DEVELOPMENT OF REGIONALLY-BASED INTERPRETATIONS OF TENNESSEE'S NARRATIVE NUTRIENT CRITERION

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Development of Regionally-Based Interpretations of Tennessee's Narrative Nutrient Criterion

A Criteria Development Document
Prepared for the

Tennessee Water Quality Control Board

by

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I. Acknowledgements

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The staff of the Department's regional environmental assistance centers (EACs) collected most of the data documented in this report. The managers of the Water Pollution Control staff in these offices are:

Terry Templeton	Memphis EAC
Pat Patrick	Jackson EAC
Joe Holland	Nashville EAC
Phil Stewart	Chattanooga EAC
Paul Schmierbach	Knoxville EAC
Andrew Tolley	Johnson City EAC

Additionally, staff of the Tennessee Department of Health's Environmental Laboratories spent hundreds of hours processing chemical and biological samples for this project. The Division of Water Pollution Control gratefully acknowledges their contributions.

II. Executive Summary

According to the Division of Water Pollution Control's 2000 305(b) Report, a significant number of impacted stream miles in Tennessee are due to pollutants for which criteria are based on narrative statements. The existing water quality standards do not provide much guidance concerning how these narrative statements should be applied. One of the most important causes of impairment is nutrients.

The purpose of this study was to develop guidance for interpretation of nutrient data based on regional reference data. These data, collected primarily from 1996 to 1999, consist of chemical, physical, and biological samples collected in least-impacted, yet representative streams in each subecoregion across the state. These streams serve as reference systems for each subregion.

Data from these reference systems provide a scientifically defensible method for regional interpretations of the existing statewide narrative criteria for nutrients. Once identified, the Division proposes to recommend that these interpretations be formalized into the General Water Quality Criteria.

Total phosphorus and nitrate+nitrite data from reference streams were compiled into databases. We used several different approaches for analyzing these data.

First, the Division analyzed the data for relationships between other parameters and nutrients levels at reference streams. Somewhat weak relationships between total organic carbon and turbidity were documented with total phosphorus levels.

Secondly, we analyzed the databases to compare nutrient concentrations from one subecoregion to another. Standard statistical methods were used to determine which of the subregions were distinct and which were not. Criteria were considered appropriately developed on a subecoregional level, but only if the databases were distinct.

Since the question was likely to be raised about the connection between biological stream health and nutrient concentrations, the relationship was explored with both reference stream data and the results of a 2000 survey of randomly selected monitoring stations in the Inner Nashville Basin. A curved-response relationship was also noted between two biological indices and nitrate+nitrite levels in reference stream data.

Very few associations between biological communities and nutrient levels were identified in the Inner Nashville Basin streams except for a very weak association between nutrients and EPT genera (aquatic insects in the generally pollution sensitive orders Ephemeroptera, Plecoptera and Trichoptera). Multiple regression analysis indicated it was the grouping of pollutants, including nutrients, which led to stream impairment.

Next, the Division compared the 75th percentiles of the reference stream databases to EPA's National Nutrient Databases at the 25th percentile.

According to EPA, the range established by these two levels is appropriate for criteria setting (USEPA, 2000). We found a significant amount of correlation between the two levels. Our findings help validate the theoretical basis for the approach advocated in EPA guidance.

Additionally, in one subecoregion (71i, Inner Nashville Basin), we compared the reference nutrient database to data collected at randomly selected stations. The purpose of this comparison was to determine if additional reference streams could be found randomly and to document the correlation between the reference stream database at the 75th percentile to the probabilistic database at the 25th percentile. Four additional streams of reference quality were found randomly and were added to the database. Nutrient data ranges between these two databases were more similar than dissimilar.

Lastly, we field-tested potential criteria levels against the randomly collected data in 71i. Potential criteria levels evaluated were the 75th and 90th percentiles of the databases. The 75th percentile of the nitrate+nitrite database was the most accurate at predicting the results of biological surveys. However, use of the 75th percentile resulted in identification of more streams as impacted than were identified by application of the proposed biocriteria levels. Thus, a 75th percentile criteria was considered overly conservative.

Based on the results of our research, we selected the 90th percentiles of the nutrient databases as the appropriate level for goal setting. Data were aggregated back to the ecoregion level when the differences in nutrient levels between subecoregions were not significant. Goals were established at the subecoregion level where the nutrient levels within subecoregions were significantly different.

Section X provides a table listing the recommended criteria levels for both total phosphorus and nitrate+nitrite. Recommendations on how the criteria should be applied are also presented in Section X. Some of the more important recommendations are:

- Subecoregional nutrient criteria should only apply to streams wholly contained (80 percent or greater) within the subecoregion. The criteria should not apply to lakes or wetlands. For these waters, the statewide narrative criterion would continue to apply.

- Nutrient criteria, if adopted, should have a different flow basis than do other fish and aquatic life criteria. Following a review of EPA guidance, we have recommended a 30Q5 flow. Additionally, the criteria should be applied as a monthly average limit.

- In streams with a 30Q5 of zero, it may be difficult for new or expanded dischargers to meet the proposed criteria at the end of the pipe. Alternatives to direct discharge may need to be explored in these cases.

- Violations of nutrient criteria should not overrule a finding that the stream has a healthy benthic community. In our view, biological integrity is the ultimate measure of fish and aquatic support.

III. The Need for Regional Interpretations of the Existing Narrative Nutrient Criterion

Water quality criteria are either numeric or narrative descriptions of the quality of water needed to support each of the seven designated uses in Tennessee.

Much attention has historically been given to the development of criteria for toxic substances such as metals and carcinogens. Many of these toxic substances were the so called “priority pollutants.” However, there are additional pollutants for which specific national criteria have never been developed. These pollutants include suspended solids, nutrients, loss of biological integrity, and habitat alteration.

The graph below illustrates the relative contributions of various pollutants causing stream impairment in Tennessee, according to the 2000 305(b) Report. The table in the opposite column provides the number of stream miles in Tennessee impacted by pollutants with only narrative criteria.

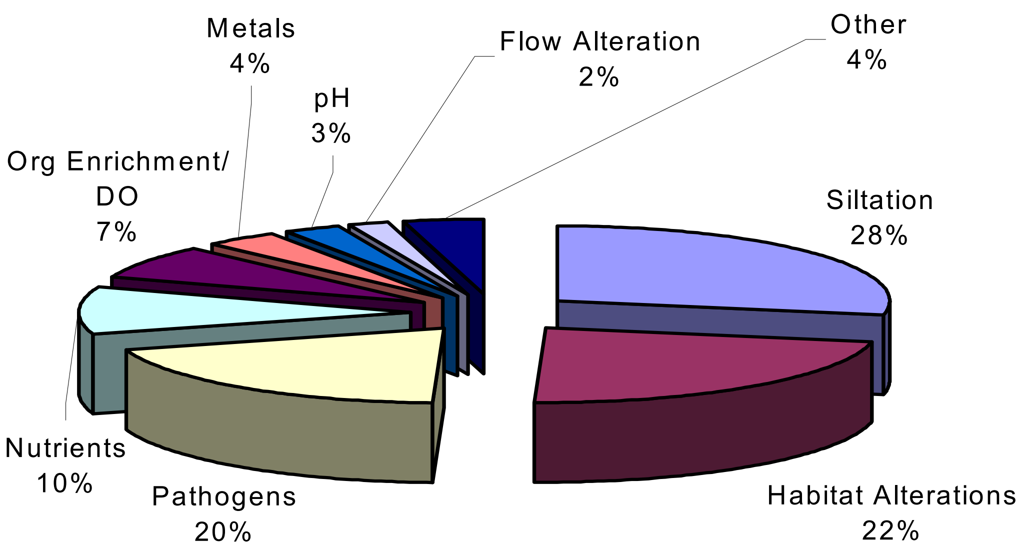
STREAM MILES ASSESSED AS IMPACTED BY POLLUTANTS WITH ONLY NARRATIVE CRITERIA

Siltation	4,163.5
Habitat Alteration	3,297.2
Nutrients	1,534.7

Source: 2000 305(b) Report

In Tennessee, these substances are the pollutants in a significant percentage of the impacted streams. (Loss of biological integrity is not currently specifically listed as a cause of impairment since it is more specifically an effect, rather than a pollutant.)

RELATIVE CONTRIBUTIONS OF POLLUTANTS CAUSING IMPACTS TO STREAMS



Given the number of streams impacted by pollutants with only narrative criteria, these problems are likely to be amplified in the future. For example:

- The “one-size-fits-all” statewide criteria approach provides stability, but lacks regional flexibility. Statewide criteria could be clearly overprotective in parts of the state, but arguably underprotective in other areas.

- Narrative criteria are based on a verbal description of water quality, rather than a number. Thus, they provide flexibility but can cause application problems because they lack an objective means to account for regional differences. For example, east Tennessee mountain streams are naturally very low in nutrients, while streams in middle Tennessee flow through geologic formations very high in phosphorus. Certainly, narrative criteria must take these regional differences into account in order to be appropriate.

- Tennessee has converted to a watershed approach. Without a sense of regional variability in water quality, there was a distinct disadvantage in goal setting for these watersheds.

- The rigors of 303(d) listing and TMDL development required an accurate local interpretation of Tennessee’s narrative water quality criteria. The possibility of legal challenges by citizens and members of the regulated community required that assessments be accurate and defensible.

- TMDLs will need to be developed for streams identified as impacted by nutrients. The current narrative criteria will complicate TMDL development.

- EPA’s Clean Water Action Plan (USEPA, 1998) established a requirement that states develop nutrient criteria for streams, rivers, and lakes. The year 2003 was cited as the deadline for making reasonable progress towards nutrient criteria. In the absence of progress by the state, EPA can promulgate a national criteria.

Unlike biological integrity, nutrients do not presently have a specific narrative criteria. Nutrients are assessed under the more generic “free from” statements found in the toxicity sections of the fish and aquatic life criteria and under the “aesthetic” sections of the recreational criteria. (Note: there is a MCL of 10 mg/L for nitrates in finished drinking water.) Thus, before any stream could be assessed as impacted by nutrients, the existence of a problem had to be established.

In addition to issues in Tennessee, national concerns over nutrient levels have been well publicized. In the eastern coastal states, *Pfiesteria* blooms have been attributed to elevated nutrient levels in estuaries.

In another example, a considerable amount of effort has gone into studying the sources of nutrients impacting the Chesapeake Bay and in developing control strategies for these sources. Additionally, the so-called “dead zone,” an area of low dissolved oxygen levels located in the Gulf of Mexico has been linked to the transport of elevated nutrient loads in the Mississippi River.

The purpose of this document is to propose subecoregion or ecoregion-specific interpretations of the narrative nutrient criteria for total phosphorus and nitrate+nitrite for the 2001 triennial review of water quality standards. These numeric goals will be used primarily for water quality assessment purposes.

Division staff have statistically analyzed nutrient levels and their ranges in each subecoregion. Where significant differences exist between subecoregions, the nutrient criteria will be established at the subecoregion level. Where no significant difference is found between subecoregions, the data will be aggregated back to the ecoregion level.

Numeric goals will provide the means to assess nutrient levels at similar streams within the same ecoregion. Streams with nutrient levels less than the selected percentile of the reference stream database will be considered to meet the narrative criteria. Streams with nutrient levels higher than the reference stream database range will be considered in violation of the narrative criteria. These streams will be added to the 303(d) list for future TMDL generation.

Additionally, the regional interpretation of the narrative criteria will provide the goal for TMDL control strategies.

Why the Division Is Recommending Stream Nutrient Criteria Instead of Lake and Reservoir Criteria

It is true that in some other states, lake and reservoir nutrient criteria will be proposed instead of stream criteria. In fact, EPA guidance on this subject suggests a requirement that states pursue nutrient criteria for all types of waterbodies, including streams, lakes, estuaries, and wetlands. While we are not opposed to nutrient criteria for these other types of waterbodies (being inland, Tennessee does not have estuaries), we have considered this issue and have some reasons for selecting the approach we have taken:

1. We have the reference stream database for use in development of stream criteria – we have no equivalent resource for lakes or wetlands. We would be dependent on EPA's National Nutrient Database for this criteria development information.

2. Most of the lakes in Tennessee are reservoirs. We are not sure that that reference condition can be adequately defined for reservoirs. Each sizable reservoir in Tennessee is defined by many characteristics other than geographic location. These characteristics include, but are not limited to: reservoir age, depth, and usage (flood storage vs. power generation).

3. Designated uses are much more complicated in lakes. Nutrients are intentionally added to some lakes in Tennessee in the belief that sport fishing will be improved. Elevated levels of algae and some aquatic plants are generally considered to improve warm water fishing. Both are considered to interfere with boating and water contact recreation.

4. Tributary streams are the source of most of the controllable nutrient loadings to reservoirs. Regulating nutrient levels in streams is a more proactive approach than waiting until a problem develops in a reservoir before taking action.

IV. The Ecoregion Project

A method was needed for comparing the existing conditions found in a stream to less impacted streams. This "reference condition" should be established within a similar area, to avoid inappropriate comparisons. It was determined that *ecoregions* were the best geographic basis upon which to make this assessment.

The "Ecoregions of the United States" map (Level III) developed in 1986 by James Omernik of EPA's Corvallis Laboratory delineated eight ecoregions in Tennessee. The DWPC arranged for Omernik and Glenn Griffith to sub-regionalize and update our ecoregions.

An ecoregion is a relatively homogeneous area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, and other ecologically relevant variables.

The Tennessee Ecoregion Project began in 1993 and was envisioned to occur in three phases:

PHASE 1: Delineate Subecoregion Boundaries

Phase I of the project involved geographic data gathering, development of a draft subregionalization scheme, and ground-truthing of the draft into a final product. This product included new maps and digitized coverages for use in the DWPC GIS system. Phase 1 began in 1993 and was completed in 1995. This refinement resulted in a total of 25 subecoregions for the state. (Level IV subecoregions are illustrated on page 8)

Phase II: Reference Stream Selection

EPA and DWPC staff identified potential reference streams. Reference streams selected were located in relatively unimpacted watersheds typical for that ecoregion. When possible, watersheds within state or federally protected areas were selected.

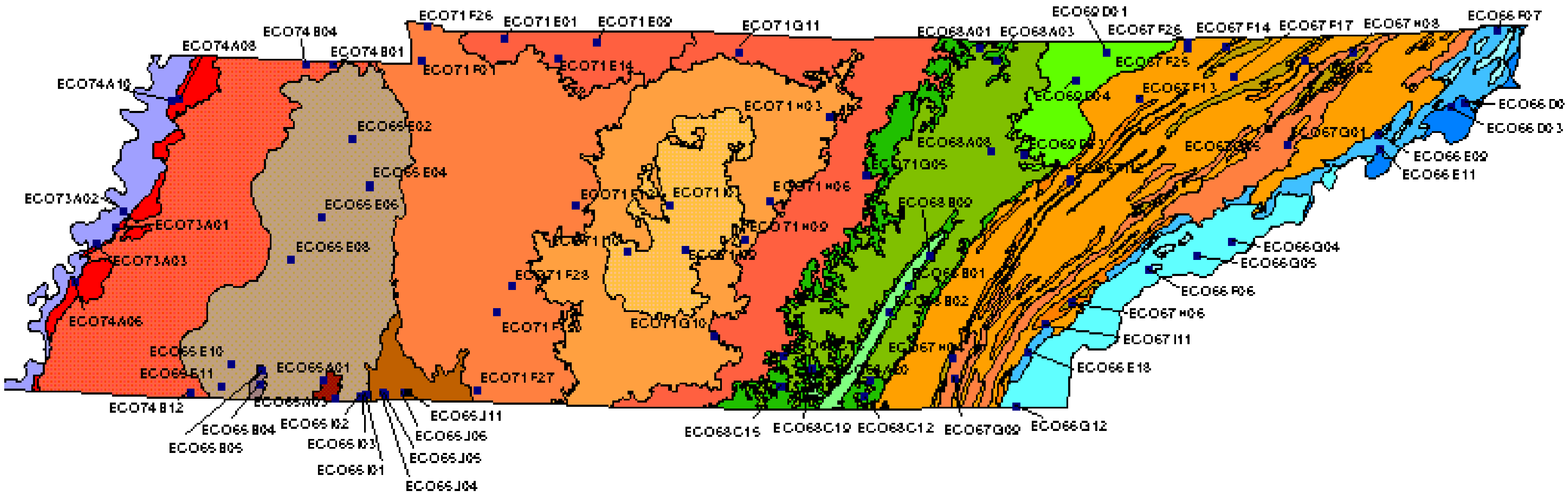
A reference stream is a least impacted waterbody within an ecoregion that can be monitored to establish a baseline to which other waters can be compared. Reference streams are not necessarily pristine or undisturbed by humans.

Division staff visited each candidate stream. Chemical and benthic macroinvertebrate sample results were used to trim the candidate streams down to a final list. Three reference streams per subecoregion were considered the minimum requirement although it was understood that in some of the small subecoregions it might be difficult to find three streams of reference quality.

Phase III: Intensive Monitoring of Reference Streams

From 1996 to 1999, final selected reference sites were monitored quarterly. During the first year of the project, water chemistry was monitored using grab samples collected on three consecutive days (if possible). After 1999, the reference streams will be monitored whenever their watershed is scheduled for intensive sampling under the rotational watershed approach.

TENNESSEE'S LEVEL IV ECOREGIONS AND GENERAL LOCATIONS OF REFERENCE STREAMS



65a Blackland Prairie
65b Flatwoods/Alluvial Prairie Margins
65e Southeastern Plains and Hills
65i Fall Line Hills
65j Transition Hills
66d Southern Igneous Ridges and 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

Chemical sampling procedures followed modified clean technique methodology as outlined in the Division's *Chemical Standard Operating Procedure: Modified Clean Technique Sampling Protocol*.

