BASINWIDE ASSESSMENT REPORT

BROAD RIVER BASIN

NORTH CAROLINA
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
Division of Water Quality
Water Quality Section
Environmental Sciences Branch

December 2001

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EXECUTIVE SUMMARY

The Broad River Basin encompasses a 1,506 mi^2 watershed drained by 1,452 miles of streams (Figure 1). The three major tributaries to the Broad River are the Green, the Second Broad, and the First Broad Rivers. The headwaters of the Broad and its major tributaries are located within the mountain ecoregion and flow towards the foothills before entering the piedmont ecoregion southeast and east of Lake Lure. From there, the Broad flows through Rutherford County and Cleveland County then into South Carolina. The basin encompasses most of Cleveland, Polk and Rutherford counties, and portions of Buncombe, Henderson, Lincoln, and Gaston counties. Larger municipalities include Forest City, Kings Mountain, Lake Lure, Rutherfordton, Shelby and Spindale.

More than half of the basin is covered in forests, but agriculture is also widespread. In 1992, the USDA Natural Resources Conservation Service estimated 20% of the basin was covered by cultivated or uncultivated crop or pastureland. Approximately 30% of the streams are classified as trout waters. Five Natural Heritage Program Priority Areas are found in this basin: the Rollins/South Mountains Natural Area, Hickorynut Gorge, Green River Gorge, Pacolet River Gorge, and Pinnacle Mountain. Sedimentation is responsible for habitat degradation in many areas of the basin. Many of the streams have a shifting sand bottom with embedded riffles and few pools.

The Broad River originates upstream of Lake Lure. Flat, Hickory, and Reedypatch Creeks are the largest tributaries above the lake. Buffalo Creek forms a major arm of the lake, and Cove Creek is a large tributary to the Broad River below the lake. Land use within the lake's watershed is predominantly forested with some urban and agricultural uses. Water quality above Lake Lure is generally high. Based upon benthic macroinvertebrate data, the Broad River above Lake Lure and Cove Creek were given Excellent bioclassifications and Reedypatch Creek, was rated Good. Fish sampling found Good-Fair water quality in Cedar Creek, a tributary of Cove Creek.

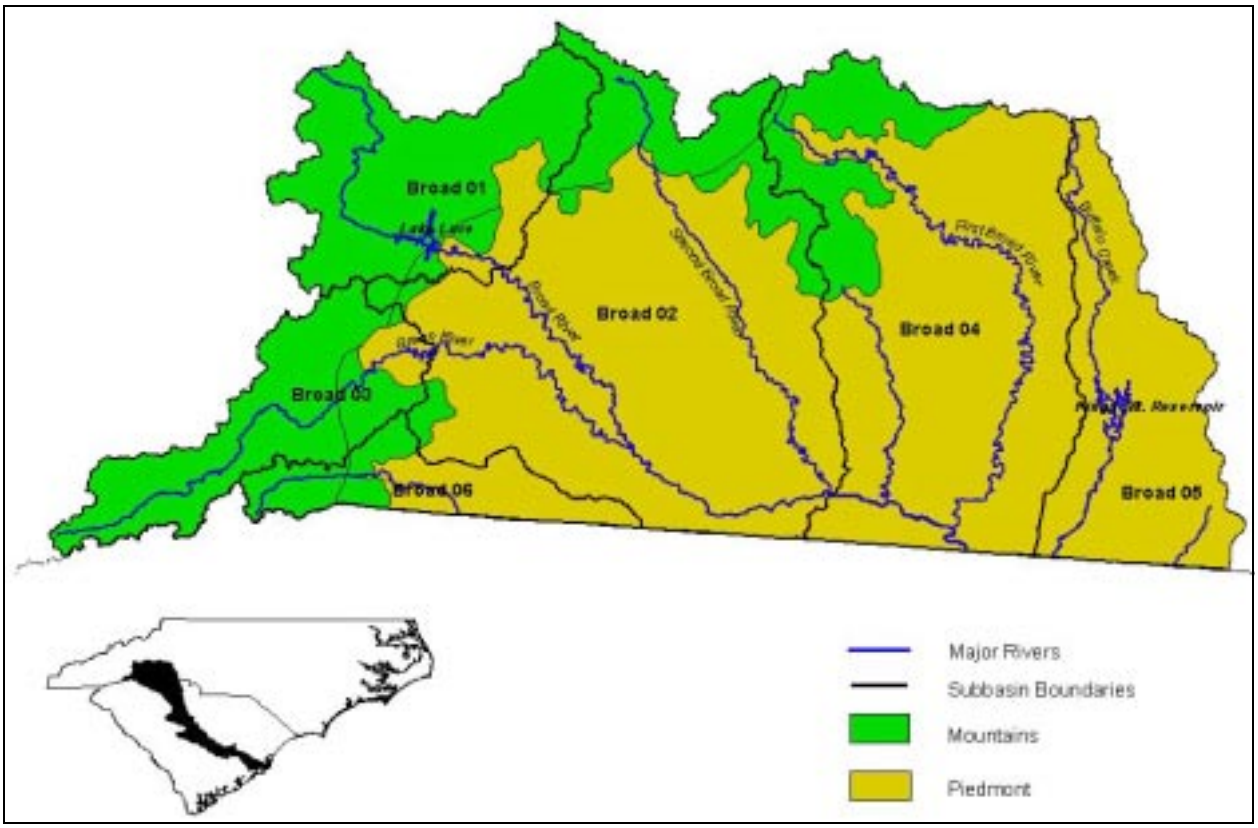


Figure 1. Geographical relationships and physiographic regions of the Broad River basin in North Carolina.

A Fair benthos bioclassification was assigned to the Broad River below Lake Lure at US 64/74 in 1984 and again in 2000. The regulated nature of the Broad River at this point and the Town of Lake Lure's WWTP appear to both play a role in causing the lower bioclassification. However, water quality recovers quickly downstream.

The middle and lower portion of the Broad River covers approximately 40 river miles from Lake Lure to the confluence of the Second Broad River near the Cleveland/Rutherford County line. During the 2000 and 1995 basin assessment, water quality of the Broad River was Good at a site below Knot Creek and at the ambient location near Cliffside, but Good-Fair at a site in between, below the Green River. Good or Good-Fair bioclassifications have been consistently recorded from the ambient monitoring location on the Broad River near Cliffside. This site is the most downstream monitoring location on the Broad River and denotes water quality conditions prior to flowing into South Carolina.

Major tributaries in this section include the Green River and the Second Broad River. These begin in the mountains, but flow into the piedmont ecoregion. Smaller tributary catchments of the Broad River include Mountain and Cleghorn Creeks. Water quality seems to be primarily Good-Fair throughout most of this area. The greatest problems appear to be associated with nonpoint sources of pollution: sedimentation and runoff from the urban areas of Rutherfordton, Spindale and Forest City. Bioclassifications increased at 4 of the 12 benthos sites sampled in both 1995 and 2000. However, most of these changes seemed to be related to lower flows in July 2000 compared to more normal flows in 1995, rather than real changes in water quality.

Two streams, however, seemed to have real increases in water quality: Walnut Creek (Fair in 1995 to Excellent in 2000), and Hollands Creek (Poor in 1988 to Fair in 2000) following removal of the Spindale WWTP discharge in late 1999. This WWTP has had problems with toxic effluent for over 10 years. Water quality in Mountain Creek declined from Good to Good-Fair. Fish sampling generally supported the conclusions of the benthos sampling: Walnut Creek had Excellent water quality, Whiteoak Creek and the Second Broad River had Good or Good-Fair water quality and Catheys Creek was impacted. Cane Creek was rated Good-Fair and Roberson Creek was rated Good (benthos data rated it Good-Fair).

The headwater reaches of the Green River in Henderson County are in the mountain ecoregion. Tributary streams are often high gradient and are capable of supporting trout populations. Apple orchards are a significant land use in upper reaches of many tributary catchments, including the Hungry River. Lower reaches of many catchments are farmed, and residential development is found throughout the watershed. The Green River Game Land between Lake Summit and Lake Adger on the Green and Hungry rivers provides an important buffer in this area. The Green River Preserve, on the headwaters of the Green River, serves a similar function.

Water quality is Excellent in the headwaters of the Green River, as reflected by its designation as Outstanding Resource Waters (ORW). Just above Lake Summit, at the bottom of the ORW area, the topography flattens and sedimentation increases, as does runoff from increasing development around Lake Summit. Macroinvertebrate sampling has given a Good-Fair rating to the Green River between Lake Summit and Lake Adger, and a Good rating to the Hungry River, which drains the eastern edge of Henderson County.

The Green River has been dammed at two locations to form Lake Summit and Lake Adger. Both reservoirs are used to produce hydroelectric power and owned by Duke Power. Lake Summit is used extensively for recreational purposes (fishing, swimming, boating) and supports a fishery consisting of catfish, sunfish, crappie, and largemouth bass.

The First Broad River originates in Rutherford County and flows into the Broad River in Cleveland County, just above the South Carolina border. This geographic area is a transitional zone between ecoregions, with some streams exhibiting mountain characteristics and other streams are more piedmont in nature. Land use is mainly a mixture of agriculture and forest. The town of Shelby is the largest urban area. Major dischargers include the Shelby WWTP, Cleveland Mills, and PPG Industries.

Most of the water quality information for the First Broad River watershed comes from benthic macroinvertebrate and fish community data. Both these datasets indicated overall Good water quality, despite very sandy substrates and low habitat scores. One exceptional area with Excellent water quality, based on both communities, is the North Fork First Broad River, a

headwater tributary of the First Broad River. The watershed for this stream is the South Mountains in Rutherford County. This area is part of the Rollins/South Mountains Natural Area. Fish also indicated Excellent water quality in Wards Creek, a tributary of the First Broad River a little further downstream in Cleveland County, which also originates in the South Mountains.

Benthos data from three sites on the First Broad River, from a headwater area near Casar to a downstream site near Earl, all resulted in Good bioclassifications. The upstream and middle site had ratings unchanged from 1995, while the site near Earl improved slightly from Good-Fair in 1995. This large, sandy site has been borderline Good to Good-Fair since 1987.

Sandy Run Creek, a large tributary that flows directly into the Broad River, not the First Broad River, had Good bioclassifications from an upstream fish community site and a downstream benthos site that is below the Boiling Springs WWTP. The benthos site improved from a Good-Fair rating found in 1995. Beaverdam Creek is another tributary of the Broad River near Boiling Springs that had a Good rating from both fish and benthos at NC 150. As with Sandy Run Creek, the benthos rating improved slightly from Good-Fair in 1995. Fish community data also indicated Good water quality in Hickory Creek, a small, sandy stream that is on the impaired streams list. Benthos data were also collected at the same site, but the severe drought conditions did not allow a rating to be given using the benthos data. However, EPT taxa richness improved from 3 in 1987 to 12 in 2000, indicating substantial improvement in the stream.

Three First Broad River tributaries received Good-Fair bioclassifications: Brushy Creek and Knob Creek, based on fish, and Hinton Creek, based on benthos. Benthos data from Knob Creek in 1995 and 2000 resulted in a Good rating. Habitat problems may account for the differences in the fish and benthos ratings. Brushy Creek was Good in its lower watershed, based on benthos data. This stream has improved greatly since the Fair ratings noted in this part of the stream in the 1980's, and should come off the impaired streams list. This better water quality is due in large part to improvements in the effluent of PPG-Shelby. Before 1999, this plant was routinely noncompliant with its whole effluent toxicity limit. The facility has been continuously compliant since August 1998, after plant modifications were made to remove the toxicity from the effluent.

Buffalo Creek and its tributaries, Muddy Fork, Beason Creek, and Kings Creek are in North Carolina, but flow into the Broad River in South Carolina. Land use is primarily a combination of agriculture and forest. Kings Mountain is the largest town in the Buffalo Creek watershed. Although a few streams in the northern portion of the watershed exhibit some montane characteristics, this area is considered to be in the piedmont ecoregion.

Water quality in the Buffalo Creek watershed was generally good using biological data. Buffalo Creek above Kings Mountain Reservoir had both benthos and fish community collections in 2000. There was a big difference in the bioclassifications assigned, with benthos noting Excellent water quality, while the fish rating was Good-Fair. However, the fish sampling site was in an area of eroding banks and very sandy substrate, and the fish community assessment integrates these habitat problems. The benthos sampling site had a boulder and bedrock substrate, providing more diverse habitat. Nonpoint source impacts were likely lower in the drought of 2000, and the benthos improved from a Good rating in 1995.

Kings Mountain Reservoir (also known as Moss Lake) is a water supply reservoir for the City of Kings Mountain. The reservoir was considered oligotrophic in 1995. Photic zone phytoplankton samples collected in June were dominated by diatoms and golden-brown algae known to produce taste and odor problems. The lake does stratify with hypoxic conditions observed at a depth of 6 to 7m.

Buffalo Creek was also sampled for benthos below the reservoir and below discharges from Kings Mountain WWTP and Grover Industries. A Good bioclassification was found, as it was in 1995. Fish community and benthos samples from Muddy Fork, a tributary of Buffalo Creek below the reservoir, indicated Good water quality. The benthos rating was unchanged from 1995.

Smaller tributaries sampled for benthos in 2000 were Kings Creek, that improved from Good-Fair in 1995 to Good in 2000 when there were less nonpoint impacts, and Beason Creek, which was Good-Fair in both basin years. Finally, a success story was found in Lick Branch where the bioclassification improved dramatically from Fair in

1995 to at least Good in 2000 following removal of the discharge from the Minette Mills textile plant. The presence of stoneflies and other intolerant taxa at this site were indicators of development of a natural community.

The North Pacolet River in Polk County has a small watershed in North Carolina in the mountain ecoregion before flowing directly into South Carolina. Tryon is the only urban area in the watershed. Based on macroinvertebrate collections in both 1995 and 2000, water quality in North Pacolet River is Good above the Town of Tryon, and declined to Good-Fair below the town and the town's WWTP.

EXECUTIVE SUMMARIES BY PROGRAM AREA

BENTHIC MACROINVERTEBRATES

Bioclassifications and Water Quality Changes

Benthic macroinvertebrates have been collected at 66 sites in the Broad River basin since 1983. The majority of these sites are considered to be in a mountain/piedmont transition ecoregion based on recent sub-ecoregion delineation and the composition of the stream fauna. However, the lower part of the basin (parts of Subbasin 4 and all of Subbasin 5) was rated with piedmont criteria.

Basinwide sampling in July 2000 generally occurred during a period of extreme low flow. Low rainfall and low runoff should reduce the impact of nonpoint source pollutants, and some slight improvement would be expected for many of the samples collected in July 2000 relative to prior basinwide samples. To evaluate the expected magnitude of this change, an evaluation was made of all the sites that were sampled both in July 1995 and July 2000, but had no known change in land use or dischargers (n = 22). For this group of sites, there was a mean increase between years of five EPT taxa, a change sometimes sufficient to change the bioclassification. Very heavy rainfall occurred in late July 2000, such that the few sites sampled in August 2000 would have had a greater chance of being affected by nonpoint source runoff. These sites, however, did not have an increase in EPT taxa richness and one site (Mountain Creek) actually had a decline in bioclassification.

For the 2000 collections, the majority of the samples (78%) received a Good (50%) or Good-Fair (28%) rating (Figure 2). The distribution of the 2000 ratings was similar to the distribution of water quality ratings for all sites sampled since 1983 (Table 1), although the drought conditions (with higher EPT taxa richness) produced a slightly higher percentage of Good sites in 2000 than in previous years.

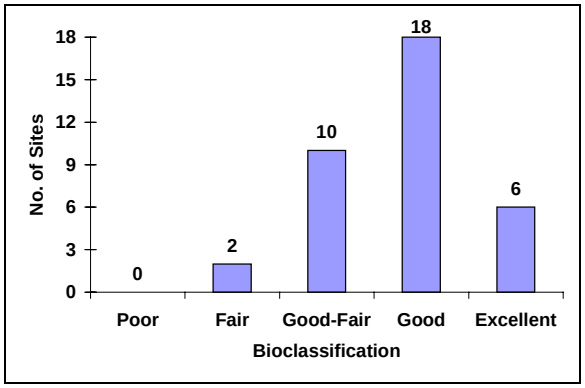


Figure 2. Bioclassifications of 36 rateable benthic macroinvertebrate sites in the Broad River basin, 2000.

Table 1. Most recent ratings for all rateable benthic macroinvertebrate sites in the Broad River basin since 1983.

	Bioclassification				
Subbasin	**Excellent**	**Good**	**Good-Fair**	**Fair**	**Poor**
01	2	2	---	1	---
02	1	6	15	2	---
03	4	3	2	---	---
04	1	12	2	1	---
05	2	4	2	1	---
06	---	1	2	---	---

Total (#)	10	28	23	5	0
Total (%)	15	42	35	8	0

Many sites had severe habitat degradation, but still received a Good bioclassification. This was especially true in Subbasins 4 and 5, where most low-gradient streams were highly entrenched with very heavy sediment loads. These data also suggested that habitat problems were of greater importance than water quality problems in most streams.

In looking at the data set since 1983, nonpoint source runoff from agricultural areas produced Good-Fair ratings in many streams. The widespread increase in EPT taxa richness during the 2000 low-flow conditions (relative to 1995) clearly indicated the importance of nonpoint source problems in the basin. Comparisons between 1995 and 2000 showed many improvements in bioclassification (usually from Good-Fair to Good), but this trend may reverse itself if higher flows occur during the next basinwide collections. Streams showing flow-related improvements included portions of the Broad River, Cleghorn Creek, Hungry River,

Sandy Run Creek, First Broad River, Beaverdam Creek, Upper Buffalo Creek, and Kings Creek.

Between-year changes in water quality were evaluated at 51 sites with most of these being short-term changes over the last five years (Figure 3). The majority of sites had no change in water quality since the last basinwide survey in 1995, other than flow-related changes in bioclassification. However, four sites showed improvement associated with changes at wastewater treatment facilities. Improvements due to management of point source dischargers was even more evident when the data were examined over a longer period of time. These changes were confined to Subbasins 2, 4, and 5.

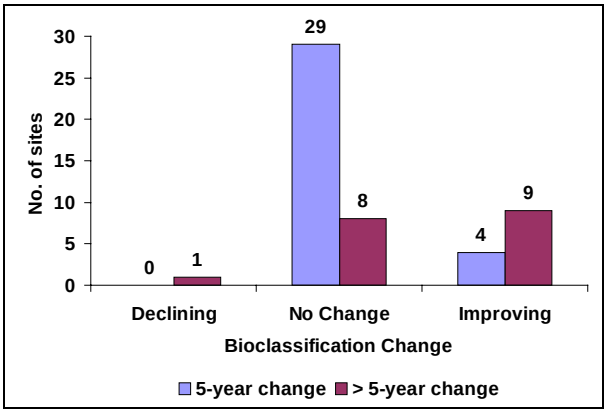


Figure 3. Number of benthos sites with a between-year (sampling period) change in bioclassification. [Note: this does not include changes that were strictly flow-related.]

New Species and Distributional Records for the Benthic Macroinvertebrate Fauna

Several rare or unusual benthic macroinvertebrate species have been collected from this basin during NCDWQ surveys. Most rare species occurred at the larger river sites, with few rare species in smaller streams:

- Ephemeroptera (mayflies)
  - *Cercobrachys* sp.: this may be *C. etowah* or a new species. Records from the Broad River (Buncombe County), First Broad River near Casar and the North Pacolet River.
  - *Drunella longicornis*: single record from North Fork First Broad River, 2000.
  - *Homoeoneuria cahabensis*: single record from the Second Broad River, 1994.
  - *Nixe* sp.: two records from the First Broad River near Casar
  - *Serratella spiculosa*: single record from Joes Creek, 2000
  - *Stenonema lenati*: many records from the Broad River below Lake Lure (Rutherford County) and the Green River in Polk County.
- Trichoptera (caddisflies)
  - *Ceraclea mentiea*: single record from the Green River, Polk County, 2000.
  - *Culoptila* sp.: single record from the Broad River, Rutherford County, 2000.
  - *Micrasema sprulesi*: single record from the Green River, 1989.
  - *Stactobiella* sp.: single record from the Broad River, Rutherford County, 2000
- Crayfish
  - There are two crayfish species that are endemic to the Broad River basin: *Cambarus spicatus* (Cooper et al. 1998) and *C. lenati* (Cooper 2000). The latter species is largely confined to the First Broad River area.

FISHERIES

Fish Community Assessment

In 2000, 15 sites in Subbasins 01, -02, -04, and -05 were sampled during early May (Figure 4). Stream flows during the period May 8 - 12, 2000 were approximately one-half the historical median flows. Under these low flow conditions, the streams were shallow and generally clear. Most of the streams had a shifting sand bottom.

Only Beaverdam Creek had been previously sampled during the initial cycle of basinwide monitoring in 1995 while the remaining 14 sites represented new monitoring sites. The new sites were selected to represent possible regional reference sites; or the sites were chosen because the stream had been previously placed on the existing impaired stream list but from which fish community basinwide data were lacking; or the sites were chosen to represent typical streams draining rural or urban watersheds and which may be impacted primarily by nonpoint source pollution.

The 15 streams were evaluated using the North Carolina Index of Biotic Integrity (Appendices F1-F3). The NCIBI ratings at these 15 sites ranged from Poor to Excellent (Figures 4 and 5) with the NCIBI scores ranging from 32 to 56. The rating at Beaverdam Creek did not change between the 1995 and 2000 sampling periods.

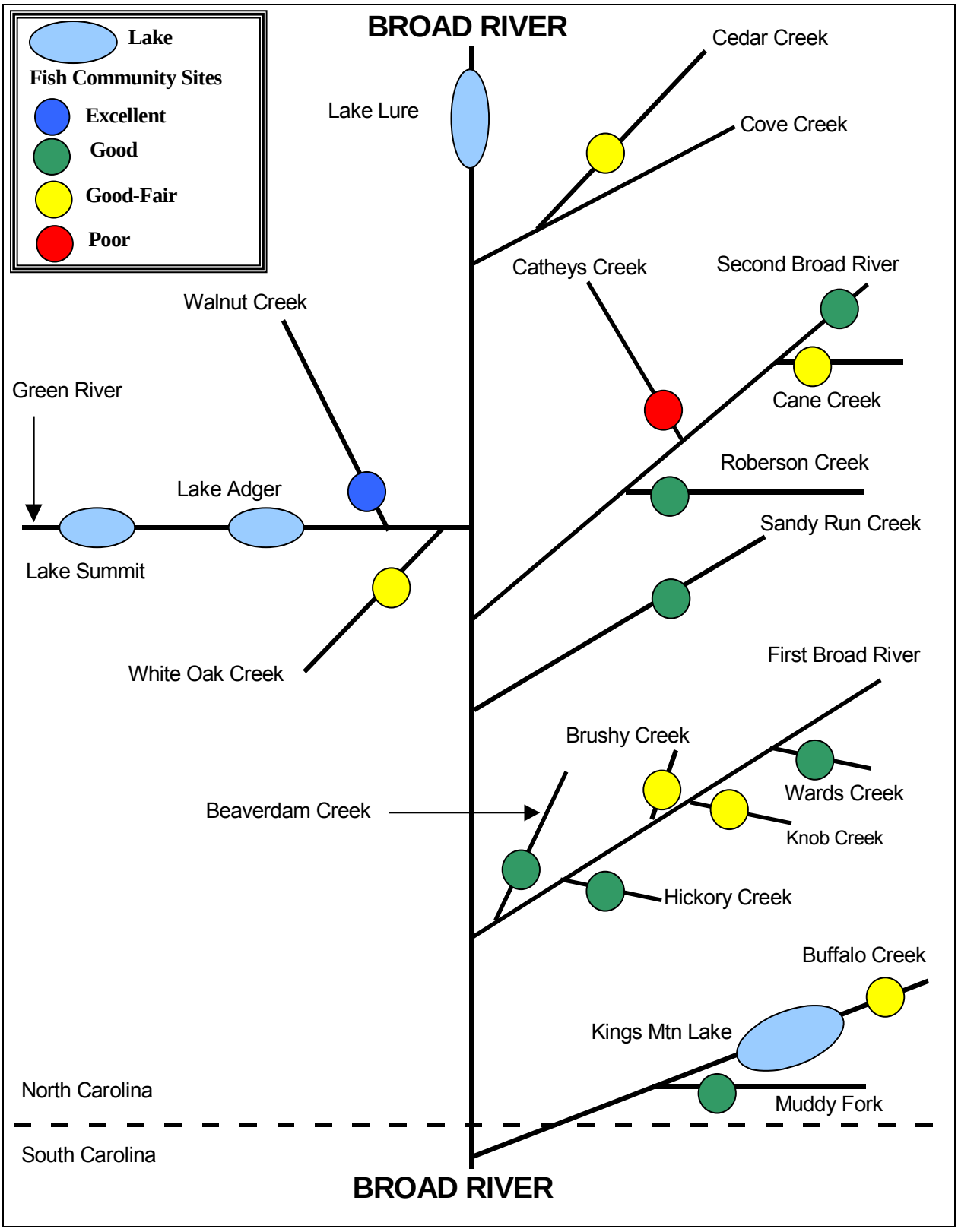


Figure 4. **Fish community assessment sites in the Broad River Basin, 2000.**

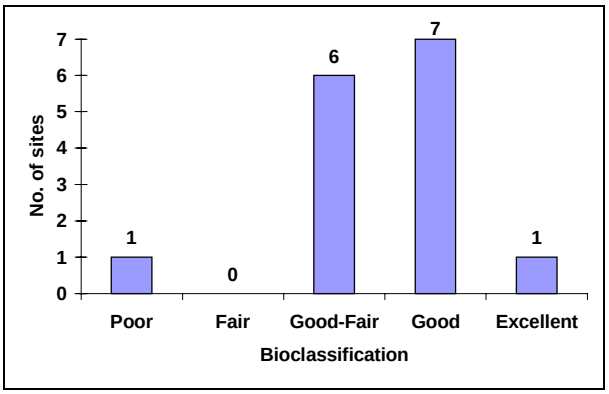


Figure 5. Bioclassifications of 15 fish community sites in the Broad River basin, 2000.

In 2000, the most widely distributed species (collected at most of the sites) were the rosyside dace, bluehead chub, Piedmont shiner, striped jumprock, and redbreast sunfish. The bluehead chub was the most abundant species; representing approximately 40% of all the fish collected. The dominance by this species also reflected that many of the sites had an elevated percentage of omnivores, indicative of an abundance of nutrients.

Based upon Menhinick (1991) and NCDWQ data, 63 species of fish are known from the Broad River basin in North Carolina. None of the 63 species has required special protection by the U. S. Department of the Interior, the North Carolina Wildlife Resources Commission, or the North Carolina Natural Heritage Program under the North Carolina State Endangered Species Act (G.S. 113-311 to 113-337 (LeGrand and Hall 1999; Menhinick and Braswell 1997). There are no species found within the river basin that are considered to be federally or state endangered, threatened, or of special concern. The Natural Heritage Program, however, considers the Santee Chub, *Cyprinella zanema*, as a significantly rare and as a S3 type species (rare or uncommon in North Carolina with 21-100 extant populations). This species was collected at seven sites scattered throughout the basin during the 2000 monitoring activities.

Fish Tissue Contaminants

No fish tissue contaminant monitoring in the basin was conducted by the NCDWQ between 1994 and 2000 because there were no basin-specific contaminant issues to be addressed. Currently, there are no basin-specific fish consumption advisories in place for the basin. Even though a statewide mercury advisory is in place for bowfin, this species does not occur within the basin.

Fish Kills

The NCDWQ has systematically monitored and reported on fish kill events across the state since 1996. No fish kills have been reported from the Broad River basin during this time period.

LAKE ASSESSMENT

Lake Lure, Lake Summit, Lake Adger, and Kings Mountain Lake were monitored as part of the Lake Assessment program (Table 2). In 2000, each lake was sampled one to three times during the summer months.

In January 2001, the NCDWQ discovered quality assurance issues with chlorophyll *a* laboratory analyses for samples from 1996 through February 2001. NCDWQ tracking efforts have identified several different quality assurance issues. In some circumstances, laboratory data for chlorophyll *a* will require re-calculation efforts. In other cases, chlorophyll *a* data cannot be recovered from the laboratory methods that were utilized. For lakes that were monitored as part of this time period, all previously reported chlorophyll *a* laboratory analyses has been withheld pending a sufficient quality assurance evaluation and/or re-calculation of chlorophyll *a* values. As a result, no North Carolina Trophic State Index (NCTSI) values were calculated for this time period.

Table 2. Lakes and reservoirs monitored in the Broad River basin in 2000.

Subbasin/Lake	County	Classification	Surface Area (Ac)	Mean Depth (ft)	Volume (X 10^6 m^3)	Watershed (mi^2)
01						
Lake Lure	Rutherford	B Tr	1500	65.6	12.1	89.6
03						
Lake Summit	Henderson	C Tr	321	32.8	11.5	41.3
Lake Adger	Polk	C	460	26.2	14.4	133.6
05						
Kings Mountain Res.	Cleveland	WS-III CA	1310	45.9	7.4	65.3

AMBIENT MONITORING SYSTEM

Ambient water quality data for the period 1995 - 2000 was reviewed and no major issues were identified. However, the highest median nitrate+nitrite nitrogen concentrations (1.2 mg/L) were found at Sugar Branch. Only one minor NPDES discharger was identified for this subbasin and the watershed is very small (1.4 miles^2). Nonpoint sources may be contributing to these high values. Elevated fecal coliform concentrations were also present.

Concentrations of copper exceeded the 7 µg/L Action Level for more than 10% of samples collected from six stations. However, the median concentration for copper at all stations was below the Action Level. Potential copper toxicity will be investigated for the most downstream monitoring station along the Second Broad River near Cliffside.

AQUATIC TOXICTY MONITORING

Eighteen facility permits in the Broad River basin currently require whole effluent toxicity (WET) monitoring. Seventeen facility permits have a WET limit; the other facility permit specifies monitoring with no limit. Since 1997, the compliance rate of those facilities with a limit has stabilized at approximately 90 - 95%.

Three facilities that have had difficulty meeting their toxicity limits were:

- **The Town of Spindale's WWTP (Subbasin 02)**
  This facility, which discharges into Cathey's Creek, has experienced problems meeting its whole effluent toxicity limit since it began monitoring in 1987. The facility signed a Special Order by Consent (SOC) with the NCDWQ in August of 1996 to perform toxicity reduction activities, construct treatment plant upgrades, and relocate its discharge from Hollands Creek to Cathey's Creek. The SOC expired in September of 1999. The discharge relocation reduced the facility's instream waste concentration (IWC) and thus its WET limit from 67% to 26%. The facility constructed a dissolved air flotation sludge thickener and added new weirs and baffles in a secondary clarifier. Initial toxicity identification procedures indicated surfactant chemicals as the source of toxicity. The facility's monitoring data indicate compliance with its new limit from October 1998 to the present, excepting June and July of 2000.

