Tennessee Valley Authority, Post Office Box 2000, Soddy Daisy, Tennessee 37384-2000

June 27, 2011

State of Tennessee
Department of Environment and Conservation
Division of Water Pollution Control
Enforcement & Compliance Section
6th Floor, L & C Annex
401 Church Street
Nashville, Tennessee 37243-1534

Dear Mr. Patrick Cromer:

SEQUOYAH NUCLEAR PLANT - 2010 BIOLOGICAL MONITORING REPORT

Enclosed is the "Biological Monitoring of the Tennessee River Near Sequoyah Nuclear Plant Discharge Autumn 2010" report. This report is submitted in accordance with Part III, Section F of the TVA - Sequoyah Nuclear Plant NPDES Permit No. TN0026450. If you have any questions or need additional information, please contact Brad Love at (423) 843-6714 or Stephanie Howard at (423) 843-6700 of Sequoyah's Environmental staff.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Michael D. Skaggs
Site Vice President
Sequoyah Nuclear Plant

Enclosures
cc (Enclosures):

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NRR

Biological Monitoring of the Tennessee River Near Sequoyah Nuclear Plant Discharge Autumn 2010

May 2011

Tennessee Valley Authority
Biological and Water Resources
Knoxville, Tennessee

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

BIP	Balanced Indigenous Population
CCW	Condenser cooling water
CFS	Cubic feet per second
MW	Megawatts
NPDES	National Pollutant Discharge Elimination System
QA	Quality Assurance
RBI	Reservoir Benthic Macroinvertebrate Index
RFAI	Reservoir Fish Assemblage Index
SAHI	Shoreline Assessment Habitat Index
SQN	Sequoyah Nuclear Plant
TRM	Tennessee River Mile
TVA	Tennessee Valley Authority
VS	Vital Signs

Introduction

Section 316(a) of the Clean Water Act (CWA) authorizes alternative thermal limits (ATL) for the control of the thermal component of a discharge from a point source so long as the limits will assure the protection of Balanced Indigenous Populations (BIP) of aquatic life. The term "balanced indigenous population," as defined in EPA's regulations implementing Section 316(a), means a biotic community that is typically characterized by:

(1) diversity appropriate to ecoregion;
(2) the capacity to sustain itself through cyclic seasonal changes;
(3) the presence of necessary food chain species;
(4) lack of domination by pollution-tolerant species; and
(5) indigenous.

Prior to 1999, the Tennessee Valley Authority's (TVA) Sequoyah Nuclear Plant (SQN) was operating under a 316(a) ATL that had been continued with each permit renewal based on studies conducted in the mid-1970s. In 1999, EPA Region IV began requesting additional data in conjunction with NPDES permit renewal applications to verify that BIP was being maintained at TVA's thermal plants with ATLs. TVA proposed that its existing Vital Signs (VS) monitoring program, supplemented with additional fish and benthic macroinvertebrate community monitoring upstream and downstream of thermal plants with ATLs, was appropriate for that purpose. The VS monitoring program began in 1990 in the Tennessee River System. This program was implemented to evaluate ecological health conditions in major reservoirs as part of TVA's stewardship role. One of the 5 indicators used in the VS program to evaluate reservoir health is the Reservoir Fish Assemblage Index (RFAI) methodology. RFAI has been thoroughly tested on TVA and other reservoirs and published in peer-reviewed literature (Jennings, et al., 1995; Hickman and McDonough, 1996; McDonough and Hickman, 1999). Fish communities are used to evaluate ecological conditions because of their importance in the aquatic food web and because fish life cycles are long enough to integrate conditions over time. Benthic macroinvertebrate populations are assessed using the Reservoir Benthic Index (RBI) methodology. Because benthic macroinvertebrates are relatively immobile, negative impacts to aquatic ecosystems can be detected earlier in benthic macroinvertebrate communities than in fish communities. These data are used to supplement RFAI results to provide a more thorough examination of differences in aquatic communities upstream and downstream of thermal discharges.

TVA initiated a study to evaluate fish and benthic macroinvertebrate communities and shoreline habitat in areas immediately upstream and downstream of SQN during 1999-2010 using RFAI and RBI multi-metric evaluation techniques. This report presents the results of autumn 2010 RFAI and RBI data collected upstream and downstream of SQN with comparisons to RFAI and RBI data collected at these sites during autumn 1999-2009.

Plant Description

Sequoyah Nuclear Power Plant (SQN) is located on the right (west) bank of Chickamauga Reservoir at Tennessee River Mile (TRM) 484.5 (Figure 1).

SQN Unit 1 began commercial operation on July 1, 1981, and Unit 2 began commercial operation on June 1, 1982. Net operating capacity is about 2,300 MW of electricity. Waste heat load is about 4,800 MW of thermal energy.

Waste heat is transferred to the condenser cooling water (CCW), pumped from the river at TRM 485.1 (Figure 1). This heat is then dissipated either to the atmosphere using two natural-draft cooling towers, to the river through a two-leg submerged multiport diffuser located at TRM 483.6, or by a combination of the two. With both units operating at maximum power, maximum water demand is 2558 cfs.

Methods

Fish and Benthic Macroinvertebrate Sample Locations Upstream and Downstream of SQN
Two sample locations, one upstream and one downstream of the plant discharge, were selected in Chickamauga Reservoir. The SQN discharge enters the Tennessee River TRM 483.6. For the fish community, the downstream site was centered at TRM 482.0 (Figures 2 and 4) and the upstream sample site was centered at TRM 490.5 (Figures 3 and 4). For the benthic macroinvertebrate community, transects across the full width of the reservoir were established at TRM 482.0 (Figure 4; downstream transect 4) and TRM 490.5 (Figure 4; upstream transect 6).

Aquatic Habitat in the Vicinity of SQN

Shoreline Aquatic Habitat Assessment

An integrative multi-metric index (Shoreline Aquatic Habitat Index or SAHI), including several habitat parameters important to resident fish species, was used to measure existing fish habitat quality in the vicinity of Sequoyah Nuclear Plant during autumn 2009. Using the general format developed by Plafkin et al. (1989), seven metrics were established to characterize selected physical habitat attributes important to reservoir resident fish populations which rely heavily on the littoral or shoreline zone for reproductive success, juvenile development, and/or adult feeding (Table 1). Habitat Suitability Indices (US Fish and Wildlife Service), along with other sources of information on biology and habitat requirements (Etnier and Starnes 1993), were consulted to develop "reference" criteria or "expected" conditions from a high quality environment for each parameter. Some generalizations were necessary in setting up scoring criteria to cover the various requirements of all species into one index.

Individual metrics are scored through comparison of observed conditions with these "reference" conditions and assigned a corresponding value: good-5; fair-3; or poor-1 (Table 1). The scores for each metric are summed to obtain the Shoreline Aquatic Habitat Index (SAHI) value. The range of potential SAHI values (7-35) is trisected to provide some descriptor of habitat quality (poor 7-16, fair 17-26, and good 27-35).

The quality of shoreline aquatic habitat was assessed while traveling parallel to the shoreline in a boat and evaluating the habitat within 10 vertical feet of full pool. This was much easier to accomplish when the reservoir was at least 10 feet below full pool during the assessment allowing accurate determination of near-shore aquatic habitat quality. Eight line-of-sight transects were established across the width of Chickamauga reservoir within the SQN downstream (TRMs 481.2 to 483.1) and upstream (TRMs 487.5 to 491.1) fish community sampling areas (Figure 4). Near-shore aquatic habitat was assessed along sections of shoreline corresponding to the left descending (LD) and right descending (RD) bank locations for each of the eight line-of-sight transects. These individual sections (8 on the LD bank and 8 on the RD bank for a total of 16 shoreline assessments) were then scored using SAHI criteria. Percentages of aquatic macrophytes in the littoral areas of the 8 LD and 8 RD shoreline sections were also estimated.

River Bottom Habitat

Along each of the 8 line-of-sight transects described above, 10 benthic grab samples were collected with a Ponar sampler at equally spaced points from the left descending bank to the right descending bank. Substrate material collected with the Ponar was dumped into a screen and substrate percentages were estimated to determine existing benthic habitat across the width of the river. Water depths at each sample location were recorded (feet). If no substrate was collected after multiple Ponar drops, it was assumed that the substrate was bedrock. For example, when the ponar was pulled shut, collectors could feel substrate consistency; if it shut easily and was not embedded in the substrate on numerous drops within the same location, substrate was recorded as bedrock.

Fish Community Sampling Methods and Data Analysis for Sites Upstream and Downstream of SQN

Fish sampling methods included boat electrofishing and gill netting (Hubert, 1996; Reynolds, 1996). Electrofishing methodology consisted of fifteen boat electrofishing runs near the shoreline, each 300 meters long with a duration of approximately 10 minutes each. The total near-shore area sampled was approximately 4,500 meters (15,000 feet).

Experimental gill nets (so called because of their use for research as opposed to commercial fishing) are used as an additional gear type to collect fish from deeper habitats not effectively sampled by electrofishing. Each experimental gill net consists of five-6.1 meter panels for a total length of 30.5 meters (100.1 feet). The distinguishing characteristic of experimental gill nets is mesh size that varies between panels. For this application, each net has panels with mesh sizes of 2.5, 5.1, 7.6, 10.2, and 12.7 cm. Experimental gill nets are typically set perpendicular to river flow extending from near-shore to the main channel of the reservoir. Ten overnight experimental gill net sets were used at each area.

Fish collected were identified by species, counted, and examined for anomalies (such as disease, deformations, or hybridization). The resulting data were analyzed using RFAI methodology.

The RFAI uses 12 fish community metrics from four general categories: Species Richness and Composition; Trophic Composition; Abundance; and Fish Health. Individual species can be utilized for more than one metric. Together, these 12 metrics provide a balanced evaluation of fish community integrity. The individual metrics are shown below, grouped by category:

Species Richness and Composition

(1) **Total number of indigenous species** -- Greater numbers of indigenous species are considered representative of healthier aquatic ecosystems. As conditions degrade, numbers of species at an area decline.

(2) **Number of centrarchid species** -- Sunfish species (excluding black basses) are invertivores and a high diversity of this group is indicative of reduced siltation and suitable sediment quality in littoral areas.

(3) **Number of benthic invertivore species** -- Due to the special dietary requirements of this species group and the limitations of their food source in degraded environments, numbers of benthic invertivore species increase with better environmental quality.

(4) **Number of intolerant species** -- This group is made up of species that are particularly intolerant of physical, chemical, and thermal habitat degradation. Higher numbers of intolerant species suggest the presence of fewer environmental stressors.

(5) **Percentage of tolerant individuals** (excluding Young-of-Year) -- This metric signifies poorer water quality with increasing proportions of individuals tolerant of degraded conditions.

(6) **Percent dominance by one species** -- Ecological quality is considered reduced if one species inordinately dominates the resident fish community.

(7) **Percentage of non-indigenous species** -- Based on the assumption that non-indigenous species reduce the quality of resident fish communities.

(8) **Number of top carnivore species** -- Higher diversity of piscivores is indicative of the availability of diverse and plentiful forage species and the presence of suitable habitat.

Trophic Composition

(9) **Percentage of individuals as top carnivores** -- A measure of the functional aspect of top carnivores which feed on major planktivore populations.

(10) **Percentage of individuals as omnivores** -- Omnivores are less sensitive to environmental stresses due to their ability to vary their diets. As trophic links are disrupted due to degraded conditions, specialist species such as insectivores decline while opportunistic omnivorous species increase in relative abundance.

Abundance

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

Fish Health

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

RFAI methodology addresses all five attributes or characteristics of a "balanced indigenous population" defined by the CWA, as described below:

(1) **A biotic community characterized by diversity appropriate to the ecoregion**: Diversity is addressed by the metrics in the Species Richness and Composition category, especially metric 1 – "total number of indigenous species." Determination of reference conditions based on the inflow zones of uppper mainstem Tennessee River reservoirs (as described below) ensures appropriate species expectations for the ecoregion.

(2) **The capacity for the community to sustain itself through cyclic seasonal change**: TVA uses an autumn data collection period for biological indicators, both VS and upstream/downstream monitoring. Autumn monitoring is used to document condition or health after being subjected to the wide variety of stressors throughout the year. One of the main benefits of using biological indicators is their ability to integrate stressors through time. Examining the condition or health of a community at the end of the "biological year" (i.e., autumn) provides insights into how well the community has dealt with the stresses through an annual seasonal cycle. Likewise, evaluation of the condition of individuals in the community (in this case, individual fish as reflected in Metric 12) provides insights into how well the community can be expected to withstand stressors through winter. Further, multiple sampling years during the permit renewal cycle adds to the evidence of whether or not the autumn monitoring approach has correctly demonstrated the ability of the community to sustain itself through repeated seasonal changes.

(3) **The presence of necessary food chain species**: Integrity of the food chain is measured by the Trophic Composition metrics, with support from the Abundance metric and Species Richness and Composition metrics. Existence of a healthy fish community indicates presence of necessary food chain species because the fish community is comprised of species that utilize multiple feeding mechanisms that transcend various levels in the aquatic food web. Basing evaluations on a sound multi-metric system such as the RFAI enhances the ability to discern alterations in the aquatic food chain.

Three dominant fish trophic levels exist within Tennessee River reservoirs; insectivores, omnivores, and top carnivores. To determine the presence of necessary food chain species, these three groups should be well represented within the overall fish community. Other fish trophic levels include benthic invertivores, planktivores, herbivores, and parasitic species. Insectivores include most sunfish, minnows, and silversides. Omnivores include gizzard shad, common carp, carpsuckers, buffalo, and channel and blue catfish. Top carnivores include bass, gar, skipjack herring, crappie, flathead catfish, sauger, and walleye. Benthic invertivores include drum, suckers, and darters. Planktivores include alewife, threadfin shad, and paddlefish. Herbivores include largescale stonerollers. Lampreys in the genus *Ichthyomyzon* are the only parasitic species occurring in Tennessee River reservoirs.

To establish expected proportions of each trophic guild and the expected number of species included in each guild occurring in upper mainstem Tennessee River reservoirs (Nickajack, Chickamauga, Watts Bar, and Fort Loudon reservoirs), data collected from 1993 to 2010 was analyzed for each reservoir zone where upstream and downstream sample stations were established to monitor effects of the SQN discharge (forebay- downstream of SQN and transition- upstream of SQN). Samples collected in the downstream vicinity of thermal discharges were not included in this analysis so that accurate expectations could be calculated with the assumption that these data represent what should occur in upper mainstem Tennessee River reservoirs absent from point source effects (i.e. power plant discharges). Therefore, data from the monitoring site downstream of SQN at TRM 482 was not included in this analysis. Data from 900 electrofishing runs (a total of 270,000 meters of shoreline sampled) and from 600 overnight experimental gill net sets were included in this analysis for forebay areas in upper mainstem Tennessee River reservoirs. For upper mainstem Tennessee River transition zones, data from 750 electrofishing runs and 500 overnight experimental gill net sets were included. From these data, the range of proportional values for each trophic level and the range of the number of species included in each trophic level were trisected. This trisection is intended to show less than expected, expected and above expected values for trophic level proportions and species occurring within each reservoir zone in upper mainstem Tennessee River reservoirs (Table 2). These data were also averaged and bound by confidence intervals (95%) to further evaluate expected values for proportions of each trophic level and the number of species expected for each trophic level by reservoir zone (Table 3).

(4) **A lack of domination by pollution-tolerant species**: Domination by pollution-tolerant species is measured by metrics 3 ("Number of benthic invertivore species"), 4 ("Number of intolerant species"), 5 ("Percentage of tolerant individuals"), 6 ("Percent dominance by one species"), and 10 ("Percentage of individuals as omnivores").

(5) **Indigenous**: Non-indigenous species reduce the quality of indigenous fish communities through increased competition for resources, predation on indigenous species, and degradation of the water quality. Metrics measuring the indigenousness of the fish communities are 1 ("Number of indigenous species") and 7 ("Percentage of non-indigenous species").

Scoring categories are based on "expected" fish community characteristics in the absence of human-induced impacts other than impoundment of the reservoir. These categories were developed from historical fish assemblage data representative of transition zones from upper mainstem Tennessee River reservoirs (Hickman and McDonough, 1996). Attained values for each of the 12 metrics were compared to the scoring criteria and assigned scores to represent relative degrees of degradation: least degraded (5); intermediate degraded (3); and most degraded (1). Scoring criteria for upper mainstem Tennessee River reservoirs are shown in Table 4.

If a metric was calculated as a percentage (e.g., "Percentage of tolerant individuals"), data from electrofishing and gill netting were scored separately and allotted half the total score for that individual metric. Individual metric scores for a sampling area (i.e., upstream or downstream) are summed to obtain the RFAI score for the area.

TVA uses RFAI results to determine maintenance of BIP using two approaches. One is "absolute" in that it compares the RFAI scores and individual metrics to predetermined values. The other is "relative" in that it compares RFAI scores attained downstream to the upstream control site. The "absolute" approach is based on Jennings et al. (1995) who suggested that favorable comparisons of the attained RFAI score from the potential impact zone to a predetermined criterion can be used to identify the presence of normal community structure and function and hence existence of BIP. For multi-metric indices, TVA uses two criteria to ensure a conservative screening of BIP. First, if an RFAI score reaches 70% of the highest attainable score of 60 (adjusted upward to include sample variability as described below), and second, if fewer than half of RFAI metrics receive a low (1) or moderate (3) score, then normal community structure and function would be present indicating that BIP had been maintained, thus no further evaluation would be needed.

RFAI scores range from 12 to 60. Ecological health ratings (12-21 ["Very Poor"], 22-31 ["Poor"], 32-40 ["Fair"], 41-50 ["Good"], or 51-60 ["Excellent"]) are then applied to scores. As discussed in detail below, the average variation for RFAI scores in TVA reservoirs is 6 ($\pm$ 3). Therefore, any location that attains an RFAI score of 45 (42 plus the upward sample variation of 3) or higher would be considered to have BIP. It must be stressed that scores below this threshold do not necessarily reflect an adversely impacted fish community. The threshold is used to serve as a conservative screening level; i.e., any fish community that meets these criteria is obviously not adversely impacted. RFAI scores below this level would require a more in-depth look to determine if BIP exists. An inspection of individual RFAI metric results and species of fish used in each metric would be an initial step to help identify if operation of SQN is a contributing factor. This approach is appropriate because a validated multi-metric index is being used and scoring criteria applicable to the zone of study are available.

A difference in RFAI scores attained at the downstream area compared to the upstream (control) area is used as one basis for determining presence or absence of impacts on the resident fish community from SQN's operations. The definition of "similar" is integral to accepting the validity of these interpretations. The Quality Assurance (QA) component of the Vital Signs monitoring program deals with how well the RFAI scores can be repeated and is accomplished by collecting a second set of samples at 15%-20% of the areas each year. Comparison of paired-sample QA data collected over seven years shows that the difference in RFAI index scores ranges from 0 to 18 points. The mean difference between these 54 paired scores is 4.6 points with 95% confidence limits of 3.4 and 5.8. The 75th percentile of the sample differences is 6, and the 90th percentile is 12. Based on these results, a difference of 6 points or less in the overall RFAI scores is the value selected for defining "similar" scores between upstream and downstream fish communities. That is, if the downstream RFAI score is within 6 points of the upstream score and if there are no major differences in overall fish community composition, then the two locations are considered similar. It is important to bear in mind that differences greater than 6 points can be expected simply due to method variation (i.e., 25% of the QA paired sample sets exceeded a difference of 6). An examination of the 12 metrics (with emphases on fish species used for each metric) is conducted to determine any difference in scores and the potential for the difference to be thermally related.