Chemical sampling at reference sites generally included the parameters historically sampled by the Division in its long-term ambient monitoring network. As a concession to resource constraints, certain parameters such as mercury, nickel, and cyanide were dropped because they were not detected in the first year of sampling. Additional parameters such as chlorophyll *a* were considered to have value, but were not sampled due to program funding limitations.

Macroinvertebrate samples were collected at ecoregion reference sites beginning in August 1996. Habitat and flow were also measured. All data were stored in either STORET or a special holding database used while STORET was being upgraded.

Finalizing the Ecoregion Reference Stream Nutrient Database

Several additional steps were taken to finalize the ecoregion nutrient database:

- **Incorporate data from other states.** It was our hope that reference streams within shared ecoregions in neighboring states could supply nutrient data that could be added into our database.

  We contacted most of the adjacent states with which we share ecoregions. Unfortunately, thus far we have been unable to uncover any stations that might provide additional information to our databases. Several states are actively looking for reference streams; if collection methodologies are similar, we might be able to share data eventually.

- **Review the database for quality assurance.** Data were checked for outliers that might represent data entry mistakes or other problems. Where data entry errors were found, they were corrected after consultation with the laboratory. The Division considered eliminating outliers based on a consistent rationale, such as values more than two standard deviations from the mean, but decided against such an approach.

  In a few streams, water quality conditions at a reference stream changed during the course of the study. In most cases, these streams were replaced with new reference streams. Data that were collected after an alteration to the stream were eliminated from the final databases.

A more thorough discussion of the ecoregion project can be found in the Division report entitled, *Tennessee Ecoregion Project* (Arnwine *et al*, 2001). This report should be consulted for a more complete discussion of subecoregions, lists of reference streams, monitoring protocols, and data summaries.

Raw data used in this study can be obtained from STORET or through the Division.

The Middle Prong Little Pigeon River near Pittman Center is not only a designated Outstanding National Resource Water, it is also an ecoregion reference stream for subecoregion 66g (Southern Metasedimentary Mountains). (Photo by Greg Denton)

V. The Distribution of Nutrient Data at Tennessee's Reference Streams

For the first time, the Division has regionally-based chemical, physical, and biological data representing least impacted conditions in Tennessee. These data are important to our program and have multiple applications.

For some time, it was known that an ecoregion specific approach to certain water quality standards would provide greater accuracy. This ecoregion project has provided the data necessary to initiate nutrient criteria discussions.

Final Validation of Reference Streams

The macroinvertebrate data from each potential reference site were compared to the other sites in the same subregion for each of the seven biological metrics selected. Box and Whisker plots were used to determine whether biological data demonstrated overlap at the 75^{th} percentile between stations. Any site that fell out of the 75^{th} percentile for the majority of metrics was re-evaluated for acceptability as representing reference condition for that subregion. This was accomplished through the evaluation of field notes, habitat scores and correspondence with field biologists who had monitored the sites.

After statistical and field evaluation, sixteen of the candidate reference sites were dropped from consideration. The majority of these sites had already been targeted by field biologists as being too impaired for reference use after intensive monitoring revealed impacts that were not observable during the initial field screening. The sites not used for final criteria development are summarized below.

ECO65B05 Prairie Branch, Hardeman Co. – Dropped fourth quarter FY98 by field staff. The portion of this subregion in Tennessee is extremely small. Only two streams were targeted for monitoring, to see if 65b stream characteristics were different than 65e. Both selected streams were known to be impacted prior to monitoring, but were the only ones available in the subregion. Biometrics from ECO65B05 showed no overlap with ECO65B04 at the 75thpercentile.

ECO65I01 Robinson Creek, Hardin Co. - The portion of this subregion in Tennessee is extremely small and suitable reference sites could not be located. Streams were monitored to determine whether 65i characteristics were different from 65e.

ECO65I03 Unnamed Tributary to East Fork Robinson Creek, Hardin Co. – The portion of this subregion in Tennessee is extremely small and suitable reference sites could not be located. Streams were monitored to determine whether 65i characteristics were different from 65e.

ECO67F08 Little Sewee Creek, Meigs Co. – Dropped by field staff after initial sampling due to impacts from agriculture and urban development. Seven other sites are being monitored in the same subregion.

ECO67F26 Indian Creek, Claiborne Co. - Dropped by field staff after sampling two seasons in 1997. Benthic results were not consistent with other reference sites. Impacts cited included heavy cattle use and excessive sedimentation. Seven other reference sites are being monitored in the same subregion.

ECO67I11 Thompson Creek, McMinn Co.- Only 2 streams were originally selected in this small subregion. Benthic data from Thompson Creek indicated a stressed community that was significantly different from the other reference stream. Field notes indicated residential and agricultural impacts with a high sediment load. Habitat scores were also comparatively low.

ECO68A21 Firescald Creek, Grundy Co. - Dropped after initial sampling due to impacts from an upstream impoundment. There are eight other streams being monitored in the same subregion.

ECO68C19 Unnamed Trib. in Pauley King Cove, Marion Co. - This stream was monitored once to compare the benthic community in a sandstone based stream to the limestone base present in all other selected reference streams in region. The benthic community was not similar to that found in the limestone reference streams. Additional sandstone streams would need to be monitored to determine if this is comparable to the reference quality limestone streams or if the benthic community was stressed.

ECO71E01, Noah Springs Branch, Montgomery Co. - Site was dropped by field staff due to hydrologic impacts from an upstream highway. The only available sampling site was downstream of culverts and the upstream area was in the Fort Campbell bombing range.

ECO71E15, Little West Fork, Montgomery Co. - Site was dropped by field staff due to poor benthic community. According to field notes, excessive sediment was present in the stream.

ECO71F01, Panther Creek, Stewart Co. This is a small stream with a very unstable gravel substrate. North Carolina Biotic Index (NCBI) and Clinger scores fell outside the expected ranges compared to other sites in the subregion. Five other sites are being monitored in the same subregion.

ECO71F26, Pryor Creek, Stewart Co. – Dropped by field staff due to the small watershed size. Five other sites are being monitored in the same subregion

ECO71G05, Cherry Creek, White Co. – Dropped by field staff. What started as minor sediment impact from agriculture and development became more serious as the project progressed. Three other sites are being monitored in 71g.

ECO71G11, West Fork Long Creek, Macon Co. - Dropped by field staff initially due to a poor macroinvertebrate community. This assessment was confirmed by statistical comparison to other sites; NCBI and the percent of oligochaetes and chironomids (%OC) values are outside 90th percentiles for the region.

ECO71H15, West Harpeth River, Williamson Co., - Dropped by field staff due to construction of SR 840.

ECO74A10, Unnamed Trib to Running Reelfoot Bayou, (Rock Branch) Obion Co., - A small stream, atypical for subregion; its macroinvertebrate population was more indicative of a spring than a creek.

The reference streams that remained following this process were used to establish the nutrient databases for each ecoregion and subecoregion.

Outliers

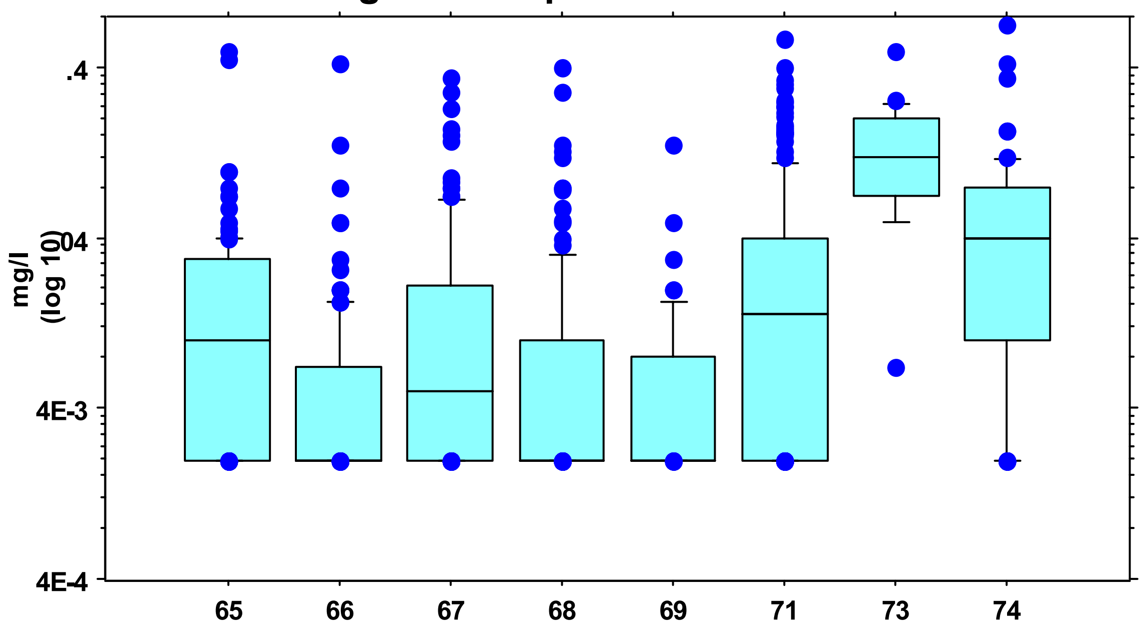
Staff considered several methodologies for excluding outliers, including the one presented in Standard Methods. In the end, we decided to include all data in the final databases.

Final Reference Stream Nutrient Databases

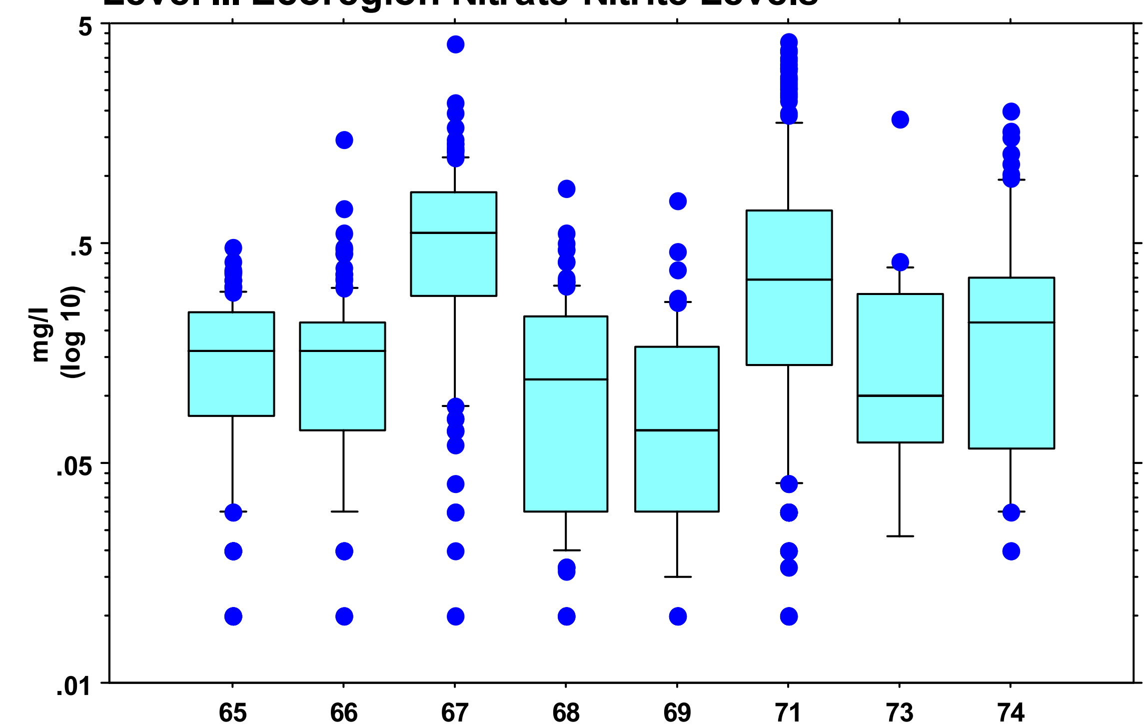
The box and whisker plots on the following page illustrate the levels of total phosphorus and nitrate+nitrite documented at reference streams within each ecoregion. The length of the box represents the middle half of the values in the distribution. The line through the box is the median value. The lower and upper hinges of the box mark the 25th and 75th percentiles. The whiskers represent the 10th and 90th percentiles.

On page 14, a chart shows total phosphorus data ranges at each subecoregion. A similar chart on page 15 illustrates nitrate+nitrite levels at subecoregion reference streams

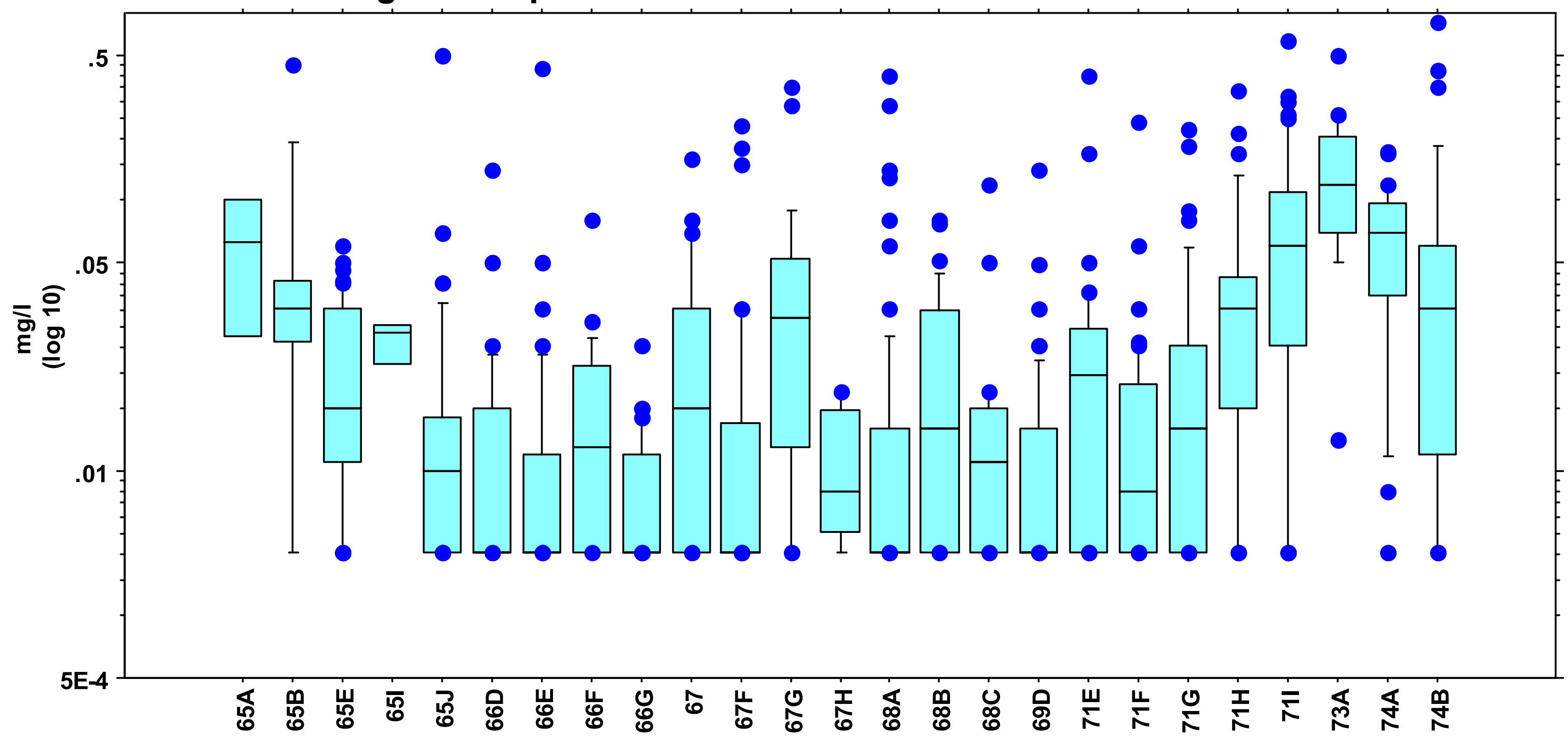
Level III Ecoregion Phosphorus Levels



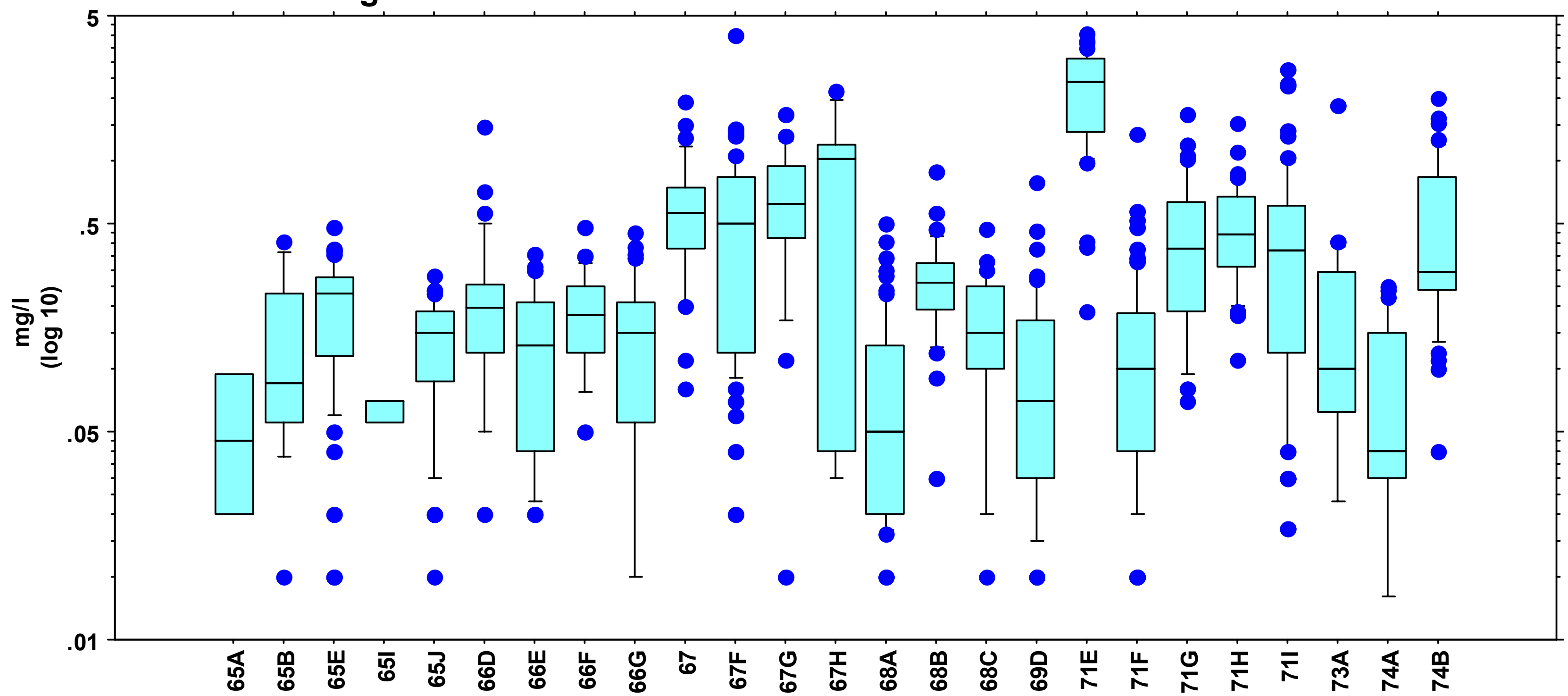
Level III Ecoregion Nitrate-Nitrite Levels



Level IV Subregion Phophorus Levels



Level IV Subregion Nitrate-Nitrite Levels



Statistical Methods for Grouping Subregions

Once the distribution of data within each subecoregion was plotted, a decision concerning the resolution of the criteria was needed. Criteria could be established by either grouping subregions or by leaving them as distinct units. There were advantages to both approaches.

