TVA into an index known as the Fish Health Assessment Index (FHAI). The largemouth bass was selected as the initial species to investigate in the Tennessee Valley because of ease of capture, widespread distribution, and position on the food chain (top predator). Results of ordered observations of both external and internal condition of individuals were entered into a portable computer and analyzed using a program (AUSUM430) developed by TVA. Abnormalities were tabulated and mathematically weighted in the calculation of the FHAI according to severity, such that as debilitating anomalies increase, the FHAI also increases. Thus better water quality is indicated by a lower FHAI. Comparisons can then be made among individual fish, size-groups of fish, sites, groups of sites, reservoirs, and/or groups of reservoirs.

The autopsy based FHAI is based on the following assumptions (Goede, 1991):

- If the appearance of the organ and tissue systems is "normal" the fish is normal.
- In response to environmental stresses some change in function of organs and tissues is necessary for homeostasis or maintenance of internal environment of the fish.
- If change in function persists because of continuing environmental stress(es), there will be change or modification of structure that is observable as a gross change in organs or tissues.
- Observable changes in structures of certain tissues and organs indicate s adaptive change in response to extrinsic environmental stresses.
- If appearance of the organ and tissue systems shows departure from normal, the fish is responding to intrinsic changes brought about by extrinsic environmental stresses.

While these assumptions generally hold true for chronic environmental stresses, there are occasions where there is (or has been) environmental stresses that yield no observable changes in gross tissue structure or appearance. Two examples are as follows:

- Changes in function may be sufficiently acute and severe that mortality occurs before gross observable change in structure and/or appearance occurs.

- Microscopic, histological structural change may occur without gross manifestation.

Degrees of "normal" or nature of "normal" are subject to some interpretation. "Normal" must be considered relative to age, sex, season, species, etc. For example, "normal" level of fat storage of healthy, free-ranging fish entering the winter season is much higher than from the same fish coming out of the winter. Results must be compared with established norms. The autopsy-based system of fish health assessment index is *not* a diagnostic tool. If it indicates that a population of fishes in a given reservoir or location is unhealthy, further investigation (e.g. histological examination of the tissue by a pathologist) may be required to determine what is causing the fish to be unhealthy.

Methods

Fish Community Monitoring

Fourteen reservoirs were studied during fall 1990 including: Kentucky, Pickwick, Wilson, Wheeler, Guntersville, Nickajack, Chickamauga, Watts Bar, Fort Loudoun, Tellico, Melton Hill, Norris, Cherokee, and Douglas. Shoreline electrofishing samples were collected during daylight hours from inflow, transition, and forebay zones of each reservoir from late September to December, 1990. The forebay area was defined as the main channel shoreline extending into the "mouths" of tributary streams within approximately three miles above the dam. The transition zone is the main reservoir reach where hydraulic and water chemistry conditions suggest a shift from a riverine to a reservoir environment. The inflow site was in the tailwater of the upstream dam or in the free-flowing stream(s) entering reservoirs farthest upstream on the tributaries. The September-December time frame was chosen as sampling all reservoirs requires an extended period of time, and distribution of fish populations is most stable in fall. A total of 10 electrofishing transects (10 minutes duration each) was sampled within each of the 42 sites (14 reservoirs). All habitats were sampled at each site, with dominant types receiving the most effort. Habitat distinctions were based on major changes in substrate (e.g., rock, riprap, or clay), and/or cover (e.g., brush or aquatic vegetation). Sample size/duration was selected based on sensitivity analysis of largemouth bass electrofishing samples in two Oklahoma reservoirs (Gilliland 1985).

Black bass species captured were measured and weighed, other major sport fish species and channel catfish were measured, and all other species were enumerated prior to release. All fish were examined for obvious external abnormalities, diseases, and parasites, and this information was noted. Fish observed but not captured were included in the records if positive identification and enumeration could be made. Estimates of young-of-year (YOY) numbers were made in instances where high densities were encountered (i.e., YOY shad and bluegill). However, estimates of these species were not made in 1989, so year to year comparisons involving shad, bluegill, total fish abundance, and species composition are not possible in this report.

Where conditions permitted, ten 100-ft-monofilament experimental gill nets with five 20-ft panels (mesh sizes of 1, 1 1/2, 2, 2 1/2, and 3 inch bar mesh) were set for one overnight period in each reservoir zone. In forebay and transition zones, nets were set in all habitat types, alternating mesh sizes toward the shoreline between sets. In inflow areas, nets were set wherever flow conditions allowed. Availability of adequate sample locations limited number of nets set to less than ten at some inflow stations.

Analyses of data included comparison of total catch rates with historical catch rates for the particular reservoir grouping and among zones within reservoirs, comparison of functional group composition, calculation of proportional stock density (PSD) and relative stock density (RSD) for principal species, and calculation of mean relative weight (Wr) for black bass species captured at each sample area. The PSD/RSD analyses compare the number of fish attaining various size categories with the total number of catchable-sized individuals of a given species (Anderson and Weithman 1978). Four size categories: quality, preferred, memorable, and trophy are based upon percentages of maximum attainable lengths (Gabelhouse 1984). Catchable or stock length includes all individuals measuring 25 percent or more of the maximum length. Quality, preferred, memorable, and trophy size fish are at least 37, 46, 59, and 74 percent of the maximum length, respectively (Appendix A). PSD, therefore is the percentage of the total catchable population of a given species represented by individuals of quality size. Relative stock densities (RSD1, RSD2, and RSD3) are percentages of preferred, memorable, and trophy sizes, respectively.

Relative weight analysis involves the development of standard weight tables from historical length-weight information, that identify "expected" weights of fish at different lengths (Anderson and Weithman 1978). Fish having "expected" weights will have Wr values of 100, while those heavier will have Wr values greater than 100. Standard weight tables were generated for five groupings of TVA reservoirs: mainstream Tennessee River, Tennessee storage, North Carolina-Georgia storage, Cherokee, and Douglas (Appendix B).

The 1990 observations (e.g., catch rates, PSD/RSD, Wr) from each reservoir were compared with averages from groupings of similar reservoirs just mentioned. The groupings were determined by principal component analysis of historical rotenone data from 25 TVA reservoirs based on the numerical abundance of the ten most frequently occurring fish species (Tom McDonough, pers. comm.).

Fish Health Assessment

A FHAI was calculated for the three locations and inflow) in each reservoir. Largemouth bass were collected as part of the electrofishing survey and were transported to a mobile laboratory for examination. Fifteen individuals greater than length were 250 mm total length were examined from each of the three locations in each reservoir. Attempts were made to minimize holding time to reduce handling stress which can alter blood chemistry results. Upon arrival at the mobile laboratory, fish were anesthetized with tricaine methanesulfonate (MS-222) in 50 mg/l (ppm) solution.

Fish were processed in the manner described in detail by Goede (1991). The body cavity of the fish was opened using sharp/blunt-ended surgical scissors by making a ventral incision from the vent forward to the pectoral girdle, cutting closely to one side of the pelvic girdle. Care was taken not to make the incision deep enough to damage internal organs. Blood was then collected by cardiac puncture and prepared for determination of using a hematocrit tube which was then sealed and centrifuged to allow measurement of hematocrit, leucocrit, and plasma protein levels. The liver was examined immediately for anomalies because of the tendency for rapid discoloration following death of the individual.

An external examination was initiated following an ordered sequence of eyes, skin, gills, fins, opercles, pseudobranchs, and thymus. Finally, an internal examination was conducted, following an ordered observation sequence of mesenteric fat, spleen, hindgut, kidney, bile, parasites, and determination of sex. The abnormalities sought are listed in table 6 for each reservoir. Abnormal conditions and other data were entered directly into a computer program developed by TVA entitled "AUSUM430". Results were calculated and printed for immediate use.

Summary Comparisons

Thirty-four selected measurements of the fish communities observed at each reservoir were compared to assess the relative health of the fisheries environment within each reservoir and each reservoir location (inflow, transition zone, and forebay). Table 7 in each of the following reservoir chapters summarizes these comparisons. Nine categories were selected for comparison: species richness, fish health, trophic composition, sensitive species, electrofishing and gill netting catch rates, relative weight of *Micropterus* spp., proportional stock densities of selected species, and overall fish abundance. The lower eight mainstream reservoirs (Kentucky to Watts Bar) were compared individually to the average values of the 34 measurements for that group of reservoirs. Similarly, Fort Loudoun and five Tennessee storage reservoirs were compared individually with the averages for that group. Results for 1990 were compared with 1989 results for each reservoir where 1989 data were available. Sampling stations within each reservoir were compared to average values of like stations for the two reservoir groups in 1990. In each comparison a condition considered more healthy than the group average was designated with a '+' sign. A condition less healthy than the average received a '-' sign. Values falling within + or - five percent of the average were given a '0.' Whenever sufficient observations for meaningful comparisons were lacking, blanks appear in the table. In most cases values higher than the group average were considered more healthy. However, this was not the case for the percentages of omnivores and tolerant species, the catch rates of gizzard shad, and the fish health assessment index. The columns of comparisons were summed to determine the overall condition of the fish community compared to the group average and the previous year. Columns with summary values greater than +2 were designated 'Better', those less than -2 were designated 'Worse,' and those within + or - 2 were designated 'Average.'

Results - Chickamauga Reservoir

Fish Community Assessment

A total of 10,070 fish, including 41 species, were captured by electrofishing and gill net sampling in 1990. Electrofishing accounted for 34 species in 5.0 hours of electrofishing and gill netting resulted in capture of 27 species in 30 net nights (table 1). The forebay zone accounted for 4881 of the total fish collected by electrofishing and 219 of the fish obtained with gill nets (table 2). No endangered or threatened species were collected. Of the taxa collected, 1 was parasitic, 1 was planktivorous, none were herbivorous, 15 were insectivorous, 5 were benthic insectivorous specialists, 6 were omnivorous, and 13 species were piscivorous (table 3).

Catch Rates of Selected Species

Comparisons of fall 1990 electrofishing catch rates of selected species with those of fall 1989 and overall average catch rates for these species in Tennessee River mainstream reservoirs (table 1) indicate largemouth bass were more numerous during fall 1990 (52.6) than fall 1989 (31.8), and were also more abundant than the average for the reservoir grouping (27.8). Smallmouth bass were more abundant during fall 1990 (2.4) than fall 1989 (0.4), but are less abundant in Chickamauga Reservoir than the average for the mainstream reservoir grouping (7.9). Spotted bass were more numerous during fall 1990 (25.6) than fall 1989 (12.0), and were also more abundant than the average for the reservoir grouping (12.7). Bluegill were more numerous during fall 1990 (259) than fall 1989 (129), and were also more abundant than the average for the reservoir grouping (133). Redear sunfish abundance declined during fall 1990 (33.6) from fall 1989 (58.4), but were still more abundant than the average for the reservoir grouping (16.9). Channel catfish were relatively uncommon in this reservoir, as evidenced by a catch rate of 1.8 fish per hour during 1989 and 1990, which is slightly less than the reservoir group average (2.5). Gizzard shad, 260 per hour during fall 1990, were less abundant than the average for the reservoir grouping (757). Whereas, threadfin shad (980) were on par with the average for the reservoir grouping (955).

The abundance of three selected groups from experimental gill netting (channel catfish, *Morone* spp, and *Stizostedion* spp.) was compared to fall 1989 and the reservoir group average catch rates (table 1). The comparisons indicate channel catfish abundance (1.2) was similar to the reservoir group average (1.3), and had tripled since the 1989 sample. The catch rate of combined *Morone* spp., 4.8 per net night, was equal to the mainstream reservoir group average (4.9), and was approximately three times greater than the 1989 abundance at Chickamauga Reservoir (1.7). *Stizostedion* spp., however, were rare in the fall samples of both years, 0.1 per net night, and were below the average abundance in mainstream reservoirs (0.5).

Comparisons of electrofishing catch rates among the three reservoir stations (table 2) showed largemouth bass were most abundant in the forebay area of the reservoir with a catch rate of 75.0 fish per hour, compared to 55.8 and 27.0 in the transition and inflow areas, respectively. Smallmouth bass were found in equal abundance (1.2) at the inflow and transition areas of Chickamauga Reservoir, but were more abundant in the forebay area (4.8). Spotted bass were more abundant in the forebay area with a catch rate of 67.8 fish per hour compared to the transition, 9.0 per hour, and were absent from the inflow area. Bluegill were most abundant in the forebay area of the reservoir with a catch rate of 543 fish per hour, compared to 154 and 81.6 in the transition and inflow areas, respectively. Redear sunfish were most abundant in the inflow area of the reservoir with a catch rate of 55.8 fish per hour, compared to 30.0 and 15.0 in the forebay and transition areas, respectively. Channel catfish were found in equal abundance (1.2) at the inflow and forebay areas of Chickamauga Reservoir, but were more abundant in the transition area (3.0). Gizzard shad were most abundant in the forebay area of the reservoir with a catch rate of 359 fish per hour, compared to 326 and 94.2 in the transition and inflow areas, respectively. Threadfin shad were found in comparable abundance in the transition and forebay areas of the reservoir with catch rates of 1605 and 1335, respectively, but were absent from the inflow area.

Variations in the spatial abundance of channel catfish, *Morone* spp., and *Stizostedion* spp., gizzard shad, and threadfin shad based on gill net samples revealed found channel catfish were equally abundant in the inflow and forebay areas of the reservoir with a catch rate of 1.4 fish per net-night, compared to 0.8 in the transition area. Combined *Morone* spp. were found in greater abundance in the inflow (5.1) and forebay (6.1) areas, than the transition area (3.2). The small numbers of *Stizostedion* were found in the inflow and transition areas, which had catch rates of 0.1 fish per net night.

Relative Abundance of Selected Groups

Trophic composition of Chickamauga Reservoir based on the combined electrofishing and gill netting catch showed the following relationships. The dominant trophic group by number was planktivores, represented by 49 percent of the sample. Following them in abundance were insectivores, which comprised 27 percent of the sample, omnivores (16 percent), piscivores (8 percent), specialist (1 percent), and parasites (tr.).

Shad were the most abundant taxonomic grouping encountered, as 3 species represented 63 percent of the total sample by number. Sunfishes, excluding *Micropterus* spp., represented 18 percent of the sample with 8 species. The 5 species of suckers amounted to 0.4 percent of the sample. Catfish (3 species) were 0.8 percent of the sample. There were 3 species of black bass (*Micropterus* spp.) present, which represented 4.2 percent of the sample.

Cyprinids (minnow family) comprised 1.0 percent of the sample with 1 species. There were 9 small cyprinid and darter species observed.

Species tolerant of degraded conditions, which included spotted gar, gizzard shad, golden shiner, and spotfin shiner, accounted for 14 percent of the sample. Species considered intolerant to pollution included spotted sucker, black redhorse, and longear sunfish accounted for 0.6 percent of the sample by number.

Relative Weights

Relative weight (Wr) indices for black bass species sampled at Chickamauga Reservoir during fall 1990 were compared with those obtained in fall 1989, whenever possible (table 4). There was little difference in relative weights of largemouth bass in fall 1990 (99) and fall 1989 (97). Smallmouth bass were not sampled in adequate numbers (15 or more) to draw useful conclusions about the relative weight of this species in this reservoir. There was little difference in relative weights of spotted bass in fall 1990 (88) and fall 1989 (86).

Largemouth bass had a higher relative weight in the forebay area (101) than the inflow area (94), but approximately the same as the transition area (98). Spotted bass had a higher relative weight in the inflow area (93) than the forebay area (87), but approximately the same as the transition area (90).

Proportional and Relative Stock Densities

The size distribution of important sportfish species is described by proportional (PSD) and relative (RSD1-3) stock densities (table 5). The percentage of quality-sized channel catfish sampled during fall 1990 at Chickamauga Reservoir was shown as a PSD value of 64. This value is essentially that that observed during fall 1989 (67). Channel catfish in the preferred size range or larger were slightly less abundant in fall 1990 (RSD1 = 8) than fall 1989 (10). Channel catfish in the memorable size range or larger were not found during 1989 or 1990.

The percentage of quality-sized bluegill sampled during fall 1990 at Chickamauga Reservoir was shown as a PSD value of 24. This value is greater than that observed during fall 1989 (15). Bluegill in the preferred and memorable size ranges were found in fall 1990 (RSD1 = 1, RSD2 = 1), but were not found in fall 1989. Bluegill in the trophy size range were not found during 1990.

The percentage of quality-sized redear sunfish sampled during fall 1990 at Chickamauga Reservoir was shown by a PSD value of 43. This value is approximately the same as that observed during fall 1989 (46). Redear sunfish in the preferred size range or larger were slightly more abundant in fall 1990 (RSD1 = 8) than fall 1989 (6). Redear sunfish in the memorable size range were found in fall 1990 (RSD2 = 1), but were absent in fall 1989. Redear sunfish in the trophy size range were not found during 1990.

The percentage of quality-sized spotted bass sampled during fall 1990 at Chickamauga Reservoir was indicated by a PSD value of 35. This value is nearly identical to that found in 1989(36). Spotted bass in the preferred size range were more abundant in fall 1990 (RSD1 = 15) than fall 1989 (4). Spotted bass in the memorable size range or larger were not found during fall 1990 or fall 1989.

The percentage of quality-sized largemouth bass sampled during fall 1990 at Chickamauga Reservoir was indicated by a PSD value of 47. This value is very nearly the same as that observed during fall 1989 (45). Largemouth bass in the preferred size range or larger were slightly more abundant in fall 1990 (12) than fall 1989 (10). Largemouth bass in the memorable size range were similar in abundance in fall 1990 (RSD2 = 3) than fall 1989 (2). Largemouth bass in the trophy size range were not found during 1989 or 1990.

