# Sediment and the Chattooga River Watershed

**Technical Report** · January 1995



William F. Hansen

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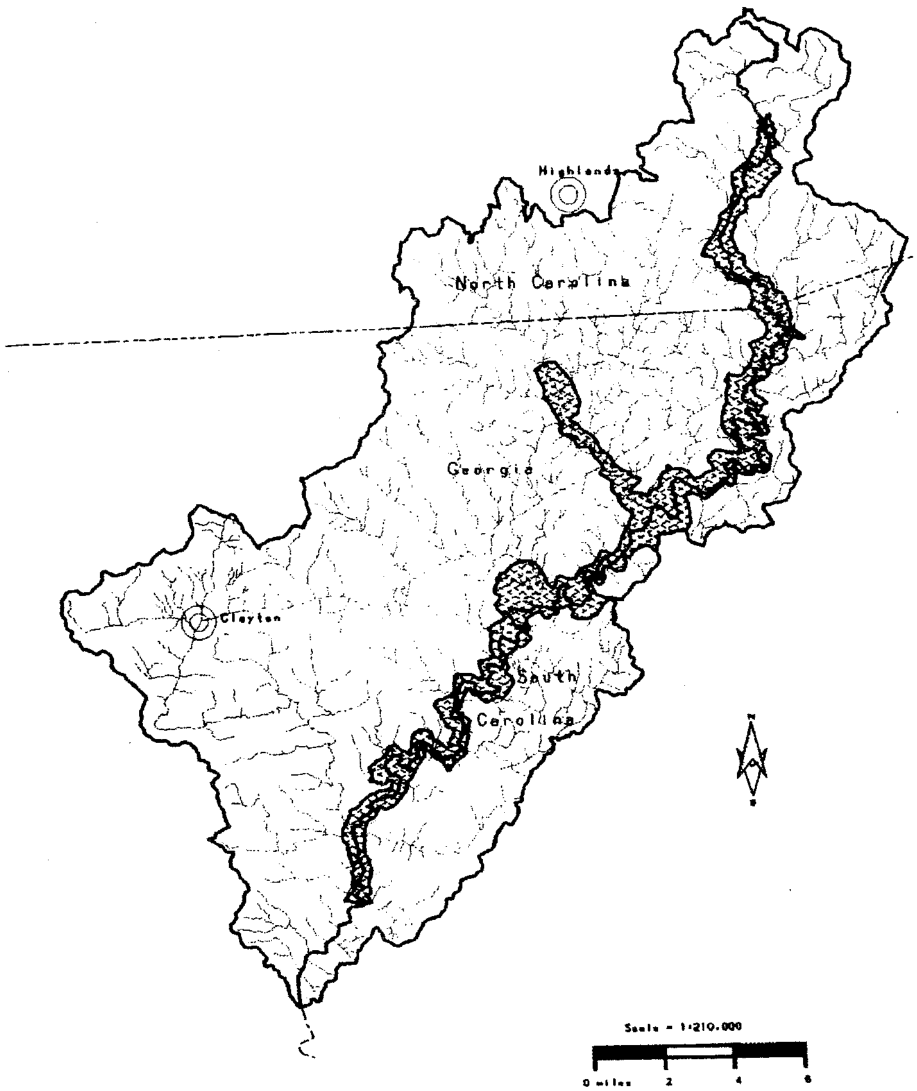


D. H. Van Lear, G. B. Taylor, and W. F. Hansen

Department of Forest Resources

Technical Paper No. 19
February 1995

CLEMSON UNIVERSITY

TROUT UNLIMITED

FOREST SERVICE
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DEPARTMENT OF AGRICULTURE

# Sedimentation In The Chattooga River Watershed

D. H. Van Lear, G. B. Taylor,
and W. F. Hansen*

February 1995

*Bowen Professor of Forestry, Department of Forest Resources, Clemson University, Clemson, SC; Environmental Consultant, JGT Inc., Mt. Pleasant, SC; and Hydrologist, US Forest Service, Columbia, SC.

This sedimentation study of the Chattooga River was jointly funded by the Chattooga Ecosystem Project of the U.S. Forest Service (USFS), Clemson University, and the Chattooga River Chapter of Trout Unlimited in a cooperative effort. Sediment was identified as a water quality issue. Primary objectives of this study were 1) to identify sources of sediment and the subbasins of the river which have highest levels of suspended sediment, 2) to aerially evaluate the extent of the fine sediments in the river's substrate, 3) to compile a map of major sediment sources in the watershed, and 4) make recommendations for their amelioration.

Major findings of this study were: 1) The Wild and Scenic River Corridor is well vegetated in mostly mature forests and contributes relatively little new sediment to the main stem of the Chattooga River. 2) Tributaries such as Stekoa Creek, Big Creek (a major tributary of the West Fork), and Whetstone Creek have highest levels of suspended sediment. 3) The West Fork, Reed Creek, and Warwoman Creek were shown from video analysis to contribute large amounts of bed-load sediments to the main river. 4) Bottom substrates of all tributaries studied are relatively unstable, i.e., bed-load sediments are dominated by sand and finer materials which are constantly moving downstream. 5) Fine sediments dominate the substrate of pools above Dick Creek, probably to the detriment of the aquatic community.

The majority of sedimentation problems (80.2% of observable sediment sources) were associated with open gravelled and unsurfaced roads, but highways, timber harvests, pastures with unfenced riparian zones, developments, land fills, and active beaver sites were also important sources. Recreational trails and facilities accounted for only 2.6% of the total number of sediment sources. However, heavy recreational use of unpaved roads increases wear and tear of the road and necessitates frequent maintenance of road surfaces, all of which increase sedimentation. The most important sources of sediment were located on a GIS map.

This report provides the background information that can be used for future restoration efforts to reduce sediment loadings in the watershed and improve water quality. With proper restoration, sources of sediment can be minimized. Over time the river can begin to recover from the land-use abuses that have accelerated sedimentation over the past century. Recommendations are provided to aid in this recovery, a process that may take decades or even centuries.

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## A. Chattooga Ecosystem Management Project

This 1-year cooperative study was funded through the USDA Forest Service's (USFS) Chattooga River Project, a pilot program for the Ecosystem Management initiative, Clemson University, and the Chattooga River Chapter of Trout Unlimited. The Chattooga River Project is a recent management approach that centers on the idea that forests are complex and dynamic systems comprised of plants, animals, soil, water, nutrients, air, and humans. Ecosystem management involves working at a variety of scales to integrate physical, chemical, biological, and social elements into sustainable land management.

Ecosystems are not bounded by property lines or state boundaries. The Chattooga watershed is defined by hydrologic boundaries which include portions of three states. Many of the issues of this area relate to the river. Goals of the Chattooga River Project include working with the public to reach a shared management vision, integrating resource management across state lines and resource needs, meeting public demands for sustainable forest uses, and working with researchers, publics, industry, regulators, and others on new ways to manage the resource.

The 57-mi long Chattooga River originates along the slopes of the Southern Appalachian Mountains and flows south for 17 mi through southwestern North Carolina. For the remaining 40 mi the river flows southwest, forming the scenic state boundary between Georgia and South Carolina. As one of the few remaining free-flowing rivers in the Southeast, the Chattooga is famous for its boating, fishing, wildlife, scenery, and aesthetic value. In 1974 Congress designated the Chattooga as one of America's Wild and Scenic Rivers, under the Wild and Scenic Rivers Act (WSRA) of 1968. WSRA protection applies only to sections of rivers bordering federal lands, and not to tributaries or sections of protected rivers which flow through private lands.

The Wild and Scenic River status of the Chattooga protects only the land adjacent to the main river and the West Fork (Figure 1) — the headwaters and portions of major tributaries are both privately held and in USFS management. Although protected by federal, state, and local ordinances, many of these tributaries are potential carriers of nonpoint source pollutants which may have far reaching downstream impacts.

## B. Sedimentation as a Major Problem

The Clean Water Act (CWA) of 1972 declared the nation's intent to restore and maintain the chemical, physical, and biological integrity of our waters, while setting national water quality goals of fishable, swimmable waters by July 1, 1983. The initial emphasis of the CWA dealt with the disposal of municipal and industrial waste in the form of point-source pollution (typically associated with discharge from pipes). While half of the nation's water pollutants comes from pipes, the remainder comes from nonpoint sources such as land, fields, and streets, and is washed into streams and rivers in the form of polluted runoff (EPA 1987). In the last decade, the CWA has been amended to include more direction to control nonpoint sources. States are actively involved with identifying preventive practices (Best Management Practices, or BMPs) and encouraging their application.

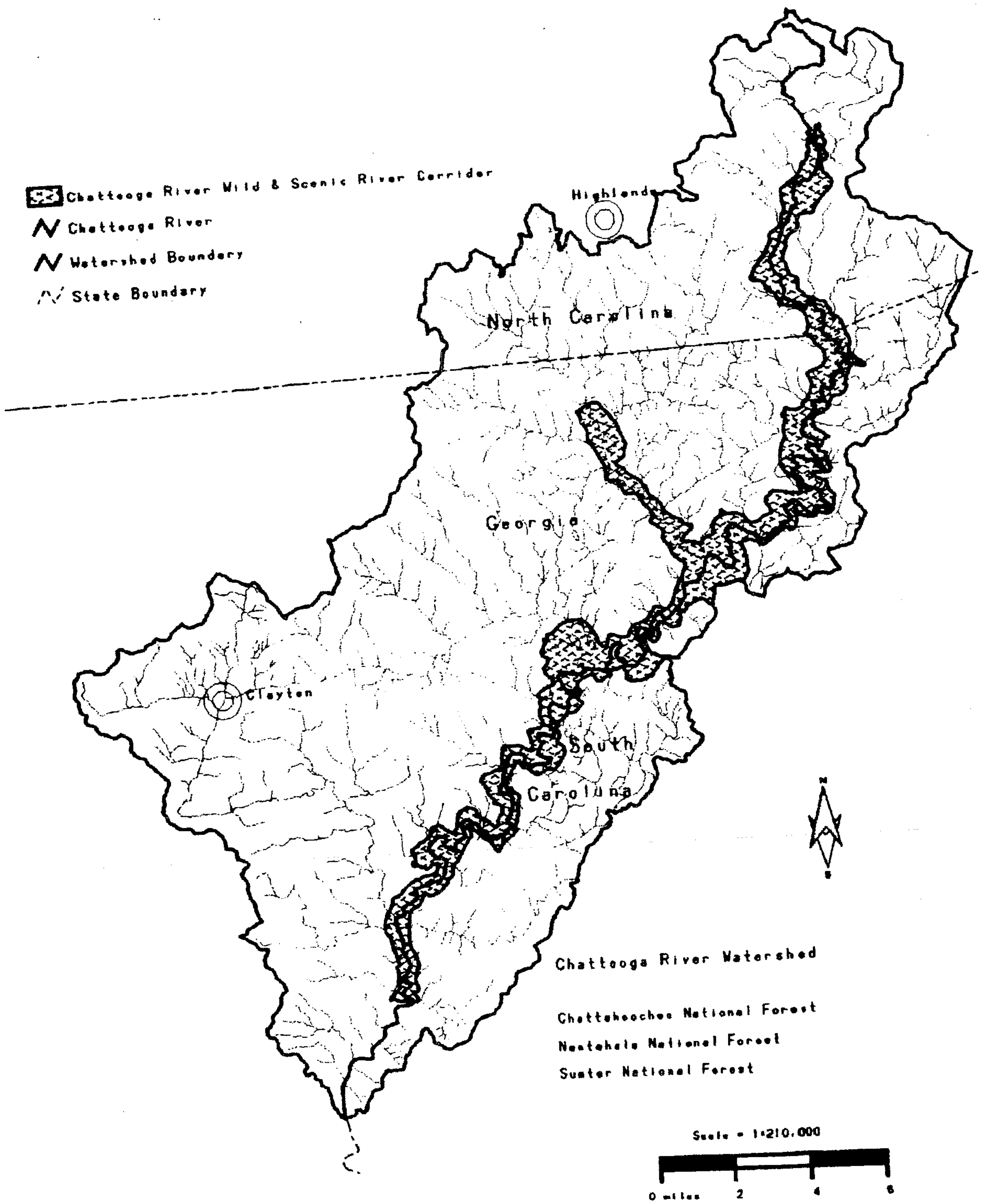


Figure 1. The Chattooga River watershed showing the Wild and Scenic River corridor and *tributaries (map compiled October 1994).*

With the exception of Stekoa Creek, which has a sewage treatment plant within its basin, few point-source discharges into the Chattooga River exist. The principle threats to water quality in the watershed lie in seemingly unrelated aspects of life, such as the way we farm, produce, consume, transport people and goods, and plan (or fail to plan) for the future. Although researchers have documented effects of these types of activities on water quality for half a century in the Southern Appalachians (Hursch 1935, Douglass 1974, Douglass and Swank 1975, Swank and Crossley 1987), until recently there has been little public recognition of the effects of land management on surface waters, groundwater, and aquatic habitat.

Sedimentation, or siltation, is the largest single contributor to pollution of the nation's rivers (EPA 1987, Lal 1994). In the late 1970's, it was estimated that sediment was entering U.S. waterways at a rate of 4 billion tons per year (Tan et al. 1978). The Second Resources Conservation Act appraisal (USDA 1989) estimated that over 54 million tons of soil was eroded from cropland in Georgia and South Carolina alone. Although cropland is currently a relatively minor land use in the Chattooga watershed, previous farming and land clearing activities contributed heavily to sedimentation in the basin (Report of the Secretary of Agriculture 1902).

Fine sediments exert detrimental effects on stream ecosystems by altering and degrading critical habitats, thereby eliminating benthic macroinvertebrates or reducing their numbers and diversity (Reiser et al. 1988, Wesche et al. 1989, Dillard 1992). Fine sediments cover and fill the interstices of gravel and cobble substrates, transforming the stream bottom to a habitat comprised of small unstable particles which can only be utilized by burrowing species. Species characteristics of stony-bottomed riffles may disappear, as will many species whose food supply is covered by sediment.

An increase in fine sediments within stream substrates generally has a negative impact on salmonids. Fine sediments prevent oxygen from reaching eggs, trap fry in the substrate, and retard the removal of toxic compounds from redds (Bjorn 1969, Lisle and Eads 1991). Accumulation of fine sediments adversely affects the diversity and number of benthic organisms, a major portion of the trout's diet. In addition, fine sediments may interfere with trout reproduction. Trout spawn most successfully in streams with substrates that remain free of fine sediments during the time when eggs and alevins are present. Studies have shown that fish survival-to-emergence decreased 2-4% for each 1% increase in fine sediments (as cited in Seehorn 1987). Deposition of fine sediments may also restrict winter cover for adult fish by filling in low-velocity habitats such as deep pools and undercut banks (Platts et al. 1989, Marcus et al. 1990).

The Water Quality Team of the Chattooga Ecosystem Management Project considers sediment the greatest threat to water quality in the Chattooga watershed. Sediment was cited as a problem in the watershed in the early years of this century (USDA 1902). Studies by the NC Department of Natural Resources and Community Development (NCDNRCD 1988), English (1990), Hopey (1993), Burrell (1994), and Hudson (1994) have documented sediment in stream substrates within the Chattooga drainage. Large amounts of fine sediments in streams and their transport have adverse effects on aquatic insects and trout (West et al.

1982, Bjornn et al. 1977, Cordone and Kelly 1961, Iwamoto et al. 1978, Everest et al. 1987, Miller 1992, Dillard 1992).

The Chattooga Watershed is coursed by many miles of unsurfaced and gravelled roads. Reports by Hansen (1987), USDA Forest Service (1989), and Mills (1993) cited these roads as major contributors of sediment to various streams in the Chattooga watershed. In small headwater streams in the mountains of north Georgia, Durniak and Ruddell (1990) noted that the portion of the stream substrate comprised of fine material was highly correlated with the density of unpaved roads.

No comprehensive study has identified and located sources of sediment in the watershed. Federal and state water resource agencies sample the river for total suspended solids (TSS) on monthly intervals at the Highway 76 bridge (SC) and on Stekoa Creek (GA), but generally during base flow when relatively little sediment transport occurs. Lacking has been a watershed analysis of sedimentation aimed at identifying problem subbasins, locating specific sources of sedimentation, quantifying the extent of fine sediment deposits in the main river, and providing specific recommendations to rectify sediment sources.

This study made no effort to document sediment reduction efforts already underway in the Chattooga Watershed. Best Management Practices have been implemented and land and road rehabilitation efforts are in place on much of the USFS lands, as well as on some private property. The purpose of this report was not to evaluate the effectiveness of these programs, but to determine where future efforts should be concentrated.