The advantage to grouping subregions was that with more data upon which to base a decision, the Division could have a higher confidence in the resulting criteria. Additionally, since the criteria would be based on a larger geographic area, it could be applied to more streams, including streams that cross subecoregion boundaries.

The advantage to subecoregion criteria is based on the original theory that the subecoregions are distinct. A subecoregional criterion would be more accurate and therefore, more appropriate on that basis. However, it would only apply to streams entirely (or almost entirely) contained within that subecoregion. Also, subecoregional criteria would be based on fewer datapoints, thus generating a slightly lower confidence in the result.

We decided to base criteria on subecoregions, but only where statistical testing showed them to be distinct. Distinct was defined as meeting statistical tests of dissimilarity. Subregions not found to be distinct could be appropriately lumped with other subregions in order to take advantage of the confidence and application issues indicated above.

Following are some additional notes about data analysis decisions.

- Concentrations lower than detection limit were set at half of the detection limit. Duplicate samples used for quality control purposes were not included in calculations.

- During the first year of sampling, many sites were collected over three consecutive days. The original belief was that such a monitoring strategy could sample over a wider set of conditions, thus better representing the data ranges. The strategy was later modified due to resource constraints. A geometric mean was calculated to generate a single value for each three-day period.

- Some subecoregions had fewer than 15 data points. These subregions were pooled with the surrounding region prior to analysis. 65a, 65b, and 65i results were pooled with 65e. 67h and 67i were pooled with 67f.

Frequency distributions were graphed for each subregion to determine the appropriate analysis method and whether data transformation was needed for grouping subregions. Fisher's Protected Least Significant Difference (Fisher's PLSD) at significance level of 5% was used to determine which subregions could be grouped together.

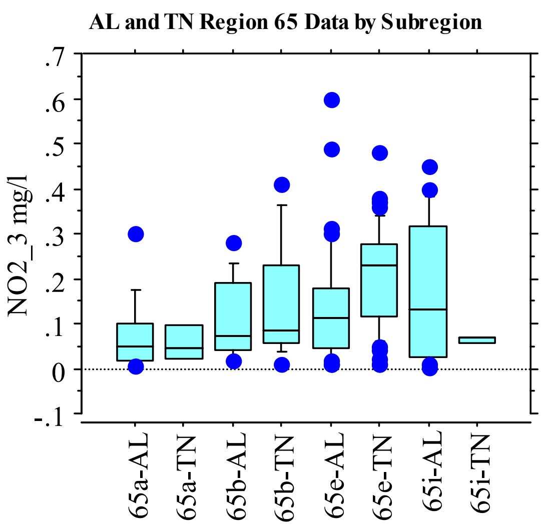
Total phosphorus data were logarithmically transformed prior to analysis. Transformation was necessary due to the extremely small values of the phosphate data as well as the non-normal distribution. Nitrate+nitrite data needed no transformation prior to analysis.

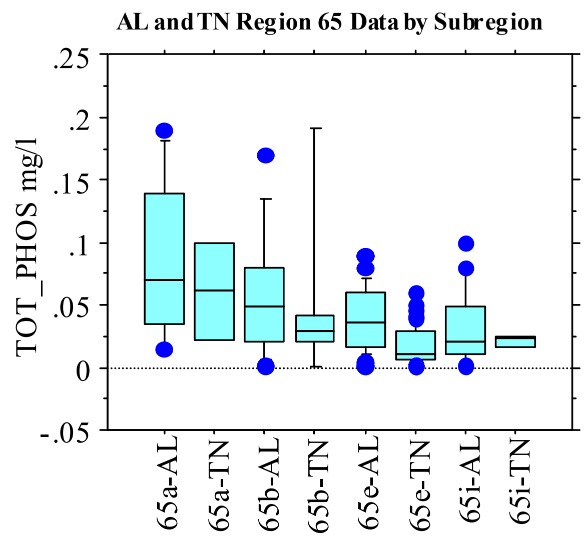
Comparison of Alabama and Tennessee Reference Data in Ecoregion 65

Nutrient data provided by the Alabama Department of Environmental Management at reference sites in subregions 65a, 65b, 65e and 65i were compared using Fisher's Protected Least Significant Difference (PLSD) to support pooling these subregions. Alabama has larger areas of Tennessee's three smaller subregions with a greater number of potential reference streams. Alabama's data demonstrated no significant difference between nitrate+nitrite levels in any of the four subregions.

A significant difference was observed within Alabama's subregion 65a for total phosphorus (15 observations). As more data are accumulated in this subregion, Tennessee may eventually need to develop separate phosphorus criteria. The graphs and tables below illustrate the data distribution in both states.

The tables on the next two pages list the means and standard deviations, as well as the 75th and 90th percentiles for the total phosphorus and nitrate+nitrite levels in each Tennessee subregion. Additionally, whether or not each subregion was statistically distinct is presented.





NO2-3	Mn	SD	N	Min	Max	Tot P	Mn	SD	N	Min	Max
65a AL	.076	.08	14	.006	.3	65a AL	.086	.061	14	.014	.190
65a TN	.057	.048	4	.02	.12	65a TN	.061	.045	4	.019	.100
65b AL	.105	.088	10	.018	.28	65b AL	.058	.05	10	.002	.170
65b TN	.144	.128	12	.01	.41	65b TN	.065	.123	12	.002	.450
65e AL	.139	.125	43	.008	.6	65e AL	.038	.025	43	.002	.090
65e TN	.210	.107	55	.01	.48	65e TN	.018	.015	55	.002	.060
65i AL	.178	.157	19	.002	.45	65i AL	.032	.03	19	.002	.100
65i TN	.063	.012	3	.05	.07	65i TN	.021	.006	3	.014	.026

Total Phosphorus Levels (mg/L) in Subecoregion Reference Streams (Subecoregions Arranged from West Tennessee to East Tennessee)

REGION	# OBSER-VATIONS	MEAN	STANDARD DEVIATION	75th / 90th PERCENTILE	*DIFFERENT?
73a	19	0.147	0.110	0.204 / 0.244	Only subregion
74a	28	0.070	0.045	0.098 / 0.117	Yes
74b	42	0.096	0.245	0.060 / 0.182	Yes
65a*	4	0.061	0.045	0.100 / NA	No
65b	12	0.065	0.123	0.041 / 0.191	No
65e	55	0.018	0.015	0.030 / 0.040	No
65i*	3	0.021	0.006	0.025 / NA	No
65j	53	0.019	0.069	0.009 / 0.032	Yes
71e	38	0.029	0.067	0.024 / 0.034	Yes
71f	69	0.053	0.343	0.013 / 0.020	No
71g	43	0.023	0.045	0.020 / 0.056	No
71h	41	0.261	1.378	0.042 / 0.133	No
71i	64	0.101	0.144	0.110 / 0.241	No
68a	73	0.019	0.061	0.008 / 0.022	No
68b	31	0.017	0.021	0.029 / 0.044	Yes
68c	28	0.011	0.023	0.010 / 0.012	No
69d	50	0.009	0.021	0.008 / 0.017	Only subregion
67**	30	0.024	0.035	0.030 / 0.070	
67f	65	0.061	0.376	0.009 / 0.030	No
67g	25	0.052	0.085	0.053 / 0.090	Yes
67h	7	0.006	0.004	0.010 / 0.012	No
66d	32	0.011	0.025	0.010 / 0.018	No
66e	37	0.017	0.070	0.006 / 0.018	No
66f	22	0.012	0.017	0.016 / 0.022	Yes
66g	45	0.004	0.004	0.006 / 0.009	No

* Is the subecoregion significantly different from other subecoregions (Level IV) within the same ecoregion (Level III)? Streams that have NA under the 90th percentile do not have enough data from which to calculate a percentile and will be pooled with the other subecoregions.

** The reference streams in this heading are not specific to a subregion and are considered reference streams for ecoregion 67 only. These data will not be used for subecoregion specific considerations.

Nitrate + Nitrite Levels (mg/L) in Subecoregion Reference Streams (Subecoregions Arranged from West Tennessee to East Tennessee)

REGION	# OBSER-VATIONS	MEAN	STANDARD DEVIATION	75th / 90th PERCENTILE	*DIFFERENT?
73a	19	0.250	0.404	0.295 / 0.386	Only subregion
74a	27	0.084	0.079	0.150 / 0.216	Yes
74b	42	0.516	0.463	0.830 / 1.189	Yes
65a*	4	0.057	0.048	0.095 / NA	No
65b	12	0.144	0.128	0.230 / 0.361	No
65e	55	0.210	0.107	0.278 / 0.340	No
65i*	3	0.063	0.012	0.070 / NA	No
65j	53	0.135	0.071	0.190 / 0.222	Yes
71e	37	2.206	1.019	3.087 / 3.480	Yes
71f	69	0.152	0.193	0.185 / 0.318	Yes
71g	43	0.475	0.361	0.640 / 0.996	No
71h	41	0.501	0.279	0.605 / 0.987	No
71i	64	0.499	0.543	0.610 / 1.029	No
68a	73	0.090	0.101	0.130 / 0.230	Yes
68b	31	0.277	0.158	0.320 / 0.434	Yes
68c	28	0.172	0.113	0.250 / 0.300	Yes
69d	50	0.118	0.141	0.170 / 0.270	Only subregion
67**	30	0.629	0.403	0.750 / 1.175	No
67f	65	0.580	0.573	0.845 / 1.020	No
67g	25	0.668	0.411	0.945 / 1.250	No
67h	7	0.807	0.806	1.200 / 1.974	No
66d	32	0.246	0.272	0.250 / 0.497	Yes
66e	38	0.139	0.099	0.210 / 0.297	No
66f	22	0.194	0.107	0.250 / 0.322	No
66g	45	0.150	0.116	0.210 / 0.320	No

* Is the subecoregion significantly different from other subecoregions (Level IV) within the same ecoregion (Level III)? Streams that have NA under the 90th percentile do not have enough data from which to calculate a percentile and will be pooled with the other subecoregions.

** The reference streams in this heading are not specific to a subregion and are considered reference streams for ecoregion 67 only. These data will not be used for subecoregion specific considerations.

VI. Data Relationships

We have taken a preliminary look at the reference stream data in an attempt to investigate relationships between sampled parameters. Examination of these relationships has two facets: (1) consideration of possible nutrient data surrogates and (2) exploring relationships between nutrient levels and biological indices.

The attempt to correlate biological data to nutrient levels had several complicating factors. Obviously, the nutrient data had to be collected in the same general time period as the biological survey, which happens less commonly than might be presumed. (Field offices are often specialized to the extent that one staff member collects chemical samples, while another group or person performs the biological work.)

An additional problem is presented by the type of biological survey performed. The Division has historically used the less intensive biorecon type surveys in doing water quality assessments. A biorecon is an abbreviated qualitative survey, where some or all benthic invertebrates are identified to family level only. While fine for general water quality assessment purposes, biorecon surveys probably do not provide sufficient information to differentiate subtle differences in water quality, such as might be caused by nutrients.

The more intensive semi-quantitative surveys (previously called RBPIII surveys) are much better suited for this purpose. However, because of the labor intensive nature of identifying benthic invertebrates to genera, fewer of these type surveys have been performed. At the time of this writing, we were able to identify only three general sources of data in which intensive biological surveys were combined with nutrient data.

- The reference stream database collected during the ecoregion project.
- The data collected during the Division's special probabilistic study of subecoregion 71i.
- Surveys in some areas of the state designed to evaluate the impacts of point source dischargers.

(We are aware that USGS has collected some data in Tennessee that would likely provide additional opportunities to correlate nutrient levels with intensive biological data. However, we did not have full access to these data at the time of this writing.)

Relationships Between Nutrient Levels and Other Chemical Constituents at Reference Streams

During a previous study documented in the USEPA report (EPA-822-B-00-002, Appendix A), the Division investigated a possible relationship between nutrient levels and other chemical constituents in the water column. If a strong correlational relationship could be established, these other values could be used as data surrogates if nutrient data were unavailable or as a less costly substitute for nutrient sampling.

Relationships were investigated primarily for turbidity, total organic carbon (TOC), and total suspended solids. We found numerous positive correlations, but the large number of data points at or below the detection level caused relationships to be suspect.

Nutrient/Biological Integrity Relationships at Reference Streams

If the correlation between either total phosphorus or nitrate+nitrite levels and the quality of biological communities can be established, a stronger rationale for ecoregion-specific numerical nutrient criteria can be provided. However, even where correlation is strong, identifying numeric nutrient criteria is dependent on knowing the biological integrity score above which the community is considered impaired. Fortunately, as in the case of nutrients, this biological integrity goal can be established from the reference stream data.

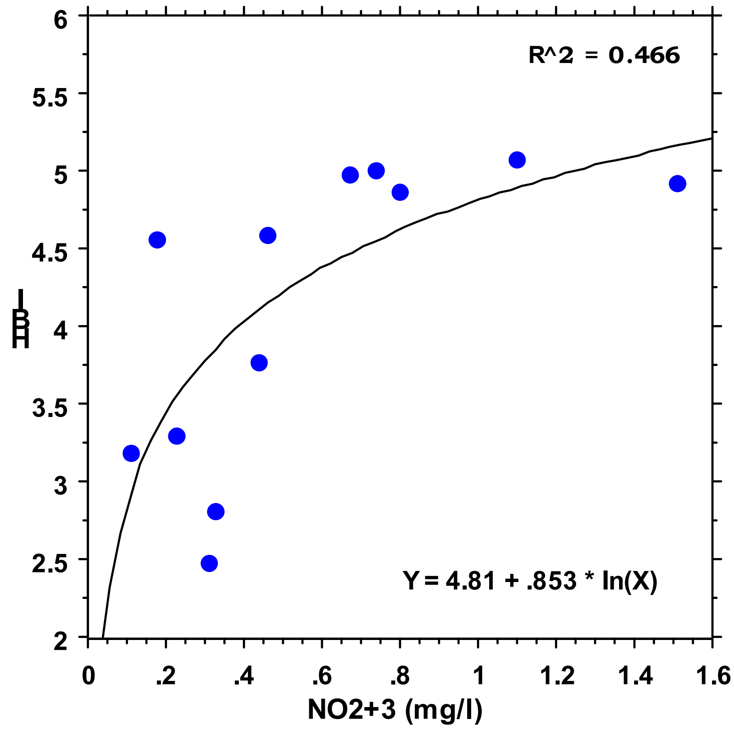
In subecoregion 71h (Outer Nashville Basin), a preliminary comparison was completed. Nitrate+nitrite levels were compared to two biological indices frequently used by the Division, the North Carolina Biotic Index (NCBI) and the Hilsenhoff Biotic Index (HBI). While there was some scatter in the dataset, a slightly stronger relationship was suggested for the Hilsenhoff index than the NCBI. (The figure on the next page compares nitrate+nitrite levels to biological indices.)

An additional comparison was done with the appearance of a relationship between nitrate+nitrite and NCBI scores. According to Division's proposed biocriteria for subecoregion 71h, the 90th percentile of the NCBI data is 4.74. Presuming that an NCBI score of 4.74 is the biological goal for subecoregion 71h, nitrate+nitrite levels should not exceed approximately 1.1 mg/L. The same approach with the Hilsenhoff scores produced a similar nitrate+nitrite level. It is not surprising that the two indices yield similar results, since the NCBI is a regionalized version of the Hilsenhoff index.