Variations in PSD and RSD1-3 values among the three sampling areas of Chickamauga Reservoir were observed. Channel catfish had the highest percentage (PSD= 80) of quality-sized individuals in the transition zone of the reservoir, compared to the inflow (53) and forebay (64) zones. There were more preferred-sized channel catfish in the transition (RSD1= 20) zone than the forebay (9) zone, but none were found in the inflow zone. No memorable-sized or larger channel catfish were found in the fall 1990 sample. There were no appreciable differences in the percentages of quality-sized bluegill among the inflow (PSD=26), transition (24), and the forebay (22) zones. Preferred-sized bluegill were only found in the transition zone (RSD1= 2). Memorable-sized bluegill were only found in the transition zone (RSD2= 2). No trophy-sized bluegill were found in the fall 1990 sample at any sampling station. Redear sunfish had the highest percentage (PSD= 81) of quality-sized individuals in the transition zone of the reservoir, compared to the inflow (20) and forebay (42) zones. Redear sunfish had the highest percentage (RSD1= 19) of preferred-sized individuals in the transition zone of the reservoir, compared to the inflow (4) and forebay (5) zones. Memorable-sized redear sunfish were only found in the transition zone (RSD2= 3). No trophy-sized redear sunfish were found in the fall 1990 sample. Largemouth bass had a higher percentage (RSD1= 20) of preferred-sized individuals in the transition zone of the reservoir compared to the forebay zone (8) and the inflow zone (12). memorable-sized largemouth bass were greater at the transition zone (RSD2= 7) than the inflow (4) and the forebay (1) zones. No trophy-sized or larger largemouth bass were found in the fall 1990 sample.

Fish Health Assessment Index (FHAI)

The FHAI for Chickamauga Reservoir averaging all areas sampled in 1990 was 54.6 (table 6). In comparison to the overall average FHAI for mainstream reservoirs, 48.1, the relative health of Chickamauga Reservoir appears to be worse. Conditions in 1990 appear to have diminished since 1989 when the reservoir average FHAI was 53.5. not appreciably changed since the previous year's value of 53.5.

The FHAI for the inflow on Chickamauga Reservoir was 28.6, and the three most frequently anomalies found involved parasites, spleen, and liver. Compared to the average FHAI for inflow zones of all the reservoirs within the mainstream reservoir group, 39.9, the apparent health of the inflow zone of this reservoir is better. The inflow FHAI for 1990 at Chickamauga Reservoir showed an improvement over the 1989 FHAI of 50.6, when the most frequently encountered anomalies were found in the hematocrit, spleen, and kidney.

The FHAI for the transition on Chickamauga Reservoir was 69.3, and the three most frequently anomalies found involved parasites, spleen, and kidney. Compared to the average FHAI for transition zones of all the reservoirs within the mainstream reservoir group, 52.8, the apparent health of the transition zone of this reservoir is worse. The transition FHAI for 1990 at Chickamauga Reservoir showed declining health of the transition zone since the 1989 FHAI of 54.0, when the most frequently encountered anomalies were found in the hematocrit, liver, and kidney.

The FHAI for the forebay on Chickamauga Reservoir was 66.0, and the three most frequently anomalies found involved parasites, plasma protein, and liver. Compared to the average FHAI for forebay zones of all the reservoirs within the mainstream reservoir group, 51.3, the apparent health of the forebay zone of this reservoir is worse. The forebay FHAI for 1990 at Chickamauga Reservoir showed declining health of the forebay zone since the 1989 FHAI of 56.0, when the most frequently encountered anomalies were found in the hematocrit, liver, and kidney.

Conclusion

In summary Chickamauga Reservoir was found to support a poorer fish community than the average Tennessee River mainstream reservoir during 1990 based on comparison of 34 measurements (table 7). The community has shown improvement over the previous year of sampling. Although the fish community in the inflow zone appears to be in worse condition than the average of inflow zones of mainstream reservoirs, the fish community in the forebay zone appears to be in better condition than the average of forebay zones of mainstream reservoirs. The transition zone supports a fish community approximately equivalent to the average transition community found in mainstream reservoirs.

Table 1. Species list and catch per unit effort of fishes sampled during fall electrofishing and gill netting on Chickamauga Reservoir, 1990, (stations combined) compared with previous year and averages for Mainstream reservoirs. Total efforts(*) shown in parentheses.

Name	Electrofishing 1990 (5.0)	Electrofishing 1989 (5.0)	Electrofishing Mainstream Average (42)	Gill netting 1990 (30)	Gill netting 1989 (30)	Gill netting Mainstream Average (237)
Chestnut lamprey	8.8	0.0	1.2	0.0	0.0	0.0
Spotted gar	0.4	0.8	1.8	0.1	T	0.1
Skipjack herring	0.0	0.0	7.7	3.9	1.2	4.7
Gizzard shad	259.6	67.0	756.8	2.3	3.2	6.7
Threadfin shad	980.0	41.4	955.0	0.0	0.0	0.0
Mooneye	0.0	0.0	T	0.1	0.1	0.1
Carp	20.2	6.2	8.3	0.1	0.0	0.4
Golden shiner	3.8	1.6	3.0	0.3	0.1	0.1
Emerald shiner	137.0	0.8	82.3	0.0	0.0	0.0
Spotfin shiner	3.4	0.2	7.8	0.0	0.0	0.0
Steelcolor shiner	1.2	0.0	0.1	0.0	0.0	0.0
Pugnose minnow	0.2	0.0	0.1	0.0	0.0	0.0
Bluntnose minnow	0.2	2.0	0.4	0.0	0.0	0.0
Bullhead minnow	1.4	0.0	0.4	0.0	0.0	0.0
Northern hogsucker	0.0	0.0	0.1	T	0.0	T
#Smallmouth buffalo	0.0	0.0	0.6	0.0	T	0.4
Spotted sucker	3.2	4.6	4.0	0.5	0.3	0.2
Silver redhorse	0.0	0.0	0.0	T	0.0	0.1
Black redhorse	0.0	0.0	0.3	0.1	0.0	T
Golden redhorse	0.8	1.0	1.4	T	T	0.1
Blue catfish	0.0	0.0	0.1	0.7	0.1	0.9
#Yellow bullhead	0.0	0.2	0.0	0.0	0.0	0.0
Channel catfish	1.8	1.8	2.5	1.2	0.4	1.3
Flathead catfish	1.8	0.6	1.6	0.2	0.1	0.2
White bass	0.4	0.0	3.2	1.6	0.3	1.8
Yellow bass	2.0	2.8	9.6	2.5	1.2	2.3
Striped bass	0.0	0.0	0.2	0.6	0.2	0.4
#Hybrid striped bass	0.0	0.0	0.0	0.0	T	0.4
Warmouth	9.2	14.4	2.7	0.0	0.2	T
Redbreast sunfish	30.8	33.6	9.1	0.0	0.0	0.0
Green sunfish	1.0	1.0	2.6	0.0	0.0	0.0
Bluegill	259.4	129.2	132.8	0.3	0.2	0.4
Longear sunfish	4.8	4.6	19.8	0.0	T	T
Redear sunfish	33.6	58.4	16.9	1.0	0.5	0.8
#Hybrid sunfish	0.0	0.2	0.1	0.0	0.0	0.0
Smallmouth bass	2.4	0.4	7.9	T	0.0	0.2
Spotted bass	25.6	12.0	12.7	0.7	0.3	0.6
Largemouth bass	52.6	31.8	27.8	0.1	0.0	0.3
White crappie	0.8	1.8	2.0	0.1	0.1	0.1
Black crappie	7.2	4.8	2.6	0.5	0.2	0.4
Yellow perch	7.6	19.4	1.8	0.1	0.1	T
Logperch	1.6	0.8	3.7	0.0	0.0	0.0
Sauger	0.2	0.0	0.2	0.1	0.1	0.4
Freshwater drum	5.4	2.6	5.3	0.1	0.4	0.4
Brook silverside	43.2	16.4	15.4	0.0	0.0	0.0
Total: CPUE	1912	462	2112	17.1	9.3	23.6
No. collected	9558	2312	87984	512	279	5593

Total: Species: 43 (and 2 hybrids)

1990: No. collected 10070

Species: 34 and 0 hybrids, electrofishing
27 and 0 hybrids, gill netting

* Electrofishing effort units are hours
Gill net effort units are net-nights
\# Species found only in 1989
T Catch per effort less than 0.05

Table 2. Species list and catch per unit effort at inflow, transition, and forebay stations during fall electrofishing and gill netting on Chickamauga Reservoir, 1990. Total efforts(*) shown in parentheses.

Common Name	Electrofishing Inflow (1.7)	Electrofishing Transition (1.7)	Electrofishing Forebay (1.7)	Gill netting Inflow (10)	Gill netting Transition (10)	Gill netting Forebay (10)
Chestnut lamprey	0.0	0.6	25.8	0.0	0.0	0.0
Spotted gar	0.0	0.0	1.2	0.0	0.0	0.3
Skipjack herring	0.0	0.0	0.0	3.4	3.0	5.2
Gizzard shad	94.2	325.8	358.8	1.1	2.6	3.1
Threadfin shad	0.0	1605.0	1335.0	0.0	0.0	0.0
Mooneye	0.0	0.0	0.0	0.1	0.1	0.0
Carp	3.6	27.6	29.4	0.0	0.0	0.2
Golden shiner	2.4	3.6	5.4	0.0	0.5	0.3
Emerald shiner	0.6	165.6	244.8	0.0	0.0	0.0
Spotfin shiner	0.6	0.6	9.0	0.0	0.0	0.0
Steelcolor shiner	0.6	0.0	3.0	0.0	0.0	0.0
Pugnose minnow	0.0	0.6	0.0	0.0	0.0	0.0
Bluntnose minnow	0.0	0.0	0.6	0.0	0.0	0.0
Bullhead minnow	1.8	1.8	0.6	0.0	0.0	0.0
Northern hogsucker	0.0	0.0	0.0	0.1	0.0	0.0
Spotted sucker	7.2	1.2	1.2	0.8	0.3	0.3
Silver redhorse	0.0	0.0	0.0	0.1	0.0	0.0
Black redhorse	0.0	0.0	0.0	0.3	0.0	0.0
Golden redhorse	2.4	0.0	0.0	0.1	0.0	0.0
Blue catfish	0.0	0.0	0.0	0.7	1.1	0.4
Channel catfish	1.2	3.0	1.2	1.4	0.8	1.4
Flathead catfish	0.0	0.0	5.4	0.2	0.3	0.1
White bass	1.2	0.0	0.0	0.9	2.2	1.8
Yellow bass	4.2	1.8	0.0	2.1	1.8	3.7
Striped bass	0.0	0.0	0.0	0.2	1.1	0.6
Warmouth	0.6	17.4	9.6	0.0	0.0	0.0
Redbreast sunfish	7.8	29.4	55.2	0.0	0.0	0.0
Green sunfish	0.6	1.8	0.6	0.0	0.0	0.0
Bluegill	81.6	153.6	543.0	0.3	0.2	0.5
Longear sunfish	0.0	5.4	9.0	0.0	0.0	0.0
Redear sunfish	55.8	15.0	30.0	0.5	1.3	1.3
Smallmouth bass	1.2	1.2	4.8	0.0	0.0	0.1
Spotted bass	0.0	9.0	67.8	0.5	0.5	1.0
Largemouth bass	27.0	55.8	75.0	0.0	0.0	0.3
White crappie	0.0	1.2	1.2	0.0	0.1	0.3
Black crappie	7.8	3.0	10.8	0.0	0.5	0.9
Yellow perch	0.0	15.6	7.2	0.0	0.2	0.0
Logperch	0.0	0.0	4.8	0.0	0.0	0.0
Sauger	0.6	0.0	0.0	0.1	0.1	0.0
Freshwater drum	8.4	6.6	1.2	0.0	0.1	0.1
Brook silverside	1.2	41.4	87.0	0.0	0.0	0.0
Total: CPUE	312.6	2493.6	2928.6	12.9	16.8	21.9
No. collected	521	4156	4881	129	168	219
Species: 41 (and 0 hybrid)						

* Electrofishing effort units are hours; gill net units are net-nights.

Table 3. Species list according to trophic designation of fish encountered during fall electrofishing and gill netting at Chickamauga Reservoir, 1990.

Common Name	Inflow	Transition	Forebay
Parasites			
Chestnut lamprey		X	X
Group total	0	1	1
Planktivores			
Threadfin shad		X	X
Group total	0	1	1
Insectivores			
Mooneye	X	X	
Emerald shiner	X	X	X
Spotfin shiner	X	X	X
Steelcolor shiner	X		X
Pugnose minnow		X	
Silver redhorse	X		
Black redhorse	X		
Golden redhorse	X		
Warmouth	X	X	X
Redbreast sunfish	X	X	X
Bluegill	X	X	X
Longear sunfish		X	X
Redear sunfish	X	X	X
Yellow perch		X	X
Brook silverside	X	X	X
Group total	12	11	10
Specialized benthic insectivores			
Bullhead minnow	X	X	X
Northern hogsucker	X		
Spotted sucker	X	X	X
Logperch			X
Freshwater drum	X	X	X
Group total	4	3	4
Omnivores			
Gizzard shad	X	X	X
Carp	X	X	X
Golden shiner	X	X	X
Bluntnose minnow			X
Blue catfish	X	X	X
Channel catfish	X	X	X
Group total	5	5	6
Piscivores			
Spotted gar			X
Skipjack herring	X	X	X
Flathead catfish	X	X	X
White bass	X	X	X
Yellow bass	X	X	X
Striped bass	X	X	X
Green sunfish	X	X	X
Smallmouth bass	X	X	X
Spotted bass	X	X	X
Largemouth bass	X	X	X
White crappie		X	X
Black crappie	X	X	X
Sauger	X	X	
Group total	11	12	12
Grand total	32	33	34

Table 4. Relative weight (Wr) analysis of principal species at Chickamauga Reservoir, 1990, compared to standard weights established for Mainstream Reservoirs.

Common Name	Inflow		Transition		Forebay		Overall		1989	
	Mean Wr	N	Mean Wr	N	Mean Wr	N	Mean Wr	N	Mean Wr	N
Channel catfish	-	-	110	5	108	2	109	7	-	-
Smallmouth bass	99	2	92	2	98	9	97	13	97	2
Spotted bass	93	5	90	18	87	120	88	143	86	45
Largemouth bass	94	42	98	90	101	123	99	255	97	159

Table 5. Proportional (PSD) and relative stock density (RSD) of principal species at Chickamauga Reservoir, 1990 . Available 1989 values included.

Common Name	N	Quality (PSD)	Preferred (RSD)	Memorable (RSD2)	Trophy (RSD3)
Channel catfish					
Inflow	15	53	0	0	0
Transition	10	80	20	0	0
Forebay	11	64	9	0	0
Overall-1990	36	64	8	0	0
1989	21	67	10	0	0
Bluegill					
Inflow	27	26	0	0	0
Transition	42	24	2	2	0
Forebay	36	22	0	0	0
Overall-1990	105	24	1	1	0
1989	400	15	0	0	0
Redear sunfish					
Inflow	51	20	4	0	0
Transition	32	81	19	3	0
Forebay	38	42	5	0	0
Overall-1990	121	43	8	1	0
1989	128	46	6	0	0
Spotted bass					
Inflow	5	100	60	0	0
Transition	14	21	14	0	0
Forebay	21	29	5	0	0
Overall-1990	40	35	15	0	0
1989	45	36	4	0	0
Largemouth bass					
Inflow	25	52	12	4	0
Transition	44	39	20	7	0
Forebay	79	49	8	1	0
Overall-1990	148	47	12	3	0
1989	128	45	10	2	0

Table 6. Fish health assessment index (FHAI) results for Chickamauga Reservoir, 1990, compared to 1989.

	Inflow 1990	Inflow 1989	Transition 1990	Transition 1989	Forebay 1990	Forebay 1989
Health Assessment Index (FHAI)	28.6	50.6	69.3	54.0	66.0	56.0
Standard Deviation	17.8	33.8	39.2	30.4	25.7	34.4
Coefficient of Variation	62.2	66.6	56.6	56.3	39.0	61.5
Sample Size	15	30	15	30	15	30
Number of Anomalies in:						
Eyes	0	0	0	0	0	0
Liver	2	11	6	11	5	12
Spleen	3	12	7	5	3	7
Kidney	0	11	6	10	4	9
Skin	1	0	1	0	2	0
Gills	0	0	1	0	1	0
Pseudobranchs	0	0	0	0	0	0
Thymus	0	1	0	0	0	0
Hind Gut	0	0	0	0	0	0
Fins	0	0	0	0	0	0
Opercles	0	1	0	0	0	0
Parasites	14	0	15	0	12	0
Hematocrit	0	13	3	19	1	13
Leucocrit	1	0	2	3	2	3
Plasma Protein	0	2	1	5	11	8

Mean FHAI for Chickamauga Reservoir:	1990	54.6
	1989	53.5
Mean FHAI for mainstream reservoirs:	1990	48.1
	1989	45.8

		Inflow	Transition	Forebay
Mean FHAI for all sites sampled in each area category (i.e., inflow, transition, and forebay) for mainstream reservoirs:	1990	39.9	52.8	51.3
	1989	47.3	49.0	42.9
Mean FHAI for all sites sampled in each area category (i.e., inflow, transition, and forebay) for all reservoirs sampled:	1990	41.5	47.8	50.0
	1989	45.4	42.3	39.3

Overall FHAI for all sites sampled in the Tennessee Valley:	1990	47.1
	1989	42.0

Table 7. Summary comparison of 34 selected measurements of the fish community sampled at Chickamauga Reservoir, 1990.*

	Chickamauga 1990 vs. Mainstream Ave.	Chickamauga 1990 vs. Chickamauga 1989	Stations within Chickamauga Reservoir vs. average values at Mainstream Reservoirs: Inflow	Transition	Forebay
Species richness					
Total species	0	+	0	+	+
Sunfish species	0	0	-	+	+
Sucker species	-	+	-	-	-
Catfish species	-	-	+	0	0
Small cyprinids**	+	+	+	+	+
Fish health					
FHAI	-		+	-	-
Trophic composition (pct)					
Omnivores	+		+	-	+
Insectivores	+		0	+	+
Planktivores	+		+	-	+
Piscivores	-		-	+	-
Specialists	-		-	+	-
Sensitive species					
Tolerant (pct)	+		+	-	+
Intolerant spp.	-	+	-	+	+
Electrofishing catch rate (no./hr)					
Total catch rate	-		-	+	+
Largemouth bass	+	+	+	+	+
Smallmouth bass	-	+	-	-	-
Spotted bass	+	+	-	+	+
Bluegill	+	+	+	-	+
Redear sunfish	+	-	+	+	+
Gizzard shad	+		+	-	+
Gill netting catch rate (no./net-night)					
Total catch rate	-	+	-	-	-
Channel catfish	-	+	+	-	-
Morone spp.	0	+	-	+	+
Stizostedion spp.	-	0	-	-	-
Relative weight					
Largemouth bass	-	0	-	0	-
Smallmouth bass				0	-
Spotted bass	-	0			
Proportional stock density					
Largemouth bass	-	0	-	-	-
Smallmouth bass					
Spotted bass	-	0		-	-
Bluegill	-	+	-	-	-
Redear sunfish	-	-	-	+	-
Channel catfish	0	0	-	+	+
Overall fish abundance					
Grand total fish	-	+	+	-	+
	-8	10	-4	-1	3
	Worse	Better	Worse	Average	Better

* Plus signs indicate a healthier condition.
Minus signs indicate a less healthy condition.
Zeroes indicate differences less than + or - 5 pct.
Blanks indicate insufficient data for comparison.