## C. Objectives

The objectives of this study were:

1. To identify present sources of sediment to the Chattooga River and determine which subbasins within the watershed have highest levels of suspended sediments,

2. To determine the extent of fine sediment domination of pool substrates in the Chattooga River,

3. To compile a map of the major sources of sediment in the watershed, and

4. Make recommendations for their amelioration.

The 180,000 ac Chattooga Watershed encompasses parts of North Carolina, South Carolina, and Georgia (Figure 1) and is located within the Blue Ridge Belt, a combination of sedimentary and metamorphic rock (NCDNRCD 1988). The watershed is underlain by crystalline bedrock composed primarily of gneisses, mica-schists, quartzes, and granites (Pehl and Brim 1985, Myers et al. 1986, Hopson et al. 1989). Loamy, erodible mountain soils have formed from these parent materials in a cool climate characterized by abundant rainfall. At higher elevations, the narrow ridges and steep slopes typically produce shallow sandy loam soils. Middle slopes and broader ridges have deeper, well drained soils of a fine sandy clay loam texture. Toe slopes and coves have the deepest soils, developed from colluvial material.

Soils in the watershed are readily erodible once the vegetative cover and forest floor have been removed. Many soils and the underlying saprolite (weathered parent material) are heavy in micaceous schist, a material that erodes easily because of its slick flat surfaces and its expandable structure (Rightmyer, personal communication[1]).

Streams in the watershed vary in gradient, both among streams and within stream reaches. Many reaches of the Chattooga River and its major tributaries have low gradients (1-2%) where sediments accumulate. This mineralogy and geomorphology cause segments of many streams in the watershed to have naturally high percentages of sand in their substrate. However, there is little doubt that man's land-disturbing activities over the past century have added large amounts of sediment to streams in the watershed (Report of the Secretary of Agriculture 1902, Hopey 1994, this report).

The Chattooga River at Highway 76 (watershed area of 207 square miles) averages 650 cubic feet/sec or 43 inches of water yield each year (U. S. Geological Survey 1991). Rainfall ranges from 70 to 90 inches/yr in the watershed.

Vegetation in the watershed varies by site conditions and past history of anthropogenic and natural disturbances. Dry ridges and upper south slopes are dominated by Virginia pine (*Pinus virginiana*), shortleaf pine (*P. echinata*), chestnut oak (*Quercus prinus*), and scarlet oak (*Q. coccinea*). Moist, cool, north slopes and coves often support white pine (*P. strobus*), eastern hemlock (*Tsuga canadensis*), yellow-poplar (*Liriodendron tulipifera*), and mixed mesophytic hardwood overstories with thick understories of rhododendron (*Rhododendron* sp.) and mountain laurel (*Kalmia latifolia*). On the intermediately moist slopes, oak-pine mixtures are the dominant forest association (Myers et al. 1986).

Aquatic resources of the Chattooga Watershed have long been recognized and used by fisherman. Three species of trout exist in the upper section of the watershed. The brook trout (*Salvelinus fontanalis*) is the only trout presumed to be native to the drainage. Both brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) have been introduced and brown trout are known to reproduce naturally in the watershed. However, the fishery is heavily subsidized by hatchery-reared fish. Below Big Bend Falls, summer water temperatures often exceed trout tolerances and their numbers decrease dramatically (Durniak 1987). Here the redeye bass (*Micropterus coosae*) and the sunfishes (*Lepomis* sp.) become more common and coexist with trout. Genetic analyses of the Chattooga redeye bass have revealed that the fish is genetically distinct from other populations in Georgia and is a very important resource worthy of protecting (Dan Rankin, personal communication[2]).

Without a put-grow-take stocking program, there would be relatively few trout in the river below Big Bend Falls. Among other species found throughout the basin are blacknose dace (*Rhinicthys atratulus*), bluehead chub (*Hybopsis leptocephala*), white suckers (*Catostomus commersoni*), northern hogsuckers (*Hypentelium nigricans*), and striped jumprock (*Moxostoma rupiscartes*) (NCDNRCD 1988, Durniak 1989).

Historical land uses of the Chattooga watershed have been timbering, farming, and livestock operations. At the turn of the century, 89% of the Tallulah-Chattooga basin was forested — the cleared land was nearly all located in the alluvial creek bottoms, with corn as the principle crop (USDA 1902). In the ensuing decades, most of the forest was cut over and farmland increased on moderately sloping lands. Uncontrolled logging operations in the early decades of this century were conducted with little regard for water quality or stream protection. Signs of skid roads in stream channels and splash dams to store and transport logs have been documented in the watershed (John Alger, personal communication[3]).

At present, corn, apples, and cabbage are major crops, accompanied by poultry and livestock husbandry. The majority of the watershed is still forested with 68% of the basin held in National Forests. In recent decades, residential development in the privately owned segments of the watershed has increased, leading to additional impacts on water quality. Public lands used for dispersed and developed recreation also have numerous signs of heavy use with resultant impacts on resource conditions.

## A. Geographic Information System (GIS) Analysis

A GIS database is currently being compiled for the Chattooga River Ecosystem Project by the U.S. Forest Service. Because this sediment study occurred early in the overall Ecosystem Project, only a limited number of GIS coverages were available for analysis. Coverages included U.S. Geological Survey blue-line streams, roads (arc or line coverage), ownership (polygon coverage), and boundaries of study watersheds (polygon coverage), which were all in a vector format. Data derived from the GIS system included subbasin boundaries, subbasin acreages, road miles, stream miles, and public/private ownership percentages. Subbasin characteristics reflect those attributes that occur above the TSS sampling stations (see C. Total Suspended Solids), and not necessarily those of the entire drainage basin of the creek. Locations of high and severe sources of sediment identified during the road survey were digitized into the GIS database.

## B. Road Survey

A road survey was conducted to assess sediment sources that could be observed from unpaved roads within the watershed. Approximately 92% of the open public unpaved roads were inventoried by locating and describing obvious sedimentation problems on data sheets. Sources of sediment that could be observed from paved roads were generally noted, but traffic hazards prevented detailed descriptions and locations. Many gated and/or signed roads not open to public access could not be inventoried.

Road mileages were recorded from known points to sources of sediment, which were noted by type, mechanism, and severity. Significant assistance in this phase of the project was provided by volunteers from the Chattooga River Chapter of Trout Unlimited.

Types of erosion were described in field notes as rill, gully, entrenched channel, bank, landslide, slump, landflow, or creep (Hewlett 1982). Sediment sources were classified into one of six categories: 1) roads, 2) timber harvest, 3) agriculture (both crop farming and livestock grazing), 4) residential development, 5) recreational trails and facilities, and 6) any other type of soil-disturbing activity. The roads category included the multipurpose system roads of the Forest Service, as well as open county and private roads. Sediment sources from the short spur roads and skid trails accessing timber harvest areas were compiled in a separate category. The timber harvest category could legitimately have been lumped into the roads category, since the great majority of sediment sources in the timber harvest category were associated with short logging roads and skid trails.

Severity of each sediment source was subjectively ranked according to Hansen (1993). Low severity included sources with a temporary impact that will naturally recover quickly and have a weak direct linkage into streams. Moderate severity indicates intermittently recurring impacts that are obvious, but the stream and aquatic biology are able to compensate, even though shifts in species and some lowering in diversity can be expected. High severity includes impacts which may vary from periodic to continuous, but occasionally overwhelm on-site and some downstream values and generally are responsible for lowering stream health and diversity. Extreme impacts are reserved for significant continuous sources of sediment into streams that dominate on-site and downstream values for some distance, often delivering more sediment than the stream or waterbody can process. Again, these rankings were subjective and were only intended to provide a scale of relative differences in impacts of different sediment sources.

## C. Total Suspended Solids (TSS)

Thirteen subbasins within the Chattooga River watershed were selected for sampling TSS (Figure 2). These subbasins comprised 58.8% of the entire Chattooga watershed and contained a wide variety of road densities, land-use histories, and ownership patterns. Watershed boundaries for the subbasins were drawn from the location of TSS and substrate sampling stations (Table 1). It should be noted that the Bull Pen subbasin is that portion of the Chattooga Watershed located above Bull Pen Bridge (NC Rd 1100), and that the Overflow Creek subbasin does not include Clear Creek.

Depth-integrated water samples were collected twice a month, usually during baseflow conditions, from each study subbasin. A vertical series of single-stage samplers (Figure 3) was used to collect stormflow samples when erosion and sediment transport are most likely to occur (Braatz 1994). The highest sampler was positioned just above the level of bank-full flow (Henson 1994). This sedimentation monitoring program is based on a similar monitoring program of TSS that has been successfully used on over 40 sites in the southern Appalachians by Duke Power Company (Braatz 1993, 1994).

Samplers were installed in early November of 1993 and sampled through early April of 1994. Bottle design followed guidelines established by the Federal Interagency Sedimentation Project (1986). For velocities up to 8 ft/sec — a velocity seldom achieved in small headwater streams of the Southern Appalachians (Henson 1994) — this design is capable of obtaining samples accurate to within 10% of the actual sediment concentration. Water samples were analyzed for TSS in laboratories at Clemson University following standard methods. The analytical detection limit was considered to be 4 mg/L TSS.

Stormflow TSS data was summarized by subbasin in three ways: 1) as an average of the event maxima, 2) as an average of all stormflow samples, and 3) as the single extreme sample. The inherent nature of the sampling strategy is such that more samples are collected nearer baseflow levels than at the higher stages, i.e., minor storms with lower sediment loading may repeatedly fill just the lowest single-stage sampler, while the most severe storms (and often highest TSS load) are represented by relatively few samples.

## D. Aerial Analysis of Fine Sediments in the Substrate

We estimated the area of fine-sediment deposits in pools using low-altitude videography. Fine sediment deposits were dominated by particles < 3.5 mm (see next section).

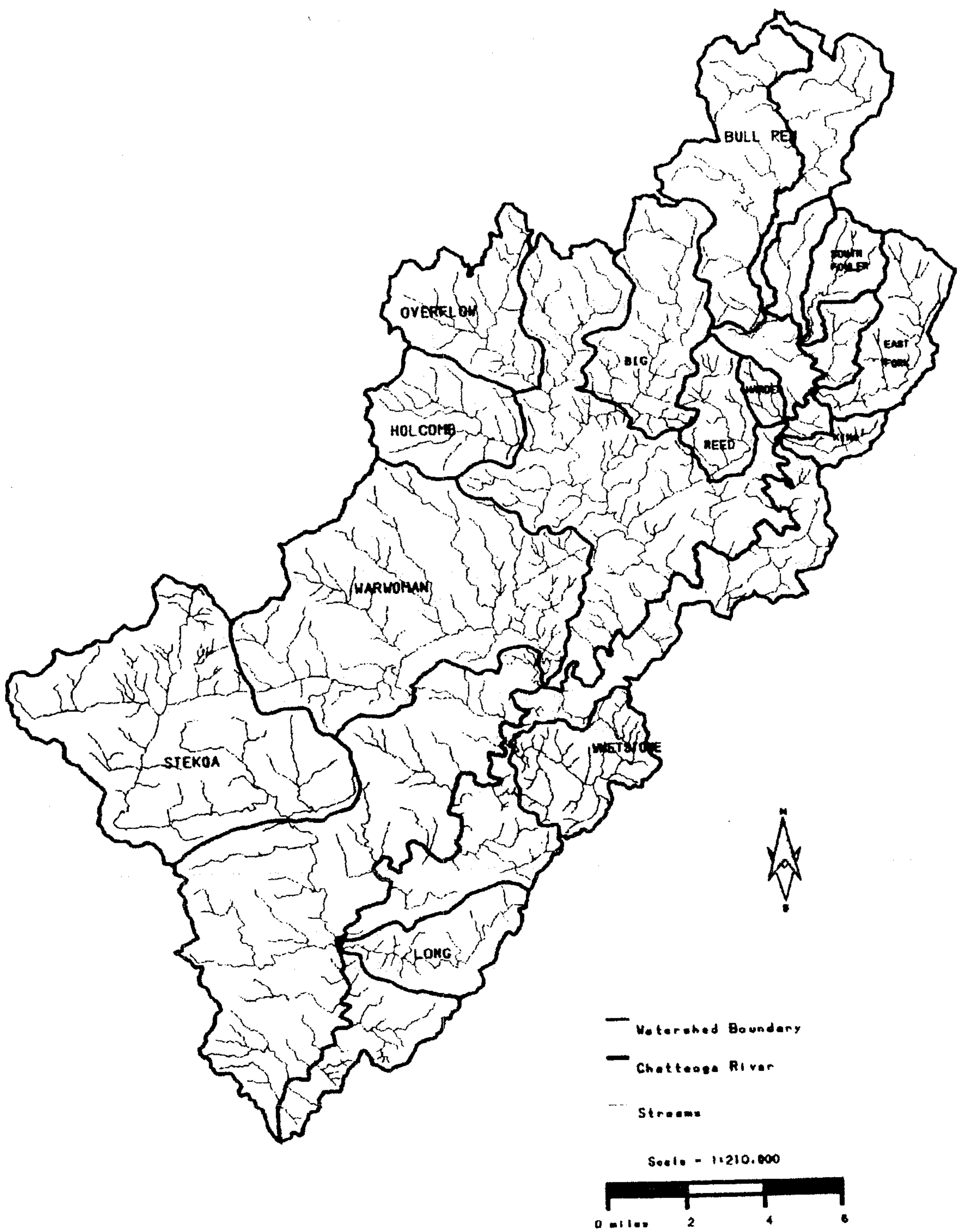


Figure 2. Study subbasins, the lower limit of which was determined by the location of the stage samplers described in Table 1 (map compiled October 1994).

Table 1. Locations of stage sampler devices for 13 study subbasins within the Chattooga River watershed.

| Stream | Latitude/ Longitude | Elevation (ft) | Approximate location of stage sampler (e.g., dsr=down stream right; dsl=down stream left; usr=up stream right; usl=up stream, left) |
|---|---|---|---|
| Bull Pen | 35 00 54/ 83 07 30 | 2380 | 20 yd dsl from intersection of Bull Pen Rd. Pen Rd. (1100/1178) and Chattooga River |
| S. Fowler Cr. | 35 00 15/ 83 06 29 | 2180 | 250 yd dsr from Bull Pen Rd. (1100/1178) bridge over S. Fowler Creek |
| Stekoa Cr. | 34 50 00/ 83 20 41 | 1420 | 150 yd dsl from last convergence of Wolf Cr. Rd. and Stekoa Creek |
| Warwoman Cr. | 34 53 06 83 13 44 | 1510 | 450 yd dsr from Warwoman Ford |
| Whetstone Cr. | 34 51 30 83 14 35 | 1450 | 400 yd usr from convergence of Whetstone Creek and Chattooga River |
| Long Cr. | 34 47 07/ 83 19 23 | 1020 | 850 yd usl from convergence of Long Creek and Chattooga River |
| Holcomb Cr. | 34 58 07 83 14 06 | 2070 | dsl from FS 86B, at convergence of Holcomb Creek and Burrell Branch |
| Overflow Cr. | 34 59 21 83 13 35 | 2130 | 40 yd dsl from last culvert over Overflow Creek on FS 86B |
| Big Cr. | 34 58 57 83 11 33 | 2210 | 200 yd dsl from Highway 28 Bridge over Big Creek |
| Reed Cr. | 34 57 12 83 09 01 | 1970 | 30 yd dsl from primitive campground off unnamed road off Burrells Ford Rd. |
| King Cr. | 34 58 09 83 07 11 | 2010 | 200 yd usl from King Creek Falls |
| East Fork | 35 59 08 83 06 07 | 2070 | 800 yd dsl from Walhalla Fish Hatchery outlet pipe |
| Harden Cr. | 34 58 31 83 07 01 | 2030 | 75 yd usr from convergence of Harden Creek and Chattooga River |

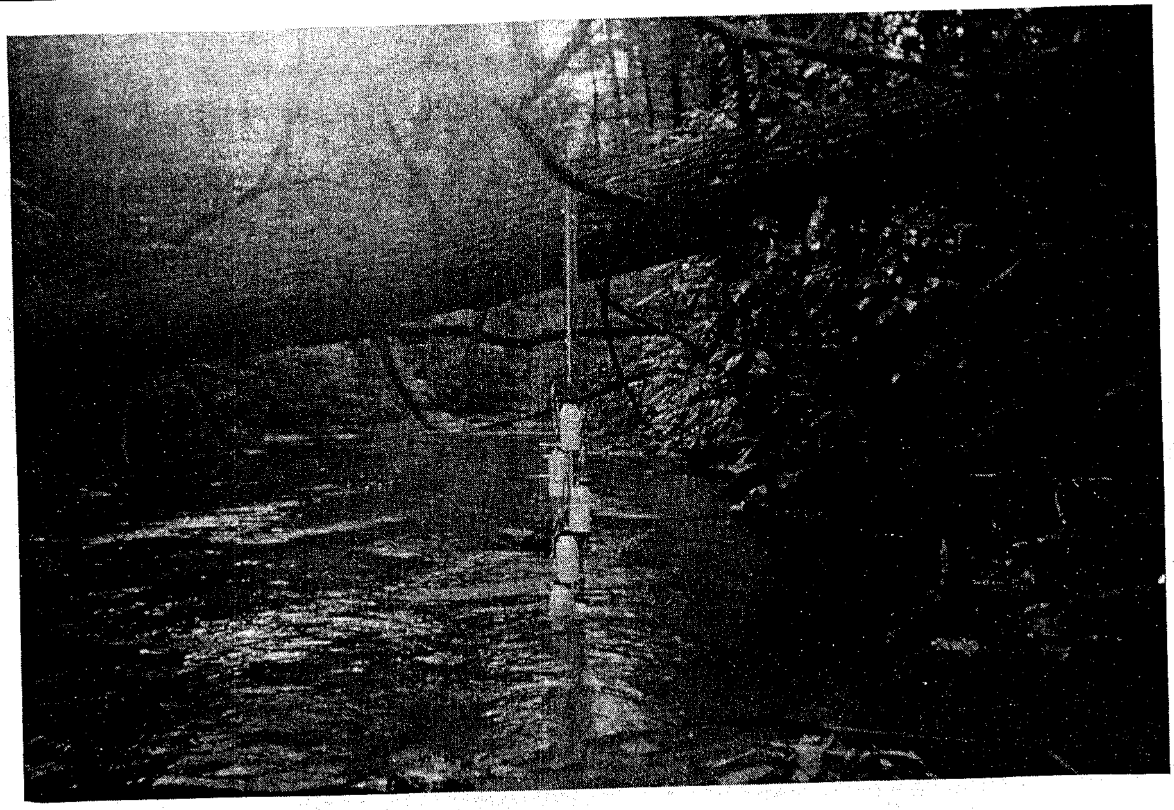

Figure 3. Single-stage samplers used to collect TSS samples.