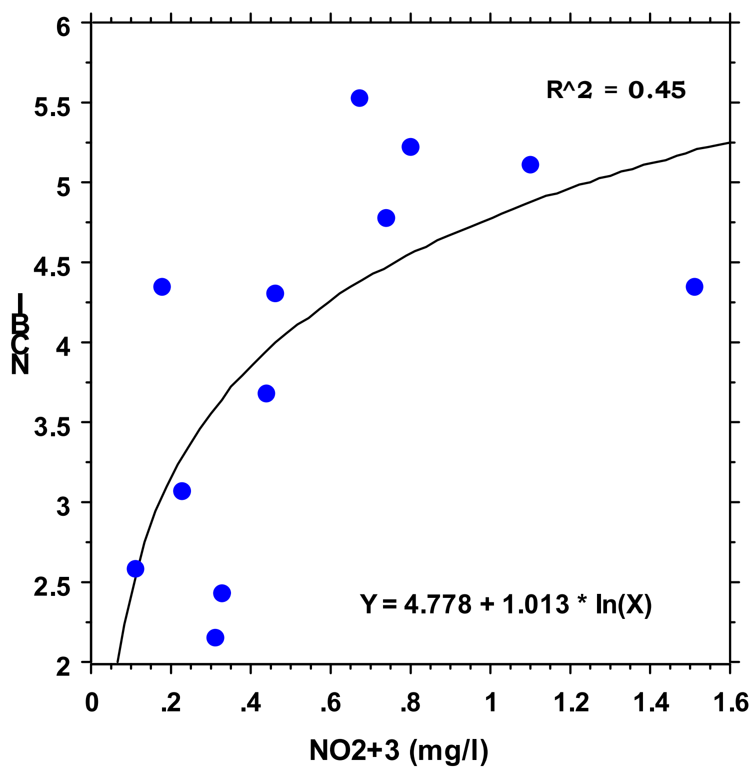
It is interesting to note that the 90th percentile of the reference stream nitrate+nitrite data for the 71h region is 0.99 mg/L. While the two values, 1.1 and 0.99 mg/L, are not exactly the same, this analysis method provides an interesting, though over-simplified, method of considering the relationship between nutrients and biological communities. It may be that there are other biological indices that would be more sensitive to changes in nutrient concentrations within a subecoregion or other water quality parameters that would exhibit a relationship with these biotic indices.

We do not mean to suggest that nutrient levels are the only factors regulating biological integrity in reference streams, but selection of reference streams was based on the generally good habitat and the lack of pollutants. It is our view that this approach can be used to strengthen the rationale for criteria recommendation or to justify a "margin of safety."

This approach also demonstrates that should the Division set the nitrate+nitrite goal for 71h at the 90th percentile, that level should generally be protective of biological integrity for that subecoregion.



Relationship of Nitrate+Nitrite Levels to Two Biological Indices in Subecoregion 71h: Hilsenhoff (top) and NCBI (bottom)



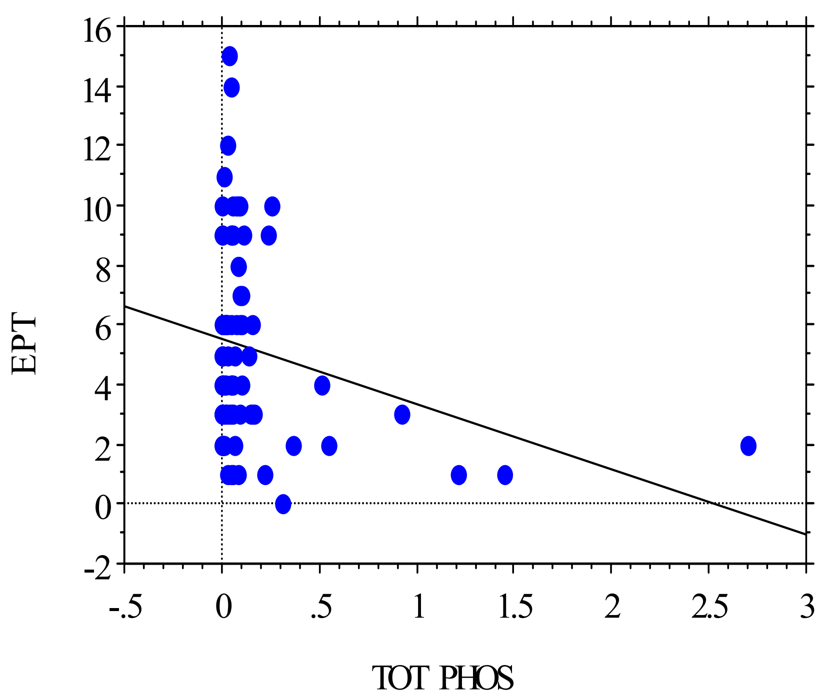
Nutrient/Biological Integrity Relationships at Randomly-Selected Streams in Subecoregion 71i

Data from the Division's probabilistic monitoring project in subecoregion 71i provided an additional opportunity to compare nutrient levels with the quality of the biological communities at the same site. (A more detailed description of this project along with a map of sampling sites appears in Chapter 8.)

A simple linear regression was used to test the relationship between nutrient levels and the integrity of the macroinvertebrate community. A strong correlation was not evident between nutrient levels and the benthic community composition. The closest relationship was between total phosphorus levels and EPT richness (R^2 = .063). A graph of this information is presented below.

Additional biological and nutrient samples were collected at these sites in the spring of 2001, but the data were not available at the time of this writing.

Relationship Between Total Phosphorus Levels and the Number of EPT Taxa at Randomly-Selected Stream Sites in Subecoregion 71i



Y = 5.54 - 2.185 * X; R^2 = .063

A slightly stronger correlation was seen between the structure of the benthic community and the amount of habitat and/or dissolved oxygen available. However, elevated nutrient levels appeared to increase the negative effects of habitat loss and/or depressed dissolved oxygen on the biota. EPT richness and the North Carolina Biotic Index were especially responsive.

These results are presented in the tables below and tend to support the theory that in streams with multiple stressors, it is extremely difficult to single out any one factor as being the cause of loss of biological integrity. Multiple pollutants, including nutrients, contribute to impairment.

Relationships (R^2) Between Nutrient Levels, Habitat Scores, Dissolved Oxygen and Biotic Integrity

Linear Regression Analysis

Biometric	$NO_2 – NO_3$	Total_P	Habitat	D.O.
Taxa Richness (TR)	0.009	0.001	0.008	0.019
EPT Richness (EPT)	0.003	0.063	0.010	0.167
EPT Abundance (% EPT)	0.008	0.003	0.031	0.003
Oligochaetes & Chironomids (% OC)	0.009	0.012	0.002	0.057
North Carolina Biotic Index (NCBI)	0.004	0.022	0.098	0.033
% Dominant Organism (% DOM)	0.004	0.010	0.027	0.002
% Clingers (% CLING)	0.002	0.002	0.060	0.004
TN Proposed Biocriteria Index	0.000	0.008	0.031	0.033

Multiple Regression Analysis

Biometric	NO_2-NO_3 , Total_P	NO_2-NO_3, Total_P, Habitat	NO_2-NO_3, Total_P D.O.	NO_2-NO_3, Total_P, Habitat, D.O.
Taxa Richness (TR)	0.012	0.024	0.033	0.045
EPT Richness (EPT)	0.063	0.071	0.184	0.194
EPT Abundance (%EPT)	0.014	0.050	0.013	0.046
Oligochaetes & Chironomids (% OC)	0.018	0.019	0.017	0.058
North Carolina Biotic Index (NCBI)	0.033	0.116	0.051	0.140
% Dominant Organism (% DOM)	0.012	0.044	0.012	0.043
% Clingers (% CLING)	0.015	0.072	0.017	0.079
TN Proposed Biocriteria Index	0.009	0.039	0.038	0.071

Nutrient/Biological Integrity Relationships at Selected Test Sites in the Western Highland Rim (71f)

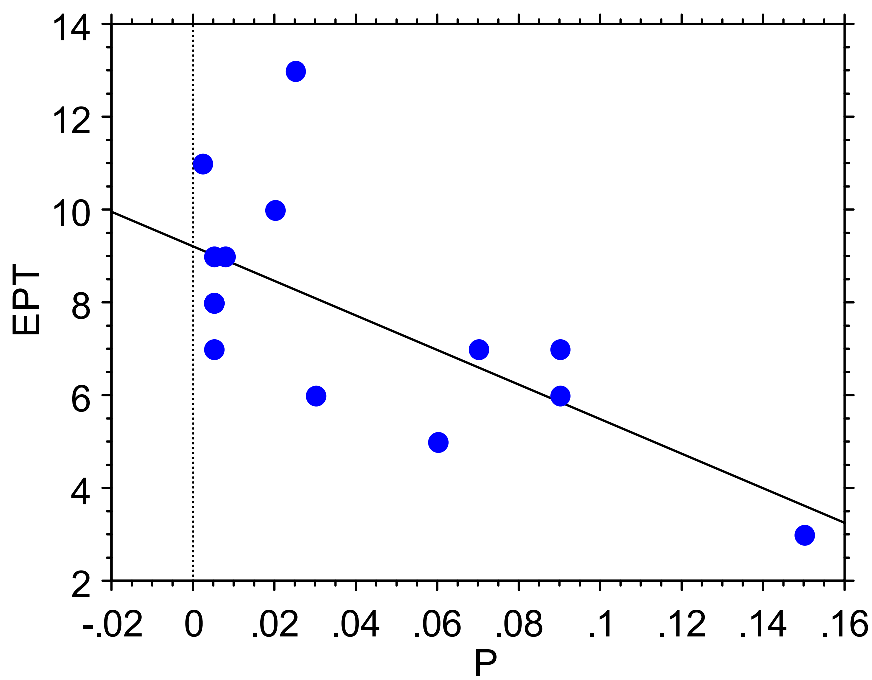
One of the lessons learned from the 71i probabilistic data was that relationships between nutrient levels and biological integrity are sometimes unclear in the presence of additional stressors. In an effort to look more closely at nutrient specific stress, the biological communities at 12 sites on 4 streams that had adequate habitat were evaluated.

All 12 sites were located in the Western Highland Rim (subregion 71f) and represent sites both upstream and downstream of known nutrient sources. These data were originally collected for enforcement/compliance purposes.

As illustrated by the following graph, a more clear correlation was seen between the number of EPT taxa and the level of total phosphorus in these streams.

These data indicated that in sites with equivalent habitat, nutrient levels can be an apparent cause for biological stress.

Relationship Between Total Phosphorus Levels and the Number of EPT Taxa at Habitat Rich Sites in Subregion 71f



$Y = 9.225 - 37.494 * X; R^2 = .461$

VII. Comparison of Reference Stream Nutrient Data to EPA's National Nutrient Databases

According to EPA guidance, reference conditions may be compared to all other nutrient data to potentially provide a range for criteria selection. EPA suggests that the range is established by comparing the reference stream data at the 75th percentile with the 25th percentile of all other data. We were curious to see if this approach would work and if so, would it provide values similar to those we had already identified?

To assist in this effort, EPA provided us with the nutrient databases from STORET for the three large nutrient regions in Tennessee. (For purposes of this initial test, only Tennessee STORET data were included.) Nutrient Ecoregion XI in east Tennessee is a combination of Level III ecoregions 66, 67, 68, and 69. Nutrient Ecoregion IX in middle and west Tennessee is composed of Ecoregions 71, 65, and 74. Ecoregion 73 in west Tennessee is Nutrient Ecoregion X.

The EPA nutrient database was primarily data collected by the Division of Water Pollution Control, the Tennessee Valley Authority (TVA), and the U.S. Geological Survey (USGS). As we were familiar with TVA's monitoring program, we were concerned that some percentage of their data was from lakes or embayments.

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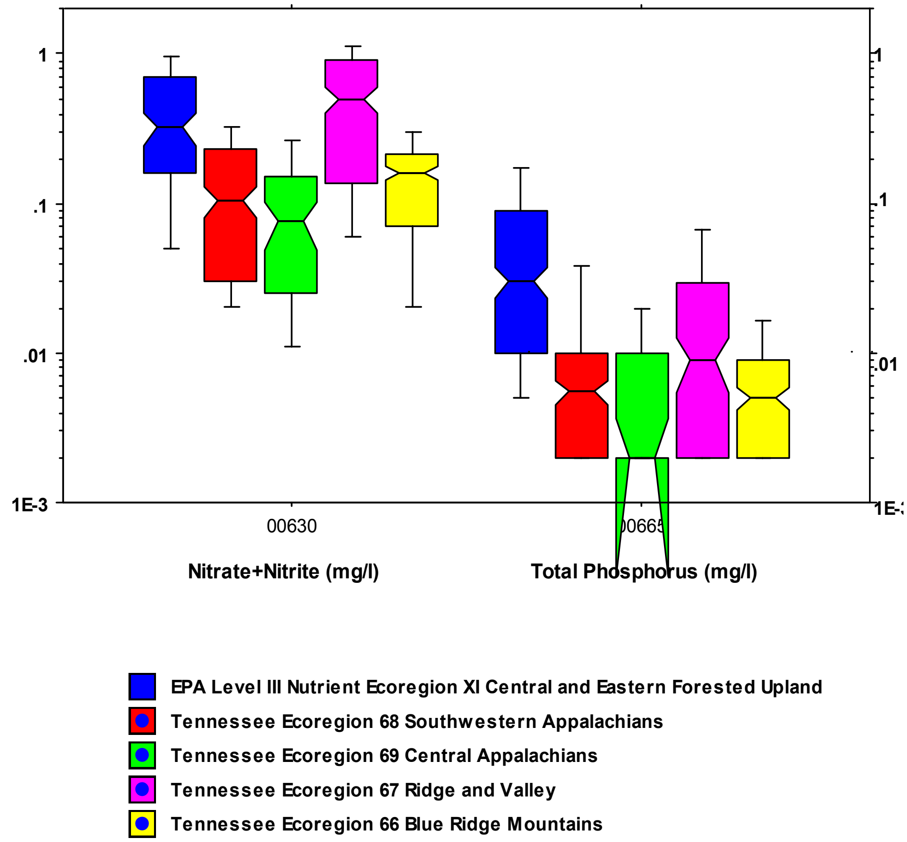
Since we were developing stream nutrient criteria rather than lake or embayment criteria, we did not consider it appropriate to include non-stream data. Lacking the time to identify and cull only the embayment or lakes data from the database, we decided to exclude all TVA data.

In the figure on page 27, the database for Nutrient Ecoregion Region XI is compared to the reference stream database for the same geographic area. The 75th percentile of the reference stream data and the 25th percentile of the nutrient database lined up well for some ecoregions (68, 69, & 66), but not for the Central Appalachian Ridge and Valley Region (67).

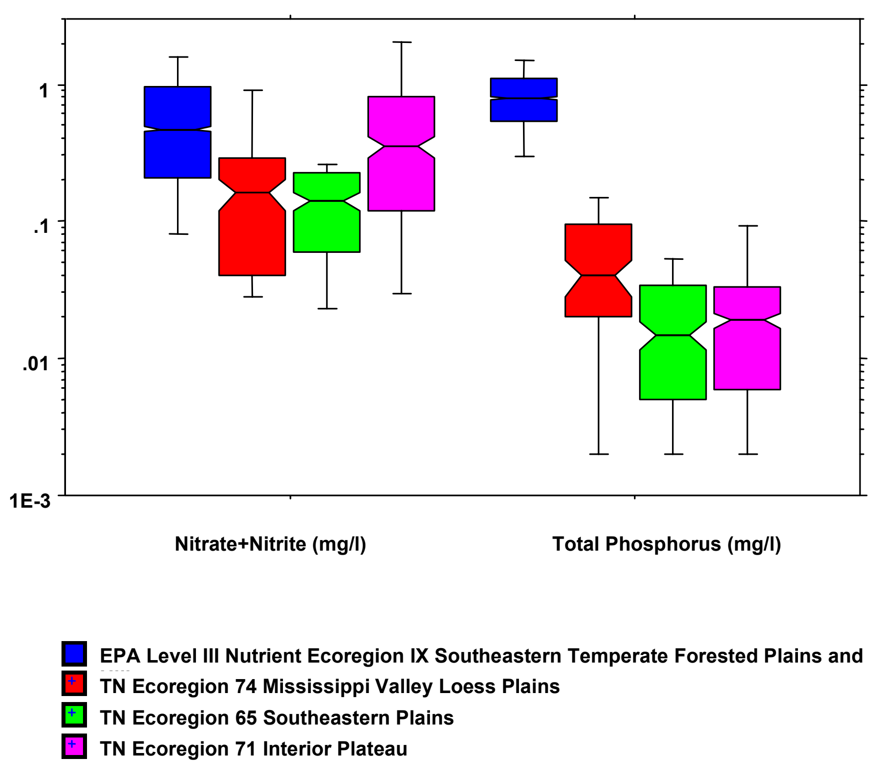
We also looked at EPA draft Nutrient Ecoregion IX in middle and west Tennessee (see figure on page 27). Data for total phosphorus were elevated nearly an order of magnitude higher than the reference stream data. We discovered that a few stations provided a sizable number of data points within the database.

It is possible that some of these data represent "storm chasing" sampling events designed to quantify worst case nutrient loadings. Another possibility is that sampling in the phosphorus-rich soils of southern middle Tennessee biased the database. If we can identify these sites, these data could be excluded and the database re-formed

EPA Nutrient Region XI Data Compared to Reference Stream Data



EPA Nutrient Region IX Data Compared to Reference Stream Data



To further satisfy our curiosity, we directly compared the EPA national nutrient database at the 25th percentile to our reference stream data at the 75th percentile. The initial comparison was made for EPA nutrient ecoregions IX and XI for multiple substances. The substances analyzed included total phosphorus, total nitrogen, and turbidity. The results are complied below.

Since the national database allowed the data to be re-aggregated at a higher resolution, we also compared EPA and Tennessee calculated total nitrogen, nitrate+nitrite, and total phosphorus data from level III ecoregions 65, 66, 67, 68, 69, 71 and 74.

Tables illustrating these data appear on the following page.

We were impressed at the consistency of results using the two different approaches. Level III ecoregion 67 is the area that appears to yield the most dissimilar results between the two methods.

However, it may be that outside of the Tennessee portion of this ecoregion, higher quality reference streams are available.