- **PPG Shelby (Subbasin 04)**
  The facility, which discharges to Brushy Creek, was routinely noncompliant with its WET limit during the period April 1995 through May 1997, with sporadic failures in 1998. The facility signed an SOC in March 1997 that expired in July 1998. During this time, the facility concluded that total dissolved solids were the source of toxicity and instituted a treatability approach to toxicity reduction. Bentonite clay addition at the aeration basin successfully removed toxicity from the effluent. Permanent modifications were made to the wastewater treatment plant effective May 1997 to implement this treatment technology. The subsequent failures in 1998 were attributed to malfunctions of that technology. The facility has been continuously compliant since August 1998.

- **The King's Mountain-Pilot Creek WWTP (Subbasin 05)**
  The facility, which discharges to Buffalo Creek, has had significant difficulty meeting its WET limit since January 1998. April 2000 Toxicity Identification Evaluation (TIE) testing implicated nickel as the primary toxicant. The source of the nickel was traced to a malfunctioning industrial user pretreatment process. That process was upgraded during October 2000. Two tests performed during that month were compliant.

INTRODUCTION TO PROGRAM METHODS

The NCDWQ uses a basinwide approach to water quality management. Activities within the NCDWQ, including permitting, monitoring, modeling, nonpoint source assessments, and planning are coordinated and integrated for each of the 17 major river basins within the state. All basins are reassessed every five years, and the Broad River basin was sampled by the Environmental Sciences Branch in 1995 and 2000.

The Environmental Sciences Branch collects a variety of biological, chemical, and physical data that can be used in a myriad of ways within the basinwide planning program. In some areas there may be adequate data from several program areas to allow a fairly comprehensive analysis of ecological integrity or water quality. In other areas, data may be limited to one program area, such as only benthic macroinvertebrate data or only fisheries data, with no other information available. Such data may or may not be adequate to provide a definitive assessment of water quality, but can provide general indications of water quality. The primary program areas from which data were drawn for this assessment of the Broad River basin include benthic macroinvertebrates, fish community, lake assessment, ambient monitoring, and aquatic toxicity monitoring.

QUALITY ASSURANCE

Laboratory measurements play a key role in the assessment and protection of water quality. Laboratory analyses are needed to identify problems and to monitor the effectiveness of management strategies to abate these problems. The relative accuracy and precision of laboratory data must be considered as part of any data interpretation or analysis of trends and use support. Absolute certainty in laboratory measurements can never be achieved. However, it is the goal of quality assurance and quality control efforts to quantify an acceptable amount of uncertainty. The evaluation of data quality is thus a relative determination. What is high quality for one situation could be unacceptable in another.

The NCDWQ's Chemistry Laboratory has recently established rigorous internal quality assurance evaluations. These evaluations may have significant implications on interpretation of historical data and how new data are generated and reviewed. NCDWQ will continue to work on ensuring the quality of water analyses in North Carolina. It is obviously beneficial to generate the highest quality information to apply a statistical level of significance to water quality observations. In addition to quantification limits, lower limits of detection, method detection limits, and instrumentation detection limits must be evaluated on a continuing basis to ensure sound data and information. Because each of these detection limits can represent different levels of confidence, water quality evaluations may change from time to time based on improved laboratory instruments, analytical methods, and improved quality assurance and quality control applications.

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates, or benthos, are organisms that live in and on the bottom substrates of rivers and streams. These organisms are primarily aquatic insect larvae. The use of benthos data has proven to be a reliable monitoring tool, as benthic macroinvertebrates are sensitive to subtle changes in water quality. Because many taxa in a community have life cycles of six months to one year, the effects of short term pollution (such as a spill) will generally not be overcome until the following generation appears. The benthic community also integrates the effects of a wide array of potential stressors.

Sampling methods and criteria (Appendix B1) have been developed to assign bioclassifications ranging from Poor to Excellent to each benthic sample from flowing fresh waters based on the number of taxa present in the intolerant groups Ephemeroptera, Plecoptera and Trichoptera (EPT S) (Appendix B1) and the value of the North Carolina Biotic Index (NCBI (BI)). This index summarizes tolerance data for all taxa in each collection. These bioclassifications primarily reflect the influence of chemical pollutants. The major physical pollutant, sediment, is not assessed as well by a taxa richness analysis. Different criteria have been developed for different ecoregions (mountains, piedmont, and coastal) within North Carolina for freshwater flowing waterbodies.

Bioclassifications listed in this report (Appendix B2) may differ from older reports because evaluation criteria have changed since 1983. Originally, total taxa richness and EPT taxa richness criteria were used, then just EPT taxa richness, and now NCBI and EPT taxa richness criteria are used for flowing freshwater sites.

Refinements of the criteria continue to occur as more data are gathered.

FISHERIES

Fish Community Structure

The NCIBI is a modification of the Index of Biotic Integrity initially proposed by Karr (1981) and Karr, et al. (1986) (Appendix F1). The IBI method was developed for assessing a stream's biological integrity by examining the structure and health of its fish community. The scores derived from this index are a measure of the ecological health of the waterbody and may not directly correlate to water quality. For example, a stream with excellent water quality, but with poor or fair fish habitat, would not be rated excellent with this index. However, a stream which rated excellent on the NCIBI should be expected to have excellent water quality.

The Index of Biological Integrity incorporates information about species richness and composition, trophic composition, fish abundance, and fish condition. The NCIBI summarizes the effects of all classes of factors influencing aquatic faunal communities (water quality, energy source, habitat quality, flow regime, and biotic interactions). While any change in a fish community can be caused by many factors, certain aspects of the community are generally more responsive to specific influences. Species composition measurements reflect habitat quality effects. Information on trophic composition reflects the effect of biotic interactions and energy supply. Fish abundance and condition information indicate additional water quality effects. It should be noted, however, that these responses may overlap. For example, a change in fish abundance may be due to decreased energy supply or a decline in habitat quality, not necessarily a change in water quality.

Fish Kills

Fish kills investigation protocols were established in 1996 by the NCDWQ to investigate, report, and track fish kill events throughout the state. Fish kill and fish health data collected by trained NCDWQ and other resource agency personnel are recorded on a standardized form and forwarded to the Environmental Sciences Branch where the data are reviewed.

Fish kill investigation forms and supplemental information are compiled in a database where the data can be managed and retrieved for use in reporting to concerned parties. Information on fish kills in other basins may be found on the NCDWQ's website.

LAKE ASSESSMENT

Lakes are valued for the multiple benefits they provide to the public, including recreational boating, fishing, drinking water, and aesthetic enjoyment. Assessments have been made at publicly accessible lakes, at lakes which supply domestic drinking water, and lakes (public or private) where water quality problems have been observed.

Physical field measurements (dissolved oxygen, pH, water temperature, and conductivity) are made with a calibrated Hydrolab™. Readings are taken at the surface of the lake (0.15 meters) and at 1 m increments to the bottom of the lake. Secchi depths are measured at each sampling station with a weighted Secchi disk attached to a rope marked off in centimeters. Surface water samples are collected for chloride, hardness, fecal coliform bacteria, and metals. A Labline™ sampler is used to composite water samples within the photic zone (a depth equal to twice the Secchi depth). Nutrients, chlorophyll *a*, solids, turbidity and phytoplankton are typically collected at this depth. Nutrients and chlorophyll *a* from the photic zone are used to calculate the North Carolina Trophic State Index score. The Labline™ sampler is also used to collect a grab water samples near the bottom of the lake for nutrients. Water samples are collected and preserved in accordance with protocols specified in (NCDEHNR 1996b).

Data are normally used to determine the trophic state of each lake, a relative measure of nutrient enrichment and productivity. These determinations will not be possible for this report based on chlorophyll *a* laboratory issues from the most recent summertime sampling (Appendices L1 - L3).

AMBIENT MONITORING SYSTEM

Assessments of water quality can be obtained from information about the fish and benthic invertebrate communities present in a body of water or from chemical measurements of particular water quality parameters. This section summarizes the field and laboratory chemical measures of water quality, typically referred to as ambient water quality measures.

The Ambient Monitoring System is a network of stream, lake, and estuarine stations strategically located for the collection of physical and chemical

water quality data. Parametric coverage is determined by freshwater or saltwater waterbody classification and corresponding water quality standards. Under this arrangement, core parameters are based on Class C waters with additional parameters appended when justified (Table 3).

Table 3. Freshwater parametric coverage for the ambient monitoring system.[1]

Parameter	All freshwater	Water Supply
Dissolved oxygen (s)	✔	✔
pH (s)	✔	✔
Conductivity	✔	✔
Temperature (s)	✔	✔
Total phosphorus	✔	✔
Ammonia as N	✔	✔
Total Kjeldahl as N	✔	✔
Nitrate+nitrite as N (s)	✔	✔
Total suspended solids	✔	---
Total dissolved solids (s)	---	✔
Turbidity (s)	✔	✔
Hardness, total (s)	✔	✔
Chloride (s)	✔	✔
Fecal coliform bacteria (s)	✔	✔
Total coliform bacteria (s)	---	✔
Aluminum (s)	✔	✔
Arsenic (s)	✔	✔
Cadmium (s)	✔	✔
Chromium, total (s)	✔	✔
Copper, total (s)	✔	✔
Iron (s)	✔	✔
Lead (s)	✔	✔
Mercury	✔	✔
Nickel (s)	✔	✔
Silver (s)	✔	✔
Zinc (s)	✔	✔
Manganese (s)	---	✔
Chlorophyll *a*[2] (s)	✔	✔

[1]A check (✔) indicates the parameter is collected and an 's' indicates the parameter has a standard or action level.
[2]Chlorophyll *a* is collected in Nutrient Sensitive Waters (NSW).

Water quality data collected at all sites were evaluated for the previous five year period. Some stations have little or no data for several parameters. However, for the purpose of standardization, data summaries for each station include all parameters. These chemistry data summaries are found at the end of the Ambient Monitoring Section.

Data collected from January 1996 to September 2000 were displayed in box plots. Box plots provide measures of central tendency and variation (Figure 6). The parameters presented in this report were also presented in the previous basin assessment report (NCDEHNR 1996a).

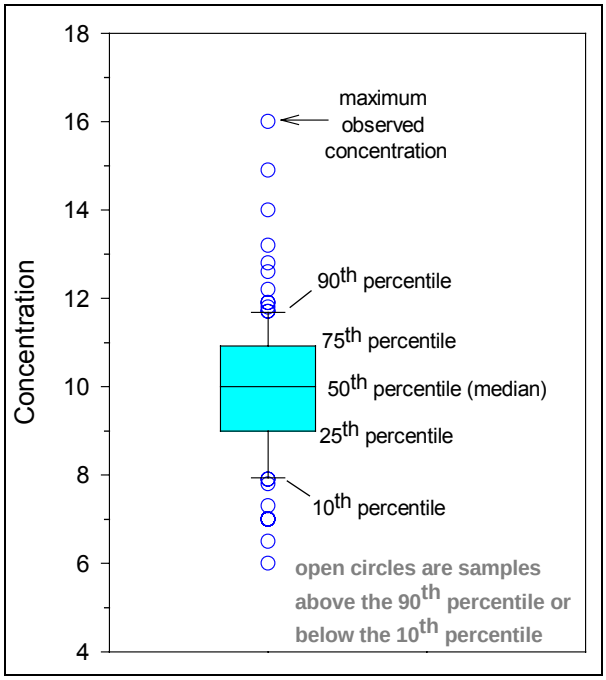


Figure 6. Explanation of box and whisker charts.

The water quality reference value may be an ecological evaluation level, a narrative or numeric standard, or an action level as specified in the North Carolina Administrative Code 15A NCAC 2B .0200 (Table 4). Zinc is included in the summaries for metals but recent (since April 1995) sampling or laboratory analyses may have been contaminated and the data may be unreliable.

In this report, conductivity is synonymous with specific conductance. It is reported in micromhos per centimeter (µmhos/cm) at 25 °C.

Table 4. Water quality standards for parameters sampled as part of the ambient monitoring system.[1]

Parameter (µg/L, unless noted)	Standards for All Freshwater			Standards to Support Additional Uses		
	Aquatic Life	Human Health	Water Supply Classifications	Trout Water	HQW	Swamp Waters
Arsenic	50					
Cadmium	2.0			0.4		
Chloride	230,000[2]		250,000			
Chlorophyll *a*, corrected	40[3]			15[3]		
Chromium, total	50					
Coliform, total (MFTCC/100 ml)[4]			50[3]			
Coliform, fecal (MFFCC/100 ml)[5]		200[3]				
Copper, total	7[2]					
Dissolved oxygen (mg/L)	5.0[6]			6.0	[7]	[3, 7]
Hardness, total (mg/L)			100			
Iron (mg/L)	1[2]					
Lead	25[3]					
Manganese			200			
Mercury	0.012					
Nickel	88		25			
Nitrate nitrogen			10,000			
pH (units)	6.0 - 9.0[3, 7]					[3, 7]
Selenium	5					
Solids, total dissolved (mg/L)			500			
Solids, total suspended (mg/L)					10 Trout, 20 other[8]	
Turbidity (NTU)	50, 25[3]			10[3]		
Zinc	50[2]					

[1]Standards apply to all classifications. For the protection of water supply and supplemental classifications, standards listed under Standards to Support Additional Uses should be used unless standards for aquatic life or human health are listed and are more stringent. Standards are the same for all water supply classifications (Administrative Code 15A NCAC 2B 0200, eff. April 1, 2001).
[2]Action level.
[3]Refer to 2B .0211 for narrative description of limits.
[4]Membrane filter total coliform count per 100 ml of sample.
[5]Membrane filter fecal coliform count per 100 ml of sample.
[6]An instantaneous reading may be as low as 4.0 mg/L, but the daily average must be 5.0 mg/L or more.
[7]Designated swamp waters may have a dissolved oxygen less than 5.0 mg/L and a pH as low as 4.3, if due to natural conditions.
[8]For effluent limits only, refer to 2B .0224(1)(b)(ii).

AQUATIC TOXICITY MONITORING

Acute and/or chronic toxicity tests are used to determine toxicity of discharges to sensitive aquatic species (usually fathead minnows or the water flea, *Ceriodaphnia dubia*). Results of these tests have been shown by several researchers to be predictive of discharge effects on receiving stream populations.

Many facilities are required to monitor whole effluent toxicity by their NPDES permit or by administrative letter. Facilities without monitoring requirements may have their effluents evaluated for toxicity by the NCDWQ's Aquatic Toxicology Laboratory. If toxicity is detected, NCDWQ may include aquatic toxicity testing upon permit renewal.

The NCDWQ's Aquatic Toxicology Unit maintains a compliance summary for all facilities required to perform tests and provides a monthly update of this information to regional offices and NCDWQ administration. Ambient toxicity tests can be used to evaluate stream water quality relative to other stream sites and/or a point source discharge.

BROAD RIVER SUBBASIN 01

Description

This subbasin is in the mountain ecoregion and contains the uppermost reaches of the Broad River from upstream of Lake Lure to approximately five river miles of the Broad River below Lake Lure (Figure 7). Land use within the Lake Lure watershed is predominantly forested with some urban and agricultural uses. Flat Creek, Hickory Creek and Reedypatch Creek are the largest tributaries above Lake Lure, Buffalo Creek forms a major arm of the lake, and Cove Creek is the only large tributary to the Broad River in this subbasin below Lake Lure.

There is a single discharger in this subbasin, the Town of Lake Lure, which discharges 1 MGD into the Broad River below Lake Lure.

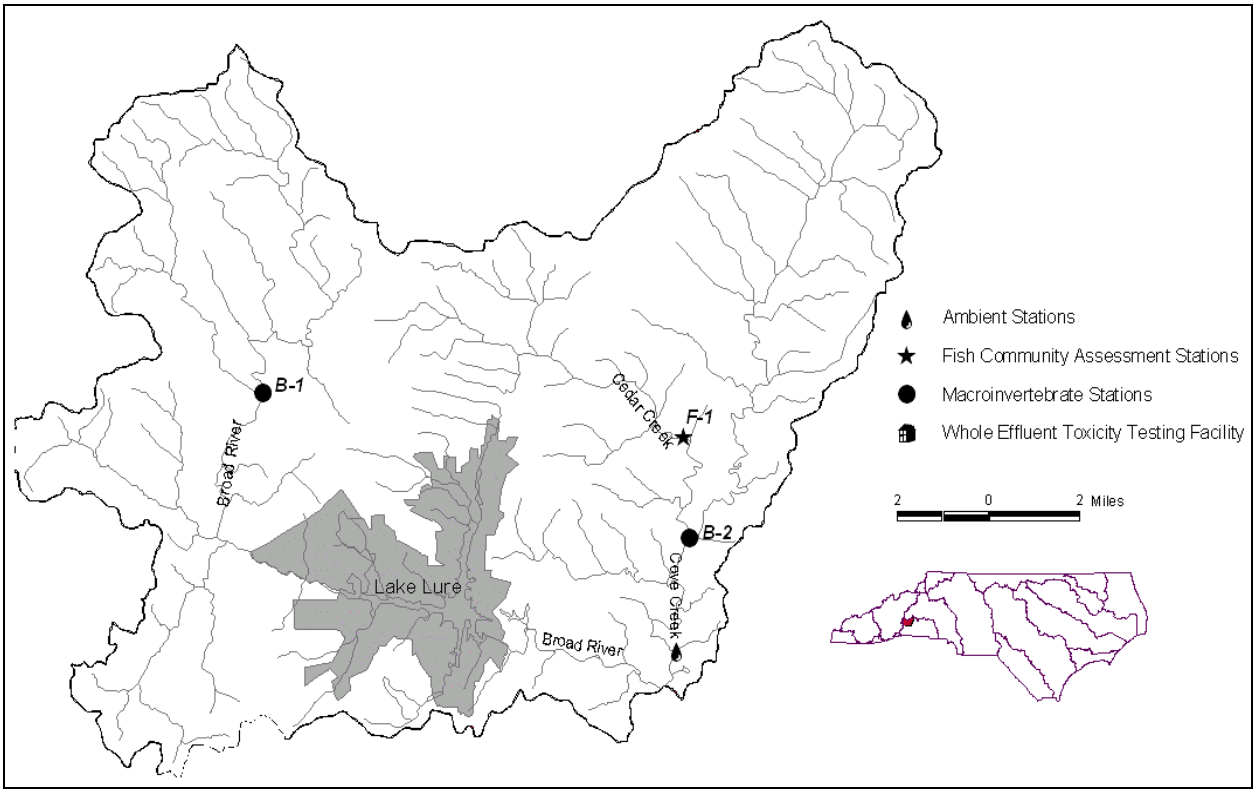


Figure7. Sampling sites in Subbasin 01 in the Broad River basin.

Overview of Water Quality

Benthic macroinvertebrate data for the Broad River above Lake Lure and Cove Creek, a major tributary to the lake, indicated Excellent conditions. Reedypatch Creek, a smaller tributary, was rated Good (Table 5). Fish sampling found Good-Fair water quality in Cedar Creek, a tributary of Cove Creek, but sources for the impairment could not be identified.

Benthic macroinvertebrate analysis for the Broad River near Uree (below Lake Lure and the Town of Lake Lure's WWTP) declined significantly. However, the river recovers as it flows into Subbasin 02.

Lake Lure, the only lake in this subbasin, was rated oligotrophic in 1995. While there was an increase in total organic nitrogen from 1995 to 2000, in addition to a slight decline in the Secchi depth, these changes were not sufficient to change the lake's water quality.

Volunteer monitoring in the Lake Lure area (Maas *et al*. 2000a) found generally good water quality in most streams around the lake with the exception of Reedypatch Creek. While median levels of all parameters were low in Reedypatch Creek, maximum values, presumably during high flow events, for several parameters such as total suspended solids, (700 mg/L), turbidity (900 NTU), ortho phosphate (0.90 mg/L), and nitrate (3.0 mg/L)) were greater than any other monitored tributary around the lake.

Table 5. Waterbodies monitored in Subbasin 01 in the Broad River basin for basinwide assessment, 1995 - 2000.

Map #[1]	Waterbody	County	Location	1995	2000
B-1	Broad R	Buncombe	SR 2802	Excellent	Excellent
B-2	Cove Cr	Rutherford	SR 1381	Excellent	Excellent
F-1	Cedar Cr	Rutherford	SR 1371	---	Good-Fair
	Lake Lure	Rutherford		Oligotrophic	---

[1]B = benthic macroinvertebrate monitoring sites; F = fish community monitoring sites.
[2]Data are available prior to 1994, refer to Appendix B2.

River and Stream Assessment

Sampling occurred in this subbasin during a three year drought of a magnitude that local meteorologists compared to the Dust Bowl. Flows in all streams were well below normal and the effects of nonpoint sources of pollution (nutrient runoff and instream scour) were minimal.

Broad River, SR 2802

The river at this site was fairly small (10 m wide) with a good substrate mix of boulder, rubble and gravel. A habitat score of 85 was due primarily to slight embeddedness, few pools and removal of the riparian zone on one side of the stream for agriculture.

Broad River at SR 2802, Buncombe County.

This site received an Excellent rating in 1995 and 2000. While the number of total taxa and EPT taxa increased from 1995 to 2000 (82 to 99 and 43 to 49, respectively), so did the Biotic Index (3.44 to 4.1). This suggested that these taxa increases were due to recolonization following a period of low rainfall, and thus reduced scour, as well as improved expertise in taxonomy

Cove Creek, SR 1381

This stream had a channel width of 20 meters. However, the wetted width was only 10 meters, reflecting the low flows in the area. The habitat score was only 62, reflecting heavy sedimentation and the lack of a riparian zone due to agriculture.

Cove Creek at SR 1381, Rutherford County.

Like the Broad River, sediment has not significantly affected the macroinvertebrate community. The site was given an Excellent bioclassification in 1995 and 2000. Also like the Broad River site, EPT taxa richness increased from 33 in 1995 to 40 in 2000. But this was probably due to improved baetid taxonomy and reduced scour.

Cedar Creek, SR 1371

The physical habitats of Cedar Creek change abruptly from above to below the bridge crossing at SR 1371. Above, the stream is swift and rocky with bedrock shelves across the channel.

Upstream view of Cedar Creek at SR 1371, Rutherford County.

Below, the stream is very sandy and slower moving. The stream is also very sandy at the next upstream bridge at SR 1008 (~0.6 mi. above).

Cedar Creek at SR 1008, Rutherford County.

Habitat assessment scores were 46 at SR 1008 and 91 at SR 1371.

Cedar Creek was evaluated as a fish community regional reference site; however, the fish community was rated only as Good-Fair. Compared to the other regional reference sites, fewer total species, species of darters, sunfish+bass+trout, and suckers were present and the trophic structure was skewed towards omnivores+herbivores.

The reason for this low rating is not completely understood. As evidenced by the large amount of sand in the stream, it is conceivable that the fish diversity continues to be depressed by the after effects of the torrential flooding and scouring that occurred in the upper Broad River Basin in early September 1996. It is also possible that despite the high quality habitat at this specific site, the water quality in this section of the stream is actually only Good-Fair. Additional sampling at this site and at the SR 1008 site is warranted.

SPECIAL STUDIES

Broad River, US 64/74

This site near Uree was sampled to determine if discharges from the Lake Lure WWTP or low flows as regulated by the Lake Lure Dam were the greater impact on water quality in this stretch of stream. It was not possible to separate out the effects of the operation of the dam from the effects of the WWTP. However, the problems did not seem to be due to sediment, enrichment, or organic loading (Biological Assessment Unit Memorandum (B001002).

Reedypatch Creek, near US 64

This site was sampled at the request of the NCDWQ' Planning Branch to determine if increased sedimentation, as reported in Maas, *et al*. (2000a), was impacting the macroinvertebrate community. While the creek bed appeared to be embedded with sand, much of the bedrock was still exposed and there were still a variety of pools.

Reedypatch Creek near US 64, Rutherford County.

A Good bioclassification was given to this site based on a high EPT taxa richness (32). While there may be some effects from sedimentation, these habitat changes were not sufficient to affect the macroinvertebrate community during low flows (Biological Assessment Unit unpublished data).

Fish Community Reference Sites

In 1998, Flat Creek at SR 2902 was evaluated as a fish community regional reference site (Biological Assessment Unit Memorandum F20000922). The high gradient stream was considered to be a "trout stream" and was not given a final rating. Only five species of fish were present and 95% (429/453) of all the fish collected were mottled sculpins.

Lake Lure

Lake Lure, a 1,500 acre reservoir, is located in the northwest corner of Rutherford County, adjacent to the Town of Lake Lure (Figure 8). The shoreline has been residentially developed. Major tributaries are the Broad River, Buffalo Creek, and Cane Creek. The watershed is primarily forested with some urban and agricultural areas. A small municipal golf course is located to the southeast of the lake and a larger golf course resort is located to the north, adjacent to the Buffalo Creek arm.

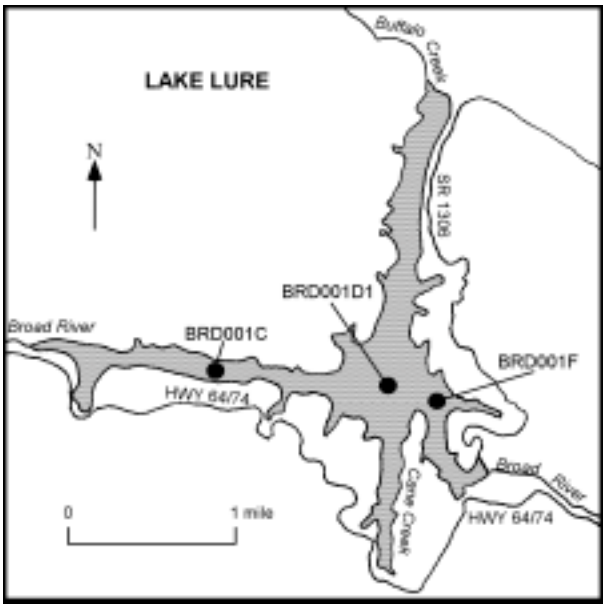


Figure 8. Monitoring sites at Lake Lure, Rutherford County.

The lake was most recently sampled during the summer of 2000 (Table 6 and Appendices L2 and L3). Mean Secchi depths ranged from 1.3 to 2.0 m. In June, the mean total phosphorus concentration was 0.02 mg/L. The concentration of ammonia in the Broad River arm was elevated (0.08 mg/L).

By July, however, total phosphorus decreased to a mean concentration of 0.01 mg/L; the mean concentrations of total Kjeldahl nitrogen and total organic nitrogen were moderate. The ammonia concentration was elevated. An analysis of the phytoplankton determined that an algae bloom was occurring and that the bloom was dominated by a green algae (Table 7). In August, Secchi depths increased and nutrient concentrations decreased.

The lake was previously sampled in 1995. Field notes indicated that the water at the sampling site in Broad River arm was greenish. The chlorophyll *a* concentration was 11 μg/L, which was greater than the concentration at the other two lake sampling sites (5 and 6 μg/L). The Secchi depth at the Broad River arm sampling site was also less than the other two sites (1.3 m *vs*. 2.2 and 2.4 m). Total phosphorus and turbidity values were greater in the Broad River arm as compared with the other lake sampling sites. In 1995, the lake was oligotrophic based on the calculated NCTSI score of –2.9.

In July 1996, the Town of Lake Lure began a volunteer water quality monitoring program to assess the conditions of tributary streams and to provide a continuous assessment of the health of the lake. According to Maas, *et al* (2000), the water quality of the lake is good, but increased algae productivity and decreased dissolved oxygen may occur if nutrient loading and sedimentation from the watershed are not carefully controlled.

Table 6. Biological and water chemistry data for Lake Lure, 1995 – 2000.

Date	NCTSI	Rating	TP (mg/L)	TON (mg/L)	CHL a (μg/L)	Secchi (m)
08/22/2000	---	---	0.01	0.19	---	2.0
07/25/2000	---	---	0.01	0.28	---	1.3
06/13/2000	---	---	0.02	0.24	---	1.8
07/31/1995	-2.9	Oligotrophic	0.01	0.16	7	2.0

Table 7. Summary of algal analysis for Lake Lure, July 25, 2000.

Station	CHL a (μg/L)	Biovolume (mm^3/m^3)	Density (units/ml)	Dominant division	Notes
BRD001C	25	9,970	31,930	Chlorophyta	*Chlorella* bloom
BRD001D1	21	11,850	33,180	Chlorophyta	*Chlorella* bloom
BRD001F	25	9,860	34,670	Chlorophyta	*Chlorella* bloom

BROAD RIVER SUBBASIN 02

Description

This subbasin includes the middle portion of the Broad River, from about five miles below the Lake Lure dam to the confluence of the Second Broad River near the Cleveland/Rutherford County line and the tributaries Mountain, Cleghorn, and Floyd Creeks (Figure 9). The entire Second Broad River drainage, including its tributaries Catheys Creek and Roberson Creek, and the lower drainage of the Green River are also included in this subbasin. Most of these streams are found on the edge of the mountain and piedmont eco-regions, but the macroinvertebrate communities have enough montane characteristics that they were evaluated using mountain criteria.

Rutherfordton, Spindale, and Forest City are the only urban areas here. The Broad River, from the confluence of Cove Creek to the town of Rutherfordton, is currently classified as WS-IV.

The Second Broad River, from its headwaters to 0.5 miles above the Cone Mills water supply intake, is currently classified as WS-IV or WS-V.

Sedimentation is a major habitat quality problem in the subbasin and is responsible for habitat degradation in many catchments. Many of the streams have a shifting sand bottom with embedded riffles and few pools.

Seven permitted discharges in this subbasin have design flows of greater than 0.5 MGD. Four of these facilities discharge within the Second Broad River catchment (Spindale WWTP, Burlington Industries, Forest City WTP and WWTP, and Cone Mills Corporation) and three facilities discharge within the Broad River catchment (Columbus WWTP, Rutherfordton WWTP, and Dan River Inc).

