Nantahala & Pisgah Forest Plan Revision – Watersheds, Hydrology & Soils

Information presented in this draft report is considered under development. It may be incomplete and is likely unedited. This may make some sections difficult to follow. An updated version if this report will be posted when it becomes available.

Soil and Water - Preliminary Outline of Assessment Report

1. What is the condition of watersheds across Nantahala and Pisgah NFs?
2. What watersheds provide drinking water to communities and what is their overall health?
3. What geology and soil types occur across Nantahala and Pisgah NFs?
4. Is the soil and water on the Nantahala and Pisgah National Forests of sufficient quality to sustain a healthy ecosystem and what are the trends?
5. How have roads impacted stream channels and what are the general trends?
6. Where is sulfidic rock a concern and what steps are taken to mitigate its potential effects to water quality?
7. What soils are sensitive to erosion and where do they occur on the landscape? How has management impacted these soils?
8. What is the status of groundwater resources and what are the potential demands on its use?

What is the condition of watersheds across Nantahala and Pisgah NFs?

Watershed Condition

A watershed or drainage basin is the area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel (Dunne & Leopold 1978). Watersheds are an effective way of understanding the hydrologic regime of an area and the hydrologic affects from management activities; although they are often not sufficient to explain the larger ecosystem. In 2010, 6th-level watersheds (typically, 10,000 to 40,000 acres) were used to define areas of restoration across the planning area using the national Watershed Condition Framework (WCF) (USFS 2010a). A watershed condition was assigned following an assessment of existing data, knowledge of the land, and professional judgment.

Watershed condition is the state of the physical and biological characteristics and processes within a watershed that affect the soil and hydrologic functions supporting aquatic ecosystems. Watershed

condition reflects a range of variability from natural pristine (functioning properly) to degraded (impaired). The Forest Service Manual (USDA Forest Service 2004) classification defines watershed condition in terms of "geomorphic, hydrologic and biotic integrity" relative to "potential natural condition." In this context, integrity relates directly to functionality. Integrity is evaluated in the context of the natural disturbance regime, geoclimatic setting, and other important factors within the context of a watershed (USFS 2010a).

The three watershed condition classes are directly related to the degree or level of watershed functionality or integrity: Class 1 - Functioning Properly, Class 2 - Functioning at Risk, and Class 3 - Impaired Function (USFS 2010a). A watershed is considered to be functioning properly (Class 1) if the physical attributes are appropriate to maintain or improve biological integrity. By contrast, a Class 3 watershed has impaired function because some physical, hydrological, or biological threshold has been exceeded. Substantial changes to the factors that caused the degraded state are commonly needed to set them on a trend of improving conditions that sustain physical, hydrological, and biological integrity (USFS 2010a).

The WCF uses 12 indicators composed of attributes related to watershed processes. Of these, the indicator of "range" was not used by the Nantahala and Pisgah NFs since the Forests do not manage for range. The indicators and their attributes are surrogate variables representing the underlying ecological functions and processes that affect soil and hydrologic function. Management activities that affect the watershed condition class are not limited to soil and water improvement activities, but include a broad array of resource program areas: hazardous fuel treatments, invasive species eradication, riparian area treatments, aquatic organism passage improvement, road maintenance and obliteration, and others. To change a watershed condition class will, in most cases, require changes within a watershed that are significant in their scope and include treatments from multiple resource areas. Sound management or improving management practices can often be as effective as implementing restoration projects and must not be overlooked (USFS 2010a).

Figure 1 illustrates the outcome of the WCF analysis of condition classes for the Nantahala and Pisgah NFs and the adjoining forests where watersheds are shared. Note the abundance of watersheds with "Functioning at Risk" classifications, and only a few "Properly Functioning" and one "Impaired Function" watershed. In general across the analysis area, physical attributes occur that put watersheds at risk of functioning at a potential natural condition, and thus may not be able to maintain biological integrity. Trends are likely improving in most watersheds, but the risk is high that a catalyst of change, such as a large storm event, could result in impaired conditions. The one impaired watershed is the Reed Creek-Chattooga River watershed; shared by the Nantahala NF, Chattahoochee NF, and Francis Marion – Sumter NF. The impairment status was established by the Francis Marion – Sumter NF as a result of aquatic habitat and biota, the road and trail network, and soils concerns.