** Small cyprinids also include darters, topminnows, and brook silversides.

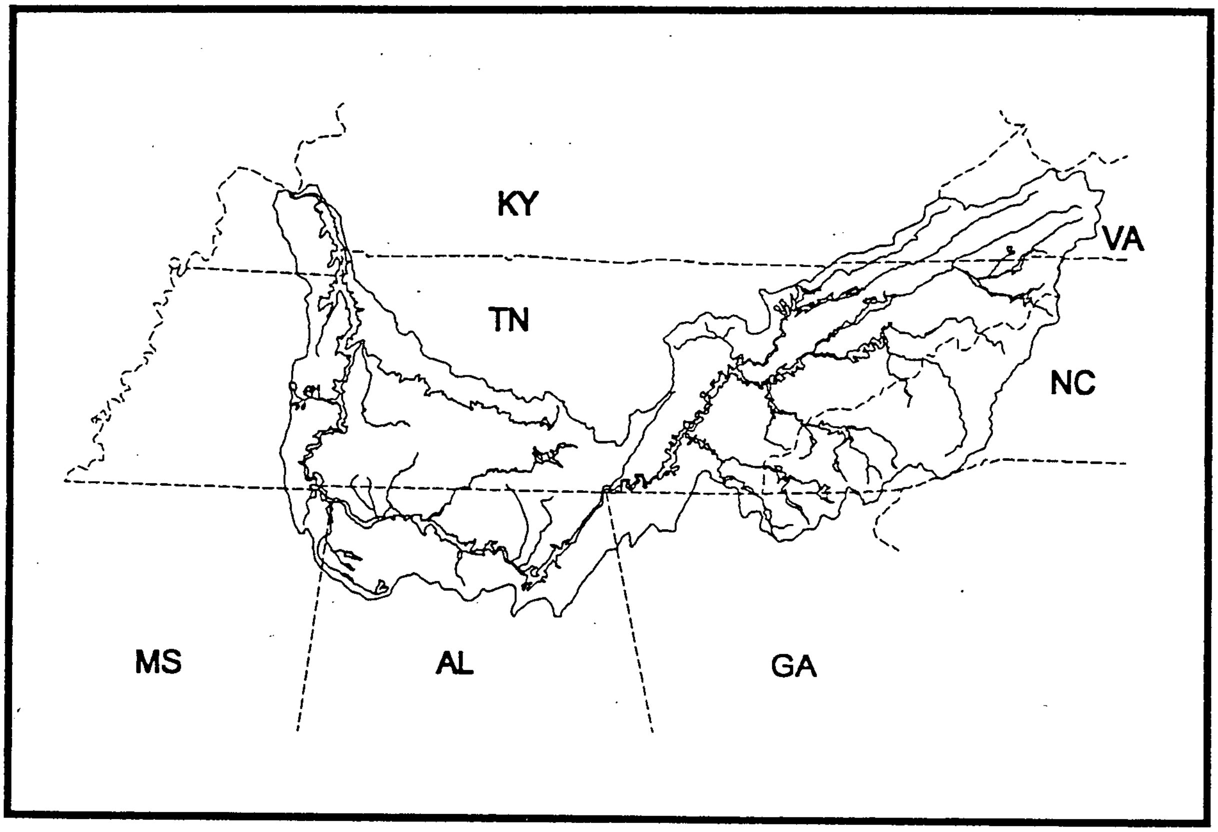
Tennessee
Valley
Authority

Water Resources Division
Chattanooga, Tennessee

TVA/WR-92/5
July 1992

RESERVOIR VITAL SIGNS MONITORING - 1991

FISH COMMUNITY RESULTS



WATER RESOURCES &
ECOLOGICAL MONITORING
WATER RESOURCES MANAGEMENT

Introduction

The Tennessee Valley Authority (TVA) operates 9 reservoirs on the Tennessee River and 37 reservoirs on its tributaries. TVA is committed to maintaining the health of aquatic resources created when the reservoir system was built. To that end, TVA conducts the Water Resources and Biological Monitoring Program that includes physical, chemical, and biological data collection components. Biological monitoring targets the following selected elements within three zones of the reservoir (inflow, transition, and forebay):

- Sediment/Water-column Acute Toxicity Screening (forebay and transition zone only)
- Benthic macroinvertebrates
- Fish

Reservoir fish monitoring is divided into the following activities:

- Fish Biomass
- Fish Tissue Contamination
- Fish Community Monitoring
- Fish Health Assessment

This report presents the results of fall 1991 fish community monitoring and fish health assessment data using a new analytical approach: Reservoir Index of Biotic Integrity (RIBI). Fish health assessment is included in this report as one of the RIBI metrics. Reports on other components and activities are published in companion reports, i.e., fish biomass (Wilson 1992) and fish tissue (Bates et al. 1992), and a summary report on the results of the monitoring program also is available (Dycus and Meinert 1992).

Philosophical Approach

The basic ecological principle underlying the community monitoring program is that characteristics of fish populations, because of their trophic status, will reflect changes in the aquatic ecosystem. The program's objective is to provide the minimum information necessary to evaluate the status of the fish community at inflow, transition zone, and forebay areas of reservoirs throughout the Tennessee Valley.

The quality of an aquatic resource, in this case fish, is indicative of the quality of its physical and chemical environment. As relatively long-lived biological indicators, fish integrate conditions of the aquatic environment over long periods of time (i.e., seasons and years). Aquatic environments that produce healthy fish communities are expected to also provide favorable conditions for other aquatic organisms, and ultimately, man.

The use of an index to evaluate reservoir fish communities is based on methods developed for stream fish surveys (Karr et al. 1986). The author of the original stream IBI, Dr. James R. Karr, and research associates, Drs. Michelle Dionne and Martin Jennings, are co-developing the reservoir index of biotic integrity (RIBI) under contract with TVA.

Like the stream IBI, the RIBI evaluates fish communities based on a series of measurements, or metrics, derived from fish samples. Each metric describes a facet of fish community functioning or structure. Comparison of metric performance over time or between areas can be useful in detecting biological responses to one or more sources of degradation in the aquatic ecosystem. The categories of RIBI metrics include:

- Species richness and composition
- Trophic composition
- Reproductive composition
- Abundance and fish health

Healthy aquatic ecosystems are recognized by the presence of diverse fish communities. Physical, chemical, or bacteriological degradation will have negative effects on species diversity and/or abundance. Species richness metrics address total species observed plus key groups of species, such as sunfish species, sucker species, and species designated as being particularly sensitive (intolerant) of habitat degradation. Just as intolerant species indicate good community health, high proportions of tolerant individuals signify degraded health of the fish community.

Trophic composition metrics describe the proportions of omnivores and invertivores. Piscivores are not included in the present analysis, but are being examined for future use. Omnivores as a group are less sensitive to environmental stresses due to their ability to vary their diet.

Spawning requirements of some reservoir species make them more vulnerable than others. Migratory spawners shed their eggs in flowing headwater areas of reservoirs or tributary streams, where egg survival is subject to prevailing stream conditions (temperature, siltation, water level fluctuation, sediment quality, dissolved oxygen, and chemical water quality). Lithophilic broadcast spawners, many of which are also migratory, shed eggs that are subject to the availability of suitable rock substrates, i.e., conducive to egg survival. Species of both groups shed their eggs over a relatively short spawning season (2-3 weeks), emphasizing the importance of favorable conditions for successful reproduction to the continued existence of the species.

Other metrics address fish abundance and health. High quality communities support large numbers of individuals (excluding shad). Fish health assessment measures environmental stress on a top predator (largemouth bass) based on rigorous external and internal examinations. Another measure of fish community health under investigation for use in future RIBI analysis is incidence of diseases, lesions, tumors, external parasites, deformities, and blindness among all species sampled.

Each metric is compared to a set of reference conditions, or scoring criteria, and rated 1, 3, or 5 with values of 1 indicating "poor" conditions, and values of 5 indicating "good" conditions. Because "natural" reservoirs do not exist, reference conditions were empirically derived from previously collected fall fish community data. Scoring criteria are designed for each reservoir zone, and ideally for each type of reservoir, although the present criteria are more applicable to mainstream reservoirs than tributary reservoirs.

The scores of the 11 metrics are summed to create the RIBI, one number that describes the overall condition of the fish community of a given reservoir zone. The RIBI can then be used to compare between zones of various reservoirs and over time, and becomes a tool for monitoring the quality of fish communities.

Methods

Fish Community Monitoring

Twenty-two reservoirs were studied during fall 1991 (table 1). Shoreline electrofishing samples were collected during daylight hours from inflow, transition, and forebay zones of each reservoir from middle September to December, 1991. The forebay area was defined as the main channel shoreline extending into the "mouths" of tributary streams within approximately three miles above the dam. The transition zone was the main reservoir reach where hydraulic and water chemistry conditions and sediment particle size suggest a shift from a riverine to a reservoir environment. In mainstream reservoirs the inflow zone was the tailwater of the upstream dam, while in tributary reservoirs the inflow zone was near the mouth of the free-flowing headwater stream(s). The September-December time frame was chosen because an extended period of time is required to sample all reservoirs, and distribution of fish populations is most stable in fall. A total of 10 electrofishing runs (10 minutes duration each) was sampled within each of the 56 sites (22 reservoirs). All habitats were sampled at each site, with dominant types receiving the most effort. Habitat distinctions were based on major changes in substrate (e.g., rock, rip-rap, or clay), and/or cover (e.g., brush or aquatic vegetation). Sample size/duration was selected based on sensitivity analysis of largemouth bass electrofishing samples in two Oklahoma reservoirs (Gilliland 1985). A range finder was used to measure shoreline distance covered during each 10 minute electrofishing run during the 1991 season.

Black bass species captured were measured and weighed, other major sport fish species and channel catfish were measured, and all other species were enumerated prior to release. All fish captured were examined for obvious external abnormalities, diseases, and parasites, and this information was noted. Fish observed but not captured were included in the records if positive identification and enumeration could be made. Estimated counts were made in instances where high densities of fish were encountered (usually shad), and were recorded in the remarks portion of the field form. Young-of-year (YOY) fish of a given species were counted separately from adults and also recorded in the remarks section, except for YOY gizzard and threadfin shad. Shad YOY were included on the field form in the usual manner, but were assigned special codes to identify them as YOY. Designations of YOY fish were at the discretion of the crew leader according to the following general guidelines: sunfish <25 mm, shad <100 mm, and black bass <100 mm. Hybrid individuals were listed on the field form as separate species. Fifteen largemouth bass from the electrofishing samples in each reservoir zone were selected for fish health assessment.

Voucher specimens of each small minnow or darter species (other than brook silversides and logperch) collected were preserved in 10 percent formalin and transported to the Norris Aquatic Biology Laboratory for verification of species identity. Any other individuals of questionable identity or hybrids were also taken to the Norris laboratory for positive identification.

Where conditions permitted, ten 100-ft-monofilament experimental gill nets with five 20-ft panels (mesh sizes of 1, 1 1/2, 2, 2 1/2, and 3 inch bar mesh) were set for one overnight period in each reservoir zone. In forebay and transition zones, nets were set in all habitat types, alternating mesh sizes toward the shoreline between sets. In inflow areas, nets were set wherever flow conditions allowed. Below dams nets were set in areas protected from river currents, such as the spilling basin, off lock and wing walls, and in pockets and side channels. Availability of adequate sample locations limited number of nets set to less than ten at some inflow stations.

Lengths and weights of all black bass species and channel catfish were recorded, as were lengths of other sport species. Counts of the remaining species were made prior to releasing. Any incidences of diseases, parasites, or anomalies were recorded in the remarks column of the field form.

Species lists and catch per effort data for both sampling gears are presented for each reservoir sampling zone in the Appendix.

Table 1. Fish community sampling locations and dates at selected reservoirs for the TVA Reservoir Monitoring Program, fall 1991 (FY 1992).

Reservoir	Inflow Location	Inflow Date	Transition Location	Transition Date	Forebay Location	Forebay Date
Mainstream						
Kentucky	TRM 205.3	11/20	TRM 117.0	11/07	TRM 22.4	11/05
Pickwick	TRM 255.0	10/29	TRM 230.7	10/30	TRM 209.1	10/31
Wilson	TRM 274.2	10/03	-	-	TRM 260.6	10/02
Wheeler	TRM 347.2	10/10	TRM 313.9	10/09	TRM 278.2	10/08
Guntersville	TRM 424.0	11/06	TRM 392.5	09/24	TRM 351.0	09/11
Nickajack	TRM 470.0	10/24	TRM 431.0	11/05	TRM 425.0	11/07
Chickamauga	TRM 529.0	10/31	TRM 490.0	10/22	TRM 472.0	10/23
Watts Bar	TRM 601.0	11/19	TRM 560.0	10/29	TRM 531.0	10/30
" "	CRM 22.0	11/20	-	-	-	
Fort Loudoun	TRM 652.0	12/10	TRM 624.0	12/09	TRM 607.8	12/06
Tellico	-	-	LTRM 20.6	12/04	LTRM 3.5	12/05
Melton Hill	CRM 59.0	12/18	CRM 44.5	12/17	CRM 25.0	12/12
Tributary						
Norris	-	-	CRM 124.0	10/08	CRM 80.5	10/09
"			PRM 30.1	11/12		
Cherokee	HRM 91.0	11/07	HRM 75.5	11/06	HRM 53.0	11/05
Boone	-	-	SHRM 27.0	10/16	SHRM 19.8	10/15
"			WRM 8.3	10/17		
South Holston	-	-	SHRM 62.0	10/22	SHRM 52.0	10/23
Watauga	WRM 44.0	10/01	-	-	WRM 37.4	10/02
Douglas	FBRM 64.5	10/29	FBRM 56.9	10/30	FBRM 33.0	10/31
Hiwassee	HiRM 90.0	10/10	HiRM 85.0	10/09	HiRM 77.0	10/08
Chatuge	-	-	-	-	HiRM 122	10/01
Nottely	-	-	-	-	NoRM 23.5	10/02
Parksville (Ocoee #1)	-	-	-	-	ORM 12.5	10/17
Blue Ridge	-	-	-	-	ToRM 54.1	10/03

Fish Health Assessment

Fifteen largemouth bass (> 250 mm total length) were collected during electrofishing surveys at the reservoir monitoring zones and transported to a mobile laboratory for examination (Goede 1991). After the fish were anesthetized with tricaine methanesulfonate (MS-222) in 50 mg/l (ppm) solution, the body cavity of each fish was opened using sharp/blunt-ended surgical scissors by making a ventral incision from the vent forward to the pectoral girdle, cutting closely to one side of the pelvic girdle. Care was taken not to make the incision deep enough to damage internal organs. Blood was then collected by cardiac puncture using a hematocrit tube which was centrifuged to allow measurement of hematocrit, leucocrit, and plasma protein levels. The liver was examined immediately for anomalies because of the tendency for rapid discoloration following death of the individual.

An external examination was made on the eyes, skin, gills, fins, opercles, pseudobranchs, and thymus. Internally, the mesenteric fat, spleen, hindgut, kidney, bile, parasites, and sex were examined. Abnormal conditions and other data were entered directly into a computer program developed by TVA entitled "AUSUM430" which calculated a fish health assessment index (FHAI) for each reservoir zone. Abnormalities were weighted according to severity such that as debilitating anomalies increased, the resulting FHAI also increased. Thus better fish health was indicated by lower FHAI values. Results were used as one metric in the RIBI.

Reservoir Index of Biotic Integrity (RIBI)

Shoreline electrofishing data collected in the manner described above were input to the preliminary RIBI analysis program developed by Drs. Karr and Jennings at the University of Washington in Seattle (Jennings and Karr 1992). The preliminary analysis was based on eleven metrics (table 2). All species present, native or introduced, were considered in the total species counts, except hybrids and species that only were present as YOY. Gizzard shad, threadfin shad, and YOY counts were not included in the total fish abundance metric or any of the proportional metrics. For the sunfish species metric only species of the genus *Lepomis* were considered. At some locations electrofishing samples did not collect sufficient numbers of largemouth bass to perform fish health assessment. In these cases scores of "3" were arbitrarily assigned.

Scoring criteria for the eleven metrics were developed from ranges in fall electrofishing data collected from TVA mainstream reservoirs in 1989 and 1990. The observed data ranges were trisected (Fausch et al. 1984), such that values falling in the upper third were designated "good", and values falling in the middle and lower thirds were designated "fair" and "poor", respectively. This manner of reference value determination is unlike that of stream IBI methods, in which scoring criteria are based on pristine, undisturbed environments, because there are, by definition, no naturally occurring, undisturbed reservoirs upon which to draw comparisons. Scoring criteria used in this analysis, drawn from mainstream reservoir data, are less applicable to tributary reservoirs, but the RIBI's calculated for tributary reservoirs are valuable for comparison of fish communities within that group. Relative lack of fall electrofishing data from TVA tributary reservoirs precluded development of reasonable scoring criteria, however as more fall data become available from monitoring tributary reservoirs, this deficiency in RIBI analysis will be removed.