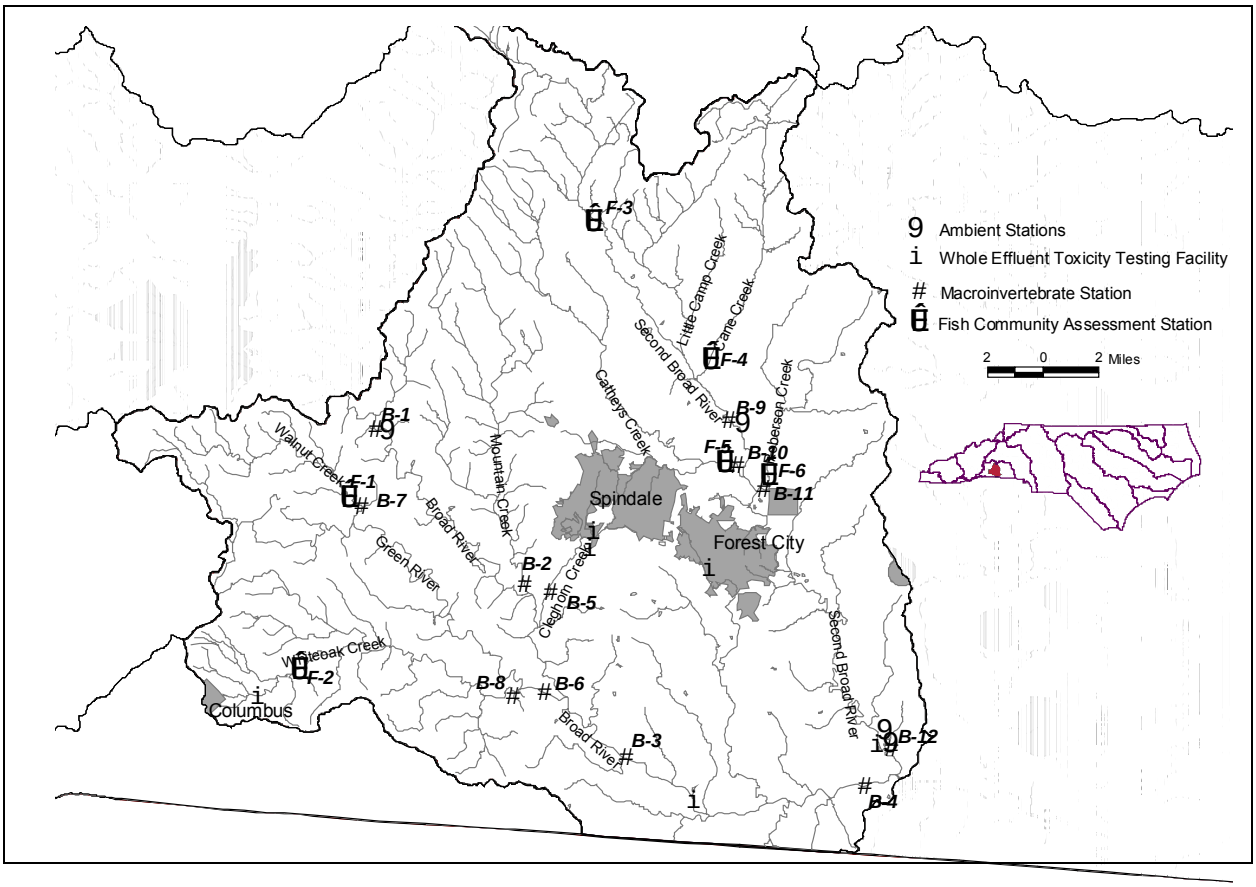


Figure 9. Sampling sites in Subbasin 02 in the Broad River basin.

Overview of Water Quality

Water quality seams to be primarily Good-Fair throughout most of this subbasin (Table 8). The greatest problems appear to be associated with nonpoint sources of pollution: sedimentation and runoff from the urban areas of Rutherfordton, Spindale and Forest City. Bioclassifications increased at 4 of the 12 benthos sites sampled in both 1995 and 2000. However, most of these changes seemed to be related to lower flows in July 2000 compared to more normal flows in 1995, rather than real changes in water quality.

Two streams, however, seemed to have real increases in water quality: Walnut Creek (Fair in 1995 to Excellent in 2000), and Hollands Creek (Poor in 1988 to Fair in 2000) following removal of the Spindale WWTP discharge in late 1999. Water quality in Mountain Creek seemed to be declining and Roberson Creek should be monitored for potential declines.

Fish sampling generally supported the conclusions of the benthos sampling: Walnut Creek had Excellent water quality, Whiteoak Creek and the Second Broad River had Good or Good-Fair water quality and Catheys Creek was impacted. Cane Creek was rated Good-Fair while Roberson Creek was rated Good (benthos data rated it Good-Fair).

Spindale's WWTP has had problems with toxic effluent for over 10 years and in 1988 upgraded its process and moved its discharge to Catheys Creek. The facility still failed 2 of 4 toxicity tests in 1999, however this was a lower failure rate than before the upgrade. Two other facilities, Cone Mills and Rutherfordton's WWTP, failed tests in 1999. However, both these facilities had previously passed over 90% of their tests.

Table 8. Waterbodies monitored in Subbasin 02 in the Broad River basin for basinwide assessment, 1995 - 2000.

Map #[1]	Waterbody	County	Location	1995	2000
B-1	Broad R	Rutherford	SR 1181	Good-Fair	Good
B-2	Mountain Cr	Rutherford	SR 1149	Good	Good-Fair
B-3	Broad R	Rutherford	SR 1106	Good-Fair	Good-Fair
B-4	Broad R[2]	Rutherford	US 221	Good-Fair	Good
B-5	Cleghorn Cr	Rutherford	SR 1149	Fair	Good-Fair
B-6	Green R[2]	Rutherford	SR 1302	Good-Fair	Good-Fair
B-7	Walnut Cr	Polk	SR 1315	Fair	Excellent
B-8	Whiteoak Cr	Polk	SR 1352	Good	Good
B-9	Second Broad R[2]	Rutherford	SR 1538	Good-Fair	Good-Fair
B-10	Catheys Cr[2]	Rutherford	SR 1549	Fair	Fair
B-11	Roberson Cr	Rutherford	SR 1561	Good-Fair	Good-Fair
B-12	Second Broad R	Rutherford	SR 1973	Good-Fair	Good-Fair
F-1	Walnut Cr	Polk	SR 1315	---	Excellent
F-2	White Oak Cr	Polk	SR 1526	---	Good-Fair
F-3	Second Broad R	Rutherford	SR 1500	---	Good
F-4	Cane Cr	Rutherford	SR 1558	---	Good-Fair
F-5	Catheys Cr	Rutherford	SR 1549	---	Poor
F-6	Roberson Cr	Rutherford	SR 1561	---	Good

[1]B = benthic macroinvertebrate monitoring sites; F = fish community monitoring sites.
[2]Data are available prior to 1994, refer to Appendix B2.

River and Stream Assessment

Sampling occurred in this subbasin during a three year drought of a magnitude that local meteorologists compared to the Dust Bowl. Flows in all streams were well below normal and the effects of nonpoint sources of pollution (nutrient runoff and in stream scour) were minimal.

Broad River, SR1181

This site, about six miles below Lake Lure, was 30 meters wide with a sand dipping operation on the right bank. The left bank supported a large mussel bed containing hundreds of *Elliptio icterina*. While the substrate was very sandy with very few riffles, there were still a good variety of pools, indicating

that sedimentation had not filled all the available habitats.

Broad River at SR 1181, Rutherford County.

EPT taxa abundant in 2000 that were absent in 1995 were the mayflies *Stenacron pallidum* and *Stenonema lenati* and the caddisfly *Hydropsyche demora*. Other groups with large changes in taxa richness included the Chironomidae (11 taxa in 1995 up to 23 in 2000) and snails (none in 1995, 5 taxa in 2000).

The Good bioclassification in 2000, while up from the Good-Fair rating in 1995, reflected a very small decline in Biotic Index (0.1 units) and a slightly larger increase in EPT Taxa Richness (3 taxa). These changes were probably due to low flows, rather than a real change in water quality.

Mountain Creek, SR 1149

The substrate at this 12 meter wide stream was almost entirely sand with filled in pools and few riffles. Sampling was postponed one month at this site because heavy rains during July 2000 made this stream too deep to sample. When it was sampled in August, EPT taxa richness had declined 32% (28 in 1995 to 19 in 2000) causing the bioclassification to decline from Good in 1995 to Good-Fair in 2000.

Part of this decline may be due to the July rains increasing sedimentation and scour just prior to sampling in August. However, this may also reflect an actual decline in water quality. The benthic community in 1995, a normal to high flow year, would also have been affected by scour. Sampling in a normal flow year will be required to determine if water quality has really declined.

Broad River, SR1106

Sampling at this site was conducted upstream of the new bridge being built. Habitat here was poor, consisting mostly of bedrock or sand. Riffles and woody debris were absent.

Construction in the Broad River at SR 1106, Rutherford County.

The bioclassification was stable here, with a rating of Good-Fair. The EPT taxa richness (EPT S) was also stable, while the Biotic Index increased from 4.84 in 1995 to 5.42 in 2000. Based on changes in the fauna between 1995 and 2000 (Table 9), it seemed that flow in this section of the river has been significantly reduced. Whether this has been due to temporary stream damming or diversion because of bridge construction or upstream water withdrawals was unclear.

Table 9. Changes in the macroinvertebrate fauna which reflected decreased flows in the Broad River at SR 1106, Rutherford County.

Taxon	1995	2000
Acroneuria abnormis	Common	Absent
Pteronarcys dorsata	Abundant	Rare
Hydropsyche venularis	Abundant	Absent
Caenis	Absent	Common
Stenacron pallidum	Absent	Common
Phylocentropus	Absent	Rare
Oecetis persimilis	Absent	Rare
Triaenodes perna	Absent	Rare

Broad River, US 221

The Broad River near Cliffside is 30 meters wide and was clearly impacted by sediment, which filled in pools and embedded riffles.

Broad River at US 221, Rutherford County.

This site has been sampled eight times since 1983 (Figure 10). In 1984 - 1987, 1989, and 1995, this site was rated Good-Fair. In 1983, only 17 EPT taxa were collected and the site was rated Fair. In 2000, 32 EPT taxa were collected and the site was rated Good.

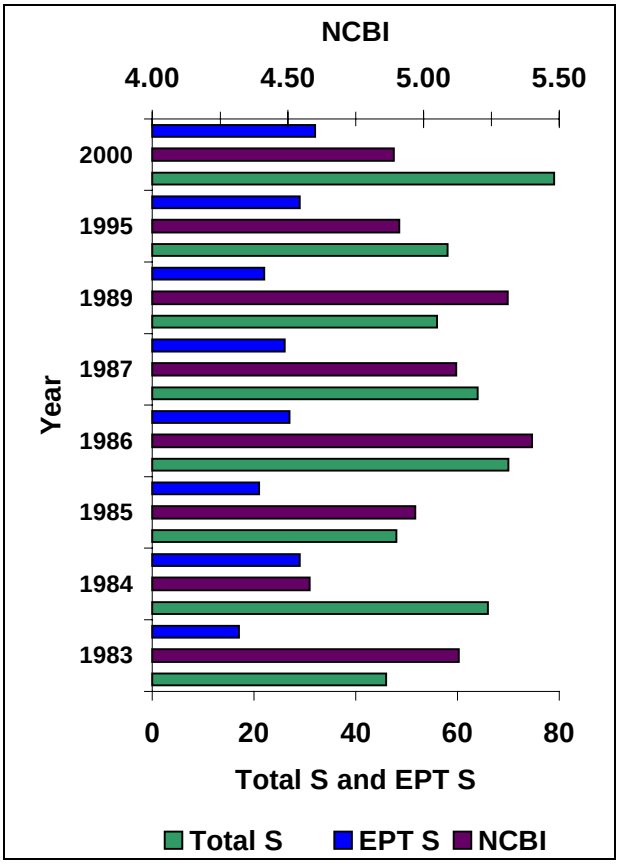


Figure 10. Total (Total S) and EPT (EPT S) taxa richness and biotic index (NCBI) at the Broad River at US 221, Rutherford County.

This increase in bioclassification in 2000 may be related to low flow conditions and reduced scour. Sampling during a normal flow year will be required to determine if this change is real or temporary.

Taxa collected in 2000 included some taxa not collected here before, including the caddisfly *Culoptila* which had previously only been found in the New River and Catawba River basins.

Cleghorn Creek, SR 1149

This seven meter stream showed definite problems with sedimentation: substrate nearly all sand, sections of vertical eroding banks, most pools filled in, and infrequent, small riffles.

Cleghorn Creek at SR1149, Rutherford County.

The bioclassification changed from Fair in 1995 to Good-Fair in 2000, due to a 41% increase in EPT taxa richness (17 to 24, respectively). The NCBI also increased (5.30 in 1995 to 6.19 in 2000). This was probably due to the increased number of Diptera collected (17 taxa in 1995, 35 taxa in 2000). This increase in dipteran diversity was mostly related to reduced scour from nonpoint sources in 2000 and would not necessarily be maintained in a normal flow year.

Green River, SR 1302

This site, near the mouth of the Green River, also shows signs of sedimentation. Many of the pools were filled in and the few riffles were heavily embedded. *Podostemum* and large amounts of periphyton were abundant, indicating nutrient enrichment as well.

Green River at SR 1302, Rutherford County.

The bioclassification was stable at Good-Fair in 1995 and 2000, but the data indicated a decline from the Good bioclassifications given to this site previously. Since 1989, EPT S has declined (Figure 11). This decline may be related to increased nutrient inputs from development around Lake Adger.

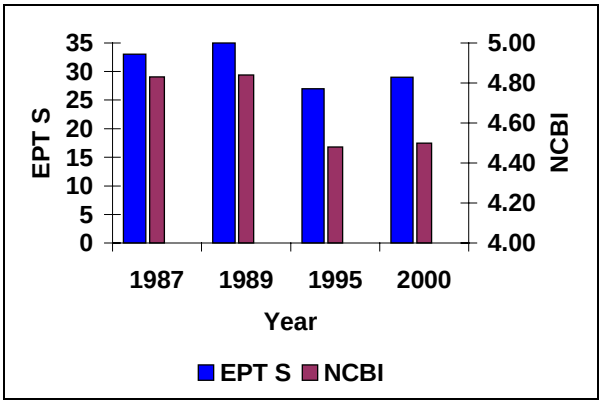


Figure 11. EPT taxa richness (EPT S) and biotic index (NCBI) at the Green River at SR 1302, Rutherford County.

Walnut Creek, SR 1315

This small tributary to the Green River drains the northeast corner of Polk County. Diverse habitats characterize Walnut Creek at SR 1315. The first 150 ft. have a cobble and boulder substrate with riffles and a swift current; the latter 450 ft. are shallow, slower moving and the substrate is sand.

Lower reach of Walnut Creek at SR 1315, Polk County.

Upper reach of Walnut Creek at SR 1315, Polk County.

Overall, the riparian zone is narrow, there are infrequent riffles, and the substrate is predominantly sand. While the riparian zone of this stream was narrow, sedimentation was less of a problem relative to other streams in this subbasin. During the summer benthos sampling period, the conductivity at this site (36 μmhos/cm) was the lowest for any stream in this subbasin.

The number of EPT taxa and the bioclassification increased from 14 taxa and a Fair rating in 1995, to 38 taxa and an Excellent rating in 2000. This increase in taxa richness occurred across all groups. It was typified by the baetid mayflies, which were absent in 1995, but were represented by five taxa in 2000. The EPT BI also declined

from 3.92 to 3.36, indicating that while much of this improvement may be an artifact of reduced scour, some portion was a real improvement in water quality.

The fish community was rated as Excellent. This stream was the only stream which was monitored in this basin in 2000 where four species of darters were collected. This was the only site from which the piedmont darter was collected. Also more species (n = 22) were collected at this site that at any other site.

White Oak Creek, SR 1526
A stream with a sand substrate, no riffles, unstable banks, and a narrow riparian zone with breaks describes White Oak Creek at SR 1526. Sampled below the Town of Columbus and several NPDES-permitted facilities, the fish community was rated as Good-Fair. There was a low diversity of darters and sunfish+bass+trout, a high percentage of omnivores+herbivores, and an absence of piscivores.

Whiteoak Creek, SR 1352
Sediment filling in pools and embedding riffles appeared to be the biggest problem at this 13 meter wide stream. This stream clearly suffers from nonpoint source problems.

Whiteoak Creek at SR 1352.

The Good bioclassification assigned to this site in 2000 was unchanged from 1995; in 1986 it was rated as Good-Fair. The slight increase in EPT taxa richness between 1995 and 2000 (36 and 40, respectively) was attributable to reduced scour in this stream. It was unlikely that improvements made to the Columbus WWTP (0.8 MGD) 15 miles above this site would be demonstrable here.

Volunteer monitoring (Maas, *et al*., 2000b) has documented elevated orthophosphate (median concentrations of 0.14 and 0.08 mg/L) at two sites in the middle section of this creek. However, concentrations decreased to normal levels at a site five miles upstream off SR 1352.

Second Broad River, SR 1500
This site on the Second Broad River qualified as a fish community regional reference site (Biological Assessment Unit Memorandum F20000922). The habitat score was 87 with good riparian and instream habitats.

The site was rated as Good. Only one species of darter (fantail darter which was abundant) and a low percentage of piscivores were present. The seagreen darter, tessellated darter, and piedmont darter are not known from that area, so the low diversity of darters may be natural. This was the only site monitored in 2000 in this basin from which the smallmouth bass was collected.

Second Broad River, SR 1538
The Second Broad River near Logan is 12 meters wide, had a very sandy substrate, and no riffles. Sparse snags and root mats provided the only habitat at this site. This site was sampled in August 2000 because rain in mid-July made this stream too deep and swift to sample at that time.

A Good-Fair bioclassification was assigned to this site based on 26 EPT taxa and a Biotic Index of 4.71. This rating is unchanged from 1995, another year with high flow events. But down from 1994, a drier year, when this site was rated Good.

Cane Creek, SR 1558
This site at the SR 1558 crossing is surrounded by pastures on all four corners. An absence of riffles (just fast chutes were present), infrequent pools, gravel substrate, collapsing vertical banks in places, and an open canopy near the bridge characterized this site.

The fish community was rated as Good-Fair. There was a lower than expected diversity of darters and sunfish+bass+trout and piscivores were absent.

Catheys Creek, SR 1549
In 1999, the Town of Spindale's WWTP discharge was rerouted from Holland Creek to Catheys Creek. The site at SR 1549 was established as a fish community basinwide assessment site to monitor any impacts from the discharge. It has

been monitored four times since 1988 using benthic macroinvertebrates.

On May 10, 2000, the water, although clear, was plum colored and the conductivity was elevated at 240 µmhos/cm. The instream habitats at this site included runs and chutes; there was an absence of riffles or pools; and the substrate was sand.

Colored water at Catheys Creek, SR 1549, Rutherford County.

Using benthic macroinvertebrates, this site was rated Fair three times (2000, 1995 and 1988); a Good-Fair bioclassification was assigned in 1994.

This change seemed to be related to sampling method rather than a change in water quality. In the three years of the Fair rating, an abbreviated collection method was used whose only assessment metric was EPT taxa richness. In 1994, a Full Scale method was used. Although EPT taxa richness was slightly lower in 1994 (17) than in 1995 or 2000 (18), additional assessment metrics, such as the NC Biotic Index and EPT abundance, brought the bioclassification up.

The fish community was rated as Poor. This site had the fewest fish (n = 65) of any site monitored in the basin in 2000 and also had a low diversity of darters and sunfish+bass+trout, a skewed trophic structure, and evidence of poor reproduction (8 of the 13 species were represented by only 1 or 2 fish/species).

In 1994 the stream was sampled as part of a special study on the ecological status of the Second Broad River basin (Biological Assessment Group Memorandum B950315). The fish community was rated as Good-Fair. The decrease in rating between 1994 and 2000 was due to change in the trophic metrics, a decrease in reproductive success, and a decrease in the number of fish collected.

Roberson (Robinson) Creek, SR 1561

Roberson Creek drains mostly agricultural land north of Forest City. Like other streams in the basin, Roberson Creek has a sandy substrate, infrequent riffles and pools, but good snags and undercut banks. The habitat score was 54.

Roberson Creek at SR 1561, Rutherford County.

Downstream view of Roberson Creek (below the bridge) at SR 1561, Rutherford County.

While the bioclassification at this site remained unchanged from 1995 to 2000 (Good-Fair), there were some indications that impacts are increasing in this creek. While most streams in this subbasin had more taxa in 2000 than in 1995 due to reduced scour, Roberson Creek's EPT taxa richness and abundance declined and the EPT BI increased between 1995 and 2000 (Figure 12). Monitoring in a normal flow year would be necessary to determine if this trend was real.

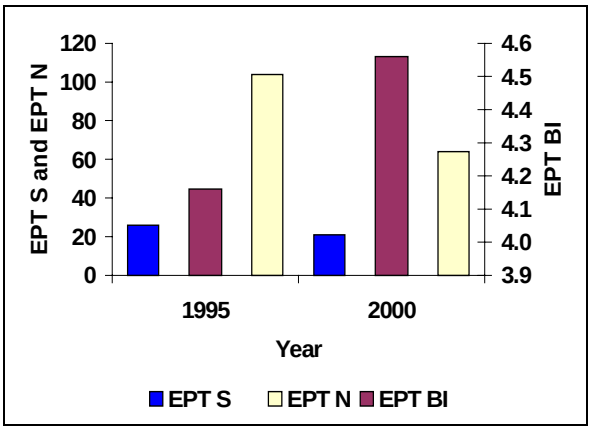


Figure 12. EPT taxa richness (EPT S), EPT abundance (EPT N), and biotic index (EPT BI) at Roberson Creek at SR 1561, Rutherford County.

However, the fish community rated the stream as Good. Only one species of darter (the fantail darter) and a low percentage of piscivores were present.

Second Broad River, SR 1973

This site near Cliffside was just upstream of the Cone Mills-Cliffside WWTP discharge and below the Cone Mills plant and reservoir. Conductivity, 368 µmhos/cm, was greater here than anywhere else in this subbasin and the water was stained black. Sedimentation had severely embedded the substrate and filled in most pools. Filamentous algae was abundant in backwater areas and suggested nutrient enrichment

Second Broad River at SR 1973, Rutherford County.

This site has been sampled seven times since 1983. Over that time, water quality has shown steady improvement (Figure 13). This site was rated Poor in 1983, Fair in 1985 and 1989, and Good-Fair ratings in 1987, 1991, 1995 and 2000.

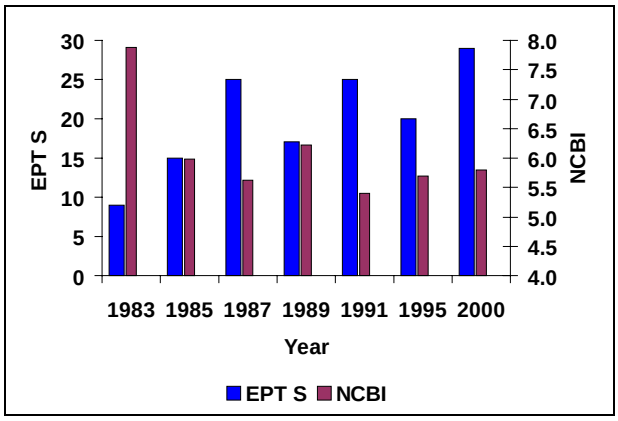


Figure 13. EPT taxa richness (EPT S) and biotic index (NCBI) at the Second Broad River at SR 1973, Rutherford County.

Most of the taxa, especially the Mollusca and Trichoptera, which were lost in 1995, following heavy sedimentation in 1994, had recovered by 2000.

SPECIAL STUDIES

Town of Spindale's WWTP - Hollands Creek

The Town of Spindale's WWTP outfall was moved from Hollands Creek to Catheys Creek in 1999. Hollands Creek at SR 1548 was sampled in 2000 to determine if any recovery had occurred in the nine months following the discharge's removal.

Hollands Creek at SR 1548, Rutherford County.

The discharge's relocation has greatly improved water quality. In 1988 the stream was rated a low Poor (3 EP); in 2000 it was rated as a high Fair (17 EPT) (Biological Assessment Unit unpublished data). Since the discharge has been removed for

less than a year, it is possible this stream may improve further as another generation of invertebrates colonizes the area.

However, the stream's watershed drains the northern part of the Town of Spindale. The stream thus, receives nonpoint sources of pollution. Sediment has embedded the few gravel riffles and filled in most of the pools. Further recovery may be limited by the extent of urban runoff to this stream and additional sampling will be required to determine the full extent of recovery.

Impact of Chip Mills

In May 1999, the Second Broad River above and below Broad River Forest Products, Inc. was sampled in association with a Duke University and North Carolina State University study on the impact of chip mills (http://taxodium.env.duke.edu/scsf/). Ten other potential chip mill sites were rejected for sampling because the nearest streams were either too small or the stream flow would become intermittent during low flow periods.

No impacts could be detected from any potential runoff from the Broad River Forest Products, Inc. chip mill. Most differences were due to habitat differences between the two sites (Biological Assessment Memorandum B990628).

BROAD RIVER SUBBASIN 03

Description

Subbasin 03 contains the headwater reaches of the Green River (Figure 14). This section of the Green River has been dammed at two locations to form Lake Summit and Lake Adger. The Hungry River is the only large tributary to the river in this subbasin. All streams within this subbasin are in the mountain ecoregion.

Apple orchards are a significant land use in the upper reaches of many tributary catchments, including the Hungry River. The lower reaches of many catchments are farmed, and residential developments are found throughout the watershed. Sedimentation is the dominant water quality problem in the subbasin. Sources of nonpoint runoff include agriculture (primarily apple orchards), and residential development. RJG Inc. (0.02 MGD), which discharges to the Green River, is the only discharger in this subbasin.

The Green River Game Land between Lake Summit and Lake Adger on the Green and Hungry rivers provides an important buffer in this area. The Green River Preserve, on the headwaters of the Green River, serves a similar function.

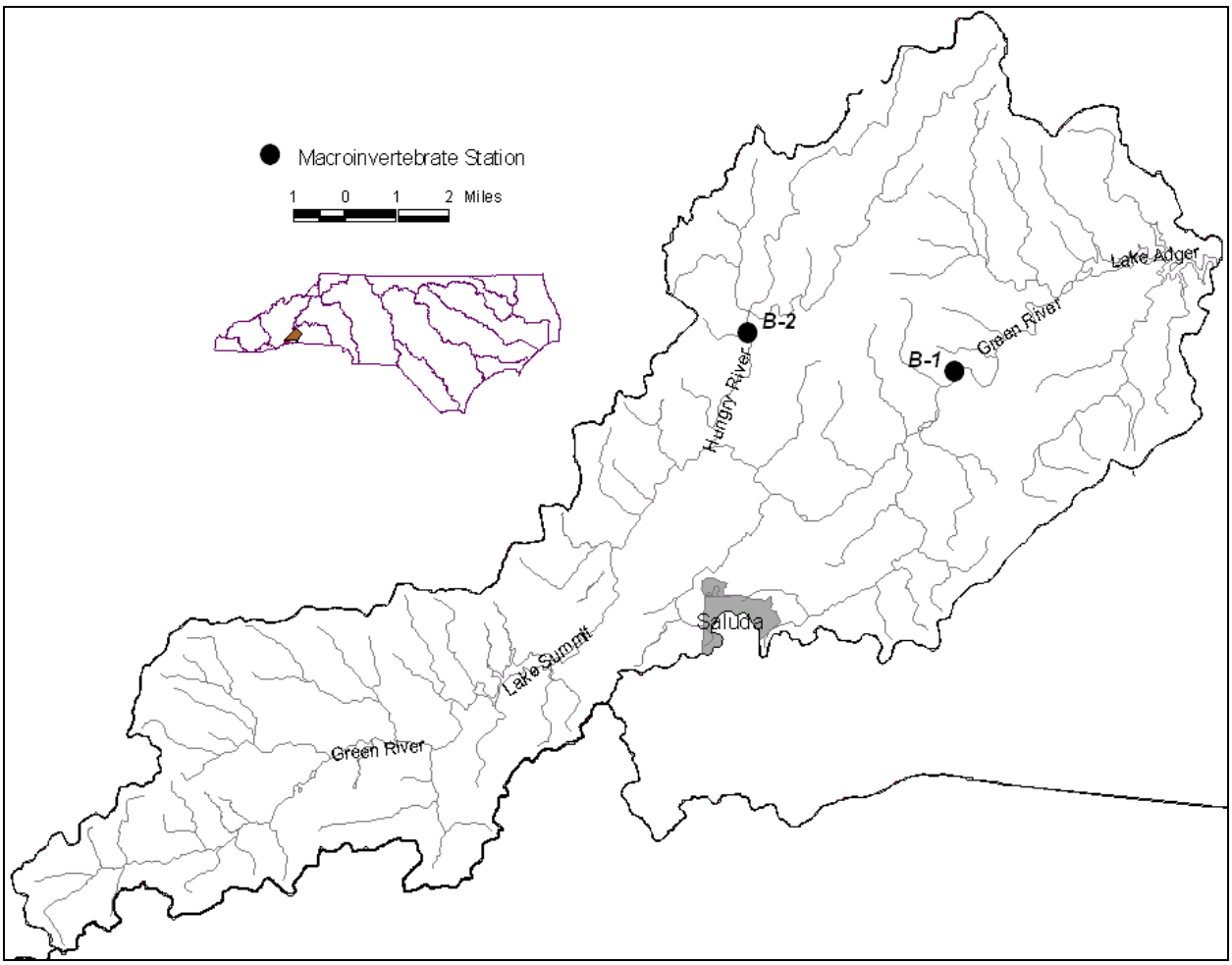


Figure 14. Sampling sites in Subbasin 03 the Broad River basin.

Overview of Water Quality

Water quality is Excellent in the headwaters of the Green River, as reflected by its designation as Outstanding Resource Waters (ORW). Just above Lake Summit, at the bottom of the ORW area, the

topography flattens and sedimentation increases, as does runoff from increasing development around Lake Summit. Macroinvertebrate sampling has given a Good-Fair rating to the Green River between Lake Summit and Lake Adger, and a Good rating to the Hungry River, which drains the eastern edge of Henderson County (Table 10).

The two lakes in this subbasin, Lake Summit and Lake Adger, were rated oligotrophic in 1995. Total organic nitrogen increased in Lake Summit between 1995 (0.07 mg/l) and 2000 (0.26 mg/l). The Secchi depth also increased during this period, indicating that the lake was phosphorous limited. Nitrogen also increased in Lake Adger during this period, and the Secchi depth declined (from 1.8 m to 0.6 m), possibly due to residential development and clearing along the shoreline.

Table 10. Waterbodies monitored in Subbasin 03 in the Broad River basin for basinwide assessment, 1995 - 2000.

Map #[1]	Waterbody	County	Location	1995	2000
B-1	Green R	Polk	SR 1151	Good-Fair	Good-Fair
B-2	Hungry R	Henderson	SR 1799	Good-Fair	Good
	Lake Summit	Polk		Oligotrophic	---
	Lake Adger	Polk		Oligotrophic	---

[1]B = benthic macroinvertebrate monitoring sites.

River and Stream Assessment

Sampling occurred in this subbasin during a three year drought of a magnitude that local meteorologists compared to the Dust Bowl. Flows in all streams were well below normal and the effects of nonpoint sources of pollution (nutrient runoff and in stream scour) were minimal.

Green River, SR 1151

The Green River was 25 meters wide at this location. While sampling for benthos in July 2000, the water level rose 15 cm as water released from Lake Summit reached the site. Habitat at this site was generally good, however a lack of stream side trees left the stream with no canopy or instream wood habitat.

Green River at SR 1151, Polk County.

A Good-Fair bioclassification was assigned to this stream in 2000 and in 1995. Reflecting between year differences, present at many other sites in the basin, Total S and EPTS both increased from 1995 to 2000. However, the NC Biotic Index did not increase.

Hungry River, SR 1799

This six meter wide stream was sampled in July and September 2000. Instream habitat was generally good; sedimentation had caused some riffle embeddedness and had filled in some pools. The riparian zone was less than 12 meters on both banks.

Hungry River at SR 1799, Henderson County.

In 2000, the site received a Good rating (EPT S = 34). The increase in bioclassification from 1995 (Good-Fair), a high flow year, to Good in 2000, a very low flow year, seemed to be due to reduced scour allowing recolonization. EPT BI increased at the same time the EPT S increased. This suggested that water quality had not actually improved. The resumption of normal flow patterns is expected to reduce taxa richness back to high Good-Fair or low Good levels.