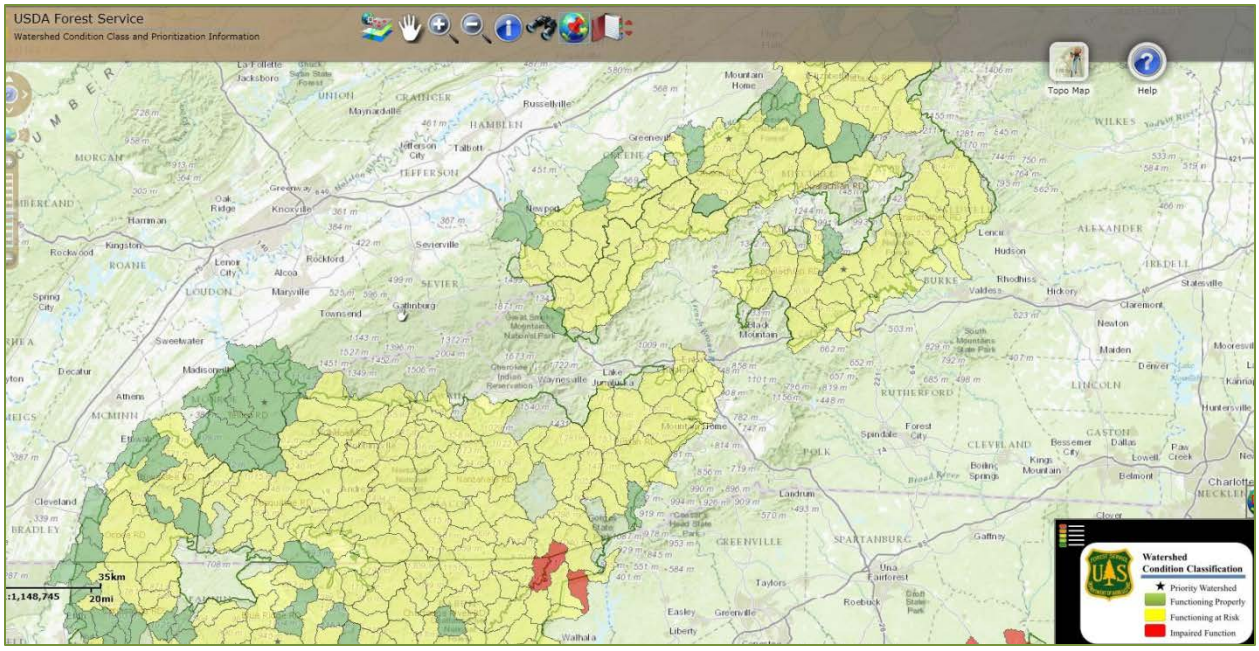

Figure 1. Photo capture of the WCF analysis output for the Pisgah and Nantahala NFs and surrounding Forests. (http://apps.fs.usda.gov/WCFmapviewer/)

Attributes found to have the greatest adverse impact on watershed condition ranking in the WCF are associated with water quality problems, large woody debris, native species, roads and trails, soil contamination, and fire condition class (Table 1). Water quality problems included a compilation of acidification, consumption advisory, and knowledge of impaired conditions in the watershed.

The acidifying or becoming acid of streams was identified in the WCF analysis in watersheds where monitoring data and modeling revealed such conditions. Water Quality problems including acidification, consumption advisory, mines, and knowledge of impaired conditions resulted in impaired function of almost 35 percent of the watersheds. These watersheds are largely scattered across the planning area in headwater areas, e.g., Headwaters Chattooga River and Upper South Toe River. Additionally contributing to impaired condition ratings was the 2010 303(d) list for North Carolina (NC), which states that all NC streams are listed for mercury contamination and thus have a fish consumption advisory (per conversation with Jeff DeBaradinis NCDWQ). Three watersheds had streams listed as “Impaired” under the appropriate state 303d list of impaired waterbodies (two of these are shared watersheds).

TABLE 1. Summary of Watershed Condition Ranking by Attribute. Those attributes in Red have a relatively high percentage (>50%) of Impaired Function.

Parameter	Indicators	Attributes	Functioning Properly	Functioning at Risk	Impaired Function	% Functioning Properly	% Functioning at Risk	% Impaired Function
Watershed Totals[1] (n=135)			14	120	1	10.4	88.9	0.7
Aquatic Physical			**75**	**59**	**1**	**55.6**	**43.7**	**0.7**
	Water Quality		85	48	2	63.0	35.6	1.5
		Impaired Waters	129	3	3	95.6	2.2	2.2
		Water Quality Problems	78	10	47	57.8	7.4	34.8
	Water Quantity		116	15	4	85.9	11.1	3.0
	Aquatic Habitat		10	118	7	7.4	87.4	5.2
		Habitat Fragmentation	56	72	7	41.5	53.3	5.2
		Large Woody Debris	0	14	120	0.0	10.4	89.6
		Channel Morphology	11	123	1	8.1	91.1	0.7
Aquatic Biological			**57**	**77**	**1**	**42.2**	**57.0**	**0.7**
	Aquatic Biota		6	121	8	4.4	89.6	5.9
		Life Form	71	58	6	52.6	43.0	4.4
		Native Species	6	7	122	4.4	5.2	90.4
		Exotic /Invasive	6	125	4	4.4	92.6	3.0
	Riparian & Wetland Vegetaion		9	114	12	6.7	84.4	8.9
Terrestrial Physical			5	60	70	3.7	44.4	51.9
	Roads & Trails		**7**	**18**	**110**	**5.2**	**13.3**	**81.5**
		Open Road Density	18	25	92	13.3	18.5	68.1
		Road Maintenance	7	6	122	5.2	4.4	90.4
		Proximity to Water	26	5	104	19.3	3.7	77.0
		Mass Wasting	14	9	109	10.6	6.8	82.6
	Soil		**8**	**126**	**1**	**5.9**	**93.3**	**0.7**
		Soil Product	120	15	0	88.9	11.1	0.0
		Soil Erosion	128	5	2	94.8	3.7	1.5
		Soil Contamination	0	10	125	0.0	7.4	92.6
Terrestrial Biological			**45**	**89**	**1**	**33.3**	**65.9**	**0.7**
	Fire Regime OR Wildfire	Fire Condition Class	0	8	127	0.0	5.9	94.1
	Forest Cover	Loss of Forest Cover	128	7	0	94.8	5.2	0.0
	Terrestrial Invasives	Extent & Rate Spread	66	69	0	48.9	51.1	0.0
	Forest Health		88	46	1	65.2	34.1	0.7
		Insects Disease	84	50	1	62.2	37.0	0.7
		Ozone	12	122	1	8.9	90.4	0.7