Benthic Macroinvertebrate Community Sampling Methods and Data Analysis for Sites Upstream and Downstream of SQN

Benthic grab samples were used to collect samples at ten equally-spaced points along the upstream and downstream transects. A Ponar sampler (area per sample 0.06 m^2) was used for most samples. When heavier substrate was encountered, a Peterson sampler (area per sample 0.11 m^2) was used. Collection and processing techniques followed standard VS procedures (OER-ESP-RRES-AMM-21.11; Quantitative Sample Collection - Benthic Macroinvertebrate Sampling with a Ponar Dredge). Bottom sediments were washed on a 533µ screen; organisms were then picked from the screen and any remaining substrate. Organisms were identified in the field to Order or Family level without magnification.

Benthic community results were evaluated using seven community characteristics or metrics. Results for each metric were assigned a rating of 1, 3, or 5 depending upon how they scored based on reference conditions developed for VS reservoir inflow sample sites. Scoring criteria for upper mainstem Tennessee River reservoirs are shown in Table 5. The ratings for the seven metrics were summed to produce a benthic score for each sample site. Potential scores ranged from 7 to 35. Ecological health ratings (7-12 "Very Poor", 13-18 "Poor", 19-23 "Fair", 24-29 "Good", or 30-35 "Excellent") are then applied to scores. The individual metrics are shown below:

(1) **Average number of taxa**—This metric is calculated by averaging the total number of taxa present in each sample at a site. Taxa generally mean family or order level because samples are processed in the field. For chironomids, taxa refers to obviously different organisms (i.e., separated by body size, head capsule size and shape, color, etc.). Greater taxa richness indicates better conditions than lower taxa richness.

(2) **Proportion of samples with long-lived organisms**—This is a presence/absence metric which is evaluated based on the proportion of samples with at least one long-lived organism (*Corbicula, Hexagenia*, mussels, and snails) present. The presence of long-lived taxa is indicative of conditions which allow long-term survival.

(3) **Average number of EPT taxa**—This metric is calculated by averaging the number of *Ephemeroptera*, *Plecoptera*, and *Trichoptera* taxa present in each sample at a site. Higher diversity of these taxa indicates good water quality and better habitat conditions.

(4) **Percentage as oligochaetes**—This metric is calculated by averaging the percentage of oligochaetes in each sample at a site. Oligochaetes are considered tolerant organisms so a higher proportion indicates poor water quality.

(5) **Percentage as dominant taxa**—This metric is calculated by selecting the two most abundant taxa in a sample, summing the number of individuals in those two taxa, dividing that sum by the total number of animals in the sample, and converting to a percentage for that sample. The percentage is then averaged for the 10 samples at each site. Often, the most abundant taxa differed among the 10 samples at a site. This allows more discretion to identify imbalances at a site than developing an average for a single dominant taxon for all samples a site. This metric is used as an evenness indicator. Dominance of one or two taxa indicates poor conditions.

(6) **Average density excluding Chironomids and Oligochaetes**—This metric is calculated by first summing the number of organisms, excluding chironomids and oligochaetes, present in each sample and then averaging these densities for the 10 samples at a site. This metric examines the community, excluding taxa which often dominate under adverse conditions. A higher abundance of non-chironomids and non-oligochaetes indicates good water quality conditions.

(7) **Zero-samples: Proportion of samples with containing no organisms**—This metric is the proportion of samples at a site which have no organisms present. "Zero-samples" indicate living conditions unsuitable to support aquatic life (i.e. toxicity, unsuitable substrate, etc.). Any site having one empty sample was assigned a score of three, and any site with two or more empty samples received a score of one. Sites with no empty samples were assigned a score of five.

A similar or higher benthic index score at the downstream site compared to the upstream site is used as basis for determining absence of impact on the benthic macroinvertebrate community related to SQN's thermal discharge. The QA component of VS monitoring shows that the comparison of benthic index scores from 49 paired sample sets collected over the past seven years range from 0 to 14 points, the 75th percentile is 4, the 90th percentile is 6. The mean difference between these 49 paired scores is 3.1 points with 95% confidence limits of 2.2 and 4.1. Based on these results, a difference of 4 points or less is the value selected for defining "similar" scores between upstream and downstream benthic communities. That is, if the downstream benthic score is within 4 points of the upstream score, the communities will be considered similar and it will be concluded that SQN has had no effect. Once again, it is important to bear in mind that differences greater than 4 points can be expected simply due to method variation (25% of the QA paired sample sets exceeded that value). When such occurs, a metric-by-metric examination will be conducted to determine what caused the difference in scores and the potential for the difference to be thermally related.

Chickamauga Reservoir Flow and SQN Temperature

Total daily average discharge from Watts Bar Dam, Appalachia Dam (Hiwassee River), and Ocoee 1 Dam (Ocoee River) was used to describe the amount of water flowing past SQN and was obtained from TVA's River Operations database.

Water temperature data was also obtained from TVA's River Operations database. Locations of water temperature monitoring stations used to compare water temperatures upstream of SQN intake and downstream of SQN discharge are depicted in Figure 5. Station 14 was used to measure the ambient temperature upstream of the SQN intake and was located at TRM 490.4. Station 8 was used to measure temperatures downstream of SQN discharge and was located at TRM 483.4. Water temperatures at both stations were computed as the average of temperature measurements at three depths: 3 feet, 5 feet, and 7 feet.

Water Quality Parameters at Fish Sampling Sites During RFAI Samples

Water quality conditions were measured using a hydrolab® which provided readings for dissolved oxygen (ppm), water temperature, conductivity (µs/cm), and pH. Readings were taken along a vertical gradient from just above the bottom of the river to approximately 0.3 meters from the surface at 1 to 2 meter intervals. Readings were conducted in the mid-channel at the most downstream and upstream boundaries of the electrofishing sample area at both stations upstream and downstream of SQN.

Results and Discussion

Aquatic Habitat in the Vicinity of SQN

Shoreline Aquatic Habitat Assessment

The SAHI methodology was used to evaluate shoreline habitat at 32 sections of shoreline located within the RFAI sample sites upstream and downstream (16 shoreline sections at 8 transects each) of SQN during autumn 2009. Eight shoreline sections were located on the left descending bank and 8 were located on the right descending bank upstream of SQN. The same distribution of shoreline sections was used for downstream of SQN.

Of the sixteen shoreline sections sampled upstream of SQN, 6% (1 transect) scored as good, 88% (14 transects) scored as fair, and 6% (1 transect) scored as poor (Table 6). The average score for transects on the left descending bank was 22 ("Fair"), while scores for transects on the right descending bank averaged 21 ("Fair"). The average percentage of aquatic macrophytes was 0% on each shoreline (Table 6).

Of the sixteen shoreline transects sampled downstream of SQN, 19% (3 transects) scored as good, 56% (9 transects) scored as fair, and 25% (4 transects) scored as poor (Table 7). The average scores for transects on the left descending bank were equal to those on the right descending bank (22 "Fair"). The average percentage of macrophytes was 2% and 5% on the left and right descending banks, respectively (Table 7).

River Bottom Habitat

A characterization of river bottom habitat was conducted along 8 transects within both the SQN downstream and upstream fish sampling areas during autumn 2009. Substrate percentages were estimated at 10 equally spaced drops along each transect. Figures 6-9 display substrate proportions as well as water depth at each sample point along each of the 8 transects downstream of SQN. Figures 10-13 display substrate proportions as well as water depth at each sample point along each of the 8 transects upstream of SQN.

The three most dominant substrate types encountered along the 8 transects downstream of SQN were mollusk shell (27.6 %), silt (19.9 %) and clay (16.4 %), while the 3 most dominant substrate types encountered along the 8 transects upstream of SQN were silt (51.2 %), mollusk shell (18.4 %), and bedrock (8.8 %) (Table 8). Overall average water depth was similar upstream and downstream of SQN.

Fish Community

In 2010, a fish community RFAI score of 39 ("Fair") was observed at both the downstream and upstream stations; therefore, the sites were considered similar and it can be concluded that BIP was maintained at the downstream site (Table 9). The upstream and downstream sites were compared using the five characteristics of BIP. For the discussion of each characteristic, the downstream site was compared to the upstream site (control) using those metrics useful in this determination.

(1) A biotic community characterized by diversity appropriate to the ecoregion
Total number of indigenous species (> 27 required for highest score for site downstream of SQN; > 29 required for highest score for site upstream of SQN)

Twenty-six indigenous species were collected at the downstream site, while 28 indigenous species were collected at the upstream site, resulting in the mid-range score for this metric at both sites (Tables 9). Brook silverside and sauger were collected at the downstream site but not at the upstream site, while white crappie, rock bass, threadfin shad, and walleye were collected at the upstream site but not downstream (Tables 10 and 11).

Total number of centrarchid species (> 4 required for highest score)

Both the upstream and downstream sites received the highest possible score for the metric "number of centrarchid species" (Table 9). Both sites contained the same seven sunfish species, with the exception of one young-of-year (yoy) white crappie that was collected at the upstream site (Tables 9, 10, and 11). Young-of-year fishes are not included in the RFAI analysis unless only one individual is collected that represents a new species.

Total number of benthic invertivore species (> 7 required for highest score)

Both the upstream and downstream sites received the lowest score for the metric "number of benthic invertivore species" (Table 9). The same three benthic invertivore species were collected at both sites (Tables 9, 10, and 11).

Total number of intolerant species (> 4 required for highest score)

Both the upstream and downstream sites received the highest score for the metric "number of intolerant species" (Table 9). Four of the five intolerant species were the same at each site; brook silverside was collected downstream of SQN but not upstream, while rock bass was collected upstream of SQN but not downstream (Tables 9, 10, and 11).

Total number of top carnivore species (> 6 required for highest score)

Both the upstream and downstream sites received the highest score for the metric "number of top carnivore species" (Table 9). Of the 10 top carnivore species collected downstream of SQN, sauger was collected at this site but not at the site upstream of SQN. Of the 12 species collected upstream of SQN, three were not encountered downstream of SQN (rock bass, walleye, and one yoy white crappie) (Tables 9, 10, and 11).

Both sites received the same score for each of the five aforementioned RFAI diversity metrics, indicating that fish community diversity was similar upstream and downstream of SQN.

(2) The capacity for the community to sustain itself through cyclic seasonal change

Autumn RFAI sampling was conducted downstream of SQN during 1996 and during 1999 to 2010. RFAI scores during this period have averaged a score of 41 "Good" and are shown in Table 12. With the exception of 1998, autumn RFAI sampling was conducted upstream of SQN from 1993 to 2010. RFAI scores during this period have averaged a score of 44 "Good" and are shown in Table 12.

The composition of the autumn sample should be indicative of the ability of the fish community to withstand the stressors of an annual seasonal cycle. The numbers of indigenous species collected during autumn RFAI samples downstream of SQN during 1996 and during 1999 to 2010 are shown in Figure 14. During this time period, the number of indigenous species ranged from 23 to 31 and the average number of indigenous species was 27. The numbers of indigenous species collected during autumn RFAI samples upstream of SQN during 1993 to 1997 and during 1999 to 2010 are shown in Figure 15. During this time period, the number of indigenous species ranged from 20 to 31 and the average number of indigenous species was 28. Although the long term average of indigenous species is similar between sites, the upstream site has consistently contained a higher number of species. Regardless, a diverse fish community has continued to persist and has exhibited the ability to sustain itself through cyclic seasonal change at both sites.

Percentage of anomalies (< 2 % required for highest score)

The percentage of anomalies (i.e. visible lesions, bacterial and fungal infections parasites, muscular and skeletal deformities, and hybridization) in the autumn sample should be indicative of the ability of the fish community to withstand the stressors of an annual seasonal cycle. Both upstream and downstream sites recorded the highest score for this metric during 2010 due to a low percentage of observed anomalies (Table 9).

(3) The presence of necessary food chain species

During autumn 2010, insectivores comprised 62.7 %, omnivores comprised 25.1 %, top carnivores comprised 9.4 %, and benthic invertivores comprised 2.9 % of the overall fish sample downstream of SQN. Proportions of insectivores exceeded the expectations calculated from historical data for upper mainstem Tennessee River reservoir forebay areas; proportions of omnivores and benthic invertivores were within historical averages; proportions of top carnivores were low and did not meet the average proportional expectations; and no planktivores or parasitic species were collected (Tables 2 and 3). Trophic levels were represented with 10 insectivorous species, 10 top carnivore species, 6 omnivorous species, and 3 benthic invertivore species (Table 10). The number of species for each observed trophic guild met or exceeded expectations, which were calculated from historical data for upper mainstem Tennessee River forebay zones (Tables 2 and 3).

During autumn 2010, insectivores comprised 67.6 %, omnivores comprised 20.1 %, top carnivores comprised 7.6 %, benthic invertivores comprised 4.7 %, and planktivores comprised 0.04 % of the overall fish sample upstream of SQN. Proportions of insectivores, omnivores, and planktivores exceeded the expectations calculated from historical data for upper mainstem Tennessee River reservoir transition areas, proportions of benthic invertivores met average expectations, and the proportion of top carnivores was lower than expectations (Tables 2 and 3). Trophic levels were represented with 9 insectivorous species, 12 top carnivore species, 6 omnivorous species, 3 benthic invertivore species, and 1 plantivorous species (Table 11). The number of species for each observed trophic guild met or exceeded expectations, which were calculated from historical data for upper mainstem Tennessee River transition zones (Tables 2 and 3).

Overall, trophic guild proportions and composition were similar between sites upstream and downstream of SQN, indicating that the thermal discharge did not affect fish community composition downstream of SQN.

(4) A lack of domination by pollution-tolerant species

Five pollution intolerant species were collected at both sites during autumn 2010 and each site received the highest RFAI score for this RFAI metric (Table 9).

Percentage of tolerant individuals (< 31 % required for highest electrofishing score; < 14% required for highest gill net score downstream of SQN-forebay criteria; < 16% required for highest gill net score upstream of SQN- transition criteria)
During 2010, both sites received the mid-range RFAI score for the electrofishing portion of this metric and the lowest score for the gill net portion of this metric. At both sites, this was primarily due to collection of a high percentage of bluegill and gizzard shad in the electrofishing samples and collection of a large percentage of gizzard shad in the gill net samples (Table 9).

Percentage of omnivores (< 24 % required for highest electrofishing score downstream of SQN-forebay criteria; < 22 % required for highest electrofishing score upstream of SQN-transition

criteria; < 17 % required for highest gill net score downstream of SQN; < 23 % required for highest gill net score upstream of SQN)
Omnivores consisted of 19.4 % of the electrofishing sample downstream of SQN and 17.2 % of the electrofishing sample upstream of SQN, resulting in the highest score for this metric at both sites (Table 9). Proportions of omnivores in the gill net samples at each site were much higher due to large numbers of gizzard shad, resulting in the lowest score for this portion of the metric for both sites (Table 9). The overall proportion of omnivores (electrofishing and gill net combined) at the upstream site was 20.1% and was 25.1 % at the downstream site. These proportions met or exceeded expectations for this trophic guild in upper mainstem Tennessee River reservoirs (Tables 2 and 3).

Percent dominance by one species
At both sites, this metric received the mid-range RFAI score for the electrofishing sample and the lowest score for the gill net sample (Table 9). The electrofishing sample downstream of SQN was dominated by inland silversides (non-indigenous) while the electrofishing sample upstream of SQN was dominated by bluegill. Gill net samples at both sites were dominated by gizzard shad (Table 9).

(5) Indigenous

In autumn 2010, 26 indigenous and 3 non-indigenous species (common carp, yellow perch, and inland silverside) were collected at the downstream site compared to 28 indigenous and 3 non-indigenous species (same 3 species) at the upstream site (Tables 10 and 11).

Percentages of non-indigenous species collected in the electrofishing sample were high at both sites (46.7 % downstream; 32.7 % upstream), with inland silverside being the dominant non-indigenous species (Table 9). The percentage of non-indigenous species collected in gill net samples was 0.5% (common carp) at the downstream site and no non-indigenous species were collected in gill nets at the upstream site (Table 9).

Compared to the upstream site, the downstream site was similar with respect to the indigenousness of its fish community.

Fish Community Summary

In conclusion, analysis of the five characteristics of BIP and their respective metrics indicated the downstream site was similar to the upstream site and that a balanced fish community was present at the site downstream of SQN in autumn 2010.

Ten of the 12 RFAI metrics received the same scores at both sites. The upstream site received a lower score for the electrofishing portion of the metric "percent top carnivores", while the downstream site received a lower score for the electrofishing portion of the metric "average number of fish collected per run" (Table 9).

Twenty-eight indigenous species were collected at the upstream site, while 26 were collected at the downstream site. Thirty-one resident important species were collected at the upstream site compared to 29 resident important species at the downstream stations (Tables 13 and 14). Representative important species are defined in EPA guidance as those species which are representative in terms of their biological requirements of a balanced, indigenous community of fish, shellfish, and wildlife in the body of water into which the discharge is made (EPA and NRC 1977).

The same three aquatic nuisance species (common carp, yellow perch, and inland silverside) were collected at both sites (Tables 13 and 14).

The same three thermally sensitive species (spotted sucker and logperch) were collected at both sites (Tables 13 and 14). Water temperatures greater than 32.2°C (90°F) are known to be lethal to the aforementioned species (Yoder et al. 2006).

Three commercially valuable species were collected at downstream site, while four were collected at the upstream site. Twenty-five recreationally valuable species were collected at the upstream site, while 23 were collected at the downstream site (Tables 13 and 14).

As discussed above, RFAI scores have an intrinsic variability of ±3 points. This variability comes from various sources, including annual variations in air temperature and stream flow; variations in pollutant loadings from nonpoint sources; changes in habitat, such as extent and density of aquatic vegetation; natural population cycles and movements of the species being measured (TWRC, 2006). Another source of variability arises from the fact that nearly any practical measurement, lethal or non-lethal, of a biological community is a sample rather than a measurement of the entire population. As long as the score is within the 6-point range, there is no certainty that any real change has taken place beyond method variability.

It should be noted that the upstream site is scored with transition criteria and the downstream site is scored using forebay criteria (Table 4). More accurate comparisons can be made between sites that are located in the same reservoir zone (i.e., transition to transition). Due to the location of SQN, it is not possible to have an upstream and downstream site within the same reservoir zone. SQN is located at the downstream end of the transition zone on Chickamauga Reservoir; therefore, the downstream site is located in the upstream section of the forebay. The physical and chemical composition of a forebay is different than that of a transition; consequently, inherent differences exist among the aquatic communities (e.g. species diversity is often higher in a transition than a forebay zone).