Special Studies

Joe Creek and Freeman Creek, in the upper Green River watershed, were listed in 1998 as Support Threatened (NCDENR 1998). The NCDWQ's Planning Branch requested these streams be resampled to determine if these streams were supporting their designated uses.

Joe Creek (four meters wide and extremely turbid) was rated as Excellent (EPT S = 38).

Joe Creek at SR 1106, Henderson County.

Freeman Creek was too small to assign a bioclassification using macroinvertebrate criteria. However, habitat scores for Joe Creek and Freeman Creek were comparable (76 and 74, respectively). Also, a quick reconnaissance showed abundant numbers of the intolerant caddisflies *Neophylax* and *Goera*, plus several species of hydropsychid caddisflies, *Pycnopsyche*, and the mayfly *Stenonema*.

Based on the similar habitat and abundance of intolerant taxa in Freeman Creek, it is likely that it also supports a natural benthos community (Biological Assessment Unit unpublished data).

Freeman Creek, upstream from Old US 25, Henderson County.

Lake Assessment

Lake Summit

Lake Summit is located in the western portion of Polk County (Figure 15). The Green River was impounded in 1920 to generate hydroelectric power. The lake has an average retention time of 75 days. The watershed is mostly forested with some small farms and many single family homes have been built around the shoreline.

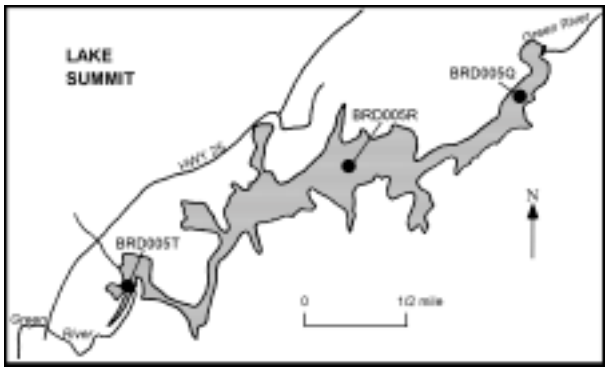


Figure 15. Monitoring sites at Lake Summit, Henderson County.

In 1994, the area around the lake was zoned residential for a distance that extends 1,000 feet from the shore (Matt Mattison, Henderson County Planning Director, pers. comm.). A number of summer camps are located in the watershed and these contribute significantly to the increase in the summer population (Robert Carter, District Conservationist, pers. comm.).

The lake was most recently sampled during the summer of 2000 (Table 11 and Appendices L2 and L3). In June and July, the shallowest Secchi depth was observed at the most upstream site where values were less than one meter. At the other two sites, Secchi depths were greater than 2.5 m, indicating that light penetration into the water column was good. In June, total phosphorus was 0.04 mg/L at the upper most site. This concentration was elevated for a mountain lake. This pattern may indicate the presence of suspended sediment particles transported into the reservoir by the Green River. As the velocity of the incoming water decreases, these particles settle out of the water column, thus increasing water clarity and decreasing total phosphorus.

Algal uptake of phosphorus in the upper end of the lake also decreases the amount of this nutrient in the photic zone. Concentrations of ammonia and total organic nitrogen were moderate at the upstream sampling site in June. Phytoplankton samples collected in June were dominated by diatoms and dinoflagellates, which are common in spring and early summer (Table 12).

In July, total phosphorus was again elevated at the upstream site (0.02 mg/L). At the mid-lake site, total Kjeldahl nitrogen (0.5 mg/L) and ammonia (0.19 mg/L) were elevated. Field notes indicated that the lake appeared green. Good light and nutrient availability within the photic zone in July were adequate to support increased algae activity at the mid and lower lake sites. Phytoplankton samples collected in July indicated that diatoms and green algae were the dominant algae (Table 12). As in June, algae counts did not support the presence of a bloom although a large colonial green algae was common in the samples.

Nutrient concentrations decreased in August. Secchi depth was also slightly greater in August as compared with July and June (range = 2.6 - 3.2 m).

The lake was previously sampled in 1995. Total phosphorus was greater at the upper lake site as compared with the mid- and lower lake sites. The same pattern was observed in 2000. Other nutrient and chlorophyll *a* concentrations were very low.

Data collected from 1989 through 2000 for three constituents of the NCTSI indicated that the median Secchi depth increased from the upper lake to the lower lake while median total phosphorus was greatest at the head of the lake. Median total organic nitrogen was greatest at the sampling site near the dam.

Table 11. Biological and water chemistry data for Lake Summit, 1995 – 2000.

Date	NCTSI	Rating	TP (mg/L)	TON (mg/L)	CHL a (µg/L)	Secchi (m)
08/23/2000	---	---	0.01	0.27	---	2.2
07/26/2000	---	---	0.01	0.33	---	2.0
06/14/2000	---	---	0.02	0.19	---	2.3
07/31/1995	-4.0	Oligotrophic	0.01	0.07	8	1.8

Table 12. Summary of algal analysis for Lake Summit, 1998 - 2000.

Station	Date	CHL *a* (µg/L)	Biovolume (mm^3/m^3)	Density (units/ml)	Dominant Division	Notes
Near Dam	5/21/98				Chlorophyta	*Tetraspora* bloom
BRD005T	6/14/00	39	2,510	2,420	Bacillariophyta, Pyrrhophyta, Chloromonadophyta	*Melosira, Synedra, Peridinium, Gonyostomum*
BRD005R	7/26/00	22	9,100	2,810	Bacillariophyta, Chlorophyta	*Tabelleria, Gloeocystis*

Lake Adger

The water in Lake Adger is used for hydroelectric power generation. Located downstream of Lake Summit, this reservoir is also used for recreational boating and fishing. The major tributary is the Green River and smaller tributaries include Panther, Rotten, Ostin and Silver creeks (Figure 16). Most of the watershed is forested woodlands with some croplands and single family homes. A residential development is located in the southern portion of the watershed. This reservoir has an average hydraulic residence time of 21 days.

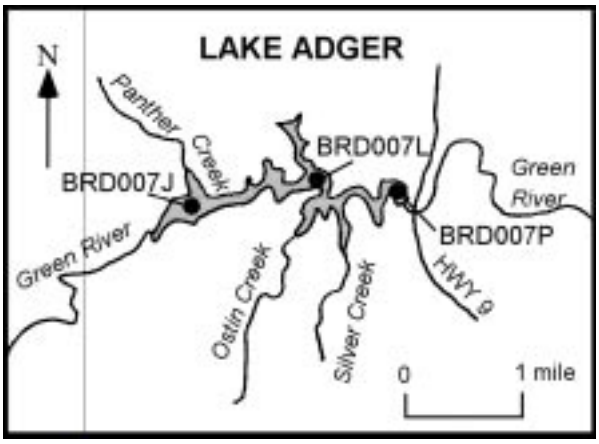


Figure 16. Monitoring sites at Lake Adger, Polk County.

The lake was most recently sampled on June 13, 2000 (Table 13). Secchi depths at all sites were less than one meter; total phosphorus concentrations at the upper and mid-lake sites were elevated for a mountain lake (Appendix L2 and L3). Field notes indicated that land clearing activities for residential developments were occurring along the shoreline. Sediment loading into the lake may have contributed to the decreased Secchi depth measurements as compared with previous years.

The lake was previously monitored in 1995. Sampling was conducted immediately following a rainfall event; however physical and chemical parameters did not reflect a significant increase in turbidity or nutrient loading. Mean Secchi depth was 1.8 m and mean total phosphorus was low (0.01 mg/L).

Table 13. Biological and water chemistry data for Lake Adger, 1995 – 2000.

Date	NCTSI	Rating	TP (mg/L)	TON (mg/L)	CHL a (µg/L)	Secchi (m)
06/13/2000	---	---	0.02	0.16	---	0.6
07/31/1995	-4.0	Oligotrophic	0.01	0.09	7	1.8

BROAD RIVER SUBBASIN 04

Description

The watershed for this subbasin is primarily the First Broad River and its tributaries (Figure 17). The First Broad River originates in Rutherford County and flows into the Broad River in Cleveland County, just above the South Carolina border. Sandy Run Creek is also in this subbasin, but it flows directly into the Broad River. This geographic area is a transitional zone between ecoregions, with some streams exhibiting mountain characteristics, while other streams are more piedmont in nature. Land use is mainly a mixture of agriculture and forest. The town of Shelby is the largest urban area. Major dischargers include the Shelby WWTP, Cleveland Mills, and PPG Industries.

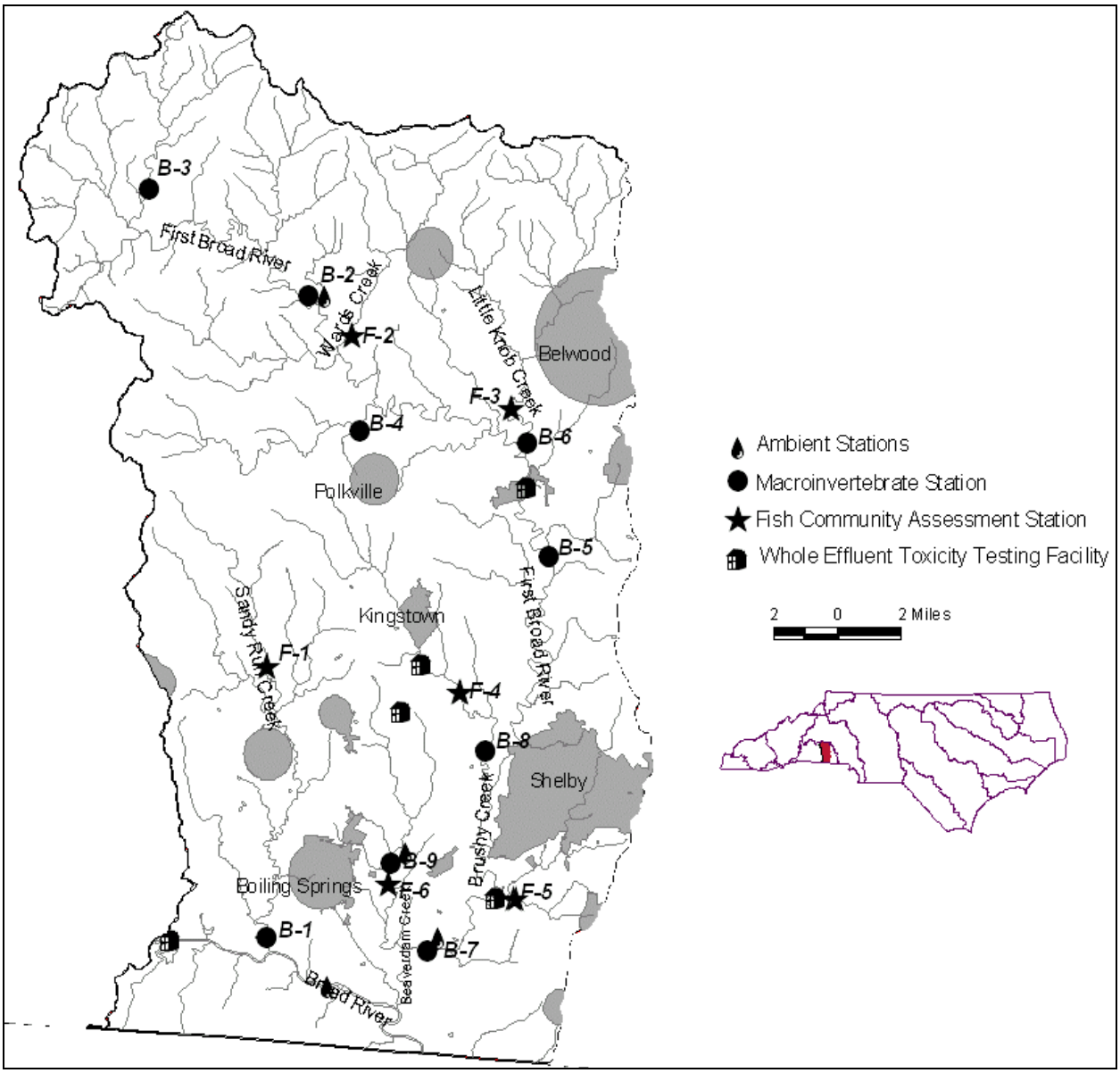


Figure 17. Sampling sites Subbasin 04 in the Broad River basin.

Overview of Water Quality

Most of the water quality information from the First Broad River watershed comes from benthic macroinvertebrate and fish community data (Table 14). Both these datasets indicated overall Good water quality, despite very sandy substrates and low habitat scores. One exceptional area with Excellent water quality, based on both communities, is the North Fork First Broad River, a headwater tributary of the First Broad River. The watershed for this stream is the South Mountains in Rutherford County. This area recently became part of the South Mountains Game Land (Rollins Tract). Fish also indicated Excellent water quality in Wards Creek, a tributary of the First Broad River a little further downstream in Cleveland County, which also originates in the South Mountains.

Benthos data from three sites on the First Broad River, from a headwater area near Casar to a downstream site near Earl, all resulted in Good bioclassifications. The upstream and middle site had ratings unchanged from 1995, while the site near Earl improved slightly from Good-Fair in 1995. This large, sandy site has been borderline Good to Good-Fair since 1987.

Sandy Run Creek, a large tributary in this subbasin that flows directly into the Broad River, not the First Broad River, had Good bioclassifications from an upstream fish community site and a downstream benthos site that is below the Boiling Springs WWTP. The benthos site improved from a Good-Fair rating found in 1995. Beaverdam Creek is another tributary of the Broad River near Boiling Springs that had a Good rating from both fish and benthos at NC 150. As with Sandy Run Creek, the benthos rating improved slightly from Good-Fair in 1995. Fish community data also indicated Good water quality in Hickory Creek, a small, sandy stream that is on the impaired streams list. Benthos data were also collected at the same site, but the severe drought conditions did not allow a rating to be given using the benthos data. However, EPT taxa richness improved from 3 in 1987 to 12 in 2000, indicating substantial improvement in the stream.

Three streams received Good-Fair bioclassifications: Brushy Creek and Knob Creek, based on fish, and Hinton Creek, based on benthos. Benthos data from Knob Creek in 1995 and 2000 resulted in a Good rating. Habitat problems may account for the differences in the fish and benthos ratings. Brushy Creek was Good in its lower watershed, based on benthos data. This stream has improved greatly since the Fair ratings noted in this part of the stream in the 1980's, and should come off the impaired streams list. This better water quality is due in large part to improvements in the effluent of PPG-Shelby. Before 1999, this plant was routinely noncompliant with its whole effluent toxicity limit. The facility has been continuously compliant since August 1998, after plant modifications were made to remove the toxicity from the effluent.

Table 14. Waterbodies monitored in Subbasin 04 in the Broad River basin for basinwide assessment, 1995 - 2000.

Map #[1]	Waterbody	County	Location	1995	2000
B-1	Sandy Run Cr	Cleveland	SR 1195	Good-Fair	Good
B-2	First Broad R[2]	Cleveland	SR 1530	Good	Good
B-3	N Fk First Broad R[2]	Rutherford	SR 1728	Excellent	Excellent
B-4	Hinton Cr	Cleveland	NC 226	Good-Fair	Good-Fair
B-5	First Broad R	Cleveland	off SR 1809	Good	Good
B-6	Knob Cr	Cleveland	SR 1004	Good	Good
B-7	First Broad R[2]	Cleveland	SR 1140	Good-Fair	Good
B-8	Brushy Cr	Cleveland	SR 1308	-	Good-Fair
B-9	Beaverdam Cr	Cleveland	NC 150	Good-Fair	Good
F-1	Sandy Run Cr	Cleveland	SR 1332	---	Good
F-2	Wards Cr	Cleveland	SR 1525	---	Good
F-3	Knob Cr	Cleveland	SR 1641	---	Good-Fair
F-4	Brushy Cr	Cleveland	SR 1342	---	Good-Fair
F-5	Hickory Cr	Cleveland	NC 18	---	Good
F-6	Beaverdam Cr	Cleveland	NC 150	Good	Good

[1]B = benthic macroinvertebrate monitoring sites; F = fish community monitoring sites.
[2]Data are available prior to 1994, refer to Appendix B2.

Sandy Run Creek, SR 1332
Aptly named, Sandy Run Creek at SR 1332 has a sandy substrate, an absence of riffles, unstable banks, and a narrow riparian zone. In the upper part of the monitored reach, there are breaks in the riparian zone and livestock have access to the stream. The lower end of the reach had a slightly wider riparian zone with more stable banks than did the upper part of the reach.

Upstream view of Sandy Run Creek, SR 1332, Cleveland County.

The fish community was rated as Good but the skewed trophic structure (an increase in the percentage of omnivores+herbivores and a decrease in insectivores and piscivores) hinted at some nutrient enrichment problems. The omnivorous bluehead chub constituted approximately 60% of the fauna.

Sandy Run Creek, SR 1195
The stream at this location was fairly large (14 meters wide), with a good boulder, rubble substrate where sampled for benthos. A habitat score of 80 denoted few problems, just some embeddedness and a few erosion areas on the banks. The stream was much sandier downstream.

Sandy Run Creek, SR 1195, Cleveland County.

A high EPT taxa richness of 37 and a BI of 4.71 resulted in a Good bioclassification. This is an improvement from the 1995 sample when EPT richness was 28, the BI was 5.16, and the rating was Good-Fair.

This site is below the Boiling Springs WWTP. The plant was authorized to begin an expansion and upgrade from 0.3 MGD to 0.6 MGD in February 1998, but this was not completed at the time of sampling in July 2000.

First Broad River, SR 1530
Flow, at this upstream site near Casar, during benthos sampling was about one third of normal. Despite this very low flow, and some habitat problems (score = 73), the sample produced a Good bioclassification, as has been found since 1986.

First Broad River at SR 1530, Cleveland County.

This site, in 2000, had the highest total taxa richness (110), and second highest EPT taxa richness (47) ever recorded from the Broad River basin. Unusual taxa collected in 2000 include, *Cercobrachys etowah, Anthopotamus myops, Nixe, Protoptila* and *Acroneuria carolina*. The EPT abundance value, probably related to the low flows, kept the site from being Excellent, using mountain criteria. However, the high amount of sand in the stream also suggested that the low flows reduced sedimentation impacts, allowing for the increased diversity.

North Fork First Broad River, SR 1728
An Excellent bioclassification was retained at this rocky bottom mountain site, with 36 taxa collected in an EPT benthos sample in 2000. The site has been borderline Good/Excellent since first sampled in 1989. Intolerant taxa such as *Epeorus, Leucrocuta* and *Heptagenia marginalis* were abundant. A habitat score of 93 reflected the good instream and riparian habitat.

North Fork First Broad River at SR 1728, Rutherford County.

Wards Creek, SR 1525
One of the fish community regional reference sites is Wards Creek at SR 1525, above the sand-dipping operations (Biological Assessment Unit Memorandum F20000922). This site is on the extreme northern edge of the basin and is in a transition zone between the foothills, piedmont, and mountains. The clear waters were of low conductivity (24 μmhos/cm).

Upstream view of Wards Creek approximately 100 yards above the bridge at SR 1525, Rutherford County.

The fish community was rated as Good, although piscivores were absent and only one species of sunfish was present. The site may receive heavy fishing pressure because of the ease of access which may also account for the absence of piscivores.

Hinton Creek, NC 226
This small, 6 meter wide, sandy stream was entrenched, had severely eroding banks, instream bar formation, infrequent and small riffles, and pools filled in with sand. A habitat score of 58 was recorded during benthos sampling in July 2000. A Good-Fair benthos classification resulted using mountain criteria, as was found in 1995. Of the 26 EPT taxa collected, most were rare, even during this low flow year.

Hinton Creek at NC 226, Cleveland County.

First Broad River, SR 1856 off SR 1809
Water levels were very low when the benthos was sampled in July 2000. The sampling site was moved a few hundred meters downstream of the

1995 SR 1809 sampling location to an old mill that provided better access to the river.

First Broad River at SR 1856, Cleveland County.

Good bioclassifications were found in 1995 and 2000, with little change in the benthic community. The habitat is poor (score = 49), mainly because the bottom is nearly all bedrock. The conductivity was very high, 313 µmhos/cm, and the water was dark. This site is below Cleveland Mills textile mill, which has a permitted discharge of 0.78 MGD.

Knob Creek, SR 1641

Another stream typical of the subbasin is Knob Creek at SR 1641. Here, the entrenched stream has vertical banks, a shifting sand substrate, no pools, and infrequent riffles.

Upstream view of Knob Creek at SR 1641, Cleveland County.

The overall diversities of the fish community and the types of sunfish+bass+trout were lower than expected. Similar to other streams in the basin, there was a skewed trophic structure with a high percentage of omnivores+herbivores and an absence of piscivores. The fish community was rated as Good-Fair.

Knob Creek, SR 1004

Many sites in this subbasin have habitats similar to Knob Creek: mainly a sand bottom and low habitat score = 49.

Knob Creek at SR 1004, Cleveland County.

During both years, this site was rated as Good. EPT abundance was low with 16 of the 30 EPT taxa found as rare. Only *Isonychia, Stenonema modestum, Cheumatopsyche, Paragnetina fumosa,* and *Acroneuria abnormis* were abundant.

First Broad River, SR 1140

This ambient site near Earl is the most downstream benthos site on the First Broad River, and has been borderline Good-Fair to Good since 1987. The river at this site is 20 meters wide, with a sand and silt substrate and low current speed.

First Broad River at SR 1140, Cleveland County.

Almost all the benthos are found on snags in the river. Piedmont criteria are now used for this site, rather than mountain criteria, based on recent subecoregion delineation, and the Piedmont character of the surrounding land.

Brushy Creek, SR 1342
This site was above the bridge at SR 1342; below the bridge was a sand-dipping operation. There is a tremendous amount of sand in the channel and the stream is attempting to cut a new channel in the deposited sand. There is minimal instream cover, the banks are easily eroded, and there are infrequent pools and riffles.

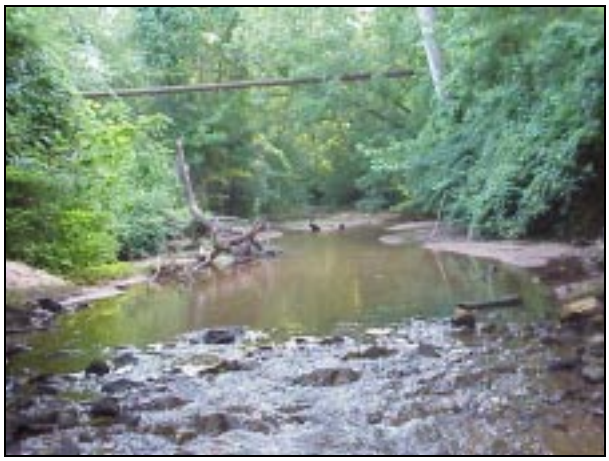
The fish community was rated as Good-Fair. As expected with 61% (176/287) of the fauna being the bluehead chub, there was a high percentage of omnivores+herbivores and a low percentage of insectivores.

Brushy Creek, SR 1308
This benthos site was added for basin monitoring in 2000, to have a site near the mouth of the watershed. Brushy Creek has been sampled at various locations since 1985. The 1985 sample was at a downstream site at US 74 and indicated upstream dischargers were impacting the stream. A Fair rating was found, with only 13 EPT taxa, and a NCBI of 6.66. Two sites were sampled further upstream, above and below the PPG Industries discharge in 1995, and Good ratings were found at both sites.

The July 2000 benthos sample was taken in the downstream segment that is on the 2000 303 (d) List (NCDENR 2000). But it was not taken at the busy US 74 site because of safety issues.

A Good bioclassification found in 2000 indicated improvement for this section of Brushy Creek, and similar conditions to what was found in 1995, further upstream above and below PPG. In 2000, total taxa richness was 62, EPT taxa richness was 24, and the BI was 5.02. Abundant EPT taxa were the mayflies, *Isonychia* and *Stenonema modestum*, the caddisflies, *Triaenodes ignitus* and *Cheumatopsyche*, and the stoneflies, *Pteronarcys dorsata*, *Paragnetina fumosa* and *Acroneuria abnormis*.

Improvements with the upstream discharge have resulted in considerable improvement in this section of Brushy Creek, which should result in its removal from the 303 (d) List. A low habitat score of 41 in 2000 indicated severe instream problems, where sand has filled in all pools and the only riffle was bridge rubble. Conductivity was high at 279 µmhos/cm.



Brushy Creek at SR 1308, Cleveland County.

Hickory Creek, NC 18
The Hickory Creek watershed drains the eastern half of the Town of Shelby. Habitat at this site is generally typical of the basin -- sandy substrate, shallow runs, infrequent and small side pools, shallow gravelly riffles, but also having a wide riparian zone. Discarded automobile tires and beverage cans deposited in the stream and along the shoreline attest to the stream's urban and suburban drainage.

Upstream view of Hickory Creek at NC 18, Cleveland County.

The fish community was rated as Good. Metrics for which the community scored lower than expected were the number of species of sunfish+bass+trout and the three trophic metrics. The scoring of these four metrics resulted from

some slight loss of pool habitat and nutrient enrichment.

Beaverdam Creek, NC 150
This site was previously sampled during basin assessment in 1995, when it was given a Fair bioclassification using mountain criteria. This stream was very difficult to sample for benthos, and should be dropped as a basin site. Beaver dams have stopped the flow where there is easy access, and samples were collected upstream of NC 150, above and below an unnamed tributary. The stream was very silty, with few riffles, and severe bank erosion. The habitat score of 57 clearly indicated habitat problems.

Beaverdam Creek at NC 150, Cleveland County.

The benthos community, however, was suprisingly diverse. The total taxa richness was 68, with 24 EPT taxa, and a BI of 5.74. This would result in a Good-Fair bioclassification using mountain criteria, but the low gradient and fauna, and recent subecoregion delineation suggest piedmont criteria are more appropriate. Using piedmont criteria this site is given a borderline Good rating.

This improvement in water quality was not expected. The number of small dischargers (4) in the watershed or their effluent quality had not changed much since 1995, when the site received a Fair bioclassification. Crest High School and Middle School connected to the Cherryville WWTP in October 2000, but were still discharging to UT Beaverdam Creek at the time of sampling. This improvement should result in removal of this stream from the 2000 303 (d) List (NCDENR 2000). The improvement also suggested that nonpoint impacts or instream erosion are impacting the benthos more than the permitted dischargers.

Downstream view of Beaverdam Creek at NC 150, Cleveland County, May 2000.

The fish community in this stream has been sampled twice -- in June 1995 and May 2000. Comparing the two samples, the metric values were very similar and the metric scores were identical. Each time, the community has been rated as Good. Similar to Hickory Creek, metrics for which the community scored lower than expected were the number of species of sunfish+ bass+trout and the three trophic metrics. The scoring of these four metrics resulted from some slight loss of pool habitat and nutrient enrichment.

SPECIAL STUDIES
Wards Creek, SR 1525
This site was sampled for benthos because fish community sampling suggested it might be a good regional reference site. An EPT sample had a taxa richness of 33, resulting in a Good bioclassification. This was an unusual site in that the substrate was mainly bedrock or sand. A habitat score of 54 during benthos sampling (compared with a habitat score of 68 during fish community sampling) reflected the erosion occurring here and the tremendous amount of sand filling in pools and eliminating riffles. This benthos community probably represents the best of the tributary sites in subbasin 04, except the North Fork First Broad River.

Wards Creek at SR 1525, Rutherford County.

Hickory Creek at NC 18 during July 2000 drought.

Hickory Creek, NC 18

This is another very small, sandy stream, that is on the 2000 303 (d) List (NCDENR 2000). It had an average width of 3 meters, with a range of 1 to 5 meters when sampled for benthos in July 2000. In 1987 only 3 EPT taxa were found. In 2000, this number improved to 12 with an EPT abundance of 27. The BI value was 6.23. The midge, *Polypedilum convictum,* was very abundant; no stoneflies were found, and no mayflies were abundant. It is clear that this stream still has some problems, yet it is so small that we would not presently assign a rating to it. It should come off the 303 (d) list based on the improvements found, and because of the diverse fish community that was found.

Fish Community Reference Sites

In 1998, Brier Creek at SR 1733 was evaluated as a fish community regional reference site (Biological Assessment Unit Memorandum F20000922). The fish community was rated as Excellent. The stream will become a basinwide monitoring site in 2005.

The North Fork First Broad River at SR 1728 was sampled in 1995 (as part of the basinwide monitoring program) and in 1999 as part of the fish community regional reference site study (Biological Assessment Unit Memorandum F20000922). In 1995, the fish community was rated as Good; in 1999 it was rated as Excellent. The stream will again become a basinwide monitoring site in 2005.

BROAD RIVER SUBBASIN 05

Description

Buffalo Creek and its tributaries, Muddy Fork, Beason Creek, and Kings Creek comprise this subbasin (Figure 18). Land use is primarily a combination of agriculture and forest. Kings Mountain is the largest town in the subbasin. The major NPDES permitted dischargers and their receiving streams are the Kings Mountain WWTP, HNA Holdings, Inc., and Grover Industries into Buffalo Creek. Although a few streams in the northern portion of the watershed exhibit some montane characteristics, this area is considered to be in the piedmont ecoregion.

Overview of Water Quality

Water quality in the Buffalo Creek watershed was generally good using biological data (Table 15). Buffalo Creek above Kings Mountain Reservoir had both benthos and fish community collections in 2000. There was a big difference in the bioclassifications assigned, with benthos noting Excellent water quality, while the fish rating was Good-Fair. However, the fish sampling site was in an area of eroding banks and very sandy substrate, and the fish community assessment integrates these habitat problems. The benthos sampling site had a boulder and bedrock substrate, providing more diverse habitat. Nonpoint source impacts were likely lower in the drought of 2000, and the benthos improved from a Good rating in 1995.

Kings Mountain Reservoir (also known as Moss Lake) is a water supply reservoir for the City of Kings Mountain. The reservoir was considered oligotrophic in 1995. Photic zone phytoplankton samples collected in June were dominated by diatoms and golden-brown algae known to produce taste and odor problems. The lake does stratify with hypoxic conditions observed at a depth of 6 to 7m.

Buffalo Creek was also sampled for benthos below the reservoir and below discharges from Kings Mountain WWTP and Grover Industries. A Good bioclassification was found, as it was in 1995. Fish community and benthos samples from Muddy Fork, a tributary of Buffalo Creek below the reservoir, indicated Good water quality. The benthos rating was unchanged from 1995.

Smaller tributaries sampled for benthos in 2000 were Kings Creek, that improved from Good-Fair in 1995 to Good in 2000 when there was less nonpoint impacts, and Beason Creek, which was Good-Fair in both basin years. Finally, a success story was found in Lick Branch where the bioclassification improved dramatically from Fair in 1995 to at least Good in 2000 following removal of the discharge from the New Minette Mills textile plant. The presence of stoneflies and other intolerant taxa at this site were indicators of development of a natural community.

Table 15. Waterbodies monitored in Subbasin 05 in the Broad River basin for basinwide assessment, 1995-2000.