[1] ***Data includes all Shared Watersheds***

Large woody debris was ranked entirely as an "Impaired Function" in all watersheds assessed in the WCF by Nantahala and Pisgah NFs. Other shared watersheds received "Functioning at Risk" rankings. The absence of large wood in stream channels resulted in impaired function of almost 90% of the watersheds in NC (Table 1). It is assumed that much of the large wood in stream ecosystems was removed from the streamside area and even from stream channels during past logging when large areas were clearcut harvested and streams were cleared of wood to facilitate the transportation of logs to the mill. Historic removal of instream wood and potential wood from the streamside area has resulted in a loss of large woody debris from the stream ecosystem in most watersheds. Although the trend is an improving one, existing amounts are currently below Forest Plan standards.

Native species information was derived from the Eastern Brook Trout Joint Venture (EBTJV), a range-wide population assessment of brook trout. The assessment identifies key threats to brook trout and their habitats and developed conservation strategies to protect, enhance and restore brook trout (http://easternbrooktrout.net). Native species was ranked entirely as an "Impaired Function" in all watersheds assessed in the WCF by Nantahala and Pisgah NFs. Other shared watersheds received "Properly Functioning" and "Functioning at Risk" rankings. Native Species resulted in the largest rating of "Impaired Function" at 90% of the watersheds in NC (Table 1). It is assumed that loss of habitat, changes in water quality from acid deposition, and the introduction and success of non-native trout species has greatly reduced brook trout populations.

Roads and trails attributes resulted in the most "Impaired Function" ratings (Table 1). This indicator addresses changes to the hydrologic and sediment regimes due to the density, location, distribution, and maintenance of the road and trail network.

Open Road Density ratings assessed road and trail miles per square mile area. Sixty-eight percent of all watersheds have open road and trail densities above 2.4 miles per square mile, and a ranking of "Impaired Function". The "Road Maintenance" attribute is related to the percentage of drainage features that are maintained in accordance with Best Management Practices (BMPs). None of the drainage features in the planning area are maintained to the standards set by NC BMPs or to the Forest Plan. There are no contracts to clean culverts and road grading does not occur as required, e.g., the roads that are graded are only graded once a year where the Forest Plan stipulates three times a year. "Proximity to Water" measured road and trail segments are located within 300 feet of a mapped stream channel. These segments were taken as a percentage of road and trail located inside the 300 foot stream buffer. Seventy-seven percent of the watersheds have greater than 25 percent of the road and trail system in the stream buffer and resulted in an "Impaired Function" ranking. This relatively high amount is attributed to system roads that were constructed decades ago, often on old railroad grades used for the transport of timber. Additionally, roads were constructed in valley bottoms where grades were relatively low and construction was less costly. Roads and trails, when constructed on slopes with geology and soils prone to movement, can result in an increased potential for land movement. Analysis characterized watersheds that had at least 10 miles of high potential to mass wasting or 20 miles of moderate potential as ranking "Impaired Function".

Extensive areas of soil contamination are present because of atmospheric deposition; sulfur and/or nitrogen deposition is above terrestrial critical load in watersheds across the planning area. Almost 93 percent of the WCF watersheds ranked "Soil Contamination" as "Impaired Function" (Table 1) due to atmospheric deposition. In contrast, "Soil Productivity" ranked "Functioning Properly" (89%) and "Functioning at Risk" (11%). In these areas, soil health may already be stressed. Trends in soil contamination from atmospheric deposition are slowly improving as air quality improves.

<u>Need statements from WCF:</u>

- Increase large woody debris in stream channels.
- Remove propagating populations of non-native aquatic species and reintroduce native brook trout.
- Reduce open road density were appropriate.
- Reduce the miles of road and trail near stream channels and reduce erosion of needed miles by improving design features and maintenance.
- Consider improving soil nutrient content where appropriate in watersheds expressing adverse effects from acid deposition.

Threats to Watershed Health

Hemlock Loss

The loss of the eastern hemlock (*Tsuga canadensis*) and Carolina hemlock (*Tsuga caroliniana*) from the southern Appalachians as a result of hemlock woolly adelgid (*Adelges tsugae*) is likely to have a notable impact on water yield, large woody debris, stream shading, and riparian composition. Annual water yield increased, in an infested Coweeta watershed, 8% and 9% for 2008 and 2009 respectively, but decreased significantly in 2011 (Brantley et al. 2011), likely due to the rapid growth response observed in co-occurring species (Ford et al. 2011). Hemlock loss also resulted in a higher frequency of high discharges

during the dormant season of October through March. Increases in peak streamflow and quick flow (amount of flow from a storm) also significantly occurred during the dormant season (Brantley et al. 2011). These results demonstrate that loss of a canopy evergreen, even in small amounts, may have significant impacts on the timing and magnitude of stream discharge and may enhance the risk of flooding during large storm events in the dormant season.