Over the sample years, the upstream site has averaged a score of 44 ("Good") while the downstream site has averaged a score of 41 ("Good"), indicating the sites were similar annually and that the SQN heated effluent is not adversely affecting the fish community in the vicinity of the plant (Table 12). RFAI scores are presented for the Chickamauga Reservoir inflow site (TRM 529.0), the forebay site (TRM 472.3), and the Hiwassee River embayment site (HiRM 8.5) to provide additional information of the health of the fish community throughout the reservoir; however, aquatic communities at these sites are not affected by SQN temperature effects and are not used to determine BIP in relation to SQN. The average RFAI scores at these three sites among all sampling years have remained in the "Good" range (Table 12).

Individual metric scores, overall RFAI scores, species collected, and catch per effort during electrofishing and gill netting for the upstream and downstream sampling sites of SQN during 1999-2009 are included in Shaffer et al. 2010.

Benthic Macroinvertebrate Community

Benthic macroinvertebrate data collected during autumn 2010 from TRM 482.0 downstream of SQN and from TRM 490.5 upstream of SQN resulted in a RBI scores of 29 ("Good") and 23 ("Fair"), respectively (Table 15). A difference of 4 points or less between upstream and downstream stations is used to define "similar" conditions between the two sites. Because the downstream site scored six points higher and was in the "Good" range, it can be determined that BIP was maintained. For the discussion of each RBI metric, the downstream site was compared to the upstream control site.

Average number of taxa
Both sites contained an average of ≥ 4.4 taxa, resulting in the highest score for this metric (Table 15).

Proportion of samples with long-lived organisms
The metric "proportion of samples with long-lived organisms" (*Corbicula, Hexagènia*, mussels, and snails) scored 2 points lower at the upstream site compared to the downstream site (Table 15). Seventy percent of samples collected at the upstream site contained at least one long-lived organism, while 90% of samples contained a long-lived organism at the downstream site.

Average number of EPT taxa
The average number of EPT taxa present in each sample was similar between sites (0.5 downstream and 0.7 upstream), resulting in the mid-range metric scores at both sites (Table 15).

Average proportion of oligochaete individuals
The average proportion of oligochaete individuals in each sample was low at each site (11.7 % downstream and 1.1 % upstream), resulting in the highest RBI score for both sites (Table 15).

Percentage as dominant taxa
The proportion of total abundance comprised by two dominant taxa was similar between sites. At the downstream site, 81.3 % of the total abundance was comprised of the two most abundant taxa (chironomids and *Corbicula*) resulting in the highest score for this metric (Tables 15 and 16). At the upstream site, the total abundance comprised of the two most abundant taxa (chironomids and fingernail clams) was 91.8 %, which resulted in the lowest score for this metric (Tables 15 and 16). These same taxa were also the most abundant taxa at each site during 2009 (Table 16).

Average density excluding chironomids and oligochaetes
Average densities excluding chironomids and oligochaetes were low (98.3 downstream and 181.7 upstream) resulting in the lowest metric score at both sites (Table 15).

Proportion of samples containing no organisms
There were no samples at either site which were void of organisms. Therefore, both sites received the highest score for this RBI metric (Table 15).

In conclusion, two metrics ("percentage as dominant taxa" and "proportion of samples with long-lived organisms") scored lower at the upstream site compared to the downstream site, resulting in the 6-point difference. All other metric scores were equal between sites (Table 15).

Individual RBI metric ratings and field scores are listed in Table 17 for comparison of samples from 2000 to 2010. RBI scores for the inflow, forebay, and Hiwassee River embayment sites are included to provide additional information on the overall health of the benthic macroinvertebrate community in Chickamauga Reservoir (Table 18). RBI scores have averaged "Good" for the inflow and forebay sites and "Fair" for the Hiwassee River embayment over all sample years.

Chickamauga Reservoir Flow and Temperature Near SQN

Total average daily flows from Watts Bar Dam, Ocoee No. 1 Dam, and Appalachia Dam from October 2009 to October 2010 are shown in Figure 16. Daily average flows were similar (total daily average flows averaged 13% higher) to historical daily average flows from 1976 through 2009.

Daily average water temperatures recorded upstream of the SQN intake and downstream of SQN discharge, October 2009 through October 2010, are shown in Figure 17. Water temperatures remained within permitted limits throughout the year.

Water Quality Parameters at Fish Sampling Sites During RFAI Samples

Observed values of water temperature, dissolved oxygen, conductivity, and pH are listed for each profile with corresponding water depth in Tables 19 and 20. Water temperatures at the sampling site upstream of SQN ranged from 75.7 °F to 77.7 °F (Table 19). Downstream of SQN, water temperatures ranged from 77.7 to 80.6 °F (Table 20). Dissolved oxygen concentrations ranged from 5.3 to 6.8 ppm at the sampling site upstream of SQN (Table 19). Dissolved oxygen readings taken at the sampling site downstream of SQN ranged from 5.8 to 6.5 ppm (Table 20). Similar pH readings were recorded upstream and downstream of SQN (Tables 19 and 20). The conductivity meter was not working properly at the time of the upstream RFAI sampling and no readings are reported (Table 19). Conductivity readings downstream of SQN were within a normal range for that portion of Chickamauga Reservoir.

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Table 1. Shoreline Aquatic Habitat Index (SAHI) metrics and scoring criteria.

Metric	Scoring Criteria	Score
Cover	Stable cover (boulders, rootwads, brush, logs, aquatic vegetation, artificial structures) in 25 to 75 % of the drawdown zone	5
	Stable cover in 10 to 25 % or > 75 % of the drawdown zone	3
	Stable Cover in < 10 % of the drawdown zone	1
Substrate	Percent of drawdown zone with gravel substrate > 40	5
	Percent of drawdown zone with gravel substrate between 10 and 40	3
	Percent substrate gravel < 10	1
Erosion	Little or no evidence of erosion or bank failure. Most bank surfaces stabilized by woody vegetation.	5
	Areas of erosion small and infrequent. Potential for increased erosion due to less desirable vegetation cover (grasses) on > 25 % of bank surfaces.	3
	Areas of erosion extensive, exposed or collapsing banks occur along > 30% of shoreline.	1
Canopy Cover	Tree or shrub canopy > 60 % along adjacent bank	5
	Tree or shrub canopy 30 to 60 % along adjacent bank	3
	Tree or shrub canopy < 30 % along adjacent bank	1
Riparian Zone	Width buffered > 18 meters	5
	Width buffered between 6 and 18 meters	3
	Width buffered < 6 meters	1
Habitat	Habitat diversity optimum. All major habitats (logs, brush, native vegetation, boulders, gravel) present in proportions characteristic of high quality, sufficient to support all life history aspects of target species. Ready access to deeper sanctuary areas present.	5
	Habitat diversity less than optimum. Most major habitats present, but proportion of one is less than desirable, reducing species diversity. No ready access to deeper sanctuary areas.	3
	Habitat diversity is nearly lacking. One habitat dominates, leading to lower species diversity. No ready access to deeper sanctuary areas.	1
Gradient	Drawdown zone gradient abrupt (> 1 meter per 10 meters). Less than 10 percent of shoreline with abrupt gradient due to dredging.	5
	Drawdown zone gradient abrupt. (> 1 meter per 10 meters) in 10 to 40 % of the shoreline resulting from dredging. Rip-rap used to stabilize bank along > 10 % of the shoreline.	3
	Drawdown zone gradient abrupt in > 40 % of the shoreline resulting from dredging. Seawalls used to stabilize bank along > 10 % of the shoreline.	1

Table 2. Expected values for upper mainstem Tennessee River reservoir transition and forebay zones calculated from data collected from 750 electrofishing runs and 500 overnight experimental gill net sets in upper mainstem Tennessee River reservoir transition areas and from 900 electrofishing runs and 600 overnight experimental gill net sets in forebay areas of upper mainstem Tennessee River reservoirs. This trisection is intended to show less than expected (-), expected or average (Avg), and above expected or average (+) values for trophic level proportions and species occurring within each reservoir zone in upper mainstem Tennessee River reservoirs.

	Upper Mainstem Tennessee River Transition						Upper Mainstem Tennessee River Forebay					
	Proportion			Number of species			Proportion			Number of species		
Trophic Guild	-	**Avg**	+	-	**Avg**	+	-	**Avg**	+	-	**Avg**	+
Benthic Invertivore	< 2.4	2.4 to 4.8	> 4.8	< 2	2 to 4	> 4	< 2.2	2.2 to 4.2	> 4.2	< 2	2 to 4	> 4
Insectivore	< 24.2	24.2 to 48.4	> 48.4	< 4	4 to 8	> 8	< 34.2	34.2 to 62.6	> 62.6	< 4	4 to 8	> 8
Top Carnivore	< 18.9	18.9 to 37.7	> 37.7	< 4	4 to 8	> 8	< 18.8	18.8 to 33.4	> 33.4	< 4	4 to 8	> 8
Omnivore	> 40.2	20.2 to 40.2	< 20.2	> 6	3 to 6	< 3	> 40.1	21.4 to 40.1	< 21.4	> 6	3 to 6	< 3
Planktivore	> 41.2	20.6 to 41.2	< 20.6	0	1	> 1	> 10.4	5.2 to 10.4	< 5.2	0	1	> 1
Parasitic	< 0.4	0.4 to 0.9	> 0.9	0	1	> 1	< 0.4	0.4 to 0.8	> 0.8	0	1	> 1
Herbivore	---	---	---	---	---	---	---	---	---	---	---	---

Table 3. Average trophic guild proportions and average number of species, bound by confidence intervals (95 %), expected in upper mainstem Tennessee River reservoir inflow and forebay zones. These values were calculated from data collected from 750 electrofishing runs and 500 overnight experimental gill net sets in upper mainstem Tennessee River reservoir transition areas and from 900 electrofishing runs and 600 overnight experimental gill net sets in forebay areas of upper mainstem Tennessee River reservoirs.

	Transition		**Forebay**	
Trophic Guild	Average Proportion	Average Number of Species	Average Proportion	Average Number of Species
Benthic Invertivore	3.1 ± 0.2	3.7 ± 0.2	2.3 ± 0.4	3.3 ± 0.3
Insectivore	44.5 ± 2.2	9.2 ± 0.5	50.4 ± 5.7	8.7 ± 0.5
Top Carnivore	18.2 ± 0.9	10.2 ± 0.5	19.0 ± 2.7	9.9 ± 0.3
Omnivore	29.5 ± 1.5	6.4 ± 0.3	22.4 ± 3.5	6.1 ± 0.3
Planktivore	5.6 ± 0.3	1.1 ± 0.1	1.8 ± 0.9	1.0 ± 0.1
Parasitic	0.04 ± 0.02	1.0 ± 0.1	0.05 ± 0.05	0.1 ± 0.08
Herbivore	0.01 ± 0.004	1.0 ± 0.1	----	----

Table 4. RFAI scoring criteria (2002) for forebay, transition, and inflow sections of upper mainstream Tennessee River reservoirs. Upper mainstream reservoirs include Chickamauga, Fort Loudoun, Melton Hill, Nickajack, Tellico, and Watts Bar.

		Scoring Criteria								
		Forebay			Transition			Inflow		
Metric	**Gear**	**1**	**3**	**5**	**1**	**3**	**5**	**1**	**3**	**5**
1. Total species	Combined	<14	14-27	>27	<15	15-29	>29	<14	14-27	>27
2. Total Centrarchid species	Combined	<2	2-4	>4	<2	2-4	>4	<3	3-4	>4
3. Total benthic invertivores	Combined	<4	4-7	>7	<4	4-7	>7	<3	3-6	>6
4. Total intolerant species	Combined	<2	2-4	>4	<2	2-4	>4	<2	2-4	>4
5. Percent tolerant individuals	Electrofishing	>62%	31-62%	<31%	>62%	31-62%	<31%	>58%	29-58%	<29%
	Gill netting	>28%	14-28%	<14%	>32%	16-32%	<16%			
6. Percent dominance by 1 species	Electrofishing	>50%	25-50%	<25%	>40%	20-40%	<20%	>46%	23-46%	<23%
	Gill netting	>29%	15-29%	<15%	>28%	14-28%	<14%			
7. Percent non-indigenous species	Electrofishing	>4%	2-4%	<2%	>6%	3-6%	<3%	>17%	8-17%	<8%
	Gill netting	>16%	8-16%	<8%	>9%	5-9%	<5%			
8. Total top carnivore species	Combined	<4	4-7	>7	<4	4-7	>7	<3	3-6	>6
9. Percent top carnivores	Electrofishing	<5%	5-10%	>10%	<6%	6-11%	>11%	<11%	11-22%	>22%
	Gill netting	<25%	25-50%	>50%	<26%	26-52%	>52%			
10. Percent omnivores	Electrofishing	>49%	24-49%	<24%	>44%	22-44%	<22%	>55%	27-55%	<27%
	Gill netting	>34%	17-34%	<17%	>46%	23-46%	<23%			
11. Average number per run	Electrofishing	<121	121-241	>241	<105	105-210	>210	<51	51-102	>102
	Gill netting	<12	12-24	>24	<12	12-24	>24			
12. Percent anomalies	Electrofishing	>5%	2-5%	<2%	>5%	2-5%	<2%	>5%	2-5%	<2%
	Gill netting	>5%	2-5%	<2%	>5%	2-5%	<2%			

Table 5. RBI scoring criteria for benthic macroinvertebrate community (field-processed samples) for forebay, transition zone, and inflow sections of mainstream Tennessee River reservoirs. TRM 482 was scored with forebay criteria and TRM 490.5 was scored with transition criteria

	Mainstem Tennessee River Reservoirs								
Benthic Community Metrics	**Forebay**			**Transition Zone**			**Inflow**		
	1	**3**	**5**	**1**	**3**	**5**	**1**	**3**	**5**
Average number of taxa	≤2.4	2.5-4.7	≥4.8	≤2.1	2.2-4.3	≥4.4	≤2.8	2.9-5.7	≥5.8
Proportion of samples with long-lived organisms	≤0.3	0.4-0.7	≥0.8	≤0.3	0.4-0.7	≥0.8	≤0.3	0.4-0.7	≥0.8
Average number of EPT taxa	≤0.4	0.5-0.7	≥0.8	≤0.3	0.4-0.7	≥0.8	≤0.3	0.4-0.7	≥0.8
Percentage as oligochaetes	≥29.7	14.9-29.6	≤14.8	≥28.0	14.0-27.9	≤13.9	≥40.0	20.1-39.9	≤20.0
Percentage as dominant taxa	≥90.7	81.4-90.6	≤81.3	≥87.8	78.8-87.7	≤78.7	≥85.0	78.8-84.9	≤78.7
Average density excluding chironomids and oligochaetes	≤118	119-235	≥236	≤291	292-580	≥581	≤568	569-1152	≥1153
Zero-samples - proportion of samples containing no organisms	≥0.2	0.1	0	≥0.2	0.1	0	≥0.2	0.1	0

Table 6. SAHI scores for 16 shoreline habitat assessments conducted within the upstream RFAI sampling area of SQN on Chickamauga Reservoir, autumn 2009. Scores are shown for eight shoreline sections on the left descending bank (LD) and eight shoreline sections along the right descending bank (RD). Scoring criteria: poor (7-16); fair (17-26); and good (27-35).

	1(LD)	2(LD)	3(LD)	4(LD)	5(LD)	6(LD)	7(LD)	8(LD)	Avg.
Latitude	35.26755	35.27312	35.27784	35.28179	35.28669	35.29674	35.20021	35.3037	
Longitude	-85.09749	-85.09602	-85.09093	-85.08571	-85.0741	-85.06678	-85.06367	-85.06049	
Aquatic Macrophytes	0%	0%	0%	0%	0%	0%	0%	0%	0%
SAHI Variables									
Cover	1	1	5	1	5	1	1	3	2
Substrate	5	1	1	1	3	5	3	5	3
Erosion	1	5	1	5	5	3	1	3	3
Canopy Cover	5	5	5	5	1	5	5	5	5
Riparian Zone	5	5	5	5	1	5	5	5	5
Habitat	1	1	3	1	3	1	1	3	2
Slope	1	1	1	1	3	3	3	3	2
Total	19	19	21	19	21	23	19	27	22
Rating	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Good	Fair

	1(RD)	2(RD)	3(RD)	4(RD)	5(RD)	6(RD)	7(RD)	8(RD)	Avg.
Latitude	35.26823	35.27665	35.28347	35.28747	35.29329	35.30095	35.30458	35.3092	
Longitude	-85.108	-85.10484	-85.09809	-85.09035	-85.08268	-85.07718	-85.07455	-85.07194	
Aquatic Macrophytes	0%	0%	0%	0%	0%	0%	0%	0%	0%
SAHI Variables									
Cover	3	1	5	5	3	3	5	1	3
Substrate	5	5	5	5	1	5	1	1	4
Erosion	1	1	5	5	5	5	5	3	4
Canopy Cover	5	5	1	3	5	3	3	1	3
Riparian Zone	5	5	1	1	5	1	1	1	3
Habitat	1	3	3	3	1	3	3	1	2
Slope	1	1	1	1	1	3	1	3	2
Total	21	21	21	23	21	23	19	11	21
Rating	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Poor	Fair

Table 7. SAHI Scores for 16 Shoreline Habitat Assessments Conducted within the Downstream RFAI Sampling Area of SQN on Chickamauga Reservoir, Autumn 2009. Scores are Shown for Eight Shoreline Sections on the Left Descending Bank (LD) and Eight Shoreline Sections Along the Right Descending Bank (RD). Scoring Criteria: Poor (7-16); Fair (17-26); and good (27-35).

	1(LD)	2(LD)	3(LD)	4(LD)	5(LD)	6(LD)	7(LD)	8(LD)	Avg.
Latitude	35.19455	35.20021	35.20443	35.20584	35.20617	35.2061	35.20865	35.21104	
Longitude	-85.11967	-85.11858	-85.11671	-85.11346	-85.10754	-85.10212	-85.09711	-85.09188	
Aquatic Macrophytes	0%	0%	15%	0%	0%	10%	0%	0%	2%
SAHI Variables									
Cover	5	5	5	5	3	1	1	3	4
Substrate	1	1	1	3	1	1	1	1	1
Erosion	3	5	3	3	3	1	3	5	3
Canopy Cover	5	3	5	5	5	5	1	1	4
Riparian Zone	5	3	5	5	5	5	1	3	4
Habitat	3	3	3	3	1	1	3	1	2
Slope	3	5	5	3	5	5	1	1	4
Total	25	25	27	27	23	19	11	15	22
Rating	Fair	Fair	Good	Good	Fair	Fair	Poor	Poor	Fair

	1(RD)	2(RD)	3(RD)	4(RD)	5(RD)	6(RD)	7(RD)	8(RD)	Avg.
Latitude	35.19718	35.20069	35.20722	35.20967	35.21449	35.21521	35.21565	35.2159	
Longitude	-85.12923	-85.12331	-85.12156	-85.11884	-85.1115	-85.10953	-85.10047	-85.09368	
Aquatic Macrophytes	0%	0%	0%	0%	10%	5%	25%	0%	5%
SAHI Variables									
Cover	3	5	5	3	1	3	5	3	4
Substrate	3	1	3	3	1	1	1	1	2
Erosion	5	5	5	5	3	3	1	5	4
Canopy Cover	5	5	5	1	1	1	5	1	3
Riparian Zone	5	5	5	1	1	1	3	5	3
Habitat	1	3	3	3	1	1	3	1	2
Slope	3	1	3	1	5	5	5	5	4
Total	25	25	29	17	13	15	23	21	22
Rating	Fair	Fair	Good	Fair	Poor	Poor	Fair	Fair	Fair

Table 8. Substrate percentages and average water depth (ft) per transect upstream (8 transects) and downstream (8 transects) of SQN.