Map #[1]	Waterbody	County	Location	1995	2000
B-1	Buffalo Cr	Cleveland	SR 1908	Good	Excellent
B-2	Buffalo Cr[2]	Cleveland	NC 198	Good	Good
B-3	Muddy Fk[2]	Cleveland	SR 2012	Good	Good
B-4	Beason Cr	Cleveland	SR 2246	Good-Fair	Good-Fair
B-5	Kings Cr	Cleveland	SR 2286	Good-Fair	Good
F-1	Buffalo Cr	Cleveland	SR 1906	---	Good-Fair
F-2	Muddy Fk	Cleveland	SR 1001	---	Good
	Kings Mountain Res.	Cleveland		Oligotrophic	---

[1]B = benthic macroinvertebrate monitoring sites; F = fish community monitoring sites.
[2]Data are available prior to 1994, refer to Appendix B2.

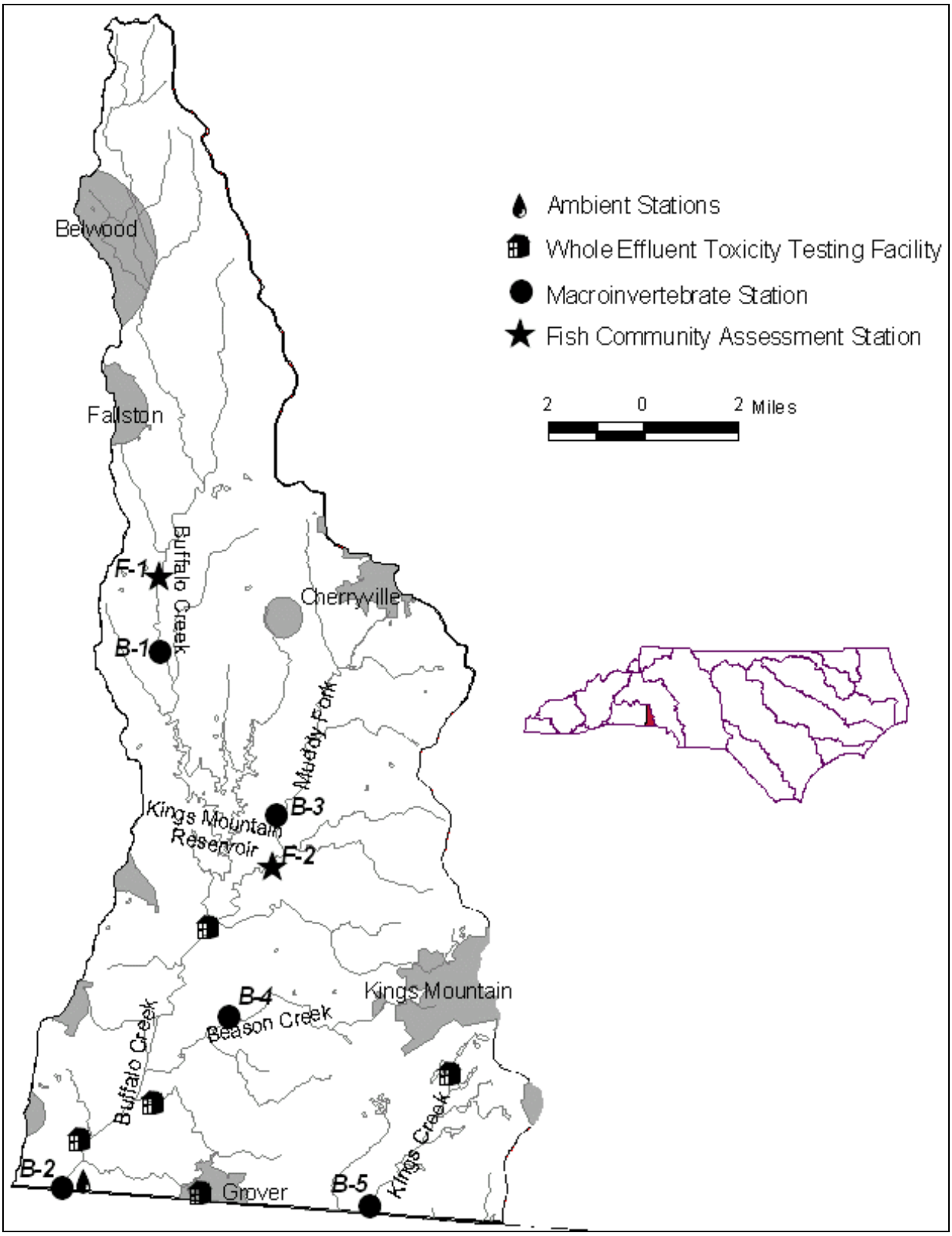


Figure 18. Sampling sites in Subbasin 05 in the Broad River basin.

Buffalo Creek, SR 1906
Like other streams in the Broad River basin, this stream is entrenched with easily eroded banks and a sandy substrate, but with a good riparian zone and forested canopy over the stream.

Upstream view of Buffalo Creek at SR 1906, Cleveland County.

This fish community site was the only monitored site in the basin from which at least one species of darter was not collected. With a slightly skewed trophic structure and a slightly lowered than expected reproductive success, the fish community was rated as Good-Fair.

Buffalo Creek, SR 1908
This upstream benthos site is located above Kings Mountain Reservoir, in an area with little development. During the drought of 2000, the width of the stream was only 8 meters, with a channel width of about 25 meters. The dominant substrate was bedrock and rubble, with some sand.

The benthos showed a substantial improvement from the 1995 basin sampling. EPT taxa richness increased from 29 to 35, while the BI dropped from 5.28 to 5.02, and the bioclassification went from Good to Excellent in 2000.

Buffalo Creek, NC 198
The second benthos site on Buffalo Creek is below Kings Mountain Reservoir and below the Kings Mountain WWTP and Grover Industries. The stream here is much larger, 25 meters wide, with a very sandy and gravely substrate.

Buffalo Creek at NC 198, Cleveland County.

Despite the poor instream habitat and eroding banks, 27 EPT taxa were collected. The BI was 4.57, better than upstream, but the final bioclassification was Good.

Buffalo Creek, US 74
A small section of Buffalo Creek between the Kings Mountain Reservoir dam and US 74 is on the 303 (d) list, based on old benthos data collected from the stream at US 74. The US 74 site is so close to the dam that it is not representative of conditions below the reservoir. Therefore, it was not sampled in 2000. Based on the Good bioclassification further downstream at NC 198, and the selection of Kings Mountain Reservoir as a reference lake by the Lakes Assessment Program, this segment of Buffalo Creek should be removed from the 303 (d) list.

Muddy Fork, SR 2012
This stream is a small (4 meters wide) tributary of Buffalo Creek, again with a sand and gravel substrate. A low habitat score (44) in 2000 resulted from the uniform sand runs, gravel riffles, streambank erosion, and limited riparian zone.

Muddy Fork at SR 2012, Cleveland County.

The 2000 benthos sample had an EPT taxa richness of 25, a BI of 5.52, and a Good bioclassification, as was found in 1995. This is an improvement from the Good-Fair ratings found in 1983 and 1990, when the site was sampled as a control site for the Kings Mountain WWTP discharge into Buffalo Creek. This stream is so small that it should be dropped from the basinwide monitoring program.

Muddy Fork, SR 1001

The upper end of this reach has an old sand dipping operation along the left shoreline and easily erodible banks which may be contributing additional sand to the stream during high flow events. The substrate is sand and there are infrequent pools and riffles.

Upstream view of Muddy Fork at SR 1001, Cleveland County.

The fish community was rated as Good with a slightly skewed trophic structure and slightly lower diversity of darters and sunfish+bass+trout than expected.

Beason Creek, SR 2246

Beason Creek was very similar to Muddy Fork in physical characteristics: four meters wide, a sand and gravel substrate, and a habitat score of 45. The 15 taxa collected in an EPT sample produced a Good-Fair rating, the same as was found in 1995. This stream is also so small that it should be dropped from the basinwide assessment program.

Beason Creek at SR 2246, Cleveland County.

Kings Creek, SR 2286

This is an unusual stream, that was rated for benthos using Piedmont criteria, even though *Tallaperla* was abundant. The stream originates in North Carolina, then flows southwest into South Carolina. Surrounding land use is agriculture and forest in a rolling hills setting, typical of the Piedmont. The stream had a layer of silt covering everything, but had a good heterogeneous substrate of boulder, rubble, gravel and sand. As elsewhere, there was a lot of bank erosion, and few riffles (habitat score = 62).

Kings Creek at SR 2286, Cleveland County.

The benthic fauna was diverse (24 EPT taxa) and somewhat intolerant (BI of 5.72). The fauna was dominated by the mayflies, *Caenis* and *Stenacron interpunctatum.* The 2000 bioclassification was Good. In 1995, the stream was rated as Good-Fair when 19 EPT taxa were collected and the BI was 6.34.

SPECIAL STUDY
Lick Branch, SR 2227

In the 1980s, Lick Branch was severely impacted by the discharge from the New Minette Mills textile plant. As of March 2000, operations at the plant have ceased as has the discharge to Lick Branch. The stream, however, is on the 303 (d) List (NCDENR 2000).

A follow-up benthos sample, taken to document recovery, showed tremendous improvement. EPT taxa richness increased from 6 in 1995 to 24 in 2000. The bioclassification improved from Fair to at least Good (the stream is too small to rate under present policy). The intolerant caddisfly *Chimarra* was abundant, three stonefly taxa were collected, and the BI was 5.47. All this indicated the development of a natural community.

Lick Branch at SR 2227, Cleveland County.

Kings Mountain Reservoir

Kings Mountain Reservoir (also known as Moss Lake) is a water supply reservoir for the City of Kings Mountain. The reservoir was constructed in 1963. Major tributaries to the lake include Buffalo Creek and White Oak Creek (Figure 19). The drainage area is characterized by rolling hills and rural areas. Access to the lake is strictly controlled by a special set of regulations which allow recreational use of the lake while protecting water quality.

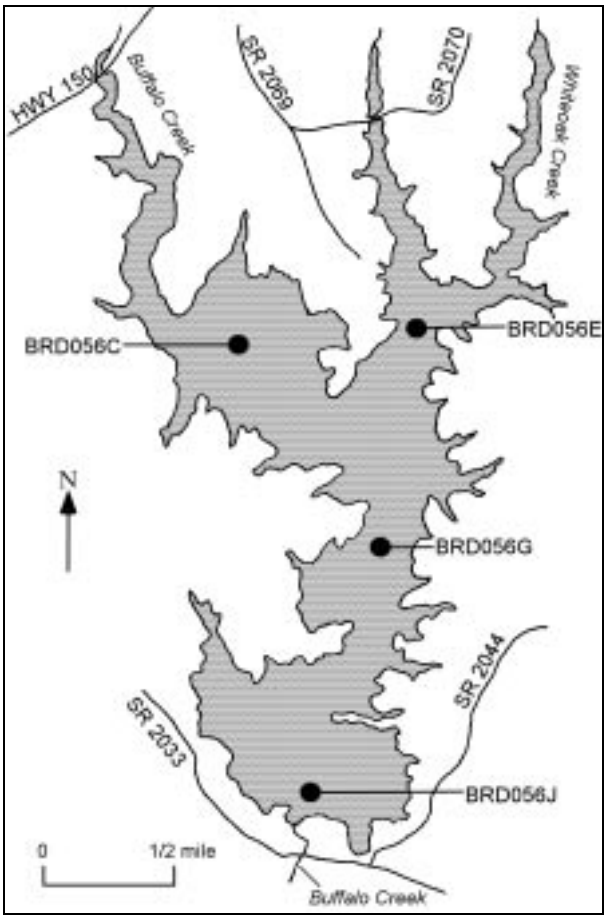


Figure 19. Monitoring sites at Kings Mountain Reservoir, Cleveland County.

The reservoir was most recently monitored by the NCDWQ during the summer of 2000 (Table 16 and Appendices L2 and L3). In June, Secchi depths at all sites ranged from 3.2 to 3.8 meters, indicating excellent light availability to the photic zone. An increase in dissolved oxygen to concentrations of 10.1 - 10.6 mg/L were observed at a depth of 5 m at each site. Nutrient concentrations were low to moderate (Appendix L3). Photic zone phytoplankton samples collected in June were dominated by diatoms and golden-brown algae (Table 17). Species identified in these samples are known to produce taste and odor problems and clog filters of water intakes.

In July, Secchi depths dropped to a range of 2.4 to 3.1 meters and mean nutrient concentrations were lower than those observed in June. A subsurface dissolved oxygen maxima was not observed, however the lake was stratified with hypoxic conditions observed at a depth of 7 meters at all sampling sites (depth to bottom ranged from 11.3 to 15.9 m).

Secchi depths decreased again in August with a range of 1.2 to 1.8 m. The lake was also stratified with hypoxic conditions observed at a depth of 6 to 7 m at Stations BRD056G and BRD056C, the two deepest sampling sites (depth to bottom = 15 and 10 m, respectively). Total phosphorus concentrations remained low, while ammonia and total organic nitrogen concentrations increased.

The reservoir was previously sampled in 1995. The lake was stratified with hypoxic conditions occurring at a depth of approximately six meters. Nitrogen and total phosphorus concentrations were low and chlorophyll *a* was moderate. Mean Secchi depth was 1.6 meters. Based on the calculated NCTSI score, Kings Mountain Reservoir was oligotrophic in August 1995.

Data collected from 1989 through 2000 for three constituents of the NCTSI indicated that the median Secchi depths and total phosphorus measurements were similar among the sites. Median total organic nitrogen and was slightly greater at the site located in the Whiteoak Creek arm as compared with the sites.

Table 16. Biological and water chemistry data for Kings Mountain Reservoir, 1995 – 2000.

Date	NCTSI	Rating	TP (mg/L)	TON (mg/L)	CHL a (µg/L)	Secchi (m)
08/23/2000	---	---	0.01	0.39	---	1.6
07/26/2000	---	---	0.01	0.26	---	2.8
06/14/2000	---	---	0.01	0.23	---	3.5
08/03/1995	-2.2	Oligotrophic	0.01	0.21	10	1.6

Table 17. Summary of algal analysis from Station BRD056E at Kings Mountain Reservoir, June 14, 2000.

CHL a (µg/L)	Biovolume (mm^3/m^3)	Density (units/ml)	Dominant division	Notes
15	1,080	740	Bacillariophyta, Chrysophyta	*Fragilaria, Dinobryon*

BROAD RIVER SUBBASIN 06

Description

This subbasin contains the North Carolina section of the North Pacolet River which flows into the Broad River in South Carolina (Figure 20). Streams within this subbasin are in the mountain and piedmont ecoregions. This is a very small subbasin containing approximately 10 miles of the North Pacolet River and many small tributaries.

Tryon is the only urban area in the subbasin. Land use in this subbasin is primarily agriculture, both row crops and livestock. Of the eight permitted dischargers in this subbasin, only the Tryon WWTP, which discharges to Vaughn Creek, is a major facility (1.5 MGD).

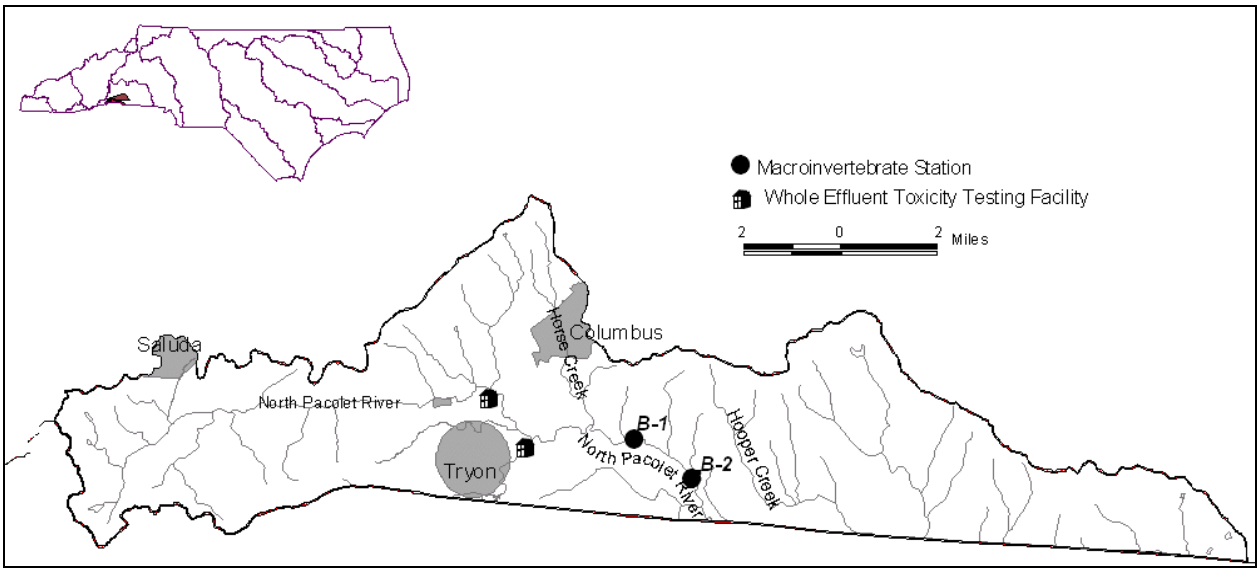


Figure 20. Sampling sites in Subbasin 06 in the Broad River basin.

Overview of Water Quality

Water quality seemed to be stable in this subbasin. Based on macroinvertebrate collections in both 1995 and 2000, water quality in the North Pacolet River was Good above the Town of Tryon, and declined to Good-Fair below the town and the town's WWTP (Table 18).

Volunteer monitoring in Polk County (Maas, *et. al* 2000b) found the highest median and maximum conductivity and orthophosphate values (104 µmhos/cm, median, 1,990 µmhos/cm, maximum, and 0.36 mg/L, median and 2.09 mg/L, maximum, respectively) in the North Pacolet River below Tryon's WWTP. The only other stream with remarkable water quality problems was Joels Creek, a small stream draining the southeast side of Saluda and below Saluda's WWTP. This stream had elevated median conductivity (62 µmhos/cm), orthophosphate (0.35 mg/L), ammonia (0.14 mg/L) and nitrite+nitrate (0.9 mg/L).

Two facilities test their effluent for toxicity in this subbasin. Both passed all their tests in 1999.

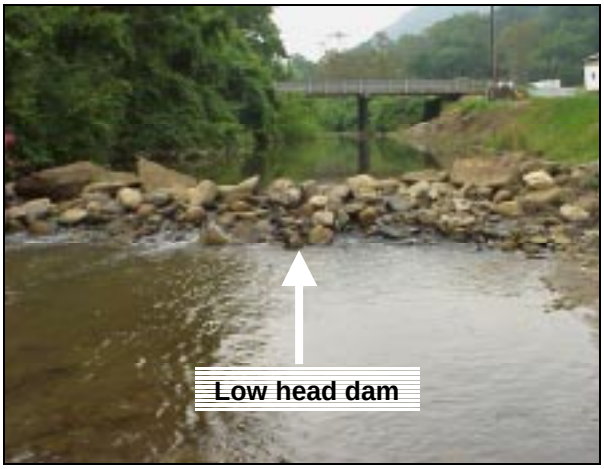
Table 18. Waterbodies monitored in Subbasin 06 in the Broad River basin for basinwide assessment, 1995 - 2000.

Map #[1]	Waterbody	County	Location	1995	2000
B-1	N Pacolet R	Polk	SR 1179	Good	Good
B-2	N Pacolet R	Polk	SR 1501	Good-Fair	Good-Fair

[1]B = benthic macroinvertebrate monitoring sites.
[2]Data are available prior to 1994, refer to Appendix B2.

Sampling occurred in this subbasin during a three year drought of a magnitude that local meteorologists compared to the Dust Bowl. Flows in all streams were well below normal and the effects of nonpoint sources of pollution (nutrient runoff and in stream scour) were minimal.

North Pacolet River, SR 1179
This site, located just west of the City of Tryon, was nine meters wide. The largest physical change in the stream since 1995 was a low head dam constructed just above the site by the adjacent landowner. This may be the possible source of enrichment noted in the benthic community. Even with the dam collecting many of the fine particulates, sediment was impacting the stream -- filling in pools and embedding the rubble and boulders.



North Pacolet River at SR 1179, Polk County.

This site was rated Good. As with most other sites in this basin, EPT taxa richness and Biotic Index increased from 31 in 1995 to 37 in 2000, reflecting recovery from scour, rather than an improvement in water quality.

North Pacolet River, SR 1501
This nine meter wide site was located just above the state North Carolina -South Carolina state line. Sedimentation appeared to be more severe here than at the site at SR 1179. The infrequent gravel bars were heavily embedded and the few remaining pools were small.

North Pacolet River at SR 1501, Polk County.

A Good-Fair rating was given to this site in 1995 and 2000. However the rating in 2000 belies shifts in the invertebrate community. Between 1995 and 2000, EPT taxa richness increased 83%, from 18 to 33 taxa. This seemed to be due to the reduced scour in 2000. The group most sensitive to scour, the Chironomidae, was the group with the greatest increase in taxa (114%, from 14 to 30). Coincidentally, the NC Biotic Index increased from 5.17 to 5.49. This may indicate that the benthic community was still a facultative community that is receiving slightly greater impacts because of decreased dilution of Tryon WWTP's effluent.

AMBIENT MONITORING SYSTEM

The NCDWQ collects ambient water quality information from approximately 420 active monitoring stations statewide. In the Broad River basin there were nine stations monitored during this assessment period (Table 19, Figure 21).

Summaries of the data collected from each station are presented in Tables 20 to 28. Percentiles were calculated using Microsoft® Excel 2000; values less than the minimum reporting level were evaluated as equal to the reporting level. Box and whisker plots (constructed using SigmaPlot® version 6) are presented only for those water quality characteristics that showed significant variation among the monitoring stations.

Table 19. Ambient monitoring system sites within the Broad River basin.

Subbasin/Station	Station No.	Location	County	Class
01				
Cove Creek	A1510000	US 64 & 74, near Lake Lure	Rutherford	C
02				
Broad River	A1520000	SR 1181, near Rock Springs	Rutherford	WS-IV
Second Broad River	A2700000	SR 1538, near Logan	Rutherford	WS-IV
Second Broad River	A4400000	SR 1538, near Cliffside	Rutherford	C
04				
Broad River	A4700000	NC 150, near Boiling Springs	Cleveland	C
First Broad River	A4800000	SR 1530, near Casar	Cleveland	WS-IV
First Broad River	A6400000	SR 1140, near Earl	Cleveland	C
Sugar Branch	A6450000	NC 150, near Boiling Springs	Cleveland	C
05				
Buffalo Creek	A8600000	NC 198, near Grover	Cleveland	C

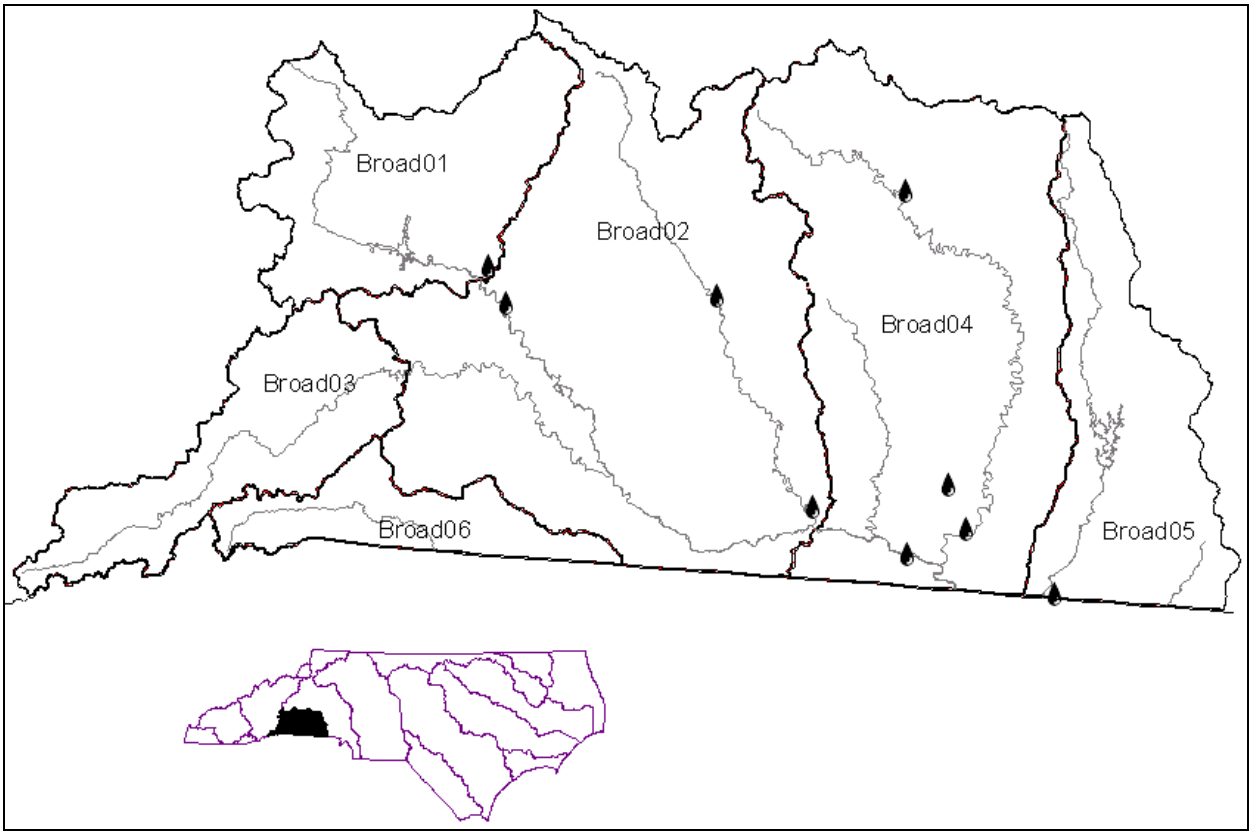


Figure 21. Ambient monitoring system sites within the Broad River basin.

Interpretation of the data should consider that laboratory or sampling related contamination may have produced higher than expected values for zinc between April 1995 and March 1999. Nitrogen and phosphorus results less than 0.05 mg/L and total Kjeldahl nitrogen results less than 1.0 mg/L did not meet desired quality assurance measures. Neither the accuracy nor bias of those results is known. The results therefore are presented as reported but should be considered with uncertainty. However, it should be noted that patterns in the concentrations of these nutrients among the stations were similar to those observed during the previous assessment period between 1992 and 1996 (NCDENR 1997a).

Among the nine monitoring stations, dissolved oxygen ranged between 6.4 and 18.2 mg/L. Although high values of turbidity (> 50 NTU) for individual samples occur at all monitoring stations, median values ranged between 3 and 12 NTU. The monitoring station at the Second Broad River at Cliffside had eight (14%) observations over the standard of 50 NTU and the highest turbidity value (380 NTU) among all the stations.

Spatial differences were observed in water quality between the two monitoring stations along the Second Broad River. The furthest upstream station is located near Logan and had substantially lower values for conductivity, nitrite+nitrate nitrogen and total phosphorus than the most downstream station located near Cliffside (Figure 22). The increases noted at the monitoring station at Cliffside may be influenced by municipal wastewater and textile plant discharges upstream.

Similar patterns could be observed between the upstream and downstream stations along the First Broad River. The upstream station near Casar had lower values for conductivity and nutrients (Figure 22) than the downstream station near Earl. This pattern also occurred for fecal coliform bacteria (Figure 23), with the geometric mean ranging between 44 and 239 colonies per 100 ml (Table 29). The patterns for all these parameters may be influenced by wastewater treatment plant discharges upstream in addition to any nonpoint sources

Nitrite+nitrate nitrogen concentrations observed at Sugar Branch were the highest among all the monitoring stations (median = 1.20 mg/L). In addition, this station had the second largest geometric mean (189 colonies/100ml) for fecal coliform bacteria. Only one minor discharger is permitted along this stream; the watershed is small (1.43 mi^2)and is predominately agricultural with some cattle operations present. Nonpoint source discharges may be the cause for high nitrite+nitrate nitrogen and fecal coliform values.

Iron concentrations at some locations exceeded the action level for more than 10% of the samples. Iron, however, is an element commonly found in soils and its natural occurrence may be responsible for this pattern. Concentration of zinc exceeded the 50 μg/L action level for approximately 10% of the 57 samples from the monitoring station along the First Broad River near Earl. However, field or laboratory contamination may have produced higher than expected values for zinc between April 1995 and March 1999.

Concentrations of copper exceeded the 7 μg/L action level for more than 10% of samples collected from six stations. However, the median concentration for copper at all stations was below the action level. Copper can show toxicity problems when present in high concentrations in a dissolved state. Currently NCDWQ analyses measure the total concentration of copper. Potential copper toxicity will be investigated for the most downstream monitoring station along the Second Broad river near Cliffside.

Summaries for fecal coliform bacteria concentrations are provided in Table 29 and Figure 23. The geometric mean of 239 colonies/100ml exceeded 200 colonies/100ml for the monitoring station along the First Broad River near Earl. Note, however, the standard for fecal coliform is based upon at least five consecutive samples examined during any 30 day period. The frequency of sampling for ambient water quality parameters, including fecal coliform bacteria, is about once for any 30 day period. The median concentrations for fecal coliform bacteria exceeded 200 colonies/100 ml at the monitoring station near Earl and at the station along Sugar Branch near Boiling Springs (Table 29.). According to the North Carolina Administrative Code [15A NCAC 02B .0211 (3)(e)] violations of the fecal coliform standard are expected during rainfall events and, in some cases, this violation is expected to be caused by uncontrollable nonpoint source pollution. No Class B waters (swimming use) were sampled in this basin.

Table 20. Summary of ambient water quality parameters from Cove Creek (A1510000; Class C) at US 64 and 74 near Lake Lure between 9/26/1995 and 5/9/2000.