Climate Change

Shifts in rainfall patterns would lead to periods of flooding and drought that can significantly impact water resources. Increases in heavy downpours and more intense hurricanes can lead to greater erosion and more sedimentation in our waterways. Increased periods of drought may lead to decreasing dissolved oxygen content and poor water quality in some areas. Groundwater-fed wetlands such as high-elevation bogs will be particularly vulnerable to changing climate as temperature and rainfall changes have the potential to lower groundwater table levels, altering the length of time that wetlands hold standing water. (TACCIMO 2013)

Flooding & Slope Instability

Flooding of streams and rivers in the planning area is of course a natural process largely mimicking natural patterns and magnitudes. Exceptions might include watersheds with large areas of compacted surfaces such as parking lots, roofs, and roads, and where man-made impoundments are present. Flooding in western North Carolina is often the result of intense rain events derived from localized thundershowers or larger scale hurricanes. More important than the treat to watershed health is the potential for loss of life from flood events. This is discussed in the Geology Report - Geologic Hazards Assessment.

On landscapes susceptible to mass soil movement saturated soils can give way and move under the force of gravity downslope in the form of landslides and debris avalanches (read more in the Geology Section). Such events can add to the damaging effects of water alone since rocks, trees, and other debris are often incorporated in the flow. For example, debris avalanches occurred across the planning area during the 2004 hurricane derived storms. Hurricanes Frances and Ivan, in succession, produced large rainfall events and subsequently large flood stages that equated to larger than a 100-year flood or return period in drainages such as the Linville River and South Toe River, and a 500-year return period in the Pigeon River watershed. Most streams in the planning area processed these extremely high flows without notable adverse impacts to stream channels and adjacent riparian areas. Exceptions occur where channels had been previously altered by railroads, agriculture, loss of in-stream large wood, roads, developed recreation, and heavy foot-traffic areas such as dispersed recreation sites. Where stream channels remain connected to their adjacent floodplains, flood flows are not expected to be a threat to watershed health.

What watersheds provide drinking water to communities and what is their overall health?

From the national forests, drinking water is provided to seven cities or towns by either a reservoir or water diversion, four towns by a spring or well, and eight water/homeowner's associations and small farms. Approximately 67 springs and small reservoirs in the planning area provide water to individual homes, churches, camps, and a fire house.

The health of surface water sources is good from these largely protected watersheds. State assessments indicate "good" water quality where assessments were completed in the North Fork Mills River and

Mackeys Creek (Table 2). The quality or sustainability of ground water is not monitored by the Forest Service, thus little is known.

TABLE 2. Summary of water quality status of drinking water provided to large communities by the National Forest.

Community	Specific Use	County	Stream Name	State Stream Water Quality Assessment Status*
Town of Weaverville	Reservoir	Buncombe	Ox Creek	No Assessment Available
Town of Robbinsville	Reservoir	Graham	Long Creek	No Assessment Available
City of Hot Springs	Reservoir	Madison	Cascade Branch	No Assessment Available
Town of Old Fort	Reservoir	McDowell	Jarrett Creek	No Assessment Available
Town of Marion	Reservoir	McDowell	Mackeys Creek	Good
City of Hendersonville	Reservoir	Henderson	N. Fork Mills R. Bradley Creek	Good No Assessment Available
City of Brevard	Water Intake/Leaf Screen	Transylvania	Catheys Creek	No Assessment Available
Town of Highlands	Spring	Macon		Unknown
Carolina Water Service Inc.	Well/Pipeline	Yancey		Unknown
Marble Community Water System	Wells (4)	Cherokee		Unknown
Town of Santeetlah	Wells (5)	Graham		Unknown

* http://ofmpub.epa.gov/waters10/attains_state.control?p_state=NC

Is the soil and water on the Nantahala and Pisgah NFs of sufficient quality to sustain a healthy ecosystem and what are the trends?

Soil & Water Quality and Past Practices

Soil development is defined by parent material and formed by the slow process of weathering. The basic ingredients that formed soils in the mountains of NC are primarily acidic igneous rocks. These rocks are rich in silicon and aluminum but poor in the life essential elements of phosphorus, calcium, and magnesium. With high rainfall amounts vegetation growth was abundant and cycling of nutrients in the forest environment promoted a vigorous and a varied forest community (Buol, Unknown year).

With the increasing influence of human activity, the occurrence of wildfire increased as Native Americans used fire to create meadow conditions for wild game management. These activities likely caused the consumption of more forest litter and the surface soil organic layer, possibly leading to increases in soil erosion following rain storm events on steep slopes. Across the planning area however, these impacts were likely small and soil development was not impacted. With the colonization of the area by European settlers, small subsistence farms, ranches, and small towns appeared and a slight shift in land use occurred from forested to more open areas. The importance of timber to the growing United States economy in the early 1900s led to the harvest of vast timber resources in the mountains. Some of the largest impacts to the soil stability are likely to have occurred during this period of time due to the extensive transportation network needed to remove timber for processing. With heavy rains, these disturbed mountainous areas likely suffered extensive soil movement in mass as landslides and debris

flows occurred on steep and shallow soil areas. Certainly, some areas appear to have been more active than others, such as the Bent Creek drainage (USFS 2005), but evidence of landslides from a century ago appears across the landscape. As regrowth of the forest occurred and tracts of land were consolidated under federal ownership, land management practices improved and soils began to recover.