NUTRIENT ECOREGION IX

PARAMETER	EPA 25th PERCENTILE	TENNESSEE 75th PERCENTILE
Total Phosphorus	36.56 ug/L	37.0 ug/L
Total Nitrogen	0.43 mg/L	0.36 mg/L
Turbidity	7.03 NTU	7.4 NTU

NUTRIENT ECOREGION XI

PARAMETER	EPA 25th PERCENTILE	TENNESSEE 75th PERCENTILE
Total Phosphorus	10.00 ug/L	11.00 ug/L
Total Nitrogen	0.31 mg/L	0.33 mg/L
Turbidity	2.3 NTU	3.1 NTU

NITRATE + NITRITE DATA COMPARISON

ECOREGION	EPA 25th PERCENTILE	TENNESSEE 75th PERCENTILE
Ecoregion 65	0.095 mg/L	0.24 mg/L
Ecoregion 66	0.058 mg/L	0.20 mg/L
Ecoregion 67	0.23 mg/L	0.86 mg/L
Ecoregion 68	0.059 mg/L	0.23 mg/L
Ecoregion 69	0.18 mg/L	0.17mg/L
Ecoregion 71	0.345 mg/L	0.71 mg/L
Ecoregion 74	0.14 mg/L	0.35 mg/L

TOTAL PHOSPHORUS DATA COMPARISON

ECOREGION	EPA 25th PERCENTILE	TENNESSEE 75th PERCENTILE
Ecoregion 65	22.50 ug/L	30.0 ug/L
Ecoregion 66	7.125 ug/L	7.0 ug/L
Ecoregion 67	10.00 ug/L	21.0 ug/L
Ecoregion 68	6.00 ug/L	10.0 ug/L
Ecoregion 69	7.625 ug/L	8.0 ug/L
Ecoregion 71	30.00 ug/L	40.0 ug/L
Ecoregion 74	75.00 ug/L	80.0 ug/L

VIII. COMPARISON OF REFERENCE STREAM DATA TO PROBABILISTIC MONITORING DATA

There are two ways to select sites to sample for water quality: targeted and probabilistic. Targeted monitoring is when a site is selected for a specific reason, such as monitoring below an outfall. Sites are randomly selected for probabilistic monitoring.

The Division of Water Pollution Control has designed and is currently conducting a probabilistic water quality study of subecoregion 71i (Inner Nashville Basin). Chemical, physical, and biological data have been collected and analyzed at approximately 50 randomly selected sites.

Sampling of the selected streams (see the map on the next page) began in January 2000. If streams were not wadeable or did not have flow when surveyed in January, they were eliminated and another randomly selected stream was substituted.

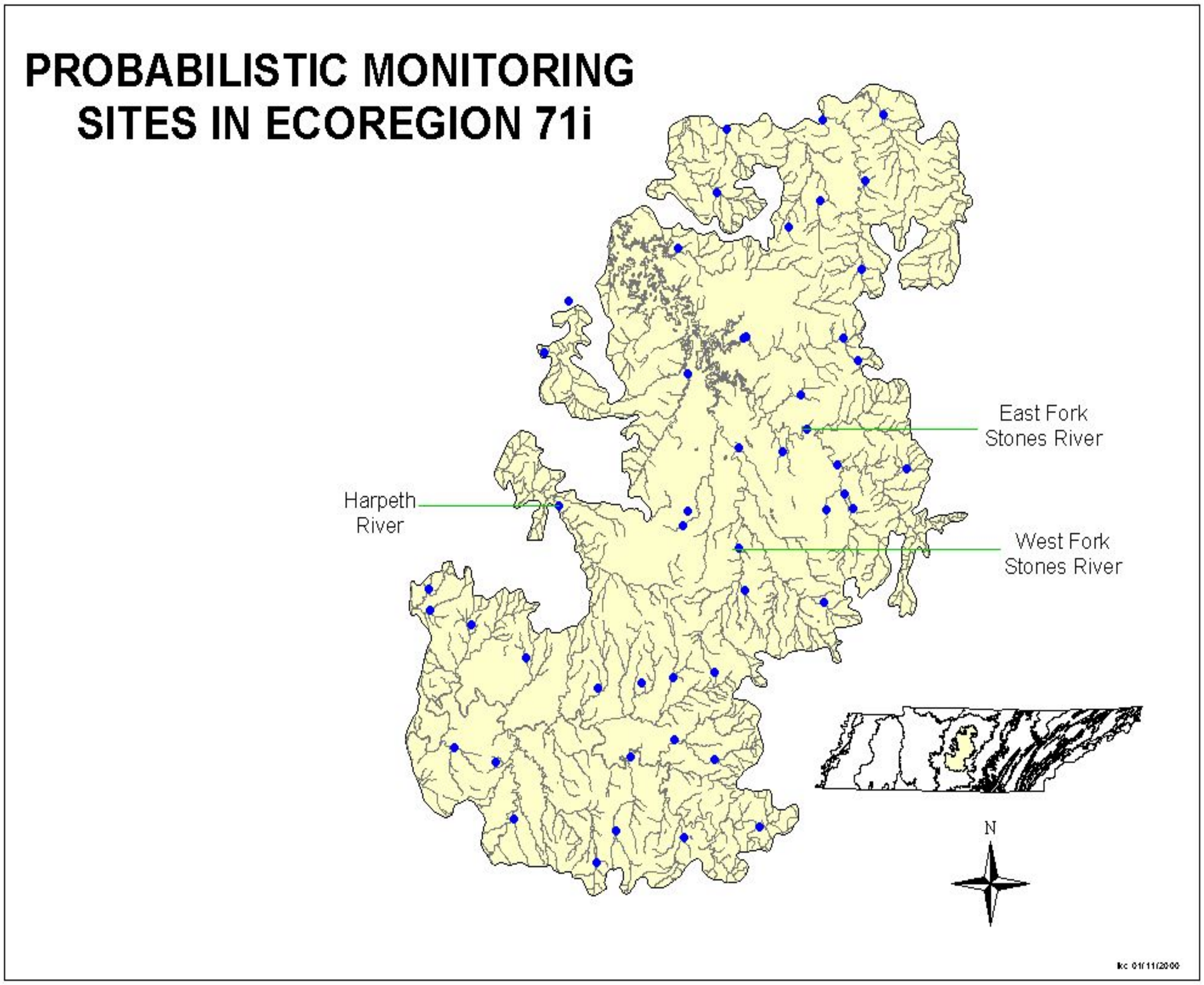
A more thorough discussion of the design and objectives of this project can be found in the 2000 305(b) Report (Denton et. al , 2000).

Two of the objectives of the probabilistic monitoring project are directly relevant to the development of nutrient criteria.

First, staff wanted to find out if probabilistic monitoring would uncover additional streams in subecoregion 71i that were of reference quality.

The biological data from four streams – the upper Harpeth River, Cedar Creek, Fall Creek, and Little Flat Creek – indicated that they were reference quality. As a result, the nutrient data from these streams were added to the reference database.

Cedar Creek in Wilson County is a typical Inner Nashville Basin stream. Subecoregion 71i streams are frequently low gradient, flowing through cedar glades and across areas of exposed limestone. This station was one of the sites identified as having good enough water quality to be considered a reference stream. (Photo by Debbie Arnwine)



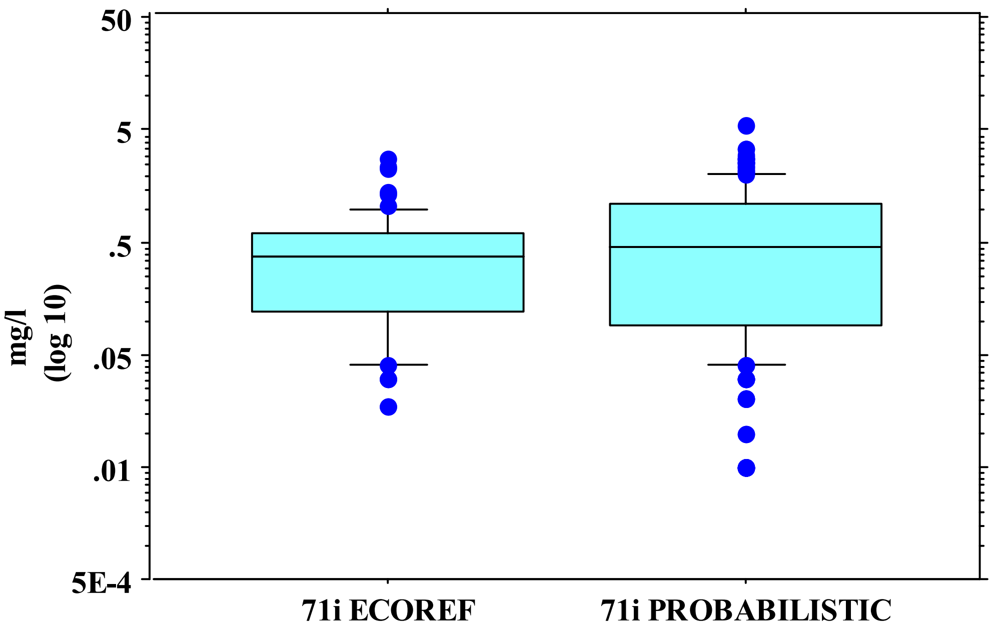
The second relevant data objective was to directly compare the results of the probabilistic monitoring to the reference condition for nutrients in 71i. Would they be different or similar? This comparison would provide a real-life answer to the anticipated question "How many streams will fail to meet a goal established at the 75th or 90th percentile of the reference database?"

A comparison of the reference stream database to the results of the probabilistic monitoring appears in the figures on the next page.

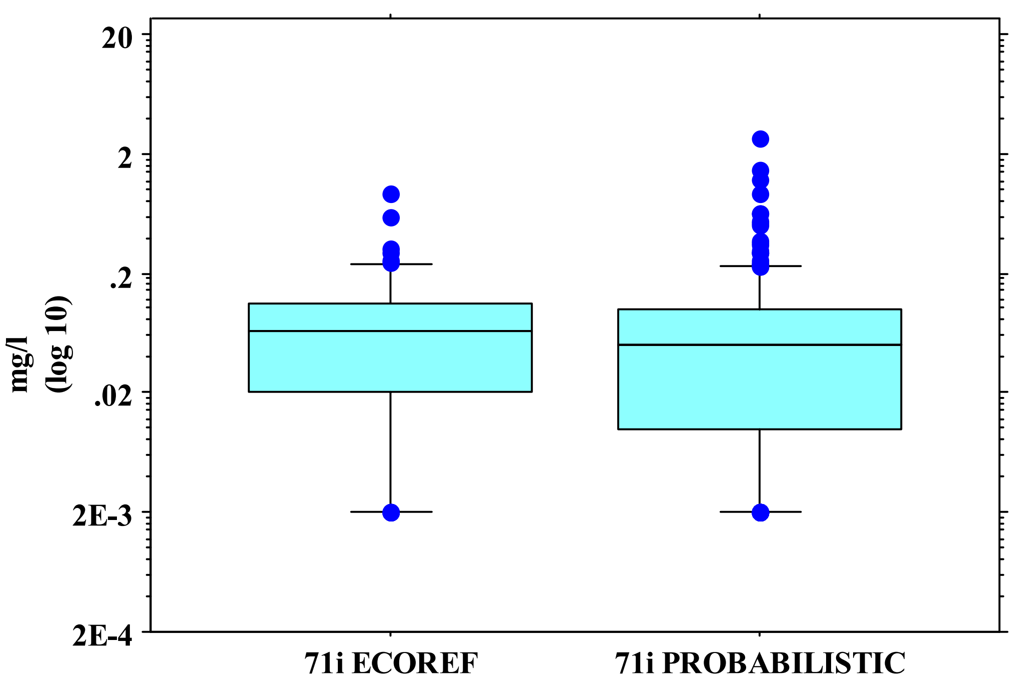
It is important to note that the reference stream database represents many observations at just a few sites. Conversely, the probabilistic data represents just a few observations at many stations. Additionally, the sampling in the reference stream database occurred over a wider time period (1996 – 2000) than did the probabilistic monitoring (2000).

Still, it is interesting to look at the comparison. In ecoregion 71i, there appears to be very little difference, at least for nutrient levels, between the reference streams and the other streams in the region. One of the obvious possible reasons for this lack of a clear difference is that in this region, even reference streams have been subjected to substantial alteration.

Comparison of Nitrate+Nitrite Levels at Probabilistic Monitoring Sites to the Reference Stream Database in Subecoregion 71i



Comparison of Total Phosphorus Levels at Probabilistic Monitoring Sites to the Reference Stream Database in Subecoregion 71i



Field Testing of the 71i Reference Database Against Probabilistic Data

The following percentiles of the nutrient databases are identified for Subecoregion 71i. (Proposed criteria differ slightly since several subregions were grouped).

	Nitrate+ Nitrite	Total Phosphorus
75^{th} Percentile	0.61	0.11
90^{th} Percentile	1.03	0.24

In the table below and continuing on the next page, data from the probabilistic monitoring project in Subecoregion 71i are presented. At each of the fifty stations, four observations of nutrient levels were generally available. The average levels of both nitrate+nitrite and total phosphorus have been compared to the 75^{th} and 90^{th} percentiles of the subecoregion reference database.

For added perspective, spring biological surveys at the same stations have been compared to the Division proposed seasonal biocriteria levels in 71i. The far right-hand column of the table below indicates whether or not the biocriteria were violated.

Comparison of Reference Nutrient Database and Proposed Biocriteria at Probabilistic Sites in Subecoregion 71i

Stream	Exceeded Nitrate+Nitrite Reference Data? 75^{th}	Exceeded Nitrate+Nitrite Reference Data? 90^{th}	Exceeded Total Phosphorus Reference Data? 75^{th}	Exceeded Total Phosphorus Reference Data? 90^{th}	Violated Proposed Biocriteria?
Alexander Creek	Yes	No	No	No	Yes
Barton Creek	No	No	Yes	No	Yes
Bradley Creek	Yes	No	No	No	No
Big Rock Creek	Yes	No	Yes	No	Yes
Bushman Creek	Yes	Yes	No	No	No
Cedar Creek	Yes	No	No	No	Yes
Cedar Creek	No	No	No	No	No
Cedar Creek	Yes	Yes	No	No	No
Christmas Creek	Yes	No	No	No	Yes
Clem Creek	Yes	Yes	No	No	Yes
Cripple Creek	No	No	No	No	Yes
Crooked Creek	No	No	No	No	Yes
Davis Creek	No	No	Yes	No	Yes
East Fork Stones River	Yes	No	No	No	No

Comparison of Reference Nutrient Database and Proposed Biocriteria at Probabilistic Sites in Subecoregion 71i (cont.)

Stream	Exceeded Nitrate+Nitrite Reference Data? 75th	Exceeded Nitrate+Nitrite Reference Data? 90th	Exceeded Total Phosphorus Reference Data? 75th	Exceeded Total Phosphorus Reference Data? 90th	Violated Proposed Biocriteria?
East Rock Creek	Yes	Yes	Yes	No	No
Fall Creek	Yes	No	No	No	Yes
Fall Creek	Yes	No	No	No	No
Fall Creek	Yes	No	Yes	Yes	No
Florida Creek	No	No	Yes	No	No
Harpeth River	No	No	Yes	Yes	No
Henry Creek	Yes	No	No	No	Yes
Hurricane Creek	No	No	No	No	Yes
Hurricane Creek	Yes	No	No	No	Yes
Johnson Creek	No	No	No	No	No
Little Creek	Yes	No	Yes	No	No
Little Flat Creek	No	No	No	No	No
Little Sinking Creek	No	No	No	No	Yes
Lytle Creek	Yes	No	No	No	Yes
McKnight Branch	No	No	No	No	Yes
Mill Creek	No	No	Yes	Yes	Yes
Mill Creek	Yes	No	Yes	No	Yes
North Fork Creek	Yes	Yes	No	No	Yes
North Fork Creek	Yes	Yes	No	No	Yes
Overall Creek	Yes	Yes	No	No	No
Rich Creek	Yes	Yes	No	No	Yes
Sinking Creek	No	No	Yes	No	Yes
Sinking Creek	No	No	Yes	Yes	Yes
Sinking Creek	Yes	No	No	No	Yes
Spencer Creek	Yes	Yes	Yes	Yes	Yes
Spring Creek	No	No	Yes	Yes	No
Spring Creek	No	No	Yes	No	No
Spring Creek	No	No	Yes	Yes	No
Stewarts Creek	Yes	Yes	No	No	Yes
Suggs Creek	No	No	No	No	Yes
Thick Creek	No	No	No	No	Yes
Wallace Creek	No	No	No	No	No
Weakley Creek	Yes	Yes	No	No	Yes
West Fork Stones River	Yes	No	No	No	Yes
West Fork Stones River	Yes	Yes	No	No	Yes
Wilson Creek	Yes	Yes	No	No	Yes

It is important to note that each probabilistic station had a maximum of five observations for nitrate+nitrite and total phosphorus. At some stations, fewer data were available. (Some of the streams were dry in the summer and fall.) Thus, sweeping conclusions cannot be drawn from these results with high confidence.

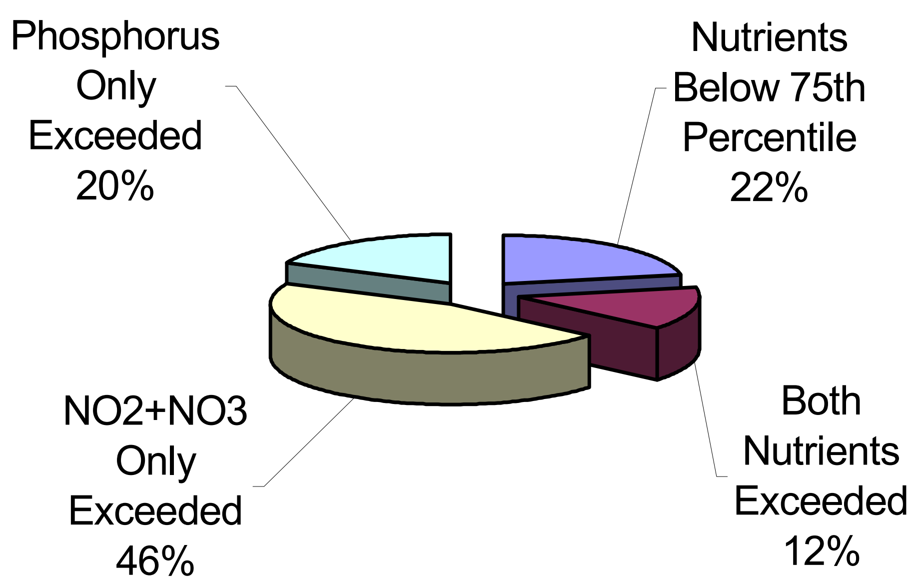
With this warning to consider, it is still interesting to review the results of the comparison of average nutrient levels at the probabilistic sites with the reference streams data for this subregion.