Parameter	N	Number < Reporting Level	Evaluation Level (EL)[1]	Number < or > EL	Proportion (%) < or > EL	Percentiles						
						Min.	10	25	50[a]	75	90	Max.
Field												
Dissolved Oxygen	55	na	<5	0	0.0	8.1	8.7	9.6	10.9	12.2	13.4	16.1
(DO; mg/L)			<4	0	0.0	.	.	.	.	.	.	.
Conductivity (µmhos/cm)	55	na	.	.	.	21	30	35	37	40	41	43
Temperature (°C)	55	na	.	.	.	1	6	9	13	20	22	26
pH (s.u.)	55	na	<6	0	0.0	6.9	7.1	7.3	7.4	7.5	7.6	8.1
			>9	0	0.0	.	.	.	.	.	.	.
Other (mg/L)												
Total Residue	1	na	.	.	.	37	37	37	37	37	37	37
Total Suspended Solids	56	3	.	.	.	1	2	2	4	7	26	410
Chloride	1	0	>230	0	0.0	2	2	2	2	2	2	2
Turbidity (NTU)	56	na	>50	4	7.1	2	2	4	5	8	21	250
			>25	5	8.9	.	.	.	.	.	.	.
			>10	10	17.9	.	.	.	.	.	.	.
Nutrients (mg/L)												
NH_3 as N	58	23	.	.	.	0.01	0.01	0.01	0.01	0.03	0.05	0.11
TKN as N	58	3	.	.	.	0.10	0.10	0.10	0.10	0.20	0.33	0.70
NO_2+NO_3 as N	58	5	>10	0	0.0	0.01	0.01	0.04	0.10	0.14	0.18	1.00
Total Phosphorus	58	9	0.05	5	8.6	0.01	0.01	0.01	0.01	0.03	0.05	0.38
Metals (µg/L)												
Aluminum (Al)	56	0	.	.	.	57	100	158	240	413	1040	19000
Arsenic (As)	56	56	>50	0	0.0	10	10	10	10	10	10	10
Cadmium (Cd)	56	0	>2	0	0.0	2	2	2	2	2	2	2
Chromium (Cr)	56	56	>50	0	0.0	25	25	25	25	25	25	25
Copper (Cu)	56	29	>7	6	10.7	2	2	2	2	3	8	72
Iron (Fe)	56	0	>1000	7	12.5	110	165	200	300	468	1300	17000
Lead (Pb)	56	53	>25	1	1.8	10	10	10	10	10	10	32
Manganese (Mn)	1	0	>200	0	0.0	16	16	16	16	16	16	16
Mercury (Hg)	56	56	>0.012	0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nickel (Ni)	56	56	>88	0	0.0	10	10	10	10	10	10	10
Zinc (Zn)	56	23	>50	4	7.1	10	10	10	13	28	43	100

[1] *Evaluation Levels (EL) are presented to facilitate review. Some levels refer to water quality standards; others may be used for ecological or Action Level review. Measurements should not exceed the range (< or >) indicated by the EL.*

[a] *The 50th percentile is also referred to as the median.*

na = not applicable

Table 21. Summary of ambient water quality parameters from the Broad River (A1520000; Class WS-IV) at SR 1181 near Rock Springs collected between 9/26/1995 and 8/8/2000.

Parameter	N	Number < Reporting Level	Evaluation Level (EL)[1]	Number < or > EL	Proportion (%) < or > EL	Percentiles						
						Min.	10	25	50[a]	75	90	Max.
Field												
Dissolved Oxygen	58	na	<5	0	0.0	7.8	8.3	9.2	10.5	12.0	13.0	16.3
(DO; mg/L)			<4	0	0.0	.	.	.	.	.	.	.
Conductivity (µmhos/cm)	58	na	.	.	.	22	32	35	39	41	42	45
Temperature (°C)	58	na	.	.	.	2	7	9	14	21	24	27
pH (s.u.)	58	na	<6	0	0.0	7.0	7.2	7.2	7.4	7.5	7.6	8.0
			>9	0	0.0	.	.	.	.	.	.	.
Other (mg/L)												
Total Residue	55	na	.	.	.	21	38	48	53	66	85	210
Total Suspended Solids	55	2	.	.	.	1	2	4	8	14	31	150
Chloride	55	3	>230	0	0.0	1	1	2	2	2	3	4
Turbidity (NTU)	58	na	>50	2	3.4	1	3	4	6	10	26	100
			>25	6	10.3	.	.	.	.	.	.	.
			>10	12	20.7	.	.	.	.	.	.	.
Nutrients (mg/L)												
NH_3 as N	60	18	.	.	.	0.01	0.01	0.01	0.03	0.05	0.09	0.27
TKN as N	60	2	.	.	.	0.10	0.10	0.10	0.20	0.30	0.31	0.40
NO_2+NO_3 as N	60	1	>10	0	0.0	0.01	0.03	0.08	0.10	0.13	0.20	2.30
Total Phosphorus	60	12	0.05	5	8.3	0.01	0.01	0.01	0.02	0.03	0.05	0.14
Metals (µg/L)												
Aluminum (Al)	55	0	.	.	.	61	114	170	320	540	1264	4500
Arsenic (As)	55	55	>50	0	0.0	10	10	10	10	10	10	10
Cadmium (Cd)	55	0	>2	0	0.0	2	2	2	2	2	2	2
Chromium (Cr)	55	55	>50	0	0.0	25	25	25	25	25	25	25
Copper (Cu)	55	32	>7	6	10.9	2	2	2	2	4	8	25
Iron (Fe)	55	0	>1000	6	10.9	130	194	255	400	665	1360	5300
Lead (Pb)	55	52	>25	0	0.0	10	10	10	10	10	10	23
Manganese (Mn)	55	0	>200	0	0.0	11	15	21	30	47	56	160
Mercury (Hg)	54	54	>0.012	0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nickel (Ni)	55	55	>88	0	0.0	10	10	10	10	10	10	10
Zinc (Zn)	55	22	>50	4	7.3	10	10	10	13	22	44	150

[1] *Evaluation Levels (EL) are presented to facilitate review. Some levels refer to water quality standards; others may be used for ecological or Action Level review. Measurements should not exceed the range (< or >) indicated by the EL.*

[a] *The 50th percentile is also referred to as the median.*

na = not applicable

Table 22. Summary of ambient water quality parameters from the Second Broad River (A2700000; Class WS-IV) at SR 1538 near Logan collected between 9/26/1995 and 8/8/2000.

Parameter	N	Number < Reporting Level	Evaluation Level (EL)[1]	Number < or > EL	Proportion (%) < or > EL	Percentiles						
						Min.	10	25	50[a]	75	90	Max.
Field												
Dissolved Oxygen	58	na	<5	0	0.0	6.5	8.2	8.9	10.2	11.3	12.5	15.2
(DO; mg/L)			<4	0	0.0	.	.	.	.	.	.	.
Conductivity (µmhos/cm)	58	na	.	.	.	30	43	52	56	59	61	67
Temperature (°C)	58	na	.	.	.	2	7	10	14	20	22	25
pH (s.u.)	58	na	<6	0	0.0	6.8	7.0	7.1	7.3	7.3	7.4	7.6
			>9	0	0.0	.	..		.	.	.	.
Other (mg/L)												
Total Residue	57	na	.	.	.	43	54	60	70	87	109	230
Total Suspended Solids	57	0	.	.	.	1	5	6	10	16	27	150
Chloride	58	0	>230	0	0.0	1	2	2	2	3	3	12
Turbidity (NTU)	60	na	>50	3	5.0	3	5	6	9	11	20	120
			>25	5	8.3	.	.	.	.	.	.	.
			>10	18	30.0	.	.	.	.	.	.	.
Nutrients (mg/L)												
NH_3 as N	59	18	.	.	.	0.01	0.01	0.01	0.02	0.05	0.07	0.23
TKN as N	59	3	.	.	.	0.10	0.10	0.10	0.10	0.20	0.30	0.50
NO_2+NO_3 as N	58	1	>10	0	0.0	0.01	0.05	0.08	0.12	0.15	0.17	0.54
Total Phosphorus	59	10	0.05	3	5.1	0.01	0.01	0.01	0.02	0.03	0.04	0.15
Metals (µg/L)												
Aluminum (Al)	54	0	.	.	.	84	173	240	350	620	1070	9000
Arsenic (As)	54	54	>50	0	0.0	10	10	10	10	10	10	10
Cadmium (Cd)	54	0	>2	0	0.0	2	2	2	2	2	2	2
Chromium (Cr)	54	54	>50	0	0.0	25	25	25	25	25	25	25
Copper (Cu)	54	32	>7	8	14.8	2	2	2	2	5	10	26
Iron (Fe)	54	0	>1000	14	25.9	300	563	640	750	1075	1810	8100
Lead (Pb)	54	51	>25	1	1.9	10	10	10	10	10	10	28
Manganese (Mn)	54	0	>200	0	0.0	29	34	38	46	56	71	190
Mercury (Hg)	54	54	>0.012	0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nickel (Ni)	54	54	>88	0	0.0	10	10	10	10	10	10	10
Zinc (Zn)	54	19	>50	4	7.4	10	10	10	14	24	45	140

[1] *Evaluation Levels (EL) are presented to facilitate review. Some levels refer to water quality standards; others may be used for ecological or Action Level review. Measurements should not exceed the range (< or >) indicated by the EL.*

[a] *The 50th percentile is also referred to as the median.*

na = not applicable

Table 23. Summary of ambient water quality parameters from the Second Broad River (A4400000; Class C) at US 221 in Cliffside collected between 9/26/1995 and 8/8/2000.

Parameter	N	Number < Reporting Level	Evaluation Level (EL)[1]	Number < or > EL	Proportion (%) < or > EL	Percentiles						
						Min.	10	25	50[a]	75	90	Max.
Field												
Dissolved Oxygen	58	na	<5	0	0.0	7.2	7.4	8.1	9.8	11.0	12.6	15.2
(DO; mg/L)			<4	0	0.0	.	.	.	.	.	.	.
Conductivity (µmhos/cm)	58	na	.	.	.	33	100	109	168	226	270	575
Temperature (°C)	58	na	.	.	.	1	7	10	15	21	24	27
pH (s.u.)	58	na	<6	0	0.0	6.9	7.0	7.1	7.2	7.3	7.4	7.8
			>9	0	0.0	.	.	.	.	.	.	.
Other (mg/L)												
Total Residue	0	na	.	.	.	.	.	.	.	.	.	.
Total Suspended Solids	56	0	.	.	.	1	3	6	9	15	73	510
Chloride	55	0	>230	0	0.0	2	9	11	14	24	27	34
Turbidity (NTU)	59	na	>50	8	13.6	4	7	9	10	19	99	380
			>25	11	18.6	.	.	.	.	.	.	.
			>10	27	45.8	.	.	.	.	.	.	.
Nutrients (mg/L)												
NH_3 as N	60	6	.	.	.	0.01	0.01	0.03	0.05	0.08	0.14	0.31
TKN as N	60	0	.	.	.	0.10	0.10	0.20	0.20	0.30	0.50	0.60
NO_2+NO_3 as N	60	0	>10	0	0.0	0.13	0.27	0.33	0.37	0.44	0.57	0.84
Total Phosphorus	60	0	0.05	59	98.3	0.05	0.08	0.11	0.13	0.19	0.26	0.47
Metals (µg/L)												
Aluminum (Al)	55	0	.	.	.	130	190	290	400	795	3500	20000
Arsenic (As)	55	55	>50	0	0.0	10	10	10	10	10	10	10
Cadmium (Cd)	55	0	>2	0	0.0	2	2	2	2	2	2	2
Chromium (Cr)	55	55	>50	0	0.0	25	25	25	25	25	25	25
Copper (Cu)	55	2	>7	18	32.7	2	3	4	5	8	12	35
Iron (Fe)	55	0	>1000	23	41.8	600	684	730	920	1450	4760	14000
Lead (Pb)	55	48	>25	1	1.8	10	10	10	10	10	12	60
Manganese (Mn)	20	0	>200	3	15.0	34	46	50	56	123	294	350
Mercury (Hg)	55	55	>0.012	0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nickel (Ni)	55	55	>88	0	0.0	10	10	10	10	10	10	10
Zinc (Zn)	55	14	>50	5	9.1	10	10	10	16	29	48	96

[1]Evaluation Levels (EL) are presented to facilitate review. Some levels refer to water quality standards; others may be used for ecological or Action Level review. Measurements should not exceed the range (< or >) indicated by the EL.
[a]The 50th percentile is also referred to as the median.

na = not applicable

Table 24. Summary of ambient water quality parameters from the Broad River (A4700000; Class C) at NC 150 near Boiling Springs collected between 9/20/1995 and 8/23/2000.

Parameter	N	Number < Reporting Level	Evaluation Level (EL)[1]	Number < or > EL	Proportion (%) < or > EL	Percentiles						
						Min.	10	25	50[a]	75	90	Max.
Field												
Dissolved Oxygen	57	na	<5	0	0.0	6.7	7.7	8.4	9.7	10.9	11.5	13.8
(DO; mg/L)			<4	0	0.0	.	.	.	.	.	.	.
Conductivity (µmhos/cm)	57	na	.	.	.	43	53	59	72	83	97	143
Temperature (°C)	57	na	.	.	.	3	8	11	15	24	27	29
pH (s.u.)	57	na	<6	0	0.0	6.0	6.9	7.1	7.3	7.6	7.9	8.9
			>9	0	0.0	.	.	.	.	.	.	.
Other (mg/L)												
Total Residue	2	na	.	.	.	100	103	108	115	123	127	130
Total Suspended Solids	58	0	.	.	.	1	3	7	15	31	84	260
Chloride	49	0	>230	0	0.0	2	4	5	6	7	8	21
Turbidity (NTU)	58	na	>50	5	8.6	3	3	6	11	24	38	270
			>25	12	20.7	.	.	.	.	.	.	.
			>10	30	51.7	.	.	.	.	.	.	.
Nutrients (mg/L)												
NH_3 as N	57	26	.	.	.	0.01	0.01	0.01	0.01	0.04	0.06	0.35
TKN as N	58	2	.	.	.	0.10	0.10	0.10	0.20	0.20	0.30	0.50
NO_2+NO_3 as N	58	0	>10	0	0.0	0.06	0.20	0.26	0.30	0.34	0.38	0.50
Total Phosphorus	58	1	0.05	35	60.3	0.01	0.03	0.04	0.06	0.09	0.12	0.38
Metals (µg/L)												
Aluminum (Al)	57	1	.	.	.	50	160	300	680	1600	3300	7100
Arsenic (As)	56	56	>50	0	0.0	10	10	10	10	10	10	10
Cadmium (Cd)	56	0	>2	0	0.0	2	2	2	2	2	2	2
Chromium (Cr)	56	56	>50	0	0.0	25	25	25	25	25	25	25
Copper (Cu)	56	21	>7	5	8.9	2	2	2	3	5	7	17
Iron (Fe)	57	0	>1000	26	45.6	200	396	540	920	1800	4480	7400
Lead (Pb)	56	56	>25	0	0.0	10	10	10	10	10	10	10
Manganese (Mn)	56	0	>200	3	5.4	10	18	27	40	54	130	330
Mercury (Hg)	56	56	>0.012	0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nickel (Ni)	56	56	>88	0	0.0	10	10	10	10	10	10	10
Zinc (Zn)	56	26	>50	1	1.8	10	10	10	11	21	35	130

[1] *Evaluation Levels (EL) are presented to facilitate review. Some levels refer to water quality standards; others may be used for ecological or Action Level review. Measurements should not exceed the range (< or >) indicated by the EL.*

[a] *The 50th percentile is also referred to as the median.*

na = not applicable

Table 25. Summary of ambient water quality parameters from the First Broad River (A4800000; Class WS-IV) at SR1530 near Casar collected between 9/20/1995 and 8/23/2000.

Parameter	N	Number < Reporting Level	Evaluation Level (EL)[1]	Number < or > EL	Proportion (%) < or > EL	Percentiles						
						Min.	10	25	50[a]	75	90	Max.
Field												
Dissolved Oxygen	57	na	<5	0	0.0	7.6	8.1	8.7	9.8	11.0	12.1	14.7
(DO; mg/L)			<4	0	0.0	.	.	.	.	.	.	.
Conductivity (µmhos/cm)	57	na	.	.	.	28	32	34	37	40	42	55
Temperature (°C)	57	na	.	.	.	1	6	10	14	20	24	27
pH (s.u.)	57	na	<6	0	0.0	6.6	6.7	6.8	7.1	7.4	7.6	8.2
			>9	0	0.0	.	.	.	.	.	.	.
Other (mg/L)												
Total Residue	57	na	.	.	.	27	33	40	46	54	68	600
Total Suspended Solids	57	6	.	.	.	1	1	1	3	6	13	57
Chloride	57	1	>230	0	0.0	1	1	2	2	2	3	6
Turbidity (NTU)	58	na	>50	1	1.7	1	2	2	3	6	14	80
			>25	2	3.4	.	.	.	.	.	.	.
			>10	8	13.8	.	.	.	.	.	.	.
Nutrients (mg/L)												
NH_3 as N	58	33	.	.	.	0.01	0.01	0.01	0.01	0.02	0.05	0.11
TKN as N	58	5	.	.	.	0.10	0.10	0.10	0.10	0.20	0.30	1.20
NO_2+NO_3 as N	58	3	>10	0	0.0	0.01	0.02	0.05	0.07	0.10	0.11	0.17
Total Phosphorus	58	26	0.05	2	3.4	0.01	0.01	0.01	0.01	0.01	0.02	0.11
Metals (µg/L)												
Aluminum (Al)	58	2	.	.	.	50	64	90	130	263	708	4600
Arsenic (As)	57	57	>50	0	0.0	10	10	10	10	10	10	10
Cadmium (Cd)	57	0	>2	0	0.0	2	2	2	2	2	2	2
Chromium (Cr)	57	57	>50	0	0.0	25	25	25	25	25	25	25
Copper (Cu)	57	37	>7	5	8.8	2	2	2	2	4	6	12
Iron (Fe)	58	0	>1000	4	6.9	95	140	190	265	415	810	4500
Lead (Pb)	57	57	>25	0	0.0	10	10	10	10	10	10	10
Manganese (Mn)	56	16	>200	0	0.0	10	10	10	12	17	24	90
Mercury (Hg)	57	57	>0.012	0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nickel (Ni)	57	57	>88	0	0.0	10	10	10	10	10	10	10
Zinc (Zn)	57	29	>50	1	1.8	10	10	10	10	19	32	150

[1] *Evaluation Levels (EL) are presented to facilitate review. Some levels refer to water quality standards; others may be used for ecological or Action Level review. Measurements should not exceed the range (< or >) indicated by the EL.*

[a] *The 50th percentile is also referred to as the median.*

na = not applicable

Table 26. Summary of ambient water quality parameters from the First Broad River (A6400000; Class C) at SR 1140 near Earl collected between 9/20/1995 and 8/23/2000.

Parameter	N	Number < Reporting Level	Evaluation Level (EL)[1]	Number < or > EL	Proportion (%) < or > EL	Percentiles						
						Min.	10	25	50[a]	75	90	Max.
Field												
Dissolved Oxygen	57	na	<5	0	0.0	6.4	7.1	7.7	9.5	11.0	12.0	14.2
(DO; mg/L)			<4	0	0.0	.	.	.	.	.	.	.
Conductivity (µmhos/cm)	57	na	.	.	.	51	60	72	95	121	157	168
Temperature (°C)	57	na	.	.	.	1	6	9	15	21	24	27
pH (s.u.)	57	na	<6	0	0.0	6.6	6.8	7.0	7.1	7.3	7.4	7.6
			>9	0	0.0	.	.	.	.	.	.	.
Other (mg/L)												
Total Residue	1	na	.	.	.	73	73	73	73	73	73	73
Total Suspended Solids	58	0	.	.	.	2	5	8	15	25	45	500
Chloride	0	0	>230	0	.	.	.	.	.	.	.	.
Turbidity (NTU)	56	na	>50	4	7.1	3	5	7	12	22	43	190
			>25	12	21.4	.	.	.	.	.	.	.
			>10	32	57.1	.	.	.	.	.	.	.
Nutrients (mg/L)												
NH_3 as N	58	6	.	.	.	0.01	0.01	0.03	0.06	0.13	0.18	0.32
TKN as N	58	0	.	.	.	0.10	0.17	0.20	0.30	0.40	0.50	0.80
NO_2+NO_3 as N	58	0	>10	0	0.0	0.44	0.53	0.61	0.67	0.79	0.86	1.10
Total Phosphorus	58	0	0.05	44	75.9	0.01	0.04	0.06	0.09	0.11	0.16	0.53
Metals (µg/L)												
Aluminum (Al)	58	0	.	.	.	67	201	348	710	1850	3360	12000
Arsenic (As)	57	57	>50	0	0.0	10	10	10	10	10	10	10
Cadmium (Cd)	57	0	>2	0	0.0	2	2	2	2	2	2	2
Chromium (Cr)	57	57	>50	0	0.0	25	25	25	25	25	25	25
Copper (Cu)	58	15	>7	11	19.0	2	2	2	4	6	10	24
Iron (Fe)	58	0	>1000	23	39.7	250	464	650	935	1950	3430	12000
Lead (Pb)	57	57	>25	0	0.0	10	10	10	10	10	10	10
Manganese (Mn)	2	0	>200	0	0.0	22	23	24	25	27	27	28
Mercury (Hg)	57	57	>0.012	0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nickel (Ni)	57	57	>88	0	0.0	10	10	10	10	10	10	10
Zinc (Zn)	57	23	>50	6	10.5	10	10	10	12	27	49	93

[1] *Evaluation Levels (EL) are presented to facilitate review. Some levels refer to water quality standards; others may be used for ecological or Action Level review. Measurements should not exceed the range (< or >) indicated by the EL.*

[a] *The 50th percentile is also referred to as the median.*

na = not applicable

Table 27. Summary of ambient water quality parameters from Sugar Branch (A6450000; Class C) at NC 150 near Boiling Springs collected between 9/20/1995 and 8/23/2000.

Parameter	N	Number < Reporting Level	Evaluation Level (EL)[1]	Number < or > EL	Proportion (%) < or > EL	Percentiles						
						Min.	10	25	50[a]	75	90	Max.
Field												
Dissolved Oxygen	57	na	<5	0	0.0	6.9	7.5	8.0	9.4	10.4	11.5	18.2
(DO; mg/L)			<4	0	0.0	.	.	.	.	.	.	.
Conductivity (µmhos/cm)	57	na	.	.	.	45	64	66	71	74	77	85
Temperature (°C)	57	na	.	.	.	4	7	11	14	21	23	25
pH (s.u.)	57	na	<6	0	0.0	6.3	6.4	6.6	6.7	6.8	7.2	7.8
			>9	0	0.0	.	.	.	.	.	.	.
Other (mg/L)												
Total Residue	2	na	.	.	.	1	7	16	31	45	54	60
Total Suspended Solids	58	8	.	.	.	1	1	1	2	3	15	140
Chloride	0	0	>230	0	.	.	.	.	.	.	.	.
Turbidity (NTU)	57	na	>50	4	7.0	1	2	3	5	8	21	100
			>25	5	8.8	.	.	.	.	.	.	.
			>10	10	17.5	.	.	.	.	.	.	.
Nutrients (mg/L)												
NH_3 as N	58	23	.	.	.	0.01	0.01	0.01	0.02	0.05	0.09	0.40
TKN as N	58	2	.	.	.	0.10	0.10	0.10	0.20	0.30	0.40	0.90
NO_2+NO_3 as N	58	0	>10	0	0.0	0.21	0.86	1.10	1.20	1.30	1.40	1.70
Total Phosphorus	58	10	0.05	6	10.3	0.01	0.01	0.01	0.01	0.02	0.05	0.18
Metals (µg/L)												
Aluminum (Al)	57	5	.	.	.	50	62	85	130	240	1140	7400
Arsenic (As)	57	57	>50	0	0.0	10	10	10	10	10	10	10
Cadmium (Cd)	57	0	>2	0	0.0	2	2	2	2	2	2	2
Chromium (Cr)	57	57	>50	0	0.0	25	25	25	25	25	25	25
Copper (Cu)	57	29	>7	4	7.0	2	2	2	2	3	6	11
Iron (Fe)	57	0	>1000	7	12.3	120	186	250	370	600	1220	4100
Lead (Pb)	57	57	>25	0	0.0	10	10	10	10	10	10	10
Manganese (Mn)	0	0	>200	0	0.0.	.	.	.	.	.	.	.
Mercury (Hg)	57	56	>0.012	0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nickel (Ni)	57	57	>88	0	0.0	10	10	10	10	10	10	10
Zinc (Zn)	57	25	>50	4	7.0	10	10	10	12	23	38	120

[1]*Evaluation Levels (EL) are presented to facilitate review. Some levels refer to water quality standards; others may be used for ecological or Action Level review. Measurements should not exceed the range (< or >) indicated by the EL.*
[a]*The 50th percentile is also referred to as the median.*

na = not applicable

Table 28. Summary of ambient water quality parameters Buffalo Creek (A8600000; Class C) at NC 198 near Grover collected between 9/20/1995 and 8/23/2000.

Parameter	N	Number < Reporting Level	Evaluation Level (EL)[1]	Number < or > EL	Proportion (%) < or > EL	Percentiles						
						Min.	10	25	50[a]	75	90	Max.
Field												
Dissolved Oxygen	55	na	<5	0	0.0	7.0	7.7	8.0	9.5	10.8	11.8	13.9
(DO; mg/L)			<4	0	0.0	.	.	.	.	.	.	.
Conductivity (µmhos/cm)	57	na	.	.	.	72	110	152	211	266	358	469
Temperature (°C)	57	na	.	.	.	3	7	9	15	21	23	24
pH (s.u.)	57	na	<6	0	0.0	6.8	6.9	7.1	7.2	7.4	7.5	7.9
			>9	0	0.0	.	.	.	.	.	.	.
Other (mg/L)												
Total Residue	1	na	.	.	.	110	110	110	110	110	110	110
Total Suspended Solids	58	0	.	.	.	1	4	6	11	20	49	380
Chloride	0	0	>230	0	.	.	.	.	.	.	.	.
Turbidity (NTU)	58	na	>50	3	5.2	2	4	5	8	13	30	180
			>25	8	13.8	.	.	.	.	.	.	.
			>10	20	34.5	.	.	.	.	.	.	.
Nutrients (mg/L)												
NH_3 as N	58	7	.	.	.	0.01	0.01	0.03	0.04	0.09	0.12	0.45
TKN as N	58	1	.	.	.	0.10	0.20	0.20	0.30	0.30	0.43	0.60
NO_2+NO_3 as N	58	0	>10	0	0.0	0.39	0.54	0.62	0.71	0.87	0.99	1.30
Total Phosphorus	58	0	0.05	57	98.3	0.04	0.11	0.18	0.27	0.38	0.48	1.00
Metals (µg/L)												
Aluminum (Al)	58	2	.	.	.	50	187	273	425	765	1860	8400
Arsenic (As)	58	58	>50	0	0.0	10	10	10	10	10	10	10
Cadmium (Cd)	58	0	>2	0	0.0	2	2	2	2	2	2	2
Chromium (Cr)	58	58	>50	0	0.0	25	25	25	25	25	25	25
Copper (Cu)	58	8	>7	15	25.9	2	2	3	5	7	11	24
Iron (Fe)	58	0	>1000	13	22.4	230	528	600	765	1000	1680	6000
Lead (Pb)	58	58	>25	0	0.0	10	10	10	10	10	10	10
Manganese (Mn)	1	0	>200	0	0.0	65	65	65	65	65	65	65
Mercury (Hg)	58	58	>0.012	0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nickel (Ni)	58	56	>88	0	0.0	10	10	10	10	10	10	11
Zinc (Zn)	58	14	>50	4	6.9	10	10	10	16	28	43	91

[1] *Evaluation Levels (EL) are presented to facilitate review. Some levels refer to water quality standards; others may be used for ecological or Action Level review. Measurements should not exceed the range (< or >) indicated by the EL.*

[a] *The 50th percentile is also referred to as the median.*

na = not applicable

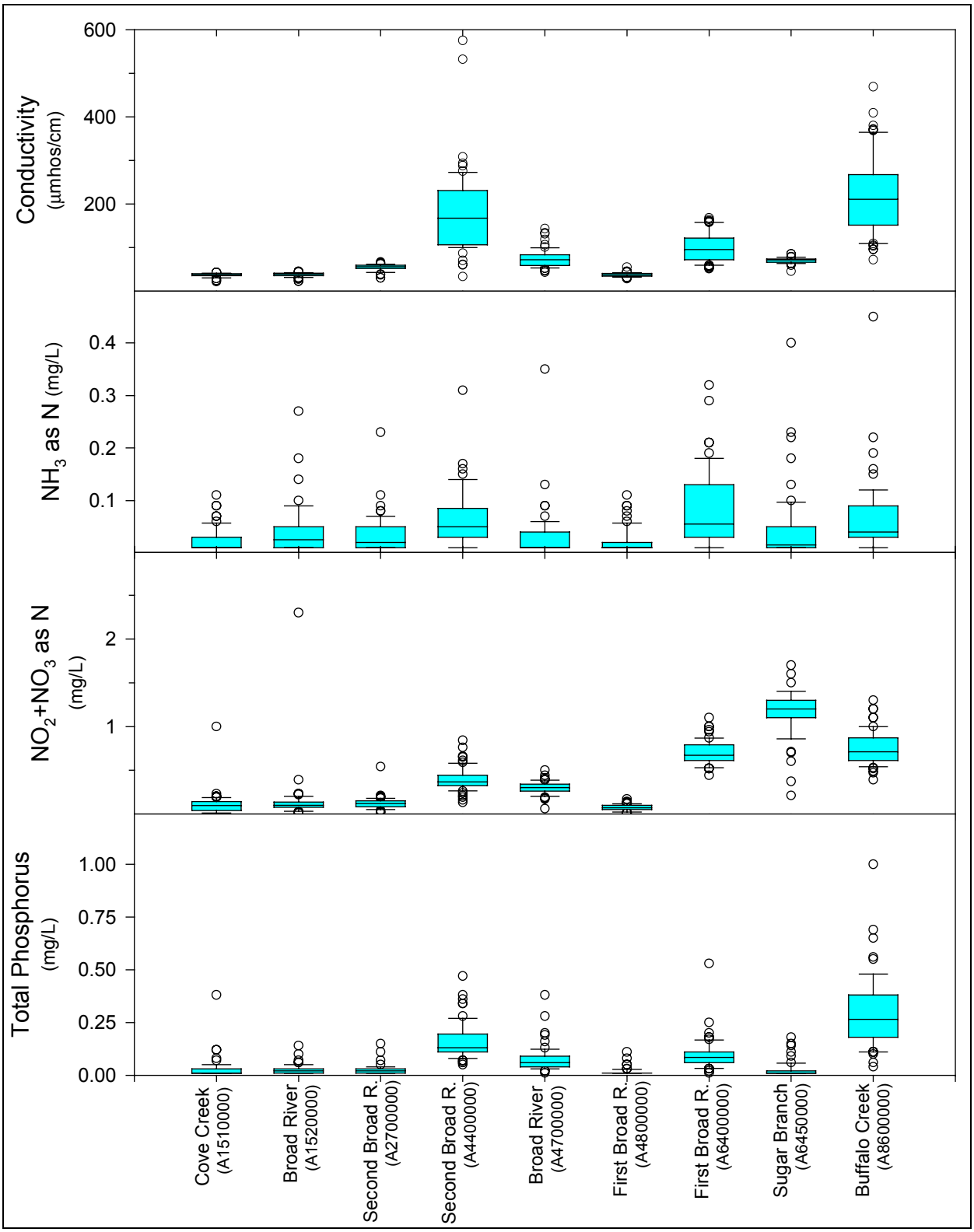


Figure 22. **Box and whisker plots for nutrients and conductivity collected from ambient monitoring stations in the Broad River Basin, 1995 - 2000.**

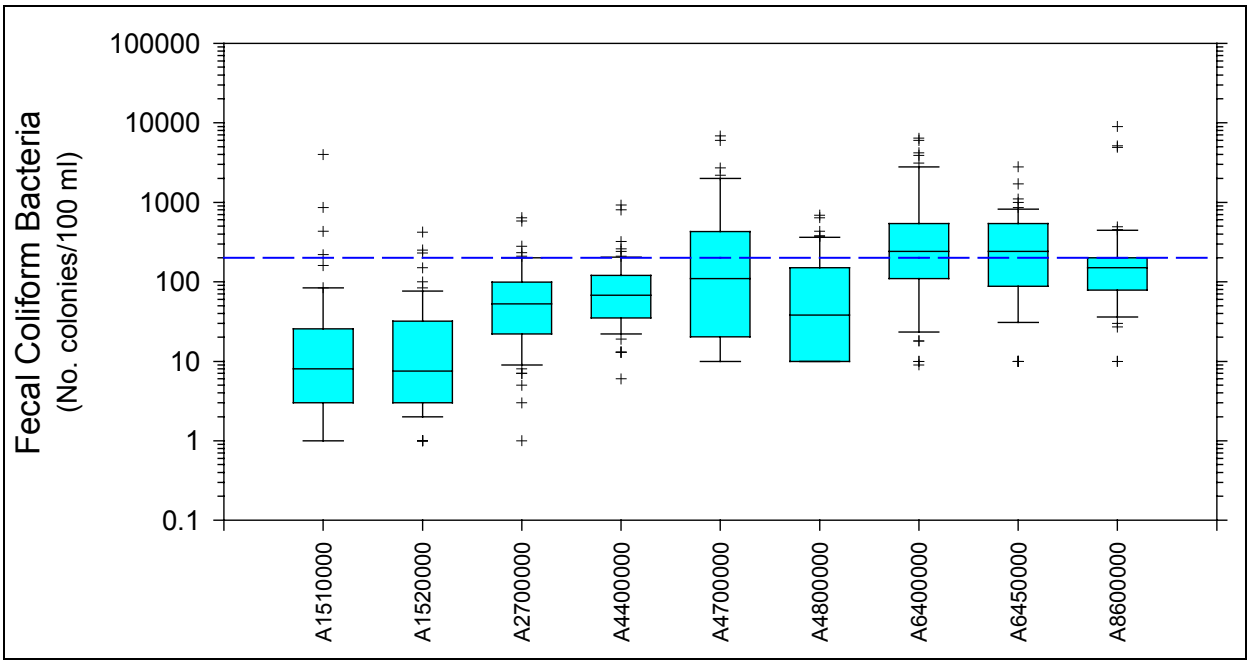


Figure 23. **Box and whisker plots depicting fecal coliform bacteria concentrations in the Broad River basin, 1995 - 2000. Horizontal line represents a reference level of 200 colonies/100 ml.**

Table 29. **Summary for fecal coliform bacteria (No. colonies/100ml) in the Broad River basin, 1995 - 2000.[1]**

Station	Location	N	N<R.L.	GeoMean	Percentiles					
					10	25	50	75	90	Max
A1510000	Cove Cr. near Lake Lure	56	5	10	1	3	8	26	107	4000
A1520000	Broad R. near Rock Springs	58	3	10	2	3	8	32	86	420
A2700000	Second Broad R. near Logan	60	.	46	8	22	53	99	200	640
A4400000	Second Broad R. at Cliffside	58	.	68	22	35	68	123	213	920
A4700000	Broad R. near Boiling Spring	55	10	118	10	18	110	450	2000	6800
A4800000	First Broad R. near Casar	52	16	44	10	10	38	150	367	690
A6400000	First Broad R. near Earl	51	2	239	20	110	240	540	3000	6400
A6450000	Sugar Br. near Boiling Springs	53	5	189	20	86	240	550	840	2800
A8600000	Buffalo Cr. near Grover	51	2	145	36	76	150	200	448	9000

[1]N = Number of samples; R.L. = Reporting level; GeoMean = Geometric mean

AQUATIC TOXICITY MONITORING

Eighteen facility permits in the Broad River basin currently require whole effluent toxicity (WET) monitoring (Figure 24 and Table 30). Seventeen facility permits have a WET limit; the other facility permit specifies monitoring with no limit.