Based on a previously conducted elevation profile (Figure 4), the river was divided into three sections for analysis of the videotape. The first section (Section A) was a steep gradient reach from Bull Pen Bridge in North Carolina to Russell Bridge, a distance of about 17 mi. The second section (Section B) was a relatively flat stretch from Russell Bridge to Dick Creek, a distance of about 10 mi. The third section (Section C), from Dick Creek to Tugaloo Lake, was a steep gradient reach of about 16 mi. Upstream of Bull Pen bridge, the narrowness of the river combined with the overhanging canopy of the riparian vegetation prevented videography.

Video footage of 46 of the Chattooga's 50 mi was shot from helicopter on March 14, 1994. Pools, i.e., portions of streams with reduced current velocity, often with water deeper than the surrounding areas (Hunter 1991), were analyzed for the percent of the stream bottom covered in fine sediment deposits. Analysis was conducted using the Beta tape, which provide better resolution than ordinary VHS tapes. About 58% of the videotape could be analyzed for habitat type (pools, riffles, and glides) and 50% could be analyzed for the extent of substrate covered in fine sediments. Due to glare from sunlight, helicopter angle, and other factors, analysis of only 4 pools was possible in Section III of the river. Insufficient financial resources prevented a reflight of the lower river section.

Videography was shot with an Ikegami HL55 Betacam using lens settings between 30 and 55 mm. Average helicopter height above the river was 150 ft for section I, 200 ft for section II and 240 ft for section III. Within each reach, the percent of pool area in fine sediment deposits was visually estimated using representative frames from the Beta tapes

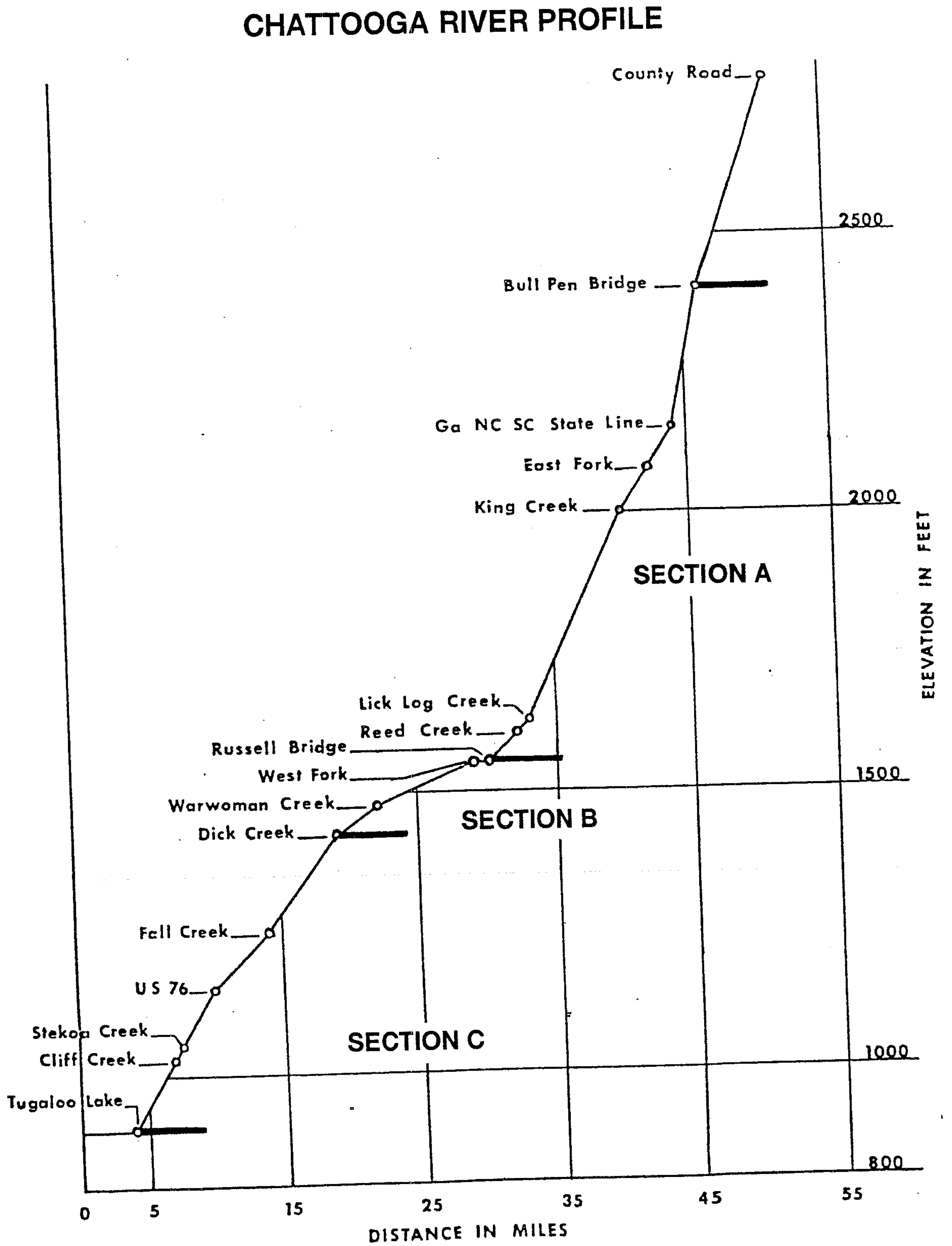


Figure 4. River gradient profile, adapted from Chattooga River Monitoring Plan, U.S. Department of Agriculture, Forest Service, Sumter National Forest, South Carolina (approved 1978).

and an on-screen grid. An average flight speed was calculated and used to convert numbers of frames (30/sec) to linear stream lengths.

Four locations were also ground-truthed to establish a relationship between estimates of the area of fine sediment deposits from the Beta tapes versus those from on-site inspections. Grab samples of the substrate material were also taken from shallow pools at these locations to determine the particle-size distribution of material classified as fine sediment in the visual estimates.

## E. Composition of Fine Bedload Sediments

The particle-size distribution of fine bedload sediments (< 3.5 mm) moving along the stream bottom was determined from samples collected in Whitlock-Vibert (W-V) boxes placed flush in the bottom substrate. Relatively little information is available concerning effects of bed-load composition on aquatic communities in the Southern Appalachians.

Whitlock-Vibert (W-V) boxes are typically used to incubate fish eggs in stream gravels. They are molded from polypropylene and measure 14 x 6.4 x 8.9 cm deep. The sides, top, and bottom of the boxes are perforated with rectangular slots to allow water circulation. Openings in the top and the largest slots in the sides are 3.5 mm x 13 mm.

Using techniques developed by Wesche et al. (1989), Hudson (1994) successfully used W-V boxes to sample fine sediment composition of the substrate of several Chattooga River tributaries. The particle-size distribution of samples collected in W-V boxes at the end of riffles by Hudson correlated well with that of freeze-core samples of the bottom substrate, considered the most accurate method of characterizing substrate particle-size distribution (Grost et al. 1991).

In the present study, W-V boxes were filled with clean gravel 12 to 25 mm in diameter prior to insertion into the stream bottom. A strip of duct tape was placed on the bottom of each box to prevent loss of trapped fine sediments through the bottom. The inner panel of each box was removed to allow the total volume to effectively act as a sediment trap. Late in January, 1994, W-V boxes were planted in each of the following streams - King Cr., Harden Cr., Reed Cr., Whetstone Cr., Long Cr., S. Fowler Cr., and Holcomb Cr.

In each stream, three boxes were placed at the tail of a riffle at equal distances across the stream. Boxes were planted flush with the top of the substrate with the long side of the rectangle perpendicular to streamflow (Hudson 1994). All W-V boxes were retrieved 35-40 days after being planted. During removal from the substrate, a lightweight metal cylinder was placed around the box to minimize washing of fine sediments by the current. The entire W-V box and transport bag was oven dried in preparation for size-fraction analysis. Once dry, the contents were emptied into a series of geometric sieves and placed in a mechanical shaker for one minute. The sorted particles in the sand and finer fraction only were then weighed by particle size class.

## A. GIS Analysis

GIS systems are important and powerful tools for integrating resource data across the landscape. A GIS system is capable of storing tabular data with the spatial data for an area, such as a subbasin in this study. We used the GIS system called ARC/INFO to provide layers of information regarding size, ownership patterns, stream length, and road mileage for each subbasin. A GIS map was prepared showing the location of major sediment sources in the Chattooga Watershed (see Road Survey, next section).

Size of subbasins varied from 906 to 24,460 acres (Table 2). King and Harden Creeks were entirely under Forest Service ownership while Stekoa Creek was predominantly (84%) privately owned. Other subbasins fell between these extremes. Stream length (blue lines, USGS topographic maps) ranged from 3.6 mi for Harden Creek to 83.5 mi for Warwoman Creek, while road length within subbasins ranged from 0 (Harden Creek) to 173.2 mi (Stekoa Creek).

Table 2. Some characteristics of study sub-basins[1] within the Chattooga Watershed based on GIS analysis.

| Subbasin | Size (ac) | Forest Service Ownership (%) | Private Ownership (%) | Stream length (mi) | Road length (mi) |
|---|---|---|---|---|---|
| Big | 8022 | 59 | 41 | 29.8 | 42.0 |
| Bull Pen | 15426 | 36 | 64 | 43.2 | 78.7 |
| East Fork | 4976 | 89 | 11 | 17.3 | 15.8 |
| Harden | 906 | 100 | 0 | 3.6 | 0.0 |
| Holcomb | 936 | 95 | 5 | 18.9 | 18.4 |
| King | 1265 | 100 | 0 | 5.1 | 3.9 |
| Long | 4770 | 33 | 67 | 13.5 | 27.6 |
| Overflow | 6753 | 87 | 13 | 21.2 | 37.4 |
| Reed | 3119 | 89 | 11 | 12.9 | 8.7 |
| S. Fowler | 2493 | 74 | 26 | 7.7 | 5.5 |
| Warwoman | 24460 | 90 | 10 | 83.5 | 78.7 |
| Stekoa | 21515 | 16 | 84 | 66.5 | 173.2 |
| Whetstone | 5406 | 45 | 55 | 27.6 | 25.9 |

[1] Study subbasins are defined from the locations of TSS stage sampling stations described in Table 1 and do not necessarily include the entire watershed of the stream.

B. Road Survey

A total of 205 mi of open, unpaved roads in the Chattooga Watershed was carefully surveyed for observable sources of sedimentation. Only open public, unpaved roads were included in the survey because many private roads were not accessible. The impact of some land uses causing sedimentation may have been underestimated because only sediment sources visible from open roads were included in the survey.

The road survey found a total of 1106 sediment sources, an average of 5.32 sediment sources/mi (Table A1). By far the greatest frequency of sediment sources (80%) in the watershed was associated with gravel and unsurfaced roads (Figure 5). The frequency of sediment sources associated with roads was highest in Georgia, followed in order by South Carolina and North Carolina (Table 3). Among the specifically noted causes of sedimentation from roads were: 1) poor location and design (Figure 6), 2) rutting, gullying, and sheet erosion of road surfaces (Figure 7), 3) road bank slumping, 4) erosion of roadside ditches (Figure 8), 5) stream and drainage crossings (Figure 9), 6) poor placement of ditch turnouts or outlets, 7) inadequate frequency or maintenance of surface drainage features, and 8) improperly located or functioning culverts. Sediment problems for each road were associated with road segments in the GIS database for the Chattooga project.

There are a variety of road types (Table 4) within the Chattooga River basin that could not be individually assessed in this report. Questions of ownership, maintenance, use, and jurisdiction associated with each road are complex and difficult to define. Jurisdiction over individual roads may include the US Forest Service, Federal Highway Department, State Departments of Transportation, Counties, Municipalities, other state or federal agencies, and private landowners.

Many of the unpaved, open roads surveyed were within the National Forest. Some of the roads within the Chattooga basin have a long history of use, well before the acquisition of the National Forests which began in 1913. These historic roads often have no legal documents to indicate ownership, but because they access private lands there are certain "prescriptive rights" often associated with these roads which require them to remain open. Counties often have the responsibility to maintain these roads. However, some landowners, including the US Forest Service, have taken over this responsibility or work cooperatively with the counties to maintain individual road sections that access their land resources. Some of these roads have been reconstructed or relocated to improve their driveability and safety, with various levels of conservation and maintenance improvements to protect water quality. Others have flaws in their location, design, and maintenance or use that make them chronic sources of sediment within the watershed.

This road survey was not designed to point fingers at responsible individuals or agencies, but to indicate road management needs to improve water quality. Financial and technical resources are often available to make improvements. Many of these improvements are more cost effective in the long run than allowing continued road erosion and damage to the point that major reconstruction is needed.

Table 3. Frequency of sediment sources (number/mi) by category in the Chattooga River watershed and their general cause, as identified by driving public, unpaved roads.

| State | Sediment Source Category[1] | Number of Sources/mi | Range of Severity | General Cause of Erosion |
|---|---|---|---|---|
| GA | 1 | 5.10 | low-med | lack of water control and gravel |
| | 2 | 0.20 | med-high | loss of cover |
| | 3 | 0.60 | med | lack of water control on roads & trails |
| | 4 | 0.21 | low-high | trampled stream banks |
| | 5 | 0.11 | low | loss of cover |
| | 6 | 0.001 | low | loss of cover |
| NC | 1 | 2.01 | low | lack of water control |
| | 2 | 0.01 | high | loss of cover |
| | 3 | 0.10 | low | lack of water control on roads & trails |
| | 4 | 0.20 | low-med | trampled stream banks |
| | 5 | 0.08 | low | loss of cover |
| | 6 | 0.01 | high | loss of cover |
| SC | 1 | 3.90 | low-med | lack of water control/overmaintenance |
| | 2 | ---- | --- | ------ |
| | 3 | 0.60 | med-high | lack of water control on roads & trails |
| | 4 | 0.30 | med-high | trampled stream banks |
| | 5 | 0.29 | low | loss of cover |
| | 6 | 0.001 | low | loss of cover |

[1] Sediment source categories: 1=gravel and unsurfaced roads, 2=development, 3=timber harvest, 4=agriculture, 5=recreation, 6=other.

