TENNESSEE'S PLAN FOR NUTRIENT CRITERIA DEVELOPMENT

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I. INTRODUCTION

This plan describes the approach the Division of Water Pollution Control, Tennessee Department of Environment and Conservation, will use to identify and adopt additional water quality standards for nutrient related parameters that protect against measurable impacts to the aquatic environment. Tennessee has already made great strides in incorporating nutrient and biological criteria into its water quality standards. This plan is designed to build upon and refine the achievements already attained in the state.

Tennessee's plan for nutrient criteria development is in response to the U.S. EPA mandate requiring the adoption of nutrient criteria into state water quality standards by 2004. EPA has stated that since both the process for developing standards and the available resources may differ significantly between states, some may not have to adopt standards by 2004 as long as evaluations of progress show that criteria development is well underway and the state's efforts are consistent with its plan.

If U.S. EPA feels a state's plan is not appropriate or if a state has not adopted standards by 2004, the U.S. EPA administrator may exercise authority under section 303(c)(4)(B) of the Clean Water Act and find that promulgation of nutrient criteria for the state is necessary to meet the requirements of the Clean Water Act.

The push for nutrient criteria adoption is driven by state water quality inventories that repeatedly cite nutrients as a major cause of water quality use impairments. EPA's national water quality summary reports to Congress consistently identify excessive nutrients as one of the top three leading causes of impairments of the nation's water (along with siltation and pathogens). In Tennessee, nutrients are the fourth leading cause of use impairment in rivers and streams after siltation, habitat alteration, and pathogens (Figure 1). Nutrients are the third leading cause of pollution in reservoirs and lakes after PCBs and siltation.

Under section 303(d), States identify waters that are not attaining water quality standards and submit a list of those impaired waters to EPA. These lists also frequently identify excessive nutrients as a leading cause of impairment. In Tennessee, more than 2,500 stream miles have been identified as impaired due to nutrients. These nutrient-impaired stream segments are found in most of the state's major watersheds.

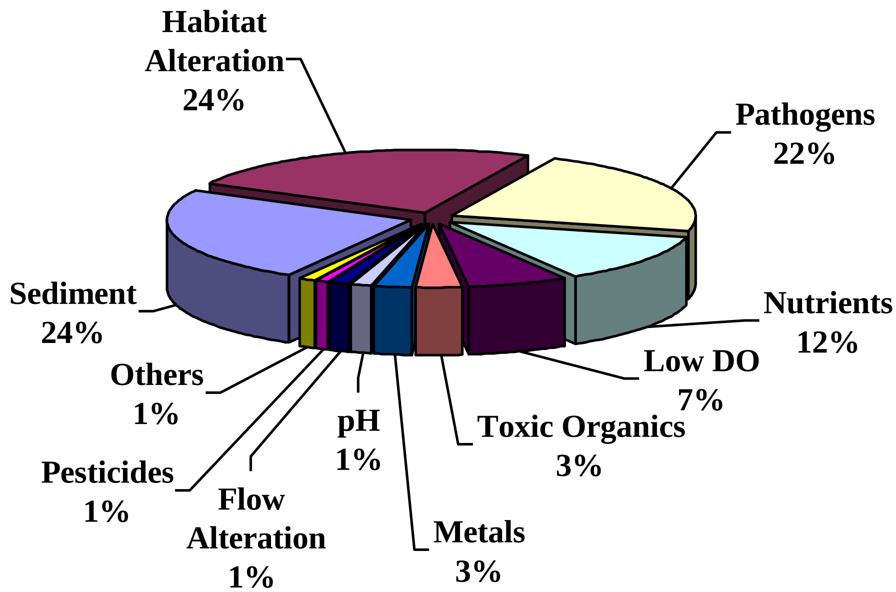


Figure 1: Relative impacts of pollution in assessed rivers and streams in Tennessee (2006 305(b) report)

Tennessee has made considerable progress developing nutrient targets for wadeable streams. However, less progress has been made for other waterbody types such as lakes, reservoirs, wetlands and large rivers. The purpose of this document is to identify methods that, resources permitting, could be used to identify nutrient goals for all the various waterbody types.

IMPORTANT NOTE:

This document is a plan that describes potential approaches for the refinement of existing nutrient criteria and the future development of specific criteria for additional waterbody types. Implementation of this plan will require either additional program resources or the diversion of resources from other program areas.

Nothing in this document should be taken to obligate the Division of Water Pollution Control to a course of action in the absence of program resources.

II. CRITERIA DEVELOPMENT OPTIONS

In 1998, EPA developed a National Nutrient Strategy for the development of a set of national criteria recommendations for nutrients for various waterbody types. The strategy was based on a statistical analysis of data aggregated from Level III ecoregions (Figure 2). Tennessee has three of these nutrient regions: Region IX (Southeastern Temperate Forested Plains and Hills), Region X (Texas-Louisiana Coastal and Mississippi Alluvial Plains), and Region XI (Central and Eastern Forested Uplands). However, only a small portion of Tennessee's land area (Mississippi River delta) is in Region X.

As of 2004, EPA has published national nutrient criteria for streams and rivers, lakes, and wetlands. However, the criteria developed for wetlands are only applicable to a small portion of Florida (Region XIII). Additionally, even for streams and lakes, not all Level III ecoregions are covered.

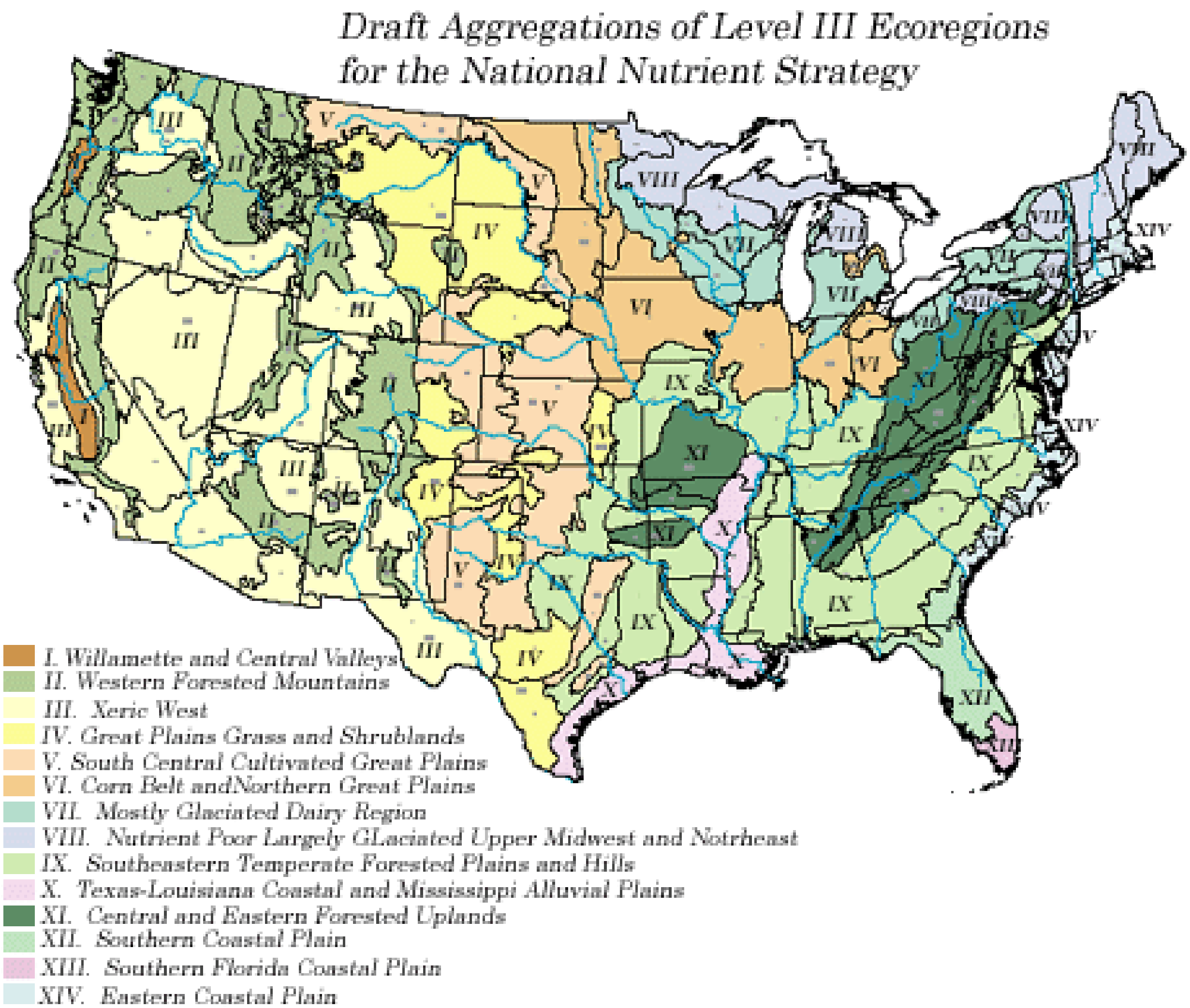


FIGURE 2. Level III ecoregions of the United States. (Source: EPA Office of Water web page.)

Dr. Sherry Wang and Greg Denton of the Tennessee Division of Water Pollution Control participated in the development of the national nutrient criteria for rivers and streams as members of the national criteria development team. A case study from Tennessee appeared in the rivers and streams criteria document. Additionally, Mr. Denton and Dr. Wang serve on the nutrient criteria Regional Technical Advisory Group (RTAG) for Region IV.

The following tables summarizes the EPA national nutrient criteria recommendations for the three Level III nutrient regions in Tennessee for rivers and streams (Table 1), plus two regions for lakes and reservoirs (Table 2). As stated previously, there are no national nutrient criteria for wetlands in any of the three Level III ecoregions in Tennessee. The source of these data was EPA's nutrient criteria webpage, Summary Table for Nutrient Criteria Documents, which can be accessed at (http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/).

Table 1. Aggregate ecoregions for rivers and streams

PARAMETER	ECOREGION IX	ECOREGION X	ECOREGION XI
Total Phosphorus (ug/L)	36.56	128.00*	10.00
Total Nitrogen (mg/L)	0.69	0.76	0.31
Chlorophyll *a* (ug/L)	0.93	2.10	1.61
Turbidity (FTU/NTU)	5.70	17.50	2.30

* EPA believes that this value may be a statistical anomaly and recommends further evaluation.

Table 2. Aggregate ecoregions for lakes and reservoirs

PARAMETER	ECOREGION IX	ECOREGION X	ECOREGION XI
Total Phosphorus (ug/L)	20.00	Under development	8.00
Total Nitrogen (mg/L)	0.36	Under development	0.46
Chlorophyll *a* (ug/L)	4.93	Under development	2.79
Secchi Depth (meters)	1.53	Under development	2.86

If EPA were required to promulgate nutrient criteria for individual states, the criteria would be based on EPA's published national recommendations. However, EPA has stated clearly that federal promulgation is not their preferred approach and instead, recommends that where-ever possible, the states should develop nutrient criteria that fully reflect localized conditions and protect specific designated uses. This is also Tennessee's preferred approach.

EPA has also stated a willingness to provide states with some flexibility concerning the parameters or constituents that provide the basis for criteria development. Causative factors are the pollutants such as nitrogen or phosphorus that stimulate excessive biomass. Response factors are measurements of the effects of the excess nutrients, such as elevated chlorophyll *a* levels, reduced water clarity or an adverse alteration in the benthic community composition. While EPA has recommended that states base criteria on both causative and response factors, many states appear to have a preference for one or the other. EPA has acknowledged that approaches that emphasize one set of factors over another can be acceptable. Tennessee's nutrient criteria development process focuses on both cause and response variables and will continue to do so for all waterbody types..

III. TENNESSEE'S WADEABLE STREAM NUTRIENT CRITERIA DEVELOPMENT

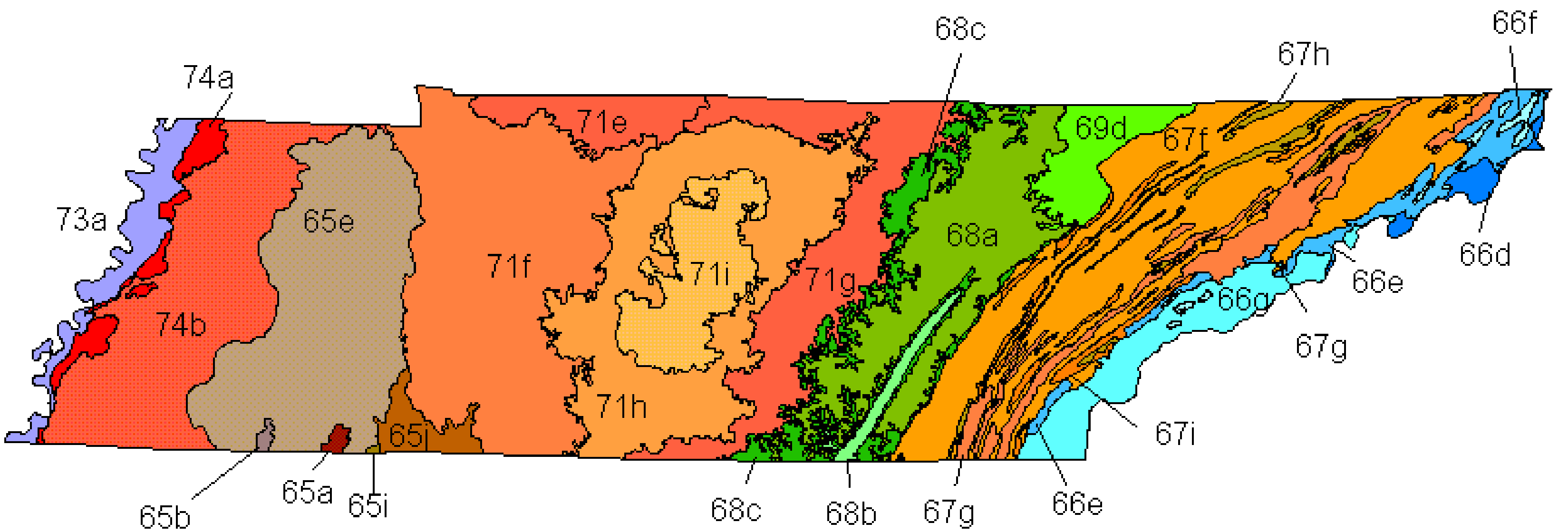
For wadeable streams, Tennessee has selected an approach to criteria development that blends recommendations from EPA with the state's own primary research into nutrient levels in various parts of the state. In fact, when the national nutrient strategy document was developed in 1998, Tennessee was already several years into a project studying water quality at carefully selected reference streams.