Results of 1991 sampling were compared to the scoring criteria, and each of the eleven metrics were rated "5" if the observed value fell within the "good" range, or "3" or "1" if the observed value fell in the "fair" or "poor" range, respectively.

Fish species common to the lower mainstream reservoirs of the Tennessee River were classified according to trophic guild, relative tolerances of environmental degradation, and reproductive guild (table 3) for use in RIBI analysis to calculate the values of the eleven metrics. These classifications are subject to future modification as our knowledge of reservoir fish community relationships increases.

The sum of the eleven metric ratings is the RIBI, the index value that summarizes the overall condition of a given reservoir fish community. The RIBI values of fall fish community surveys, 1989-1991 (Jennings and Karr 1992) were also trisected to designate "good", "fair", and "poor" fish communities at inflow, transition, and forebay zones of TVA reservoirs. Mainstream and tributary reservoirs were considered jointly because they were analyzed according to the same scoring criteria. However, future analyses will be based on at least two reservoir groupings.

The nine Tennessee River reservoirs plus Melton Hill and Tellico were designated mainstream reservoirs. The latter two were included because they are also "run-of-the-river" reservoirs, having in common navigation and relatively minor winter drawdown zones. The remaining tributary reservoirs have no navigation locks and experience major winter drawdowns.

Table 2. Preliminary RIBI metrics and scoring criteria developed for TVA mainstream reservoirs. Scoring reflects relative fish community quality, with a score of 5 representing highest quality, and a score of 1 the poorest (from Jennings and Karr 1992).

Metric	Inflow			Transition			Forebay		
	5	3	1	5	3	1	5	3	1
Species richness and composition									
1. Total species	>27	20-27	<20	>26	21-26	<21	>23	19-23	<19
2. Sunfish species	>4	3-4	<3	>4	3-4	<3	>4	3-4	<3
3. Sucker species	>5	3-5	<3	>3	2-3	<2	>2	2	<2
4. Intolerant species	>3	2-3	<2	>3	2-3	<2	>3	2-3	<2
5. Percent of individuals as tolerant species	<7.5	7.5-15	>15	<7.5	7.5-15	>15	< 7.5	7.5-15	>15
Trophic composition									
6. Percent of individuals as omnivores	<2.5	2.5-5	>5	<5	5-10	>10	<5	5-10	>10
7. Percent of individuals as invertivores	>70	55-70	<55	>80	70-80	<70	>80	70-80	<70
Reproductive composition									
8. Migratory spawning species	>3	2-3	<2	>2	1-2	0	>2	1-2	0
9. Lithophilic spawning species	>6	4-6	<4	>4	2-4	<2	>4	2-4	<2
Abundance and fish health									
10. Total number of individuals	>600	300-600	<300	>800	400-800	<400	>600	300-600	<300
11. Fish health assessment index (FHAI)	<45	45-70	>70	<45	45-70	>70	<45	45-70	>70

Table 3. Core fish species list with trophic, tolerance, and reproductive designations(*) for use in preliminary electrofishing Reservoir Index of Biotic Integrity (RIBI) for TVA reservoirs, 1991.

Species	Trophic Guild	Tolerance	Migratory Spawner	Lithophilic Spawner
Chestnut lamprey	PS		M	
Spotted gar	PI			
Longnose gar	PI	TOL		
Shortnose gar	PI	TOL		
Bowfin	PI			
American eel	PI			
Skipjack herring	PI	INT	M	
Gizzard shad	OM	TOL		
Threadfin shad	PL			
Mooneye	IN		M	L
Chain pickerel	PI			
Central stoneroller	HB			
Goldfish	OM	TOL		
Common carp	OM	TOL		
Silver chub	SP	INT		
Golden shiner	OM	TOL		
Emerald shiner	IN			
Ghost shiner	IN			
Spotfin shiner	IN	TOL		
Mimic shiner	IN			
Steelcolor shiner	IN			
Pugnose minnow	IN			
Bluntnose minnow	OM			
Fathead minnow	OM			
Bullhead minnow	IN			
River carpsucker	OM		M	
Quillback	OM		M	
Northern hog sucker	SP	INT	M	L
Smallmouth buffalo	OM		M	
Bigmouth buffalo	PL		M	
Black buffalo	OM		M	
Spotted sucker	IN	INT	M	L
Silver redhorse	IN		M	L
Shorthead redhorse	IN		M	L
River redhorse	SP	INT	M	L
Black redhorse	IN	INT	M	L
Golden redhorse	IN		M	L
Blue catfish	OM			
Black bullhead	OM	TOL		
Yellow bullhead	OM	TOL		
Brown bullhead	OM	TOL		
Channel catfish	OM			
Flathead catfish	PI			
Blackstripe topminnow	IN			
Blackspotted topminnow	IN			
Mosquitofish	IN	TOL		
Brook silverside	IN			
White bass	PI		M	L
Yellow bass	PI		M	L
Rock bass	PI	INT		
Redbreast sunfish	IN	TOL		
Green sunfish	IN	TOL		
Warmouth	IN			
Orangespotted sunfish	IN			
Bluegill	IN			
Longear sunfish	IN	INT		
Redear sunfish	IN			
Spotted sunfish	IN			
Smallmouth bass	PI			
Spotted bass	PI			
Largemouth bass	PI			
White crappie	PI			
Black crappie	PI			
Yellow perch	IN			
Logperch	SP			L
Sauger	PI		M	L
Walleye	PI		M	L
Freshwater drum	IN			

* Designations:
trophic- herbivore (HB), parasitic (PS), planktivore (PL), omnivore (OM), insectivore (IN), piscivore (PI), specialized benthic insectivore (SP)
tolerance- tolerant (TOL), intolerant (INT)
migratory spawning species (M)
lithophilic spawning species (L)

Table 7a. Preliminary scoring of electrofishing results for the eleven metrics and overall reservoir index of biotic integrity (RIBI) for Chickamauga Reservoir, 1991.

Metric	Inflow Obs.	Inflow Score	Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition						
1. Total species	25	3	21	3	21	3
2. Sunfish species	5	5	6	5	6	5
3. Sucker species	1	1	1	1	0	1
4. Intolerant species	1	1	2	3	1	1
5. Percent of individuals as tolerant species	12	3	7	5	1	5
B. Trophic composition						
6. Percent of individuals as omnivores	6	1	5	5	1	5
7. Percent of individuals as invertivores	72	5	90	5	94	5
C. Reproductive composition						
8. Migratory spawning species	4	5	2	3	1	3
9. Lithophilic spawning species	5	3	3	3	2	1
D. Abundance and fish health						
10. Total number of individuals	696	5	885	5	1744	5
11. Fish health assessment index (FHAI)	79	1	75	1	83	1
RIBI		33 fair		39 good		35 good

Table 7b. Species list and catch per unit effort at inflow, transition, and forebay stations during fall electrofishing and gill netting on Chickamauga Reservoir, 1991. Total efforts(*) shown in parentheses.

Common Name	Designation+	Electrofishing Inflow (1.7)	Electrofishing Transition (1.7)	Electrofishing Forebay (1.7)	Gill netting Inflow (4)	Gill netting Transition (10)	Gill netting Forebay (10)
Longnose gar	PI,TOL	0.0	0.0	0.0	9.0	0.0	0.0
Skipjack herring	PI,INT,M	0.0	0.0	0.0	0.8	4.6	6.5
Gizzard shad	OM,TOL	190.2	127.8	34.2	1.0	3.4	2.8
Threadfin shad	PL	1.8	1.2	0.0	0.0	0.0	0.0
Yoy threadfin shad		60.0	0.0	184.8	0.0	0.0	0.0
Carp	OM,TOL	3.6	10.8	8.4	0.3	0.1	0.2
Golden shiner	OM,TOL	0.0	15.0	0.6	0.0	0.0	0.1
Emerald shiner	IN	10.8	263.4	676.8	0.0	0.0	0.0
Spotfin shiner	IN,TOL	43.8	0.0	0.0	0.0	0.0	0.0
Bluntnose minnow	OM	1.8	0.0	0.0	0.0	0.0	0.0
Quillback carpsucker	OM,M	0.0	0.0	0.0	1.0	0.0	0.0
Smallmouth buffalo	OM,M	0.0	0.0	0.0	0.3	0.0	0.0
Spotted sucker	IN,INT,M,L	4.2	0.6	0.0	0.0	0.3	0.1
Blue catfish	OM	0.6	0.0	0.0	2.8	0.5	1.0
Channel catfish	OM	20.4	0.6	0.0	5.8	0.5	1.2
Flathead catfish	PI	7.8	1.2	2.4	0.5	0.1	0.2
White bass	PI,M,L	7.2	0.0	0.6	0.3	1.3	0.3
Yellow bass	PI,M,L	38.4	1.8	0.0	2.3	0.4	0.4
Striped bass		0.0	0.0	0.0	0.0	0.2	0.1
Hybrid striped bass		0.0	0.0	0.0	0.0	0.3	0.2
Warmouth	IN	2.4	7.2	1.8	0.0	0.0	0.0
Redbreast sunfish	IN,TOL	4.2	11.4	3.6	0.0	0.0	0.0
Green sunfish	PI,TOL	4.2	1.8	0.6	0.0	0.0	0.0
Bluegill	IN	159.6	142.2	252.0	0.3	0.0	0.0
Longear sunfish	IN,INT	0.0	2.4	2.4	0.0	0.0	0.0
Redear sunfish	IN	44.4	24.6	24.0	0.0	1.2	1.2
Hybrid sunfish		1.2	0.0	0.0	0.0	0.0	0.0
Smallmouth bass	PI	9.0	3.6	10.8	0.0	0.0	0.0
Spotted bass	PI	15.6	5.4	22.8	0.3	1.6	1.1
Largemouth bass	PI	13.8	14.4	15.6	0.0	0.2	0.2
White crappie	PI	0.0	0.0	3.0	0.0	0.3	0.0
Black crappie	PI	1.8	0.0	0.6	0.3	0.1	0.1
Yellow perch	IN	9.6	4.2	1.2	0.0	0.1	0.1
Logperch	IN,L	1.8	18.6	7.2	0.0	0.0	0.0
Sauger	PI,M,L	0.6	0.0	0.0	0.0	0.1	0.0
Walleye	PI,M,L	0.0	0.0	0.0	0.5	0.1	0.0
Freshwater drum	IN	0.0	1.8	0.0	1.0	0.4	0.8
Brook silverside	IN	10.8	0.0	12.0	0.0	0.0	0.0
Total: CPUE		669.6	660.0	1265.4	26.0	15.8	16.6
No. collected		1116	1100	2109	104	158	166
Species: 35 (and 2 hybrids)							

* Electrofishing effort units are hours; gill net units are net-nights.
\+ Designations:
trophic- herbivore (HB), parasitic (PS), planktivore (PL), omnivore (OM), invertivore (IN), specialist benthic invertivore (SP)
tolerance- tolerant (TOL), intolerant (INT)
migratory spawning species (M), lithophilic broadcast spawning species (L)

RESERVOIR VITAL SIGNS MONITORING - 1992

FISH COMMUNITY RESULTS TABLES

INTRODUCTION

Fish communities of 12 TVA reservoirs have been monitored under the "Vital Signs" program since fall 1989. An additional 11 reservoirs were added to the program in 1991. Reservoir fish monitoring is divided into fish biomass, tissue contamination, community monitoring, and health assessment. These tables represent results of fall 1992 fish community monitoring and fish health assessment.

METHODS

Fish Community Monitoring

Twenty-three reservoirs were studied during fall 1992. Shoreline electrofishing samples were collected during daylight hours from inflow, transition, and forebay zones of each reservoir (one zone may have been omitted from specific reservoirs for various reasons) from mid-September to December, 1992. A total of 10 electrofishing transects 1000 feet in length were collected from each of the reservoir zones. All habitats were sampled in proportion to their occurrence in the zone.

Black bass species captured were measured and weighed, other major sport species and channel catfish were measured, and all other species were enumerated prior to release. Fish observed but not captured were included in the records if positive identification and enumeration could be made. Estimated counts were made in instances where high densities of fish were encountered, and were recorded. Young-of-year (YOY) fish were counted separately from adults. Fifteen largemouth bass from the electrofishing samples in each reservoir zone were selected for fish health assessment.

Where conditions permitted, 12 100-ft-monofilament experimental gill nets with five 20-ft panels (mesh sizes of 1, 1 1/2, 2, 2 1/2, and 3 inch bar mesh) were set for one overnight period in each reservoir zone. In forebay and transition zones, nets were set in all habitat types, alternating mesh sizes toward the shoreline between sets. In inflow areas, nets were set wherever flow conditions allowed. Availability of adequate sample location limited number of nets set at some inflow stations.

Fish Health Assessment

Fifteen largemouth bass greater than 250 mm total length were collected during electrofishing surveys at the reservoir monitoring zones and transported to a mobile laboratory for examination. An external and internal examination to observe anomalies was conducted and data entered directly into a computer program developed by TVA entitled "AUSUM 430" which calculated a fish health assessment index (FHAI) for each reservoir zone. Results were used as one metric in the Reservoir Fish Assemblage Index (RFAI).

Reservoir Fish Community Index (RFAI)

Shoreline electrofishing data collected in fall 1992 were input in to a preliminary (RFAI) developed by TVA and Drs. Karr and Jennings at the University of Washington in Seattle. The RFAI employs 11 fish community metrics:

(A) species richness and composition - total number of species, sunfish species, sucker species, intolerant species, and percentage of tolerant individuals sampled;

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

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

(D) Overall fish abundance; and

(C) fish health assessment index of largemouth bass.

Scoring criteria for the eleven metrics were developed from ranges in fall electrofishing data collected from TVA reservoirs in 1989 through 1991. The observed data ranges were trisected, such that values falling in the upper third were designated "good", and values falling in the middle and lower thirds were designated "fair" and "poor", respectively. Independent scoring criteria were developed for each area (inflow, transition, and forebay) of both run-of-the-river and tributary reservoirs. Results of 1992 sampling were compared to the scoring criteria, and each of the eleven metrics were rated "5" if the observed value fell within the "good" range, or "3" or "1" if the observed value fell in "fair" or "poor" range, respectively.

The sum of the eleven metric ratings constituted the RFAI index value which summarizes the overall condition of a given reservoir fish community. Attainable RFAI values were divided into five categories (excellent, good, fair, poor, and very poor) to generally discribe the environmental condition of that section of a reservoir based on attributes of the resident littoral zone fish community.

Table 5. Species list and catch per unit effort at the inflow, transition, and forebay during fall electrofishing and gill netting on Chickamauga Reservoir, 1992. (Electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights.)

	Electrofishing			Gill Netting		
Common name	Inflow	Transition	Forebay	Inflow	Transition	Forebay
Longnose gar	.	.	.	4.5	.	0.2
Skipjack herring	.	.	.	2.5	4.0	2.5
Gizzard shad	17.6	0.8	3.7	6.3	5.4	5.9
Threadfin shad	2620.0	100.6	20.0	.	.	.
Hybrid shad	.	.	.	0.3	0.1	0.1
Mooneye	.	.	.	0.3	0.2	0.1
Carp	0.1	2.8	0.1	.	0.1	0.6
Golden shiner	.	.	.	.	0.4	0.9
Emerald shiner	.	.	43.3	.	.	.
Spotfin shiner	.	.	0.3	.	.	.
Northern hog sucker	.	.	.	.	.	0.1
Smallmouth buffalo	.	.	.	0.3	.	.
Spotted sucker	0.3	.	.	.	1.0	0.1
Shorthead redhorse	.	.	.	.	0.1	.
Black redhorse	0.1	.	.	.	.	.
Blue catfish	.	.	.	0.5	0.2	0.4
Channel catfish	0.3	.	.	6.8	0.6	0.7
Flathead catfish	.	.	0.3	0.8	0.2	0.1
White bass	0.1	.	0.1	1.3	1.9	0.2
Yellow bass	1.4	.	.	9.5	3.9	1.9
Striped bass	0.4	.	.	0.8	0.1	.
Hybrid striped x white bass	.	.	.	0.3	.	.
Warmouth	0.5	0.2	.	.	0.1	0.1
Redbreast sunfish	0.1	0.4	0.9	.	.	.
Green sunfish	0.4	.	0.1	.	.	.
Bluegill	9.0	2.0	29.8	.	0.1	0.1
Longear sunfish	0.2	.	.	.	.	.
Redear sunfish	2.8	0.9	1.4	0.8	1.8	0.6
Smallmouth bass	0.3	.	8.6	0.3	0.2	.
Spotted bass	0.4	0.5	3.6	1.3	2.5	2.5
Largemouth bass	1.9	1.3	0.7	0.8	0.4	0.7
White crappie	.	.	0.2	.	.	.
Black crappie	.	.	.	0.5	0.4	1.1
Yellow perch	.	0.9	0.2	.	0.1	.
Logperch	.	.	0.3	.	.	.
Sauger	.	.	.	2.5	0.1	.
Walleye	.	.	.	1.3	0.1	.
Freshwater drum	0.1	0.4	0.1	0.8	0.7	0.1
Brook silverside	.	4.4	7.1	.	.	.
Total: CPUE	2656.0	115.2	120.8	41.8	24.7	19.0
Number of samples	10	10	10	4	10	10
Number collected	26560	1152	1208	167.2	247	190
Species: 37						

Table 5b. Scoring of electrofishing results for the eleven metrics and overall Reservoir Fish Association Index (RFAI) for Chickamauga Reservoir.