	% Substrate per transect downstream of SQN								
	1	2	3	4	5	6	7	8	AVG
Mollusk shell	15.5	32	20.5	26	24.5	22.5	26.5	52.9	27.6
Silt	37.5	12	11	13	23.5	36	19.5	7	19.9
Clay	14	16	9	31.5	8	29.5	6	17	16.4
Sand	19.5	14	22	6	12	3.5	28.5	2.5	13.5
Bedrock	10	9	17.5	20	20	0	10	16	12.8
Detritus	2.5	4.5	3.5	3.5	3	5	3	4.6	3.7
Gravel	0	3	7	1	8	3.5	3.5	0.5	3.3
Cobble	1	9.5	9	0.5	1	0	3	0.5	3.1
Avg. depth (ft)	27.1	39.7	32.6	33.2	27	29.8	35.1	44.7	33.7
Actual depth range: 7.4 to 78.5 ft									

	% Substrate per transect upstream of SQN								
	1	2	3	4	5	6	7	8	AVG
Silt	30.5	43	56.5	22	45.5	71	63.5	77.5	51.2
Mollusk shell	25	19.5	15.5	33.5	20	10	15.5	8	18.4
Bedrock	10	20	0	20	20	0	0	0	8.8
Detritus	7	7	8.5	7.5	2.5	10.5	9	8	7.5
Clay	14	0	0	5	7	8.5	8	6.5	6.1
Cobble	4	5	10	0	2.5	0	4	0	3.2
Sand	7.5	5.5	7.5	4.5	0.5	0	0	0	3.2
Gravel	2	0	2	7.5	2	0	0	0	1.7
Avg. depth (ft)	33	30.1	34.9	33.6	26.2	31.8	32.2	26.1	31.0
Actual depth range: 6.4 to 55.2 ft									

Table 9. Individual Metric Scores and the Overall RFAI Scores Downstream (TRM 482.0) and Upstream (TRM 490.5) of Sequoyah Nuclear Plant Discharge, Autumn 2010.

Autumn 2010	TRM 482.0		TRM 490.5	
Metric	Obs	Score	Obs	Score
A. Species richness and composition				
1. Number of indigenous species (Tables 10 and 11)	26	3	28	3
2. Number of centrarchid species (less *Micropterus*)	7 Black crappie Bluegill Green sunfish Longear sunfish Redbreast sunfish Redear sunfish Warmouth	5	8 Black crappie Bluegill Green sunfish Longear sunfish Redbreast sunfish Redear sunfish Warmouth White crappie	5
3. Number of benthic invertivore species	3 Freshwater drum Logperch Spotted sucker	1	3 Freshwater drum Logperch Spotted sucker	1
4. Number of intolerant species	5 Brook silverside Longear sunfish Skipjack herring Smallmouth bass Spotted sucker	5	5 Longear sunfish Rock bass Skipjack herring Smallmouth bass Spotted sucker	5

Table 9. (Continued)

Autumn 2010		TRM 482.0		TRM 490.5	
Metric		Obs	Score	Obs	Score
5. Percent tolerant individuals	Electrofishing	**42.3%** Bluegill 20.1% Bluntnose minnow 1.6% Common carp 0.2% Gizzard shad 16.3% Golden shiner 0.6% Green sunfish 0.2% Largemouth bass 2.4% Redbreast sunfish 0.4% Spotfin shiner 0.5%	1.5	**54.0%** Bluegill 34.8% Bluntnose minnow 0.2% Common carp 0.1% Gizzard shad 16.7% Golden shiner 0.2% Green sunfish 0.2% Largemouth bass 0.6% Redbreast sunfish 0.9% Spotfin shiner 0.3%	1.5
	Gill Netting	**55.4%** Bluegill 0.9% Common carp 0.5% Gizzard shad 52.1% Golden shiner 0.5% Largemouth bass 1.4%	0.5	**46.5%** Bluegill 1.0% Gizzard shad 39.2% Golden shiner 5.3% Largemouth bass 1.0%	0.5
6. Percent dominance by one species	Electrofishing	**46.2%** Inland silverside	1.5	**34.8%** Bluegill	1.5
	Gill Netting	**52.1%** Gizzard shad	0.5	**39.2%** Gizzard shad	0.5

Table 9. (Continued)

Autumn 2010		TRM 482.0		TRM 490.5	
Metric		Obs	Score	Obs	Score
7. Percent non-indigenous species	Electrofishing	**46.7%** Common carp 0.2% Inland silverside 46.2% Yellow perch 0.2%	0.5	**32.7%** Common carp 0.1% Inland silverside 32.5% Yellow perch 0.1%	0.5
	Gill Netting	**0.5%** Common carp 0.5%	2.5	**0%**	2.5
8. Number of top carnivore species		**10** Black crappie Flathead catfish Largemouth bass Sauger Skipjack herring Smallmouth bass Spotted bass Spotted gar White bass Yellow bass	5	**12** Black crappie Flathead catfish Largemouth bass Rock bass Skipjack herring Smallmouth bass Spotted bass Spotted gar Walleye White bass White crappie Yellow bass	5

Table 9. (Continued)

Autumn 2010		TRM 482.0		TRM 490.5	
Metric		Obs	Score	Obs	Score
B. Trophic composition					
9. Percent top carnivores	Electrofishing	**6.3%** Black crappie 1.1% Flathead catfish 0.1% Largemouth bass 2.4% Smallmouth bass 0.4% Spotted bass 0.6% Spotted gar 1.6% Yellow bass 0.1%	1.5	**4.1%** Black crappie 0.9% Flathead catfish 0.8% Largemouth bass 0.6% Rock bass 0.1% Smallmouth bass 0.2% Spotted bass 1.0% Spotted gar 0.5%	0.5
	Gill Netting	**29.2%** Black crappie 2.8% Flathead catfish 1.4% Largemouth bass 1.4% Sauger 0.5% Skipjack herring 0.9% Smallmouth bass 0.9% Spotted bass 5.1% Spotted gar 1.4% White bass 2.8% Yellow bass 12.0%	1.5	**42.7%** Black crappie 6.7% Flathead catfish 1.9% Largemouth bass 1.0% Skipjack herring 2.9% Spotted bass 1.0% Walleye 0.5% White bass 4.8% Yellow bass 23.9%	1.5

Table 9. (Continued)

Autumn 2010		TRM 482.0		TRM 490.5	
Metric		Obs	Score	Obs	Score
10. Percent omnivores	Electrofishing	**19.4%** Bluntnose minnow 1.6% Channel catfish 0.6% Common carp 0.2% Gizzard shad 16.3% Golden shiner 0.6% Hybrid shad 0.1%	2.5	**17.2%** Bluntnose minnow 0.2% Channel catfish 0.1% Common carp 0.1% Gizzard shad 16.6% Golden shiner 0.2%	2.5
	Gill Netting	**62.7%** Blue catfish 7.8% Channel catfish 1.8% Common carp 0.5% Gizzard shad 52.1% Golden shiner 0.5%	0.5	**47.9%** Blue catfish 3.4% Gizzard shad 39.2% Golden shiner 5.3%	0.5
C. Fish abundance and health					
11. Average number per run	Electrofishing	93.7	0.5	139.3	1.5
	Gill Netting	21.7	1.5	20.9	1.5
12. Percent anomalies	Electrofishing	0.9%	2.5	0.4%	2.5
	Gill Netting	0.0%	2.5	0.0%	2.5
Overall RFAI Score			**39**		**39**
			Fair		**Fair**

Table 10. Species Collected, Trophic level, Indigenous and Tolerance Classification, Catch Per Effort During Electrofishing and Gill Netting at Areas Downstream (TRM 482.0) of Sequoyah Nuclear Plant Discharge, Autumn 2010. Trophic: benthic invertivore (BI), insectivore (IN), omnivore (OM), parasitic (PS), planktivore (PK), top carnivore (TC). Tolerance: tolerant (TOL), intolerant (INT).

Common Name	Scientific name	Trophic level	Sunfish species	Native species	Tolerance	Electrofishing Catch Rate Per Run	Electrofishing Catch Rate Per Hour	Total fish EF	Gill Netting Catch Rate Per Net Night	Total Gill net fish	Total fish Combined
Gizzard shad	*Dorosoma cepedianum*	OM	.	X	TOL	15.27	64.87	229	11.30	113	342
Common carp	*Cyprinus carpio*	OM	.	.	TOL	0.20	0.85	3	0.10	1	4
Golden shiner	*Notemigonus crysoleucas*	OM	.	X	TOL	0.53	2.27	8	0.10	1	9
Spotfin shiner	*Cyprinella spiloptera*	IN	.	X	TOL	0.47	1.98	7	.	.	7
Bluntnose minnow	*Pimephales notatus*	OM	.	X	TOL	1.47	6.23	22	.	.	22
Redbreast sunfish	*Lepomis auritus*	IN	X	X	TOL	0.33	1.42	5	.	.	5
Green sunfish	*Lepomis cyanellus*	IN	X	X	TOL	0.20	0.85	3	.	.	3
Bluegill	*Lepomis macrochirus*	IN	X	X	TOL	18.80	79.89	282	0.20	2	284
Largemouth bass	*Micropterus salmoides*	TC	.	X	TOL	2.27	9.63	34	0.30	3	37
Skipjack herring	*Alosa chrysochloris*	TC	.	X	INT	.	.	.	0.20	2	2
Spotted sucker	*Minytrema melanops*	BI	.	X	INT	0.13	0.57	2	0.40	4	6
Longear sunfish	*Lepomis megalotis*	IN	X	X	INT	0.47	1.98	7	.	.	7
Smallmouth bass	*Micropterus dolomieu*	TC	.	X	INT	0.33	1.42	5	0.20	2	7
Brook silverside	*Labidesthes sicculus*	IN	.	X	INT	0.20	0.85	3	.	.	3
Spotted gar	*Lepisosteus oculatus*	TC	.	X	.	1.53	6.52	23	0.30	3	26
Hybrid shad	Hybrid *dorosoma*	OM	.	X	.	0.07	0.28	1	.	.	1
Blue catfish	*Ictalurus furcatus*	OM	.	X	.	.	.	.	1.70	17	17
Channel catfish	*Ictalurus punctatus*	OM	.	X	.	0.53	2.27	8	0.40	4	12
Flathead catfish	*Pylodictis olivaris*	TC	.	X	.	0.13	0.57	2	0.30	3	5
White bass	*Morone chrysops*	TC	.	X	.	.	.	.	0.60	6	6
Yellow bass	*Morone mississippiensis*	TC	.	X	.	0.07	0.28	1	2.60	26	27
Warmouth	*Lepomis gulosus*	IN	X	X	.	0.07	0.28	1	.	.	1
Redear sunfish	*Lepomis microlophus*	IN	X	X	.	3.07	13.03	46	0.80	8	54
Spotted bass	*Micropterus punctulatus*	TC	.	X	.	0.53	2.27	8	1.10	11	19
Black crappie	*Pomoxis nigromaculatus*	TC	X	X	.	1.07	4.53	16	0.60	6	22
Yellow perch	*Perca flavescens*	IN	.	.	.	0.20	0.85	3	.	.	3
Logperch	*Percina caprodes*	BI	.	X	.	2.07	8.78	31	.	.	31
Sauger	*Stizostedion canadense*	TC	.	X	.	.	.	.	0.10	1	1
Freshwater drum	*Aplodinotus grunniens*	BI	.	X	.	0.40	1.70	6	0.40	4	10
Inland silverside	*Menidia beryllina*	IN	.	.	.	43.33	184.14	650	.	.	650
Total						**93.74**	**398.31**	**1,406**	**21.70**	**217**	**1,623**
Number Samples						**15**			**10**		
Species Collected						**26**			**19**		

Table 11. Species Collected, Trophic level, Indigenous and Tolerance Classification, Catch Per Effort During Electrofishing and Gill Netting at Areas Upstream (TRM 490.5) of Sequoyah Nuclear Plant Discharge, Autumn 2010. Trophic: benthic invertivore (BI), insectivore (IN), omnivore (OM), parasitic (PS), planktivore (PK), top carnivore (TC). Tolerance: tolerant (TOL), intolerant (INT).

Common Name	Scientific name	Trophic level	Sunfish species	Native species	Tolerance	Electrofishing Catch Rate Per Run	Electrofishing Catch Rate Per Hour	Total fish EF	Gill Netting Catch Rate Per Net Night	Total Gill net fish	Total fish Combined
Gizzard shad	*Dorosoma cepedianum*	OM	.	X	TOL	23.20	100.58	348	8.20	82	430
Common carp	*Cyprinus carpio*	OM	.	.	TOL	0.13	0.58	2	.	.	2
Golden shiner	*Notemigonus crysoleucas*	OM	.	X	TOL	0.33	1.45	5	1.10	11	16
Spotfin shiner	*Cyprinella spiloptera*	IN	.	X	TOL	0.40	1.73	6	.	.	6
Bluntnose minnow	*Pimephales notatus*	OM	.	X	TOL	0.33	1.45	5	.	.	5
Redbreast sunfish	*Lepomis auritus*	IN	X	X	TOL	1.27	5.49	19	.	.	19
Green sunfish	*Lepomis cyanellus*	IN	X	X	TOL	0.27	1.16	4	.	.	4
Bluegill	*Lepomis macrochirus*	IN	X	X	TOL	48.47	210.12	727	0.20	2	729
Largemouth bass	*Micropterus salmoides*	TC	.	X	TOL	0.80	3.47	12	0.20	2	14
White crappie	*Pomoxis annularis*	TC	X	X	TOL	0.07	0.29	1	.	.	1
Skipjack herring	*Alosa chrysochloris*	TC	.	X	INT	.	.	.	0.60	6	6
Spotted sucker	*Minytrema melanops*	BI	.	X	INT	0.13	0.58	2	0.20	2	4
Rock bass	*Ambloplites rupestris*	TC	.	X	INT	0.07	0.29	1	.	.	1
Longear sunfish	*Lepomis megalotis*	IN	X	X	INT	1.33	5.78	20	.	.	20
Smallmouth bass	*Micropterus dolomieu*	TC	.	X	INT	0.33	1.45	5	.	.	5
Spotted gar	*Lepisosteus oculatus*	TC	.	X	.	0.67	2.89	10	.	.	10
Threadfin shad	*Dorosoma petenense*	PK	.	X	.	0.07	0.29	1	.	.	1
Blue catfish	*Ictalurus furcatus*	OM	.	X	.	.	.	.	0.70	7	7
Channel catfish	*Ictalurus punctatus*	OM	.	X	.	0.20	0.87	3	.	.	3
Flathead catfish	*Pylodictis olivaris*	TC	.	X	.	1.07	4.62	16	0.40	4	20
White bass	*Morone chrysops*	TC	.	X	.	.	.	.	1.00	10	10
Yellow bass	*Morone mississippiensis*	TC	.	X	.	.	.	.	5.00	50	50
Warmouth	*Lepomis gulosus*	IN	X	X	.	0.80	3.47	12	.	.	12
Redear sunfish	*Lepomis microlophus*	IN	X	X	.	4.67	20.23	70	1.30	13	83
Spotted bass	*Micropterus punctulatus*	TC	.	X	.	1.40	6.07	21	0.20	2	23
Black crappie	*Pomoxis nigromaculatus*	TC	X	X	.	1.27	5.49	19	1.40	14	33
Yellow perch	*Perca flavescens*	IN	.	.	.	0.20	0.87	3	.	.	3
Logperch	*Percina caprodes*	BI	.	X	.	6.40	27.75	96	.	.	96
Walleye	*Stizostedion vitreum*	TC	.	X	.	.	.	.	0.10	1	1
Freshwater drum	*Aplodinotus grunniens*	BI	.	X	.	0.27	1.16	4	0.30	3	7
Inland silverside	*Menidia beryllina*	IN	.	.	.	45.27	196.24	679	.	.	679
Total						**139.35**	**604.08**	**2,091**	**20.90**	**209**	**2,300**
Number Samples						**15**			**10**		
Species Collected						**25**			**15**		

Table 12. Summary of RFAI Scores from Sites Located Directly Upstream and Downstream of Sequoyah Nuclear Plant as Well as Scores from Sampling Conducted During 1993-2010 as Part of the Vital Signs Monitoring Program in Chickamauga Reservoir.