Using the 71i reference stream data at the 75th percentile, out of 50 streams only 11 (22%) were within an acceptable range for both nitrate+nitrite and total phosphorus. Using the 90th percentile of the reference data as the goal, 31 streams (62%) were within an acceptable range for both parameters.

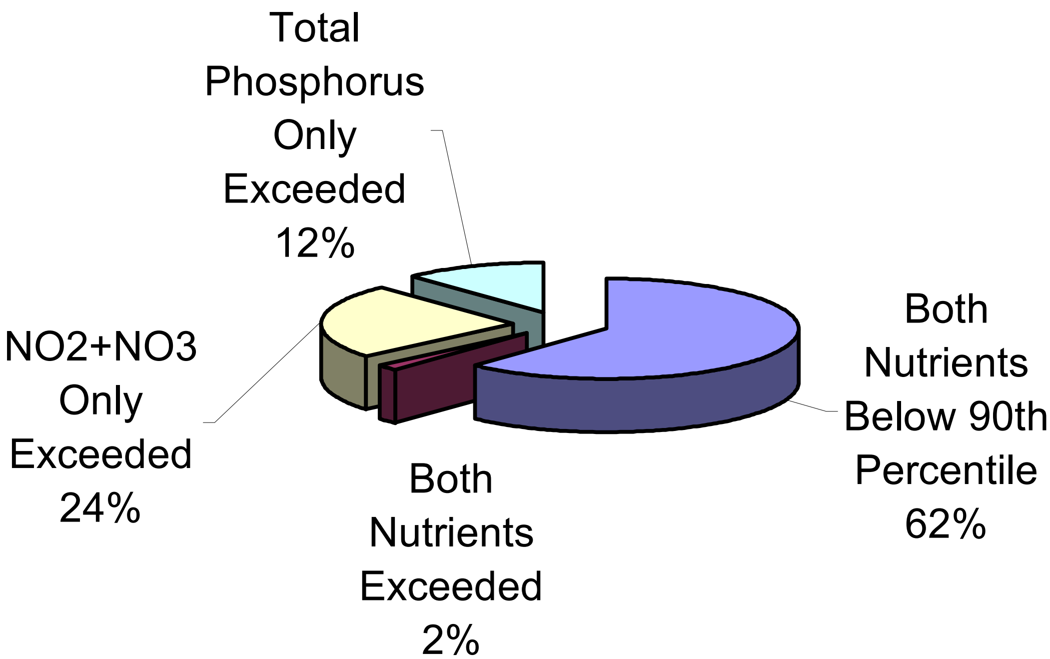
The figure below illustrates the distribution of probabilistic site data compared to the 75th percentile of reference data for the subregion. Only one site in five met both criteria. At the 75th percentile, nitrate+nitrite was the most frequently violated criteria.

On the next page, the same information is presented for the data at the 90th percentiles. At the 71i probabilistic sites, 31 (62%) fell within acceptable ranges at the 90th percentile. Nitrate+nitrite exceeded the 90th percentile most often (13 sites). Total phosphorus levels were excessive at only seven sites when the 90th percentile was used as a goal.

Moving from the 75th percentile to the 90th percentile dramatically reduced the number of streams that would be considered to have elevated nitrate+nitrite levels. Also, the number of streams that fell above acceptable levels for both parameters was reduced.



Comparison of Nutrient Levels at the 75th Percentile at Probabilistic Stations in Subecoregion 71i.



Comparison of Nutrient Levels at the 90th Percentile at Probabilistic Stations in Subecoregion 71i.

Before we use these data to decide which percentile is more appropriate for use as a criteria level, we must revisit the issue of "establishing harm." A very important issue to be investigated is which percentile provides the best protection against biological harm, without being more protective than necessary to prevent harm.

Used without discretion, nutrient criteria derived from the 75th percentile would result in an assessment of 78 percent of the 71i probabilistic stations as violating the criteria. However, according to the biological surveys performed at the same stations, the Division's proposed biocriteria (Arnwine and Denton, 2001) are only violated at 64 percent of the stations.

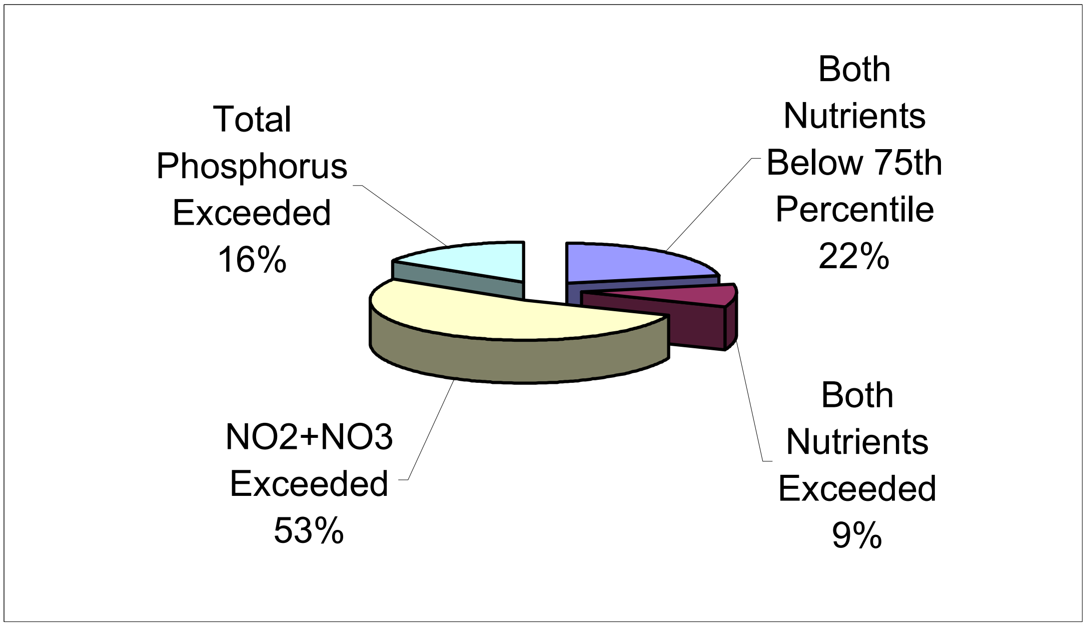
This suggests that a nutrient criteria at the 75th percentile would be too conservative since it captured more streams as being impacted than did the biocriteria.

In contrast, only 38 percent of the stations violated one or both of the nutrient criteria at the 90th percentile.

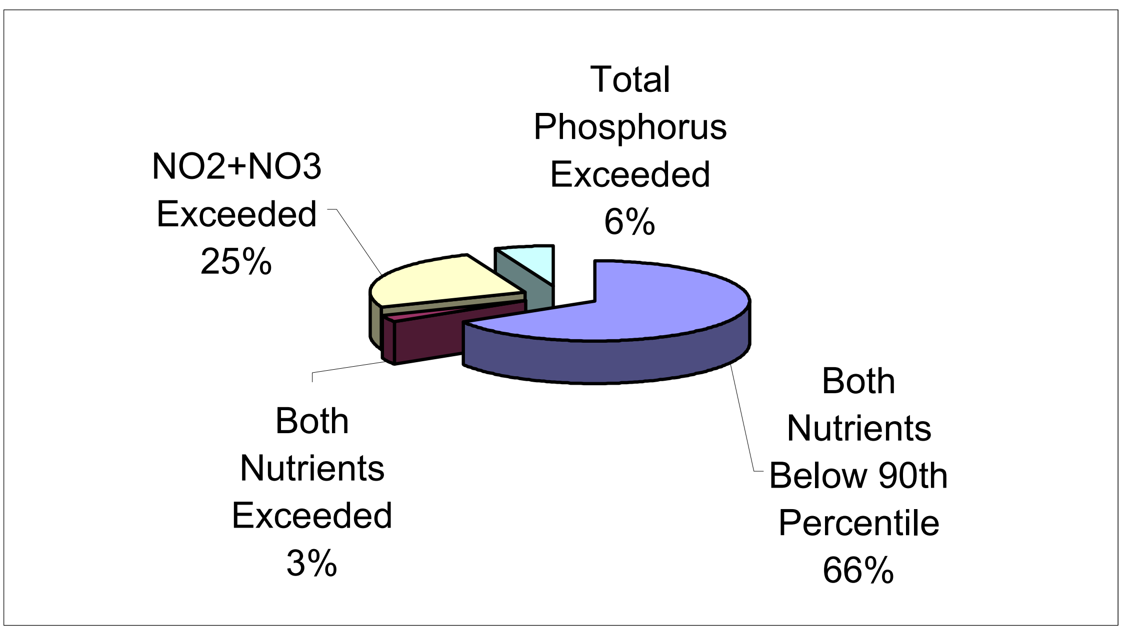
In the previous section, the association between nutrient levels and the quality of biological communities in Subecoregion 71i was explored. Although hampered by the limited amounts of available data, associations were either weak or generally absent.

Clearly, the relationship between pollutants such as nutrients and biological communities is not conveniently simple, especially in areas where streams have been subject to considerable stress from land-use practices.

On the next page, the percentages of streams that violated biocriteria in Subecoregion 71i that also had nutrient levels above the 75th and 90th percentiles are presented.



Percentage of Probabilistic Stations Where Biocriteria Were Exceeded That Also Had Violations for Nutrient Criteria at the 75th Percentile



Percentage of Probabilistic Stations Where Biocriteria Were Exceeded That Also Had Violations for Nutrient Criteria at the 90th Percentile

As indicated in the illustrations on the previous page, many of the streams that violated biocriteria also had elevated nutrient levels, especially at the 75th percentiles.

But fair questions can be asked about this line of reasoning. How accurately did elevated nutrient levels predict biological use support? Did compliance with nutrient goals predict that a stream would have a healthy biological community? Conversely, did nutrient levels above the 75th or 90th percentiles equate to impacted biology?

The figure below attempts to answer these questions. The frequency that each of the nutrient percentiles accurately predicted biological use support is presented.

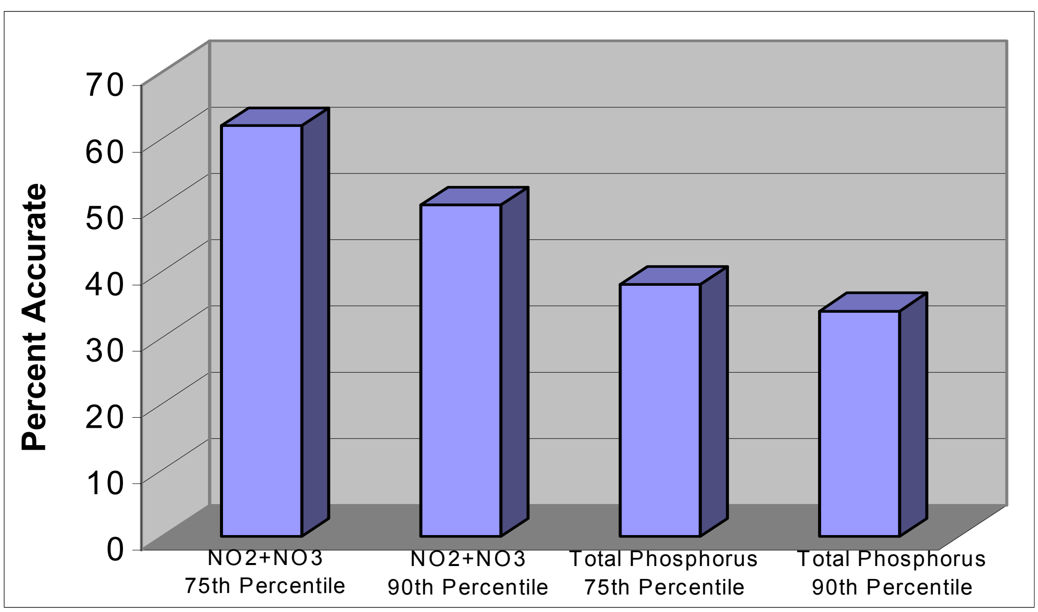
Again, the reader should be warned there are limitations to the confidence that can be assigned to conclusions drawn from a relatively small amount of data available at each of the probabilistic stations.

A casual review of the illustration below suggests that in subecoregion 71i, nitrate+nitrite criteria at either the 75th or 90th percentile are a more accurate indicator of biological use support than are phosphorus criteria.

While this might be true in 71i, it may not be true elsewhere. Phosphorus levels are naturally higher in 71i, due to phosphorus-rich rock formations in the area so the benthic communities in this region may be adapted to this phenomena.

Clearly, none of the potential nutrient criteria illustrated below were excellent predictors of the status of biological communities in subregion 71i.

It has already been shown that in subregion 71f, phosphorus was a more accurate predictor of EPT richness. An additional review of historic data from other subregions presented in the next section further supports this view.



Accuracy of Potential Nutrient Criteria Levels in Predicting the Status of Biological Communities at Probabilistic Monitoring Sites

IX. Comparison of Proposed Nutrient Criteria to Historic Monitoring Data in Various Subregions

In order to further test the practicality of using the 90th percentile for criteria development, existing data from subregions in other areas of the state as well as data from sites that had multiple samples were compared to the reference database.

Comparison of Multiple Test Sites to Proposed Subregional Nutrient Criteria

Data from 41 sites that had a minimum of six nutrient samples collected between 1996 and 1999 were compared to the proposed nutrient criteria at both the 75th and 90th percentiles.

These sites represented nine subecoregions across the entire state. The sites were from 13 different watersheds.

Forty-one percent of the test stations were on stream segments cited in the 2000 305(b) report as being impaired due to nutrients. If nutrient criteria were set at the 75th percentile, 85 percent of the sites would fail to meet either nitrate+nitrite or total phosphorus criteria.

At the 90th percentile, only 51 percent would fail to meet criteria. This value is closer to the 41 percent that had been assessed as having excessive nutrient levels as a primary concern.

Of the sites that would fail nutrient criteria set at the 75th percentile, 85 percent had been assessed as having impaired biology. At the 90th percentile, 96 percent were assessed as having impaired biology.

At the test sites, the 75th percentile is more likely to target streams as being impaired for nutrients in the presence of a healthy benthic community. As demonstrated earlier, total phosphorus does appear to have a closer correlation with biotic integrity, especially EPT richness, which was the primary metric used to establish biological harm at these sites. This should be viewed with some caution, however, since biorecons, which are a less intensive, qualitative type of survey, were used to assess the benthic community rather than the proposed biocriteria.

The table on page 40 provides information on the sites, ecoregions, and whether proposed nutrient criteria were violated.

The table indicates that the 90th percentile critera more closely follows historic assessment practices. It also provides additional support to the theory that in streams where nutrient enrichment is the primary water quality problem, nutrient levels can be an accurate barometer of biological integrity.

As noted earlier, in contrast to 71i, in these subregions total phosphorus criteria were exceeded more often than nitrate and nitrite.