The Tennessee Ecoregion Project began in 1993 when Tennessee, with the help of 104(b)(3) funds, arranged for James Omernik and Glen Griffith from the EPA National Health and Environmental Research Laboratory to subregionalize and update the national Level III ecoregions that were developed in 1986.

During the delineation process, maps containing information on bedrock and surface geology, soil, hydrology, physiography, topography, precipitation, land use and vegetation were reviewed. Interagency cooperation widened the base of maps, information and resources available to delineate subregions. Much of this information was digitized to produce draft maps of ecoregion and subregion boundaries.

Multiple agencies were invited and represented at three ecoregion meetings held during 1994-95. Attendees included aquatic biologists, ecologists, foresters, chemists, geographers, engineers, university professors and regulatory personnel from 37 state and federal agencies as well as universities and private organizations. The judgment of these experts was applied throughout the selection, analysis and classification of data to determine the final ecoregion and subregion boundaries in Tennessee (Griffith, 1997).

Ecoregion delineation culminated in 1997 with the publication of a map outlining 25 Level IV ecoregions (Figure 3).



65a Blackland Prairie

65b Flatwoods/Alluvial Prairie Margins

65e Southeastern Plains and Hills

65i Fall Line Hills

65j Transition Hills

66d Southern Igneous Ridges & Mtns

66e Southern Sedimentary Ridges

66f Limestone Valleys and Coves

66g Southern Metasedimentary Mtns.

67f Southern Limestone/Dolomite Valleys and Low Rolling Hills

67g Southern Shale Valleys

67h Southern Sandstone Ridges

67i Southern Dissected Ridges & Knobs

68a Cumberland Plateau

68b Sequatchie Valley

68c Plateau Escarpment

69d Cumberland Mountains

71e Western Pennyroyal Karst

71f Western Highland Rim

71g Eastern Highland Rim

71h Outer Nashville Basin

71i Inner Nashville Basin

73a Northern Mississippi Alluvial Plain

74a Bluff Hills

74b Loess Plains

Figure 3: Level IV ecoregions of Tennessee

In parallel with the delineation efforts, in 1994, work began to identify reference streams throughout the state (Arnwine et al, 2000). Reference streams were least impacted, but representative, waterbodies in each of the subecoregions. Candidate reference streams were selected based on land-use and the general absence of land-disturbing activities. Candidate streams were initially surveyed and approximately 100 were selected for intensive monitoring. Except for some of the very small subecorogions, three to five reference streams were established in each area.

For the next three years, the division intensively monitored each reference stream for physical, biological, and chemical characteristics. Total phosphorus and nitrate+nitrite data were included in these analyses, however, total nitrogen was not. Reference sites have continued to be sampled since then, but in conjunction with the watershed cycle, rather than intensively as before.

In 2001, the division published a document entitled, *Development of Regionally-based Interpretations of Tennessee's Narrative Nutrient Criterion* (Denton et al, 2001). The report:

1. Documented the 75th and 90th percentiles of the total phosphorus and nitrate+nitrite data from each subecoregion.

2. Identified adjoining Level IV subregions that could be combined due to the lack of a statistically significant difference in the data from each.

3. Tested both the 75th and 90th percentiles with the benthic community survey results at test sites to see how well each potential criteria level predicted biological impairment.

4. Proposed the 90th percentile as the basis for clean water goal setting.

5. Established an implementation procedure for application of the narrative criteria.

In 2002, the division formally proposed to the Water Quality Control Board that the total phosphorus and nitrate+nitrite targets based on the 90th percentile established in the 2001 nutrient document be promulgated as water quality criteria. Additionally, the division suggested that a narrative nutrient criterion for protection of the recreational use be adopted. The following language was suggested:

The waters shall not contain nutrients in concentrations that stimulate aquatic plant life and/or algae growth to the extent that the public's recreational uses of the stream or other downstream waters are detrimentally effected.

The set of revisions was drafted and rulemaking procedures were initiated.

In the spring of 2003, a court case challenged the division's ability to identify nutrient-impaired waters and to set permit limitations for nutrients, due to the lack of a water quality criterion specific to that condition. In response, the Board approved an emergency rule for nutrients. The emergency rule, which was narrative in nature, stated:

> *(m) The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that aquatic habitat is substantially reduced and /or the biological integrity fails to meet regional goals. Additionally, the quality of downstream waters shall not be detrimentally affected.*
>
> *Interpretation of this provision may be made using the document Development of Regionally-based Interpretations of Tennessee's Narrative Nutrient Criterion and/or other scientifically defensible methods.*

The wording of the emergency rule did several significant things. First, as part of the criteria for protection of fish and aquatic life, it applied to all waters, since all waters in Tennessee have that designated use assigned to them. Since the criterion was non-specific, it applied to all waterbody types and established the importance of physical (habitat) and biological data in interpreting the criterion. Additionally, for wadeable streams, it established the division's procedure based on reference stream data, as the preferred method of interpretation. This emergency rule, once promulgated, was then approved by EPA in December, 2003.

In August, 2003, EPA raised concerns about the promulgation of numeric criteria based on the 90^{th} percentile of the reference stream data. Additionally, the public and the regulated community did not appear to support numeric criteria. In response, the division removed the proposed numeric criteria and substituted the narrative criterion language from the emergency rule.

All the proposed revisions to water quality standards were promulgated by the Board in September, 2003. Following certification by the Attorney General's office, the rulemaking hearing rules were transmitted to EPA. The state rulemaking process was completed in January, 2004. In September 2004, EPA formally approved almost all of Tennessee's revisions, including the narrative nutrient criterion. (As stated previously, EPA had already approved the same language in the emergency nutrient criterion.)

There are several reasons that Tennessee chose not to use EPA's national nutrient criteria recommendations for wadeable streams. The first and most obvious is that EPA stated a preference that states develop their own regionally-based nutrient criteria. The national database used by EPA included data from large rivers and streams that crossed Level IV (and sometimes Level III) ecoregion boundaries. Tennessee's reference database was restricted to streams that had at least 80% of the upstream drainage included within the targeted Level IV subregion.

A Level IV or ecological subregion approach is much more refined and indicative of local conditions. Subregions in Tennessee were often statistically different from other subregions in the same Level III ecoregion. Basing criteria on Level III data is not sensitive to obvious regional differences.

Another source of concern about EPA's national nutrient criteria recommendations is that a statistical approach was used to derive the national criteria without consideration of cause-effect relationships. Tennessee has utilized an approach that incorporates not only the identification of the reference condition, but also considers the effects of nutrient enrichment to the biological community. The state considers this approach a more appropriate method of determining nutrient thresholds for the protection of designated uses.

Regarding other waterbody types such as lakes and reservoirs, Tennessee is not certain that an ecoregional framework will be as helpful as it was with rivers and streams. Although Florida used such an approach for their lakes, most of their lakes are of natural origin, while most of Tennessee's are impoundments. The characteristic of reservoirs seem to be more controlled by the size and type of dam, the contours of the flooded valley, retention times, and inflow and outflow rates.

Tennessee is waiting on guidance from EPA before attempting to develop nutrient criteria for wetlands.

IV. CLASSIFICATION BY WATERBODY TYPE

As previously stated, all waterbody types in Tennessee are currently covered by the state's EPA-approved narrative nutrient criterion. Under this rule, a methodology for interpreting the criterion in wadeable streams is specified. In order to continue development of more specific nutrient criteria, groups need to be identified for the various waterbody types. Classification refers to the way waterbodies can be grouped for criteria development.

Tennessee plans to classify waterbodies in the following manner:

Streams and Rivers

<u>Wadeable Streams</u>

For nutrient criteria purposes, these waters have also been grouped by nutrient regions (total phosphorus and nitrate+nitrite) based on statistical similarity between reference data in the Level IV ecological subregions (Figures 4 and 5). From the 25 Level IV subregions in Tennessee, nutrient regions have been grouped into 15 nitrate+nitrite and 15 total phosphorus. Although both groups have 15 regions, they do not exactly overlap.

Reference conditions have not yet been established for wadeable streams that cross more than one nutrient region. However, the majority of the state's wadeable streams are covered. If a stream crosses more than one region, a decision is made on which region has the most influence on the stream flow and the criterion for that region is used.

The wadeable stream criteria are used in conjunction with regional biocriteria for a cause and effect approach. Macroinvertebrates were selected as the principal indicator of nutrient enrichment although algal density is also considered when assessing streams. Tennessee selected macroinvertebrates rather than periphyton as a nutrient indicator in wadeable streams because of the state's existing expertise and large reference database. Shifts in the macroinvertebrate community such as an increase in the abundance of nutrient tolerant organisms, an increase in filterers and scrapers, an increase in worms and midges and a decrease in EPT taxa are generally measured in nutrient enriched waters. These changes are generally a response to an increase in algal growth which results in dissolved oxygen depletion, loss of habitat and a shift in available food types.

The division recognizes the value of periphyton as an additional nutrient indicator. Periphyton density measures are already used in special studies such as the probabilistic monitoring of streams below impoundments and diurnal dissolved oxygen study conducted in 2004 and 2005. However, based on these preliminary studies periphyton density was not always a reliable predictor of nutrient levels. At many test sites, nutrients were elevated, but periphyton abundance was similar to reference levels. Many streams, especially small ones, have dense canopies that block sunlight and keep water temperatures down which inhibits algal growth. In addition, the abundance of grazing animals such as snails would have an impact on algal density. As federal funding and expertise is made available, the state will consider the development of a periphyton index for use in wadeable streams as a supplement to the macroinvertebrate index. Algal density will continue to be a supplemental tool in special studies.

Non-wadeable streams and rivers

It is likely that Tennessee will continue to use the ecoregion approach to establish nutrient criteria in these systems. Cause-effect relationships between nutrient concentrations and macroinvertebrates, and possibly fish and algae, will be explored. Nitrate+nitrite, total phosphorus, turbidity and suspended solids data will also be analyzed. The first challenge will be to try and target reference reaches on these large systems. A review of TVA's fixed station monitoring has begun. Data from other sources has been requested.

Reference conditions have been established for non-wadeable waters in ecoregions 74b and 73a (for both nitrate+nitrite and total phosphorus). Reference streams have not been established for non-wadeable flowing water in other regions or for those waters that cross multiple subregions. Four potential reference sites were targeted and monitored as part of a 104(b)(3) grant in summer 2004 for rivers and large streams crossing ecoregions 65e and 74b in west Tennessee (Arnwine et. al, 2005).

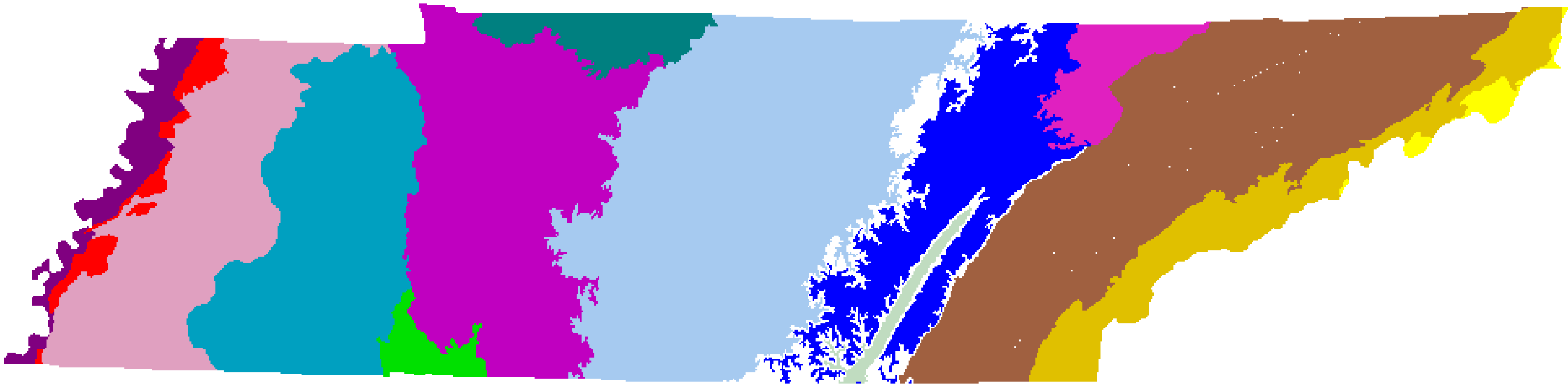


Figure 4: Nitrate+Nitrite regions for wadeable streams in Tennessee

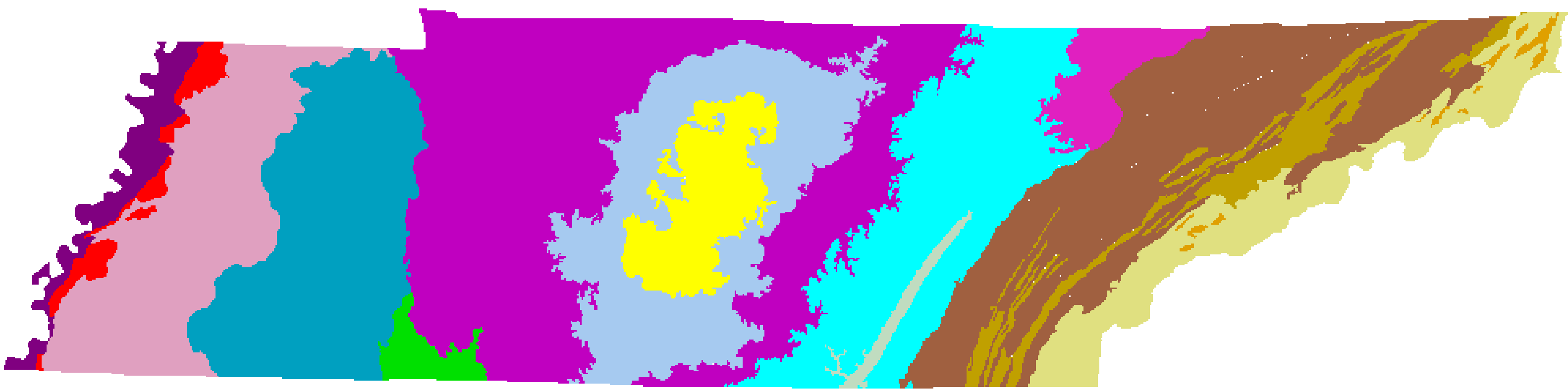


Figure 5: Total phosphorus regions for wadeable streams in Tennessee

Lakes and Reservoirs

Tennessee initiated development of specific nutrient guidelines for lakes and reservoirs beginning with a review of existing data. For the initial review of data, lentic systems were divided into the following broad categories. It is possible they will be further divided into sub-categories or that small and medium reservoirs will be grouped. It is too early to determine whether the ecoregion concept will be applicable to lakes and reservoirs or whether some other classification approach needs to be developed. It is likely that a different approach that focuses on lake management and retention times will need to be used for larger reservoirs that are managed for power production or flood control. It is possible the ecoregion approach may be used for smaller reservoirs that are contained within a single bioregion and are not routinely drawn down or fertilized to promote fish production.