The operation of coal burning energy plants to the west brought a more silent threat to soil quality as prevailing winds delivered elevated levels of sulfur and nitrogen that fell as acid rain on the naturally acidic soils. Once in the soil, sulfur and nitrogen attached to calcium, magnesium, and phosphorous (cations), and restricted these important nutrients from vegetation uptake. Where soils had abundant amounts of cations they are considered to have a high "buffering capacity" to the adverse effects of the sulfur and nitrogen, and were impacted the least. However, over time, the loss of cations was extensive and the soil's ability to effectively buffer incoming levels of acid was diminished. Consequently, soils became more acidic and within these watersheds ground water and surface water in streams and reservoirs likely became more acidic. Regulations on coal energy plant emissions began in the 1970s and steady reductions in sulfur and nitrogen emissions were established. In many watersheds damage to soils had already been done and soils will not likely recover for centuries. What this means to soil productivity is difficult to determine since reference soil nutrient conditions do not exist. Plant composition may have shifted to favor rhododendron, but this was more likely a result of historic clearcut harvesting. Plant growth does not seem to show notable degradation of soil productivity.

Forest Management Impacts on Soil Quality

Extensive logging in the early 1900s, resulted in an extensive network of skid and haul roads on the landscape. Overtime many of these roads were abandoned; some were closed while others left to stabilize on their own. The stabilization of these "old woods" roads has been an ongoing effort of the Forest Service since the land was acquired to reduce erosion and improve soil productivity. Areas of soil compaction, such as on these old woods roads, continue to improve as compaction is reduced by natural processes, such as frost heave and disturbance by roots and ground dwelling animals, thus slowly improving soil productivity.

Soil disturbance can occur as a result of heavy equipment use during logging. Areas of concentrated use, such as log landings and skid roads are most affected. Compaction of these areas would increase the bulk density of the soils and result in a decrease in pore space, soil air, infiltration rate, and the water holding capacity of the soils and would increase water runoff. These effects are considered detrimental to plant growth. The degree and depth of compaction depends on the number of passes the equipment makes and the moisture content of the soil at the time the passes are made. Changes in pore space do not normally occur on well-drained soils, such as those that occur over most of the planning area, until three or more passes have occurred.

The effects of timber sale activities and system and temporary road development on soil resources in the planning area can be described in terms of short and long term effects on the productivity of the soils. Short-term effects are those effects lasting three years or less, and are associated with the recovery period in which disturbed soils become reestablished with vegetative cover. Short-term effects imply that the existing soil profile is left intact. Surface disturbances, such as displacement of vegetation over a small area of ground, are the primary impacts. Such a disturbance has been noted during soil quality monitoring from typical skid trails. In contrast, long-term effects are associated with activities that displace the upper portions of the soil profile (topsoil) or alter soil structure, e.g. compaction. Many years are needed for the soil to recover its original productivity when the surface layers are removed.

The Forest Service is directed by national policy (per FSH 2509.18 – Soil Management Handbook, Chapter 2, Soil Quality Monitoring) to: 1) Design and implement management practices to maintain or improve the long-term inherent productive capacity of the soil resource. 2) Plan and conduct soil quality monitoring to determine if soil management goals, objectives, and standards as outlined in Forest plans are being achieved. 3) Use the results of monitoring to evaluate resource management actions and recommend adjustments to practices or mitigation measures to prevent significant impairment of long-term soil productivity.

Important factors considered in evaluating effects to soil resources are the extent of the area where long-term soil productivity might be impacted. Effects to the soils from projects are considered not significant when 85 percent of the activity area is unaffected and retains its potential long-term soil productivity (Forest Service Handbook, R8, 2509.18.2.2, Soil Quality Standards). In other words, no more than 15 percent of the activity area and each individual harvest unit are affected and lose potential long-term soil productivity.

Soil Quality Monitoring (SQM) was conducted on the Nantahala and Pisgah NFs using the Forest Soil Disturbance Monitoring Protocol (Page-Dumroese et al. 2009). The monitoring was done to determine if there was significant change in land productivity due to timber harvest activities. “Significant change” is defined as detrimental soil disturbance exceeding 15 percent of each individual harvest unit.

A summary of the 2009 - 2012 SQM is presented in Table 3. All timber sale units surveyed were predominantly ground-based harvested and had some degree of detrimental soil disturbance. Only two units were found to have disturbance above the significant level. The detrimental soil disturbance found in Farmers Branch Timber Sale in harvest Unit 4 in 2010 (15.7 percent detrimental disturbance) was mitigated in 2011 by subsoiling detrimentally compacted soils on skid roads and landings (Figure 2). Detrimental soil disturbance in this unit is now well below the 15 percent standard and land productivity has been restored too much of the area. Likewise, Eagle Fork Timber Sale Unit 2, determined to have a detrimental soil disturbance of 16.3 percent in 2009, was also mitigated in 2012 (Figure 2), bringing the detrimental soil disturbance in this unit well below the 15 percent threshold. Several units, surveyed pre-harvest in 2009 and 2010, were resurveyed in 2011 following logging. Although an increase in disturbed area occurred from pre-harvest, the units surveyed maintained appropriate soil productivity.

Table 3. NFsNC 2009 - 2012 Soil Quality Monitoring Results with Detrimental Soil Disturbance.