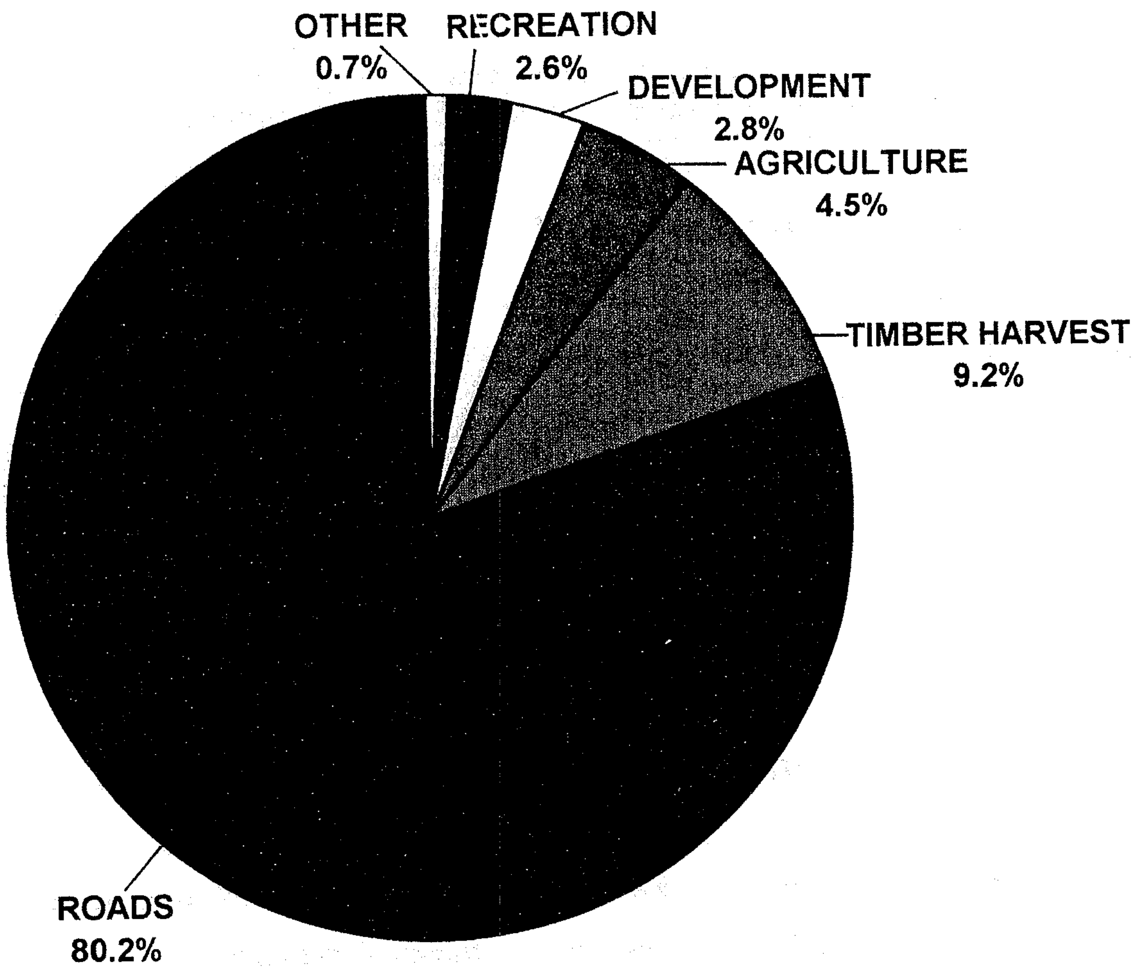


Figure 5. The distribution of observable sediment sources as identified from a survey of public, unpaved roads in the Chattooga Watershed.

Multipurpose roads with the greatest frequency of sediment sources were generally those with heavy vehicular traffic. Heavy vehicle use, especially during wet weather, causes rutting of road surfaces which increases the need for maintenance. Over-maintenance, as well as under-maintenance, is a major cause of sedimentation of streams in the Chattooga River watershed, especially where vegetative buffer strips are inadequate to filter loosened sediments. Heavily used roads may be graded as many as 7-8 times/yr (Abercrombie, personal communication[4]). During grading, loose materials are pushed off the edge of the road, often into drainage channels, and inside road ditches are "pulled", exposing a fresh erodible soil surface or causing slumping of the upslope bank. In addition, "crusher run", a mixture of gravel and sand, is applied to graded surfaces and may be readily washed into drainage ditches. These sediments are eventually flushed by runoff to the nearest stream.

There were relatively few sources of sediment within the Wild and Scenic Corridor of the main stem of the Chattooga River. However, Overflow Creek Road (FS 86) heavily impacts the corridor of the West Fork as it steeply ascends to Three Forks, the confluence of Big, Overflow, and Holcomb Creeks. The West Fork has a heavy bedload of fine sediments, especially in its lower portions.

Figure 6. Location of unpaved road adjacent to Warwoman Creek—break in road berm allows sediment to enter directly into creek.

Figure 7. Ruts in unpaved road drain directly into Warwoman Creek.

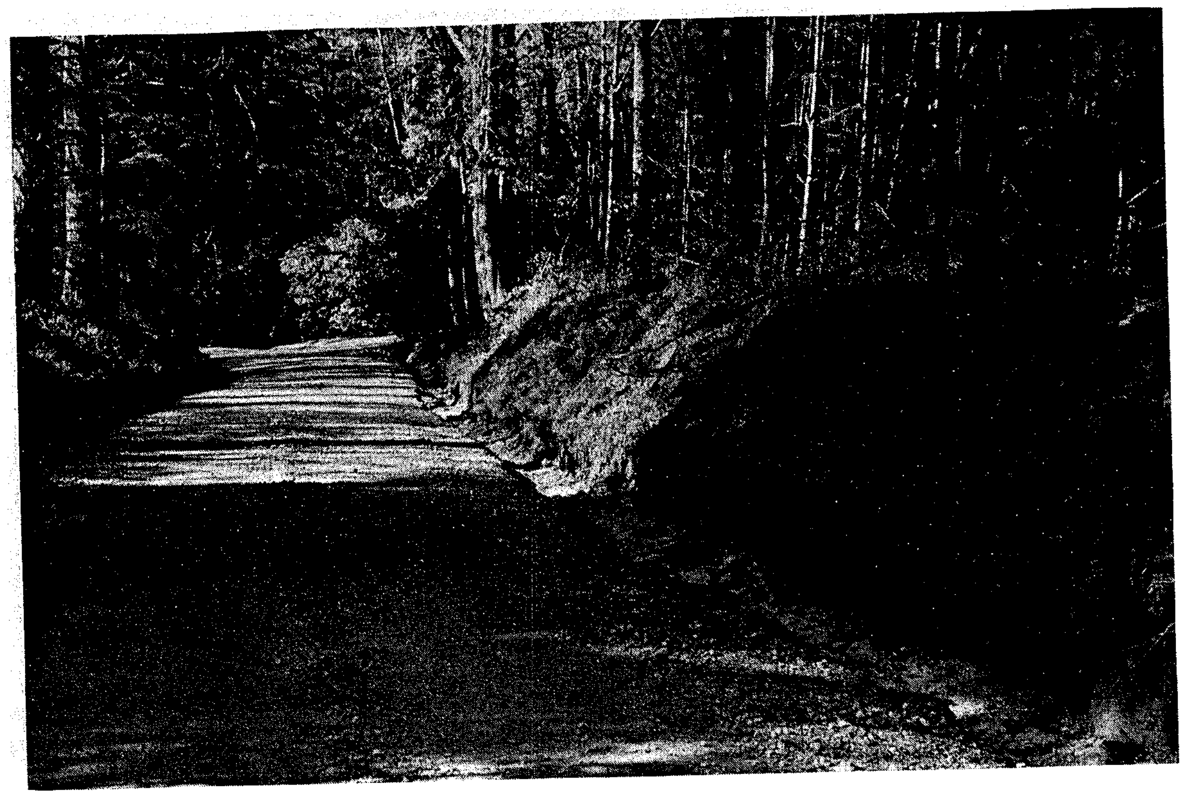

Figure 8. Roadside ditches are sources of sediment when cut banks slump and when road surface materials are washed into ditches.

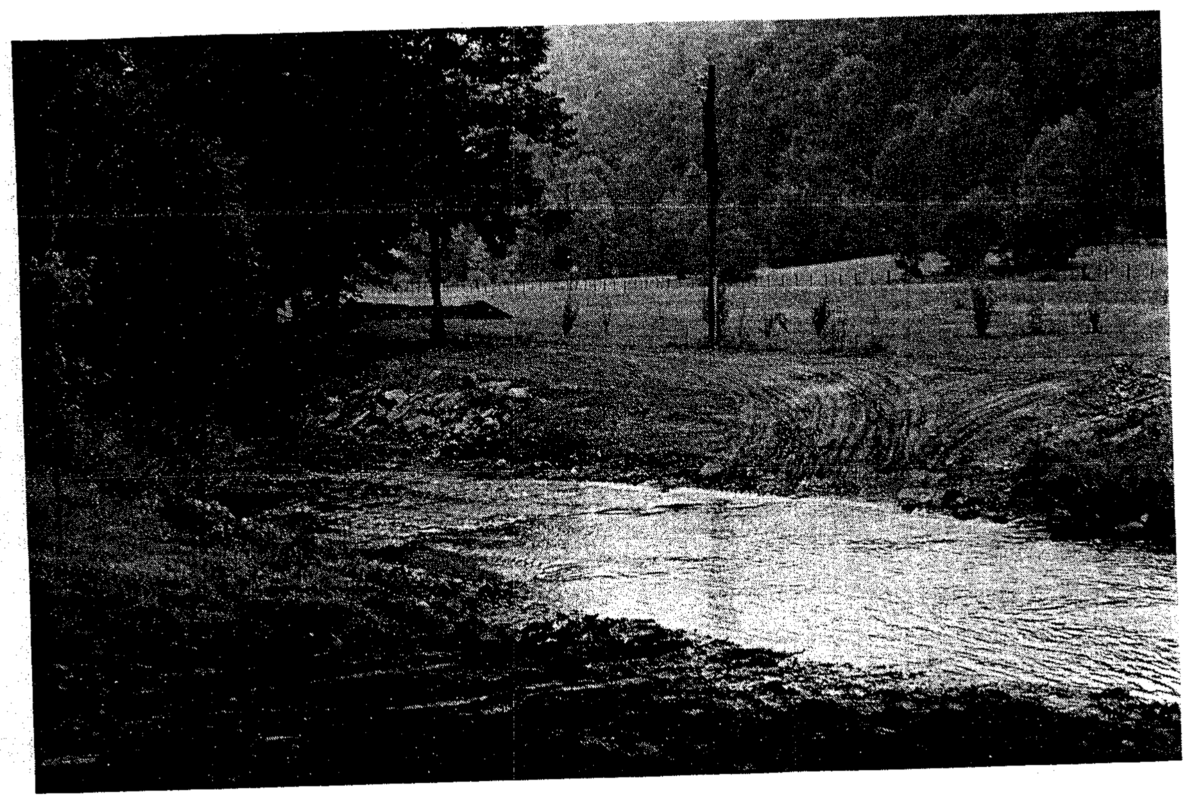

Figure 9. Poorly planned stream crossings are major sources of sediment.

Table 4. Road types within the Chattooga River watershed.

| Road Type | Description |
|---|---|
| USFS | Constructed and maintained by USFS. Sections crossing private ownership are made through easements and maintained by USFS and/or landowners as agreed. |
| Private | Owned and maintained by landowner. Access to private tracts crossing national forest lands can be developed if stipulations on maintenance responsibilities, standards of construction, and other special use provisions are met. |
| Federal/State | Federal or state rights of way crossing National Forest by Highways special use permit/easement. |
| County/Local | All other roads including historic roads and trails built prior to National Forest acquisition. Sometimes termed prescriptive right roads. Maintenance and operation is responsibility of county or locality unless otherwise agreed. |

About 9% of the sediment sources observed during the road survey were attributed to timber harvesting operations (Figure 5). The great majority of these sources were associated with short (generally less than 1 mi) logging access roads which connected to the multipurpose roads, rather than to the cutting of timber. Research has shown that it is rarely the cutting of timber that causes erosion; rather, it is generally the transportation system required to remove the harvested trees (Kochenderfer and Aubertin 1975, Hewlett 1979, Ursic and Douglass 1979, Van Lear and Douglass 1982). Many of the sediment sources associated with timber harvest were old roads and trails which were not adequately stabilized or closed following prior timber harvest. Some of these roads are now used for other purposes. In more recent years, temporary roads and trails to and within timber sales are subject to best management practices and are normally stabilized and closed following harvesting, especially on public land.

If timber is the primary use, roads should be surfaced more frequently with aggregate dominated by large rock (particles 3-4 inches in size). These roads will normally be closed or maintained for high clearance vehicles (levels 1 and 2). On roads necessitating higher speeds and passenger car traffic (levels 3 and above), timber should not be listed as the primary use. These roads should be listed as multiple-purpose roads and surfaced with a coarse gravel foundation for stability prior to adding finer surfacing materials. Aggregates with too high a proportion of fines should be avoided. Open roads were obviously a major source of sediment in the Chattooga River watershed. Many of these roads evolved from old wagon trails near the turn of the century and naturally occur on the flatter terrain, which often is along stream courses. From a water quality standpoint, roads adjacent to streams are in the worst possible location. Use of the National Forests for multiple purposes has increased dramatically in recent decades, aggravating sedimentation problems from roads, many of which were already poorly located and constructed. To accommodate increased use, some roads have been widened beyond the design standard for which they were originally developed, with no plan of action to control sedimentation. For example, certain roads used previously for timber access (1 lane) are now being used for river access (2 lane).

Paved roads, such as Rt 107 in South Carolina and Rt 76 in Georgia, also contribute sediment to streams in the Chattooga River watershed. The primary impact of paved highways on sedimentation occurs during their construction or reconstruction phases (Figure 10) and during the cleaning and restructuring of roadside ditches. However, the presence of deeply incised ditches along many paved roads is evidence that they have been chronic sediment producers for decades. Federal and state highway agencies should reexamine their road ditch maintenance policies and consider the benefits of stable vegetation as an effective cover to prevent erosion and minimize maintenance costs.

During the road survey, it became obvious that Forest Service gated roads whose surfaces were gravelled and vegetated were no longer a significant source of sediment to adjacent streams (Figure 11). These roads are open to foot traffic but closed to vehicles, except in the cases of extreme need. It is well documented that these restored and gated roads become heavily used linear wildlife strips (Davis 1992, Martin 1993), which are aesthetically attractive. At the same time, they can be periodically mowed to keep them accessible for forest management emergencies or other needs. They seldom need grading so maintenance costs (mowing and occasional liming and fertilization) are relatively low. The US Forest Service has numerous examples of how to manage intermittent or low use roads to maintain investment but protect water quality.

Agriculture accounted for 4.5% of the identified sediment sources from the road survey. Many of the agricultural sources of sediment may not have been observed so few conclusions can be drawn regarding their relative frequency and severity. However, most observed agricultural impacts were associated with grazing in the riparian zones of small streams (Figure 12). Much of the sediment in small streams flowing through pastures comes from stream bank erosion (Davis et al. 1992). Stream bank fencing is a simple and effective way for farmers to improve water quality, maintain soil productivity, and protect their livestock from waterborne bacteria.

Oconee County in South Carolina recently received a substantial grant through the Water Quality Incentive Program to reduce sedimentation (Bauknight, personal communication[5]). Approximately 800 ac of apple orchards are in this program. Nearly 75% of all orchard acreage contains grass filter strips to help control erosion. Special emphasis is currently being given to controlling erosion on haul-out roads while future plans call for investments in riparian zone protection along streams flowing through pastures.

Figure 10. A slumping road cut during reconstruction of Highway 76 near Clayton, GA, impacting Chechero Creek, a tributary of Stekoa Creek.


Figure 11. Restored roads that are gated to restrict vehicles provide wildlife habitat and contribute minimum sediment to streams.