Natural Lakes

Many of Tennessee's significant natural lakes are in West Tennessee, especially along the Mississippi River in the Alluvial and Loess Plains ecoregions. (It is often, but not correctly, said that Reelfoot Lake is Tennessee's only natural lake. Reelfoot Lake is by far the largest at 10,950 acres. The other natural lakes are well under 250 acres in size. While it might be possible to have an ecoregional basis for these small natural lakes, the problem in West Tennessee would be that the significant amount of agricultural land conversion and extensive hydrological modification (leveeing and channelization of tributaries) would make it difficult to find suitable reference sites. However, 16 small natural lakes located in wildlife refuges and state natural areas in these two ecoregions may provide baseline information. A representation of these lakes will be monitored when staffing and money are available. It may also be possible that neighboring states may have reference quality lakes in this subregion.

Extensive water quality investigations were conducted at Reelfoot Lake in the 1980s (TDHE, 1984 and Denton, 1987). This lake is already listed as nutrient impaired due to elevated chlorophyll *a* levels and nuisance aquatic plants. The dense stands of aquatic plants interfere with recreational boating.

Large Reservoirs (> 1000 acres)

Tennessee has 29 large reservoirs over one thousand acres. They range in size from the 1,749 acre Chilhowee Reservoir on the Little Tennessee River to the 99,500 acre Kentucky Lake on the Tennessee River. Twenty-seven of these reservoirs are managed by the Tennessee Valley Authority (TVA) or the U.S. Army Corps of Engineers (USACE). Chilhowee is managed by Alcoa Aluminum and Woods is managed by US Air Force's Arnold Engineering Development Center. All but four of these large reservoirs are routinely monitored by the management agency. Six are shared with other states including Kentucky Lake, Lake Barkley and Dale Hollow (Kentucky); South Holston Lake (Virginia); Guntersville Lake (Alabama); and Pickwick Lake (Alabama and Mississippi). Expertise and data are available from all these sources and will be useful as part of the criteria development process. In the 2006 water quality standards, WPC has adopted nutrient criteria for Pickwick Lake based on Alabama's criteria and monitoring stations in Tennessee, contingent on EPA approval.

Medium Reservoirs (251 – 1000 acres)

Tennessee has 16 reservoirs falling in this category. Five are fishing lakes managed by the Tennessee Wildlife Resources Agency (TWRA). Reelfoot-Indian Creek #1 was one of 10 reservoirs that was constructed to control sediment transport into Reelfoot Lake and is now managed as a recreational lake by TWRA. Eight of the reservoirs are managed by TVA, mostly for flood control. Three of these are routinely monitored as part of TVA's Vital Signs Monitoring Program. Calderwood is managed by Alcoa Aluminum for power production. Meadow Park Lake, is a water supply reservoir for the city of Crossville on the Cumberland Plateau. A factor to consider is that the TWRA impoundments are fertilized to promote fish production and are periodically drained. While the Division of Water Pollution Control has strong reservations about this practice, it may be that criteria in these fishing reservoirs need to focus more on the protection of downstream reaches, rather than prevention of over enrichment in the reservoir water column.

Small Reservoirs (< 250 acres)

Tennessee has 1,302 documented reservoirs under 250 acres (Figure 6). This number only includes reservoirs that were permitted under the Safe Dams or ARAP (Aquatic Resources Alteration Permit) programs. There are probably many more. The documented reservoirs include one TVA managed reservoir (Wilbur Lake), municipal lakes, state parks, city parks, resorts, community developments, agricultural ponds and private lakes. There is little historic data on many of these impoundments. The studies that have been done indicate that many of these lakes are eutrophic. It is possible that an ecoregion approach can be used on these lakes since they are generally contained in one ecological subregion although lake management will need to be a consideration.

Wetlands

Tennessee has approximately 787,000 acres of wetlands. The Division has identified 54,811 impacted wetland acres. The largest single cause of impact to existing wetlands is loss of hydrologic function due to channelization and leveeing.

Wetlands are currently covered under the general narrative nutrient criteria. Tennessee does not currently have the resources or data available for development of wetland specific nutrient criteria. Protection and restoration of wetlands from physical alterations has historically been considered a higher priority.

Tennessee was one of the first states in the nation to have a wetlands protection strategy and has been recognized by EPA as establishing a national model for wetlands planning. The division is currently reviewing the draft guidance provided by EPA . Wetland nutrient criteria will be considered after nutrient criteria for flowing waters and reservoirs are established and federal assistance for monitoring and criteria development is provided.

V. CRITERIA DEVELOPMENT APPROACH BY WATERBODY TYPE

The focus of Tennessee's nutrient criteria strategy is based primarily on the linkage between nutrient concentrations and impairment of designated uses. Both causative variables such as phosphorus and nitrate+nitrite as well as response variables such as the health of the macroinvertebrate community, algal density and chlorophyll *a* levels are taken into consideration. The establishment of nutrient criteria has been and will continue to be founded on the results of comprehensive cause and effect-based study and analysis for all waterbody types.

Wadeable Streams

Tennessee has been researching nutrient levels in wadeable streams since 1995 and has used these data to develop nutrient criteria as outlined in the document *Development of Regionally-Based Interpretations of Tennessee's Narrative Nutrient* Criterion, (Denton et al, 2001). This document is referenced as a translator (along with other scientifically defensible data) in Tennessee's narrative nutrient criterion, which became a state rule in January 2004. The nutrient criterion is tied-in with the biological criteria for an effects-based approach.

The guidelines are based on data collected primarily from 1996 to 1999, consisting of chemical, physical and biological samples collected in least-impacted, yet representative, streams in 25 Level IV ecological subregions across the state. Data continues to be collected from these streams on the five-year watershed cycle. Several studies have been conducted to develop and refine the regionalized nutrient criteria guidelines.

<u>Ecoregion Reference Stream Study</u>

Three hundred and fifty-three potential reference sites were evaluated as part of the ecoregion project. The reference sites were chosen to represent the best attainable conditions for all streams with similar characteristics in a given subregion. Reference conditions represented a set of expectations for physical habitat, general water quality and the health of the biological communities in the absence of human disturbance and pollution.

Selection criteria for reference sites included minimal impairment and representativeness. Streams that did not flow across subregions were targeted so the distinctive characteristics of each subregion could be identified. Based on EPA recommendations, three reference streams per subregion were considered the minimum necessary for statistical validity. Only two streams could be found in some smaller subregions. Seventy streams were targeted for intensive monitoring beginning in 1996. After analysis of the first year's data, it was determined that a minimum of five streams per subregion would be more appropriate. Where possible, additional reference streams were added. However, in smaller subregions or those with widespread human impact this was not possible. Forty-four reference streams were added to the study resulting in intensive monitoring at 114 sites beginning in fall 1997. There were between two and eight reference streams targeted in each subregion.

All reference sites were monitored quarterly for three consecutive years. Since 1999, sites have been monitored quarterly as part of the five year watershed cycle. New reference sites are added as they are located during watershed or probabilistic monitoring. Conversely, some of those originally selected have been dropped due to increased disturbances or unsuitability. There are currently 104 active reference sites.

During the nutrient criteria development process, the data were analyzed for relationships between other parameters and nutrient levels at reference streams. Relationships were investigated primarily for turbidity, total organic carbon (TOC) and total suspended solids. Somewhat weak relationships between total organic carbon and turbidity were documented with total phosphorus levels. This study is documented in the USEPA report (EPA-822-B-00-002, Appendix A). These relationships will continue to be analyzed as more data become available.

Nutrient concentrations were compared between each subregion to determine groupings for nutrient regions. Fisher's Protected Least Significant Difference at significance level of 5% was used to determine which subregions could be combined. Reference data from the Alabama Department of Environmental Management was used to support pooling of small subregions in the Southeastern Plains (65).

Tennessee's regional nutrient guidelines were set at the 90^{th} percentile of reference data for each region (Denton et al 2001). Since Tennessee is using causal responses based on macroinvertebrate communities to define nutrient criteria violations, both the 90^{th} and 75^{th} percentile of reference data were evaluated for criteria development. Relationships between biological stream health and nutrient concentrations were explored using reference stream data, probabilistic data, and data from targeted monitoring.
Based on a comparison to biocriteria guidelines throughout the state, the 75^{th} percentile often targeted streams as nutrient enriched that showed no biological impairment. Therefore, regional nutrient criteria were proposed for both NO2+NO3 and total phosphorus at the 90^{th} percentile of reference data.

In 2006, biological data were once again compared to the 90^{th} and 75^{th} percentile of regional reference data and EPA's nutrient criteria recommendations to evaluate which level had the best match for cause and effect (Figure 6). Ninety six sites where the macroinvertebrate community passed regional guidelines and both nitrate+nitrite and total phosphorus samples had been collected were used in the evaluation. For both nitrate+nitrate and total phosphorus, the 90^{th} percentile of Tennessee's ecoregion reference had the clearest relationship with biological integrity. At sites where the macroinvertebrate community did not respond to nutrients above the 90^{th} percentile, the stream was well-shaded or there were other factors that would retard algal growth.

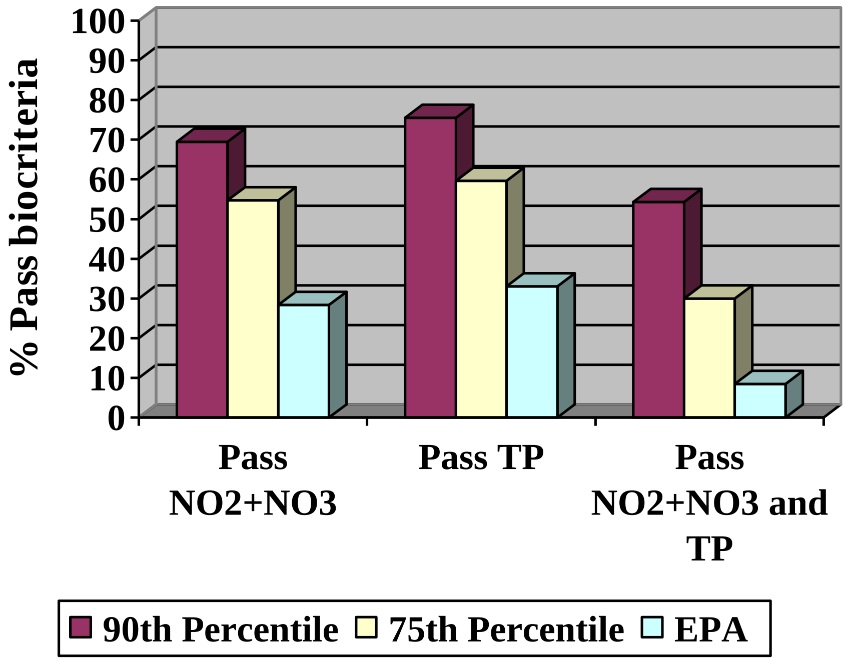


Figure 6: Comparison of sites supporting biological integrity with proposed nutrient criteria at 75th and 90th percentiles of reference data and EPA recommended nutrient criteria.

At the time the guidelines were published in 2001, 916 data points from reference streams were used to calculate regional criteria guidelines for total phosphorus and nitrate+nitrate at the 90th percentile. Values are checked annually using additional data collected from reference sites through the year (Tables 4 and 5). In 2007 there were twice as many data points. There has been very little change over the last five years indicating that the criteria are an accurate reflection of background levels in each region.

Tennessee intends to continue to investigate nutrient levels at reference and test sites. However, the division is satisfied that guidelines set at the 90th percentile using regional reference data are appropriate and can be justified. The fourteen years of research and eleven years of data collection used to establish these regional guidelines indicate that the 90th percentile is a better predictor of biological impairment in Tennessee ecoregions than the EPA's guidelines based on the 25th percentile of aggregated Levels III data or the 75th percentile of Tennessee data.

After several year's experience, the division has found the use of numeric translators of the nutrient criteria in conjunction with biocriteria to be an effective tool for assessments while providing flexibility to use more stringent numbers for TMDLs. Tennessee will continue to refine and test implementation of the narrative nutrient criteria with numeric translators. The state will consider the possibility of promulgating the translators as numeric criteria depending on EPA's progress toward developing categorical permit limits and providing further clarification about implementation of numeric criteria including the incorporation of biological response criteria.

Table 4: 90th and 75th percentile of reference total phosphorus data by ecological subregion (mg/L)

August 2001 N = 916				September 2007 N = 1835			
Grouped Subregions	90th	75th	Count	Grouped Subregions	90th	75th	Count
73a	0.25	0.19	19	73a	0.32	0.23	57
74a	0.12	0.11	28	74a	0.17	0.11	55
74b	0.10	0.06	42	74b	0.12	0.06	91
65a, 65b, 65e, 65i	0.04	0.04	74	65a, 65b, 65e, 65i	0.10	0.04	142
65j	0.04	0.01	53	65j	0.04	0.01	81
71e	0.04	0.02	38	71e,	0.04	0.03	69
71f, 71g	0.03	0.02	112	71f, 71g	0.05	0.02	254
71h, 71i	0.18	0.10	105	71h	0.09	0.06	94
71i				71i	0.24	0.13	152
68a, 68c	0.02	0.01	101	68a, 68c	0.03	0.01	212
68b	0.04	0.03	31	68b	0.08	0.04	50
69d	0.02	0.01	50	69d	0.03	0.01	102
67f, 67h, 67i	0.04	0.02	72	67f, 67h, 67i	0.04	0.02	217
67g	0.09	0.06	25	67g	0.09	0.05	54
66d, 66e, 66g	0.01	0.01	114	66d, 66e, 66g	0.02	0.01	252
66f	0.02	0.02	22	66f	0.03	0.02	53

Table 5: 90th and 75th percentile of reference nitrate+nitrite data by ecological subregion (mg/L)

August 2001 N = 885				September 2007 N = 1834			
Grouped Subregions	90th	75th	Count	Grouped Subregions	90th	75th	Count
73a	0.39	0.26	19	73a	0.35	0.24	59
74a	0.22	0.15	27	74a	0.25	0.15	53
74b	1.19	0.72	42	74b	1.04	0.56	91
65a, 65b, 65e, 65i	0.34	0.25	74	65a, 65b, 65e, 65i,	0.32	0.25	142
65j	0.22	0.19	53	65j	0.25	0.22	82
71e	3.48	3.11	37	71e	3.69	3.12	70
71f	0.38	0.19	69	71f	0.38	0.25	175
71g, 71h, 71i	0.94	0.64	148	71g, 71h, 71i	0.93	0.67	325
68a	0.23	0.13	73	68a	0.22	0.12	153
68b	0.45	0.33	31	68b,	0.48	0.36	50
68c	0.31	0.25	28	68c	0.34	0.29	59
69d	0.27	0.16	50	69d	0.27	0.16	100
67f, 67g, 67h, 67i	1.22	0.95	97	67f, 67g, 67h, 67i	1.12	0.88	272
66d	0.50	0.22	32	66d	0.52	0.29	92
66e, 66f, 66g	0.31	0.21	105	66e, 66f, 66g	0.30	0.21	213

The use of regional reference data follows EPA's recommendation that states establish localized guidelines when possible. The use of the 90^{th} percentile meets Tennessee's desire to base nutrient guidelines on a cause and effect relationship rather than a purely statistical approach and is consistent with both Tennessee's and EPA's goals to protect designated uses. Past concerns EPA has expressed with Tennessee's approach have been considered and are addressed in Appendix A.