	Inflow		Transition		Forebay	
Metric	Obs.	Score	Obs.	Score	Obs.	Score
A. Species richness and composition						
1. Number of species	19	1	12	1	19	3
2. Sunfish species	6	5	4	3	4	3
3. Sucker species	2	1	0	1	0	1
4. Intolerant species	3	3	0	1	0	1
5. Percent tolerant species	3	5	23	1	1	5
B. Trophic composition						
6. Percent omnivores	2	5	20	1	0	5
7. Percent insectivores	73	5	67	3	86	5
C. Reproductive composition						
8. Migratory spawning species	4	3	0	1	1	1
9. Lithophylic spawning species	4	3	0	1	3	3
D. Abundance and fish health						
10. Number of individuals	184	1	137	1	971	5
11. Fish Health Assessment Index	52	3	36	3	54	3
RFAI		35 Fair		17 Very poor		35 Fair

RESERVOIR VITAL SIGNS MONITORING - 1993

FISH COMMUNITY RESULTS TABLES

INTRODUCTION

Fish communities of TVA reservoirs have been sampled for littoral and bottom-dwelling pelagic species since fall 1989 to provide insight into the environmental quality of these reservoirs based on measurements of various parameters of the resident fish populations. Only 12 reservoirs were sampled in 1989-90, an additional 11 were added in 1991, and 7 more were added in 1993. The following tables detail results obtained during the 1993 fall fish community samples.

METHODS

Fish Community Monitoring

Shoreline electrofishing samples were collected during daylight hours from inflow, transition, and forebay zones of most reservoirs from September to mid-November, 1993. On relatively small reservoirs only one or two zones were sampled, with the forebay area always selected. A total of 15 electrofishing transects, each covering 300m of shoreline, were collected from each of the sampled zones. All habitats were sampled in proportion to their occurrence in the zone. Where conditions permitted, 12 experimental gill nets with five 6.1m panels (mesh sizes of 2.5, 5.1, 7.6, 10.2, and 12.7cm) were set for one overnight period in each reservoir zone. In forebay and transition zones, nets were set in all habitat types, alternating mesh sizes toward the shoreline between sets. Nets in inflow areas were set where flow conditions allowed which restricted the number of nets set in this zone.

Total length (mm) and weight (g) was obtained for all black bass species captured, length only was taken of other sport species and channel catfish, with other species being enumerated prior to release. Fish observed but not captured during electrofishing were included if positive identification could be made. Estimated counts were also used in electrofishing samples when high densities of fish were encountered, as long as identification was possible. Young-of-year fish were counted separately from adults and juveniles. All fish measured were inspected for external signs of disease, parasites, and anomalies. Natural hybrids were included as an anomaly.

Reservoir Fish Assemblage Index

Shoreline electrofishing and gill netting data collected during fall 1993 were input into a Reservoir Fish Assemblage Index (RFAI) developed by TVA and Dr. James Karr (University of Washington). A separate index used for electrofishing and gill netting. The RFAI uses 12 fish community metrics which can be broken into five general catagories:

1. Species richness and composition -- total number of species, piscivore species, sunfish species, sucker species, intolerant species, and percent tolerant individuals;
2. Trophic composition -- percent omnivores and percent insectivores;
3. Reproductive composition -- number of lithophilic spawners;
4. Abundance and health -- total catch per unit effort and percent individual with external diseases, parasites, and/or anomalies.

Scoring criteria for the 12 metrics were developed from ranges in fall electrofishing and gill netting data collected from TVA reservoirs from 1990 through 1993. The observed data for each gear type were trisected, such that values falling in the upper third were designated "good", and values falling in the middle and lower thirds were designated "fair" and "poor", respectively. In addition to gear type, independent scoring criteria were developed for each area (inflow, transition, and forebay) of both run-of-the-river and tributary reservoirs. Results of 1993 sampling were compared to the scoring criteria, and each of the 12 metrics were rated "5" if the observed value fell within the "good" range, or "3" or "1" if the observed value fell in "fair" or "poor" range, respectively.

The sum of the 12 metric ratrings constituted the RFAI value which summarizes the overall condition of a given reservoir fish community. Attainable RFAI values were divided into five categories (see below) to generally discribe the environmental condition of that section of a reservoir based on attributes of the resident littoral and bottom-dwelling pelagic fish communities. The average of the electrofishing and gill netting RFAIs was used to describe the overall fish community of a site.

Fish Community Evaluation

Total Score	Rating
12-21	Very Poor
22-31	Poor
32-41	Fair
42-51	Good
52-60	Excellent

Table 7. Species list and catch per unit effort at the inflow, transition, and forebay during fall electrofishing and gill netting on Chickamauga, 1993 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Common name	Electrofishing Inflow	Electrofishing Transition	Electrofishing Forebay	Gill Netting Inflow	Gill Netting Transition	Gill Netting Forebay
Spotted gar	.	.	.	.	0.1	.
Longnose gar	0.1	.	.	1.5	.	.
Skipjack herring	1.7	.	.	3.5	4.8	3.3
Gizzard shad	38	26.9	19.3	2.8	4.7	4.4
Threadfin shad	3559.9	1707.4	810.2	.	.	.
Mooneye	.	.	.	.	0.3	.
Central stoneroller	.	0.1	.	.	.	.
Carp	1.5	1.1	0.3	0.3	0.1	.
Golden shiner	.	2.8	.	.	0.1	0.8
Emerald shiner	59	60.1	50.3	.	.	.
Spotfin shiner	0.9	0.9	0.1	.	.	.
Steelcolor shiner	2.6	.	0.1	.	.	.
Striped shiner	0.1	.	.	.	.	.
Bluntnose minnow	0.1	.	.	.	.	.
Quillback carpsucker	.	.	.	0.3	.	.
Northern hog sucker	0.1	.	.	.	.	.
Smallmouth buffalo	.	0.2	0.1	0.8	0.1	.
Spotted sucker	1.1	1	.	0.5	0.5	.
Black redhorse	0.1	.	.	.	.	.
Golden redhorse	0.5	.	.	.	.	.
Blue catfish	0.1	0.1	0.1	0.3	1.8	0.3
Channel catfish	0.7	.	.	2.5	1.3	0.3
Flathead catfish	0.7	0.1	0.1	0.3	0.5	0.2
White bass	0.7	.	0.1	5	9	0.9
Yellow bass	5.3	0.1	.	13	6.2	2.8
Striped bass	0.5	.	.	1.5	.	.
Hybrid striped x white bass	.	.	.	0.3	.	.
Warmouth	1.1	0.7	0.1	0.3	0.1	.
Redbreast sunfish	0.3	1	1.8	.	.	.
Green sunfish	0.1	.	0.2	.	.	.
Bluegill	30.7	30.1	11.7	0.3	0.5	0.3
Longear sunfish	0.2	0.5	0.1	.	.	.
Redear sunfish	10	4.4	1.8	1.3	2.2	0.7
Smallmouth bass	2.6	0.4	1.3	.	0.1	0.2
Spotted bass	5.7	6.2	7.3	1.3	2.5	2.3
Largemouth bass	8.1	6.6	1.3	0.5	0.3	0.2
White crappie	0.3	0.1	.	.	0.3	0.5
Black crappie	1	1.4	.	0.3	1.2	1.2
Yellow perch	0.2	1	0.1	.	0.8	0.1
Logperch	0.5	5.3	0.2	.	.	.
Sauger	.	.	0.1	1	0.1	0.1
Walleye	.	.	.	1	.	.
Freshwater drum	0.3	0.4	0.1	1.8	0.7	0.8
Brook silverside	0.8	8.7	8.5	.	.	.
Total	3735.4	1867.5	915.1	39.8	37.9	19.1
Number of samples	15	15	15	4	12	12
Number collected	56031	28013	13727	159	455	229
Species collected	35	26	24	23	24	18

Table 7b. Scoring results for tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Chickamauga Reservoir.

Metric	Electrofishing						Gill Netting			
	Inflow		Transition		Forebay		Transition		Forebay	
	Obs.	Score	Obs.	Score	Obs	Score	Obs.	Score	Obs.	Score
A. Species richness and composition										
1. Number of species	35	5	26	5	24	3	24	5	18	3
2. Piscivore species	11	5	7	3	6	1	11	5	10	5
3. Sunfish species	6	5	5	3	6	5	3	5	2	3
4. Sucker species	4	3	2	3	1	1	2	3	0	1
5. Intolerant species	5	5	2	3	1	1	2	3	1	1
6. Percent tolerant species	56.6%	3	59.7%	3	67.1%	1	12.8%	5	27.1%	3
7. Dominance (% composition of most abundant	33.7%	3	39.2%	5	61.4%	1	23.8%	5	23.1%	5
B. Trophic compostion										
8. Percent omnivores	23.1%	5	20.0%	5	3.6%	5	21.1%	5	30.1%	5
9. Percent insectivores	62.0%	5	70.7%	5	90.2%	5	13.2%	3	9.2%	3
C. Reproductive composition										
10. Lithophilic spawning species	8	5	4	3	4	3	5	3	3	1
D. Fish abundance and health										
11. Average number of individuals	174.9	5	153.3	5	81.9	3	37.8	5	19.1	1
12. Percent anomalies	2.2%	3	2.5%	3	2.3%	3	0.2%	5	0.0%	5
RFAI		52 excellent		46 good		32 fair		52 excellent		36 fair

Tennessee
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Water Resources Division
Chattanooga, Tennessee

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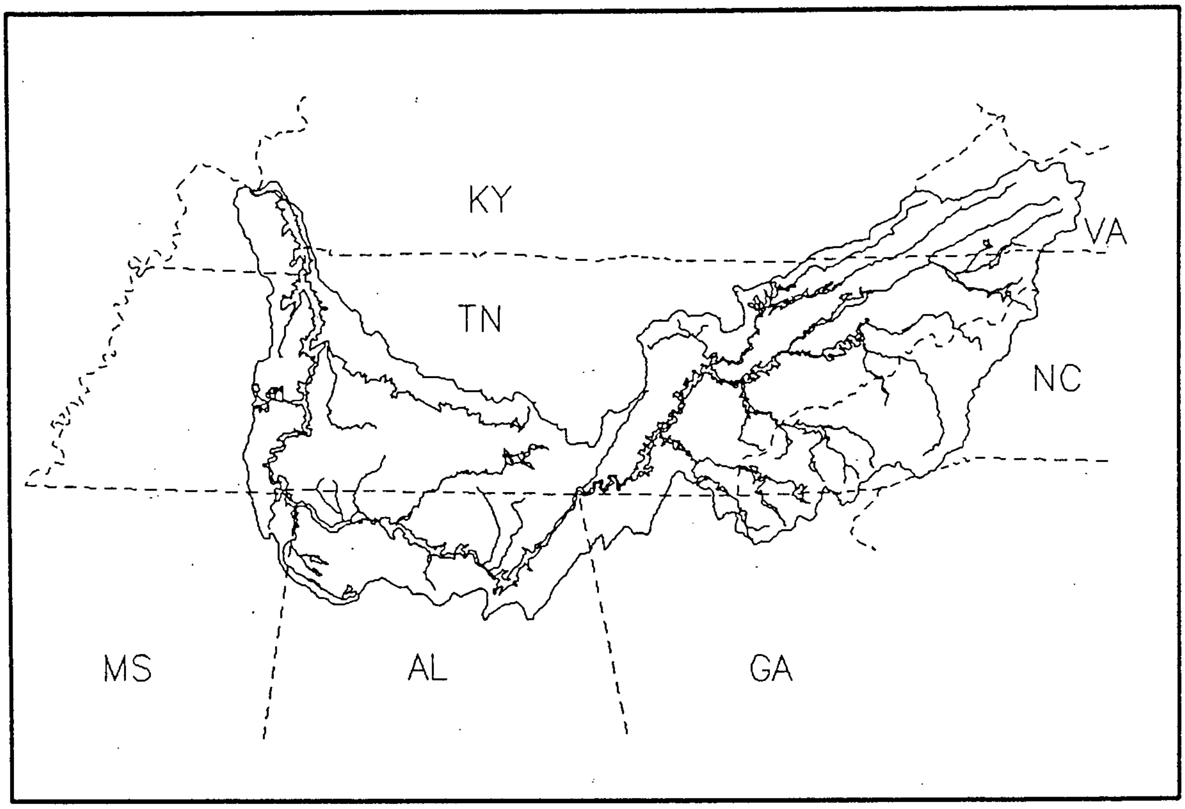
RESERVOIR MONITORING - 1990

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



WATER RESOURCES &
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Chickamauga Reservoir

Chickamauga Reservoir could be described as an "average" mainstream Tennessee River reservoir. With the dam at TRM 471.0, it has a length of 59 miles, a shoreline of 810 miles, and a surface area of 35,400 acres at full pool. The average annual discharge is 33,099 cfs which provides an average hydraulic retention of ten days.

Vital Signs Monitoring on Chickamauga Reservoir in 1990 identified generally healthy conditions, although some undesirable conditions were found, especially at the inflow site. Overall, the "health" of the aquatic resources in Chickamauga Reservoir were in the midrange compared to the other mainstem reservoirs.

Lack of thermal and DO stratification, presence of an active algal community, water clarity, generally good sediment quality, and healthy/diverse benthic and fish communities at the forebay and transition zone were all desirable characteristics. Relatively few benthic macroinvertebrate taxa and number of organisms per square-meter as well as low number of fish collected in electrofishing efforts were indicative of undesirable conditions at the inflow site.

A high silt content of sediments and relatively high chlorophyll concentrations at the transition zone indicate this site may be too far downstream. Results from 1991 will be reviewed closely to determine if movement of this site upstream is appropriate.

Synopsis of 1990 conditions:

Water--Maximum water temperature was generally cooler at the forebay (28.0°C) and transition zone (26.5°C) than at comparable sites on other mainstream reservoirs. There were no substantial surface-to-bottom differences in temperature and DO. The minimum DO (at bottom) was 3.1 mg/l in June at the forebay and 4.2 mg/l in July at the transition zone. Supersaturated DO levels and high pH values (>8.5) occurred in April and May at both the forebay and transition zone sites indicating photosynthetic activity. Maximum chlorophyll-a concentrations of 24 ug/l at the forebay and 17 ug/l at the transition zone occurred in June. Relatively low phosphorus concentrations may have been a factor limiting algal growth on some occasions. Bacteriological levels were acceptable except for one sample (440/100 ml) collected at the forebay in January during high reservoir flows.

Sediment--Chemical analyses of sediments revealed no metal or organic analyte to be a concern. Toxicity tests detected a slight decrease in light emitted by the test organism, indicating a potential for toxicity at both the forebay and transition zone. Particle size analysis showed forebay sediments were almost totally silt and clay (98 percent). Likewise sediments at the transition zone were comprised of mostly silt and clay (84 percent silt and clay and 16 percent sand). Results for the transition zone may indicate this site needs to be moved upstream.

Benthic Macroinvertebrates--The benthos at the forebay and transition zone were both abundant and diverse (14 taxa and 614 organisms at the forebay; 12 taxa and 956 organisms at the transition zone) compared to similar sites on the other mainstream reservoirs. At the inflow only six taxa and 191 organisms were collected, which was quite low compared to other mainstream reservoir inflows sites. The hardy tubificid worms were dominant (49 percent) at the inflow, whereas the more typically encountered chironomid Coelotanyopus was the most numerous taxon at the forebay (30 percent) and transition zone (18 percent).

Fish--Fish collections in the open water areas of Chickamauga Reservoir were overwhelmingly dominated by threadfin shad (100, 98, and 98 percent at the forebay, transition zone, and inflow, respectively). Threadfin shad densities may have been enhanced by a considerable decline in aquatic vegetation during 1990 over that observed during the previous five years. This habitat change was caused by increased inflow and resulting turbidity and nutrient loading during late winter and spring 1990. Both number of fish and biomass were similar to or greater than levels observed in the other mainstream reservoirs.

Fish collections at near shore areas and offshore bottom areas showed threadfin shad to be the most abundant species at the forebay and transition zone comprising 46 percent of the 2,929 fish per unit effort of electrofishing at the forebay and 64 percent of the 2,493 fish at the transition zone. Threadfin shad were absent from inflow samples with gizzard shad being the most numerous species making up 30 percent of the 313 fish collected. Collection success at the inflow was poor relative to other mainstream inflows. The number of fish species was relatively good at all three site (34, 33, and 32 from downstream to upstream). The FHAI showed the health of largemouth bass to be better than the mainstream average (40) at the inflow (29) and poorer than averages (53 and 51) for the transition zone (69) and forebay (66).

The fish assemblage on Chickamauga Reservoir was worse than the average fish community sampled on other Tennessee River mainstream reservoirs. Problems contributing to this below average status include low values for species richness; largemouth bass health; density of piscivores and specialist feeders; number of intolerant species; overall electrofishing catch rate; gill netting catch rates; relative weight of bass; PSDs of selected species; and overall fish abundance. Inspection of fish assemblages within the reservoir revealed that the quality of the forebay environment was slightly better than that found in the average mainstream forebay, the transition zone environment was average and the inflow was worse than the average mainstream reservoir. Comparison of the 1990 results with those obtained in 1989 showed considerable improvement in the fish assemblage of the reservoir between the two years.

Watts Bar Reservoir

Watts Bar Reservoir impounds water from both the Tennessee River and one of the major tributaries to the Tennessee River, the Clinch River. The three dams which bound Watts Bar Reservoir are Watts Bar Dam (located at TRM 529.9), Fort Loudoun Dam (located at TRM 602.3), and Melton Hill Dam located at Clinch River Mile (CRM) 23.1. The total length of Watts Bar Reservoir including the Clinch River arm is 96 miles, the shoreline is 783 miles, and the surface area is 39,000 acres. The average annual discharge from Watts Bar is 27,145 cfs providing as average hydraulic retention time of 19 days.

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

Vital Signs Monitoring results for Watts Bar Reservoir in 1990 identified several undesirable conditions. At least one monitoring tool (in most cases more than one) identified undesirable conditions at all sample sites. As a result, aquatic environmental resources in Watts Bar would grade below the midrange compared to the other mainstem reservoirs.

The most significant problems were presence of a strong oxycline with near anoxic conditions during summer at the forebay, presence of relatively high levels of mercury and toxic conditions in the sediments at the transition zone, and relatively poor benthic macroinvertebrate faunas (in terms of abundance and species richness) at both the Tennessee and Clinch River inflow sites as well as few fish collected at the Clinch inflow site.