					Percent Detrimental Soil Disturbance		
Forest	**Timber Sale**	**Unit #**	**Pre-harvest (Pre) or Post-harvest (Post)**	**Unit Area (acres)**	**Skid Roads & Landings**	**Other within Unit**	**Total**
Pisgah	Baldwin Gap	2	Post	11	9.4	0	9.4
		3	Post	27	3.2	0	3.2
		8	Post	23	9.1	0	9.1
Pisgah	Case Camp	3	Post	13	9.2	1.6	10.8
		6	Post	8	2.5	0.1	6.2
		8	Post	12	1.7	3.3	5
Pisgah	Shope Creek	23-12A	Pre/Post	12	4.7/9.3	0/2.2	4.7/10.9
		23-13	Pre/Post	9	1.2/2.5	0/0	1.2/2.5
		23-12B	Pre/Post	6	0/5.0	0/0	0/5.0

Pisgah	Mulberry Globe	2	Post	37	0.3	0	0.3
		3	Post	22	12.3	0	12.3
Pisgah	Pressley Fields	1	Post	17	1	0	1
		2	Post	11	3.5	0	3.5
		3	Post	2	10	0	10
		7	Post	16	8.2	0	8.2
Pisgah	Stateline	1	Post	30	7	0	7
		2	Post	19	11	0	11
Nantahala	Eagle Fork	1	Post	25	2.4	0	2.4
		2	Post	16	16.3	0	16.3
		3	Post	25	9.6	1.4	10.8
Nantahala	Locust Cove	1	Post	10	0.7	0	0.7
		2	Post	18	1.1	3.2	4.4
		3	Post	17	0.5	0	0.5
Nantahala	Slipoff	8	Post	8	4.4	3.1	7.5
		10	Pre/Post	24	0.3/3.6	0/3.3	0.3/7.0
		11	Pre/Post	19	0/6.3	0/0	0/6.3
Nantahala	Farmer Branch	1	Pre	25	0.6	0	0.6
		2	Post	20	3.2	0	3.2
		3	Post	10	6.5	0	6.5
		4	Post	14	15.7	0	15.7
		5	Post	18	9.8	0	9.8

Overall, timber harvest activities are not having significant changes in land productivity relative to soil quality. Monitoring determined that the Nantahala and Pisgah NFs have met the soil quality performance standard in 94% of the Post-harvest units surveyed between 2009 and 2012. It appears that the Nantahala and Pisgah NFsare successfully designing and implementing the extraction of timber to minimize soil disturbance, specifically minimizing excavated skid roads and the size of log landings. In the two cases where detrimental soil disturbance exceeded the standard level, mitigation of the soil disturbance has been completed. Thus, corrective action is being taken to put the Nantahala and Pisgah NFs into 100% compliance with the 15% standard in these surveyed units, and thus soil quality is being maintained to sustain a healthy ecosystem.

Figure 2. Farmers Branch Timber Sale in harvest unit 4 (left) and Eagle Fork Timber Sale Unit 2 (right) subsoiling to reduce soil compaction and detrimental soil disturbance from skid roads and landings.

Forest management is influenced by various soil and site related factors and considerations. Steep to very steep slopes, stoniness, and bedrock outcrops are common management limitations or hazards in much of the planning area. Highly erodible micaceous soils (widely scattered in gneiss/schist areas) and soils from steeply dipping, thinly bedded metasedimentary rocks such as phyllite are unstable when disturbed by deep cuts. Another hazard is the potentially harmful acid production that could occur when substrata high in sulfides are exposed during excavation.

Landslides or debris avalanches are sporadic but catastrophic occurrences in mountainous terrain. Such events generally occur during periods of long-duration and/or high-intensity rainfall, which create saturated soil conditions. Slides can occur irrespective of geologic type, vegetative cover, or prior site disturbance. However, they are most commonly associated with shallow to moderately deep soils on sustained slopes greater than 50 percent (usually greater than 70 percent at the point of break) and steeply dipping bedrock of metasedimentary origin. Management activities, such as road building, that involve displacement of soil and substrata materials, may change slope stability by removing lateral support and interrupting the internal movement of soil water. A review of damage from hurricanes Frances and Ivan from 2004 and the more recent storm of January 2013 on the Nantahala NF confirm this to be true since roads were the major cause of landslides in the planning area.

However, if soil disturbance is minimized, timber harvesting and other vegetative management practices seem to have little effect on slope stability. Landslides are not often triggered by silvicultural treatments in the Appalachian Mountains because of the living root system of the hardwood-conifer forests (Neary et al. 1986). Rapid re-vegetation from these roots maintains the stability of the soils and a relatively rapid return to pre-harvest hydrologic conditions (Swank et al. 2001). Since the loss of moisture through evaporation from the soil and transpiration for plants (evapotranspiration) is less immediately following harvest, soil moisture will increase. The growth of non-woody vegetation is stimulated, and growth/regrowth of woody vegetation from both seeds and stump sprouts is rapid.

Forest Management Impacts on Water Quality

Timber Harvest & Nutrients

Research at Coweeta Hydrologic Lab in western NC determined that soil nitrogen (N) availability and stream nitrate (NO_3 –N) increased following clear cut logging. Since harvest in the late 1970's, nitrogen concentrations remain elevated (Clinton 2011) in the Coweeta watershed. These new levels are attributed to changes in vegetation that has altered the nutrient cycling patterns of the watershed. In the Ray Branch Study on the Nantahala Ranger District, Coweeta (Clinton 2011) documented the importance of streamside zones to help buffer increases in nutrient delivery to streams. See the "Riparian Areas" section for more information.