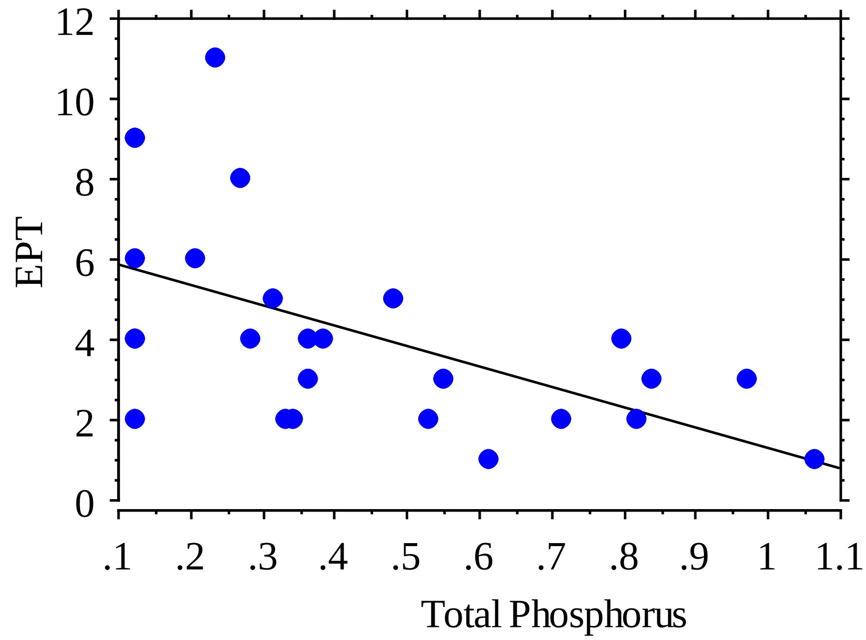
Tennessee is performing many studies relating to nutrient enrichment as described in the next section. These studies are expected to enhance the understanding of the effects of nutrient enrichment on streams. However, Tennessee feels that the regional nutrient guidelines at the 90^{th} percentile in conjunction with documentation of macroinvertebrate assemblages is an effective way to assess nutrient impairment and intends to go forward with this as the primary approach.

Inner Nashville Basin Probabilistic Monitoring Study

In 2001, 104(b)(3) grant monies were awarded to extend a probabilistic study of water quality in the Inner Nashville Basin (ecoregion 71i). The focus of this phase of the study was to explore the relationship between nutrient levels and the biological community (Arnwine et. al., 2003). The metric with the strongest response to total phosphorus was EPT richness (Figure 7). The percent chironomids and oligochaetes (%OC) was the biometric most affected by nitrate+nitrite concentrations (Figure 8).

The relationships between nutrients and macroinvertebrate biometrics were strengthened when percent canopy was included as a variable (Tables 6 and 7). Data show the absence of canopy played a significant role in the response of macroinvertebrates to elevated nutrient levels.

This study has resulted in percent canopy measures routinely being added to biological surveys. When possible, periphyton abundance is also measured, especially if nutrients are a concern. Due to manpower, expertise and funding constraints, it is unlikely Tennessee will include periphyton surveys requiring taxonomic identification as a regular survey activity although it may be included in special projects.



Y = 6.372 - 5.041 * X; R^2 = .302,   p = .004

Figure 7: Relationship between total phosphorus levels and EPT taxa richness during low flow conditions. Data represents 21 probabilistic monitoring sites and two ecoregion reference sites in the Inner Nashville Basin.

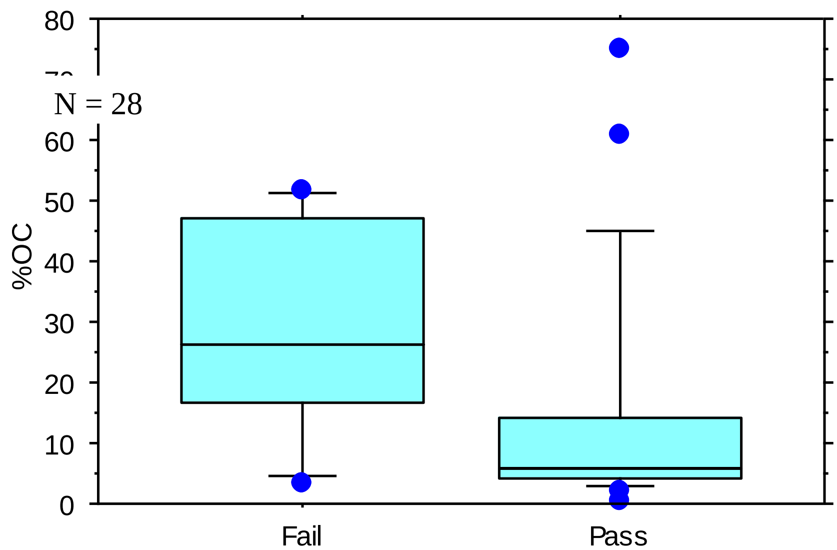


Figure 8: Distribution of Oligochaeta and Chironomidae abundance at sites with nitrate+nitrite levels above (fail) and below (pass) regional guidelines. Data represent 21 probabilistic sites and two ecoregion reference sites collected in fall 2000 in the Inner Nashville Basin.

Table 6: Relationship (adjusted R^2) between nutrient levels and nine biometrics at 50 test sites and two reference sites. Values in bold $p < 0.05$.

	Fall			Spring		
Biometric	**NO2-3**	**TP**	**NO2-3 TP**	**NO2-3**	**TP**	**NO2-3 TP**
Count	26	26	26	101	101	101
TMI	-.001	-.086	.010	-.001	+.025	.005
TR	+.049	-.014	..057	-.006	+.012	.016
EPT	+.071	**-.302**	**.283**	-.002	+.004	.005
%EPT	**-.149**	-.016	.110	+.004	+.00003	.004
%OC	**+.190**	+.004	.137	+.003	+.025	.011
NCBI	-.042	+.117	.067	-.020	-.011	.015
%DOM	-.005	+.002	.006	+.001	-.036	.016
%CLING	+.009	-.133	.060	-.002	-.091	.073
%NUTOL	**+.221**	+.009	**.186**	-.003	+.013	.015

Table 7: Relationships (adjusted R^2) between nutrient levels, canopy cover and nine biometrics. Samples collected at 50 probabilistic monitoring sites and two reference sites. Values in bold are statistically significant ($p < 0.05$)

	Fall				Spring			
Bio-metric	**Canopy**	**CanopyNO2-3**	**CanopyTP**	**Canopy NO2-3 TP**	**Canopy**	**CanopyNO2-3**	**CanopyTP**	**Canopy NO2-3 TP**
Count	16	16	16	16	92	90	90	90
TMI	**+.243**	.161	**.566**	**.549**	+.007	.007	.013	.002
TR	+.080	.082	.084	.017	+.012	.001	.031	.023
EPT	+.053	.058	**.280**	.237	-.022	.017	.002	.025
%EPT	+.039	.143	.078	.103	-.021	.002	.018	.026
%OC	+.027	**.567**	.131	**.615**	**-.046**	.036	**.057**	**.064**
NCBI	-.180	.054	**.417**	**.373**	**+.087**	**.108**	.089	**.108**
%DOM	-.030	.033	.125	.126	+.001	.002	.028	.019
%CLING	+.221	.133	**.641**	**.626**	-.018	.006	**.055**	.078
%NUTOL	+.001	.018	.082	.062	-.016	.015	.016	.017

<u>Update of Tennessee Macroinvertebrate Index for Wadeable Streams</u>

In 2006, the state revised the Tennessee Macroinvertebrate Index as part of the annual Quality System Standard Operating Procedure (QSSOP) review and the triennial review of Water Quality Standards. In an effort to make the index more sensitive to nutrient and sediment impairment, the percent dominant taxon metric was replaced with the percent nutrient tolerant metric presented in a paper on determining nutrient impairment using biological and other non-chemical indicators in Kentucky (Brumley et al, 2003).

The metric combines 14 taxa that were frequently found in streams containing elevated total phosphorus (TP) and nitrogen (TN). In order for taxa to be selected, they individually comprised a minimum of >5% of the total number of individuals in the sample. The %NUTOL was significantly ($p<0.0001$) correlated with increasing TN, TP, and the interaction term (Pearson's $r=0.48$, 0.58, and 0.59, respectively). During the Southeaster Water Pollution Biologist Association annual meeting in 2005, Kentucky biologists indicated the metric was a better indicator of sedimentation. The seven taxa included *Cheumatopsyche, Lirceus, Physella, Baetis, Psephenus, Stenelmis, Simulium, Elimia, Oligchaeta, Polypedilum, Rheotanytarsus, Stenacron, Cricotopus* and *Chironomus* spp. With the exception of *Stenacron*, and *Psephenus*, these taxa are often abundant in nutrient enriched streams in Tennessee.

In 2003, WPC began calculating this metric on all semi-quantitative macroinvertebrate samples to determine if the metric was more sensitive than the percent dominant metric to various levels of impairment. It had been observed by the division's biologists that the percent dominant was generally only sensitive in cases of severe impairment, although it is also considered a nutrient indicator.

Although the biological assessment would not change at most of the sites where the index score was lowered, the use of the %NUTOL would enable the division to pick up more subtle changes in the benthic community. This would help biologists keep track of which sites may have begun degrading or were starting to show improvement. The use of this metric would also help in determination of causes of impairment. Sites meeting nutrient and sediment guidelines generally scored a 6 (highest possible score) in %NUTOL (Figure 9).

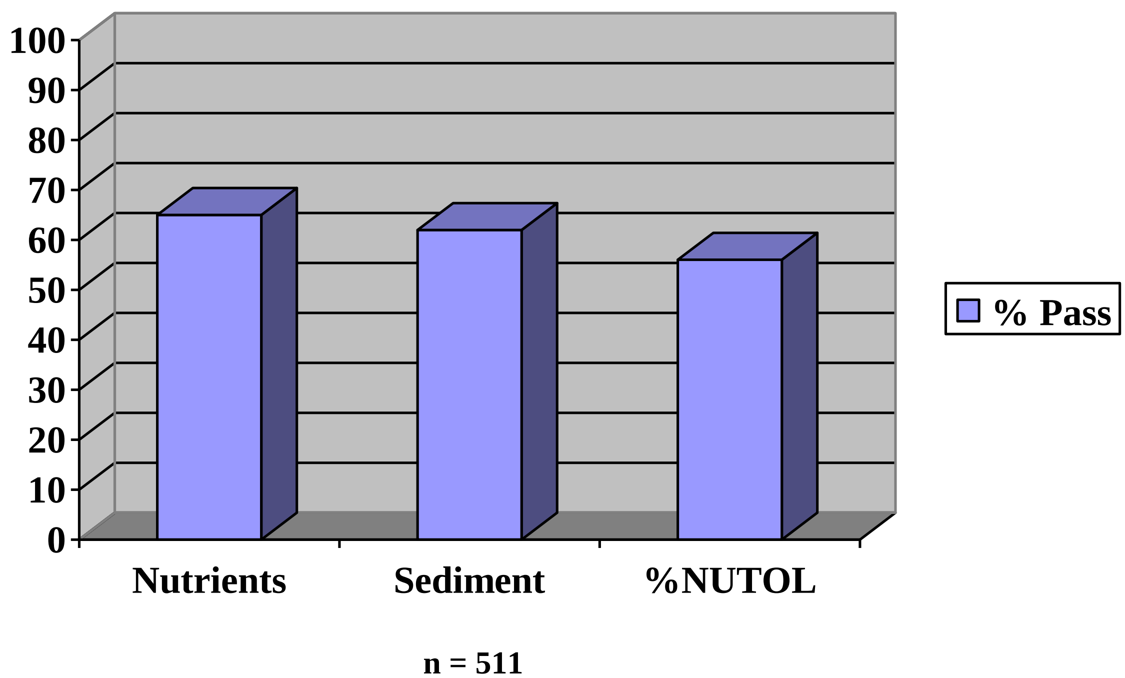


Figure 9: Comparison of samples passing regional nutrient and/or sediment guidelines to samples scoring a 6 in %NUTOL metric.

First Order Streams

Nutrient guidelines developed for larger wadeable streams are currently being applied to first order streams although the response variable (macroinvertebrates) is adjusted. The existing biocriteria does not apply to first order streams in all bioregions. When first order test streams are sampled, an upstream or watershed reference is collected at the same time. The division is gathering this information into a first order reference database. When enough data are available, a multi-metric index and regional expectations specific to first order streams will be developed. This will help fine-tune the existing wadeable stream nutrient criteria to these smaller systems. This process could be accelerated if federal assistance were provided for the targeting and monitoring of first order reference streams.

Periphyton

Tennessee recognizes the value of additional biological indicators although the macroinvertebrate index has proven to be a reliable assessment tool for nutrient impairment. When possible, generally as part of special studies funded by 104(b) grants, the division is conducting rapid periphyton density surveys as a supplement to the macroinvertebrate surveys. The first priority has been to get baseline data on reference streams. At least one and typically two or more, periphyton density surveys have been completed on every reference stream with suitable substrate. Preliminary estimates of background levels of microalgae and macroalge have been made.

In 2002, Tennessee was awarded federal nutrient criteria development funds to conduct algal density field surveys and nutrient sampling for comparison to diurnal dissolved oxygen patterns of 78 reference and impaired streams in 15 ecological subregions (Arnwine and Sparks, 2003).

Based on this preliminary study, periphyton density was not always a good predictor of nutrient enrichment. At many test sites, nutrients were elevated, but periphyton abundance was similar to reference levels. Many streams, especially small ones, have canopies that block sunlight and keep water temperatures down which inhibits algal growth. In addition, the abundance of grazing animals such as snails would have an impact on algal density.

Dissolved oxygen levels appeared to be affected by the amount of periphyton present in the streams. Although levels generally stayed above regional criteria, diurnal fluctuations were more pronounced when algal densities were above reference stream conditions (Figures 10 and 11). Previous studies have indicated that extreme changes in dissolved oxygen levels can have a detrimental affect on aquatic life even when criteria for minimum concentrations are met. The type of periphyton (macroalgae or microalgae) did not appear to be as strong an influence on dissolved oxygen fluctuations as the abundance.