Station	Location	1993	1994	1995	1996	1997	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Inflow	TRM 529.0	52	52	48	42	44	42	44	46	48	48	42	42	42	42	44	44	44	**45**
Transition SQN Upstream	TRM 490.5	51	40	48	44	39	45	46	45	51	42	49	46	47	44	34	41	39	**44**
Forebay SQN Downstream	TRM 482.0	---	---	---	47	---	41	48	46	43	45	41	39	35	38	38	37	39	**41**
Forebay	TRM 472.3	43	44	47	---	40	45	45	48	46	43	43	46	43	41	41	42	40	**44**
Hiwassee River Embayment	HiRM 8.5	46	39	39	---	40	43	43	47	---	36	42	45	---	41	---	42	---	**42**

TRM 482 scored with forebay criteria, TRM 490.5 scored with transition criteria (Refer to Table 4).
RFAI Scores: 12-21 ("Very Poor"), 22-31 ("Poor"), 32-40 ("Fair"), 41-50 ("Good"), or 51-60 ("Excellent")

Table 13. Fish species collected including provisions for the identification of the resident important species at areas downstream (TRM 482.0) of Sequoyah Nuclear Plant Discharge, Autumn 2010. Trophic: benthic invertivore (BI), insectivore (IN), omnivore (OM), parasitic (PS), planktivore (PK), top carnivore (TC). Tolerance: tolerant (TOL), intolerant (INT)

Common Name	Scientific name	Trophic Level	Indigenous Species	Representative Important Species	Aquatic Nuisance	Tolerance (Pollution)	Thermally Sensitive Species	Threatened or Endangered (Federal Status)	Commercially Valuable Species	Recreationally Valuable Species
Gizzard shad	*Dorosoma cepedianum*	OM	X	X	.	TOL	.	.	X	X
Common carp	*Cyprinus carpio*	OM	.	X	X	TOL	.	.	.	.
Golden shiner	*Notemigonus crysoleucas*	OM	X	X	.	TOL	.	.	.	.
Spotfin shiner	*Cyprinella spiloptera*	IN	X	X	.	TOL	.	.	.	.
Bluntnose minnow	*Pimephales notatus*	OM	X	X	.	TOL	.	.	.	X
Redbreast sunfish	*Lepomis auritus*	IN	X	X	.	TOL	.	.	.	X
Green sunfish	*Lepomis cyanellus*	IN	X	X	.	TOL	.	.	.	X
Bluegill	*Lepomis macrochirus*	IN	X	X	.	TOL	.	.	.	X
Largemouth bass	*Micropterus salmoides*	TC	X	X	.	TOL	.	.	.	X
Skipjack herring	*Alosa chrysochloris*	TC	X	X	.	INT	.	.	.	X
Spotted sucker	*Minytrema melanops*	BI	X	X	.	INT	X	.	.	.
Longear sunfish	*Lepomis megalotis*	IN	X	X	.	INT	.	.	.	X
Smallmouth bass	*Micropterus dolomieu*	TC	X	X	.	INT	.	.	.	X
Brook silverside	*Labidesthes sicculus*	IN	X	X	.	INT	.	.	.	X
Spotted gar	*Lepisosteus oculatus*	TC	X	X	.	.	.	.	.	.
Hybrid shad	Hybrid *dorosoma*	OM	X	X	.	.	.	.	.	.
Blue catfish	*Ictalurus furcatus*	OM	X	X	.	.	.	.	X	X
Channel catfish	*Ictalurus punctatus*	OM	X	X	.	.	.	.	X	X
Flathead catfish	*Pylodictis olivaris*	TC	X	X	.	.	.	.	.	X
White bass	*Morone chrysops*	TC	X	X	.	.	.	.	.	X
Yellow bass	*Morone mississippiensis*	TC	X	X	.	.	.	.	.	X
Warmouth	*Lepomis gulosus*	IN	X	X	.	.	.	.	.	X
Redear sunfish	*Lepomis microlophus*	IN	X	X	.	.	.	.	.	X
Spotted bass	*Micropterus punctulatus*	TC	X	X	.	.	.	.	.	X
Black crappie	*Pomoxis nigromaculatus*	TC	X	X	.	.	.	.	.	X
Yellow perch	*Perca flavescens*	IN	.	X	X	.	.	.	.	X
Logperch	*Percina caprodes*	BI	X	X	.	.	X	.	.	X
Sauger	*Stizostedion canadense*	TC	X	X	.	.	.	.	.	X
Freshwater drum	*Aplodinotus grunniens*	BI	X	X	.	.	.	.	.	X
Inland silverside	*Menidia beryllina*	IN	.	X	X	.	.	.	.	.
Totals			**26**	**29**	**3**		**2**	**0**	**3**	**23**

Table 14. Fish species collected including provisions for the identification of the resident important species at areas upstream (TRM 490.5) of Sequoyah Nuclear Plant Discharge, Autumn 2010. Trophic: benthic invertivore (BI), insectivore (IN), omnivore (OM), parasitic (PS), planktivore (PK), top carnivore (TC). Tolerance: tolerant (TOL), intolerant (INT)

Common Name	Scientific name	Trophic Level	Indigenous Species	Representative Important Species	Aquatic Nuisance	Tolerance (Pollution)	Thermally Sensitive Species	Threatened or Endangered (Federal Status)	Commercially Valuable Species	Recreationally Valuable Species
Gizzard shad	*Dorosoma cepedianum*	OM	X	X	.	TOL	.	.	X	X
Common carp	*Cyprinus carpio*	OM	.	X	X	TOL	.	.	.	.
Golden shiner	*Notemigonus crysoleucas*	OM	X	X	.	TOL	.	.	.	.
Spotfin shiner	*Cyprinella spiloptera*	IN	X	X	.	TOL	.	.	.	.
Bluntnose minnow	*Pimephales notatus*	OM	X	X	.	TOL	.	.	.	X
Redbreast sunfish	*Lepomis auritus*	IN	X	X	.	TOL	.	.	.	X
Green sunfish	*Lepomis cyanellus*	IN	X	X	.	TOL	.	.	.	X
Bluegill	*Lepomis macrochirus*	IN	X	X	.	TOL	.	.	.	X
Largemouth bass	*Micropterus salmoides*	TC	X	X	.	TOL	.	.	.	X
White crappie	*Pomoxis annularis*	TC	X	X	.	TOL	.	.	.	X
Skipjack herring	*Alosa chrysochloris*	TC	X	X	.	INT	.	.	.	X
Spotted sucker	*Minytrema melanops*	BI	X	X	.	INT	X	.	.	.
Rock bass	*Ambloplites rupestris*	TC	X	X	.	INT	.	.	.	X
Longear sunfish	*Lepomis megalotis*	IN	X	X	.	INT	.	.	.	X
Smallmouth bass	*Micropterus dolomieu*	TC	X	X	.	INT	.	.	.	X
Spotted gar	*Lepisosteus oculatus*	TC	X	X	.	.	.	.	.	.
Threadfin shad	*Dorosoma petenense*	PK	X	X	.	.	.	.	X	X
Blue catfish	*Ictalurus furcatus*	OM	X	X	.	.	.	.	X	X
Channel catfish	*Ictalurus punctatus*	OM	X	X	.	.	.	.	X	X
Flathead catfish	*Pylodictis olivaris*	TC	X	X	.	.	.	.	.	X
White bass	*Morone chrysops*	TC	X	X	.	.	.	.	.	X
Yellow bass	*Morone mississippiensis*	TC	X	X	.	.	.	.	.	X
Warmouth	*Lepomis gulosus*	IN	X	X	.	.	.	.	.	X
Redear sunfish	*Lepomis microlophus*	IN	X	X	.	.	.	.	.	X
Spotted bass	*Micropterus punctulatus*	TC	X	X	.	.	.	.	.	X
Black crappie	*Pomoxis nigromaculatus*	TC	X	X	.	.	.	.	.	X
Yellow perch	*Perca flavescens*	IN	.	X	X	.	.	.	.	X
Logperch	*Percina caprodes*	BI	X	X	.	.	X	.	.	X
Walleye	*Sander vitreum*	TC	X	X	.	.	.	.	.	X
Freshwater drum	*Aplodinotus grunniens*	BI	X	X	.	.	.	.	.	X
Inland silverside	*Menidia beryllina*	IN	.	X	X	.	.	.	.	.
Totals			**28**	**31**	**3**		**2**	**0**	**4**	**25**

Table 15. Individual Metric Ratings and the Overall RBI Field Scores for Downstream and Upstream Sampling Sites Near Sequoyah Nuclear Plant, Chickamauga Reservoir, Autumn 2010.

	Downstream TRM 482.0		Upstream TRM 490.5	
Metric	**Obs**	**Rating**	**Obs**	**Rating**
1. Average number of taxa	5	5	4.4	5
2. Proportion of samples with long-lived organisms	0.9	5	0.7	3
3. Average number of EPT taxa	0.5	3	0.7	3
4. Percentage as oligochaetes	11.7	5	1.1	5
5. Percentage as dominant taxa	81.3	5	91.8	1
6. Average density excluding chironomids and oligochaetes	98.3	1	181.7	1
7. Zero-samples – proportion of samples containing no organisms	0	5	0	5
Benthic Index Score		**29**		**23**
		Good		**Fair**

*TRM 482 scored with forebay criteria, TRM 490.5 scored with transition criteria (Refer to Table 5). Reservoir Benthic Index Scores: 7-12 ("Very Poor"), 13-18 ("Poor"), 19-23 ("Fair"), 24-29 ("Good"), 30-35 ("Excellent")

Table 16. Comparison of Average Mean Density Per Square Meter of Benthic Taxa Collected at Upstream and Downstream Sites Near Sequoyah Nuclear Plant, Chickamauga Reservoir, Autumn 2009 and Autumn 2010.

	2010		2009	
Taxa	**Downstream TRM 482**	**Upstream TRM 490.5**	**Downstream TRM 482**	**Upstream TRM 490.5**
Oligocheata				
Oligochaetes	30	8	15	18
Hirudinea	10	2	---	7
Insecta				
Ephemeroptera				
Mayflies other than *Hexagenia*	---	---	---	3
Ephemeridae				
Hexagenia (< 10 mm)	13	12	2	2
Hexagenia (> 10 mm)	20	13	37	18
Chironomidae				
Chironomids	125	505	164	285
Gastropoda				
Snails	7	5	13	5
Bivalvia				
Unionoida				
Unionidae				
Mussels	---	---	2	---
Veneroida				
Corbiculidae				
Corbicula (< 10mm)	17	50	40	5
Corbicula (> 10mm)	18	2	11	12
Sphaeriidae				
Fingernail clams	13	85	26	27
Dreissenidae				
Dreissena polymorpha	---	---	9	3
Density of organisms per meter²	**253**	**682**	**348**	**296**
Number of samples	**10**	**10**	**10**	**10**
Total area sampled (meter²)	**0.6**	**0.6**	**0.6**	**0.6**

Table 17. Individual Metric Ratings and the Overall RBI Field Scores for Downstream and Upstream Sampling Sites Near SQN, Chickamauga Reservoir, Autumn 2000-2010. Reservoir Benthic Index Scores: 7-12 ("Very Poor"), 13-18 ("Poor"), 19-23 ("Fair"), 24-29 ("Good"), 30-35 ("Excellent").

Downstream (TRM 482.0)	**2000**		**2001**		**2002**		**2003**		**2004**		**2005**		**2006**		**2007**		**2008**		**2009**		**2010**	
Metric	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**
Avg No. Taxa	3.7	3	6.2	5	5.4	5	5.7	5	6.3	5	6.6	5	4.9	5	4.1	3	5.8	5	4.2	3	5	5
% Long-Lived	0.9	5	0.8	5	1	5	0.6	3	1	5	0.9	5	0.9	5	0.6	3	0.6	3	0.7	3	0.9	5
Avg. No. EPT taxa	0.3	1	0.6	3	0.4	1	0.3	1	0.5	3	0.7	3	0.7	3	0.5	3	0.6	3	0.5	3	0.5	3
% Oligochaetes	27.9	3	27.1	3	19.4	3	9.4	5	8.8	5	15	3	17.3	3	6.3	5	21.7	3	4.4	5	11.7	5
% Dominant Taxa	87.6	3	80.8	5	78.6	5	79.8	5	68.4	5	79	5	78.1	5	90.6	3	83.9	3	83.9	3	81.3	5
Density excl chiro and oligo	230	3	348.3	5	365	5	580	5	563.3	5	573.3	5	265	5	125	3	166.7	3	104.4	1	98.3	1
Zero Samples	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5
Overall Score		**23**		**31**		**29**		**29**		**33**		**31**		**31**		**25**		**25**		**23**		**29**

Upstream (TRM 490.5)	**2000**		**2001**		**2002**		**2003**		**2004**		**2005**		**2006**		**2007**		**2008**		**2009**		**2010**	
Metric	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**
Avg No. Taxa	4.7	5	6	5	6.4	5	7.4	5	7.2	5	6.8	5	5.4	5	4.7	5	5.4	5	5	5	4.4	5
% Long-Lived	0.9	5	0.9	5	1	5	0.9	5	0.9	5	0.9	5	0.8	5	0.5	3	0.3	1	0.8	5	0.7	3
Avg. No. EPT taxa	0.3	1	0.4	3	0.2	1	0.7	3	0.7	3	0.9	5	0.5	3	0.3	1	0.1	1	0.6	3	0.7	3
% Oligochaetes	7.7	5	14.8	3	8.4	5	10.7	5	6.4	5	4.4	5	2.5	5	5.2	5	16.7	3	7.2	5	1.1	5
% Dominant Taxa	88.4	1	79.4	3	85	3	71	5	78	5	79.8	3	83.1	3	93.4	1	95	1	81.2	3	91.8	1
Density excl chiron and oligo	218.3	1	230	1	168.6	1	341.7	3	571.7	3	479.2	3	223.3	1	56.7	1	31.7	1	81.7	1	181.7	1
Zero Samples	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5
Overall Score		**23**		**25**		**25**		**31**		**31**		**31**		**27**		**21**		**17**		**27**		**23**

Table 18. Summary of RBI Scores from Sites Located Directly Upstream and Downstream of Sequoyah Nuclear Plant as Well as Scores from Sampling Conducted During 1994-2010 as Part of the Vital Signs Monitoring Program in Chickamauga Reservoir.

Station	Location	1994	1995	1997	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Inflow	TRM 527.4	---	---	---	---	---	29	27	33	35	31	---	23	23	23	21	27
Inflow	TRM 518.0	19	31	25	21	23	29	23	27	35	29	33	25	---	31	---	27
Transition SQN Upstream	TRM 490.5	33	29	31	31	23	25	25	31	31	31	27	21	17	27	23	27
Forebay SQN Downstream	TRM 482.0	---	---	---	---	23	31	29	29	33	31	31	25	25	23	29	28
Forebay	TRM 472.3	31	27	29	25	27	27	21	27	29	27	29	19	25	23	---	26
Hiwassee River Embayment	HiRM 8.5	17	27	25	21	---	21	---	31	---	25	---	13	---	19	---	22

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

Table 19. Water quality parameters taken at the most downstream sampling point and at the most upstream sampling point of the RFAI sample upstream of SQN.

Most downstream RFAI sampling point upstream of SQN				
Depth (meters)	**Water Temperature (°F)**	**Conductivity (µs/cm)**	**Dissolved Oxygen (ppm)**	**pH**
0.3	77.7	N/A	6.8	7.81
1	77.0	N/A	6.36	7.73
2	76.9	N/A	6.22	7.7
3	76.5	N/A	5.68	7.62
4	76.4	N/A	5.59	7.62
5	76.3	N/A	5.58	7.59
6	76.3	N/A	5.5	7.59
7	76.3	N/A	5.53	7.56
8	76.3	N/A	5.38	7.54
9	76.3	N/A	5.38	7.52
10	76.2	N/A	5.35	7.49
11	76.3	N/A	5.36	7.43
12	76.2	N/A	5.35	7.39

Most upstream RFAI sampling point upstream of SQN				
Depth (meters)	**Water Temperature (°F)**	**Conductivity (µs/cm)**	**Dissolved Oxygen (ppm)**	**pH**
0.3	76.4	N/A	5.74	7.7
1	76.1	N/A	5.54	7.63
2	75.9	N/A	5.35	7.58
3	75.8	N/A	5.25	7.63
4	75.8	N/A	5.24	7.58
5	75.8	N/A	5.23	7.53
6	75.8	N/A	6.26	7.54
7	75.7	N/A	5.29	7.52
8	75.7	N/A	5.35	7.48
9	75.7	N/A	5.33	7.62

Table 20. Water quality parameters taken at the most downstream sampling point and at the most upstream sampling point of the RFAI sample downstream of SQN.

Most downstream RFAI sampling point downstream of SQN				
Depth (meters)	**Water Temperature (°F)**	**Conductivity (µs/cm)**	**Dissolved Oxygen (ppm)**	**pH**
0.3	79.9	179.5	6.55	7.66
1.5	79.1	179.5	6.42	7.62
3	78.9	179.1	6.41	7.59
4	78.9	179	6.39	7.57
6	78.7	178.7	6.28	7.57
8	78.8	178.5	6.32	7.59
10	78.7	178.7	6.14	7.55
12	78.6	178.8	5.97	7.54
14	78.5	178.8	5.88	7.51
16	78.4	179	5.84	7.62
18.5	78.3	179.2	5.82	7.46

Most upstream RFAI sampling point downstream of SQN				
Depth (meters)	**Water Temperature (°F)**	**Conductivity (µs/cm)**	**Dissolved Oxygen (ppm)**	**pH**
0.3	80.6	180.3	6.15	7.52
1.5	80.5	180.6	6.12	7.51
3	80.3	179.8	6.08	7.5
4	80.2	179.9	6.08	7.54
6	79.7	180.4	6.07	7.48
8	79.3	179.6	6.02	7.48
10	78.1	179.5	5.97	7.46
12	77.9	179.5	5.97	7.45
14	77.8	179.6	5.88	7.44
16	77.8	179.3	5.87	7.41
18	77.7	179.3	5.81	7.31

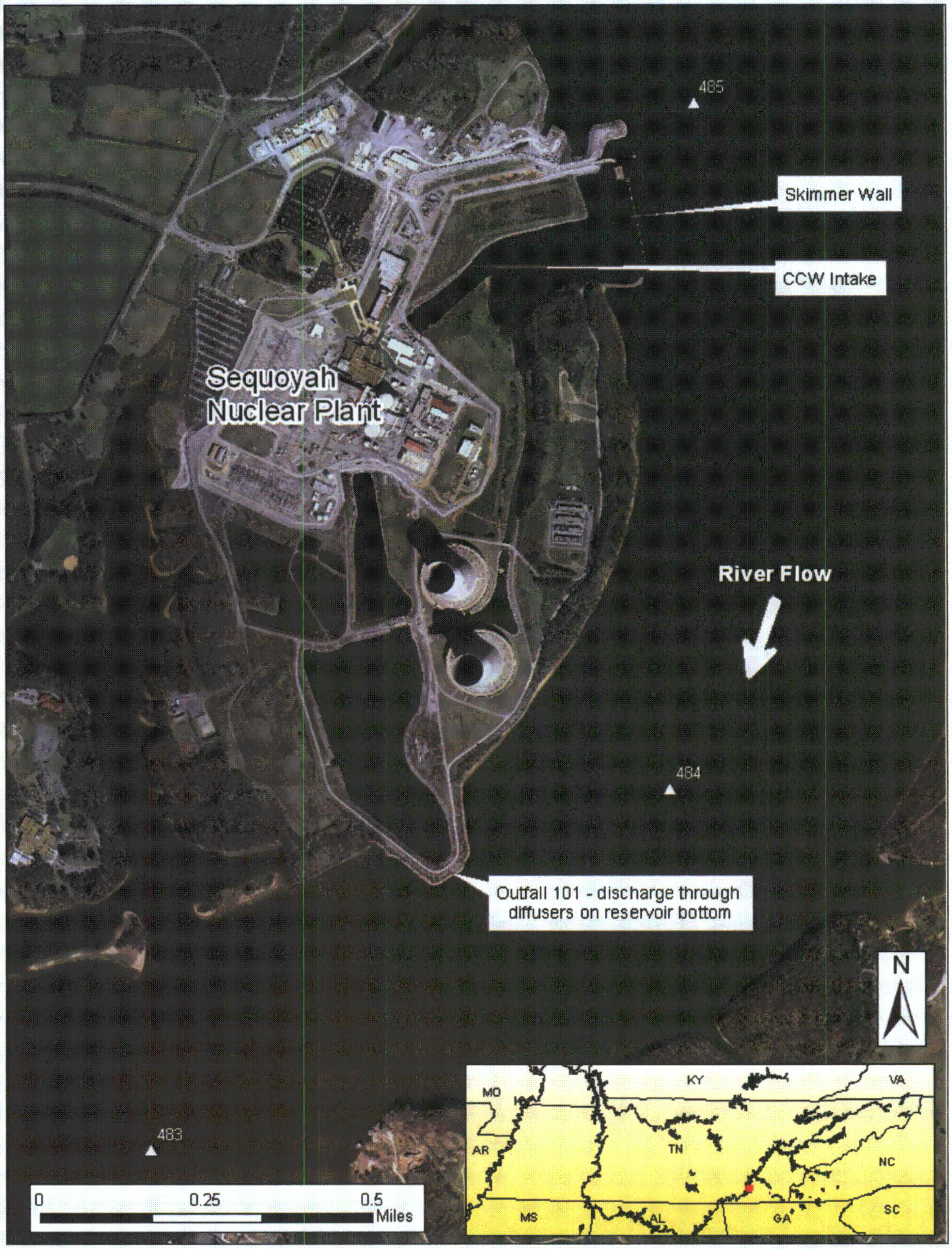

Figure 1. Map of SQN showing location of CCW intake and discharge.