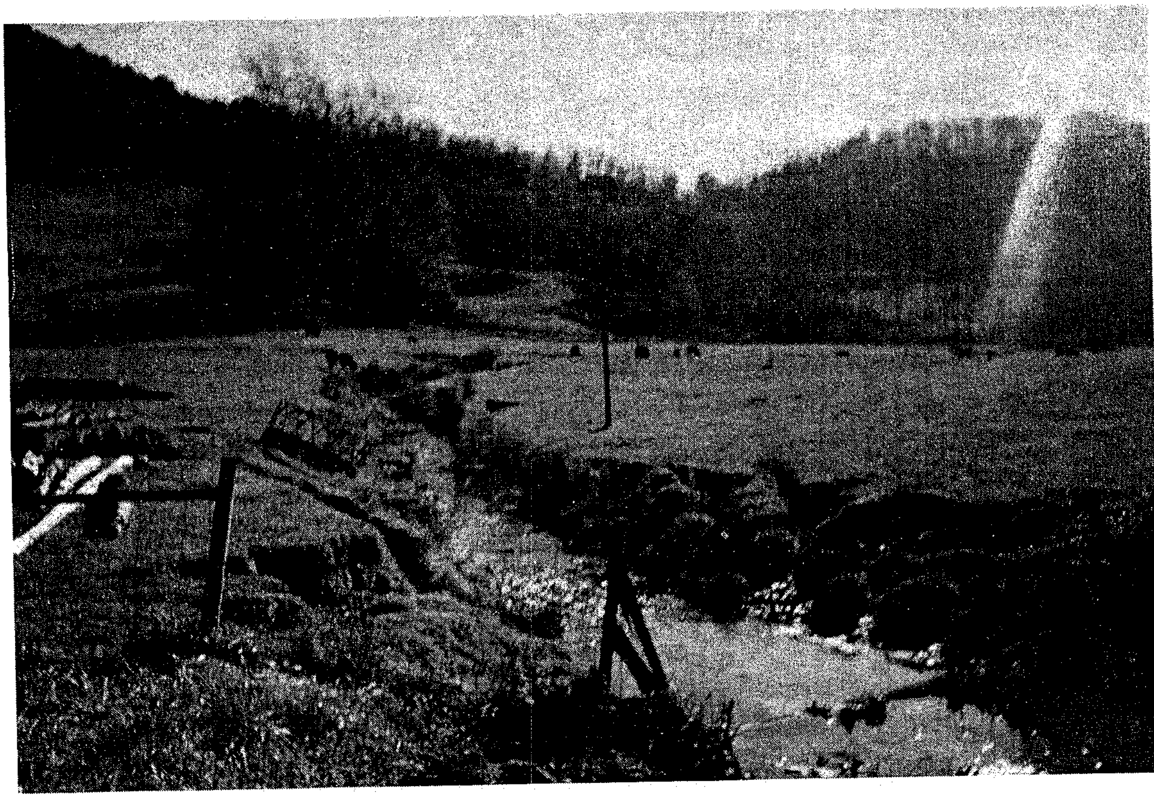

Figure 12. Streambanks trampled by livestock are primary sources of sedimentation from agriculture.

Various stewardship, conservation and pollution abatement funding is available for private landowners to install practices which protect streams and improve water quality (Table A2). Soil and Water Conservation Districts, State Environmental, Water, Forestry, and Agricultural Agencies are good contacts to discuss cost-share opportunities. Work on National Forest roads is conducted through appropriated soil and water improvement funds and excess timber sale receipts (when available). Funding for state and county roads typically comes through federal, state, and local taxes, but may include other federal and state pollution abatement funding opportunities.

About 3% of the noted sediment sources were related to residential development (Figure 5). These sources were generally new house sites and the driveways leading to these sites. The rate of development is increasing throughout the mountains (Healy 1985), so this category of sedimentation could escalate in the future. Strict enforcement of Section 404 of the Federal Clean Water Act and state and local sediment control laws would reduce development-related sedimentation in the Chattooga River watershed. Recreational impacts accounted for only a small percentage (2.6%) of the observed sources of sediment. This figure is misleading, however. Recreationists of all pursuits, including rafters, anglers, hunters, hikers, campers, and scenic drivers, account for most of the traffic on the road network (Bailey and Smathers, personal communication[6]). Roads would require less maintenance and contribute far less sediment if they were not heavily used. Thus, much of the impacts on water quality attributed to roads might reasonably be attributed to recreational use of the watershed.

Sediment sources falling in the "other" category range from landfills to beaver impacts. These sources are probably underestimated because they often are not visible from roads. Beaver activity in smaller tributaries is especially difficult to document from a road survey. However, Barnes (1993) found that about 60% of the tributaries of the adjacent Chauga River drainage were impacted to varying degrees by beaver. Many tributaries of the Chattooga River also have beaver activity. Beaver accelerate sedimentation by cutting stream bank vegetation and burrowing under banks, both of which cause stream bank slumping. When their dams break, huge quantities of stored sediment are released, which may overwhelm the sediment transport capacities of small streams. Bauknight (personal communication[7]) believes that breached beaver ponds on Whetstone Creek may produce more sediment than cattle damage to riparian zones in that creek.

Another potential sediment source noted by Clemson researchers (Kapeluck, personal communication[8]) is rooting damage by wild hogs. Wild hog rooting was observed in riparian zones of Indian Camp Creek, a tributary of the East Fork. Although Singer et al. (1984) noted no increase in sedimentation from hog rooting in seeps in the North Carolina mountains, rooting within bank-full widths of ephemeral drains may accelerate erosion during heavy storm events and warrants further investigation.

Although not a complete listing of all sediment sources in the Chattooga River watershed, this road survey samples many of the types of land uses responsible for sedimentation in the watershed and suggests their relative frequency. The multipurpose road network is the major category of land use that causes sedimentation. However, heavy recreational use of these unpaved roads causes wear on road surfaces and results in the need for frequent maintenance, both of which greatly aggravate sediment problems associated with roads.

Those gravel roads that are most responsible for sedimentation problems and most in need of attention are identified and general remedial actions are suggested for each road (Table 5). The methods recommended are generally the most cost-effective. In some cases more costly options are available if managers want to maintain poorly located roads. Cost-effective measures to control and dispose of runoff on existing roads to reduce sedimentation have been described by Swift (1984, 1987), Tew et al. (1985), and Burns (1994). Data sheets describing the type and location of the more than 1000 sediment sources identified in the road survey are on file in the Department of Forest Resources, Clemson University, and in the Ranger District offices of the US Forest Service.

Since unpaved roads (and their use) are by far the major contributors of sediment to the Chattooga River and its tributaries, it is obvious that closing and restoring those unpaved roads that are not heavily used or necessarily kept open would reduce impacts on water quality. These closed roads could be valuable resource attributes if they were gated, gravelled, and vegetated, becoming linear wildlife strips for both game and non-game species. With appropriate education, these restricted roads would be used by hunters, fishermen, hikers, and others for foot traffic and perhaps seasonal (dry weather) access with minimal impact on the streams of the area. A significant reduction in the density of open gravelled and unsurfaced roads would have a greater influence on water quality in the Chattooga River watershed than any other single recommendation.

Table 5. Sedimentation problems identified from a 1993-94 road survey of the Chattooga River watershed, by road and state, and recommendations for reclaiming them.

| Road and State | Problem description and Recommendation |
|---|---|
| FS 86 (Overflow Cr. Rd.), GA | Problem: deep rutting during winter, erosive ditches, water diversion into ephemeral streams, sheet erosion in steep stretches, lack of effective water control features<br>Recommendation: use larger gravel to prevent rutting, pave or redesign steep gradients, install water control features, close and vegetate old logging roads, use large gravel to line ditches |
| FS 646/708 (Burrell's Ford Rd.), GA/SC | Problem: road receives heavy spring and summer traffic, several sections of deep ruts and gullying, sediment clogged culverts, erosive ditches, several spur roads leading directly to streams<br>Recommendation: use larger gravel to slow traffic speed and reduce rutting, gravel and vegetate erosive ditches, install more water diversion structures in road, close all unnecessary spur roads, consider paving erosive portions of road |
| Big Cr. Rd. (124), GA | Problem: numerous unfenced riparian zones utilized by livestock, livestock, water diversion into stream, overmaintenance of road shoulders<br>Recommendation: fence livestock away from streams, direct water away from streams, vegetate road shoulders, gravel road surfaces and ditches |
| FS 86B, GA | Problem: lack of water control features, numerous stretches of rutting and sheetwash<br>Recommendation: use larger gravel size to control rutting of road surface and gullying of ditches, install water control features, vegetate shoulders and cut slopes |
| Sandy Ford Rd., GA | Problem: road ends as a sediment flume to the Chattooga River, River, steep erosive banks along roadbed, open logging roads<br>Recommendation: close road 1/2 mi from river, vegetate erosive banks, close and vegetate old logging roads, use larger gravel to armour road surface |
| Poole Cr. Rd., GA | Problem: unfenced riparian zones heavily used by horses and cows, land clearing for development, open logging roads, lack of water diversion features, erosive gullies and ditches<br>Recommendation: fence animals away from streams, employ silt fence and sediment traps around development, close and vegetate old logging roads, install more water diversion features in road |

Table 5. (Continued)

| Road and State | Problem description and Recommendation |
|---|---|
| Camp Cr. Rd., GA | Problem: overmaintenance of cut banks and road shoulders, sheetwash, water turnout into stream<br>Recommendation: vegetate cut banks and shoulders, direct water away from streams, use larger gravel on road surfaces and ditches |
| Earle's Ford Rd., GA | Problem: close proximity of road to Warwoman Creek, erosive power line ATV trail, erosive ditches and cut banks, open logging roads, water diversion into streams, road fords stream<br>Recommendation: close road as far away from the Warwoman ford as possible, close and vegetate old logging roads, close power line trail, pave road in section where road is directly parallel to stream, use large gravel on road surface and ditches |
| FS 152, GA | Problem: overmaintenance of road shoulders, gullying, sheet erosion, water turnout into ephemeral drainages<br>Recommendation: vegetate road shoulders, install more water control features, redirect turnouts away from drainages, use large gravel |
| Boggs Mtn. Church Rd., GA | Problem: exposed soil around Rabun City landfill, sheet erosion, gullying, open logging road<br>Recommendation: install silt fence and sediment traps around landfill, install water control features and use larger gravel to prevent rutting, close and vegetate old logging roads |
| FS 156A, GA | Problem: sheet erosion, rutting, and open logging roads<br>Recommendation: use larger gravel, install more water control features, close and vegetate old logging roads |
| FS 511B, GA | Problem: numerous sections of rutting and sheet erosion, open logging roads<br>Recommendation: pave or use larger gravel to reduce rutting, close and vegetate old logging roads |
| FS 511, GA | Problem: numerous sections of rutting and sheet erosion, over-maintenance of road shoulders, numerous open logging roads<br>Recommendation: pave or use larger gravel to reduce rutting, close and vegetate old logging roads |

Table 5. (Continued)

| Road and State | Problem description and Recommendation |
|---|---|
| Claude Smith Rd., GA | Problem: road shoulder graded into stream, water diversion into stream, unfenced riparian zone utilized by livestock<br>Recommendation: install sediment traps or move road away from stream, fence livestock away from stream |
| Wilson Gap Rd., NC | Problem: road is frequented by numerous heavy vehicles using landfill, overmaintenance, water turnouts into streams, sediment coming from exposed soil in landfill<br>Recommendation: pave, redirect water from road away from streams, employ silt fence and sediment traps around landfill |
| FS 721 (193, Whetstone Rd.), SC | Problem: unfenced riparian zones used by cattle, unvegetated logging road, overmaintenance due to heavy recreational use in summer, water diversion into streams<br>Recommendation: fence cattle away from stream, close and vegetate old logging roads, consider paving to eliminate continual maintenance problems or use large gravel |
| FS 722 (Fall Cr. Rd.), SC | Problem: road is being used as a skid trail to a private inholding, causing extensive, chronic sedimentation into the subbasin and severely impacting wild brown trout population in Swafford Branch.<br>Recommendation: close and vegetate road, or reroute road |
| FS 709 (Big Bend Rd.), SC | Problem: deep rutting, erosive ditches, water diversion to ephemeral streams, lack of effective water control features<br>Recommendation: reconstruction to minimum standards, use large gravel on road surfaces and ditches, vegetate road banks. Area adjacent to Crane Creek needs special attention and should be given highest priority |

The use of large gravel aggregate (dominated by particles 3-4 inches in diameter and 3-6 inches deep), adequate surface drainage and vegetative cover for bare surfaces can greatly improve troublesome low-intensity use roads. These measures will minimize the need for continued maintenance. Needless pulling of ditches with the associated delivery of fresh sediments to streams can often be avoided through design adjustments involving cover, armoring ditches and proper drainage outlet frequency. Swift (1984) and others have reported on the successful use of these methods.

Roads left open due to high use associated with recreation passenger traffic should be built and maintained to handle increased traffic and wear associated with this use. These roads need a quality base of coarse aggregate prior to paving or adding finer aggregate surfacing to smooth the surface. Sections with moderate to high gradients using the finer aggregates will have rapid deterioration and high maintenance needs if the road surface is not frequently and adequately drained. These sections also contribute disproportionately to water quality problems because of the repeated need to grade and resurface them.

Careful attention to providing an aggregate mix of particle sizes that can be compacted into a quality surface is critical to achieve some balance between driveability and erosion protection. Mixtures that are too fine or coarse can create a variety of problems, from rapid erosion associated with fines to the lower traction likely with uniform-sized gravel acting as "ball bearing marbles." Road managers must be able to get the materials that they need to properly maintain the road. It should not be the option of the gravel pit as to what materials will be supplied.

## C. TSS

Stekoa and Big Creeks had by far the highest levels of stormflow TSS of any of the 13 study streams, with both storm event maximums and storm event means averaging over 2000 mg/L and single extreme samples of 21,018 and 16,462 mg/L (Table 6). These two creeks are heavily impacted by gravel and paved roads, pastures with unfenced riparian zones, residential development, and other sources of sediment — even municipal landfills.

Whetstone had the third highest level of stormflow TSS. Failure to provide riparian zone protection in pastures is a major cause of sediment here, although a road to a private logging operation along Old Fall Creek Road is also a primary contributor during stormflow events. Beaver activity has also contributed significantly to sedimentation in Whetstone Creek.

There was no TSS sampling station on the West Fork of the Chattooga, although its three major tributaries (Big, Overflow, and Holcomb) were sampled. The senior author has observed heavy suspended sediment levels in Tottery Pole Creek, a tributary of the West Fork that is heavily impacted by Overflow Creek Road (FS 86). During high intensity storms, Overflow Creek Road dumps heavy sediment loads at numerous locations into the West Fork.

Warwoman, King, Reed, East Fork, and Long Creeks had average TSS storm event maximums that ranged between 167 and 110 mg/L. Earle's Ford Road, a road of mixed jurisdiction, is in close proximity to Warwoman Creek for nearly its entire length and contributes heavily to its sedimentation during storm events. King Creek is paralleled for most of its length by the Burrell's Ford Road, one of the most heavily travelled gravel roads in the watershed and therefore one of the most frequently maintained roads. The Reed Creek subbasin is also impacted by this road. A road problem inventory (Hansen 1987) and some improvements in the Reed Creek drainage were recently made by the Tallulah Ranger District (USDA Forest Service 1989, Hansen et al. 1991).

Table 6. The relative ranking of subbasins within the Chattooga River Watershed based on average storm event maxima for Total Suspended Sediment (TSS) readings.

| Subbasin | Ranking | Avg. of Storm Event Max. TSS (mg/L) | Storm Flow mean TSS (mg/L) | Max. TSS (mg/L) | Base Flow mean TSS (mg/L) |
|---|---|---|---|---|---|
| Stekoa | 1 | 3057 (8)[1] | 2501 (18) | 21018 | 13 (10) |
| Big | 2 | 2197 (9) | 2255 (19) | 16462 | 10 (10) |
| Whetstone | 3 | 619 (6) | 734 (8) | 1523 | 16 (10) |
| Warwoman | 4 | 167 (9) | 128 (20) | 359 | 10 (10) |
| King | 5 | 151 (5) | 151 (5) | 489 | 23 (9) |
| Reed | 6 | 150 (7) | 118 (12) | 476 | 10 (9) |
| East Fork | 7 | 144 (7) | 94 (15) | 503 | 16 (9) |
| Long | 8 | 112 (9) | 99 (15) | 274 | 11 (10) |
| Bull Pen | 9 | 93 (6) | 71 (23) | 142 | 11 (7) |
| Harden | 10 | 84 (5) | 93 (7) | 300 | 10 (9) |
| Holcomb | 11 | 66 (9) | 39 (30) | 182 | 13 (9) |
| S. Fowler | 12 | 65 (6) | 57 (10) | 132 | 9 (8) |
| Overflow | 13 | 64 (9) | 51 (21) | 138 | 7 (10) |

[1] Mean with number of samples in parenthesis.