This study demonstrated the value of collecting and comparing canopy measurements and macroinvertebrate data (grazer abundance) when conducting periphyton surveys.

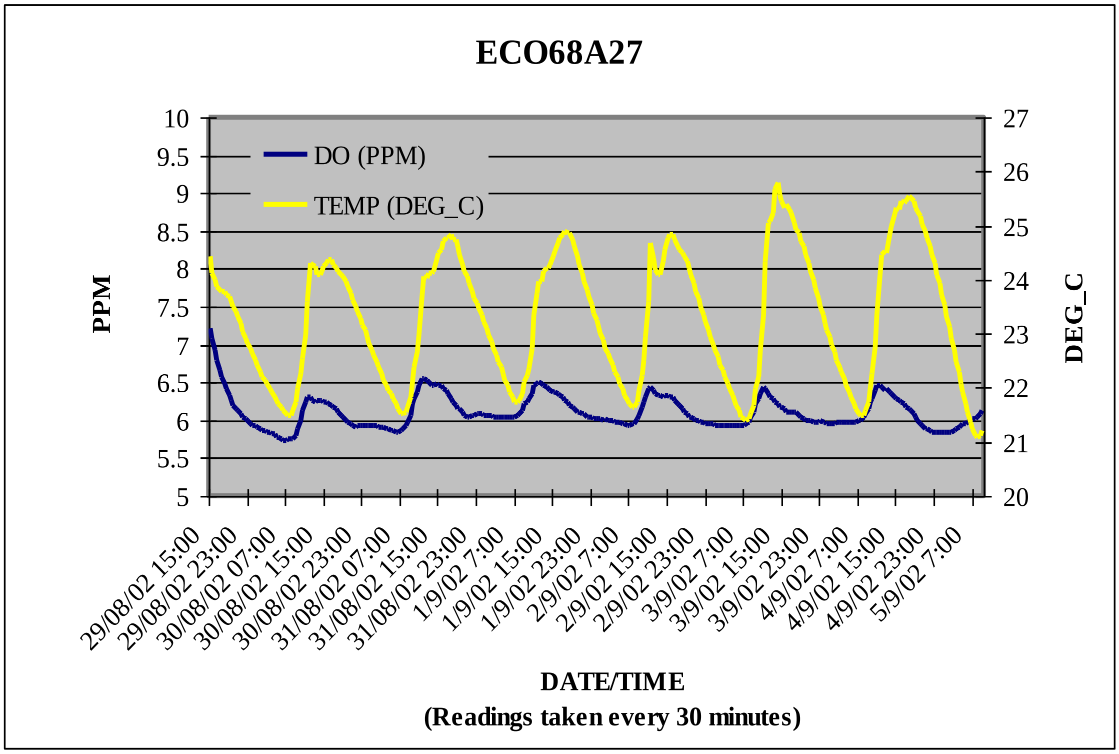


Figure 10: Diurnal dissolved oxygen and temperature data, Island Creek reference site, Cumberland Plateau (68a). Readings every 30 minutes for 162 hours.

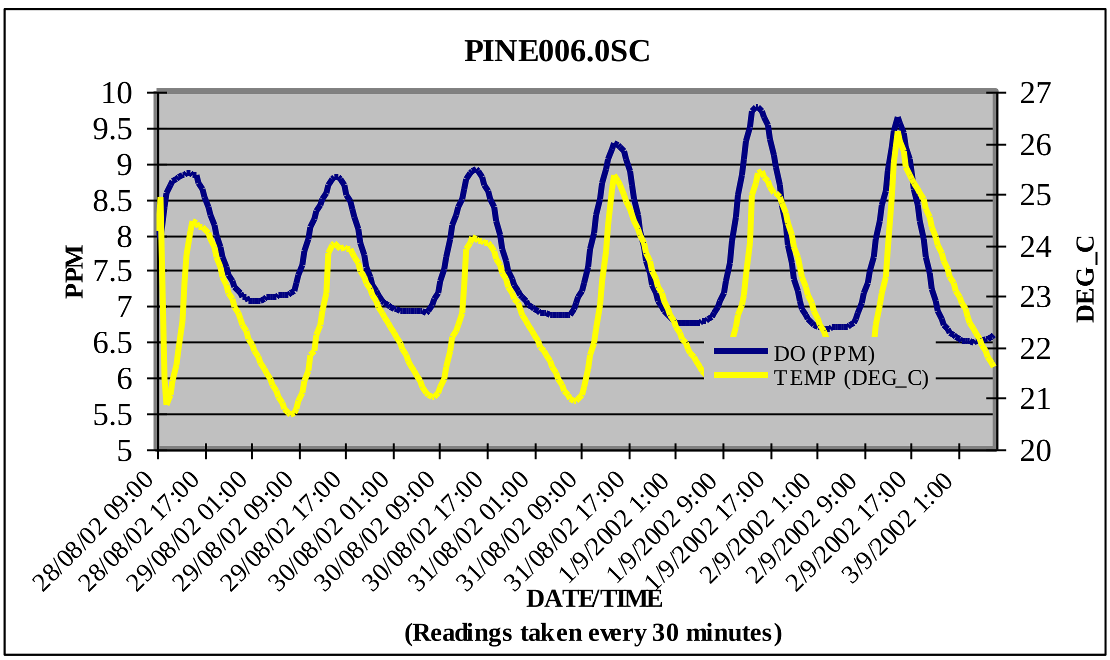


Figure 11: Diurnal dissolved oxygen and temperature data, Pine Creek test site, Cumberland Plateau (68a). Readings every 30 minutes for 142 hours.

A second diurnal dissolved oxygen study was conducted in summer 2004. This study included nutrient sampling, macroinvertebrate collections and periphyton abundance surveys (Arnwine et al, 2005). One of the goals of this study was to characterize periphyton abundance in reference streams where data were not available. Typical background levels of periphyton were estimated for 19 ecological subregions. Periphyton were typically not abundant in reference streams. Ecological subregions in the Interior Plateau generally had the highest densities.

There were two goals for the nutrient data collection. One was to increase the reference database to further test regional goals. The second was to test the reliability of using nitrate probes that could potentially cut monitoring time and analysis costs while providing diurnal nutrient information. The nitrate probes proved unreliable during field testing.

Nutrient Periphyton abundance surveys were also included in the 2004 probabilistic survey of 75 streams below impoundments (Arnwine, et al, 2006). When compared to ecoregion or first order reference sites, about half of the impounded streams had elevated periphyton density. Algae were abundant at more sites in the fall than in the summer probably due to less canopy and lower flow in the fall. More sites had elevated microalgal density than filamentous macroalgae. However, the sites with filamentous algae had more severely impaired macroinvertebrate communities. Macroalgae showed a direct relationship with TKN and percent canopy ($R^2 = 0.71$). There were no measurable correlations with microalgae.

In general, it appears that streams with an abundance of either microalgae or macroalgae affect macroinvertebrate populations in different ways. Microalgae are more likely to shift the population toward a high abundance of a few facultative EPT taxa that filter or collect algae such as *Cheumatopsyche* spp. Sites with an abundance of filamentous macroalgae support an increase in oligochaetes and chironomids. Macroinvertebrate index scores tend to be substantially lower in sites with abundant macroalgae.

Below the impoundments, macroinvertebrate communities were a better indicator of nutrient enrichment than periphyton abundance. At the 71 sites where both macroinvertebrate and periphyton were surveyed, 54% of the sties had elevated total phosphorus. The majority of these sites had failed to meet macroinvertebrate biocriteria while approximately half had elevated periphyton density (Figure 12). All of the sites with elevated nitrate+nitrite failed to meet macroinvertebrate criteria. Half the sites had elevated periphyton density. This supports Tennessee’s decision to use macroinvertebrates as a key indicator of nutrient enrichment in wadeable streams although algal density will continue to be used as a supplemental indicator.

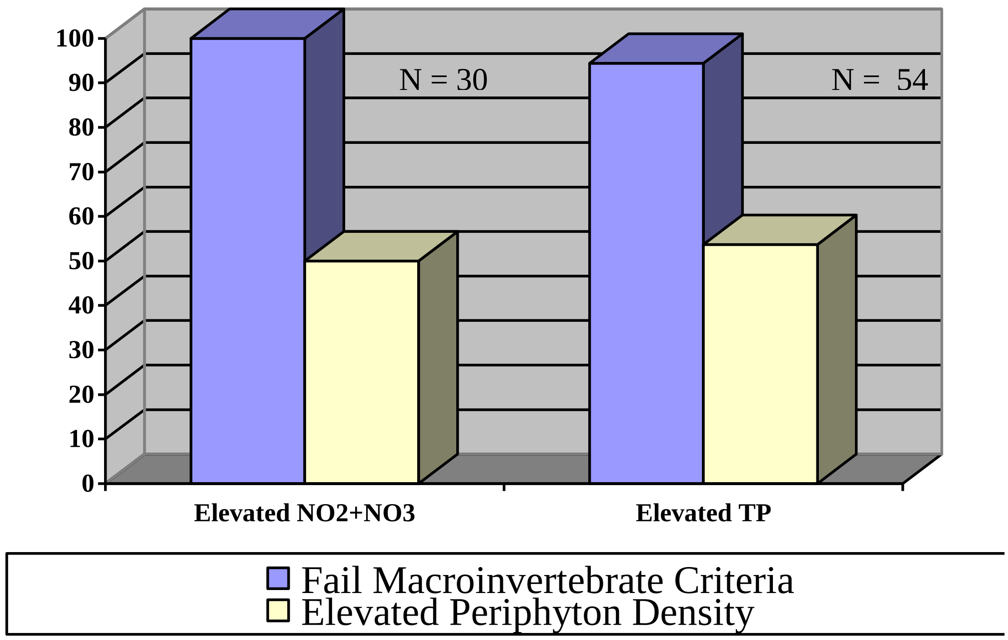


Figure 12: Percent of impounded streams sites failing to meet nutrient and macroinvertebrate criteria and those with dense algal populations compared to reference condition.

In 2005, Tennessee participated in EPA's Southeastern Plains in-stream nutrient and biological response (SPINBR) Study. At the 2005 Periphyton Workshop in Athens, GA Region 4 biologists agreed to a regional approach for developing a diagnostic diatom tool for use in investigating nutrient dynamics in streams. A collaborative project was proposed that included collecting periphyton samples and aquatic nutrient samples from a large number of streams within a common ecoregion in Region 4. The streams were selected from a broad range of impairment conditions so that the relationship of nutrients and periphyton could be analyzed along a gradient of disturbance. The participating parties included biologists from all Region 4 states and from EPA SESD. The ultimate goal of the project is to describe the relationship between human disturbance, periphyton occurrence, and nutrient concentration levels. The Jackson Environmental Field Office collected samples at ten survey sites as part of this study. Dependent on EPA support, Tennessee hopes to continue to participate in this and similar projects.

Ecoregion delineation updates

Tennessee was one of the first states in the southeast to have Level IV subecoregions delineated. The bordering states have now completed the process. Three of Tennessee's existing subecoregions have been further divided into five Level IV ecoregions while the nomenclature has changed on three others. Federal support is needed to update the ecoregion delineations in Tennessee and publish a new map which will match the regional boundary lines and nomenclature in bordering states. This would facilitate data sharing and help the division determine where additional reference data are needed. The estimated cost for this activity is $70,000 to update the maps and $13,000 for printing (Jim Omernik/Glen Griffith).

In ecoregion 66, the Blue Ridge Mountains, four subregions were delineated in Tennessee: 66d (Southern Crystalline Ridges and Mountains), 66e (Southern Sedimentary Ridges), 66f (Limestone Valleys and Coves), and 66g (Southern Metasedimentary Mountains). The area of southeastern Tennessee known as the Copper Basin was included with subecoregion 66g.

Tennessee proceeded to identify and intensively monitor reference streams in each subregion. In 66g, the reference sites were five very high quality streams: the Middle Prong Little Pigeon River, the Little River, Citico Creek, North River, and Sheeds Creek. None of the reference streams for 66g were located in the Copper Basin, an area dramatically impacted by historical copper mining activities.

A few years later, the subecoregions of both North Carolina and Georgia were delineated. At that time, it was noted that areas similar to the Copper Basin appeared in both states. It was decided that these areas were distinct enough to warrant subecoregion status and were called subecoregion 66j, Broad Basins. In addition to the Copper Basin, 66j includes areas around the communities of Hiawassee and Blue Ridge, Georgia, plus Franklin, Canton, and Asheville in North Carolina.

Unlike the other subecoregions in Tennessee, the division does not have a clear sense of what the biological integrity and nutrient goals should be in the Broad Basins. This information will be critical to the state's ability to set clean water goals, especially in light of ongoing restoration efforts in the Copper Basin. Unfortunately, due to the dramatic alterations of the Copper Basin area, suitable reference streams may not be available in Tennessee.

Tennessee has requested EPA assistance, along with our counterparts in North Carolina and Georgia, to help us identify suitable reference streams in subecoregion 66j and to collect data consistent with Tennessee's SOPs for biological surveys and chemical monitoring. (It may be that reference streams have already been established in these areas in Georgia and North Carolina.) Tennessee will perform the analysis of biological samples and will share the information with EPA, Georgia, and North Carolina. Additionally, the division's biologists will seek suitable reference streams in the portion of 66j in Tennessee in the hope that some suitable sites occur outside of the impacted area.

Tennessee would also be available to assist in the reconnaissance of potential sites in conjunction with North Carolina and Georgia. These data would be helpful to all three states in setting nutrient goals.

Until remapping is accomplished it is unknown whether reference streams are located in the other ecological subregions that have been divided. These include another subregion in the Blue Ridge - 66i (High Mountains), two subregions in the Cumberland Mountains – 69d (Dissected Appalachian Plateau) and 69e (Cumberland Mountain Thrust Block) and one subregion in the Mississippi Alluvial Plain – 73b (Pleistocene Valley Trains).

Non-wadeable streams and rivers

Non-wadeable streams and rivers are covered under the general narrative nutrient criteria for fish and aquatic life in the 2004 water quality standards. Now that regional guidelines have been developed for wadeable streams and rivers, Tennessee is beginning to focus on non-wadeable flowing water. Because Tennessee feels strongly that nutrient criteria should consider the cause/effect relationships, biological guidelines for non-wadeable streams will be developed at the same time.

Nutrient and biological guidelines have already been developed for non-wadeable streams contained within the Loess Plains ecoregion (74a) and the Northern Mississippi Alluvial Plain (73a) as part of the wadeable streams criteria development. The division intends to collaborate with other resource agencies in the effort to develop regional guidelines for nonwadeable streams and rivers in other ecoregions. While these guidelines are being developed, the state is taking steps to maintain the quality of these downstream waters. Protection of these waters is accomplished through assessments of headwaters, larger feeder streams and upstream wadeable portions that contribute to the nutrient loading of these larger systems, nutrient monitoring and biological sampling in the nonwadeable portions, TMDL development, coordination with the Tennessee Department of Agriculture for BMPs and the addition of nutrient limits and/or monitoring requirements to pertinent discharge permits.