The number of facilities in this basin monitoring whole effluent toxicity has increased steadily since 1985, the first year that monitoring was required (Figure 25). Whole effluent toxicity limits were written into permits in North Carolina beginning in 1987. The compliance rate of those facilities has risen since the inception of the program. Since 1997, the compliance rate has stabilized at approximately 90-95% (Figure 25 and Table 31).

The Town of Spindale's WWTP (Subbasin 02) has experienced problems meeting its whole effluent toxicity limit since it began monitoring in 1987. The facility signed a Special Order by Consent (SOC) with the NCDWQ in August of 1996 to perform toxicity reduction activities, construct treatment plant upgrades, and relocate its discharge from Hollands Creek to Catheys Creek. The SOC expired in September of 1999. The discharge relocation reduced the facility's instream waste concentration (IWC) and thus its WET limit from 67% to 26%. The facility constructed a dissolved air flotation sludge thickener and added new weirs and baffles in a secondary clarifier. Initial toxicity identification procedures indicated surfactant chemicals as the source of toxicity. The facility's monitoring data indicates compliance with its new limit from October 1998 to the present, excepting June and July of 2000.

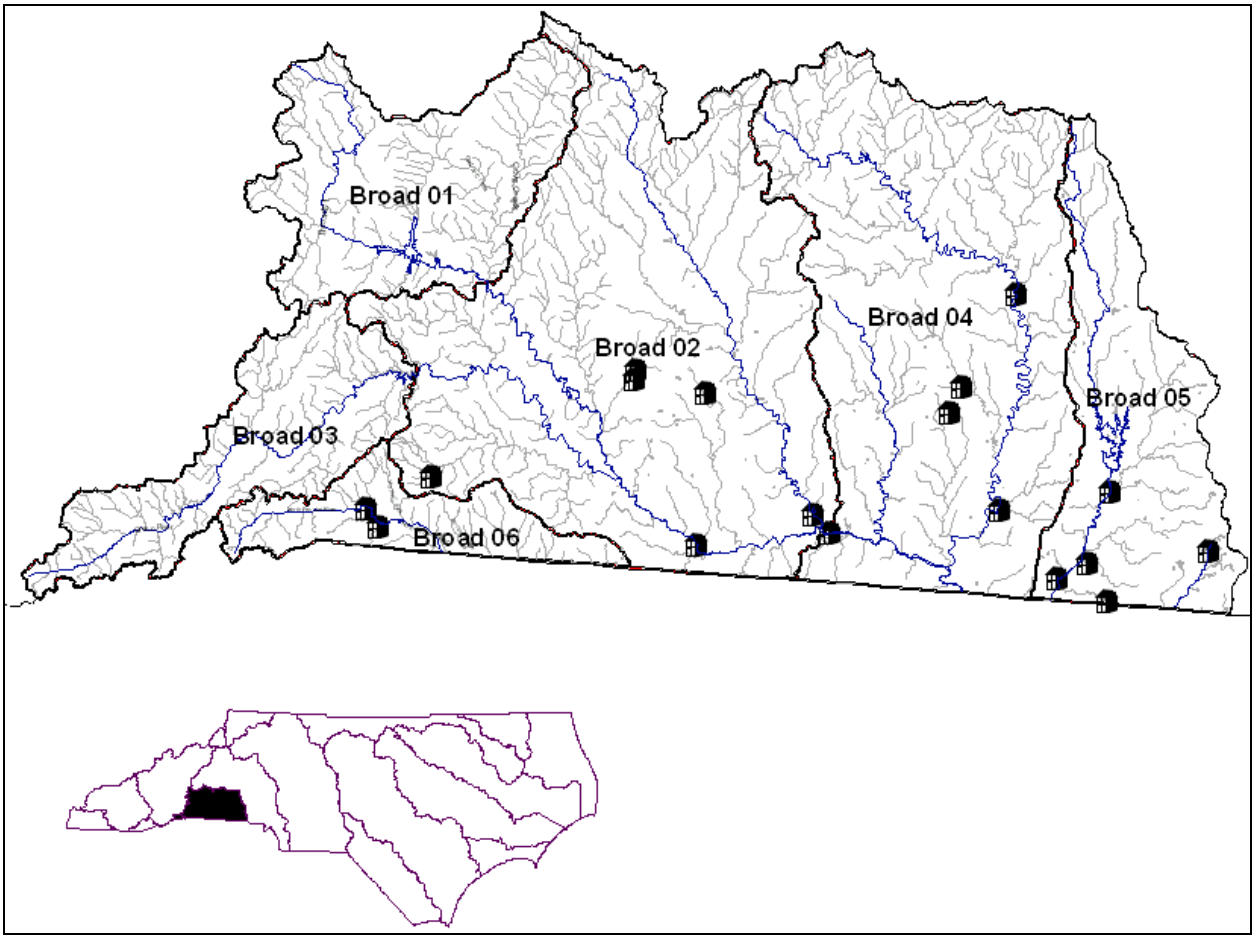


Figure 24. Facilities required to perform toxicity testing in the Broad River basin.

Table 30. Facilities in the Broad River basin required to perform whole effluent toxicity testing.

Subbasin/Facility	NPDES Permit No.	Receiving Stream	County	Flow (MGD)	IWC (%)	7Q10
02						
Columbus WWTP	NC0021369/001	UT White Oak Cr.	Polk	0.8	37.08	2.1
Cone Mills - Cliffside	NC0004405/001	Second Broad R.	Rutherford	1.75	4.19	62.10
Dan River Inc. Harris Facility	NC0083275/001	Broad R.	Rutherford	0.91	0.75	186
Duke Power-Cliffside	NC0005088/002	Broad R.	Rutherford	8.8	4.53	287
Forest City WWTP	NC0025984/001	Second Broad R.	Rutherford	4.95	18.0	34.8
Rutherfordton WWTP	NC0025909/001	Cleghorn Cr.	Rutherford	3.0	71	1.7
Spindale WWTP	NC0020664/001	Catheys Cr.	Rutherford	4.5	26	20
04						
Cleveland Mills/001	NC0004120/001	First Broad R.	Cleveland	0.78	2.4	49.40
Jefferson Smurfit Corp.	NC0005061/001	E. Fk Beaverdam Cr.	Cleveland	0.010	11.0	0.12
PPG-Shelby -001	NC0004685/001	Brushy Cr.	Cleveland	1.3	33	4.0
Shelby WWTP	NC0024538/001	First Broad R.	Cleveland	6.0	17.0	44.3
05						
Cyprus Foote Mineral Co./001	NC0033570/001	Kings Cr.	Cleveland	NA	17	0.9
Grover Industries, Inc.	NC0083984/001	Buffalo Cr.	Cleveland	0.38	1.8	32
HNA Holdings, Inc.	NC0004952/001	Buffalo Cr.	Cleveland	0.8	5.8	20.0
King's Mtn.-Pilot Cr. WWTP	NC0020737/001	Buffalo Cr	Cleveland	6.0	33	19.0
New Minette Textiles	NC0004235/001	Lick Branch	Cleveland	0.20	61	0.2
06						
Grover Industries, Inc.	NC0004391/001	N. Pacolet R.	Polk	0.45	6.07	10.8
Tryon WWTP	NC0021601/001	Vaughn Cr.	Polk	1.5	37.0	4.00

PPG Shelby was routinely noncompliant with its WET limit during the period April 1995 through May 1997, with sporadic failures in 1998. The facility signed an SOC in March 1997 that expired in July 1998. During this time the facility concluded that total dissolved solids were the source of toxicity and instituted a treatability approach to toxicity reduction. Bentonite clay addition at the aeration basin successfully removed toxicity from the effluent. Permanent modifications were made to the wastewater treatment plant effective May 1997 to implement this treatment technology. The subsequent failures in 1998 were attributed to malfunctions of that technology. The facility has been continuously compliant since August 1998.

The King's Mountain-Pilot Creek WWTP has had significant difficulty meeting its WET limit since January 1998. April 2000 Toxicity Identification Evaluation (TIE) testing implicated nickel as the primary toxicant. The source of the nickel was tracked to a malfunctioning industrial user pretreatment process. That process was upgraded during October 2000. Two tests performed during that month were compliant.

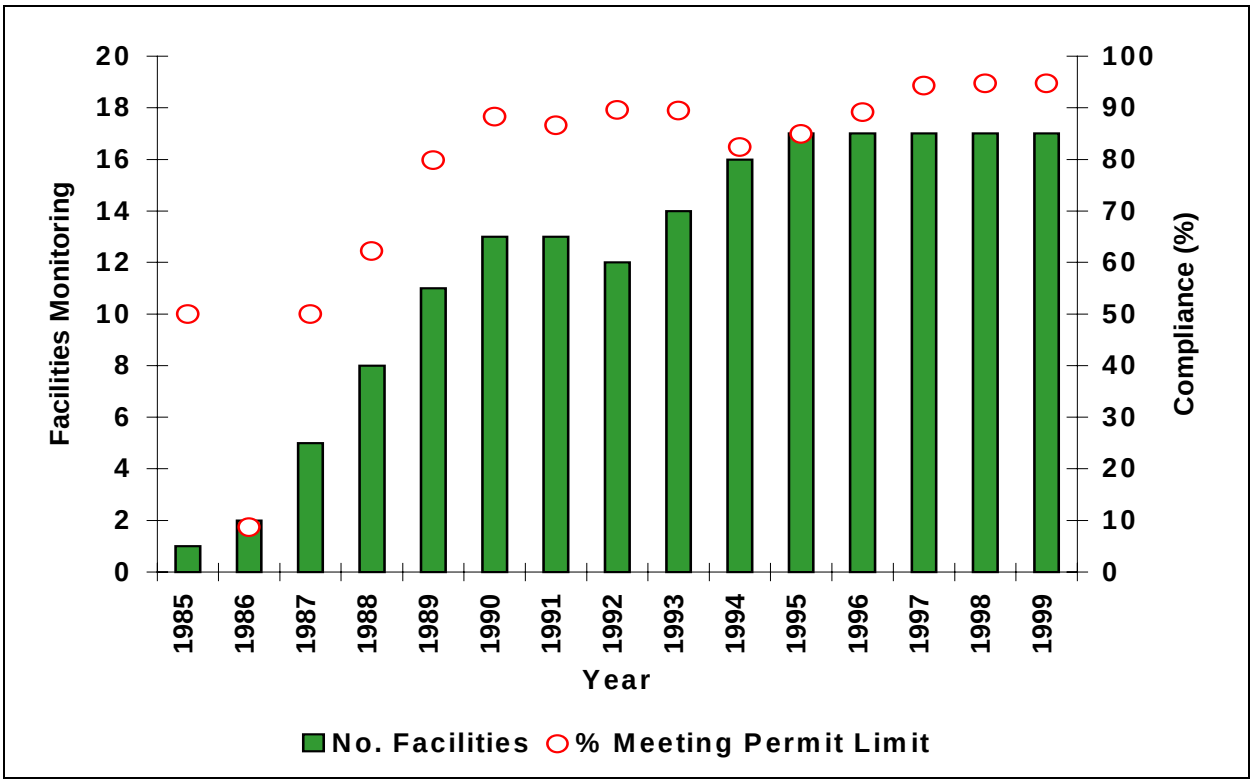


Figure 25. **Whole effluent toxicity monitoring in the Broad River basin, 1985 - 1999. The compliance values were calculated by determining whether a facility was meeting its ultimate permit limit during the given time period, regardless of any SOCs in force.**

Table 31. **Compliance record of facilities performing whole effluent toxicity testing in the Broad River basin.**

Subbasin	Facility	NPDES Permit No.	Pre 1999 Passes[1]	Pre 1999 Fails	1999 Passes	1999 Fails
02	Columbus WWTP	NC0021369/001	47	42	3	0
	Cone Mills - Cliffside	NC0004405/001	46	5	4	2
	Dan River Inc. Harris Facility	NC0083275/001	23	3	3	0
	Duke Power-Cliffside	NC0005088/002	41	0	2	0
	Forest City WWTP	NC0025984/001	50	3	4	0
	Rutherfordton WWTP	NC0025909/001	51	4	3	2
	Spindale WWTP	NC0020664/001	37	32	4	2
04	Cleveland Mills/001	NC0004120/001	40	2	3	0
	Jefferson Smurfit Corp.	NC0005061/001	23	7	3	0
	PPG-Shelby -001	NC0004685/001	62	34	4	0
	Shelby WWTP	NC0024538/001	40	3	4	0
05	Cyprus Foote Mineral Co./001	NC0033570/001	8	2	1	0
	Grover Industries, Inc.	NC0083984/001	16	0	5	0
	HNA Holdings, Inc.	NC0004952/001	27	1	3	0
	King's Mtn.-Pilot Cr. WWTP	NC0020737/001	49	13	3	7
	New Minette Textiles	NC0004235/001	48	89	0	0
06	Grover Industries, Inc.	NC0004391/001	44	2	4	0
	Tryon WWTP	NC0021601/001	42	8	3	0

[1]Note that "pass" denotes meeting a permit limit or, for those facilities with a monitoring requirement, meeting a target value. The actual test result may be a "pass" (from a pass/fail acute or chronic test), LC_{50}, or chronic value. Conversely, "fail" means failing to meet a permit limit or target value.

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GLOSSARY

7Q10	A value which represents the lowest average flow for a seven day period that will recur on a ten year frequency. This value is applicable at any point on a stream. 7Q10 flow (in cfs) is used to allocate the discharge of toxic substances to streams.
Bioclass or Bioclassification	Criteria have been developed to assign bioclassifications ranging from Poor to Excellent to each benthic sample based on the number of taxa present in the intolerant groups (EPT) and the Biotic Index value.
cfs	Cubic feet per second, generally the unit in which stream flow is measured.
CHL *a*	Chlorophyll *a*.
Class C Waters	Freshwaters protected for secondary recreation, fishing, aquatic life including propagation and survival, and wildlife. All freshwaters shall be classified to protect these uses at a minimum.
Conductivity	In this report, synonymous with specific conductance and reported in the units of μmhos/cm at 25 ^{o}C. Conductivity is a measure of the resistance of a solution to electrical flow. Resistance is reduced with increasing content of ionized salts.
Division	The North Carolina Division of Water Quality.
D.O.	Dissolved Oxygen.
Ecoregion	An area of relatively homogeneous environmental conditions, usually defined by elevation, geology, vegetation, and soil type. Examples include mountains, piedmont, coastal plain, sandhills, and slate belt.
EPT	The insect orders (Ephemeroptera, Plecoptera, Trichoptera); as a whole, the most intolerant insects present in the benthic community.
EPT N	The abundance of Ephemeroptera, Plecoptera, Trichoptera insects present, using values of 1 for Rare, 3 for Common and 10 for Abundant.
EPT S	Taxa richness of the insect orders Ephemeroptera, Plecoptera and Trichoptera. Higher taxa richness values are associated with better water quality.
HQW	High Quality Waters. Waters which are rated as excellent based on biological and physical/chemical characteristics through Division monitoring or special studies, primary nursery areas designated by the Marine Fisheries Commission, and all Class SA waters.
Major Discharger	Greater than or equal to one million gallons per day discharge (≥ 1 MGD).
MGD	Million Gallons per Day, generally the unit in which effluent discharge flow is measured.
Minor Discharger	Less than one million gallons per day discharge (< 1 MGD).
NPDES	National Pollutant Discharge Elimination System.

NCBI (EPT BI)	North Carolina Biotic Index, EPT Biotic Index. A summary measure of the tolerance values of organisms found in the sample, relative to their abundance. Sometimes noted as the NCBI or EPT BI.
NCIBI	North Carolina Index of Biotic Integrity (NCIBI); a summary measure of the effects of factors influencing the fish community.
NSW	Nutrient Sensitive Waters. Waters subject to growths of microscopic or macroscopic vegetation requiring limitations on nutrient inputs.
NTU	Nephelometric Turbidity Unit.
ORW	Outstanding Resource Waters. Unique and special waters of exceptional state or national recreational or ecological significance which require special protection to maintain existing uses.
Parametric Coverage	A listing of parameters measured and reported.
SOC	A consent order between an NPDES permittee and the Environmental Management Commission that specifically modifies compliance responsibility of the permittee, requiring that specified actions are taken to resolve non-compliance with permit limits.
Total S (or S)	The number of different taxa present in a benthic macroinvertebrate sample.
UT	Unnamed tributary.
WWTP	Wastewater treatment plant.

Appendix B1. Benthic macroinvertebrate sampling methods and criteria.

Freshwater wadeable and flowing waters

Benthic macroinvertebrates can be collected from wadeable, freshwater, flowing waters using two sampling procedures. The Biological Assessment Unit's standard qualitative sampling procedure includes 10 composite samples: two kick-net samples, three bank sweeps, two rock or log washes, one sand sample, one leafpack sample, and visual collections from large rocks and logs (NCDEHNR 1997). The samples are picked "on-site". The purpose of these collections is to inventory the aquatic fauna and produce an indication of relative abundance for each taxon. Organisms are classified as Rare (1-2 specimens), Common (3-9 specimens), or Abundant ($\geq$ 10 specimens).

Benthic macroinvertebrates can also be collected using an EPT sampling procedure. [Note: "EPT" is an abbreviation for Ephemeroptera + Plecoptera + Trichoptera, insect groups that are generally intolerant of many kinds of pollution.] Four rather than 10 composite qualitative samples are taken at each site: 1 kick, 1 sweep, 1 leafpack and visual collections. Only EPT groups are collected and identified, and only EPT criteria are used to assign a bioclassification.

Several data-analysis summaries (metrics) can be produced from standard qualitative and EPT samples to detect water quality problems (Tables B1 and B2). These metrics are based on the idea that unstressed streams and rivers have many invertebrate taxa and are dominated by intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and are dominated by tolerant species. The diversity of the invertebrate fauna is evaluated using taxa richness counts; the tolerance of the stream community is evaluated using a biotic index.

Table B1. Benthos classification criteria for flowing water systems in the mountain ecoregion.

Metric	Sample type	Bioclass	Score
EPT S	10-sample Qualitative	Excellent	> 41
		Good	32 - 41
		Good-Fair	22 - 31
		Fair	12 - 21
		Poor	0 - 11
	4-sample EPT	Excellent	> 35
		Good	28 - 35
		Good-Fair	19 - 27
		Fair	11 - 18
		Poor	0 - 10
Biotic Index (range 0 – 10)	10-sample Qualitative	Excellent	< 4.05
		Good	4.06 - 4.88
		Good-Fair	4.89 - 5.74
		Fair	5.75 - 7.00
		Poor	> 7.00

Table B2. Benthos classification criteria for flowing water systems in the piedmont ecoregion.

Metric	Sample type	Bioclass	Score
EPT S	10-sample Qualitative	Excellent	> 31
		Good	24 – 31
		Good-Fair	16 - 23
		Fair	8 – 15
		Poor	0 - 7
	4-sample EPT	Excellent	> 27
		Good	21 - 27
		Good-Fair	14 - 20
		Fair	7 - 13
		Poor	0 - 6
Biotic Index (range 0 – 10)	10-sample Qualitative	Excellent	< 5.19
		Good	5.19 - 5.78
		Good-Fair	5.79 - 6.48
		Fair	6.49 - 7.48
		Poor	> 7.48

For standard qualitative samples, EPT taxa richness (EPT S) is used with NCDWQ criteria to assign water quality scores. Higher EPT taxa richness values usually indicate better water quality. Water quality ratings also are based on the relative tolerance of the macroinvertebrate community as summarized by the North Carolina Biotic Index (NCBI).

Both tolerance values for individual species and the final biotic index values have a range of 0-10, with higher numbers indicating more tolerant species or more polluted conditions. Water quality scores assigned with the biotic index numbers are

combined with EPT taxa richness scores to produce a final bioclassification, using criteria for coastal plain streams. EPT abundance (EPT N) and total taxa richness calculations also are used to help examine between-site differences in water quality. If the EPT taxa richness score and the biotic index differ by one, the EPT abundance value is used to determine the final site rating.

Both EPT taxa richness and biotic index values also can be affected by seasonal changes. DWQ criteria for assigning bioclassification are based on summer sampling: June - September. For samples collected outside summer, EPT taxa richness can be adjusted by subtracting out winter/spring Plecoptera or other adjustment based on resampling of summer site. The biotic index values also are seasonally adjusted for samples outside the summer season.

Criteria have been developed to assign bioclassifications ranging from Poor to Excellent to each benthic sample. These bioclassifications primarily reflect the influence of chemical pollutants. The major physical pollutant, sediment, is not assessed as well by a taxa richness analysis.

Flow Measurement

Changes in the benthic macroinvertebrate community are often used to help assess between-year changes in water quality. Some between-year changes in the macroinvertebrates, however, may be due largely to changes in flow. High flow years magnify the potential effects of nonpoint source runoff, leading to scour, substrate instability, and reduced periphyton. Low flow years may accentuate the effect of point source dischargers by providing less dilution of wastes. For these reasons, all between-year changes in the biological communities are considered in light of flow conditions (high, low, or normal) for one month prior to the sampling date. Daily flow information is obtained from the closest available USGS monitoring site and compared to the long-term mean flows. High flow is defined as a mean flow > 140% of the long-term mean for that time period, usually July or August. Low flow is defined as a mean flow < 60% of the long-term mean, while normal flow is 60-140% of the mean. Although broad scale regional patterns are often observed, there may be large geographical variation within the state, and large variation within a single summer period.

Habitat Evaluation

The NCDWQ has developed a habitat assessment form to better evaluate the physical habitat of a stream. The habitat score has a potential range of 1 - 100, based on evaluation of channel modification, amount of instream habitat, type of bottom substrate, pool variety, bank stability, light penetration, and riparian zone width. Higher numbers suggest better habitat quality, but no criteria have been developed to assign impairment ratings.

Appendix B2. Benthic macroinvertebrate data, Broad River Basin, 1983 - 2000. Basinwide sites sampled in 2000 are bolded.

Subbasin/Waterbody	Location	County	Index No.	Date	ST	EPT	BI	EPTBI	BioClass
1									
Broad R	SR 2802	Henderson	9-(1)	7/10/00	99	49	4.10	3.26	Excellent
				7/10/95	82	43	3.44	2.81	Excellent
Broad R	US 64/74	Rutherford	9-(22)	9/12/00	54	18	5.98	4.75	Not rated
				8/30/84	35	14	5.62	4.70	Not rated
Reedypatch Cr	US 64	Rutherford	9-15	7/10/00	-	32	-	3.34	Good
Cove Cr	SR 1381	Rutherford	9-23-(9)	7/12/00	-	40	-	3.39	Excellent
				7/10/95	-	37	-	3.06	Excellent
Cove Cr	US 64/74	Rutherford	9-23-(9)	7/26/89	77	33	4.20	3.64	Good
				7/21/86	95	40	4.47	3.82	Good
2									
Broad R	SR 1181	Rutherford	9-(22)	7/12/00	81	31	4.78	3.40	Good
				7/12/95	57	28	4.89	4.25	Good-Fair
Mountain Cr	SR 1149	Rutherford	9-25-(5)	8/17/00	53	19	4.96	4.09	Good-Fair
				7/12/95	-	28	-	3.76	Good
Broad R	SR 1106	Rutherford	9-(25.5)	7/11/00	71	24	5.42	4.69	Good-Fair
				7/12/95	52	23	4.84	3.79	Good-Fair
Broad R	US 221	Rutherford	9-(25.5)	7/19/00	79	32	4.89	3.97	Good
				9/20/95	58	29	4.91	4.03	Good-Fair
				7/25/89	56	22	5.31	4.67	Good-Fair
				7/21/87	64	26	5.12	4.38	Good-Fair
				7/22/86	70	27	5.40	4.32	Good-Fair
				9/4/85	48	21	4.97	3.82	Good-Fair
				8/30/84	66	29	4.58	3.76	Good-Fair
				8/11/83	46	17	5.13	4.33	Fair
Cleghorn Cr	SR 1149	Rutherford	9-26	7/13/00	85	24	6.19	5.42	Good-Fair
				7/12/95	49	17	5.30	4.96	Fair
Green R	SR 1331	Polk	9-29-(33)	10/28/93	69	29	5.28	4.32	Good-Fair
Green R	SR 1302	Polk	9-29-(33)	7/12/00	70	29	4.5	3.65	Good-Fair
				7/11/95	52	27	4.48	4.03	Good-Fair
				7/26/89	83	35	4.84	4.20	Good
				7/21/87	74	33	4.83	4.15	Good
Walnut Cr	SR 1315	Polk	9-29-44	7/11/00	-	38	-	3.36	Excellent
				7/11/95	-	14	-	3.92	Fair
UT Whiteoak Cr	Upstream WWTP	Polk	9-29-46	5/15/95	84	38	4.81	4.14	Good-Fair
UT Whiteoak Cr	Downstream WWTP	Polk	9-29-46	5/15/95	69	35	5.51	4.44	Good-Fair
UT Whiteoak Cr	SR 1532	Polk	9-29-46	10/28/86	73	29	4.65	3.48	Good-Fair
UT Whiteoak Cr	SR 1519	Polk	9-29-46	10/28/86	51	8	6.69	2.86	Poor
Whiteoak Cr	SR 1531	Polk	9-29-46	10/29/86	76	27	5.25	4.12	Good-Fair
Whiteoak Cr	SR 1526	Polk	9-29-46	10/29/86	-	19	-	4.17	Good-Fair
Whiteoak Cr	SR 1352	Polk	9-29-46	7/11/00	96	40	4.72	3.96	Good
				7/11/95	63	36	4.69	4.14	Good
				5/15/95	84	38	4.84	3.47	Good
				10/29/86	-	24	-	3.75	Good-Fair
Second Broad R	above Chip Mill	Rutherford	9-41-(10.5)	5/19/99	82	47	4.31	3.70	Good
Second Broad R	below Chip Mill	Rutherford	9-41-(10.5)	5/19/99	84	44	4.09	3.59	Good
Second Broad R	SR 1538	Rutherford	9-41-(10.5)	8/16/00	64	26	4.71	3.73	Good-Fair
				7/13/95	51	26	4.40	3.59	Good-Fair
				6/28/94	68	33	4.57	3.92	Good
Gap Br	SR 1512	Rutherford	9-41-11-1	3/18/86	88	35	3.66	2.69	Good
Second Broad R	US 74 Bus	Rutherford	9-41-(12.3)	6/28/94	71	30	5.18	4.09	Good-Fair
Catheys Cr	SR 1549	Rutherford	9-41-13-(6)	8/16/00	-	18	-	4.59	Fair
				7/13/95	-	18	-	3.94	Fair
				6/27/94	49	17	5.27	3.57	Good-Fair
				3/23/88	-	15	-	3.98	Fair
Hollands Cr	SR 1547	Rutherford	9-41-13-7-(3)	3/23/88	63	27	5.23	4.31	Good-Fair
Hollands Cr	SR 1548	Rutherford	9-41-13-7-(3)	7/13/00	-	17	-	3.26	Fair
				3/23/88	29	3	7.47	4.67	Poor
Roberson Cr	SR 1561	Rutherford	9-41-14	7/13/00	-	21	-	4.56	Good-Fair
				7/13/95	-	26	-	4.16	Good-Fair
Second Broad R	US 221A	Rutherford	9-41-(21.5)	6/28/94	65	23	5.58	4.41	Good-Fair

Appendix B2 (continued).