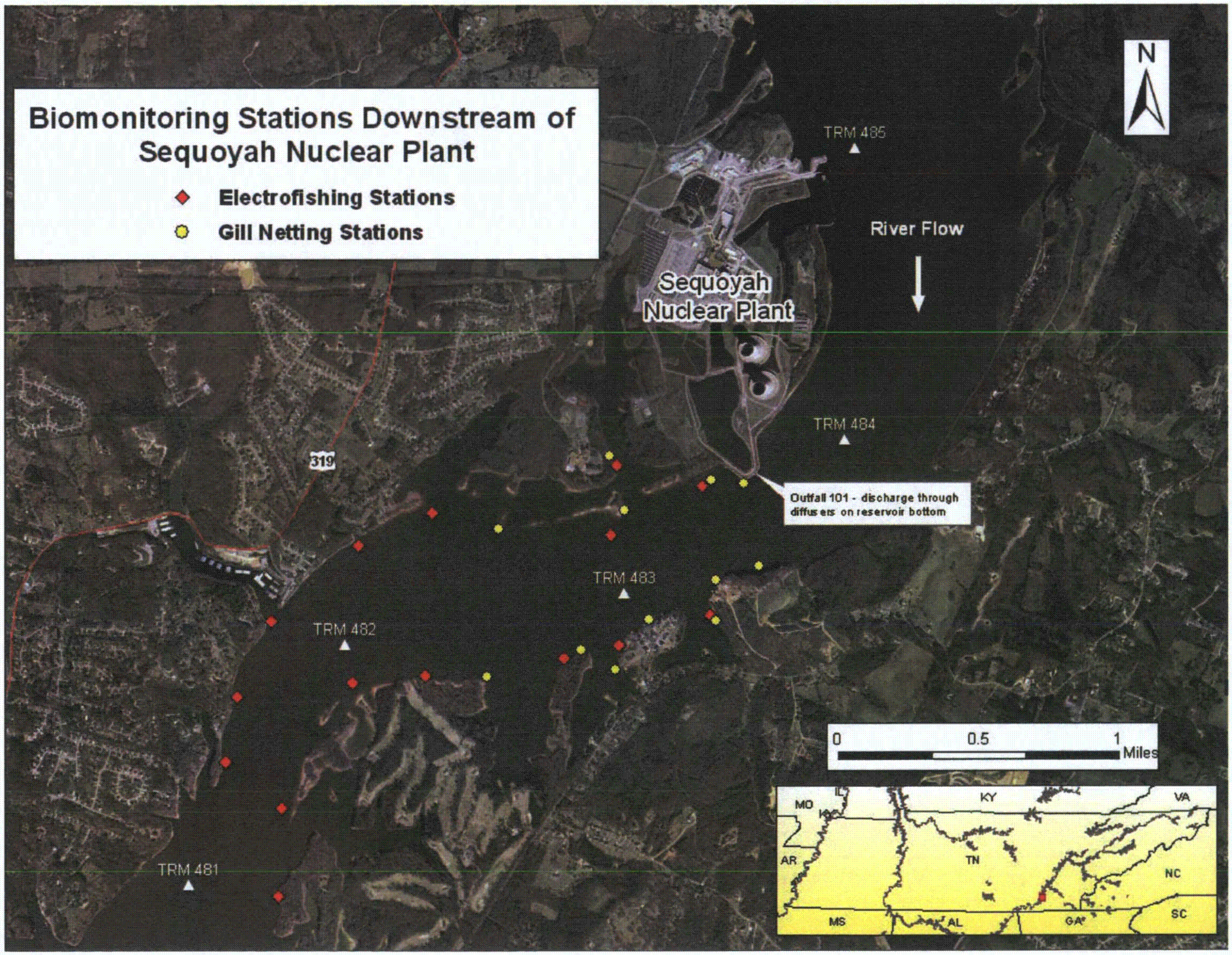

Figure 2. RFAI electrofishing and gill net locations downstream of Sequoyah Nuclear Plant.

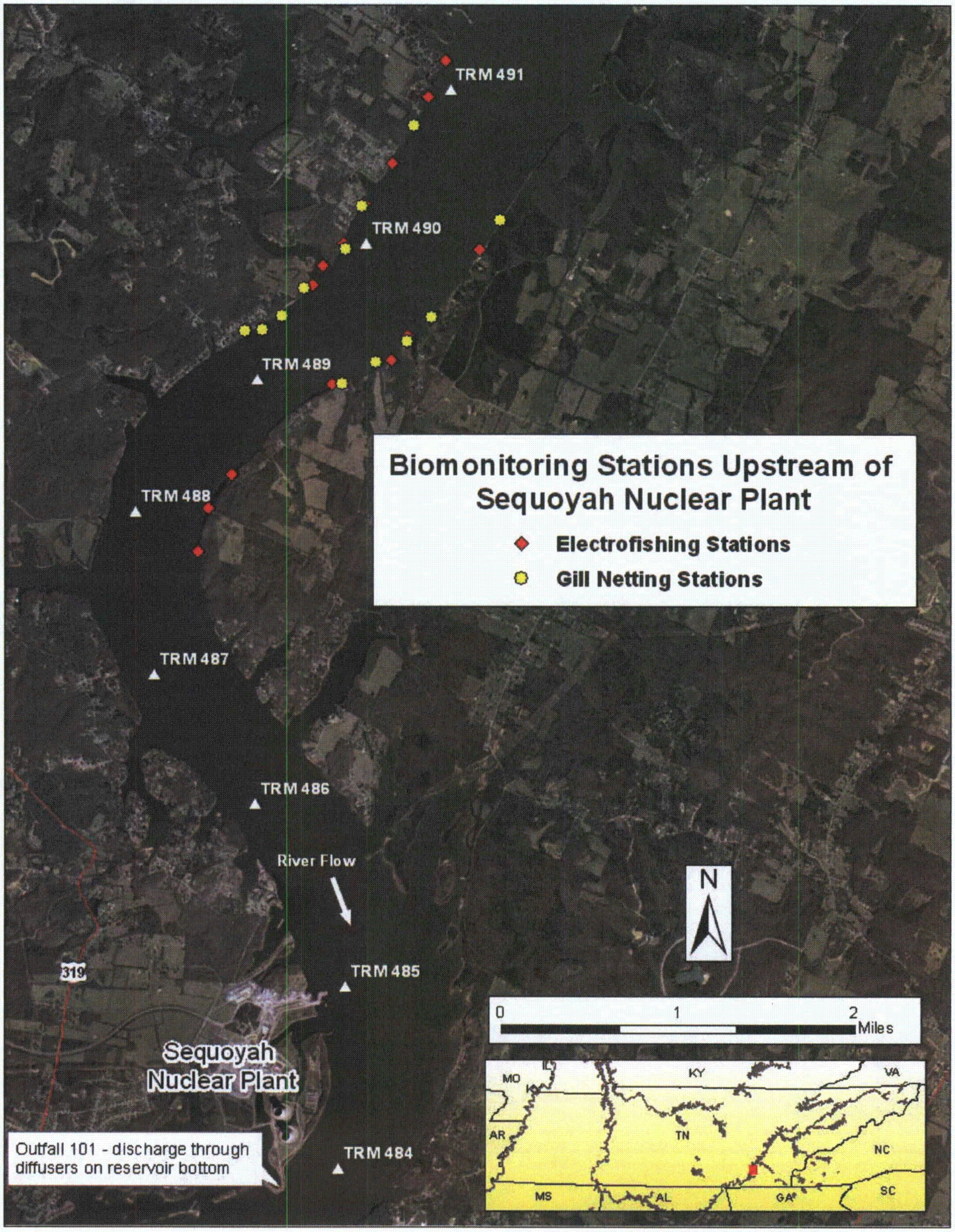

Figure 3. RFAI electrofishing and gill net locations upstream of Sequoyah Nuclear Plant.

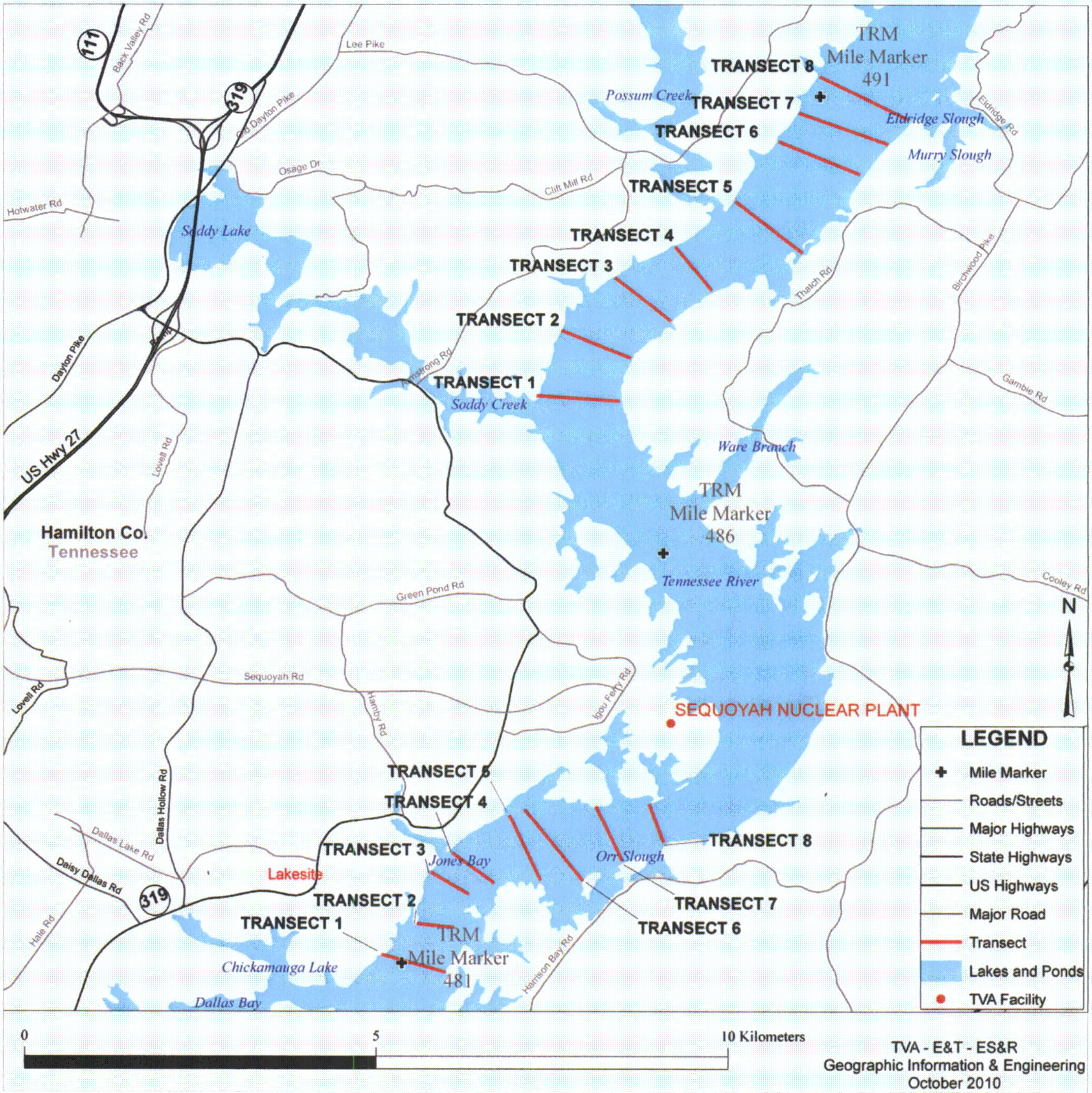

Figure 4. Benthic habitat transects within the fish community sampling area upstream and downstream of SQN. SAHI data was collected on the left and right descending banks at endpoints of each transect. Benthic macroinvertebrate samples were collected along transect 4 downstream of SQN and along transect 6 upstream of SQN.

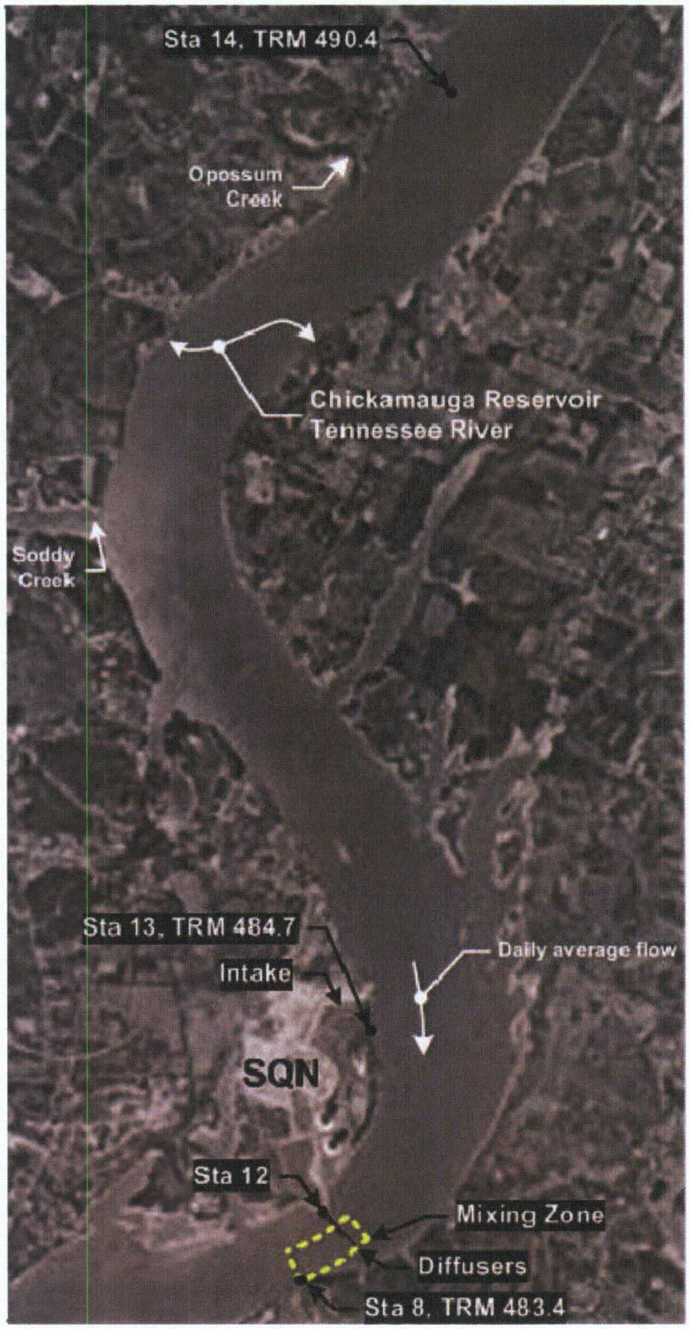

Figure 5. Locations of water temperature monitoring stations used to compare water temperatures upstream of SQN intake and downstream of SQN discharge during October 2009 through November 2010. Station 14 was used for upstream ambient temperatures of the SQN intake and was located at TRM 490.4. Station 8 was used for temperatures downstream of SQN discharge and was located at TRM 483.4.

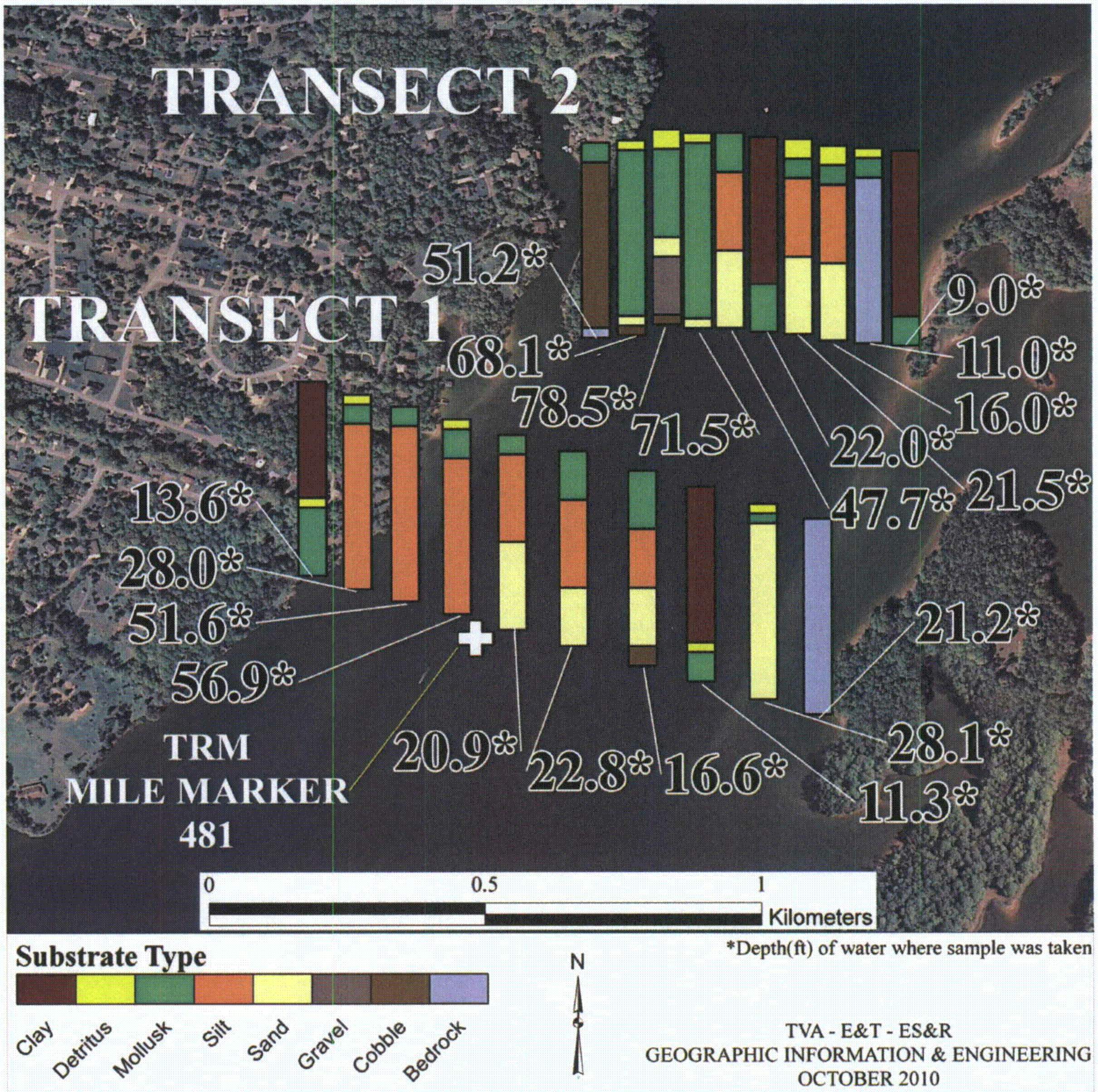

Figure 6. Substrate composition at ten equally spaced points per transect across the Tennessee River downstream of SQN. *Water depth (ft) at each point is denoted. Transects 1 and 2 are the most downstream transects of the eight transects downstream of the SQN discharge.