Timber Harvest Water Yield & Sediment

In recently harvested areas in the planning area, there exists an elevated risk to stream channels from flooding since the removal of trees reduces water loss from the soil. Following vegetation removal, the soil saturates quicker during a storm event and stays saturated longer, thus more water is available to move to streams and at a faster rate than if the preexisting vegetation remained. Streamflow from the Coweeta watershed study (Swank et al. 2001) experienced a 28% increase during the first year following clearcut harvest of the entire watershed. With a rapid recovery of vegetation, streamflow returned back to pre-harvest within six years (Swank et al. 2001). The larger increases in streamflow occurred in the low flow months of August to October, and initial flow and peakflow rates also increased. Coweeta's results are considered typical for much of the planning area. Increases in flow during stream lowflow periods would be beneficial to aquatics; however peakflow increases may be a concern where channels are not stable due to infrequent woody debris or disconnection from floodplains. In both cases, increased flow energy could scour stream bed and banks. Sediment yield from Coweeta roads was greatly reduced during logging and yields were insignificant after logging. Still, it took 15 years for the majority of road derived sediment to move out of the watershed stream system.

Existing Forest Plan standards have done well to mitigate potential adverse effects of short-term increases in peakflow. The establishment and management of Management Area 18 - Riparian Protection Areas (MA-18) under the current Forest Plan are instrumental in this. These areas are managed only for the benefit of riparian and aquatic ecosystems. Where stream channels are present within a harvest unit, MA-18 buffers streams from potential adverse effects from increases in streamflow. Swank et al. (1989) found that where areas that were not harvested (leave strips) along streams are in place, vegetation partially utilizes the extra soil water from the harvested area, and thus diminishes streamflow increases.

On the Nantahala, Pisgah and Uwharrie NFs between 2009 and 2013, Forestry BMPs were monitored to determine whether or not BMPs were implemented and effective at controlling sediment and other pollutants during timber sale and road reconstruction and maintenance activities. One hundred two harvest units and 70 roads from 25 different timber sales were selected for the reviews. Specific BMPs were selected from the *Nantahala Pisgah Land and Resource Management Plan*, the *North Carolina Forest Practice Guidelines Related to Water Quality Regulations* and the 7730/2520 letter dated November 28, 1990, "*Specified Road Construction and Water Quality*."

A total of 1,964 individual BMPs were checked over the last five years for implementation and effectiveness. Of these, 1,186 BMPs were related to sediment delivery to streams. By determining implementation rates, the Forest Service is attempting to answers the question, "Have the rules been properly applied?" By determining effectiveness, the Forest Service is attempting to answers the

question, “Were the rules effective in preventing sediment or other pollutants from impacting water quality?”

The overall implementation rate was 94.8% (1,861 out of 1,964 times the practice met or exceeded the BMP rules) (Table 4). In 63 instances (3.2%), there was a minor departure from the rules; 35 times (1.8%) there was a major departure from the rules and five times (0.3%) there was a gross departure from the rules. The overall effectiveness rate was 95.3 %; 1,871 out of 1,964 times the practice prevented the pollutant from impacting water quality. In 53 instances (2.7%), there was a minor or temporary impact to the stream. Twenty-eight times (1.4%), there was a major short-term impact that requires corrective action. Twelve times (0.6%), there was a major long-term impact. The 12 “major long-term impact” ratings were related to legacy system road problems and fish passage obstructions. These identified problems all preceded the timber sale activities.

The last observation was to determine if visible sediment was entering streams. In 1,146 of 1,186 BMP checks (96.6%), sediment was not entering the stream channel. In 35 instances (3.0%), non-critical visible sediment reached the stream and five times (0.4%) critical visible sediment flow reached the stream channel.

Table 4. Forestry Best Management Practices implementation and effectiveness monitoring summary for 2009-2013 data.

BMP Category (2009-2013)	Implementation				Effectiveness					Visible Sediment[1]		
	Meets or Exceeds	Minor Departure	Major Departure	Gross Departure	Improvement Over Past	Adequate Protection	Minor/Temp. Impact	Major Short-Term Impact	Major Long-Term Impact	No Visible Sediment	Non-Critical Visible	Critical Visible
Harvest Area Including Skid Trails/Log Decks	97.8%	1.7%	0.6%	0.0%	0.1%	97.5%	2.0%	0.5%	0.0%	99.7%	0.3%	0.0%
Skid Trail Stream Crossings	92.9%	5.1%	2.0%	0.0%	5.1%	88.8%	4.1%	2.0%	0.0%	92.3%	7.7%	0.0%
Roads	93.1%	5.0%	1.2%	0.7%	0.7%	94.0%	3.3%	1.2%	0.7%	94.6%	4.3%	1.1%
Road Stream Crossings	88.5%	5.1%	5.9%	0.5%	0.0%	89.5%	3.8%	4.3%	2.4%	92.6%	6.6%	0.8%
Total Percent	**94.8%**	**3.2%**	**1.8%**	**0.3%**	**0.5%**	**94.8%**	**2.7%**	**1.4%**	**0.6%**	**96.6%**	**3.0%**	**0.4%**

[1]A non-critical amount of visible sediment is a low volume, short term sediment source that does not adversely affect aquatic habitats. A critical amount of visible sediment is a large volume, which may be deposited over a long term. The component structure of the stream is altered, which adversely affects aquatic habitats. A stream that has a critical sediment source is obvious, even to the casual observer.