Violations of Proposed Nutrient Criteria Nutrient Criteria at Selected Test Sites

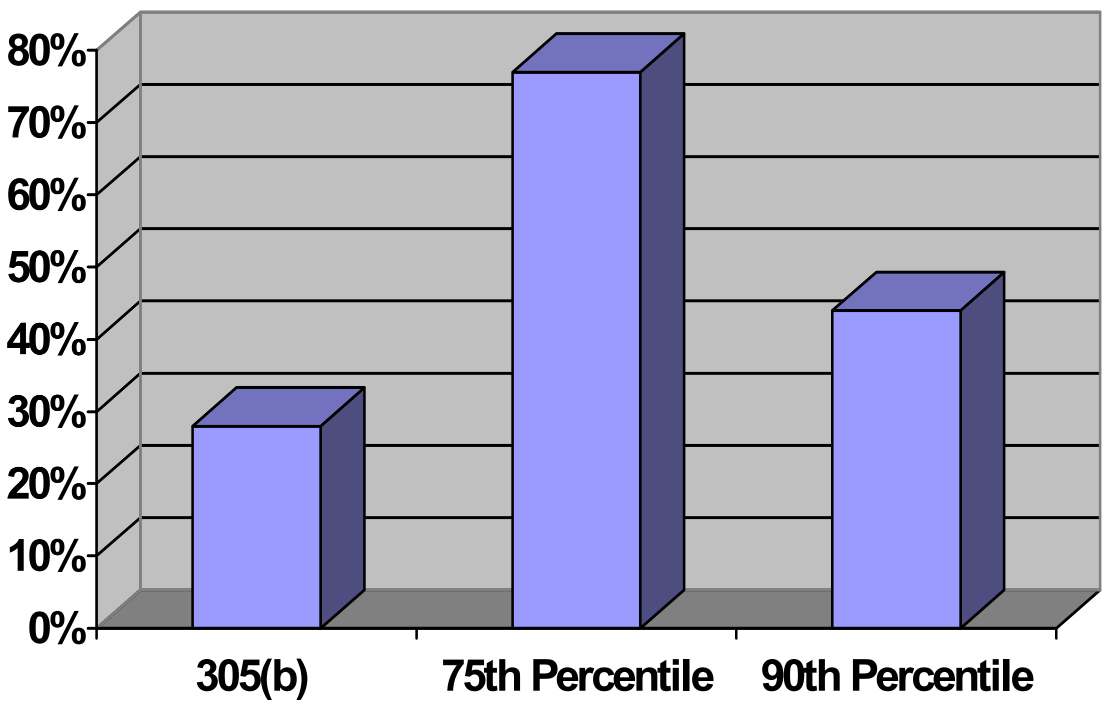
Station	Eco sub-region	303(d) Poll-utant	Violated NO2+NO3 at 75th Percentile	Violated NO2+NO3 at 90th Percentile	Violated Total Phosphorus at 75th Percentile	Violated Total Phosphorus at 90th Percentile	Impaired Biota
HATCH122.1HR	65E	NONE	NO	NO	NO	NO	NO
BEAVE003.5KN	67F	NUT+	YES	YES	YES	YES	YES
BEAVE010.1KN	67F	NUT+	YES	YES	YES	YES	YES
BEAVE012.5KN	67F	NUT+	YES	YES	YES	YES	YES
BEAVE023.5KN	67F	NUT+	NO	NO	YES	YES	YES
BEAVE023.6KN	67F	NUT+	NO	NO	YES	YES	YES
BEAVE031.8KN	67F	NUT+	NO	NO	YES	NO	YES
BEAVE036.7KN	67F	NUT+	NO	NO	NO	NO	YES
BEAVE040.2KN	67F	SILT+	NO	NO	YES	NO	YES
CHATT000.9HM	67F	PCB+	NO	NO	YES	YES	YES
PRYOR002.0ST	71F	NONE	YES	YES	YES	YES	YES
CHERR003.8WH	71G	NONE	YES	YES	YES	YES	YES
WFLON004.0MA	71G	NONE	YES	YES	YES	NO	YES
BBIG008.5MY	71H	NUT+	YES	NO	YES	YES	NO
WFSTO006.2RU	71I	ORG+	YES	YES	YES	YES	YES
COLD14.4LE	73A	NONE	NO	NO	NO	NO	NO
TODD001.6SH	73A	ORG+	YES	NO	YES	YES	YES
ROCK000.8OB	74A	NONE	NO	NO	YES	NO	NO
BENNETTS000.2	74B	NONE	NO	NO	YES	NO	NO
BIG001.0SH	74B	NUT+	YES	YES	YES	YES	YES
BIG013.6SH	74B	NUT+	NO	NO	YES	YES	YES
CLEAR001.4	74B	HAB+	NO	NO	YES	YES	YES
CLEAR001.6FA	74B	NONE	NO	NO	NO	NO	NO
CYPRE000.4SH	74B	NUT+	NO	NO	YES	YES	YES
FLETC000.6SH	74B	HAB+	NO	NO	YES	YES	YES
GOLDEN00.7	74B	NONE	YES	NO	YES	NO	NO
GRAYS01.7SH	74B	NUT+	NO	NO	YES	YES	YES
HARRI001.8SH	74B	NUT+	NO	NO	YES	YES	YES
LOOSA005.0SH	74B	HAB+	NO	NO	NO	NO	YES
LOOSA028.6SH	74B	HAB+	NO	NO	YES	NO	YES
LOOSA015.8SH	74B	HAB+	NO	NO	YES	YES	YES
LOOSA022.7SH	74B	HAB+	NO	NO	YES	YES	YES
LOOSA030.2SH	74B	HAB+	NO	NO	YES	NO	YES
SFFDE030.6HY	74B	HAB+	NO	NO	YES	YES	YES
SHAW007.2FA	74B	ORG+	NO	NO	YES	YES	YES
WOLF001.5SH	74B	SILT+	NO	NO	YES	YES	YES
WOLF018.9SH	74B	SILT+	NO	NO	YES	YES	YES
WOLF031.8SH	74B	NONE	NO	NO	YES	NO	NO
WOLF009.3SH	74B	SILT+	NO	NO	YES	YES	YES
WOLF1T01.6FA	74B	NUT	YES	NO	NO	NO	YES
WOLF044.4FA	74B	NONE	NO	NO	NO	NO	NO

Comparison of Test Data in Subregion 67f (Southern Limestone/Dolomite Valleys and Low Rolling Hills) to the Reference Database

In an effort to further test the applicability of the 90th percentile as a criteria limit, existing nutrient data from sites within subregion 67f were compared to the reference database. This subregion is located in the Ridge and Valley Region of east Tennessee.

All data were collected between 1996 and 2001. Seventy-four sites from 17 watersheds were used in the comparison.

As illustrated by the following chart, 28 percent of the sites had been assessed in the 2000 305(b) report as being impaired due to elevated nutrient levels. At the 75th percentile level, 77 percent of the sites would fail to meet nutrient criteria. Using the 90th percentile, 44 percent would exceed criteria. This level is closer to the 28 percent of sites previously assessed as being impaired due to nutrients.



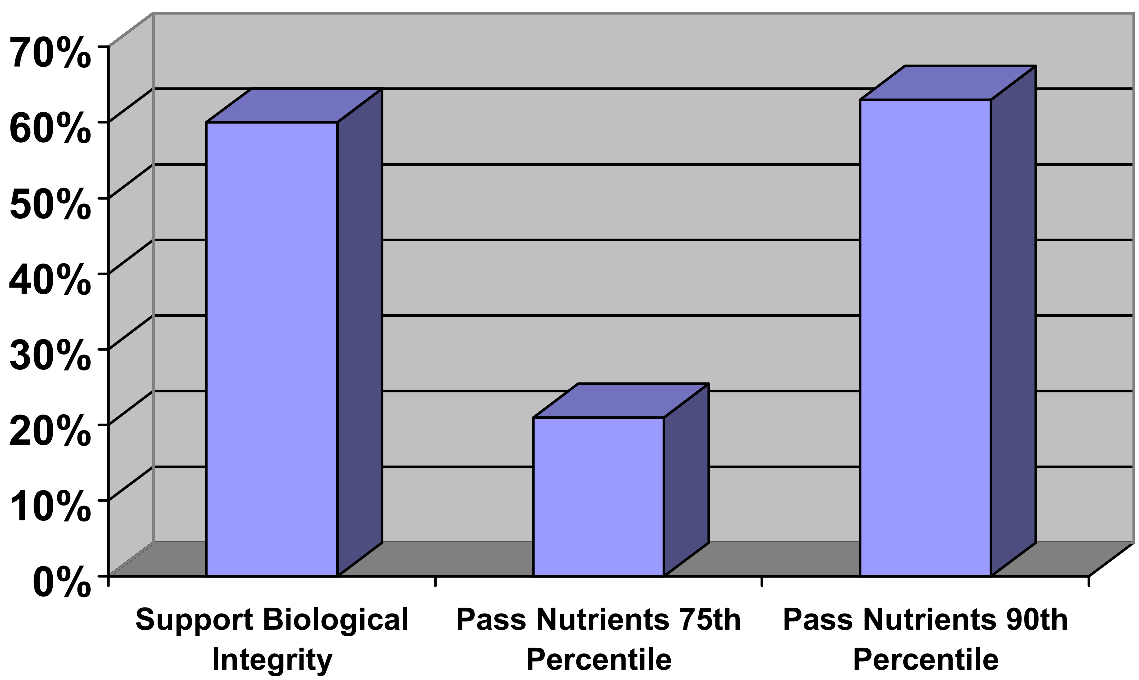
Sites in Subregion 67f Failing to Meet Nutrient Criteria

N = 74

Thirty-eight of the sites had biorecons conducted to assess biological integrity. Of these, 60 percent were found to be fully supportive of aquatic life. At the 75th percentile, only 21 percent of the sites would meet criteria for both nitrate+nitrite and total phosphorus.

However, using the 90th percentile, 63 percent would meet the proposed nutrient criteria for both parameters. This is only a three percent difference from the sites that were considered to be supportive of a healthy benthic community.
As illustrated by the following graph, use of the 90th percentile to establish nutrient criteria in this subregion would mean that most streams supporting a healthy biological community would not violate nutrient criteria.

As in all regions tested except 71i, when only one criterion was violated, phosphorus (13 sites) was exceeded more often than nitrate+nitrite (three sites). This may account for the closer association with biological integrity.



Comparison of Sites Supporting Biological Integrity With Proposed Nutrient Criteria at 75th and 90th Percentiles

N = 38

Comparison of Test Data in Subregion 65e (Southeastern Plains and Hills) to the Reference Database

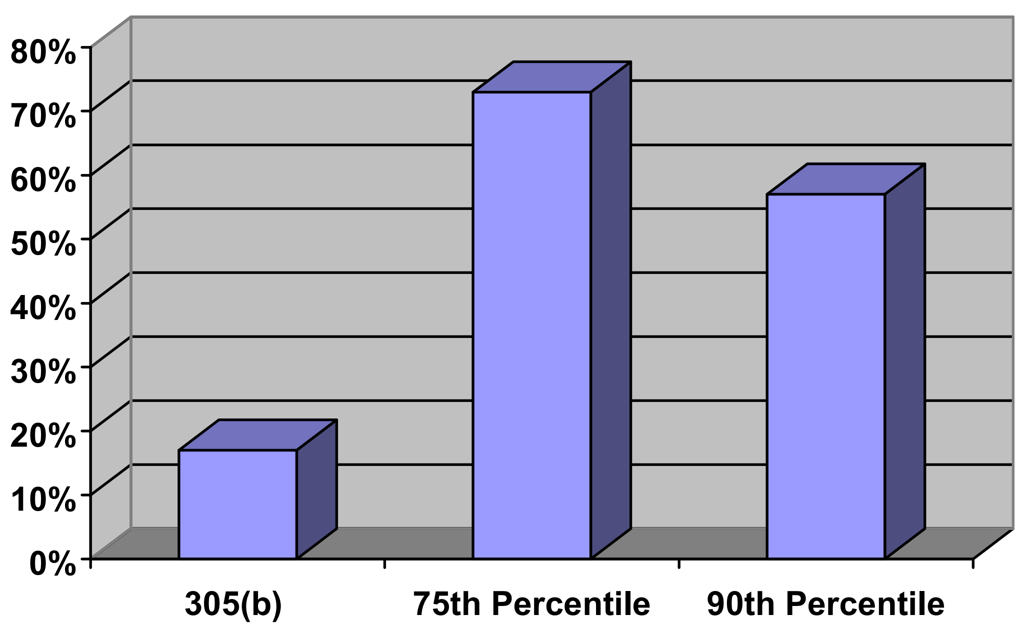
In a further effort to test the applicability of the 90th percentile as a criteria limit in representative subregions across the state, existing nutrient data from sites within subregion 65e were compared to the reference database. This subregion is located in the Southeastern Plains of west Tennessee. All data were collected between 1996 and 2001. Thirty sites from six watersheds were used in the comparison.

As illustrated by the following chart, 17 percent of the sites had been assessed in the 2000 305(b) report as being impaired due to elevated nutrient levels.

At the 75th percentile level, 73 percent of the sites would fail to meet nutrient criteria. Using the 90th percentile, 57 percent would exceed criteria. Although both values are well above the 17 percent originally assessed as impaired, the 90th percentile would assess fewer sites as impaired by nutrients.

The comparison should be viewed with some caution. It is possible that the 17 percent originally assessed as impaired due to nutrients under represents impairment in this region since, unlike other regions, there were very little biological data upon which to confirm assessments in these streams.

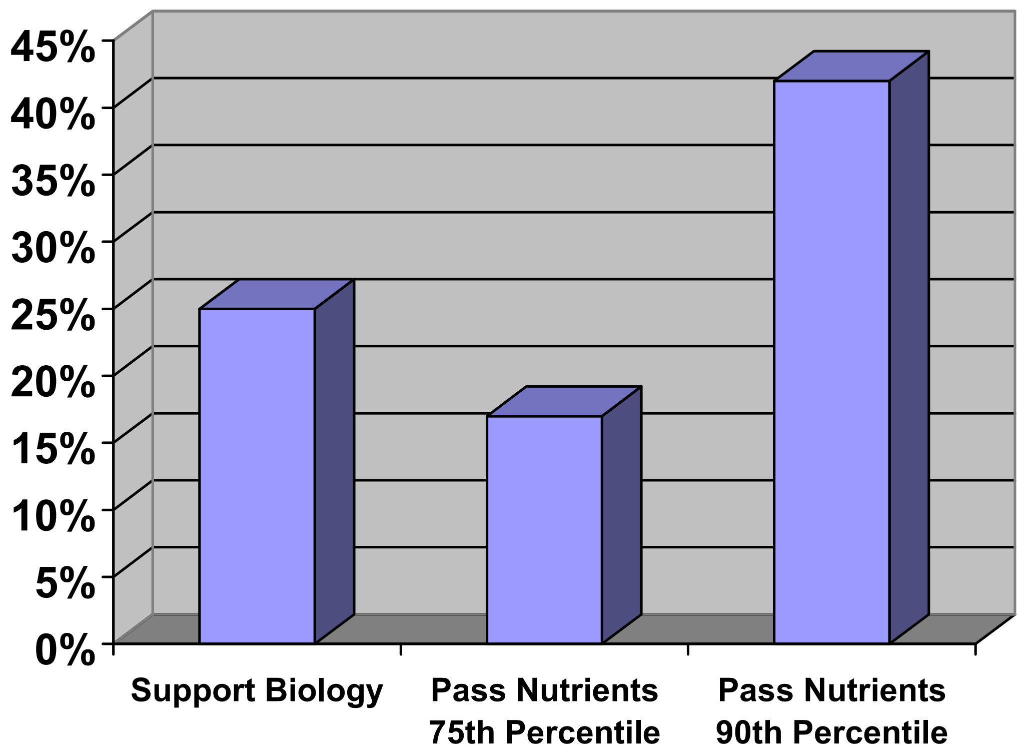
Once again, total phosphorus (12 sites) exceeded the criterion more often than nitrate+nitrite (two sites) when only one criterion was violated.



Sites in Subregion 65e Failing to Meet Nutrient Criteria
N = 30

Twelve of the sites had biorecons conducted to assess biological integrity. Of these, 25 percent were found to be fully supporting of aquatic life. At the 75th percentile, only 17 percent of the sites would meet criteria for both nitrate+nitrite and total phosphorus.

However, using the 90th percentile, 42 percent would meet the proposed nutrient criteria for both parameters. Therefore sites that supported a healthy benthic community were not penalized for nutrient criteria at the 90th percentile while they would be at the 75th percentile.

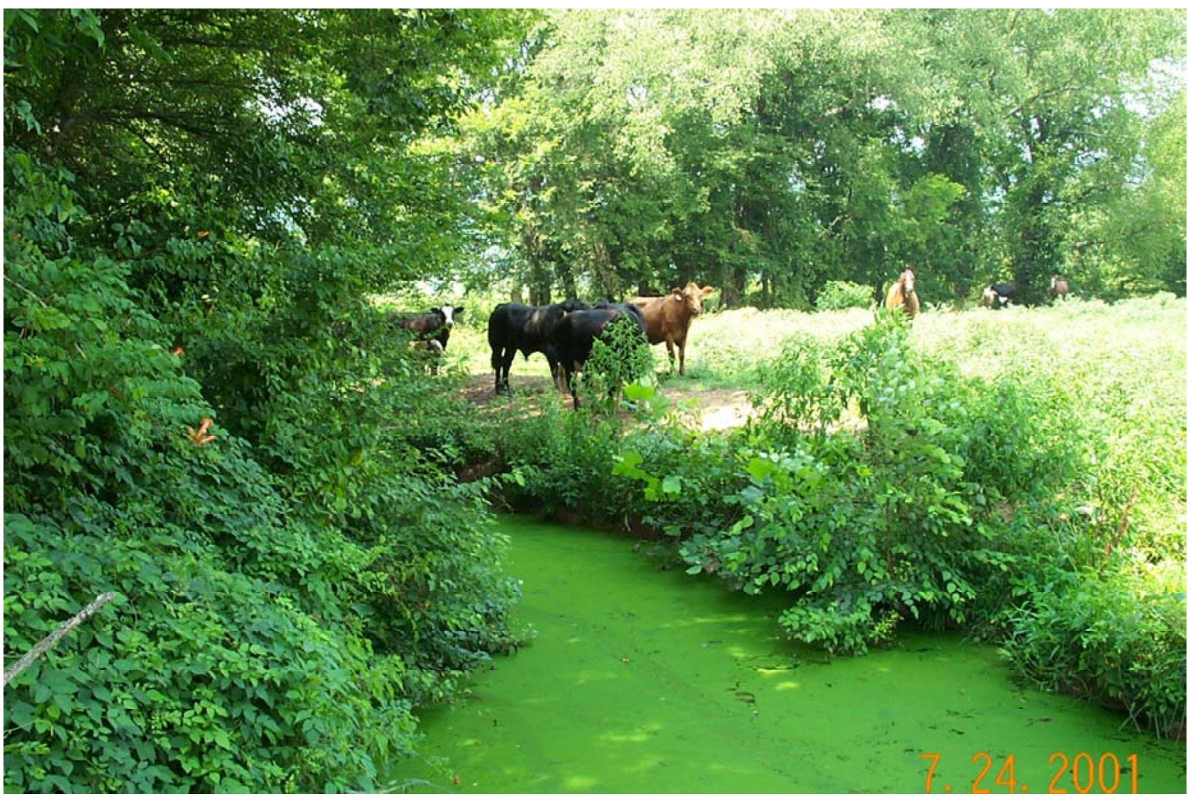


Comparison of Sites Supporting Biological Integrity With Proposed Nutrient Criteria at 75th and 90th Percentiles

N = 12

This review of data from regions that do not have naturally high phosphorus levels indicates that phosphorus levels most often exceed proposed criteria in regions where streams have stressed biota in the presence of elevated nutrients. These regions appear to have a more obvious association between nutrient levels and the biotic community structure than those such as 71i that are naturally high in phosphorus. This argues the case for region specific nutrient criteria. It also emphasizes the necessity of evaluating multiple components, including nutrient levels, when assessing factors that affect the biological community.