Individuals with expertise in large river water quality from TDEC, TVA, and EPA have been contacted for review of strategies to develop nutrient and biological guidelines in non-wadeable flowing waters. There are three potential strategies for collecting macroinvertebrates. TDEC currently uses rooted bank samples on smaller non-wadeable rivers in west Tennessee but this may not be sufficient in larger rivers or other areas of the state. TVA uses PONAR grabs and has supplied 10 years of macroinvertebrate data from 18 fixed stations. Seven of these are potentially useful as reference sites. Although an extensive amount of water quality data were collected at these sites in the 1980's and early 90's, limited samples have been collected since then. It is likely this method will prove too labor intensive and costly for the state's assessment program. The large river bioassessment protocols being developed by Joe Flotemersch, EPA are also under consideration. Tennessee intends to participate in the national rivers assessment project and is sending a representative to the planning meeting in January 2007. Participation in this project will help the state determine what protocols are most practical and may provide data useful for establishing baseline conditions in some regions.

One of the difficulties associated with non-wadeable streams and rivers is they often cross Level IV and even Level III ecoregional boundaries. Potential reference reaches in rivers crossing regions 65e and 74b have already been targeted and were monitored as part of a federally funded 104(b) diurnal dissolved oxygen study in 2004 (Arnwine et al, 2005). The reaches selected for study were fully supporting river reaches where existing macroinvertebrate data demonstrated a healthy community, habitat scores were high for the region and water quality data were within acceptable ranges.

Four stations were found to be meeting these guidelines: Hatchie River at mile 80.8, Wolf River at mile 44.4, South Fork Forked Deer River at mile 65.6, and the North Fork Forked Deer River at mile 20.5. These four rivers represent all the major drainages that cross these two subregions, except the Obion and Loosahatchie where potential reference reaches could not be located based on existing data.

The potential reference reaches were monitored for diurnal dissolved oxygen, nutrients, flow, macroinvertebrates, temperature, conductivity and pH. In addition, fluvial geomorphological, canopy and habitat measurements are being taken. For comparison, the same study was conducted at five impaired sites on the Middle Fork Obion, North Fork Forked Deer, South Fork Forked Deer and Loosahatchie Rivers. These sites are also non-wadeable and drain ecoregions 65e and 74b.

Results of the non-wadeable stream monitoring indicated that data were generally not comparable to existing wadeable stream guidelines (Table 8). It is likely that separate biological and nutrient guidelines will need to be developed for these stream types. Additional monitoring will be necessary before this can be accomplished. The division intends to follow up on this as soon as funding and personnel are available for monitoring and laboratory analyses.

Table 8: Comparison of nutrient data from biologically diverse non-wadeable streams in the Southeastern Plains and Hills and the Loess Plains in Tennessee. Data are in mg/l.

	Nitrate+Nitrite (mg/l)	Number of Observations	Total Phosphorus (mg/l)	Number of Observations
65e Guidelines for Wadeable Streams	0.34	42	0.04	42
90^{th} Percentile Non-wadeable 65e Streams with Good Macroinvertebrate Diversity	0.88	9	0.13	9
74b Guidelines for Wadeable and Non-wadeable Streams	1.19	42	0.11	42
90^{th} percentile 74b Non-wadeable Reference Stream (1)	0.32	31	0.31	31
90^{th} percentile Non-wadeable Streams Crossing 65e/74b with Good Macroinvertebrate Diversity	0.64	41	0.28	41

As funding allows, non-wadeable reference reaches will be targeted in other regions. When possible, these will be selected based on existing data. It is hopeful that three to five potential reference sites can be located in each targeted region. Due to the lack of existing data, a minimum of three years of reference stream monitoring will need to be conducted prior to development of preliminary guidelines. (During Tennessee's wadeable stream criteria development process, EPA recommended ten years of data).

If sufficient sites cannot be located based on existing data, field reconnaissance and screening of water quality and biological parameters will be used to supplement existing data. Since TDEC does not currently have staff or funding available for this activity, monitoring and subsequent criteria development in non-wadeable systems will be dependent on federal funds and/or assistance from other agencies. TVA has already indicated that they will not be able to assist due to an agency moratorium on additional monitoring activities.

Ecoregions and groups of ecoregions that will be targeted for non-wadeable reference monitoring will be:

73a	Northern Mississippi Alluvial Plain (completed)
74b	Loess Plains (completed)
65e/74b	Loess Plains draining Southeastern Plains and Hills (One year completed, subsequent monitoring dependent on federal funding)
65e	Loess Plains
71f	Western Highland Rim (TVA fixed station monitoring on Buffalo River)
71f/71h	Western Highland Rim draining Outer Nashville Basin
71h/71i	Outer Nashville Basin draining Inner Nashville Basin
71h/71g	Outer Nashville Basin draining Eastern Highland Rim
71i/71h	Inner Nashville Basin draining Outer Nashville Basin
67fghi	Ridge and Valley (TVA fixed station monitoring and TDEC data are available for the upper Clinch, Powell and North Fork Holston Rivers.) . Note that although the North Fork Holston does not meet recreation uses due to legacy mercury, it supports a diverse benthic community and should not have elevated nutrients.
67g/66e/66g	Southern Shale Valleys draining the Blue Ridge Mountains: TVA fixed station monitoring available from the Hiwassee River.

67f/66g	Southern Limestone/Dolomite Valleys and Low Rolling Hills draining Southern Metasedimentary Mountains (TVA fixed station monitoring on French Broad River)
66g	Southern Metasedimentary Mountains
67f/66e	Southern Limestone/Dolomite Valleys and Low Rolling Hills draining Southern Sedimentary Ridges
66e/66d	Southern Sedimentary Ridges draining Southern Crystalline Ridges and Mountains
68a/69d	Cumberland Plateau draining Cumberland Mountains. (TVA fixed station monitoring data available on the Emory River near Deermont.)

Lakes and Reservoirs

Lakes and reservoirs are covered under the general narrative nutrient criterion for fish and aquatic life established in the 2003 emergency rule and promulgated in the 2004 Water Quality Standards. Tennessee intends to work closely with TVA, USACE, USGS, neighboring states and other agencies to develop more specific reservoir criteria. It is unlikely that Tennessee will choose to adopt EPA's national criteria recommendations for lakes and reservoirs. Instead, for large lakes and reservoirs, the state will seek to develop site-specific goals. The state will review with interest the findings of the national lake and reservoir study. As with nutrient development in wadeable streams, cause and effect relationships will be used.

<u>Natural Lakes</u>

Reelfoot is the only natural lake larger than 250 acres. As mentioned earlier, extensive water quality investigations were conducted at Reelfoot Lake in the 1980s (TDHE, 1984 and Denton, 1987). This lake is already listed as nutrient impaired due to elevated chlorophyll *a* levels and nuisance aquatic plants. The dense stands of aquatic plants interfere with recreational boating.

The majority of smaller natural lakes are in two ecoregions in west Tennessee. Provided suitable reference lakes can be found, it is likely that the ecoregion reference approach will be applicable to develop nutrient criteria for these lakes. Sixteen small natural lakes located in wildlife refuges and state natural areas in these two ecoregions may provide sufficient baseline information. A representation of these lakes will be monitored when staffing and money are available.
<u>Large Reservoirs</u> (> 1000 acres)

As part of the 2006 triennial review of water quality standards, TDEC has adopted nutrient criterion in a reservoir shared with Alabama, contingent on EPA approval. Pickwick Reservoir includes those waters impounded by Pickwick Dam on the Tennessee River. The reservoir has a surface area of 43,100 acres at full pool, 9,400 acres of which are within Tennessee. The criterion states that the mean of the photic-zone composite chlorophyll <u>*a*</u> samples collected monthly April through September shall not exceed 18 µg/l, as measured over the deepest point, main river channel, dam forebay. This was an adoption of Alabama's criteria and do not necessarily reflect how criteria in other reservoirs will be developed. Pickwick was randomly selected as one of the reservoirs included in the National Lakes Assessment and will be monitored in 2007 as part of that study.

For other large reservoirs, there has been a data search and compilation to target data gaps and monitoring needs. The majority of available data has been be provided by TVA and USACE. Data are available on 27 of the 29 reservoirs. There are no current data available on Chilhowee Reservoir, which is managed by Alcoa Alluminum and Woods Reservoir, which is managed by the U.S. Air Force Arnold Engineering Development Center.

TVA conducts vital signs monitoring on 18 of these reservoirs (Dycus and Baker, 2001). Data that may be pertinent to developing nutrient criteria include secchi disc, temperature, pH, DO, conductivity, chlorophyll, nutrients, TOC, benthic macroinvertebrates and fish. These parameters will be used to help determine if there are reservoirs that can be used to establish a reference condition for nutrient enrichment or to develop reservoir specific criterion.

The U.S. Army Corps of Engineers collects the same data, except fish and macroinvertebrates on the seven lakes they manage in Tennessee. They have macroinvertebrate data on five of these lakes. However, sampling techniques are different from TVA and may not be comparable. It is unlikely that TDEC will use fish assemblages since many of these lakes are stocked and do not have ecologically balanced assemblages. Also, previous comparison studies in impaired systems have shown fish tend to be less sensitive to nutrient enrichment than macroinvertebrates.

Tennessee has agreed to participate in EPA's National Lakes survey in 2007 and has been an active participant in the method development and planning phase of this study. Twelve reservoirs have been randomly selected in Tennessee. Participation in the project will help develop reservoir monitoring protocols. It is also possible that data from the national lake and reservoir study will be useful in determining what constitutes a healthy reservoir. Five of the randomly selected reservoirs are over 1,000 acres: Nickajack, Ocoee, Pickwick, Cheatham and Douglas and will help supplement existing information. The other seven reservoirs are under 250 acres.

The data search was completed in 2006 and is currently being reviewed. The time frame for criteria development will be dependent on data availability, sampling needs, the comparability of biological sampling protocols and how much additional sampling can be provided by TVA and USACE. TVA has already indicated they will not be able to assist with additional monitoring outside of their vital signs monitoring. If the state must collect data, federal funding will be necessary and criteria development may be delayed.

Until these preliminary tasks are accomplished, it is uncertain how lakes and reservoirs will be grouped for criteria development. Although the ecoregion framework will be evaluated, it is unlikely that this classification system alone will be adequate for developing criteria especially in the larger reservoirs. Other factors such as retention times, seasonal management, and depth will have to be considered.

Medium Reservoirs (251 – 1000 acres)

Tennessee has 16 impoundments between 251 and 1000 acres. They include three impoundments routinely monitored by TVA as part of their vital signs monitoring program. The data search showed that additional data is needed on the 13 reservoirs not currently monitored by TVA. Federal assistance will be needed for this activity.

Ecoregion boundaries may be a more useful framework for establishing guidelines in these moderately sized systems. Most are contained within a single ecoregion (or even subregion). It is also possible these can be grouped with the smaller lakes.

Lake management will need to be considered, especially the five TWRA lakes in this size category that are routinely fertilized to promote game fish production. It is likely that TDEC will use stream data immediately downstream of the impoundments to establish guidelines to insure protection of both systems.

Once data are available, the parameters that will be evaluated include chlorophyll, secchi readings, turbidity, nutrients, dissolved oxygen and macroinvertebrates. As mentioned previously, fish are considered less appropriate since many of these lakes are stocked and do not have ecologically balanced assemblages. Also, previous comparison studies in impaired systems have shown fish tend to be less sensitive to nutrient enrichment than macroinvertebrates.

Small Reservoirs (250 acres or smaller)

Reservoirs less than 251 acres will be treated separately (unless data show these are similar to the moderately sized impoundments). Tennessee has 1,302 documented reservoirs under 251 acres (Figure 13). They include one TVA reservoir, TWRA fishing lakes, municipal lakes, state parks, city parks, resorts, community developments, farm ponds and private lakes. There are many more that are not referenced in any database.

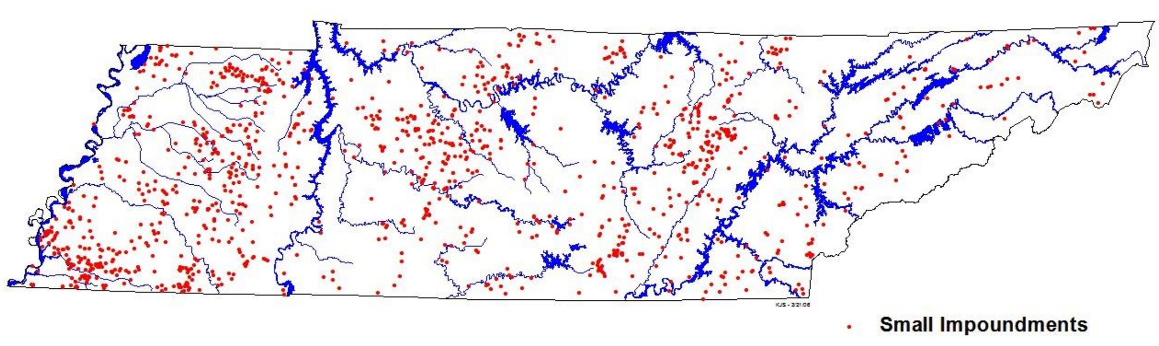


Figure 13: Location of documented impoundments less than 250 acres in Tennessee

None of these small impoundments are routinely monitored although there are some historical data. Although small, these reservoirs are often in headwater areas and have the potential to affect downstream areas. They are generally contained with a single ecological subregion and this approach may be use useful for assessment providing suitable references can be found. There are 36 small reservoirs on protected lands (state natural areas, state parks, national forest, state forest, state historic area, national wildlife refuge) that could be monitored to determine if this approach is feasible for establishing baseline conditions (Figure 14).

These reservoirs occur in 15 ecological subregions that represent all bioregions except the Transition Hills (65j), the Cumberland Mountains (69d), the Sequatchie Valley (68b) and the Mississippi Valley Alluvial Plain (73a). Only two percent of the documented reservoirs in the state have been constructed in these four regions Although ecoregion guidelines may be useful, there may need to be additional groupings based on type of reservoir. It is also possible that an emphasis on downstream impacts, especially in the smaller impoundments, will prove more appropriate,

Two of these reservoirs, have been selected for monitoring as part of the National Lake's Assessment. They are Lake Woodhaven in Montgomery Bell State Park (Ecoregion 71f) and Burgess Falls Lake in Burgess Falls State Park (Ecoregion 71g). The data from Lake Woodhaven may be useful for evaluating background levels, but the Burgess Falls Lake is heavily silted in.