The frequency which roads crossed drainages has been positively correlated with the amount of fine substrate and embeddedness in Wyoming trout streams (Eaglin and Hubert 1993). Similar findings have been noted by Durniak and Ruddell (1990) in north Georgia and Swift (1984) in western North Carolina. The East Fork receives stormflow sediment from development and road-ditch maintenance along Highway 107 and from recreational impacts in the vicinity of the Walhalla National Fish Hatchery. Long Creek is affected by roads, farming activity, development, and beaver influences. A major tributary, Indian Camp Creek, is impacted by the rooting of wild hogs.

Streams with the lowest stormflow TSS levels included Bullpen, Harden, Holcomb, S. Fowler, and Overflow Creeks (above the confluence with Clear Creek). Most of the lengths of these streams above the sampling location were in forest cover, a land-use associated with little or no overland flow during storm events and, therefore, relatively little sedimentation potential (Douglass and Swank 1985, Swank et al. 1987). In addition, all of these streams were at relatively high elevations, above 2000 ft (Table 1). Parent materials in these higher drainages may have been subject to less weathering and were therefore less likely to produce fine suspended sediments. All of these streams have heavy loads of bedload sediments which may have been in the stream channels for decades or longer; however, suspended stormflow sediments are relatively low.

Baseflow TSS conditions were similar across all study subbasins, with averages ranging from 6 to 23 mg/L. Levels of TSS are usually under 20 mg/L during baseflow conditions for South Carolina Foothills streams, even those which are chronically turbid during storm events (Braatz 1993). The low levels of baseflow TSS from all thirteen subbasins emphasize the importance of sampling representative storm events to obtain a realistic comparison of suspended sediment transport by different streams.

Results of this analysis of stormflow TSS levels show that subbasins of the Chattooga Watershed vary widely in their concentrations of suspended sediment. Those tributaries with lower levels of suspended sediment are under the predominant influence of forest cover and are not generally adjacent to unpaved roads or unfenced pastures. Tributaries with higher concentrations are associated with types of land use where mineral soil or erodible sediments are exposed, such as heavily used unpaved roads, cultivated fields, erosive stream banks, prepared sites for development or reforestation, or landfills. Locations of major sediment sources, i.e., those ranked as extreme or high in the road survey, are shown in Figure 13 and described in Appendix A3.

The single-stage samplers used in this study were effective and inexpensive, yet simple to install and use. They could be used in streamwatch programs by volunteer organizations to monitor water quality, although users should be aware of the limitations of the technique. The samplers used here provide only representative sediment concentrations from various stages of the storm hydrograph. Discharge must also be considered before sediment contributions from each site can be calculated. In future monitoring programs, it would be useful to develop stage:discharge relationships so that instantaneous sediment transport rates could be calculated and sediment transport could be partitioned throughout the watershed (Braatz 1993).

## D. Videotape Analysis of Fine Sediments

The river was extremely clear and at normal flow for the time of year when the low altitude helicopter videography was conducted (March 14, 1994). Fine sediments could clearly be detected in the two upper sections of the river on the videotape and, using the grid overlay on the monitor, the area covered by these sediments could be readily determined. Analysis of grab samples indicated that about 90% of the weight of these fine sediments was composed of particles less than 3.5 mm.

Hilton and Lisle (1993) suggested that the amount of fine sediment in pools can be used as an indicator of the relative mobility of bedload sediments. They calculated the proportion of the pool volume occupied by fine sediments by measuring the thickness of fine sediment deposits along transects in streams. This technique works well in streams where fine sediments overlie a coarser substrate of coarse gravel, cobbles, or boulders. While this technique would appear to have merit in the Chattooga River, time and budget restraints prevented its application in this study. Therefore, the proportion of pool area occupied by fine sediments was calculated from analysis of the videotape.

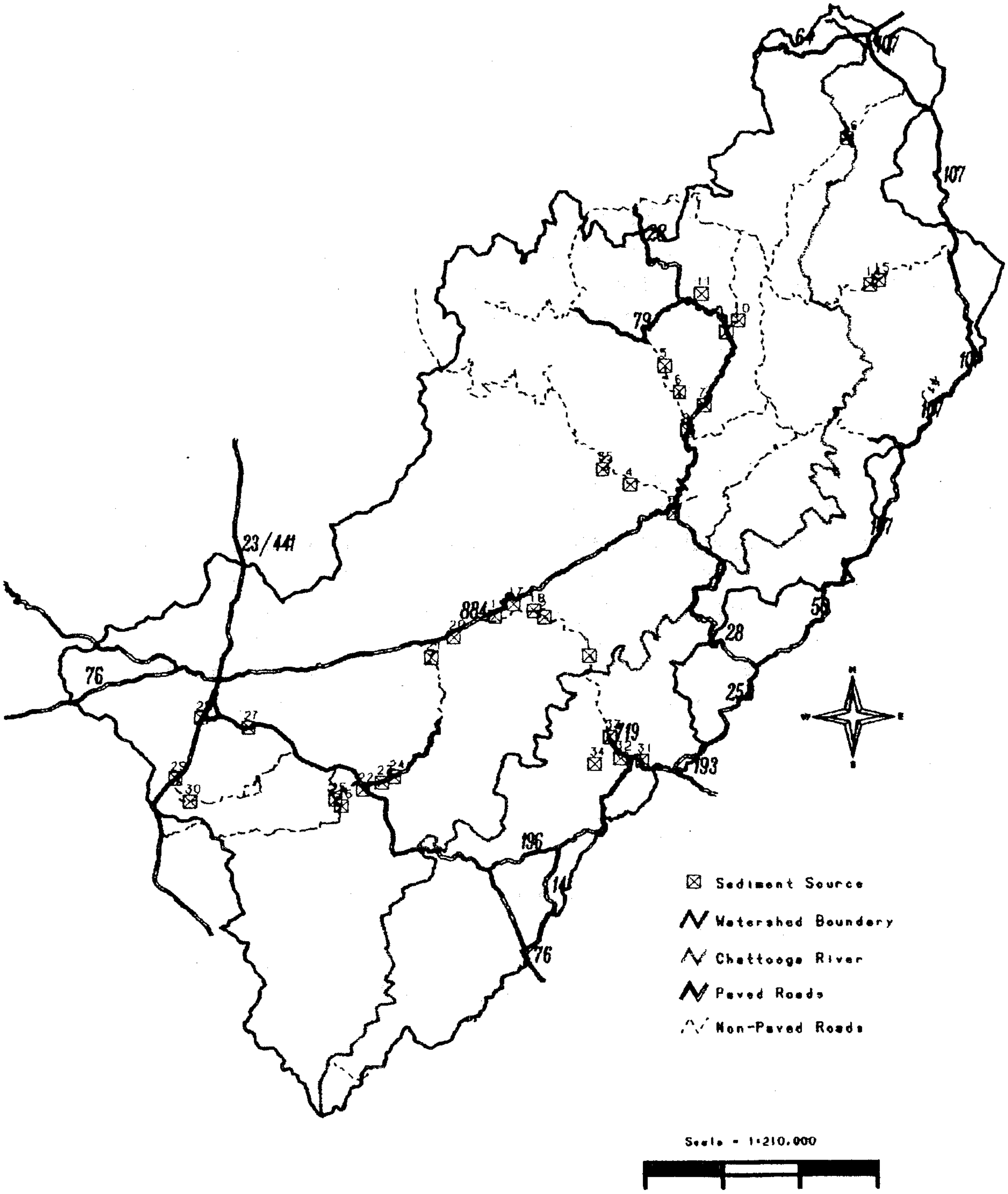


Figure 13. The location of major sediment sources as described in Table A3 within the Chattooga River watershed (map compiled October 1994).

A total of 22 pools were analyzed in Section A between Bull Pen Bridge and Russell Bridge on South Carolina Rt. 28 (Table 7). Fine sediments covered about 63% of the pool's substrate in Section A. The percentage of the pool area dominated by fine sediments increased in Section B (Russell Bridge to Dick Creek) to 85%. This increase is attributed to a combination of increased sediment inputs, primarily from tributaries, and a decreased ability of the river, due to a lower gradient, to flush the sediment downstream.

The river gradient decreases markedly from 44 ft/mi to 15 ft/mi as the river enters Section B (Figure 3), slowing the rate at which the river naturally transports sediments downstream and creating several reaches characterized by long, slow moving, sediment-filled pools. The videotape illustrates that about 2 mi upstream from Russell Bridge, the beginning of section B, sediment inputs from Reed Creek exert a significant influence on substrate composition. Sedimentation from Reed Creek is complemented at the beginning of the section B when a massive load of fine sediments enters the Chattooga from the West Fork (Figure 14). Also present within this reach, just downstream of the West Fork, are several sections of slumping streambanks associated with old farm fields.

Near the end of Section B, Warwoman Creek significantly increases the volume of the river by approximately 30%. Sandy Ford, an area located on the Georgia side of the river just below the mouth of Warwoman Creek may be accessed by vehicle, as was illustrated by a van parked less than 20 ft from the Chattooga during filming. This road has likely contributed vast quantities of sediment to the Chattooga over the decades it has been in use, as evidenced by its localized deep entrenchment into the terrain.

Figure 14. Fine bedload sediments entering the Chattooga River from the West Fork. Water in both main river and tributary was clear when aerial videotaping occurred.

Table 7. Domination of pool habitats of the Chattooga River by fine sediments, defined as particles <3.5 mm diameter, as estimated from analysis of aerial videotape.

| Section[1] | Gradient (ft/mi) | No. of Pools Sampled | Ave. Coverage of Pool Substrate by Fine Sediment (%) |
|---|---|---|---|
| A | 44 | 22 | 63 |
| B | 15 | 23 | 85 |
| C | 31 | 4[2] | 35 |

[1] A. Bull Pen Bridge to Russell Bridge, B. Russell Bridge to Dick Creek, C. Dick Creek to Tugaloo Lake

[2] Because of depth of pools, water turbulence, helicopter angle, and other factors, only four pools could be sampled in this section.

Because of greater pool depth, water turbulence, glare, and helicopter angle in the steeper Section C, only four pools could be analyzed for fine sediment coverage. Due to the small sample, relatively little confidence can be placed in the estimate of 35% coverage of pools by fine sediment. Perhaps the lower coverage of fine sediments in pools of this section is due to the increased volume of water and steeper stream gradient, which enables transport of more sediment. The stream channel in Section C is tightly constrained by geology. These data are included because they indicate that even in this rather steep gradient section of the stream where water volume is relatively high, fine sediments still occupy a significant portion of the stream bottom. Stekoa Creek, a significant source of sediment and other pollutants, enters midway through this section and was the only source of visibly turbid water seen the entire flight (Figure 15).

The aerial analysis of the river illustrated several important points. First, sources of sediment to the Chattooga River, other than natural channel scouring, rarely originate within the Wild and Scenic River corridor. Rather, anthropogenically-related sources are usually located at considerable distances from the main river along tributaries. Sediments, both suspended and bedload, are generated by land uses that cause mineral soil exposure, overland flow of water, or slumping of streambanks. Video analysis illustrates that fans of bedload sediment are produced downstream of major tributaries such as Reed Creek, the West Fork, Warwoman Creek, Whetstone Creek, and Stekoa Creek.

Secondly, there is a tremendous amount of stored sediment in the Chattooga River channel. Because of the geology of the watershed, much of this stored sediment is undoubtedly a natural feature of the river. It is equally certain that man's activities have contributed large quantities of sediment to the river. Because of the huge quantities of stored sediment in the channel and its embeddedness in the substrate, it may take decades or even centuries for the

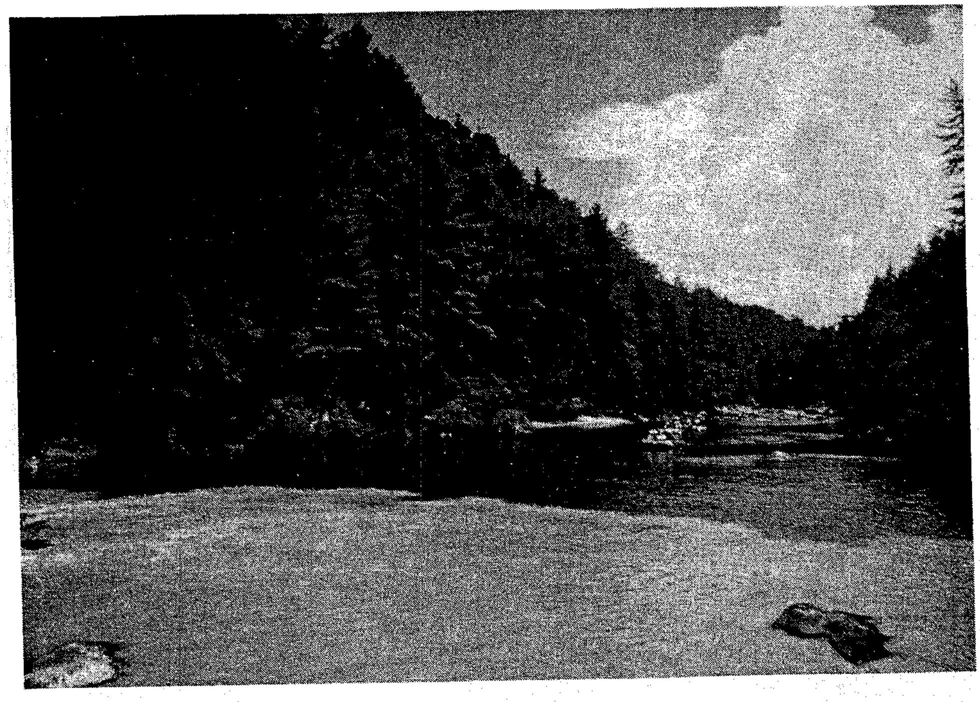

Figure 15. Turbid waters from Stekoa Creek entering the Chattooga River.
Photo Credit: Tom Stults

river bottom to approach full recovery, assuming that anthropogenic sources of sediment are minimized. Most of the river is currently in relatively good biological health, as indicated by recent assessments of benthic macroinvertebrates (English 1990) and fish populations (Durniak 1989). Nevertheless, now is the time to initiate a major watershed effort to control sedimentation and allow the river and its tributaries to begin progressing toward their full biological and aesthetic potential.

Tributaries of the Chattooga River are the major contributors of fine sediments to the river (Figure 16). Until their sedimentation problems are corrected, it will be impossible to reduce the suspected impacts of sedimentation on the aquatic community within the main river. However, research on Howard Creek, a high gradient stream in South Carolina, illustrated dramatically that, if sources of sedimentation are reclaimed, a stream can exhibit remarkable resiliency and begin to recover in a relatively short time (Dillard 1992, Miller 1992).

## E. Composition and Mobility of the Fine Sediment Fraction of the Substrate

The W-V technique can be used to sample the composition, or particle-size distribution, of the mobile fine sediment fraction of the substrate surface (Wesche et al. 1989, Hudson 1994). Sand and finer sized particles made up about 90% of the materials collected in the W-V boxes. The distribution of particles in the sand and finer fraction only is shown in Figure 17.

Durniak and Ruddell (1990) noted a strong correlation between the composition of fine sediments in north Georgia streams and the density of unpaved roads. They also observed

Figure 16. Excessive fine bedload sediments in Big Creek, a major tributary of the West Fork of the Chattooga River.

that the negative effects of stream discharge on stocked trout fingerlings were most detrimental when the stream substrate was high in fine sediments. The "crusher run" gravel used to surface many of the unpaved roads in the watershed has a high percentage of sand and finer materials, which are readily washed from the road surface and eventually reach streams. Considering that some roads are maintained as many as 10 times/year, it would appear that "crusher run" with excessive fines should not be used as road surfacing aggregate. Suitable particle-size mixes must be made available or sought out to provide a reasonable balance between stability, driveability, and water quality.

The fine sediment fraction of the seven sampled streams was highly mobile. The W-V boxes placed in the tails of riffles captured between 430 (King Creek) and 740 g (Reed Creek) of fine sediments during the 35-40 day sampling period. These gritty materials scour algae and mosses from the more stable substrate and fill interstitial spaces among larger substrate components to the detriment of the aquatic community (Platts et al. 1989, Iwamoto et al. 1978, Reiser et al. 1988, Young 1989).

Other habitat factors, such as high water temperatures, low fertility, and lack of coarse woody debris, also limit production of trout streams in the Southern Appalachians (Habera and Strange 1993) and may override the importance of fine sediments. Nevertheless, the amount of fine sediment captured by the W-V boxes strongly suggests that the mobility of these materials may negatively affect macroinvertebrates and fish within streams of the Chattooga Watershed.