Synopsis of 1990 conditions:

Water--The maximum water temperature (28.3°C) was observed in July with the greatest surface to bottom temperature differential (6°C) observed during approximately the same time frame. Otherwise, only weak thermal stratification was observed during the monitoring period. A rather strong oxygen gradient (up to 11 mg/l difference between surface and bottom) existed from June through August. DO concentrations near bottom were below 1 mg/l during much of this period. Upper strata DO levels were high, generally supersaturated, throughout much of this period. These supersaturated DO levels, coupled with high pH values (e.g., 9.2 in June) indicate a high rate of algal photosynthesis. Obviously, nutrients and water clarity were sufficient to support this luxuriant algal growth. Chlorophyll-a concentrations were highest in May, with 20 ug/l at the forebay and 14 ug/l at the transition zone. Although a few of the bacteriological samples were positive, none exceeded a water contact recreation guideline of 200/100 ml.

Sediment--A relatively high concentration of mercury (0.95 ug/g dry weight) and the most toxic response from the sediments tested draw concern for the transition zone on Watts Bar Reservoir. A slight toxic response was also noted in tests on forebay sediments. Particle size analysis showed the substrate at the both the forebay and transition zone to be greater than 99 percent silt and clay.

Benthic Macroinvertebrates--The benthos was average or below in species richness and abundance at all four sample sites. At the forebay, the number of taxa (9) was relatively low, the number of organisms (498 per square-meter) was typical of other forebays, and Chironomus was the most numerous taxon (40 percent of the total). The transition zone was represented by an average to high number of taxa (12) yet a low number of organisms (316) with the mayfly (Hexagenia) the most numerous taxon. The inflow on the Tennessee River had an average to high number of taxa (11) but a very low number of organisms (58) with Corbicula the most numerous organism (31 percent). The inflow on the Clinch River had the poorest benthic macroinvertebrate community of all inflows with only three taxa and 42 organisms, dominated by Corbicula (83 percent).

Fish--Fish data for the open water areas showed Watts Bar to have relatively high density and biomass at all four sample sites. In several instances these were the highest (density or biomass) levels observed at any Vital Signs Monitoring reservoir. Threadfin shad was practically the only species present making up almost 100 percent of the catch at the forebay, transition zone, and Clinch River inflow, and 98 percent at the Tennessee River inflow.

Near shore area and offshore area bottom collections of fish were generally typical of other mainstream reservoirs. A distinct exception was a very low average number of fish (57 per unit effort) collected in electrofishing efforts at the inflow on the Clinch River. Also, number of fish collected at the forebay (757 per unit effort) was low relative to other forebay areas. Number of species (33, 35, 37, and 28 from downstream to upstream on the Tennessee and at the Clinch inflow, respectively) was generally representative of comparable areas on other mainstream reservoirs. Number of fish collected per unit effort of electrofishing at the transition zone (2,178) and Tennessee River inflow (1,783) were typical to high. Threadfin shad was dominant at the forebay (32 percent), the transition zone (52 percent), the Tennessee River inflow (84 percent), but absent at the Clinch River inflow where gizzard shad was most numerous (40 percent of the catch). The FHAI scored the health of largemouth bass to be about average at the forebay (48), less than average at the Tennessee River inflow (53), and better than average at the transition zone (27). Largemouth bass were not captured in sufficient numbers to obtain reliable results in the Clinch inflow.

The fish assemblage on Watts Bar Reservoir (all areas combined) was worse than average for other mainstream Tennessee River reservoirs. Characteristics of the fish community which were below average included species richness, trophic composition, electrofishing catch rates of selected species, overall fish abundance, gill net catch rates of Stizostedion species, mean relative weight of bass, and PSDs of smallmouth bass and channel catfish. Inspection of fish assemblages within reservoir zones revealed that the quality of the Clinch River inflow was worse and the Tennessee River inflow was similar to that found in the average mainstream inflow. The transition zone on Watts Bar maintained a fish community slightly better than that found in the mainstream average and the fish assemblage in the forebay was slightly worse than average. Comparison of 1990 results with those obtained in 1989 revealed a slight decline in the fish assemblage of the reservoir, mainly in species richness, gill net catch rates, and overall fish abundance.

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Chattanooga, Tennessee

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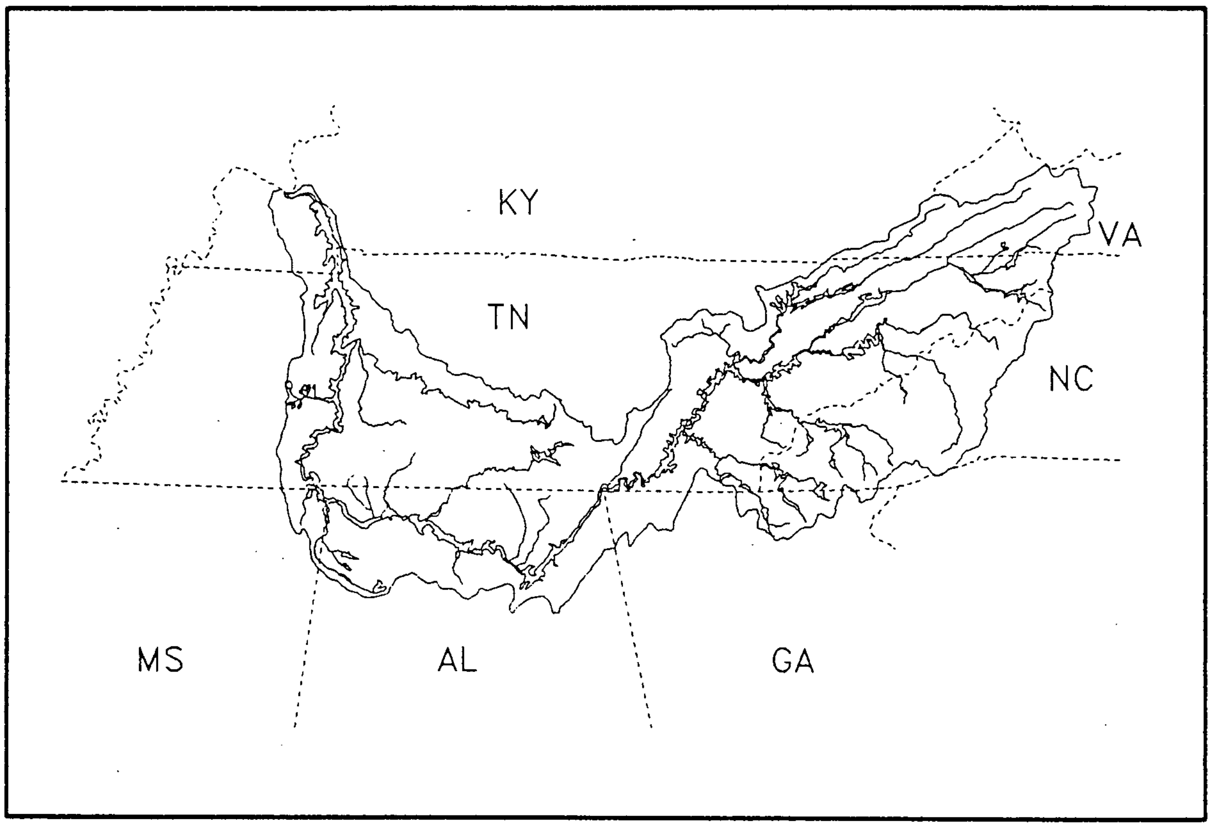
RESERVOIR VITAL SIGNS MONITORING - 1991

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



WATER RESOURCES &
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4.7 Chickamauga Reservoir

4.7.1 Physical Description

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

4.7.2 Reservoir Health

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

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

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

4.7.3 Reservoir Use Suitability

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

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

4.7.4 Synopsis of 1991 Conditions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.8 Watts Bar Reservoir

4.8.1 Physical Description

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

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

4.8.2 Reservoir Health

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

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

4.8.3 Reservoir Use Suitability

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

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

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

4.8.4 Synopsis of 1991 Conditions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Tennessee
Valley
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Water Management
Chattanooga, Tennessee

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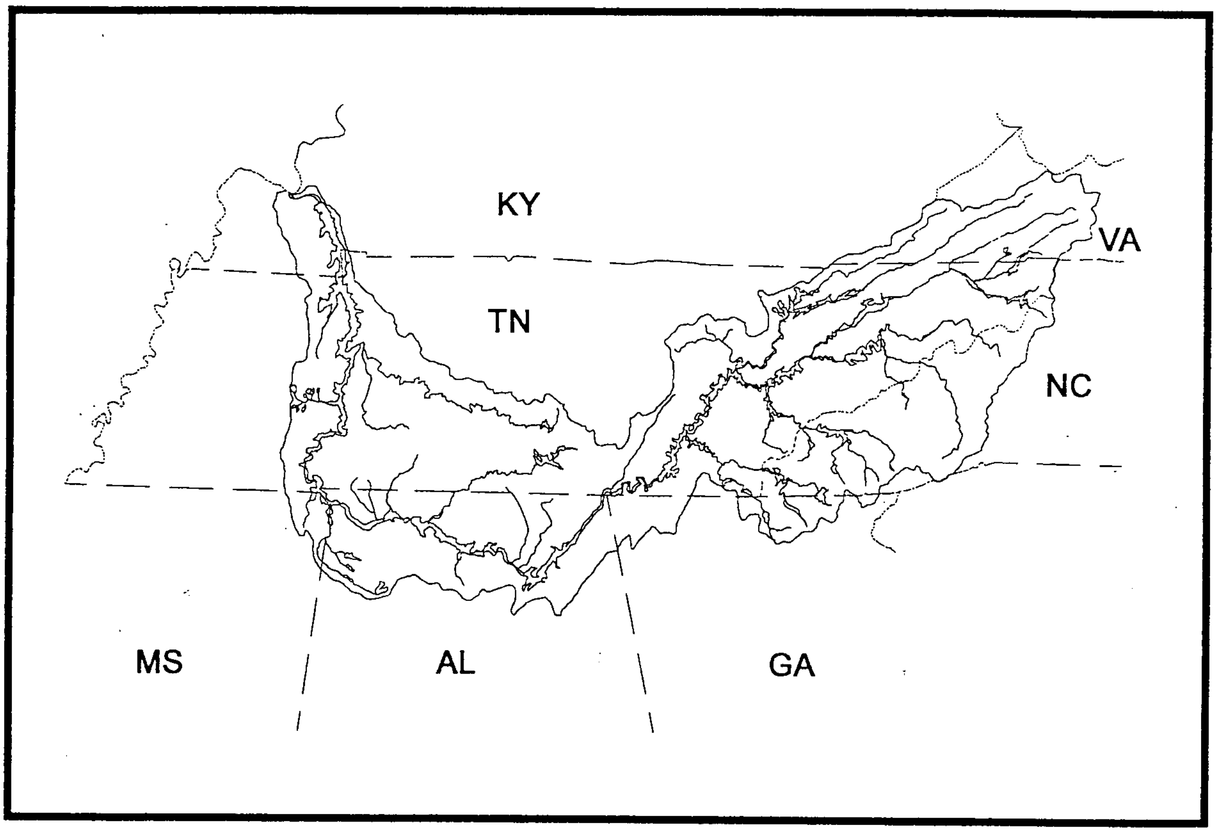
RESERVOIR MONITORING - 1992

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



CLEAN WATER INITIATIVE

4.7 Chickamauga Reservoir

4.7.1 Physical Description

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

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

4.7.2 Reservoir Health

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

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

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

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

4.7.3 <u>Reservoir Use Suitability</u>

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

4.7.4 Synopsis of 1992 Conditions

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

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

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

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

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

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

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

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

Particle size analysis showed sediments were 97 percent silt and clay at the forebay; and transition zone sediments were mostly silt and clay (80 percent) and sand (20 percent).

Benthic Macroinvertebrates--The forebay and transition zone benthic macroinvertebrate communities rated good, while the inflow communities rated poor. The forebay had 13 taxa and 900 organisms/m^2. The most numerous taxa collected were the mayfly *Hexagenia* sp (36 percent of the total), the chironomid *Coelotanyopus* sp (23 percent), and the asiatic clam *Corbicula* sp

(17 percent). The transition zone which had an average number of taxa (14) and had the greatest number of organisms collected (1312 per square meter) among all the Vital Signs transition zones sampled in 1992. Hexagenia sp accounted for 32 percent of the total while Sphaeriidae and Corbicula sp accounted for an additional 19 and 18 percent, respectively. The Chickamauga Reservoir inflow site had the fewest taxa (12) from among the Vital Signs inflow sites sampled in 1992; however, this is an increase at this site over the 1990 and 1991 collections. The number of organisms (933 per square meter) also increased substantially from previous years with 80 percent of the species collected being Corbicula sp. The forebay and transition zone densities slightly increased while the number of taxa remained similar.

Fish Community--Fish data collected in littoral (20 electrofishing transects) and offshore zones (15 net-nights) of Chickamauga forebay resulted in the collection of 37 species (1737 individuals). Emerald shiner was the most abundant species (collected at the rate of 43 per 300 meter transect), accounting for 25 percent of the total number of fish collected. Bluegill comprised 23 percent of the samples, gizzard shad (17 percent), largemouth bass (7 percent), smallmouth bass (6 percent) and spotted bass (4 percent). Due to large numbers of emerald shiners, fish abundance was twice as great in the forebay as the inflow. If emerald shiners are disregarded, the forebay still contained one-third more individuals than the inflow. A representative sample could not be collected in the transition zone of Chickamauga Reservoir in fall 1992 due to adverse weather conditions on the day of the survey. Electrofishing RFAI analysis showed a fair quality littoral fish community in both the inflow zone (RFAI=35) and forebay (RFAI=35). Both areas of Chickamauga Reservoir ranked in the middle 30 percentile when compared to mainstream reservoirs. Metrics receiving good rankings for both included percent omnivores, invertivores, and tolerant individuals. Few number of sucker species were present at either location resulting in poor scores for that metric. The health of largemouth bass was fair at both the inflow zone (FHAI=52) and forebay (FHAI=54).

Fish Tissue--There are no fish tissue consumption advisories in effect for Chickamauga Reservoir. Samples for screening studies were conducted in autumn 1991 and 1992. Fillets from five channel catfish were collected from the inflow, transition zone, and forebay, composited by site, and examined for a broad array of analyses (selected metals, pesticides, and PCBs on the EPA Priority Pollutant List). Results from samples collected from all locations in 1991 had low or nondetectable levels of metals and pesticides. PCB concentrations were 0.4, 0.7, and 1.2 $\mu g/g$ at the forebay, transition zone, and inflow, respectively. This general trend had been documented in several previous studies but not always as pronounced as in the 1991 results. Such was the case for 1992 results - PCB concentrations were 0.6, 0.7, and 0.7 $\mu g/g$ at the forebay, transition zone, and forebay, respectively. All other analytes were not detected or found in low concentrations in the 1992 fish samples.

4.8 Watts Bar Reservoir

4.8.1 Physical Description

Watts Bar Reservoir impounds water from both the Tennessee River and one of the major tributaries to the Tennessee River, the Clinch River. The three dams which bound Watts Bar Reservoir are Watts Bar Dam (located at TRM 529.9), Fort Loudoun Dam (located at TRM 602.3), and Melton Hill Dam located at Clinch River mile (CRM) 23.1. The total length of Watts Bar Reservoir, including the Clinch River arm is 96 miles, the shoreline length is 783 miles, and the surface area is 39,000 acres. The average annual discharge from Watts Bar is approximately 27,800 cfs providing an average hydraulic retention time of about 18 days.

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

A major tributary to the Clinch River arm of Watts Bar Reservoir is the Emory River which supplies on the average about 5 percent of the total flow through Watts Bar Reservoir. The Tennessee and Little Tennessee Rivers (i.e., discharge from Fort Loudoun Dam) account for about 75 percent of the flow and the Clinch River (i.e., discharge from Melton Hill Dam) accounts for about 15 percent through Watts Bar Reservoir.

4.8.2 Reservoir Health

The ecological health of Watts Bar was fair in 1992, same as in 1991. During both years this fair rating was only slightly below the level considered good. Algae was rated good at both the forebay and transition zone locations sampled in 1992. The sediment quality testing at the forebay and the transition zone in 1992 found low survival of test organisms and high concentrations of either ammonia or zinc. In August, concentrations of dissolved oxygen were less than 5 mg/L in the Tennessee River inflow to Watts Bar Reservoir due to the release of water with low DOs from Fort Loudoun Dam. Bottom-dwelling animals rated poor in both 1992 and 1991 at the Tennessee River inflow to Watts Bar Reservoir, possibly related to the low DOs from Fort Loudoun Dam.

Aquatic plants have declined from about 700 acres in the late 1980s to about 10 acres in 1992.

The overall ecological health of the Emory River at the fixed station monitoring site was fair in 1992. The primary problem was with poor sediment quality, evidenced by poor survival of test organisms, suggesting that toxicity may be emanating from active and abandoned coal mines in the watershed.

.8.3 Reservoir Use Suitability

Use Suitability Monitoring activities have not identified any bacteriological problems on Watts Bar Reservoir. The swimming areas at Roane County Park and Riley Creek campground fully support recreation. The informal recreation area near the upper end of Caney Creek embayment partially supports recreation. These evaluations are based on 1990 survey results. Bacteriological sampling in 1992 on Watts Bar Reservoir was limited to midchannel collections in association with Vital Signs Monitoring activities. Fecal coliform bacteria were below levels of detection in all samples.

As a result of PCB contamination, the Tennessee Department of Environment and Conservation (TDEC) has issued advisories on consumption of several fish species from Watts Bar Reservoir. In the Tennessee River portion catfish, striped bass, and striped bass/white bass hybrids should not be eaten. Also a precautionary advisory (children and pregnant or lactating women do not eat fish; all others limit fish consumption to 1.2 pounds per month) is in effect for largemouth bass, white bass, sauger, carp and smallmouth buffalo. In the Clinch River arm striped bass should not be eaten and a precautionary advisory is in effect for catfish and sauger.

Also, TDEC has issued a do not eat advisory for fish taken from the East Fork of Popular Creek due to mercury, metals, and organic chemical contamination.