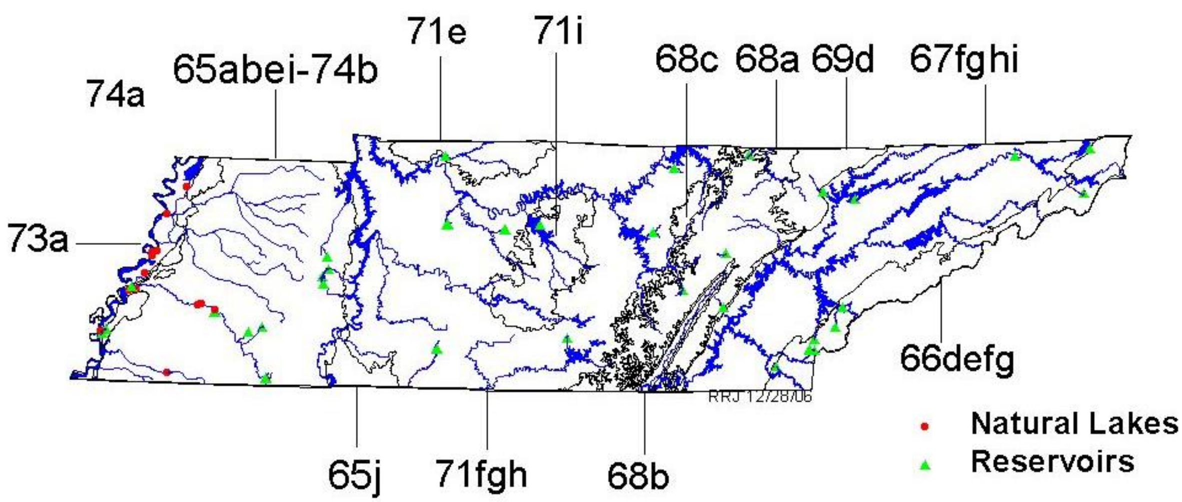


Figure 14: Location of small lakes and reservoirs located on protected lands in Tennessee

If additional federal funding is available, these impoundments as well as downstream reaches will be monitored for three years to establish nutrient levels that support designated uses. Additional impoundments will be selected based on review of existing biological data of downstream reaches and field reconnaissance for any large ecoregions where suitable impoundments were not located during the probabilistic study. Selection of suitable impoundments for nutrient criteria development will be based primarily on downstream biotic assemblages. Ideally, three to five impoundments will be targeted in each bioregion (15). Impoundment monitoring will include, at minimum, nutrients, turbidity, secchi reading, macroinvertebrates, chlorophyll, temperature and dissolved oxygen. The same parameters will be measured downstream of the impoundment. The large reservoir work-group will be asked to review the small to medium impoundment strategy as it is developed.

In 1991, the Division conducted a survey of forty selected lakes and reservoirs throughout the state as part of the Clean Lakes Program (Hansel et al, 1992). This was a continuation of a survey conducted in 1980. Thirty-three of the sites were impoundments less than 250 acres. The Carlson Index was used to determine trophic status. Sixty one percent of the small impoundments were either eutrophic or hypereutrophic. Of these, only two showed improvement from an earlier survey conducted in 1980. Five years later a survey was conducted on 13 TWRA and two municipal managed lakes (Arnwine, 1996). All but one of the lakes in the 1996 study were either eutrophic or hypereutrophic.

Although they are small, these reservoirs are often in headwater areas and have the potential to affect downstream reaches. As part of a 104(b)(3) probabilistic study, Tennessee is monitored the downstream reaches of 75 small reservoirs across the state. The report was published in September 2006 (Arnwine et al). Only four of the streams passed biological criteria downstream of the reservoirs. Eighty-four percent had elevated levels of total phosphorus and/or nitrate+nitrite at least one season sampled (Figures 15 and 16).

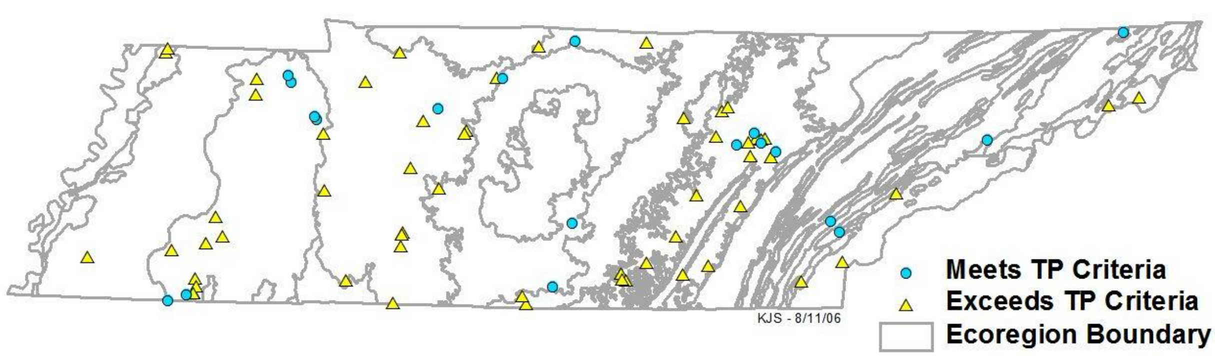


Figure 15: Location of impounded test sites with total phosphorus concentrations above regional guidelines.

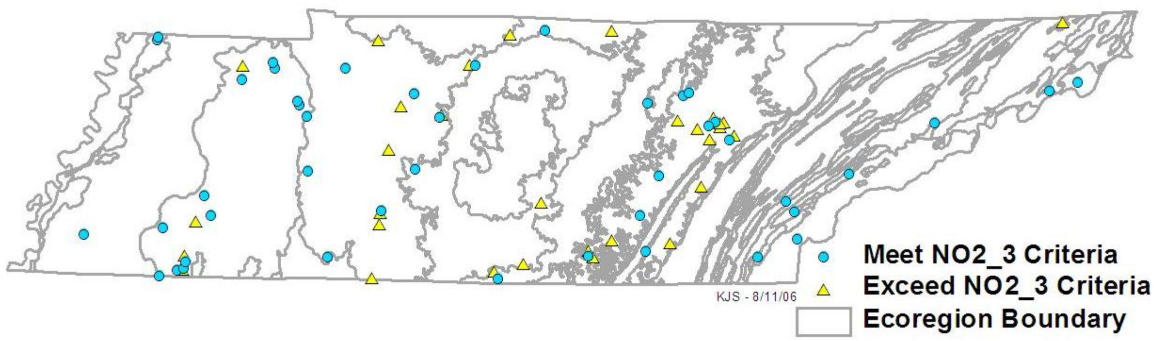


Figure 16: Location of impounded test sites with nitrate+nitrite concentrations above regional guidelines for one or more seasons.

Wetlands

Like reservoirs, wetlands are covered under the emergency nutrient rule in 2003 and were promulgated in the 2004 Water Quality Standards.. At this time, the division is uncertain what approach might be best for nutrient criteria development for wetlands. It may be possible to select reference quality wetlands based on wetland functions. The division is currently reviewing EPA's December 2006 draft guidance. Once the guidance is finalized, the Planning and Standards Section will work with the Natural Resources Section to develop a plan. Due to lack of state funding, federal assistance will be needed to implement wetland criteria development.

VI. PUBLIC PARTICIPATION AND PEER REVIEW PROCESS

In general, public participation for nutrient criteria development is conducted as part of TDEC's rule revision/adoption process. This involves public notices, public hearings and receiving comments from the public regarding the proposed changes to the rules.

All findings are published and made available to the public through the department's web site, mailings and various public meetings. Additionally, many of our publications are housed at the 13 state document repositories. These repositories include the state library and archives, state university, and public libraries.

When funding for travel is available, TDEC staff present findings and papers to professional organizations. In the past, presentations have been given at meetings such as the Region 4 Regional Technical Advisory Group (RTAG), the TNAWRA (Tennessee Section of the American Water Resources Association), SWPBA (Southeastern Water Pollution Biologists Association) and NABS (North American Benthological Society).

TDEC is considering forming a reservoirs workgroup for the purpose of gathering input and peer review from individuals who have expertise in limnology, reservoir management and other fields related to nutrient criteria development. The group will most likely be composed of representatives from TVA, USACE, TWRA, academia and TDEC. A similar work-group will be developed for large rivers.

TDEC has dedicated time and staff to actively participate as a state member of the EPA Region 4 Regional Technical Advisory Workgroup (RTAG).

VII. TIMELINE

This timeline outlines the steps TDEC has taken since 1995 as well as future goals in nutrient criteria development. The plan is resource intensive and represents only a small portion of staff responsibilities. This plan is dependent on availability of additional federal resources being provided to the state. Due to budget constraints, changes in priorities, or personnel availability, plans may not progress on schedule.

This timeframe presents the ideal process and is dependent on additional federal funding. Obviously, future activities are subject to revision.

1995

Initiation of ecoregion delineation and reference stream targeting.

Initial field reconnaissance of potential reference streams.

1996

Intensive reference stream monitoring.

Monitoring of 15 moderate size lakes as part of the clean lakes program.

1997

Intensive reference stream monitoring.

1998

Intensive reference stream monitoring.

1999

Intensive reference stream monitoring ends. (Monitoring continues in conjunction with the 5-year watershed cycle.)

TDEC staff members Denton and Wang participate in national workgroup for development of nutrient criteria for rivers and streams.

2000

Publication of *Tennessee Ecoregion Project* (Arnwine et al, 2001).

Data reduction for regional nutrient criteria development of wadeable streams and rivers.

Data reduction of macroinvertebrate data for development of regional biological criteria

Publication of EPA national nutrient criteria document for rivers and streams. Document contains a case study from Tennessee.

2001

Probabilistic study of 50 streams in the Inner Nashville Basin initiated.

Publication of *Development of Regionally-Based Interpretations of Tennessee's Narrative Nutrient Criterion* (Denton et al, 2001).

Publication of *Development of Regionally-based Numeric Interpretations of Tennessee's Narrative Biological Integrity Criterion* (Arnwine and Denton, 2001).

Staff proposal for initiation of triennial review process. Promulgation of numeric nutrient and biological integrity criteria recommended.

2002

Continuation of probabilistic study with added emphasis on nutrient and macroinvertebrate relationships.

Continuation of triennial review process for nutrient and biological criteria.

2003

Rulemaking process is initiated for water quality criteria revisions.

Emergency narrative nutrient criteria is promulgated by the Board, then approved by EPA.

Based on EPA and public concerns, nutrient criteria and biological integrity proposal is changed from numeric to narrative with numeric guidelines referenced.

Promulgated rulemaking hearing rules, including narrative nutrient criteria for protection of fish and aquatic life and recreation in all types of waterbodies is submitted to EPA for approval.

Publication of *Probabilistic Monitoring in the Inner Nashville Basin with Emphasis on Nutrient and Macroinvertebrate Relationships* (Arnwine et al, 2003).

Publication of *Nutrient Levels, Periphyton Densities and Diurnal Dissolved Oxygen Patterns in Impaired and Reference Quality Streams in Tennessee* (Arnwine and Sparks, 2003).

Initiation of probabilistic monitoring of 75 streams below small impoundments.

2004

New water quality standards, including narrative nutrient criteria referencing regional guidelines and revised biological criteria, become a state regulation.

Nutrient criteria development plan drafted and submitted to EPA for comments.

EPA approves water quality standards including narrative nutrient criteria for all waterbodies with regional guidelines for wadeable streams as well as the biological criteria, which are referenced in nutrient criteria. EPA takes no formal action on the proposed flow basis for application of nutrient criteria.

Initiation of new diurnal dissolved oxygen, periphyton, and nutrient study. New project includes study of non-wadeable streams in two ecoregions.

Completion of monitoring for probabilistic study of streams below small impoundments.

Revised nutrient criteria document resubmitted to EPA.

2005

Retrieval and compilation of existing data for large reservoirs and non-wadeable rivers. Obtained existing data from TVA and USACE. Identified data gaps.

Chemical and physical data evaluation on probabilistic monitoring below small impoundments.

Published report on Regional Characterization of Streams in Tennessee with Emphasis on Diurnal Dissolved Oxygen, Nutrients, Habitat, Geomorphology and Macroinvertebrates (Arnwine et al, 2005). Used dissolved oxygen study to help characterize background nutrient levels and target reference reaches in non-wadeable streams in west Tennessee.

Attended EPA periphyton Workshop in Region 4.

Attended large river monitoring workshop at Southeast Water Pollution Biologists Association meeting in Mississippi.

2006

Biological data evaluation on probabilistic monitoring below small impoundments and publication of report characterizing the effects of small impoundments on nutrient levels, biota, and other factors (Arnwine et al, 2006).

Promulgated nutrient response criterion for Pickwick Reservoir based on Alabama criterion. Pickwick Reservoir: those waters impounded by Pickwick Dam on the Tennessee River. The reservoir has a surface area of 43,100 acres at full pool, 9,400 acres of which are within Tennessee. Chlorophyll a (corrected, as described in *Standard Methods for the Examination of Water and Wastewater, 20th Edition*, 1998): the mean of the photic-zone, composite chlorophyll a samples collected monthly April through September shall not exceed 18 µg/l, as measured over the deepest point, main river channel, dam forebay.

Participated in planning phase of National Probabilistic Monitoring of Lakes and Reservoirs Study. Attended planning meeting, numerous conference calls and reviewed study plans. Performed reconnaissance of 24 reservoirs to determine suitability for study.

Participated in regional study sponsored by EPA to study in-stream nutrient and biological response in the Southeastern Plains (ecoregion 65). Monitored nutrients and periphyton at ten survey sites along a disturbance gradient. In 2005, Tennessee participated in EPA's Southeastern Plains in-stream nutrient. Tennessee hopes to continue to participate in this project.

Identified small lakes and reservoirs on protected lands as potential sources of baseline data to develop nutrient criteria on small lakes and reservoirs.

Added percent nutrient tolerant organisms to multi-metric macroinvertebrate index for wadeable streams to increase sensitivity of index to nutrient and sediment impacts.

2007

Compiled data from large and medium reservoirs. Is in the process of forming interagency work group to discuss options for criteria development based on existing data.

Participated in national probabilistic lake monitoring study by sampling 12 lakes.

Looked, without success, for funding sources for monitoring of small lakes and reservoirs on public lands to establish baseline.

Paticipated in planning stage of probabilistic study of the Nation's Large Rivers. Participated in biocriteria and reference condition workgroups.

Compiled existing non-wadeable stream and river data. Reviewed existing data to determine additional monitoring needs on large rivers.

Began monitoring of periphyton in reference streams and probabilistic monitoring streams for potential development of wadeable stream index. (Although sampling was done with existing staff, analyses of samples will be dependent on outside funding).