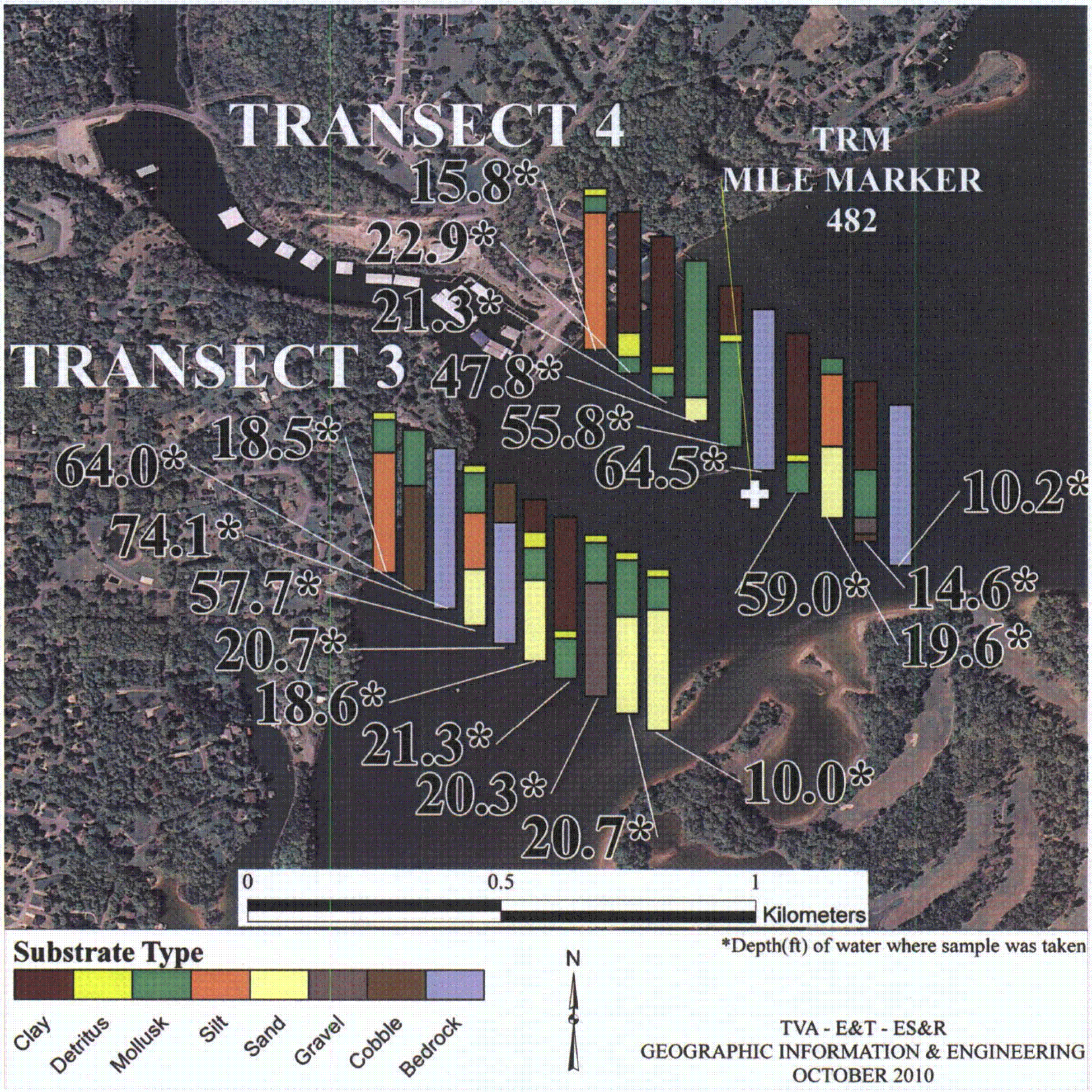

Figure 7. Substrate composition at ten equally spaced points per transect across the Tennessee River downstream of SQN. *Water depth (ft) at each point is denoted.

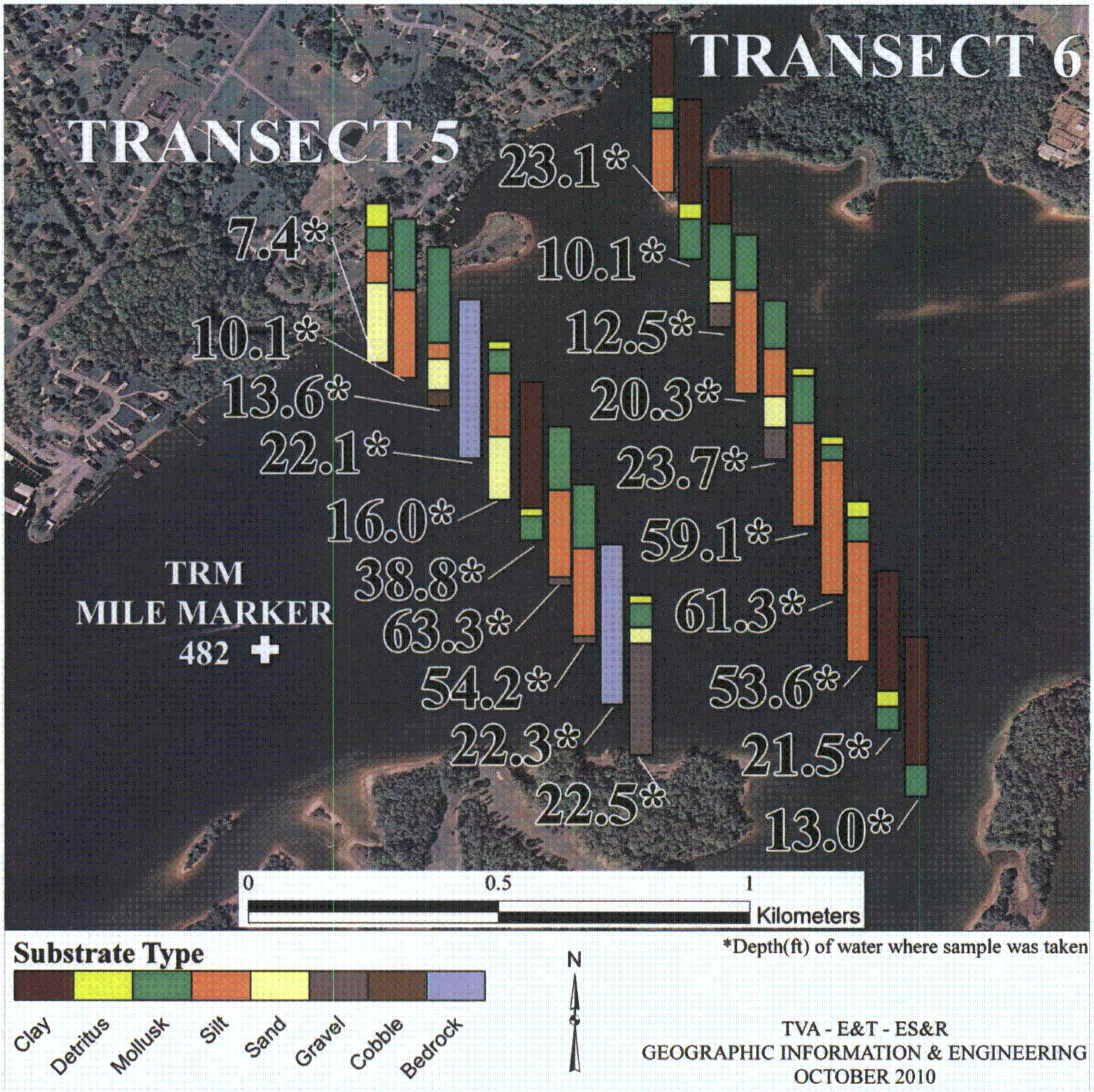

Figure 8. Substrate composition at ten equally spaced points per transect across the Tennessee River downstream of SQN. *Water depth (ft) at each point is denoted.

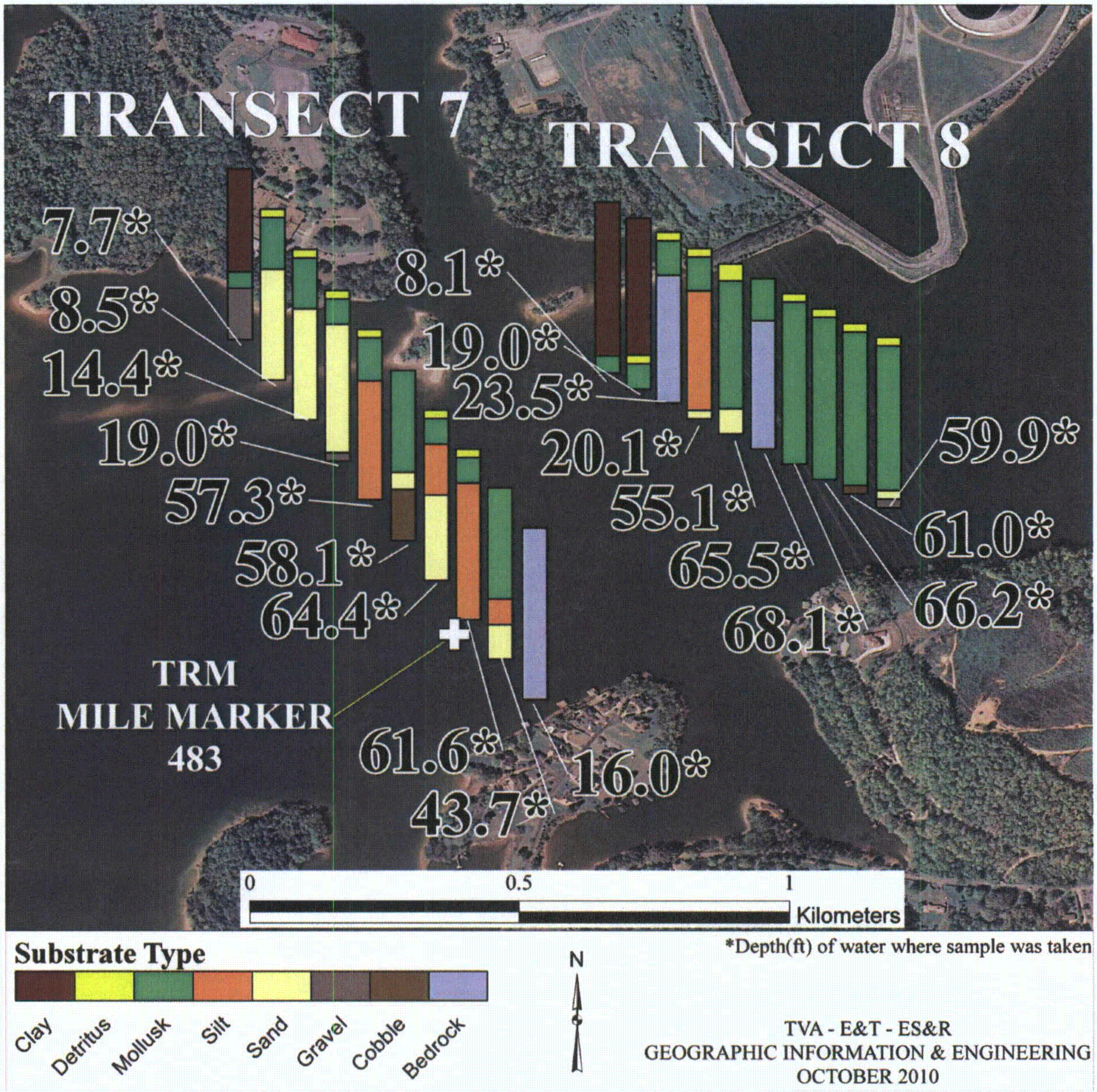

Figure 9. Substrate composition at ten equally spaced points per transect across the Tennessee River downstream of SQN. *Water depth (ft) at each point is denoted.

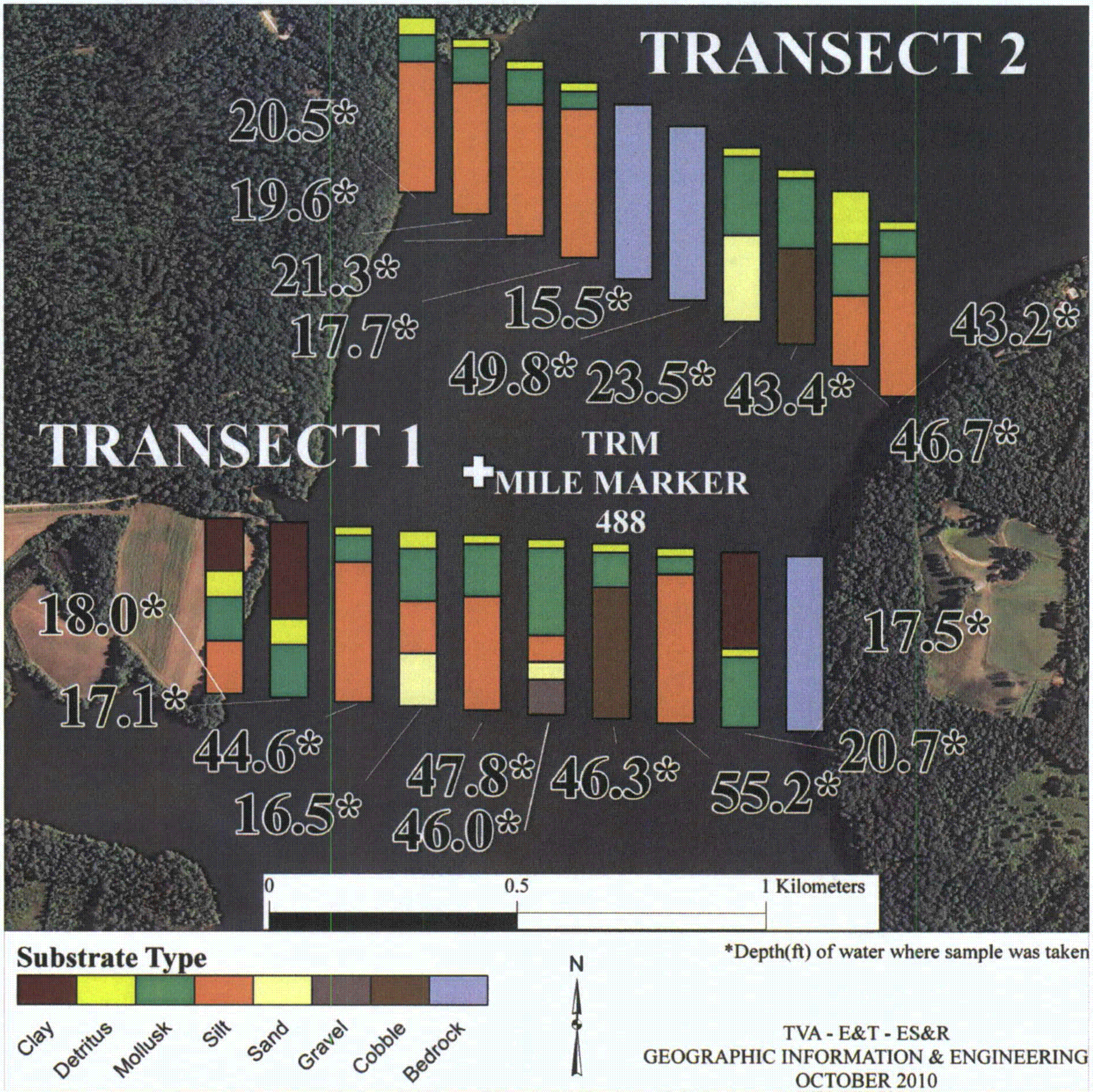

Figure 10. Substrate composition at ten equally spaced points per transect across the Tennessee River upstream of SQN. *Water depth (ft) at each point is denoted. Transects 1 and 2 are the most downstream transects of the eight transects upstream of the SQN discharge.

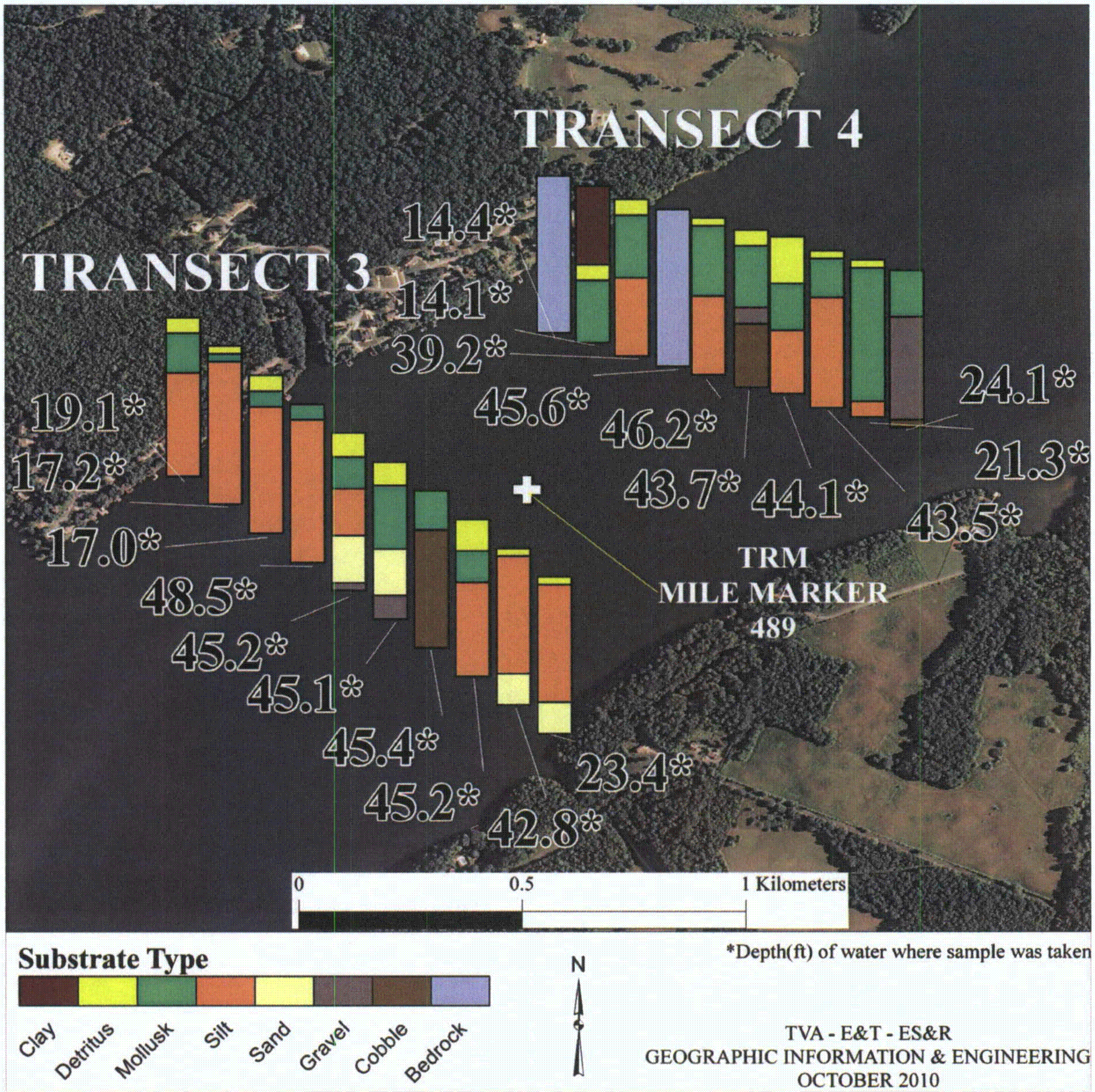

Figure 11. Substrate composition at ten equally spaced points per transect across the Tennessee River upstream of SQN. *Water depth (ft) at each point is denoted.