4.8.4 Synopsis of 1992 Conditions

Water--Surface water temperatures ranged from 6.0°C in January to 27.3°C in July in the forebay and from 6.2°C to 26.3°C for these same months at the transition zone. Values for DO at the 1.5-meter depth ranged from 11.6 mg/L in January (as well as 11.6 mg/L in April due to high photosynthetic activity) to 6.3 mg/L in September at the forebay; and, from 11.4 mg/L in January to 5.8 mg/L in September at the transition zone. The minimum observed DO concentration in Watts Bar Reservoir in 1992 was 0.6 mg/L at the bottom of the forebay in July.

Temperature and dissolved oxygen data show that during the summer of 1992, Watts Bar Reservoir developed a moderate degree of both thermal and oxygen stratification in the forebay. Surface to bottom temperature differentials (ΔTs) were 7.0°C in April (during the period of low flows) and exceeded 6°C in May and June. DO versus depth data showed a rather strong oxycline to develop in the forebay of Watts Bar Reservoir from May through August. During these four months surface to bottom differences in DO were consistently greater than 7.0 mg/L, and near bottom DO concentrations in the hypolimnion were less than 1 mg/L in July. The transition zone was much more well mixed during the summer of 1992. Maximum ΔTs were 4.1°C (in April) and the minimum bottom DO measured was 5.5 mg/L (in September).

Values of pH ranged from 6.7 to 9.1 on Watts Bar Reservoir. Throughout the summer (April-August) near surface values of pH in the forebay were often high, exceeding 8.5, with DO saturation values commonly exceeding 100 percent, indicating high rates of photosynthesis.

The average total phosphorus concentrations observed in Watts Bar Reservoir (0.029 mg/L at the forebay and 0.033 mg/L at the transition zone) were among the lowest of the Tennessee River Vital Signs Monitoring locations. In addition, the average dissolved orthophosphorus concentrations of 0.008 mg/L and 0.010 mg/L, respectively, at the forebay and transition zones were also among the lowest observed at any of the Tennessee River Vital Signs Monitoring locations in 1992.

The highest chlorophyll-a concentrations were measured in June at the forebay (14 μg/L) and in May at the transition zone (14 μg/L). Surface concentrations of chlorophyll-a averaged about 7 μg/L at the forebay and about 8 μg/L at the transition zone in 1992. The high TN/TP ratios observed at the transition zone indicate the possibility of phosphorus limitation on primary productivity.

Forebay Secchi depth and suspended solids measurements averaged 1.4 meters and 4.9 mg/L, respectively. These values indicate the light transparency of Watts Bar Reservoir forebay to be relatively high compared with other mainstem Tennessee River reservoirs in 1992.

Fecal Coliform Bacteria--These were no swimming beaches on Watts Bar Reservoir examined as part of this monitoring program in 1992. (The swimming areas at Roane County Park and Riley Creek campground were sampled in 1990, at which time they fully supported water contact recreation. The informal recreation area near the upper end of Caney Creek embayment partially supports recreation, based on 1990 survey results.) Monthly samples collected in midchannel of Watts Bar Reservoir, at the forebay and transition zone as part of the 1992 Vital Signs Monitoring activities, all had concentrations at or less than the detection limit (10 fecal coliform colonies per 100 mL).

Sediment--Slightly elevated concentrations of mercury were detected in the sediment of Watts Bar Reservoir in 1992. Concentrations of 0.50 and 0.60 mg/kg were measured in the forebay and transition zone, respectively. The most likely source of this contamination is past operations at Oak Ridge National Laboratory where major environmental cleanup activities are now underway. In addition, elevated sediment zinc concentrations (220 mg/kg) were found in the transition zone, and high concentrations of un-ionized ammonia (470 μg NH_3/L) in sediment pore water were found in the forebay of Watts Bar Reservoir. Sediments were almost entirely silt and clay (97-98 percent) at both the forebay and transition zone.

The toxicological screening of sediment using rotifers (Rotox®) and light emitting bacteria (Microtox®) in Watts Bar Reservoir in 1992 found indications of toxicity at both locations. Low survival of rotifers (50 percent survival) was found using sediment pore water collected in the forebay of Watts Bar Reservoir, and Microtox® tests provided an indication of toxicity in sediment pore water collected at the transition zone.

Benthic Macroinvertebrates--In 1992, the forebay area of Watts Bar Reservoir and the Clinch River inflow had fair benthic communities. The transition zone had a good benthic community, while the Tennessee River inflow had a poor benthic community.

The forebay had 19 taxa and 693 organisms/m^2 which is an increase from 1991. Tubificidae comprised 41 percent of the organisms collected and Chironomus sp 27 percent. The transition zone density (868 organisms/m^2) and number of taxa (16) were similar to 1991 with the most numerous taxa being Musculium sp (34 percent) and Hexagenia sp (27 percent). The Tennessee River inflow location had 23 taxa and 547 organisms/m^2, which was an increase in number of taxa compared to 1991, but similar densities. The dominant taxon was Corbicula sp (62 percent). The Clinch River had 20 taxa and 335 organisms/m^2 dominated by Corbicula sp (43 percent) and the chironomid Dicrotendipes sp (28 percent).

Aquatic Macrophytes--Aquatic plants have declined from about 700 acres in the late 1980s to an estimated 10 acres in 1992. Eurasian watermilfoil and spinyleaf naiad were the dominant species prior to the recent decline.

Fish Community--Shoreline electrofishing (40 transects) and offshore gill netting (46 net-nights) sampled a total of 4081 fish represented by 41 species. Two species made up the majority of the overall sample: gizzard shad (54 percent) and bluegill (13 percent). These species were followed in abundance by emerald shiners (4 percent), brook silversides (2 percent), and largemouth bass (1 percent). Fish were most abundant in the Clinch River inflow zone (1565) followed by the Tennessee River inflow zone [illegible]316), transition zone (769), and forebay (521). Number of taxa present ranged from 23 in the Clinch River inflow zone to 38 in the Tennessee River inflow zone. FHAI analysis found largemouth bass health to be fair in the forebay (FHAI=53) and transition zone (FHAI=67) and poor in the Tennessee River inflow zone (FHAI=73). No FHAI was possible in the Clinch River inflow zone due to low numbers of largemouth bass collected.

RFAI analysis of shoreline electrofishing data indicated fair littoral fish communities in the two inflow zones (Clinch River Arm RFAI=37, Tennessee River Arm RFAI=37) and the transition (RFAI=31). The forebay fish community was poor (RFAI=27). Compared to respective zones of other mainstream reservoirs, both inflow zones ranked in the upper third, while the forebay and transition zone ranked in the middle 30 percentile. Conditions exhibited in the two inflow stations indicated more species and more diversity in sucker, intolerant, migratory spawning, and lithophilic spawning species than either the transition zone or forebay. Sunfish diversity was rated good in the transition zone, forebay, and Tennessee River inflow. Metrics contributing to the poor forebay designation were a high percentage of tolerant individuals, low fish abundance, and low numbers of sucker, migratory spawning, intolerant, and lithophilic spawning species.

Fish Tissue--Fish from Watts Bar Reservoir have been under intensive investigation for several years because of PCB contamination. TDEC has issued an advisory warning the public not to eat certain species and to limit consumption of other species. Four of these species (channel catfish, striped bass including striped bass/white bass hybrids, sauger, and largemouth bass) were reexamined in autumn 1991 as part of the continuing study to remain abreast of conditions in this reservoir. These fish were examined individually for PCBs. Average PCB concentrations among sample sites ranged 1.1 to 2.6 μg/g for channel catfish (eight locations), 0.6 to 2.4 μg/g for striped bass (three locations), 0.1 to 0.8 μg/g for sauger (three locations), and 0.3 to 0.5 μg/g for largemouth bass (four locations). (Note: some of the above channel catfish data and all largemouth bass data are part of a Department of Energy study on Watts Bar Reservoir and are still considered preliminary.) In 1992 three of the above four species were reexamined. White bass were examined in 1992, and largemouth bass were not. Average PCB concentrations among sample sites were 0.4 to 1.9 μg/g for channel catfish (five sites), 1.0 to 1.1 μg/g for striped bass (two sites), 0.2 to 0.6 μg/g for sauger (three sites), and the average for white bass at the single location was 0.7 μg/g. Additional data for channel catfish and striped bass collected in autumn 1992 will be available in the future from the above referenced DOE study.

Tennessee Valley Authority

Water Management

Chattanooga, Tennessee

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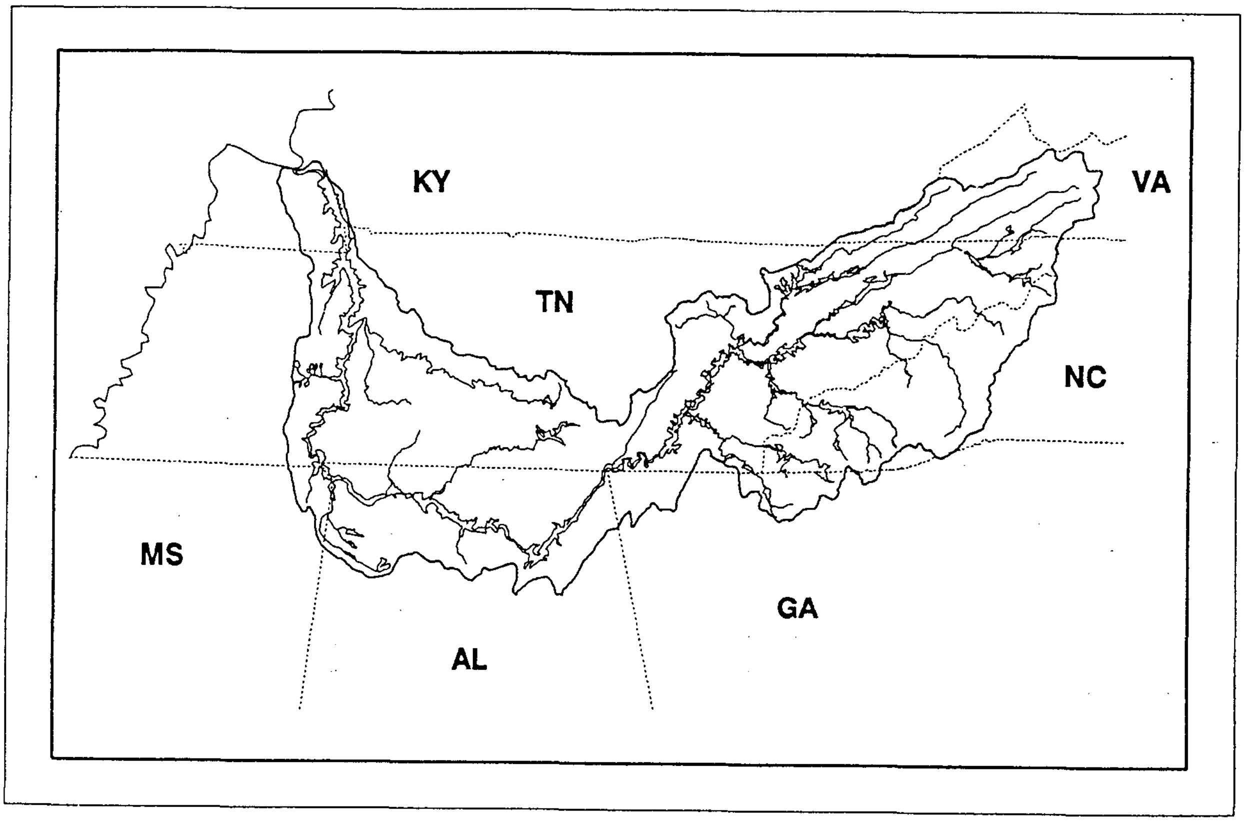
TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993

SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

VOLUME II



CLEAN WATER INITIATIVE

Chickamauga Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the April-September 1993 monitoring period, coolest surface water temperatures in Chickamauga Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 17.0°C to a maximum of 31.7°C at the forebay; from 16.2°C to 30.1°C at the transition zone; and from 19.1°C to 28.8°C in the Hiwassee River embayment. Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.9 mg/l in September to a high of 11.4 mg/l in April at the forebay; from 5.7 mg/l in September to 10.3 mg/l in April at the transition zone; and from 7.3 mg/l in August to 9.9 mg/l in April at the sampling location in the Hiwassee River embayment. At the inflow sampling site (i.e., the tailrace of Watts Bar dam) a minimum DO of 3.7 mg/l was recorded in August. Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature data depict seasonal warming and weak thermal stratification in Chickamauga Reservoir from May through July. The maximum observed surface to bottom temperature differentials (ΔT's), occurred in July. ΔT's were 5.5°C at the forebay, 3.2°C at the transition zone, and 4.1°C in the Hiwassee River embayment. There was also an oxycline at the forebay and transition zone in June and July when differences between surface and bottom DO's (DO's) were about 6 to 9 mg/l at the forebay and transition zone. In July 1993, a minimum DO of less than 0.1 mg/l was measured on the bottom at the forebay and a minimum of 1.6 mg/l was measured on the bottom at the transition zone. Better DO conditions were observed in the Hiwassee River embayment portion of Chickamauga Reservoir, where maximum DO's were only 1.7 mg/l and near bottom DO's only slightly below 6 mg/l.

DO ratings used in the overall reservoir ecological health evaluation for Chickamauga Reservoir were good at the forebay; good to excellent at the transition zone; excellent in Hiwassee River embayment; and fair at the inflow. The forebay would have rated higher had it not been for the low near bottom oxygen concentrations which existed in July. The fair rating at the inflow sampling site on Chickamauga Reservoir was a result of oxygen levels being measured about 1.5 mg/l below the Tennessee criteria (5 mg/l, at the 1.5 meter depth) in the releases from Watts Bar dam.

Values of pH ranged from 6.8 to 8.8 on Chickamauga Reservoir, in 1993. Near surface pH values exceeding 8.5 (and DO saturation values exceeding 100 percent) were observed on only two occasions (April and July), both at the forebay. Both of these periods of high pH and high oxygen saturations were also coincident with high chlorophyll *a* concentrations, indicative of periods of high photosynthetic activity. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Total nitrogen (TN), total phosphorus (TP), and dissolved ortho phosphorus (DOP) were low in the Tennessee River portion of Chickamauga Reservoir in 1993. TN averaged only 0.37 mg/l at the forebay, the lowest TN concentration measured at any of the Tennessee River sampling sites in 1993. At both the forebay and the transition zone, TP and DOP concentrations averaged only about 0.026 mg/l and 0.005 mg/l, respectively, and were among the lowest TP and DOP concentrations measured at any of the Tennessee River sampling sites in 1993. Because of these low concentrations (and because TN/TP ratios often exceeded 20), periods of phosphorus limitation on algal productivity were likely to have occurred.

In 1993, Chickamauga Reservoir chlorophyll *a* concentrations averaged 8.5 µg/l, 7.8 µg/l, and 5.5 µg/l, respectively, at the forebay, transition zone, and Hiwassee River embayment. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Chickamauga Reservoir were good (i.e., falling in the 3 to 10 µg/l range) at all three locations.

Sediment Quality—As in 1990, 1991, and 1992, chemical analyses of sediments from Chickamauga Reservoir in 1993 found high levels of copper (64 mg/kg) and zinc (320 mg/kg) in the forebay. High levels of copper (50 mg/kg) were also found in the Hiwassee River embayment, which was sampled for the first time in 1993. Chlordane was also detected in the forebay (16 µg/g) and the transition zone (15 µg/g). Toxicity tests indicated no acute toxicity to either species from the three sites tested, but survival of rotifers (75 percent survival) was reduced in the transition zone. Toxicity to rotifers was detected in both forebay and transition zone samples in 1992. Particle size analysis showed sediments from the forebay were 97 percent silt and clay; from the transition zone were 86 percent silt and clay, 14 percent sand; and from the Hiwassee River embayment were 63 percent silt and clay, 37 percent sand.

Sediment quality ratings used in the overall Chickamauga Reservoir ecological health evaluation for 1993 were fair at the forebay (presence of copper, zinc and chlordane); fair at the transition zone (presence of chlordane and reduced survival of rotifers); and, good in the Hiwassee River embayment (presence of copper).

Benthic Macroinvertebrates—The forebay and transition zone sites had excellent benthic communities, and the inflow site was fair. The Hiwassee embayment, a major component of Chickamauga Reservoir, was also included in the ecological health rating. It was shown to support a good benthic community. The forebay site had 19 taxa and 847 organisms/m^2. The most numerous taxa collected were the chironomid *Coelotanypus* sp (29 percent), the mayfly *Hexagenia limbata* (20 percent), the asiatic clam *Corbicula fluminea* (19 percent) and Tubificidae (17 percent). The transition zone was represented by 25 taxa and 897 organisms/m^2 with *Hexagenia limbata* comprising 26 percent of the total organisms and Tubificidae comprising 18 percent of the total organisms. The inflow had 21 taxa and 845 organisms/m^2. *Gammarus fasciatus*, an amphipod, was the dominant species present comprising 36 percent of the total organisms. The Hiwassee embayment had the greatest diversity and abundance of organisms than any other site on Chickamauga Reservoir. It had 2312 organisms/m^2 representing 49 species; Tubificidae were the dominant taxa collected (36 percent) followed by the snail *Musculium transversum* (17 percent).

The forebay on Chickamauga supported an excellent benthic community, however, the overall benthic score was lowered due to an elevated chironomid community and lowered EPT community. The transition zone also received an excellent rating but fell short of perfect because of an elevated chironomid community and lowered numbers of long-lived taxa. The inflow site rated fair primarily because of an absence of long-lived organisms such as *Corbicula* sp and *Hexagenia* sp, and because of reduced diversity and EPT taxa present. The Hiwassee embayment supported a good benthic community in 1993 because of an excellent EPT representation, diversity, low numbers of Chironomids, and evenness of the dominant species. An abundance of tubificids and a lack of long-lived species contributed to this site receiving a good rating instead of an excellent rating.

Aquatic Macrophytes—Coverage of aquatic macrophytes increased from 387 acres in 1992 to 1,185 acres in 1993. Most macrophytes were in Dallas Bay embayment and in small embayments and overbank habitat upstream of TRM 499. Aquatic macrophytes on Chickamauga Reservoir peaked at about 7,500 acres in 1988 and continuously declined until 1993 when coverage increased. Spinyleaf and southern naiad were the dominant species in 1993 although small colonies of Eurasian watermilfoil, American pondweed, and American lotus also were present.