Subbasin/Waterbody	Location	County	Index No.	Date	ST	EPT	BI	EPTBI	BioClass
2									
Second Broad R	SR 1973	Rutherford	9-41-(24.7)	7/19/00	83	29	5.80	4.69	Good-Fair
				7/13/95	42	20	5.69	4.94	Good-Fair
				7/8/91	59	25	5.41	4.56	Good-Fair
				7/25/89	60	17	6.23	5.21	Fair
				7/21/87	65	25	5.64	4.51	Good-Fair
				9/4/85	44	15	5.99	4.77	Fair
				8/11/83	26	9	7.88	4.45	Poor
3									
Green R	SR 1104	Henderson	9-29-(1)	10/27/93	103	51	3.60	2.48	Excellent
	off SR 1106	Henderson	9-29-(1)	10/27/93	78	42	3.00	2.19	Excellent
				1/18/89	87	42	3.67	2.54	Good
				1/18/89	-	40	-	2.14	Good
	SR 1103	Henderson	9-29-(1)	10/27/93	93	38	4.04	2.89	Good
Rock Cr	SR 1106	Henderson	9-29-12	10/28/93	-	37	-	2.84	Excellent
				1/19/89	-	32	-	2.71	Good
Joe Cr	SR 1106	Henderson	9-29-14	7/10/00	-	38	-	2.97	Excellent
				1/19/89	-	28	-	2.92	Good
Bobs Cr	SR 1103	Henderson	9-29-15	1/19/89	-	35	-	2.68	Good
Freeman Cr	SR 1115	Henderson	9-29-18	1/18/89	-	20	-	3.36	Good-Fair
Green R	SR 1151	Henderson	9-29-(22)	7/11/00	71	29	4.46	3.54	Good-Fair
				7/10/95	54	25	4.44	4.07	Good-Fair
Hungry R	SR 1799	Henderson	9-29-30	9/12/00	-	34	-	3.20	Good
				7/10/00	-	34	-	2.74	Good
				7/10/95	-	25	-	2.45	Good-Fair
4									
Sandy Run Cr	SR 1195	Cleveland	9-46	7/19/00	80	38	4.71	4.00	Good
				7/11/95	61	28	5.16	4.36	Good-Fair
First Broad R	SR 1726	Cleveland	9-50-(1)	7/25/89	83	36	4.28	3.40	Good
First Broad R	SR 1530	Cleveland	9-50-(1)	7/17/00	110	47	4.49	3.67	Good
				7/10/95	92	39	4.43	3.94	Good
				10/28/93	-	35	-	3.57	Good
				7/24/89	92	37	4.51	4.02	Good
				7/27/88	96	42	4.51	3.79	Good
				7/22/86	91	37	4.84	3.87	Good
N Fk First Broad R	SR 1728	Rutherford	9-50-4	7/17/00	-	36	-	3.56	Excellent
				7/10/95	84	40	3.83	3.39	Excellent
				7/24/89	-	35	-	3.21	Good
Wards Cr	SR 1525	Cleveland	9-50-12	7/17/00	-	33	-	4.17	Good
Wards Cr	SR 1533	Cleveland	9-50-12	7/24/89	-	21	-	4.82	Good-Fair
Duncans Cr	SR 1749	Rutherford	9-50-13	7/10/95	-	28	3.20	3.20	Good
Hinton Cr	NC 226	Cleveland	9-50-15	7/17/00	-	26	-	3.90	Good-Fair
				7/10/95	-	22	-	3.51	Good-Fair
First Broad R	off SR 1809 at SR 1856	Cleveland	9-5-(15.5)	7/18/00	83	32	4.73	3.96	Good
	SR 1809	Cleveland	9-5-(15.5)	7/11/95	74	31	4.79	3.86	Good
Knob Cr	SR 1004	Cleveland	9-50-19-(4)	7/17/00	-	30	-	3.94	Good
				7/11/95	75	31	4.66	4.05	Good
First Broad R	SR 1140	Cleveland	9-50-(28)	7/20/00	70	23	5.37	4.11	Good
				7/12/95	51	19	5.53	4.56	Good-Fair
				7/25/89	73	23	5.75	4.57	Good-Fair
				7/21/87	69	26	5.65	4.04	Good
				9/5/85	44	12	6.79	5.28	Fair
				8/11/83	57	21	5.95	4.67	Good-Fair
Brushy Cr	above SR 1323	Cleveland	9-50-29	5/16/95	72	34	5.33	4.60	Good
Brushy Cr	below SR 1323	Cleveland	9-50-29	5/16/95	80	32	5.17	4.50	Good
Brushy Cr	SR 1308	Cleveland	9-50-29	7/20/00	62	24	5.02	3.94	Good
Brushy Cr	US 74	Cleveland	9-50-29	9/4/85	49	13	6.66	5.64	Fair
Brushy Cr	below US 74	Cleveland	9-50-29	11/9/88	12	12	5.47	5.47	Fair
Brushy Cr	below US 74	Cleveland	9-50-29	11/9/88	-	11	-	5.31	Fair
Hickory Cr	SR 1110	Cleveland	9-50-30	2/9/87	-	11	-	5.30	Fair
Hickory Cr	NC 18	Cleveland	9-50-30	7/20/00	46	12	6.23	5.87	Not rated
Hickory Cr	below NC 18	Cleveland	9-50-30	2/9/87	-	3	-	6.13	Poor

Appendix B2 (continued).

Subbasin/Waterbody	Location	County	Index No.	Date	ST	EPT	BI	EPTBI	BioClass
Beaverdam Cr	NC 150	Cleveland	9-50-32	7/19/00	68	24	5.74	5.01	Good
				7/11/95	57	20	5.87	5.09	Good-Fair
5									
Buffalo Cr	SR 1908	Cleveland	9-53-(1)	7/18/00	79	35	5.02	4.42	Excellent
				7/11/95	67	29	5.28	4.71	Good
Buffalo Cr	US 74	Cleveland	9-53-(5)	9/13/90	54	11	6.80	4.97	Fair
				11/14/83	43	7	7.32	6.07	Fair
Buffalo Cr	NC 198	Cleveland	9-53-(5)	7/20/00	75	27	5.25	4.57	Good
				7/12/95	56	24	5.37	4.83	Good
				7/27/88	80	14	6.65	5.85	Fair
				8/6/84	55	18	6.07	5.25	Good-Fair
				11/14/83	59	15	6.87	5.38	Fair
Muddy Fk	SR 2012	Cleveland	9-53-6	7/18/00	72	25	5.52	4.83	Good
				7/13/95	74	23	5.69	5.21	Good
				9/13/90	74	17	6.02	5.46	Good-Fair
				11/14/83	75	18	6.16	4.58	Good-Fair
Beason Cr	SR 2252	Cleveland	9-53-8	3/17/86	68	19	6.02	4.55	Good-Fair
Beason Cr	SR 2246	Cleveland	9-53-8	7/18/00	-	15	-	5.11	Good-Fair
				7/12/95	59	18	5.59	5.19	Good-Fair
				6/10/87	69	17	6.11	5.42	Good-Fair
Long Br	Battlewood Rd	York, SC	9-53-8-1	3/18/86	90	38	4.62	3.31	Excellent
Lick Br	SR 2227	Cleveland	9-53-11	7/20/00	68	24	5.47	4.70	Not impaired
				7/12/95	49	6	6.21	6.39	Not rated
				3/17/86	51	13	6.61	5.30	Not rated
				11/15/83	35	6	7.44	6.00	Not rated
Lick Br	SR 2229	Cleveland	9-53-11	3/17/86	33	3	7.99	6.61	Poor
Kings Cr	SR 2286	Cleveland	9-54	7/21/00	72	24	5.72	4.83	Good
				7/13/95	57	19	6.34	5.73	Good-Fair
6									
N Pacolet R	SR 1179	Polk	9-55-1-(1)	7/11/00	83	37	4.58	3.96	Good
				7/11/95	68	31	4.33	3.67	Good
N Pacolet R	SR 1517	Polk	9-55-1-(10)	8/10/83	67	24	5.73	4.87	Good-Fair
N Pacolet R	SR 1501	Polk	9-55-1-(10)	7/11/00	96	33	5.49	4.47	Good-Fair
				7/11/95	67	24	5.73	4.87	Good-Fair

Appendix F1. Fish community sampling methods and criteria.

Sampling Methods

At each sample site, a 600 ft. section of stream was selected and measured. The fish in the delineated stretch of stream were then collected using two backpack electrofishing units and two persons netting the stunned fish. After collection, all readily identifiable fish were examined for sores, lesions, fin damage, or skeletal anomalies, measured (total length to the nearest 1 mm), and then released. Those fish that were not readily identifiable were preserved and returned to the laboratory for identification, examination, and total length measurement. Detailed descriptions of the sampling methods may be found at: http://www.esb.enr.state.nc.us/bau.html.

NCIBI Analysis

The assessment of biological integrity using the North Carolina Index of Biotic Integrity (NCIBI) is provided by the cumulative assessment of 12 parameters or metrics. The values provided by the metrics are converted into scores on a 1, 3, or 5 scale. A score of 5 represents conditions which would be expected for undisturbed reference streams in the specific river basin or ecoregion, while a score of 1 indicates that the conditions deviate greatly from those expected in undisturbed streams of the region. Each metric is designed to contribute unique information to the overall assessment. The scores for all metrics are then summed to obtain the overall NCIBI score. Finally, the score (an even number between 12 and 60) is then used to determine the ecological integrity class of the stream from which the sample was collected.

The NCIBI has been revised since the 1997 Standard Operating Procedures were printed (NCDEHNR 1997b). Recently, the focus of using and applying the NCIBI has been restricted to wadeable streams that can be sampled by a crew of four persons. The bioclassifications and criteria have also be recalibrated against regional reference site data (Biological Assessment Unit Memorandum F-20000922) (Tables F1 and F2).

Table F1. Revised scores and classes for evaluating the fish community of a wadeable stream using the North Carolina Index of Biotic Integrity in the Broad, Catawba, Savannah, and Yadkin River basins.

NCIBI Scores	NCIBI Classes
> 54	Excellent
48 -52	Good
42-46	Good-Fair
36-40	Fair
≤ 34	Poor

Criteria and ratings applicable only to wadeable streams in the mountain and piedmont regions of the Broad River basin are the same as those for the Catawba, Savannah, and Yadkin River basins. The definition of the mountain and piedmont for these four river basins is based on a map of North Carolina watersheds by Fels (1997). Metrics and ratings should not be applied to non-wadeable streams and trout streams in each of these basins. These streams are currently not rated.

Table F2. Scoring criteria for the NCIBI for wadeable streams in the Broad, Catawba, Savannah, and Yadkin River basins with watershed drainage areas ranging between 2.8 and 245 mi^2.

No.	Metric		Score
1	**No. of species**		
	where Y is the number of species in the sample and X is the stream's drainage area in mi^2:		
	$Y \geq 9.5*Log_{10}X+1.6$		5
	$4.8*Log_{10}X+0.8 \leq Y < 9.5*Log_{10}X+1.6$		3
	$Y < 4.8*Log_{10}X+0.8$		1
2	**No. of fish**		
	Mountains	Piedmont	
	≥ 300 fish	≥ 150 fish	5
	200-299 fish	100-149 fish	3
	< 200 fish	< 100 fish	1
3	**No. of species of darters**		
	where Y is the number of species of darters in the sample and X is the stream's drainage area in mi^2.		
	$Y \geq 1.6*Log_{10}X$		5
	$0.8*Log_{10}X \leq Y < 1.6*Log_{10}X$		3
	$Y < 0.8*Log_{10}X$		1
	If the drainage area is > 70 mi^2, then ≥ 3 species = 5		
4	**No. of species of sunfish, bass, and trout**		
	≥ 3 species		5
	2 species		3
	0 or 1 species		1
5	**No. of species of suckers**		
	≥ 2 species		5
	1 species		3
	0 species		1
6	**No. of intolerant species**		
	Mountains	Piedmont	
	≥ 3 species	≥ 1 species	5
	1or 2 species	(no middle criteria or score)	3
	0 species	0 species	1
7	**Percentage of tolerant individuals**		
	Mountains	Piedmont	
	≤ 12%	≤ 25%	5
	13-25%	26-35%	3
	> 25%	> 35%	1
8	**Percentage of omnivorous and herbivorous individuals**		
	10-35%		5
	36-50%		3
	> 50%		1
	< 10%		1
9	**Percentage of insectivorous individuals**		
	60-90%		5
	45-59%		3
	< 45%		1
	> 90%		1
10	**Percentage of piscivorous individuals**		
	≥ 1.0%		5
	0.25-1.0%		3
	≤ 0.24%		1
11	**Percentage of diseased fish (DELT = diseased, fin erosion, lesions, and tumors)**		
	< 0.75%		5
	0.76-1.25%		3
	> 1.25%		1
12	**Percentage of species with multiple age groups**		
	Mountains	Piedmont	
	≥ 65% of all species have multiple age groups	≥ 55% of all species have multiple age groups	5
	45-64% all species have multiple age groups	35-54% all species have multiple age groups	3
	< 45% all species have multiple age groups	< 35% all species have multiple age groups	1

Appendix F2. Fish community data collected from wadeable streams in the Broad River basin, 1994 - 2000. Basinwide sites sampled in 2000 are bolded.

Subbasin/Stream	Location	County	Map #	Index No.	Date	NCIBI Score	NCIBI Rating
01							
Flat Cr	SR 2802	Buncombe		9-12	09/29/98	---	Not rated
Cedar Cr	SR 1371	Rutherford	F-1	9-23-14	05/11/00	44	Good-Fair
02							
Green R	SR 1302	Polk		9-29-(33)	06/19/95	46	Good-Fair
Walnut Cr	SR 1315	Polk	F-1	9-29-44	05/12/00	56	Excellent
White Oak Cr	SR 1526	Polk	F-2	9-29-46	05/12/00	46	Good-Fair
Second Broad R	SR 1500	Rutherford	F-3	9-41-(0.5)	05/11/00	52	Good
Second Broad R	SR 1538	Rutherford		9-41-(10.5)	06/20/94	56	Excellent
Second Broad R	US 74	Rutherford		9-41-(21.5)	06/20/94	50	Good
Second Broad R	US 221A	Rutherford		9-41-(24.7)	06/20/94	50	Good
Cane Cr	SR 1558	Rutherford	F-4	9-41-12-(5.5)	05/10/00	44	Good-Fair
Catheys Cr	SR 1549	Rutherford	F-5	9-41-13-(6)	05/10/00	32	Poor
					06/20/94	46	Good-Fair
Roberson Cr	SR 1561	Rutherford	F-6	9-41-14	05/10/00	52	Good
04							
Sandy Run	SR 1332	Cleveland	F-1	9-46	05/10/00	48	Good
N Fk First Broad R	SR 1728	Rutherford		9-50-4	06/07/99	58	Excellent
					06/20/95	50	Good
Brier Cr	SR 1733	Rutherford		9-50-8	09/28/98	56	Excellent
Wards Cr	SR 1525	Cleveland	F-2	9-50-12	05/09/00	52	Good`
Knob Cr	SR 1641	Cleveland	F-3	9-50-19-(2.5)	05/09/00	42	Good-Fair
Brushy Cr	SR 1342	Cleveland	F-4	9-50-29	05/09/00	46	Good-Fair
Hickory Cr	NC 18	Cleveland	F-5	9-50-30	05/08/00	50	Good
Beaverdam Cr	NC 150	Cleveland	F-6	9-50-32	06/20/95	48	Good
					05/08/00	50	Good
05							
Buffalo Cr	SR 1906	Cleveland	F-1	9-53-(1)	05/09/00	46	Good-Fair
Muddy Fk	SR 1001	Cleveland	F-2	9-53-6	05/08/00	48	Good
06							
N Pacolet R	SR 1501	Polk		9-55-1-(10)	06/19/95	48	Good

Appendix F3. Fish community metric values from wadeable streams in the 2000 Broad River basinwide monitoring program.[1]

Subbasin Waterbody	Location	County	Eco-region	d. a. (mi2)	Date	No. Species	No. Fish	No. Sp. Darters	No. Sp. Sunfish + Bass+ Trout	No. Sp. Suckers	No. Intol. Sp.	% Tolerant	% Omni. + Herb.	% Insect.	% Pisc.	% DELT	% MA
01																	
Cedar Cr	SR 1371	Rutherford	MT	22.0	05/11/00	11	787	2	2	1	3	3	41	59	0.0	0.0	82
02																	
Cane Cr	SR 1558	Rutherford	P	24.6	05/11/00	13	280	1	2	2	2	5	39	61	0.0	0.0	46
Catheys Cr	SR 1549	Rutherford	P	44.0	05/10/00	13	65	1	2	2	3	5	63	37	0.0	0.0	23
Roberson Cr	SR 1561	Rutherford	P	26.0	05/10/00	20	440	1	4	3	3	5	38	61	0.5	0.0	70
Second Broad R	SR 1500	Rutherford	MT	25.9	05/11/00	18	728	1	4	3	4	3	35	65	0.1	0.0	67
Walnut Cr	SR 1315	Polk	P	16.9	05/12/00	22	428	4	3	3	6	3	43	56	1.2	0.0	77
White Oak Cr	SR 1526	Polk	P	11.3	05/12/00	13	345	1	2	3	1	11	51	49	0.0	0.0	85
04																	
Beaverdam Cr	NC 150	Cleveland	P	16.9	05/08/00	18	726	3	1	2	4	4	39	61	0.0	0.0	78
Brushy Cr	SR 1342	Cleveland	P	20.0	05/09/00	16	287	1	2	3	3	10	64	36	0.3	0.0	63
Hickory Cr	NC 18	Cleveland	P	18.6	05/08/00	18	606	3	2	2	3	4	48	52	0.2	0.0	61
Knob Cr	SR 1641	Cleveland	P	33.3	05/09/00	13	305	2	1	2	2	3	51	49	0.0	0.0	85
Sandy Run	SR 1332	Cleveland	P	11.2	05/10/00	15	722	3	3	2	3	10	60	40	0.1	0.0	67
Wards Cr	SR 1525	Cleveland	P	17.5	05/09/00	16	800	3	1	2	5	9	23	77	0.0	0.0	88
05																	
Buffalo Cr	SR 1906	Cleveland	P	40.3	05/09/00	14	250	0	3	2	2	11	44	55	0.8	0.0	50
Muddy Fk	SR 1001	Cleveland	P	31.3	05/08/00	16	811	2	2	3	2	11	46	54	0.0	0.0	63

[1]Abbreviations are d.a. = drainage area, No. = number, Sp. = species, Intol. = intolerants, Omni. + Herb. = omnivores+herbivores, Insect. = insectivores, Pisc. = piscivores, DELT = disease, erosion, lesions, and tumors, and MA = species with multiple age groups.

Appendix L1. Lake assessment program.

Numerical indices are often used to evaluate the trophic state of lakes. An index was developed specifically for North Carolina lakes as part of the state's original Clean Lakes Classification Survey (NCDNRCD 1982). The North Carolina Trophic State Index (NCTSI) is based on total phosphorus (TP in mg/L), total organic nitrogen (TON in mg/L), Secchi depth (SD in inches), and chlorophyll *a* (CHL in µg/L). Lakewide means for these parameters are used to produce a NCTSI score for each lake, using the equations:

TON_{Score} = ((Log (TON) + 0.45)/0.24)*0.90

TP_{Score} = ((Log (TP) + 1.55)/0.35)*0.92

SD_{Score} = ((Log (SD) – 1.73)/0.35)*-0.82

CHL_{Score} = ((Log (CHL) – 1.00)/0.48)*0.83

NCTSI = $TON_{Score} + TP_{Score} + SD_{Score} + CHL_{Score}$

In general, NCTSI scores relate to trophic classifications (Table L1). When scores border between classes, best professional judgment is used to assign an appropriate classification. NCTSI scores may be skewed by highly colored water typical of dystrophic lakes. Some variation in the trophic state of a lake between years is not unusual because of the potential variability of data collections which usually involve sampling a limited number of times during the growing season.

Table L1. Lakes classification criteria.

NCTSI Score	Trophic classification
< -2.0	Oligotrophic
-2.0 – 0.0	Mesotrophic
0.0 – 5.0	Eutrophic
> 5.0	Hypereutrophic

Lakes are classified for their "best usage" and are subject to the state's water quality standards. Primary classifications are C (suited for aquatic life propagation /protection and secondary recreation such as wading), B (primary recreation, such as swimming, and all class C uses), and WS-I through WS-V(water supply source ranging from highest watershed protection level I to lowest watershed protection V, and all class C uses). Lakes with a CA designation represent water supplies with watersheds that are considered Critical Areas (i.e., an area within 0.5 mile and draining to water supplies from the normal pool elevation of reservoirs, or within 0.5 mile and draining to a river intake).

Supplemental classifications may include SW (slow moving Swamp Waters where certain water quality standards may not be applicable), NSW (Nutrient Sensitive Waters subject to excessive algal or other plant growth where nutrient controls are required), HQW (High Quality Waters which are rated excellent based on biological and physical/chemical characteristics), and ORW (Outstanding Resource Waters which are unique and special waters of exceptional state or national recreational or ecological value). A complete listing of these water classifications and standards can be found in Title 15 North Carolina Administrative Code, Chapter 2B, Section .0100 and .0200.

Appendix L2. Surface waters data collected from the lakes in the Broad River basin, 1995 - 2000.[1]

Subbasin/Lake	Date	Station	Dissolved oxygen (mg/L)	Temperature (°C)	pH (s.u.)	Conductivity (µmhos/cm)	Secchi depth (m)
01							
Lake Lure	8/22/00	BRD001C	8.1	27.2	7.6	37	1.9
	8/22/00	BRD001D1	7.8	27.0	7.5	37	2.0
	8/22/00	BRD001F	8.2	27.2	7.7	38	2.1
	7/25/00	BRD001C	8.2	25.9	7.7	35	1.4
	7/25/00	BRD001D1	8.1	25.9	7.6	35	1.3
	7/25/00	BRD001F	8.2	26.0	7.6	35	1.1
	6/13/00	BRD001C	9.4	26.1	7.2	31	1.1
	6/13/00	BRD001D1	8.8	26.5	7.0	30	2.2
	6/13/00	BRD001F	8.8	26.6	7.0	30	2.0
	7/31/95	BRD001C	8.7	28.7	6.5	38	1.3
	7/31/95	BRD001D1	7.8	29.3	6.4	37	2.4
	7/31/95	BRD001F	7.5	30.0	6.8	38	2.2
03							
Lake Adger	6/13/00	BRD007J	8.7	27.3	7.2	31	0.4
	6/13/00	BRD007L	9.4	27.9	7.6	30	0.7
	6/13/00	BRD007P	9.1	28.3	7.9	29	0.7
	7/31/95	BRD007J	7.9	29.6	6.5	30	1.2
	7/31/95	BRD007L	8.0	29.3	6.6	29	1.8
	7/31/95	BRD007P	7.6	30.1	7.2	29	2.3
Lake Summit	8/23/00	BRD005Q	8.1	24.9	7.8	31	3.2
	8/23/00	BRD005R	7.8	24.9	7.7	31	2.6
	7/26/00	BRD005Q	8.2	24.2	7.1	29	2.8
	7/26/00	BRD005R	7.6	24.5	7.3	30	2.6
	7/26/00	BRD005T	6.7	22.4	7.2	33	0.7
	6/14/00	BRD005Q	8.7	25.9	7.1	24	3.2
	6/14/00	BRD005R	8.7	25.5	7.2	24	3.2
	6/14/00	BRD005T	7.7	25.7	7.0	27	0.4
	7/31/95	BRD005Q	7.6	28.0	6.5	25	1.8
	7/31/95	BRD005R	7.8	28.2	6.8	26	1.8
	7/31/95	BRD005T	7.6	28.6	6.9	27	1.7
05							
Kings Mountain Res.	8/23/00	BRD056C	7.8	27.6	8.4	58	1.2
	8/23/00	BRD056E	7.7	27.5	8.2	50	1.8
	8/23/00	BRD056G	7.8	27.5	8.3	58	1.6
	8/23/00	BRD056J	7.9	27.7	8.2	58	1.6
	7/26/00	BRD056C	8.3	26.2	7.7	56	2.4
	7/26/00	BRD056E	8.4	26.4	7.5	56	2.8
	7/26/00	BRD056G	8.1	26.3	7.8	56	2.8
	7/26/00	BRD056J	8.1	26.4	7.8	56	3.1
	6/14/00	BRD056C	9.1	28.5	7.8	56	3.2
	6/14/00	BRD056E	9.7	28.7	7.9	56	3.2
	6/14/00	BRD056G	9.0	28.3	7.7	56	3.8
	6/14/00	BRD056J	8.9	27.9	7.8	56	3.8
	8/3/95	BRD056C	7.9	29.3	7.3	50	1.3
	8/3/95	BRD056E	7.7	29.2	7.2	49	1.6
	8/3/95	BRD056G	7.9	29.2	7.5	49	1.7
	8/3/95	BRD056J	7.7	29.1	7.5	49	1.8

[1]Samples are collected 0.15 m below the surface.

Appendix L3. Photic zone data collected from lakes in the Broad River basin, 1995 - 2000.[1]

Subbasin/Lake	Date	Station	TP	TKN	NH_3	NO_x	TN	TON	TIN	Chl a	Total Solids	Susp. Solids	Turbidity
01													
Lake Lure	8/22/00	BRD001C	0.01	0.2	< 0.01	< 0.01	0.21	0.20	0.01		47	4	2.4
	8/22/00	BRD001D1	0.01	0.2	0.01	< 0.01	0.21	0.19	0.02		46	4	1.8
	8/22/00	BRD001F	0.01	0.2	0.02	< 0.01	0.21	0.18	0.03		51	3	1.6
	7/25/00	BRD001C	0.01	0.4	0.08	<0.01	0.41	0.32	0.09		42	1	3.3
	7/25/00	BRD001D1	0.01	0.3	0.08	< 0.01	0.31	0.22	0.09		43	1	1.8
	7/25/00	BRD001F	0.01	0.3	0.01	< 0.01	0.31	0.29	0.02		38	1	2.2
	6/13/00	BRD001C	0.02	0.3	0.08	< 0.01	0.31	0.22	0.09		49	1	1.0
	6/13/00	BRD001D1	0.03	0.3	< 0.01	< 0.01	0.31	0.30	0.01		52	4	2.4
	6/13/00	BRD001F	0.01	0.2	< 0.01	< 0.01	0.21	0.20	0.01		56	1	1.1
	7/31/95	BRD001C	0.02	0.2	0.04	<0.01	0.21	0.16	0.05	11	79	5	2.5
	7/31/95	BRD001D1	0.01	0.2	0.04	< 0.01	0.21	0.16	0.05	6	72	3	1.4
	7/31/95	BRD001F	0.01	0.2	0.05	< 0.01	0.21	0.15	0.06	5	79	2	1.3
03													
Lake Adger	6/13/00	BRD007J	0.03	0.2	0.02	0.08	0.28	0.18	0.10		58	7	4.5
	6/13/00	BRD007L	0.02	0.1	< 0.01	0.05	0.15	0.10	0.06		56	2	2.1
	6/13/00	BRD007P	< 0.01	0.2	< 0.01	0.03	0.23	0.20	0.04		53	2	2.2
	7/31/95	BRD007J	0.01	0.1	0.04	0.06	0.16	0.06	0.10	6	62	6	3.8
	7/31/95	BRD007L	< 0.01	0.1	0.04	0.04	0.14	0.06	0.08	9	34	7	2.7
	7/31/95	BRD007P	0.01	0.2	0.004	0.03	0.23	0.20	0.03	7	33	4	1.8
Lake Summit	8/23/00	BRD005Q	< 0.01	0.3	0.05	< 0.01	0.31	0.25	0.06		34	3	1.2
	8/23/00	BRD005R	0.01	0.3	< 0.01	< 0.01	0.31	0.30	0.01		35	2	1.4
	7/26/00	BRD005Q	0.01	0.3	< 0.01	0.01	0.31	0.30	0.02		84	2	1.4
	7/26/00	BRD005R	0.01	0.5	0.19	0.02	0.52	0.31	0.21		45	1	1.4
	7/26/00	BRD005T	0.02	0.4	< 0.01	< 0.01	0.41	0.40	0.01		40	8	4.9
	6/14/00	BRD005Q	0.02	0.3	< 0.01	< 0.01	0.31	0.30	0.01		49	1	1.0
	6/14/00	BRD005R	0.01	0.3	0.02	< 0.01	0.31	0.28	0.03		50	2	1.0
	6/14/00	BRD005T	0.04	0.3	< 0.01	0.02	0.32	0.30	0.03		52	13	5.3
	7/31/95	BRD005Q	< 0.01	0.1	0.03	< 0.01	0.11	0.07	0.04	8	49	6	1.9
	7/31/95	BRD005R	< 0.01	0.1	0.03	< 0.01	0.11	0.07	0.04	7	52	5	2.3
	7/31/95	BRD005T	0.03	0.1	0.03	0.02	0.12	0.07	0.05	8	67	5	2.7
05													
Kings Mountain Res.	8/23/00	BRD056C	0.02	0.8	0.26	< 0.01	0.81	0.54	0.27		48	4	2.0
	8/23/00	BRD056E	0.01	0.3	< 0.01	< 0.01	0.31	0.30	0.01		50	4	2.5
	8/23/00	BRD056G	0.01	0.4	0.06	< 0.01	0.41	0.34	0.07		51	3	1.8
	8/23/00	BRD056J	0.01	0.4	0.02	< 0.01	0.41	0.38	0.03		46	3	1.5
	7/26/00	BRD056C	0.01	0.2	0.04	0.03	0.23	0.16	0.07		41	1	1.9
	7/26/00	BRD056E	0.01	0.3	< 0.01	0.05	0.35	0.30	0.06		45	1	2.2
	7/26/00	BRD056G	0.01	0.3	< 0.01	< 0.01	0.31	0.30	0.01		30	1	1.6
	7/26/00	BRD056J	0.01	0.3	< 0.01	0.01	0.31	0.30	0.02		3200	10	1.3
	6/14/00	BRD056C	0.01	0.3	< 0.01	0.18	0.48	0.30	0.19		42	2	3.7
	6/14/00	BRD056E	0.01	0.3	< 0.01	0.15	0.45	0.30	0.16		41	2	2.9
	6/14/00	BRD056G	0.01	0.2	< 0.01	0.16	0.36	0.20	0.17		41	1	3.7
	6/14/00	BRD056J	0.01	0.2	0.05	0.14	0.34	0.15	0.19		46	1	4.1
	8/3/95	BRD056C	0.01	0.3	0.02	< 0.01	0.31	0.28	0.03	11	48	7	3.1
	8/3/95	BRD056E	0.01	0.2	0.02	< 0.01	0.21	0.18	0.03	10			
	8/3/95	BRD056G	0.01	0.2	0.01	< 0.01	0.21	0.19	0.02	9	39	7	2.8
	8/3/95	BRD056J	0.01	0.2	0.02	< 0.01	0.21	0.18	0.03	10	37	8	2.6

[1]Abbreviations are TP = total phosphorus, TKN = total Kjeldahl nitrogen, NH_3 = ammonia nitrogen, No_x = nitrate + nitrite nitrogen, TON = total organic nitrogen, TIN = total inorganic nitrogen, and Chl *a* = chlorophyll *a*. Units of measure are mg/L, except for chlorophyll *a* which is µg/l and turbidity which is NTU. Photic zone samples are taken through the water column between 0.15 m below the surface and twice the Secchi depth.