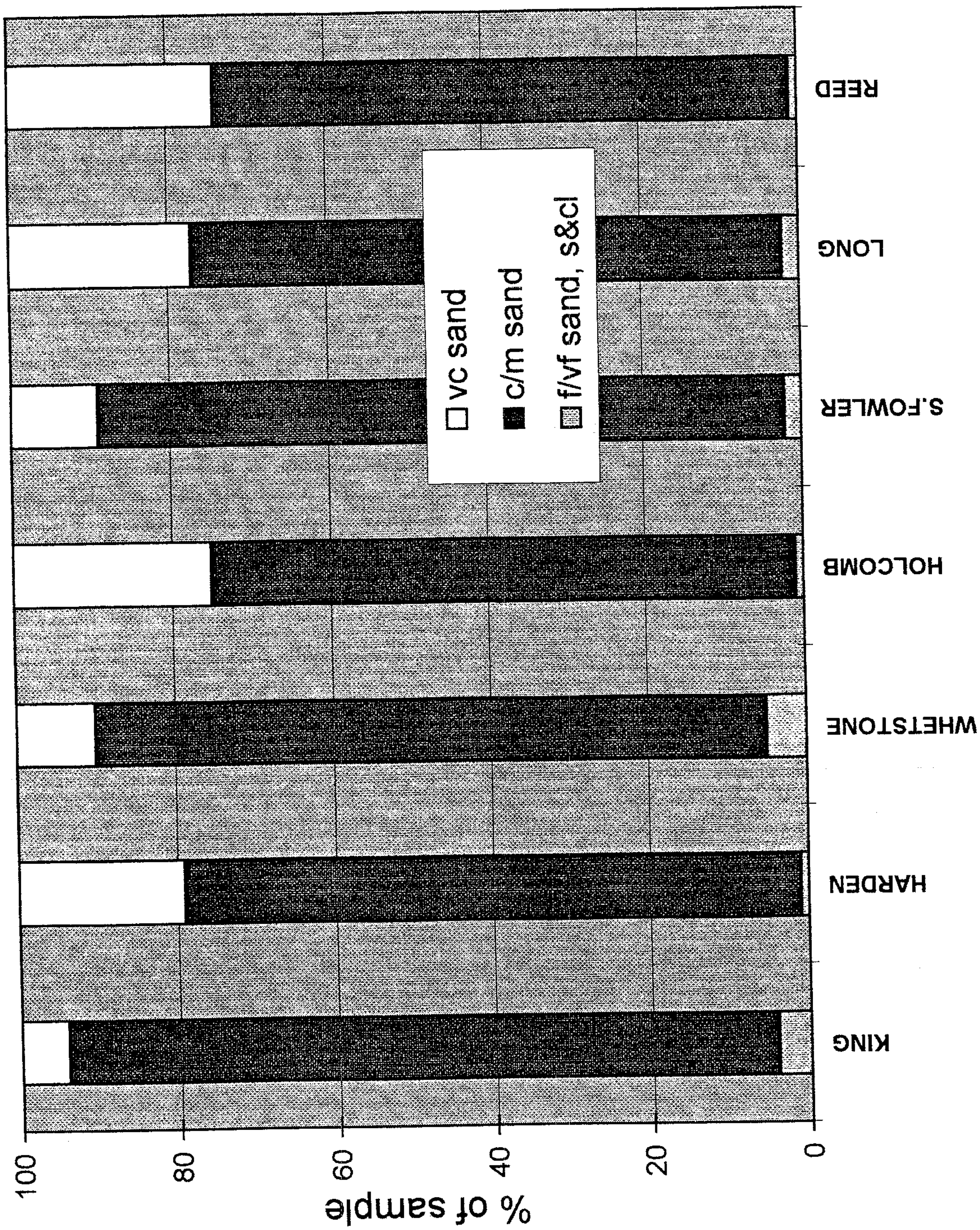


Figure 17. Distribution of particle-size fractions (vc sand and finer) in W-V boxes collected in tails of riffles of study streams.

# CONCLUSIONS

This study utilized various methods, including a road survey, water quality sampling, helicopter videography, and substrate sampling, to monitor sedimentation in the Chattooga River watershed. The report identifies subbasins within the Chattooga River watershed which have high concentrations of suspended sediment, provides visual evidence of those tributaries which yield large quantities of bedload sediment to the river, documents the extent of fine sediment coverage in pools of the river, and presents recommendations to minimize sedimentation from land-use activities. Major conclusions are:

- Unpaved multipurpose roads were associated with about 80% of the sediment sources observed from roads in the Chattooga River watershed. The remaining sources of sediment identified were categorized as timber harvest, agriculture, residential development, recreation, and miscellaneous.

- Although roads were identified as the major source of sediment, users of these unpaved gravel roads contribute to their degradation through heavy trafficking and by increasing the need for maintenance, both of which aggravate sedimentation.

- Suspended sediment levels were highest in subbasins drained by Stekoa and Big Creeks, subbasins heavily impacted by adjacent roads, pastures with unfenced riparian zones, residential development, and other sources of sediment. Subbasins with relatively low suspended sediment levels included Overflow, S. Fowler, Holcomb, Harden, and Bull Pen, all of which were dominated by forest cover and had relatively low road densities and little, if any, agricultural use.

- Fine sediments (< 3.5 mm) occupied 63% of the area of pools in Section A (Bull Pen Bridge to Russell Bridge) and 85% of the area in pools in Section B (Russell Bridge to Dick Creek). The majority of these fine sediments were very coarse sand (1-2 mm) and finer fractions. Pools in Section C (Dick Creek to Tugaloo Lake) also contained considerable sediments but because of water depth and turbulence, glare, and helicopter angle in the sinuous, relatively deep gorge, it was not possible to quantify fine sediment coverage with great confidence.

- Land-uses in drainages of major tributaries that expose and/or compact mineral soil (e.g., roads, skid trails, and development) or result in streambank slumping (e.g., grazing in pastures with unfenced riparian zones) are the major causes of high stormflow levels of suspended sediment in the Chattooga River. The Wild and Scenic corridor of the main stem of the river contributes relatively little new sediment, other than occasional bank slumping along a few alluvial floodplains and erosion from occasional unclosed forest roads.

- Aerial analysis of the main river channel indicates that it stores large quantities of fine sediments, both of natural and anthropogenic origin, which are gradually being flushed downstream, primarily during major stormflow events.

- The West Fork of the Chattooga Wild and Scenic River System receives a heavy load of sediment from Overflow Creek Road (FS 86) and Big Creek, a major tributary. The West Fork, in turn, deposits tremendous loads of sediment into the main river.

- The fine sediment fraction is highly mobile in tributaries of the Chattooga River. The majority of these captured sediments were coarse to medium sands.

- Historic and current land use within the Chattooga River watershed has significantly contributed to excessive sedimentation of the river. A major effort by all landowners, both public and private, and users to reduce and reclaim sources of sedimentation could quickly initiate a recovery of the watershed and lead to continuing enhancement of resource values associated with the river and its tributaries.

- The river contains huge quantities of stored sediment in its channel, much of which is embedded in the substrate. It may take decades or even centuries for the river bottom to approach full recovery, assuming that anthropogenic sources of sediment are minimized. Nevertheless, now is the time to initiate a major watershed effort to control sedimentation and allow the river and its tributaries to progress toward their full biological and aesthetic potential.

1. Closure of roads which are chronic producers of sediment, or at least paving troublesome portions of these roads, should be considered wherever possible. Pollutants from these roads may be subject to Clean Water Act regulation if they are not maintained properly or closed when no one accepts responsibility. Closure to vehicular traffic and revegetation would enhance wildlife habitat, and in several cases would create large forested areas free of vehicular traffic. Roads would still be passable for emergency uses such as fire control or salvage operations, and foot traffic would be encouraged.

2. Where closure or paving is not feasible, the use of larger gravel sizes on problem road surfaces would reduce frequency and intensity of maintenance, as well as the amount of sediment washed from the road surface by overland flow. Placement of large gravel in roadside ditches would reduce the need for maintenance and protect this very sensitive portion of the road. Inexpensive water control features should be used where appropriate.

3. Spur roads to access logging areas should follow state Best Management Practices, which include proper planning and locating, surface drainage, stabilization, closure following use and maintenance if left open. Surfacing with aggregate material (gravel) may be required if year-round access or steep gradients cannot be avoided.

4. Seasonal road closures during periods of heavy rains or continual freeze-thaw cycles should be employed to preserve desired road conditions, and thereby reduce maintenance costs and sedimentation impacts.

5. Federal funds should be directed through farm and landowner assistance programs toward improvement of water quality. Programs are in place, e.g., the Water Quality Incentive Program of the Natural Resource Conservation Service and the Stewardship Incentives Program administered through the state Forestry Commissions, to address sedimentation as a major issue. A significant effort should be directed toward encouraging landowners to fence riparian areas and providing alternate watering systems for livestock. Federal cost-share programs are available to assist the landowner in defraying the cost of these improvements. Several cost-share proposals to abate erosion and other sources of pollution are under consideration by the EPA in the Stekoa Creek drainage.

6. Improve erosion controls at landfills. Both the Macon County and Rabun County landfills were cited as sediment producers. The inherent nature of a landfill involves exposed mineral soil. However, appropriate use of silt fences, brush barriers, sediment traps, and vegetation barriers would prevent most of the sedimentation from public and private landfill operations from reaching streams.

7. Federal, state and county Departments of Transportation need a stronger commitment to erosion control.

8. Although a growing number of individuals are cooperative with conservation efforts, stricter and more enforceable sedimentation plans for residential and commercial development are necessary to protect water quality within the Chattooga Watershed. There is a need for stronger compliance enforcement of existing sedimentation laws as development accelerates in the mountains. Consolidation of Forest Service lands through acquisition of private property would provide the best assurance of water quality protection in the Chattooga River watershed.

9. Periodic sampling of streams in the watershed is recommended to monitor water quality trends. The single stage samplers used in this study to measure suspended sediment proved to be effective, efficient, and inexpensive. Periodic repetition of the aerial survey and analysis of the videotape, perhaps at intervals of 5 years, may indicate if fine sediment domination of the bottom substrate is decreasing.

10. Further studies in heavily impacted subbasins of the Chattooga River watershed are warranted, especially studies designed to evaluate effects of conservation measures on protection and enhancement of water quality.

11. Periodic surveys of road conditions and other activities are essential to document sediment sources, as well as evaluate the effectiveness of sediment control and restoration efforts, if water quality in the Chattooga River watershed is to be improved.

12. Significant reduction of sediment delivery to the Chattooga River will require a watershed approach. Efforts to foster partnerships among management agencies, landowners, and concerned publics throughout the watershed should be encouraged to provide the most timely and cost-effective results.

13. Establish long-term reference sites to monitor chemical, physical, and biological properties of the river (see #9 above).

14. Update and strengthen maintenance plans for easements that involve National Forest lands.

## FOOTNOTES

1. Rightmyer, Richard, Soil Scientist, US Forest Service, Chattahoochee National Forest, GA.
2. Rankin, Dan, Fisheries Biologist, SC Department of Natural Resources, Clemson, SC.
3. Alger, John, Forestry Consultant, Buckdancer, Swannanoa, NC.
4. Abercrombie, Jim, Assistant District Ranger (retired), US Forest Service, Sumter National Forest, SC.
5. Bauknight, Dennis, District Conservationist, Natural Resource Conservation Service, Walhalla, SC.
6. Bailey, Kameron, and Webb Smathers, Graduate Student and Professor, respectively, Department of Agricultural Economics, Clemson University, Clemson, SC
7. Bauknight, Dennis, District Conservationist, Natural Resource Conservation Service, Walhalla, SC.
8. Kapeluck, P. R. 1994. Research Forester, Clemson University, Clemson, SC.

## ACKNOWLEDGMENTS

Many people provided invaluable assistance in the preparation of this report. Special thanks go to Ms. Charlene Neihardt, GIS Coordinator, Chattooga Ecosystem Project, USFS; Mr. David Braatz, Hydrologist, Duke Power Co.; Mr. Jeff Durniak, Fisheries Biologist, Georgia DNR; Mr. Randy Geddings and Mr. Dan Rankin, Fisheries Biologists, South Carolina DNR; Mr. Dave Cawrse, Project Leader, Chattooga Ecosystem Project, USFS; Mr. Jim Abercrombie, Forester, USFS, Sumter National Forest (retired); Mr. Jim Kidd, Forester, USFS, Chattahoochee National Forest; Mr. Monte Seehorn, Fisheries Biologist, USFS, Chattahoochee National Forest; Dr. Lloyd Swift, Hydrologist, USFS, Coweeta Hydrologic Laboratory; Mr. Dennis Bauknight, District Conservationist, NRCS; Ms. Amy Wright, GIS Specialist, USFS; and to the numerous volunteers of the Chattooga River Chapter of Trout Unlimited. We gratefully acknowledgment the field assistance of Mr. Wayne Carroll, graphic assistance by Mr. Rick Myers, and the word processing skills of Ms. Mary Alice Cromer and Ms. Jeanne Campbell, all with the Department of Forest Resources, Clemson University.

Financial support for this project was supplied by the Chattooga Ecosystem Project of the US Forest Service, Clemson University, and the Chattooga River Chapter of Trout Unlimited.

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# APPENDIX

Table A1. Sediment problems identified from the road survey. Sediment source categories are as follows: 1=road maintenance, location, and design, 2=development, 3=timber harvest, 4=agriculture, 5=grazing, 6=recreation facilities, 7=trails, 8=other. (In Figure 5 in text, grazing was combined with agriculture and trails was combined with recreation.)

| Road | State | mi | Total # of problems | # of problems/category 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FS 164 CHURCH RD | GA | 1.0 | 0 | | | | | | | | |
| FS 153 CAMPGROUND RD | GA | 1.0 | 1 | | | 1 | | | | | |
| FS 511B DANIEL CR RD | GA | 1.0 | 14 | 13 | | 1 | | | | | |
| CLAUDE SMITH RD | GA | 0.9 | 9 | 7 | | | | 2 | | | |
| JAMES RD | GA | 0.6 | 4 | 3 | 1 | | | | | | |
| SEED TICK EXTENSION RD | GA | 0.7 | 3 | 1 | 1 | | | | | | |
| CAMP CR COMMUNITY RD | GA | 0.9 | 3 | 2 | | 1 | | | | | |
| ICE PLANT RD | GA | 1.3 | 8 | 4 | | | | 4 | | | |
| BETHEL CHURCH RD | GA | 1.4 | 2 | | 1 | | | 1 | | | |
| RICKMAN AIRFIELD RD | GA | 1.4 | 8 | 5 | 1 | 1 | 1 | | | | |
| S. RICKMAN MTN RD | GA | 1.3 | 2 | 1 | | | | | | | |
| FS 290 WOODALL SHOALS | GA | 1.1 | 17 | 15 | | 2 | | | | | |
| STEKOA FALLS RD | GA | 1.2 | 1 | | | | | 1 | | | |
| DAVIS RD | GA | 1.2 | 3 | | 1 | | | 2 | | | |
| FS 123 E. MOCASSIN CK | GA | 0.6 | 4 | 1 | | | | 1 | | | |
| ENGLISH RD | GA | 0.1 | 2 | 1 | 1 | | | | | | |
| WATTS DR | GA | 0.3 | 5 | 3 | 2 | | | | | | |
| UNNAMED RD | GA | 0.3 | 5 | 4 | | | | 1 | | | |
| ANNIE PERRY RD | GA | 0.1 | 2 | 1 | 1 | | | | | | |
| FS 779 | GA | 1.3 | 6 | 6 | | | | | | | |
| FS 155 WALNUT CR | GA | 0.0 | 2 | 1 | | 1 | | | | | |
| KELL CEMETERY RD | GA | 0.1 | 3 | 3 | | | | | | | |
| SPUR OFF 646 | GA | 0.4 | 7 | 7 | | | | | | | |
| McCRACKEN RD | GA | 0.5 | 6 | 6 | | | | | | | |
| BUCKEYE BRANCH RD | GA | 0.5 | 2 | 2 | | | | | | | |
| SHE CR RD | GA | 0.4 | 4 | 3 | 1 | | | | | | |
| UNNAMED RD | GA | 0.3 | 6 | 5 | | 1 | | | | | |
| LEFT FORK FS 8 | GA | 0.3 | 7 | 7 | | | | | | | |
| SMITH COURT | GA | 0.4 | 4 | 3 | 1 | | | | | | |
| FS 8 UPPER CLIFF CK | GA | 1.4 | 11 | 8 | | 3 | | | | | |
| POOLE CR SPUR | GA | 4.6 | 9 | 9 | | | | | | | |
| FS 156 SARAH CK | GA | 4.6 | 43 | 34 | | 2 | | | 7 | | |
| CAMP CREEK RD | GA | 4.9 | 14 | 14 | | | | | | | |
| GLADE RD | GA | 4.5 | 15 | 14 | | 1 | | | | | |
| WOLF CR RD | GA | 3.7 | 8 | 8 | | | | | | | |
| FS 511 WATERGAUGE | GA | 3.8 | 38 | 24 | | 14 | | | | | |
| FS 86C TOTTERY POLE RD | GA | 4.5 | 17 | 10 | | 7 | | | | | |
| FS 646 BURRELL'S FORD RD | GA | 6.8 | 29 | 27 | | 2 | | | | | |
| FS 86 OVERFLOW CR RD | GA | 6.9 | 56 | 55 | | | | | 1 | | |