Nutrients are most likely an indirect, rather than a direct factor in predicting the integrity of benthic populations. High nutrient levels are not necessarily stressful to the biota. What is more likely is that the high nutrient levels cause an increase in algae which results in fluctuations in dissolved oxygen as well as making the substrate unavailable for colonization by benthic organisms. These factors can directly affect the macroinvertebrate community.



Euglena sp. bloom resulting from nutrient enrichment in Browns Creek, Sequatchie Valley (Subregion 68b) Photo provided by Tammy Hutchinson, Chattanooga EAC, TDEC

X. Study Conclusions and Criteria Recommendations

With assistance from EPA, the Tennessee Division of Water Pollution Control subdelineated ecoregions from Level III to Level IV. Reference streams were identified in each subecoregion to establish a database of least-impacted conditions. These databases have been used to develop regional interpretations of the existing narrative criteria for nutrients. (Analysis of other potential criteria for additional substances will be presented in other technical reports.)

As a point of interest, the Division investigated whether other substances could be used as surrogates for nutrients. Attempts to identify a relationship between nutrient levels and turbidity, TOC, and suspended solids were confounded by the amount of reference stream data below the detection level. While data relationships were indicated, they were not strong. Further investigations might include similar comparisons using the national nutrient database values.

Relationships between nutrient data and biological indices were explored to see if positive or negative correlations could be established. Such correlations could be used to strengthen a criteria justification and to insure that potential criteria values will be protective of biological integrity. While the preliminary results appeared promising, it should be remembered that our approach to comparisons may perhaps oversimplify the complicated relationship between nutrient levels and biological quality. However, we feel that the approach may be used to corroborate the results of other analyses.

Associations were found between nutrient levels and the quality of biological communities in some reference streams. When the same type analysis was preformed on data from randomly selected monitoring stations in Subecoregion 71i, only a weak association between nutrient levels and the number of EPT genera was observed. Additional samples were collected at these stations in the spring of 2001 and are pending analysis.

Stronger correlations were seen in subregions 71g, 71h, 67f and 65e. These data were not random, but pooled from existing databases. The data seem to indicate that nutrients and biological integrity are most directly linked when other factors such as habitat quality are not limited.

It is likely that nutrients are indirectly associated with biological health. Under the right conditions, increased nutrient levels generally result in algal blooms. High levels of algae affect dissolved oxygen as well as render habitat unavailable for colonization by macroinvertebrates. This in turn causes stress to the benthic population.

Tennessee's reference stream data were also compared to values from the National Nutrient Database. In most ecoregions, the 75th percentile of the reference data corresponded well with the 25th percentile of the national database. However, certain subecoregions did not correspond well, possibly suggesting that there are distinct differences within the EPA large nutrient ecoregions. We have considered these differences in setting nutrient goals.

Additionally, reference stream data were compared to the results of probabilistic monitoring data to see if the 75th percentile of the reference database would be similar to the 25th percentile of the probabilistic data.

This comparison was made in subecoregion 71i (Inner Nashville Basin). In 71i, the two databases were more similar than dissimilar for nutrients suggesting that streams in 71i have been subject to significant stress and alteration.

The Division used standard statistical methods to identify differences in nutrient concentrations between subecoregions. Where differences were significant, the adoption of subecoregion-based criteria is considered appropriate due to improved accuracy. However, where differences between subecoregions were not significant, it was considered advantageous to aggregate subecoregions so that the resulting criteria could apply to streams that cross subecoregion boundaries.

Test data from across the state were used to field test potential criteria levels. When criteria levels were compared to probabilistic data from 71i, the results indicated that while nitrate+nitrite criteria at the 75th percentile were most accurate at predicting biological use support, use of the 75th percentiles for both nitrate+nitrite and total phosphorus resulted in more streams appearing impacted than were indicated by the application of the Division's proposed biocriteria alone. Thus, for Subecoregion 71i, criteria set at the 75th percentile appeared overly conservative.

Existing data from subregions 67f and 65e as well as pooled data from multiple subregions that had 6 or more data points were used to further test the use of the 90th percentile for setting criteria.

Every subregion tested supported the use of the 90th percentile as a less restrictive nutrient criteria that did not penalize streams supporting a healthy benthic community.

Criteria Recommendations

Our findings indicate that nutrient criteria could have two different rationales:

- Consistency with the reference condition

- Identification of the level that is likely to cause harm in a specific stream while not misidentifying streams as impacted when biological data indicate full use support.

Our criteria development strategy has combined the two approaches. We have compiled a reference database in order to identify the reference condition. Nutrient concentrations at other streams can be compared to the reference condition. In our view, similarity to the reference stream is an appropriate and attainable goal.

We have used the second approach to help guide the selection of the percentiles to use as the specific criteria levels. In our field tests of the potential criteria levels, we were very mindful of the need to not identify more streams as being impacted by nutrients than were generally identified as not meeting biological goals.

As a result of these analyses, the 90th percentiles of the reference stream databases have been selected as the most appropriate criteria levels for total phosphorus and nitrate+nitrite. While criteria at the 75th percentile might have been useful, we have concluded that, at least in some subecoregions, it was perhaps arguably overprotective. A 90th percentile criteria also best accommodates uncertainty.

Where the subecoregion data are significantly different from other subecoregions, distinct criteria have been identified. Otherwise, the data have been aggregated back to the ecoregion (Level III) level.

The tables on pages 49 and 50 list the recommended regional interpretations of the existing narrative criteria. These numbers should only apply to streams that are similar to those in the reference stream database. We intend to interpret the previous statement to mean that a stream must be entirely or mostly (80 percent) within a subecoregion or ecoregion (depending whether or not the criteria is based on the subecoregion or ecoregion levels) in order for the criteria interpretations to be applicable.

Additional information about the Division's intentions regarding implementation of these recommended criteria can be found in the next section.

Reference site in the Eastern Highland Rim (71g).
Photo provided by Jimmy Smith, Nashville EAC, TDEC

REGIONAL INTERPRETATIONS OF THE EXISTING NARRATIVE CRITERIA FOR TOTAL PHOSPHORUS (Data in mg/L)

REGION	Recommended Interpretation of the Existing Narrative Criteria for Total Phosphorus
73a	0.25
74a	0.12
74b	0.10
65a, 65b, 65e, & 65i	0.04*
65j	0.04*
71e	0.04
71f & 71g	0.03
71h & 71I	0.18
68a & 68c	0.02
68b	0.04
69d	0.02
67f, 67h, & 67i	0.04
67g	0.09
66d, 66e, & 66g	0.01
66f	0.02

* Variability between data was significantly different as measured by Fisher's PLSD therefore subregions were not grouped despite 90th percentiles matching.

REGIONAL INTERPRETATIONS OF THE EXISTING NARRATIVE CRITERIA FOR NITRATE+NITRITE
(Data in mg/L)

REGION	Recommended Interpretation of the Existing Narrative Criteria for Nitrate+Nitrite
73a	0.39
74a	0.22
74b	1.19
65a, 65b, 65e, & 65i	0.34
65j	0.22
71e	3.48
71f	0.32
71g, 71h, & 71I	0.92
68a	0.23
68b	0.43
68c	0.30
69d	0.27
67f, 67g, 67h, & 67i	1.22
66d	0.50
66e, 66f, & 66g	0.31

XI. Implementation Questions and Answers

Why has the Division made the recommendation to formalize regional interpretations of the existing narrative criteria for nutrients?

We believe that regional interpretations of the existing nutrient criteria will be more appropriate than a statewide interpretation. The reference stream data collected across the state provide a scientifically defensible approach to this effort. By defining reference conditions, we can set attainable goals, regulate nutrient levels reasonably, and protect water resources appropriately, without being more conservative than necessary to protect water quality in certain areas of the state.

What has the Division recommended and what is the basis for the selected approach?

The Division has recommended that the 90th percentiles of the reference databases be established as the regional nutrient goals. A 90th percentile criterion establishes that above those levels, streams are no longer similar to the reference condition and will be considered to violate the criteria, unless it has been conclusively demonstrated that no loss of biological integrity or adverse downstream effects have occurred.

Criteria at the 75th percentile were considered, but rejected when they appeared overly conservative during field-testing. Criteria based on the 90th percentile were considered to more accurately reflect the true use-support status of the test streams.

Why has the Division chosen to base criteria on causal variables (total phosphorus, nitrate+nitrite) instead of response variables (chlorophyll a, low DO)?

If we had chosen to propose numeric lake criteria, then we may have selected an approach based on response variables. Regulating response variables has an obvious advantage, people can be aware of the exact nature of the problem before control efforts begin (fish kills, algae blooms, toxic conditions) and will likely be more supportive of control strategies. The problem with this approach is that by the time problems become obvious, they can be difficult to reverse.

When developing stream criteria, which is what the Division is proposing, the advantage of causal variables becomes obvious. Numeric criteria for total phosphorus and nitrate+nitrite can be directly used as a goal for TMDLs, or if appropriate, can be applied to discharge permits and established as goals of nonpoint source control programs, unlike response variables such as chlorophyll *a*.

Does setting the criteria at the 90th percentile mean that 10% of the reference streams failed to meet criteria?

No. The reference database is composed of multiple data-points (samples) and should not be thought of as representing individual streams.

Each stream had multiple samples collected seasonally over a 5 year period (up to 20 data points per stream).

All samples from every reference streams within a region or group of regions were pooled. The 90^{th} percentile was calculated from this pooled data.

The data points falling outside of the 90^{th} percentile represent individual observations that were outside of the usual distribution of the data. Environmental data commonly contain these outliers.

Comparison of test sites to criteria will be based on multiple samples rather than an individual sample. Therefore, test sites will not be penalized for this natural variability.

What is the linkage between the criteria the Division is proposing and stream-use classifications?

A common criticism of nutrient criteria development efforts is a perceived failure to link these criteria with use classifications. While we understand this comment, we consider it to be more valid in some states than others.

Some states are developing lake nutrient criteria. Lakes have more complicated and potentially competitive uses than do streams. Additionally, some states have tiered approaches to their fish and aquatic life protection classified use and thus would perhaps need a tiered approach to nutrient criteria.

If we were developing lake criteria or if Tennessee had multiple layers under the fish and aquatic life use, perhaps inappropriate linkage to designated uses would be more of a concern.

However, neither of these is the case. We are proposing a set of criteria to protect the fish and aquatic life designated use in streams of a certain size. All Tennessee streams are currently classified for this use.

The proposed criteria will not apply to lakes, wetlands, or streams that cross multiple ecoregions. (In these cases, the existing statewide narrative criteria will apply.)

While not specifically designed for this purpose, it is our opinion that the criteria we are proposing will also prevent violations of the aesthetic provision found under the current recreation use criteria.

Has the Division proved that nutrient concentrations above the recommended targets cause an effect in streams?

It is important to note that cause and effect in streams are often difficult to prove or disprove, because multiple interrelated chemical, physical, and biological factors control stream quality.

Of course, effects in the immediate stream are not the only reason to control nutrient concentrations – downstream cumulative effects must also be considered.

In our efforts to ground truth the proposed criteria, we investigated this issue in three subecoregions. In one test of data from reference streams in 71h, we found a curved-response association between elevated nutrient levels and declining integrity of biological communities.

Assessments of non-reference streams with equivalent habitat in subecoregion 71g, demonstrated an association between elevated phosphorus levels and loss of EPT taxa.

In the more generally impacted Inner Nashville Basin (71i), there was no clearly discernable association between nutrient levels and biological communities, except for a weak association between nutrient levels and the number of EPT genera. However, multiple regression analysis indicated that a combination of pollutants, including nutrients, was the likely cause of use impairment in 71i.

In setting the criteria at the recommended level (90^{th} percentile of the reference database), we make no assertion that violations cause an acute effect on the biology of the stream. However, we do generally presume a chronic effect. We consider this position to be supported by our study results.

Because of our acknowledgement of uncertainty concerning this issue, we will recommend that the promulgated criteria for nutrients contain a clause that establishes that violations of the nutrient criteria should not supercede a finding that the biology of any individual stream is consistent with the reference condition.

In plain words, the Division will not assess a stream as impacted on the basis of violations of the nutrient criteria if the biology of the stream is verifiably good.

One possible exception would be if a TMDL or other valid study determines, the stream should be assessed as causing impairment due to downstream effects.

Would the Division's recommended approach violate EPA's Rule of Independent Applicability?

The Rule of Independent Applicability has long been EPA's established position on the relationship between instream chemical concentrations, bioassay results, and the quality of biological communities. The rule contends that all three are interrelated. In EPA's view, streams must comply with all three sets of criteria or limits in order to be considered fully supporting.

Recently, EPA has been more open to the "biology rules" line of reasoning that states the stream's biological quality is the best and most important indicator of water quality. EPA has published guidance on how states may use a "weight of evidence" approach when chemical sampling or bioassay results indicate a problem, but biological monitoring indicates full use support.

It is our opinion that the relationship between nutrient levels and biological communities is complex. It has been our observation that elevated nutrients lare a frequent cause of use impairment.

However, in fairness, we have also noted that biological communities appear able to adapt to some degree to elevated nutrient concentration if such levels are generally a feature of the subecoregion in which they are found.

We have strong sympathies with the "biology rules" movement and believe that the approach we have recommended is the best blend of science and policy. We intend to use our nutrient criteria primarily as a tool to help decipher biological information.

If these criteria are promulgated, does it mean that all NPDES permittees will be required to have nutrient limits?

No. Only those facilities that discharge into nutrient impacted streams and/or have the reasonable potential to add to or create a problem, will be considered for a permit limit. Permit limits would not necessarily be automatically set at the criteria level. On the other hand, there is no foundation for a belief that if Tennessee fails to adopt numeric nutrient criteria, NPDES permittees will escape regulation.

How will nutrient criteria be applied to NPDES permits?

If a new or expanded discharge has a reasonable potential to cause or perpetuate a violation of the nutrient criteria, or if a TMDL has been developed that demonstrates that upstream nutrient controls are necessary to correct a downstream Iimpact, nutrient limits for contributing point sources will be necessary.

For existing dischargers, we would not object to a criteria provision that allows nutrient discharges to continue at current loadings, as long as neither the biology of the receiving stream is impaired nor an approved TMDL has indicated that loading reduction is required.

How will NPDES permit limits for nutrients be derived?

As with any other pollutant, NPDES nutrient limitations are calculated on the basis of the stream's ability to assimilate the pollutant. This assimilative capacity of the stream is based on the background concentration of the pollutant in the stream, the amount of stream flow, the volume of the discharge, and perhaps other factors such as the amount of elevation change in the stream.

Any criterion needs a flow basis for proper application. For example, current water quality standards stipulate that fish and aquatic life criteria be applied on the basis of the lowest flow that would be expected over a seven-day period every ten years. This amount of flow is commonly called a 7Q10. Other criteria have a different flow basis.

Although the new nutrient goals will be fish and aquatic life criteria, we feel that we should use a different flow basis than a 7Q10, since the endpoint being controlled is not specifically a toxic effect. We will recommend a 30Q5 flow as the proper basis for application of the nutrient criteria as recommended by EPA for non-carcinogens (EPA/505/2-90-001).

Additionally, since the effect of nutrients is considered to be chronic, in our view permit limits should be based on a monthly average concentration.

Does the development of numeric nutrient criteria provide opportunities for nutrient trading?

The development of nutrient criteria alone does not make it more or less likely that nutrient trading could occur. However, the criteria will assist this process by providing a clear sense of the proper clean water goals that should be met in any individual watershed.

Under the right set of circumstances, we believe that nutrient trading could be used to help restore water quality in a stream. How it might work is that after a TMDL has been developed and approved, the Division's proposed set of nutrient control strategies would be reviewed on the local level.

In the TMDL control strategy, the Division would propose a set of actions to reduce nutrient loadings. In the case of NPDES permittees, the control strategy might include reductions in allowable permit limits. For non-regulated sources, the Division would partner with other agencies to implement voluntary controls.

Nutrient trading might occur as a result of approved revisions to the Division's control strategy. For example, if it was more cost effective for an NPDES discharger to implement upstream source controls instead of building more treatment capabilities at the treatment facilities, such a plan could be allowed, as long as the net result insures that the TMDL allocation for the stream will be met.

Will full implementation of nutrient criteria make it difficult for the Division to authorize new or expanded discharges to zero-flow situations?

It was never a goal of nutrient criteria development to eliminate new or expanded discharges to zero-flow streams. But in practicality, it may be difficult to provide the treatment necessary to meet end-of-pipe limits without the benefits of stream flow to dilute effluents. Fortunately, there are practical alternatives to direct stream discharges, such as land application or connection to an existing municipal sewer.

Will these criteria regulate agricultural sources?

Our authority is established in the Tennessee Water Quality Control Act enacted by the Legislature. Provisions of the Act establish that the Division's authority cannot be extended to regulate certain agricultural and forestry activities. Revisions to criteria or development of new ones do not enable us to circumvent the limits of our program authority, nor should they.

Agricultural sources of nutrients will be controlled in the manner that they have traditionally been addressed—through implementation of voluntary best management practices and other controls. Public funds are available to assist in the implementation of controls, especially in streams that are violating water quality standards. The Division is fully supportive of these efforts.

What will happen if the Water Quality Control Board decides to retain the existing narrative nutrient criteria rather than promulgate the Division's recommendation?

The Division's proposal to formalize regional interpretations of the existing narrative nutrient is simply a science-based recommendation. We consider it in the interests of Tennesseans to explore these issues in a public forum, like the one provided by the rulemaking process.

It is the responsibility of the Board to consider the advice they are given, not only from the Division, but also from other informed sources.

If this recommendation is not established in the water quality standards - and nothing else is put in its place - then we would likely revert back to the original narrative criteria, which gives the Division a large amount of flexibility on how to interpret the existing language. In fact, nothing would preclude the Division from using our original recommendation less formally.

Of course, water quality standards are ultimately approved or disapproved by EPA. EPA has taken the position that if states fail to make reasonable progress in the establishment of numeric nutrient criteria by 2003, then EPA would be compelled to establish federal numeric criteria specifically for Tennesse.

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