2008

Monitor large and medium reservoirs to fill data gaps if needed and assistance is provided.

Begin monitoring reference reaches of large rivers (dependent on funding)

Begin monitoring small to medium reservoirs on public lands including downstream reaches (dependent on federal funding or help from other sources). Enlist help of TWRA, state parks and municipalities if possible.

Participate in monitoring phase of probabilistic study of Nation's Large Rivers.

Review findings of National Lake and Reservoir Survey. Consider development of criteria for large reservoirs with adequate existing data.

Review EPA criteria develop guidance for wetlands**.** Begin plan development (implementation of plan will be contingent on federal funding).

2009

Continue monitoring reference reaches of large rivers and small impoundments (dependent on funding)

Continue monitoring of large and medium reservoirs to fill data gaps if needed, (dependent on outside assistance or funding). Consider recommendation of criteria for large reservoirs with sufficient existing data dependent on findings of national lake and reservoir survey.

Continue small impoundment monitoring (dependent on funding). Enlist help of TWRA, state parks and municipalities if possible.

2010

Continue monitoring reference reaches of large rivers and small impoundments (dependent on funding)

Continue monitoring of large and medium reservoirs to fill data gaps if needed, (dependent on outside assistance or funding).

Continue small impoundment monitoring (dependent on funding). Enlist help of TWRA, state parks and municipalities if possible.

2011

Complete data analysis and evaluation of small, large and medium reservoir monitoring. Draft nutrient and biological guidelines for large reservoirs (and possibly chlorophyll or other related criteria if warranted based on data).

Complete data analysis and evaluation of large river monitoring data. Draft nutrient and biological guidelines for large rivers.

Complete data analysis and evaluation of small impoundments . Draft nutrient and biological guidelines.

2012

Initiate next triennial review of water quality standards, including nutrient and biological criteria for natural lakes, small, medium and additional large impoundments and non-wadeable rivers. Consider move from numeric translators to numeric criteria for wadeable streams depending on continued ability to incorporate biological response indicators, the functionality of criteria for TMDLs and EPAs progress toward clarification of implementation in permits.

VIII. NEEDS ASSESSMENT FOR TENNESSEE'S NUTRIENT CRITERIA DEVELOPMENT PROGRAM

Tennessee has traditionally had a strong water quality monitoring, assessment and criteria development program. In the last seven years, water quality monitoring and related activities have increased by more than 400%. New procedures such as diurnal, dissolved oxygen monitoring, rapid periphyton surveys and probabilistic monitoring have been used to supplement targeted biological and water quality monitoring.

Despite the increase in water quality activities, there has not been an increase in staffing during this period. In 1998 through 2006, 94 personnel were assigned in whole or part to water quality monitoring and assessment activities (including both technical and support staff). The increased ability to conduct monitoring, assessments and criteria development without a net increase in the number of positions has been a result of standardization of methods, replacing intensive surveys with rapid field techniques, improved technology and shifting priorities from other programs. Approximately $3.7 million, ($1.5 million federal) were allocated to cover salaries and benefits to support this program in 1998. The costs had risen to $5.06 million in 2004 for the same number of staff. Another $2.05 million is spent on travel, printing, utilities, communications, maintenance, professional services, supplies, rent, insurance, vehicles and equipment in support of this program.

The funding necessary to maintain the current program has also risen steadily. This is due to rising lab expenditures from increased sample collections, use of lab personnel for field support and rising analytical costs. The amount spent on laboratory activities has more than doubled from $0.6 million in 1998 to $1.52 million in 2003.

As always, the division is interested in improving its water quality assessment program and serving the public by protecting the waters of Tennessee. It is evident that Tennessee already spends a great deal of time, effort and money on water quality monitoring. However, a significant funding gap does exist if EPA requirements and guidance for nutrient criteria development are to be met. Without a steady source of federal funding **in addition** to current funding, it is not likely that the monitoring needed for nutrient criteria development and assessment for non-wadeable rivers, reservoirs or lakes will be feasible.

Additional staffing and funding must be permanent and not in the form of competitive or temporary grants to expand programs. TDEC is not expecting additional funding from other sources for these activities over the next ten years. As mentioned previously, it does not appear that TVA will be able to provide as much monitoring support as anticipated due to an agency moratorium on additional monitoring. Therefore, federal funding increases would be vital for implementation of all or part of the nutrient criteria goals. The following outlines the staff, equipment and additional federal funding that would be necessary to implement a criteria development, monitoring and assessment plan for rivers and reservoirs.

Personnel costs are based on average year expenses per full-time employee and includes salary, , benefits, travel, printing, maintenance, professional services, supplies, rent and insurance, vehicle operation, equipment and services.

Indirect costs are listed separately at the FY 2007 rate of 23% (rate is recalculated annually). Laboratory analyses are based on the FY 2007 pricing list provided by the Environmental Laboratories, Tennessee Department of Health.

The estimated costs would include a full reservoir and large river water quality program including criteria development, monitoring in support of criteria development as well as 305(b) and 303(d) assessments, TMDLs and data management. Activities would continue to be coordinated with other agencies performing reservoir and river monitoring to share resources and to prevent duplication of efforts.

Additional Annual Funding needed: $ 1,395,000
Plus $160,000 one time purchase for equipment to start program.
Plus $73,000 one time funding for update of ecoregion delineation and publish revised map.

Additional Field Staff needed:	16 biologists (two in each of eight field offices) Staff would be used to increase percentage of watershed assessments for 305(b) reports after nutrient criteria development.
Additional Central Office Staff:	Biologist in Planning and Standards Section (criteria development, monitoring coordination, data processing, data management, mapping, water quality assessments)

Laboratory analysis = $450,000 per year (with approx. 5% annual increase)

Equipment Needs = $160,000 (one time costs)

3 large boats and 3 canoes/jon boats (to be shared by field offices in each of the 3 main regions of the state, 5 multiparameter probes with 25 meter cable for temperature/DO profiles, 5 field filter apparatus for chlorophyll samples, Fluorometer for cholophyll analysis to be used by central laboratory, block digester and flow injection analyzer for nutrient analysis

In addition to staffing needs, Tennessee would also like assistance in developing a monitoring design and statistical interpretation of results specifically for reservoirs and large rivers.

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APPENDIX A

Division of Water Pollution Control Responses to EPA Comments

EPA Comment: Comparison of the state's proposed level IV ecoregion nutrient criteria to the national ecoregional criteria recommendations indicates that the state proposed levels are generally substantially in excess of the national recommendations.

We do not believe that a direct comparison of the state's subregional (Level IV) nutrient data to the national Level III ecoregion data is appropriate. Many of the data from the Level IV subregions are statistically different from the larger Level III ecoregion at the state level. The national database contains subregions not even found in Tennessee. Our Level III ecoregions were delineated into subregions in order to provide this more accurate and localized assessment process.

Additionally, EPA's National Database included data from large rivers and non-wadeable streams that cross Level IV ecoregion boundaries. The state reference database was restricted to wadeable streams that had at least 80% of the upstream drainage included within the targeted subregion. Therefore, the state data are much more refined and indicative of local conditions and stream size. Tennessee plans to develop separate guidelines for large rivers and non-wadeable streams that are more pertinent to these systems.

Tennessee's regional nutrient guidelines for wadeable streams are based on nine years' data (1995-2003), roughly the same spread of years as EPA's national study. Tennessee's use of reference streams at the level IV (ecological subregion) follows EPA's recommendation that State's develop localized criteria whenever possible.

EPA Comment: In the Sequatchie Valley (68b) the nitrate +nitrite and TP proposals are higher than the recommendation for the Southwestern Appalachians.

The Sequatchie Valley is a very small and unique area found only in Tennessee and Alabama. It is considerably different than the other areas of the Southwestern Appalachians. In fact, the Sequatchie Valley is sometimes considered part of ecoregion 67, the Ridge and Valley (Griffith, 1997).

Both TP and NO2+NO3 levels data in 68b were significantly different from subregions 68a and 68c, the other two areas of the Southwestern Appalachians in Tennessee. It is unlikely that it was well represented in the national database compared to the amount of data from the rest of the Level III ecoregion, which also includes subregions not found in Tennessee.

EPA Comment: In the Southern Igneous Mountains and Ridges (66d) nitrate+nitrate proposal is higher than national recommendation for the Blue Ridge. The subregion has a much larger area in NC.

The proposed total phosphorus criterion in this region was in line with the national recommendations for the Blue Ridge Mountains. The proposed NO2+NO3 levels were higher than the national criterion. This is not surprising since this subregion tested significantly different from the other three Blue Ridge subregions in Tennessee for this parameter.

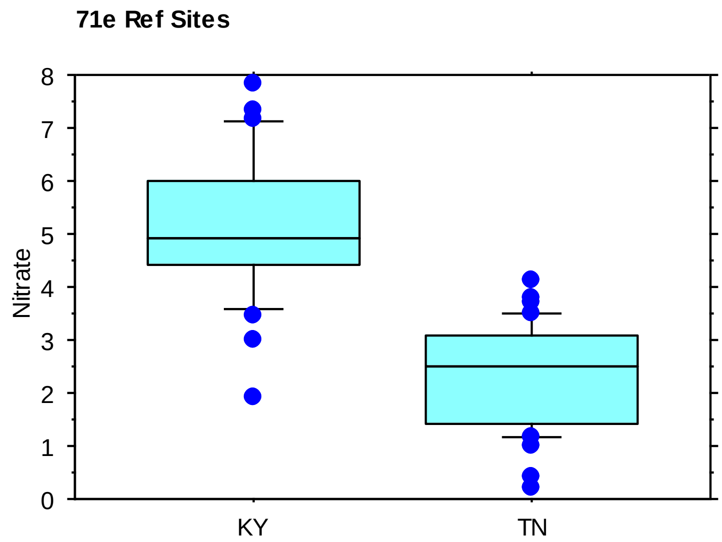
The five ecoregion reference sites in this region are all on protected lands in the Cherokee National Forest or Roan Mountain State Park. Land use is 92-100% forested upstream of the reference sites so it is likely the NO2+NO3 levels measured at these sites represent natural background conditions.

EPA Comment: In the Inner Nashville Basin (71i) TP proposal is higher than national recommendation for Interior Plateau.

The Inner Nashville Basin is unique to Tennessee. The total phosphorus levels are not comparable to any of the other regions in Tennessee and should not be compared to the entire Interior Plateau on a national level. This region is naturally high in phosphorus. Tennessee has data from seven reference sites (105 samples) representing four major watersheds in this region so the background phosphorus levels are well documented.

EPA Comment: In the Western Pennyroyal Karst (71e) nitrate+nitrite is higher than the national recommendation for the Interior Plateau. This subregion is mostly in Ky.

This region only occurs in Kentucky and Tennessee. Background NO2+NO3 levels are naturally very high in this region and should not be compared to the rest of the Interior Plateau (Level III). In response to EPA's concerns, Kentucky reference data were compared to Tennessee's data to verify the high levels of nitrates being observed in reference streams (Figure 17). Kentucky data were higher than Tennessee's. We believe that this information supports the proposed criteria levels, since this region occurs in no other states.



71e Ref

	Nitrate, Total	Nitrate, KY	Nitrate, TN
Mean	3.498	5.146	2.280
Std. Dev.	1.858	1.381	.965
Std. Error	.227	.256	.159
Count	67	29	37
Minimum	.190	1.930	.190
Maximum	7.830	7.830	4.110
# Missing	1	0	1
Median	3.150	4.920	2.520

Results for totals may not agree w ith results for individual cells because of missing values for split variables.

Percentiles
Split By: State

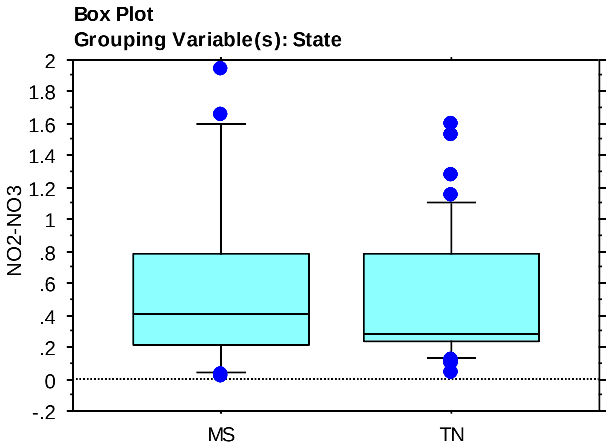
	Nitrate: Total	Nitrate: KY	Nitrate: TN
10	1.332	3.566	1.176
25	1.935	4.428	1.430
50	3.150	4.920	2.520
75	4.750	5.998	3.087
90	6.102	7.140	3.480

Results for totals may not agree w ith results for individual cells because of missing values for split variables.

Figure 17: Comparison of nitrate (KY) and nitrate+nitrite (TN) levels at reference streams in Ecoregion 71e. Note: TN is nitrate+nitrite

EPA Comment: In 74b, the Mississippi Valley Loess Plains nitrate+nitrite proposal is higher than national recommendation for Mississippi Valley Loess Plains, considerably larger area in Mississippi.

Nitrate+nitrite levels in this subregion were significantly higher than the only other 74 subregion in Tennessee (74a – Bluff Hills). Therefore the values for Tennessee should only be compared to data in 74b not the entire Level III ecoregion. The national database included larger rivers that crossed ecoregions. In response to EPA's comments, the NO2+NO3 data from 74b reference streams in Tennessee were compared to those in Mississippi where this region is considerably larger (Figure 18). Ranges were comparable with the median levels in Tennessee reference streams being lower indicating the proposed criteria are appropriate.



Descriptive Statistics
Split By: State

	Mean	Std. Dev.	Std. Error	Count	Minimum	Maximum	Median
NO2-NO3, Total	.514	.455	.061	55	.020	1.940	.320
NO2-NO3, MS	.579	.555	.139	16	.020	1.940	.405
NO2-NO3, TN	.487	.412	.066	39	.040	1.600	.280

Results for totals may not agree with results for individual cells because of missing values for split variables.

Percentiles
Split By: State

	NO2-NO3: Total	NO2-NO3: MS	NO2-NO3: TN
10	.120	.040	.128
25	.240	.210	.240
50	.320	.405	.280
75	.787	.785	.787
90	1.150	1.596	1.102

Results for totals may not agree with results for individual cells because of missing values for split variables.

Figure 18: Comparison of nitrate+nitrite levels of Mississippi and Tennessee reference streams in the Mississippi Loess Plains

EPA Comment: In 67g, the Southern Shale Valleys, the TP proposal is higher than national recommendation for Ridge and Valley.

Total phosphorus data in the Southern Shale Valley subregion were statistically different from the other three Ridge and Valley subregions in Tennessee. Since the national database is an aggregate of data from all subregions in the Ridge and Valley ecoregion, it should not be directly compared to this distinct subregion.