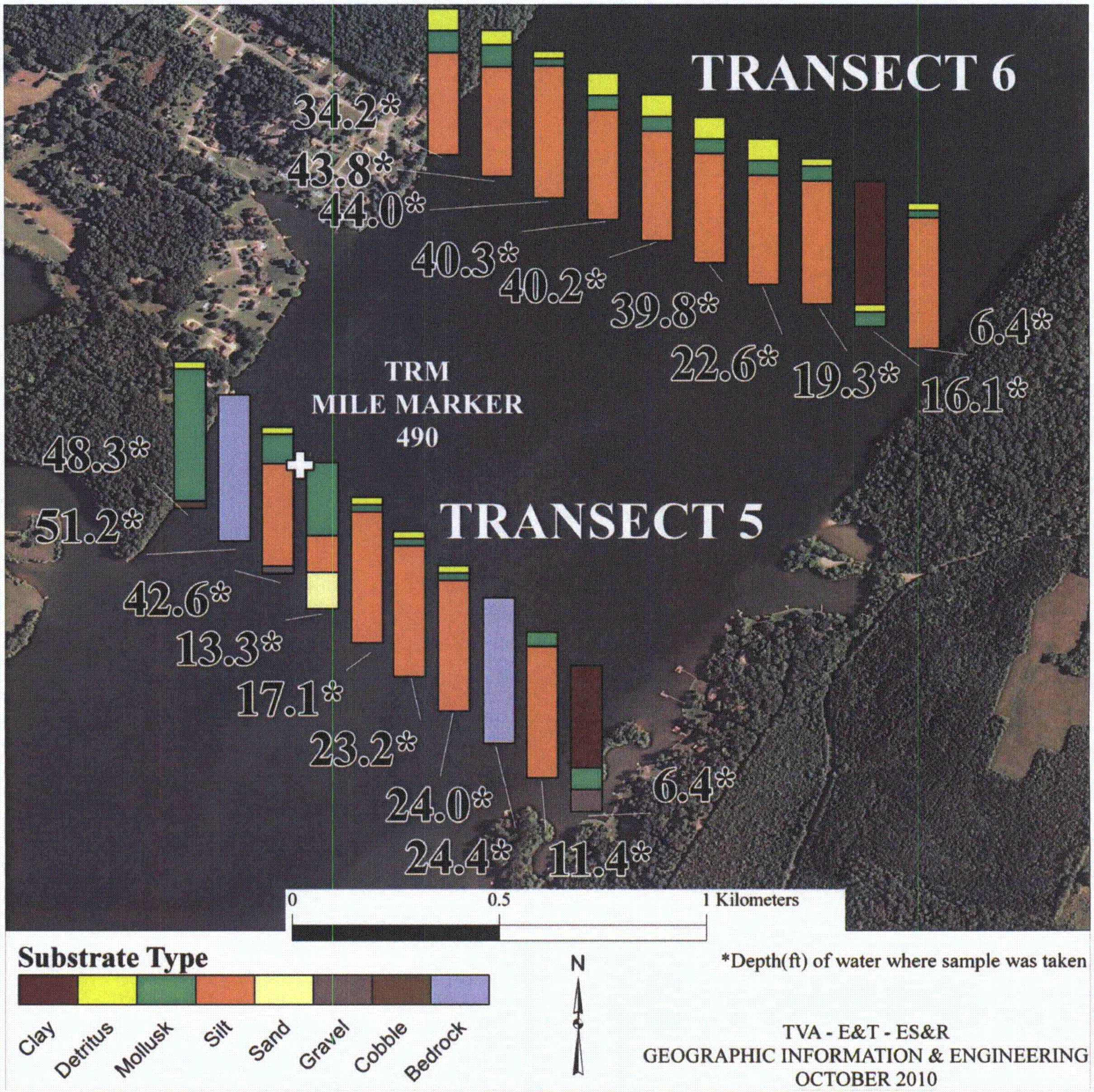

Figure 12. Substrate composition at ten equally spaced points per transect across the Tennessee River upstream of SQN. *Water depth (ft) at each point is denoted.

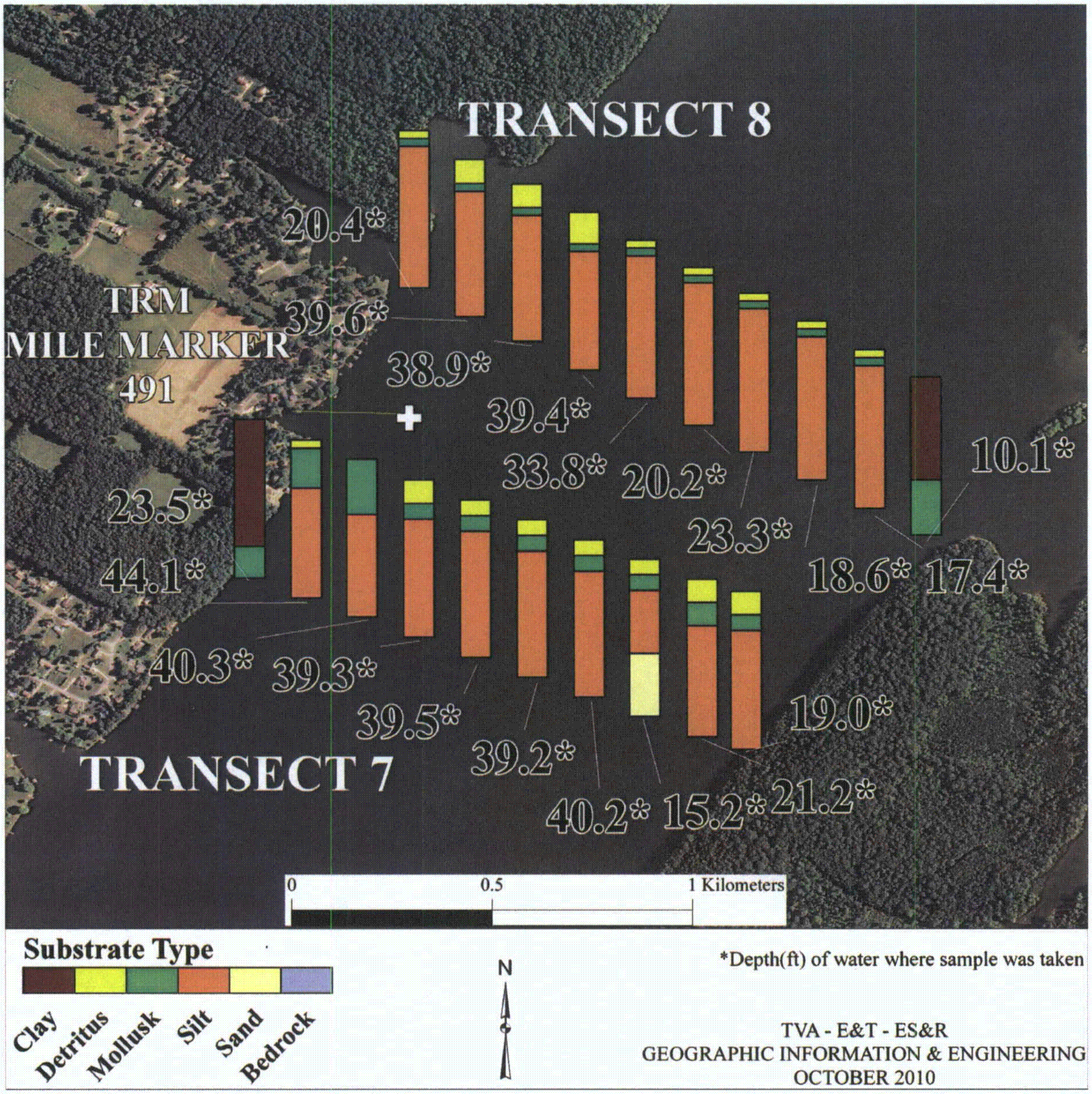

Figure 13. Substrate composition at ten equally spaced points per transect across the Tennessee River upstream of SQN. *Water depth (ft) at each point is denoted.

Figure 14. Number of indigenous species collected during every RFAI sample downstream of SQN (TRM 482), 1996 and 1999 to 2010.

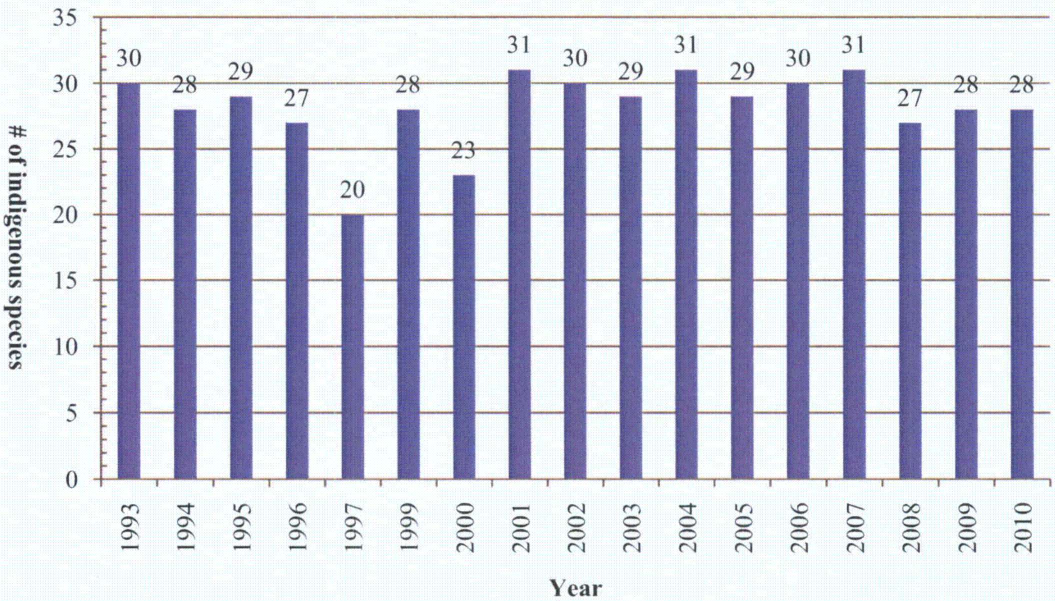

Figure 15. Number of indigenous species collected during every RFAI sample upstream of SQN (TRM 490.5), 1993 to 1997 and 1999 to 2010.

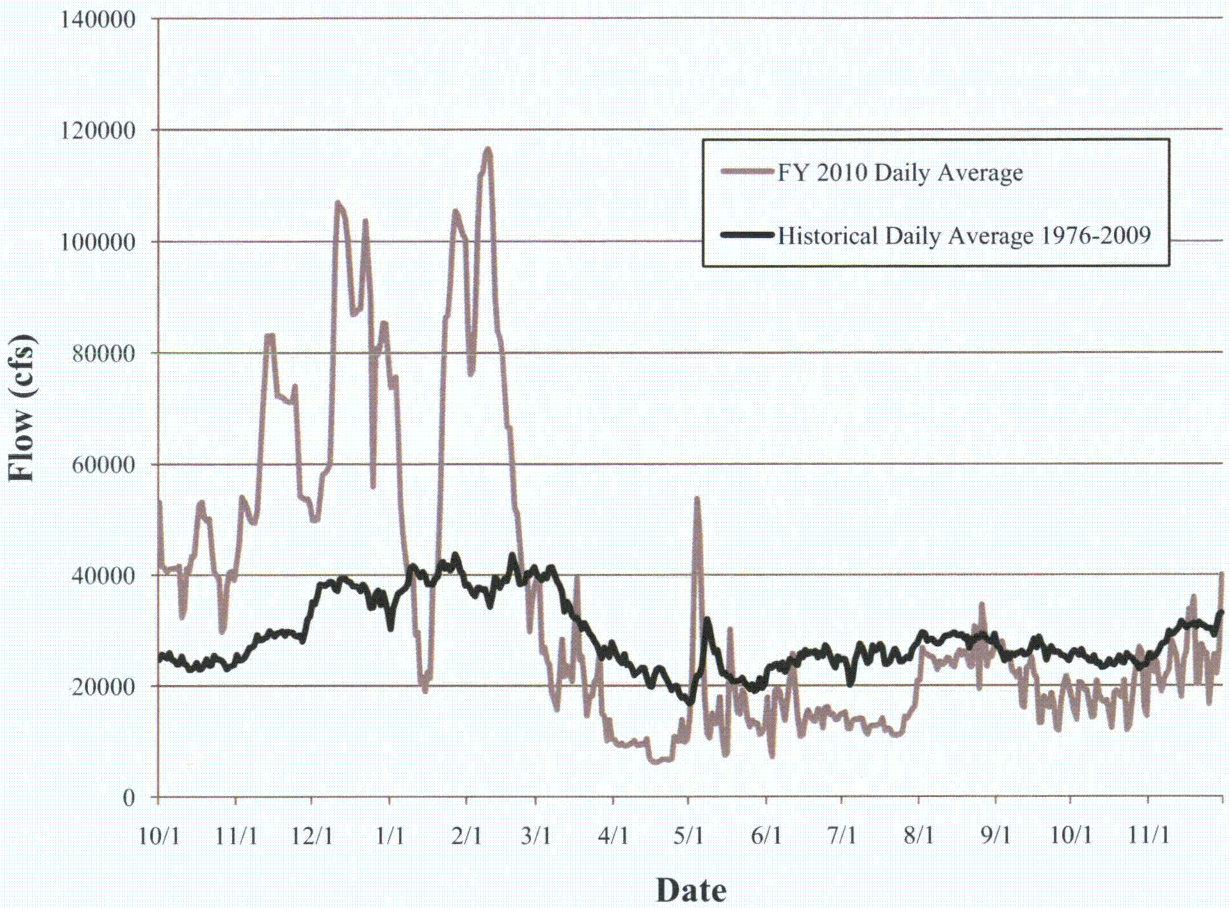

Figure 16. Total daily average flows (cubic feet per second) from Watts Bar, Apalachia, and Ocoee 1 Dams, October 2009 through November 2010 and historic total daily average flows averaged for the same period 1976 through 2009.

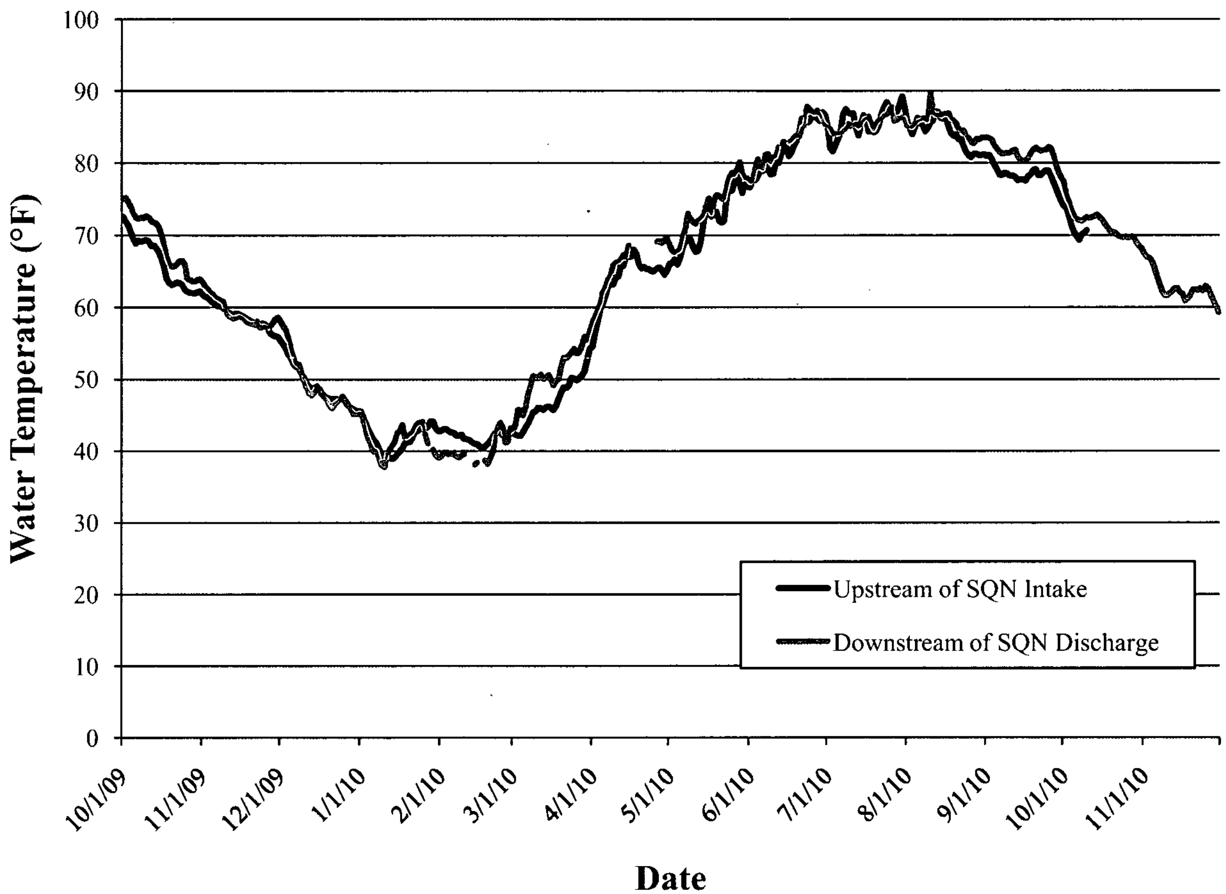

Figure 17. Daily average water temperatures (°F) at a depth of five feet, recorded upstream of SQN intake (Station 14) and downstream of SQN discharge (Station 8), October 2009 through November 2010.