Table A1. (Continued)

| Road | State | mi | Total # of problems | # of problems/category 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HALE RIDGE RD | GA | 9.9 | 42 | 37 | 1 | 4 | | | | | |
| BIG CR RD (124) | GA | 6.4 | 38 | 31 | | 2 | | 3 | | | 2 |
| SANDY FORD RD | GA | 5.2 | 26 | 20 | | 4 | | 1 | 1 | | |
| POOLE CR RD | GA | 5.2 | 34 | 28 | | 1 | | 5 | | | |
| FS 86B BILLINGSLY CK | GA | 6.2 | 35 | 33 | | 2 | | | | | |
| EARLE'S FORD RD | GA | 3.2 | 40 | 28 | | 7 | | | 4 | | 1 |
| N. RICKMAN MTN RD | GA | 2.0 | 26 | 21 | 1 | 4 | | | | | |
| FS 977 | GA | 2.1 | 5 | 3 | | 2 | | | | | |
| SEED TICK RD | GA | 2.2 | 4 | | 3 | | | 1 | | | |
| TIMBER BLUFF RD | GA | 1.9 | 17 | 17 | | | | | | | |
| FS 512 HORSE CK BR | GA | 1.4 | 16 | 14 | 2 | | | | | | |
| SEED TICK EXTENSION RD | GA | 1.6 | 12 | 10 | 1 | | | 1 | | | |
| FS 156A SARAH CK BR | GA | 1.7 | 16 | 12 | | 4 | | | | | |
| WOLF CR CH RD | GA | 2.8 | 19 | 11 | | 8 | | | | | |
| FS 153 TUCKALUGE RD | GA | 3.0 | 41 | 40 | | | | | 1 | | |
| FS 159 POLLYWAH RD | GA | 3.2 | 11 | 7 | | 4 | | | | | |
| FS 152 FINNEY CK | GA | 2.6 | 30 | 29 | | | | | 1 | | |
| BIG CREEK RD | GA | 2.2 | 19 | 10 | 3 | | | 6 | | | |
| BOGGS MTN CHURCH RD | GA | 2.3 | 9 | 5 | 2 | 1 | | | | | 1 |
| EASTMAN MTN RD | GA | 2.4 | 16 | 10 | 6 | | | | | | |
| | | 133.8 | 831 | 673 | 30 | 79 | 1 | 29 | 16 | 1 | 5 |
| | | | | | | | | | | | |
| FS 77 BROWN GAP | NC | 0.9 | 3 | 3 | | | | | | | |
| FS 367 LITTLE YELLOW MTN | NC | 4.8 | 7 | 6 | | | | | | | |
| FS 79 BLUE VALLEY | NC | 4.5 | 6 | 4 | | 1 | | | | 1 | |
| SR 1101 | NC | 1.2 | 5 | 4 | 1 | | | | | | |
| FS 4563 CHESTNUT MTN | NC | 0.3 | 3 | 2 | | 1 | | | | | |
| SR 1178 BULL PEN | NC | 8.3 | 22 | 20 | | | | | | 2 | |
| FS 1610 | NC | 0.4 | 1 | | | | | 1 | | | |
| FS 1611 (SASSAFRASS GAP RD) | NC | 1.3 | 5 | 3 | | | | 2 | | | |
| FS 1109 | NC | 1.0 | 2 | 2 | | | | | | | |
| FS 301 WILSON LAKE | NC | 0.8 | 4 | 2 | | 1 | | 1 | | | |
| FS 1618 | NC | 1.6 | 7 | 5 | | 1 | | 1 | | | |
| FS 1107 | NC | 7.9 | 15 | 14 | | | | 1 | | | |
| WILSON GAP RD (401) | NC | 3.8 | 17 | 14 | | | | | 1 | | 2 |
| FS 1613 | NC | 3.5 | 5 | 2 | | | | 3 | | | |
| SR 1607 GLADE MTN | NC | 2.5 | 15 | 15 | | | | | | | |
| SR 1608 WALKING STICK | NC | 2.5 | 1 | 1 | | | | | | | |
| | | 45.3 | 118 | 97 | 1 | 4 | 0.0 | 9 | 1 | 3 | 2 |

Table A1. (Continued)

| Road | State | mi | Total # of problems | # of problems/category 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FL 709 BIG BEND RD | SC | 0.9 | 16 | 16 | | | | | | | |
| C37CH50 NICHOLSON FD RD | SC | 1.2 | 1 | 1 | | | | | | | |
| C37PU2 BARBANA RD | SC | 0.8 | 5 | 5 | | | | | | | |
| FS 721 B DOUBLE SHACK BR | SC | 0.3 | 3 | 2 | | | | | 1 | | |
| WHETSTONE COVE RD | SC | 0.5 | 0 | | | | | | | | |
| FS 722 FALL CR RD | SC | 2.5 | 25 | 10 | | 15 | | | | | |
| FS 719 WHETSTONE MTN | SC | 2.3 | 4 | 2 | | 1 | | | | 1 | |
| FS 782 CUSTOM SAWMILL RD | SC | 2.2 | 5 | 5 | | | | | | | |
| FS 721(193) WHETSTONE RD | SC | 4.0 | 16 | 11 | | 1 | 1 | 2 | | 1 | |
| FS 708 BURRELLS FORD RD | SC | 2.7 | 20 | 18 | | | | | 1 | | 1 |
| FS 755 TURKEY RIDGE | SC | 2.7 | 2 | 2 | | | | | | | |
| FISH HATCHERY RD | SC | 1.7 | 10 | 10 | | | | | | | |
| C37PU47 CONLEY RD | SC | 1.6 | 9 | 7 | | | | 2 | | | |
| FS 719A PHILLIPS BEND | SC | 1.5 | 7 | 4 | | | | | | 3 | |
| ROCKY GAP RD | SC | 2.1 | 13 | 6 | | 1 | 2 | 3 | | 1 | |
| FS 757 WOODALL SHOALS | SC | 2.1 | 9 | 9 | | | | | | | |
| FS 721A SANDY FORD | SC | 1.8 | 12 | 12 | | | | | | | |
| | | 30.8 | 157 | 120 | 0 | 18 | 3 | 7 | 2 | 6 | 1 |

Table A2. Funding sources for water quality improvement projects.

| | |
|---|---|
| Name: | EPA 319 funds |
| Who Can Apply: | Entities with legal standing in court (Federal, state and local govts; schools; and businesses are examples) |
| Restrictions: | None |
| Funds Available: | No individual limit, but total funds are limited. |
| Limitations: | Need 40% non-federal matching funds. Need to focus on nonpoint source pollution. |
| Type of Work: | Aquatic habitat improvements. Education and monitoring can be included, but the proposal should have the implementation of a practice to conserve water quality related to nonpoint source pollution. |
| Contact: | Local State Environmental Protection Division |
| Name: | Forest Stewardship Program and Stewardship I Incentive Program |
| Who Can Apply: | Landowners with 10 or more acres. |
| Restrictions: | Private lands only. |
| Funds Available: | $10,000 per year maximum |
| Limitations: | Need to be in Forest Stewardship program; up to 75% of the cost of a practice can be funded. |
| Type of Work: | The Forest Stewardship program offers technical assistance to forest landowners to manage their lands for multiple resources. The Stewardship Incentive Program provides cost-share assistance to Forest Stewardship Program participants who install conservation practices on their land with respect to water quality, including 1) soil and water protection and improvements such as stream crossing and cross drainage on roads and trails provided that state BMPs are implemented, and 2) riparian and wetland protection such as improving and restoring forested wetlands and riparian areas, and streambank stabilization. |
| Contact: | Local State Forestry Office |

Table A2. Continued

| | |
|---|---|
| Name: | Southern Rivers Council |
| Who Can Apply: | Anyone |
| Restrictions: | None |
| Funds Available: | No individual limit, but total funds are limited. Will match up to 50% of non-federal and/or skilled labor funds. |
| Limitations: | Need to identify potential non-federal partners in application. No federal funds or unskilled volunteer labor can be matched. |
| Type of Work: | Aquatic ecosystem enhancement projects (including education) |
| Contact: | Regional Fisheries Biologist, USDA Forest Service, 1720 Peachtree Road, NW, Atlanta, GA 30367. Ph: (706) 782-3112 |

| | |
|---|---|
| Name: | USDA Consolidated Farm Service Agency |
| Who Can Apply: | Landowners with farms or pastures. |
| Restrictions: | Private lands only. |
| Funds Available: | $3500 maximum per year. |
| Limitations: | Requires five year commitment. |
| Type of Work: | Stream bank restoration (fencing), new grass planting, grassing improvement, feed pad construction, forestry planting, forestry improvement. |
| Contact: | Local Consolidated Farm Service Agency |

Table A3. GIS site number (refer to Figure 13), subbasin, cause, and severity of sediment sources in the Chattooga River watershed (only extreme and high impact sites are included).

| GIS Site Number | Watershed | Severity | Cause and Recommendations |
|---|---|---|---|
| 1 | Warwoman | Extreme | Cause: old, erosive roadbed fords creek<br>Recommendation: close road as far from creek as possible |
| 2 | Warwoman | Extreme | Cause: road runs directly parallel to creek and slumps into creek<br>Recommendation: establish sediment barricade between road and creek, relocate road section, or pave road section |
| 3 | West Fork | High | Cause: erosive stream banks<br>Recommendation: vegetate with stabilizing vegetation |
| 4 | West Fork | High | Cause: erosive stream banks<br>Recommendation: vegetate with stabilizing vegetation |
| 5 | Big | High | Cause: field plowed to edge of Talley Mill Cr.<br>Recommendation: establish grass/tree buffer strip between field and creek |
| 6 | Big | High | Cause: livestock allowed free access to stream<br>Recommendation: fence livestock away from stream and provide alternate water source, vegetate stream banks |
| 7 | Big | High | Cause: dam has broken on old pond, flushing large amounts of sediment downstream during storm events<br>Recommendation: vegetate exposed lake bottom and exposed sections of dam |
| 8 | Big | High | Cause: livestock allowed free access to stream<br>Recommendation: fence livestock away from stream and provide alternate water source, vegetate stream banks |

Table A3. (Continued)

| GIS Site Number | Watershed | Severity | Cause and Recommendations |
|---|---|---|---|
| 9 | Big | High | Cause: long section of road in very poor condition draining directly into Big Cr. Recommendation: install water management structures and sediment traps to prevent sediment from reaching stream |
| 10 | Big | High | Cause: long section of road in very poor condition draining directly into Big Cr. Recommendation: install water management structures and sediment traps to prevent sediment from reaching stream |
| 11 | Big | Extreme | Cause: exposed mineral soil around Macon County landfill Recommendation: install silt fence, sediment traps and sediment barriers around exposed areas |
| 14 | S. Fowler | High | Cause: road runs directly parallel to creek and slumps into creek Recommendation: establish sediment barricade between road and creek, relocate road section, or pave road section. |
| 15 | S. Fowler | High | Cause: long section of road draining into stream, overmaintenance pushes road material into stream Recommendation: pave erodible sections or reduce maintenance, install water maintenance structures to prevent sediment from reaching stream |
| 16 | Bull Pen | High | Cause: livestock allowed free access to stream Recommendation: fence livestock away from stream and provide alternate water source, vegetate stream banks |
| 17 | Warwoman | High | Cause: road runs directly parallel to creek and slumps into creek Recommendation: establish sediment barricade between road and creek, relocate road section, or pave road section. |

Table A3. (Continued)

| GIS Site Number | Watershed | Severity | Cause and Recommendations |
|---|---|---|---|
| 18 | Warwoman | Extreme | Cause: power line right of way being used as ATV trail, sediment is being washed directly into Warwoman Creek<br>Recommendation: fence right of way, vegetate exposed soil, and install sediment traps between trail and creek |
| 19 | Warwoman | High | Cause: livestock allowed free access to stream<br>Recommendation: fence livestock away from stream and provide alternate water source, vegetate stream banks |
| 20 | Warwoman | High | Cause: livestock allowed free access to stream<br>Recommendation: fence livestock away from stream and provide alternate water source, vegetate stream banks |
| 21 | Warwoman | High | Cause: road runs directly parallel to creek and slumps into creek<br>Recommendation: establish sediment barricade between road and creek, relocate road section, or pave road section |
| 22 | Stekoa | Extreme | Cause: land on both sides of She Creek has been cleared for development, with She Creek crossed numerous times by heavy equipment and mineral soil left exposed<br>Recommendation: vegetate stream banks, install silt fence, stabilize exposed mineral soil away from stream banks as well, use suitable stream crossing structures |
| 23 | Stekoa | High | Cause: horses allowed free access to stream<br>Recommendation: fence livestock away from stream and provide alternate water source, vegetate stream banks |
| 24 | Stekoa | Extreme | Cause: livestock allowed free access to stream, dog kennels being cleaned out directly into stream<br>Recommendation: fence livestock away from stream, locate kennels away from stream, use suitable waste disposal measures |

Table A3. (Continued)

| GIS Site Number | Watershed | Severity | Cause and Recommendations |
|---|---|---|---|
| 25 | Stekoa | Extreme | Cause: road runs directly parallel to creek and slumps into creek<br>Recommendation: establish sediment barricade between road and creek, relocate road section, or pave road section, vegetate stream banks and fill slopes |
| 26 | Stekoa | Extreme | Cause: road runs directly parallel to creek and slumps into creek<br>Recommendation: establish sediment barricade between road and creek, relocate road section, or pave road section, vegetate stream banks/fill slopes |
| 27 | Stekoa | High | Cause: highway expansion project has overloaded sediment fence and other structures installed to prevent erosion<br>Recommendation: install heavier sediment fence and control structures, and maintain these structures regularly, use techniques to dewater cut and fill slopes to reduce failures. Require bonded sedimentation control plans for major road construction projects in the watershed |
| 28 | Stekoa | Extreme | Cause: majority of non point source pollution produced by the City of Clayton drains into this creek<br>Recommendation: strengthen and enforce existing sedimentation and non point source pollution laws |
| 29 | Stekoa | High | Cause: road runs parallel to creek and slumps towards creek, fill material has been dumped on slope and contributes additional sediment to Stekoa Creek<br>Recommendation: establish sediment barricade between road and creek, vegetate fill slopes |

Table A3. (Continued)

| GIS Site Number | Watershed | Severity | Cause and Recommendations |
|---|---|---|---|
| 30 | Stekoa | High | Cause: road runs directly parallel to creek and slumps into creek<br>Recommendation: establish sediment barricade between road and creek, relocate road section, or pave road section, vegetate fill slopes |
| 31 | Whetstone | High | Cause: barn and equipment shed for farm located adjacent to stream, exposed soil along stream banks<br>Recommendation: install sediment barriers and silt fence, vegetate exposed soil, consider locating barn farther from stream |
| 32 | Whetstone | High | Cause: livestock allowed free access to stream<br>Recommendation: fence livestock away from stream, provide water source |
| 33 | Whetstone | High | Cause: livestock allowed free access to stream<br>Recommendation: fence livestock away from stream, provide stock water source away from stream |
| 34 | Whetstone | Extreme | Cause: Old Fall Creek Rd. being used as a skid trail, with no gravel or water management structure, allowing large amounts of sediment to flow into Swafford Creek<br>Recommendation: close and vegetate road and install sediment traps to prevent further sediment transport into Swafford Creek, install water diversion structures. Forest Service purchase of private "inholding" would help remedy sedimentation problem |
| 35 | West Fork | Extreme | Cause: erosive roadbed on Overflow Creek Rd.<br>Recommendation: surface road with large gravel, install water management structures. Consider closing in wet weather |

CLEMSON UNIVERSITY

College of Forest and
Recreation Resources
Clemson, South Carolina 29634-1003