Fish Assemblage—Fish data collected in littoral (45 electrofishing transects) and offshore zones (28 net-nights) of the forebay resulted in the collection of 44 species (6,994 individuals). Emerald shiner was the most abundant species (collected at the rate of 56 per 300 meter electrofishing transect), accounting for 36 percent of the total number of fish collected. Gizzard shad comprised 16 percent of the sample, followed closely by bluegill at 14 percent. Electrofishing results showed approximately twice as many individuals in the inflow (2,624) and transition (2,300) zones as the forebay (1,229), due to numbers of gizzard shad and bluegill in the sample. Numbers of YOY threadfin shad followed a similar pattern with high catch rates in the forebay (CPUE=810 per 300m transect) and transition (CPUE=1,707 per 300m transect) and very high catch rates in the inflow zone (CPUE=3,559 per 300m transect). Gill netting fish abundance was higher in the transition (454) than the forebay (229); although abundance at the inflow zone (158) was lower because of reduced effort, catch rate was similar to the transition zone.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the forebay (RFAI=32), good in the transition (RFAI=46), and excellent in the inflow (RFAI=52) zones of Chickamauga Reservoir. The inflow index of 52 was the highest score observed for run-of-the-river reservoir inflows and received maximum scores for all metrics except number of sucker and tolerant species, dominance by a single specie, and percent anomalies. In 1992 the inflow rated only fair (RFAI=34).

The gill netting RFAI rated the transition zone excellent (RFAI=52) and the forebay fair (RFAI=36). The excellent score of 52 in the transition zone was the second highest ever observed for run-of-the-river reservoirs and resulted from maximum scores for all metrics except number of sucker, intolerant, and lithophilic spawning species, and percent insectivores. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

The combined electrofishing and gill netting RFAI score for the transition (RFAI=49) and forebay (RFAI=34) were rated good and fair, respectively. The electrofishing RFAI for the inflow (RFAI=52) zone received an excellent rating, which was one of the highest scores for all inflows sampled in 1993.

Combined fish samples in shoreline electrofishing (15 transects) and offshore gill netting (12 net-nights) produced a total of 2263 individuals including 31 species in the Hiwassee River embayment of Chickamauga Reservoir. The three most abundant species were redear sunfish (29 percent), gizzard shad (19 percent), and bluegill (16 percent). There were six times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of sunfishes inhabiting shoreline areas.

The electrofishing RFAI score of 36 rated the embayment community as fair and gill netting results indicated good (RFAI=50) fish community conditions. Combining RFAI scores (RFAI=43) rated the Hiwassee River embayment good (scoring criteria for run-of-the-river transition was used to obtain RFAI ratings). Metrics for both electrofishing and gill netting that influenced the high scoring included low percent dominance by a single species, low percent omnivores, and high numbers of lithophilic spawning species.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation sites in Chickamauga Reservoir in 1993. Fecal coliform bacteria concentrations at the monthly Vital Signs locations, the forebay, transition zone, and Hiwassee River Embayment, were all 10/100 ml or less except for one sample. The April sample in the Hiwassee River Embayment had a concentration of 300/100 ml.

Fish Tissue—There are no fish tissue consumption advisories in effect for Chickamauga Reservoir. Samples for screening studies were conducted in autumn 1991 and 1992. Fillets from five channel catfish were collected from the inflow, transition zone, and forebay, composited by site, and examined for a broad array of analyses (selected metals, pesticides, and PCBs on the EPA priority pollutant list). Results from samples collected from all locations in 1991 had low or nondetectable levels of metals and pesticides. PCB concentrations were 0.4, 0.7, and 1.2 µg/g at the forebay, transition zone, and inflow, respectively. This general trend had been documented in several previous studies but not always as pronounced as in the 1991 results. Such was the case for 1992 results - PCB concentrations were 0.6, 0.7, and 0.7 µg/g at the forebay, transition zone, and forebay, respectively. All other analytes were not detected or found in low concentrations in the 1992 fish samples.

Watts Bar Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the April-September 1993 monitoring period, surface water temperatures ranged from a minimum of 18.3°C in April to a maximum of 30.2°C in July in the forebay; and from 16.7°C to 29.8°C (for the same months) at the transition zone. The State of Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Values for DO at the 1.5m depth ranged from a low of 6.5 mg/l in September to a high of 12.6 mg/l in April at the forebay, and from 7.1 mg/l to 11.3 mg/l (for the same months) at the transition zone. At the inflow sampling site on the Tennessee River arm of Watts Bar Reservoir (i.e. the tailrace of Fort Loudoun dam) a minimum DO of 3.9 mg/l was recorded in September. At the inflow sampling site on the Clinch River arm of Watts Bar Reservoir (i.e., the tailrace of Melton Hill dam) a minimum DO of 6.3 mg/l was recorded in March. Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature and dissolved oxygen data show that Watts Bar Reservoir developed a moderate degree of both thermal and oxygen stratification throughout most of the summer of 1993. For the period April through August, monthly surface to bottom temperature differentials (ΔT's) were: 5.2°C, 5.5°C, 7.4° C, 7.3°C, and 4.0°C at the forebay; and 2.3°C, 2.6°C, 3.9°C, 6.2°C, and 2.2°C at the transition zone.

DO versus depth data show that a rather strong oxycline also developed in Watts Bar Reservoir, particularly from June through August. During these three months, surface to bottom differences in DO were: 9.2 mg/l, 9.2 mg/l, and 5.8 mg/l at the forebay; and 7.2 mg/l, 5.8 mg/l, and 3.1 mg/l at the transition zone. At the forebay, near bottom DO concentrations in the hypolimnion were less than 2 mg/l in June and July. In addition, the proportion of the hypolimnion with low DO's (i.e. less than 2 mg/l) averaged about 13 percent of the total cross sectional area, higher than in any other Tennessee River reservoir. The minimum observed DO concentration in Watts Bar Reservoir in 1993 was 0.6 mg/l at the bottom of the forebay in July, but DO's were never less than 4 mg/l at the transition zone.

DO ratings used in the overall reservoir ecological health evaluation for Watts Bar Reservoir were poor at the forebay; excellent at the transition zone and at the inflow sampling site on the Clinch River; and fair at the inflow site on the Tennessee River. The low forebay rating was due to the large proportion of the forebay hypolimnion with low DO concentrations (i.e., less than 2 mg/l). The fair rating at the inflow sampling site on the Tennessee River arm of Watts Bar Reservoir was a result of oxygen levels being measured about 1 mg/l, below the Tennessee criteria (5 mg/l, at the 1.5 meter depth) in the releases from Fort Loudoun dam.

Historically, the pH's of water in Watts Bar Reservoir has been higher than other Tennessee River sampling site. This is due to the addition of the cool, clear, well oxygenated, nitrate rich, and hard water of the Clinch River which combines with the Tennessee River (and Watts Bar Reservoir) at TRM 567.9, about seven miles upstream from the transition zone sampling site. In the summer of 1993, values of pH ranged from 6.8 to 9.0 on Watts Bar Reservoir. During much of the April-September sample period, near surface values of pH frequently exceeded 8.5 at both the forebay and the transition zone, with DO saturation values commonly exceeding 100 percent, indicating high rates of photosynthesis. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

The average total phosphorus concentrations observed in Watts Bar Reservoir (0.029 mg/l at the forebay and 0.035 mg/l at the transition zone) were among the lowest of the Tennessee River Vital Signs Monitoring locations in 1993. In addition, the average dissolved ortho phosphorus concentrations of 0.007 mg/l and 0.004 mg/l, respectively, at the forebay and transition zones were also among the lowest observed at any of the Tennessee River Vital Signs Monitoring locations in 1993. TN/TP ratios on Watts Bar Reservoir are higher than on any other Tennessee River reservoir. The low phosphorus concentrations in combination with the relatively high nitrogen concentrations (supplied by both the Clinch and Tennessee River inflows) results in the high TN/TP ratios in Watts Bar (particularly at the transition zone) and suggest periods of phosphorus limitation on primary productivity.

The highest chlorophyll *a* concentrations were measured in August at the forebay (10 μg/l) and in May at the transition zone (11 μg/l). Surface concentrations of chlorophyll *a* averaged about 7 μg/l at the forebay and about 8 μg/l at the transition zone in 1993. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Watts Bar Reservoir were good (i.e., falling in the 3 to 10 μg/l range) at both locations.

Forebay Secchi depth and suspended solids measurements averaged 1.5 m and 6.3 mg/l, respectively. These values indicate the light transparency of Watts Bar Reservoir forebay to be relatively high compared with other mainstem Tennessee River reservoirs in 1993.

Sediment—Chemical analyses of sediments in Watts Bar Reservoir in 1993 indicated elevated levels of un-ionized ammonia (240 μg/l) in the forebay, and the presence of chlordane (18 μg/kg) in the transition zone. Mercury was also detected at the transition zone at a slightly elevated level (0.72 mg/kg), but at a level below sediment quality guidelines for mercury (i.e. 1.0 mg/kg). Toxicity tests detected acute toxicity to daphnids and rotifers (40 percent survival each) in the forebay. The forebay was also toxic to rotifers in 1992. Particle size analysis showed sediments from the forebay were near 100 percent silt and clay; and 98 percent silt and clay from the transition zone.

Sediment quality ratings used in the overall Watts Bar Reservoir ecological health evaluation for 1993 were "poor" at the forebay (acute toxicity to test animals and presence of ammonia); and "good" at the transition zone (presence of chlordane).

Benthic Macroinvertebrates—The forebay site had a good benthic macroinvertebrate community, the transition zone fair, and both the Tennessee River and Clinch River inflow sites had poor benthic communities. The forebay on Watts Bar had 805 organisms/m^2 representing 18 taxa; the dominant species were the chironomids Chironomus sp (32 percent) and Coelotanypus tricolor (16 percent). The transition zone had 14 taxa and 1,280 organisms/2 with the snail Musculium transversum (34 percent), the mayfly Hexagenia limbata (27 percent) and the chironomid Chironomus sp (17 percent) as the dominant species present. The Tennessee River inflow site had 314 organisms/m^2 representing 20 taxa; Corbicula fluminea was the dominant species comprising 71 percent of the total organisms. The Clinch River inflow site had 145 organisms/m^2 made up of 16 taxa; Corbicula fluminea (49 percent), Pseudochironomus sp (18 percent) and Tubificidae (18 percent), were the dominant taxa.

The Watts Bar forebay scored well on all metrics except for the paucity of EPT taxa and the preponderance of chironomids. Those two factors kept this site from obtaining an excellent rating. The transition zone exhibited a fair community. Reduced diversity, minimal numbers of long-lived species, above average numbers of chironomids, and unevenness associated with the dominant species all contributed to the fair rating this site received. The Tennessee River and Clinch River inflow sites both had a poor benthic communities because of the lack of diversity, EPT taxa, and long-lived species. The unevenness of dominant taxa also negatively impacted these benthic communities. Interestingly, the percent of the total organisms comprised of tubificids and chironomids, normally considered tolerant organisms, was relatively low at both inflows.

Aquatic Macrophytes—Aquatic plants have declined from about 700 acres in the late 1980's to an estimated 10 acres in 1993. Eurasian watermilfoil and spinyleaf naiad were the dominant species prior to the recent decline.

Fish Community—Shoreline electrofishing (60 transects) and offshore gill netting (39 net-nights) sampled a total of 5,174 fish represented by 50 species. Three species made up the majority of the overall sample: gizzard shad (37 percent), bluegill (13 percent), and emerald shiners (12 percent). Electrofishing results showed catch rates to be similar in the Clinch River inflow (CPUE=51 per 300m transect), Tennessee River inflow (CPUE=53 per 300m transect), and forebay (CPUE=56 per 300m transect) but much higher at the transition zone (CPUE=129 per 300m transect). The higher catch rate in the transition was attributed mainly to abundance of emerald shiners and bluegill. Threadfin shad YOY catch rates were moderate in all sample zones except the Tennessee River inflow which was considered high. Gill netting catch rates were much the same in all four sample areas.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) good in the transition (RFAI=48), fair in the forebay (RFAI=34) and Tennessee River inflow (RFAI=34), and poor in the Clinch River inflow (RFAI=30). The lower Clinch River inflow rating (compared to the Tennessee River inflow) resulted from slightly fewer numbers of sunfish and intolerant species. The gill netting RFAI rated both the transition zone (RFAI=38) and forebay (RFAI=32) fair. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=33) received a fair rating, followed by the transition (RFAI=43) zones which was rated good. Electrofishing RFAI scores for the Tennessee (RFAI=34) and Clinch River (RFAI=30) inflow zones were rated fair and poor, respectively.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Fourteen swimming areas were tested for fecal coliform bacteria 12 times each in 1993. Only one sample at each site was collected within 48 hours of a rainfall of at least one-half inch. Bacteria concentrations were generally higher after rainfall. If the one rainfall sample is excluded, all sites met Tennessee's water quality criteria for geometric mean concentration. However, four sites had one or more concentrations to exceed 1000/100 ml, Tennessee's maximum concentration for one sample. Only three of the fourteen areas had very low geometric mean concentrations for all samples (<20/100 ml), a much lower ratio than the other Tennessee River Reservoirs. All monthly fecal coliform bacteria samples taken at the two Vital Signs locations were <10/100 ml.

Fish Tissue—Fish from Watts Bar Reservoir have been under intensive investigation for several years because of PCB contamination. TDEC has issued an advisory warning the public to avoid eating certain species and to limit consumption of other species. Four of these species (channel catfish, striped bass including striped bass/white bass hybrids, sauger, and white bass) were reexamined in autumn in 1992. Average PCB concentrations among sample sites ranged from 0.4 to 1.9 µg/g for channel catfish (five sites), 1.0 to 1.1 µg/g for striped bass (two sites), 0.2 to 0.6 µg/g for sauger (three sites), and the average for white bass at the single location was 0.7 µg/g. Additional data for channel catfish and striped bass collected in autumn 1992 will be available in the future from studies conducted for DOE study. This is also true for additional fish collected for TVA studies in autumn 1993.

FIGURE 1
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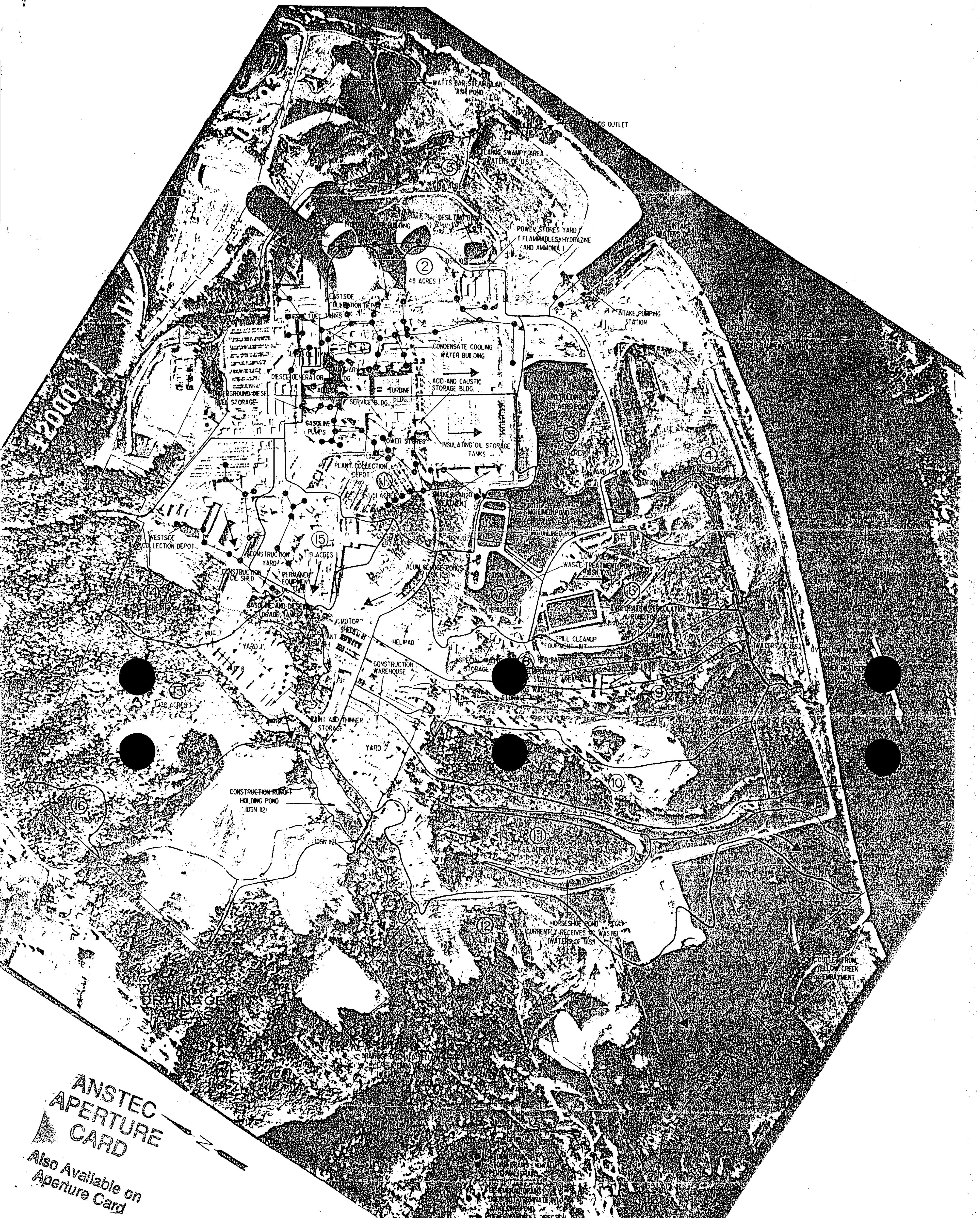
STORM WATER DRAINAGE MAP



WATTS BAR NUCLEAR PLANT

1" = 800

DATE OF COMPILATION: 28 SEPTEMBER 1989
DATE OF PHOTOGRAPHY: 2 DECEMBER 1987

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