Implementation and effectiveness rates for the BMP category *Harvest Area Including Skid Trails/Log Decks* was 97.8 and 97.6%, respectively (Table 4). This is a very good implementation and effectiveness rate that indicates the application of BMPs is working in this category and sediment or other pollutants are generally not reaching streams (Figure 3).

Figure 3. Successful skid trail stabilization on the Baldwin Gap Timber Sale, Pisgah Ranger District.

Implementation and effectiveness of BMPs in the category *Skid Trail Stream Crossings* was 92.9 and 97.6%, respectively (Table 4). Non-critical visible sediment was delivered to the stream 7.7% of the time. Critical visible sediment was never observed coming from skid trails. Because it is difficult not to contribute some sediment to the stream with skid trail crossings, these practices are avoided to the extent possible during timber sale planning.

The 2009-2013 Forestry BMP monitoring was compared to BMP implementation and effectiveness monitoring done between 1992 and 2000 (Table 5). The difference in BMP implementation, effectiveness and visible sediment between these two data sets is substantial. BMP implementation improved from 68.1 to 94.8% while BMP effectiveness improved from 73.3 to 95.3%. Visible sediment delivery to streams declined from 19.3 to 3.4% of the practices.

Table 5. BMP monitoring summary data comparing Forestry BMP implementation and effectiveness monitoring on the NFsNC done between 1992-2000 and 2009-2013.

BMP Monitoring Period	Implementation				Effectiveness					Visible Sediment		
	Meets or Exceeds	Minor Departure	Major Departure	Gross Departure	Improvement Over Past	Adequate Protection	Minor/Temp. Impact	Major Short-Term Impact	Major Long-Term Impact	No Visible Sediment	Non-Critical Visible	Critical Visible
1992-2000 Total	785	310	56	2	5	833	219	83	3	435	84	20
Percent in Class	68.1%	26.9%	4.9%	0.2%	0.4%	72.9%	19.2%	7.3%	0.3%	80.7%	15.6%	3.7%
2009-2013 Total	1861	63	35	5	9	1862	53	28	12	1146	35	5
Percent in Class	94.8%	3.2%	1.8%	0.3%	0.5%	94.8%	2.7%	1.4%	0.6%	96.6%	3.0%	0.4%

From the information collected and analyzed over the last five years it is evident that the Nantahala and Pisgah NFs are implementing BMPs during timber sales that are effective in protecting streams and water quality. There has been a dramatic improvement in BMP implementation and effectiveness and a decrease in sediment delivery to streams since the last decade of BMP monitoring. It is expected that this improving trend will continue with the design of new and more effective practices, such as the placement of logging slash on skid trails/roads and the use of temporary bridge crossings of streams.

Prescribed & Wild Fire

Fire has proven to be an effective tool for maintaining and restoring ecosystems of the Natahala and Pisgah NFs (Clinton et al. 1998, Elliot et al. 2004), although it does not come without its challenges. Unless properly managed, fire can have adverse effects on soil and water where the forests litter and humus layers are consumed, exposing mineral soil.

In Macon County, NC on the Blue Valley Experimental Forest, Clinton et al. (1998) found the consumption of litter and humus layers (duff layer) on the forest floor was positively correlated with flame temperature during an understory burn in a mixed white pine-hardwood stand. Over all stands, 50 percent of the mass in small wood and litter was lost during burning, and 20 percent of the humus layer was consumed. The humus layer is an important nutrient reservoir for plant growth. Maintaining this layer through careful selection of burning conditions minimizes losses during burning and maintains long-term site productivity (Clinton et al. 1998). Burned areas are most vulnerable to surface erosion immediately post-fire and during extreme rainfall events (Elliott and Vose 2006).

Fire and Soil Erosion

When mineral soil is exposed by fire the potential for soil erosion is increased, however this is not typically the case. Swift et al. (1993) found little to no erosion after light to moderate intensity fires in the southeastern U.S. Twenty three percent of the burned surfaces were covered by new growth and 62 percent by residual forest floor and woody debris at the end of the first growing season. On the Appalachian Ranger District, the Burned Area Emergency Response assessment of the Stoney Fork Wildfire of 2010 (USFS 2010b) also identified very little disturbance to the forest duff layer due to the low residence time of the fire in one give area. Exceptions were observed only where logs burned and retained heat for a longer time resulting in a localized loss of the duff layer, but in most cases the deeper organic duff layer remained intact. At no time were soils found to have hydrophobic characteristics.

Under more extreme fire conditions observed in the Linville Gorge following the Pinnacle Fire on the Grandfather Ranger District much of the burned area experienced overstory mortality, consumption of the duff layer, exposed mineral soil, and localized hydrophobic soil conditions (USFS 2010c). The burned area was treated with an aerial application of grass seed and lime (550 and 350 acres, respectively) (USFS 2007a). Because of drought conditions following the fire, grass seed did not germinate, but the site reestablished with natural regeneration within a 2-year period without notable soil erosion (Figure 4). The overwhelming success of natural revegetation may be attributed to the liming treatment since it was found to improve the cation depleted soils (USFS 2010c).

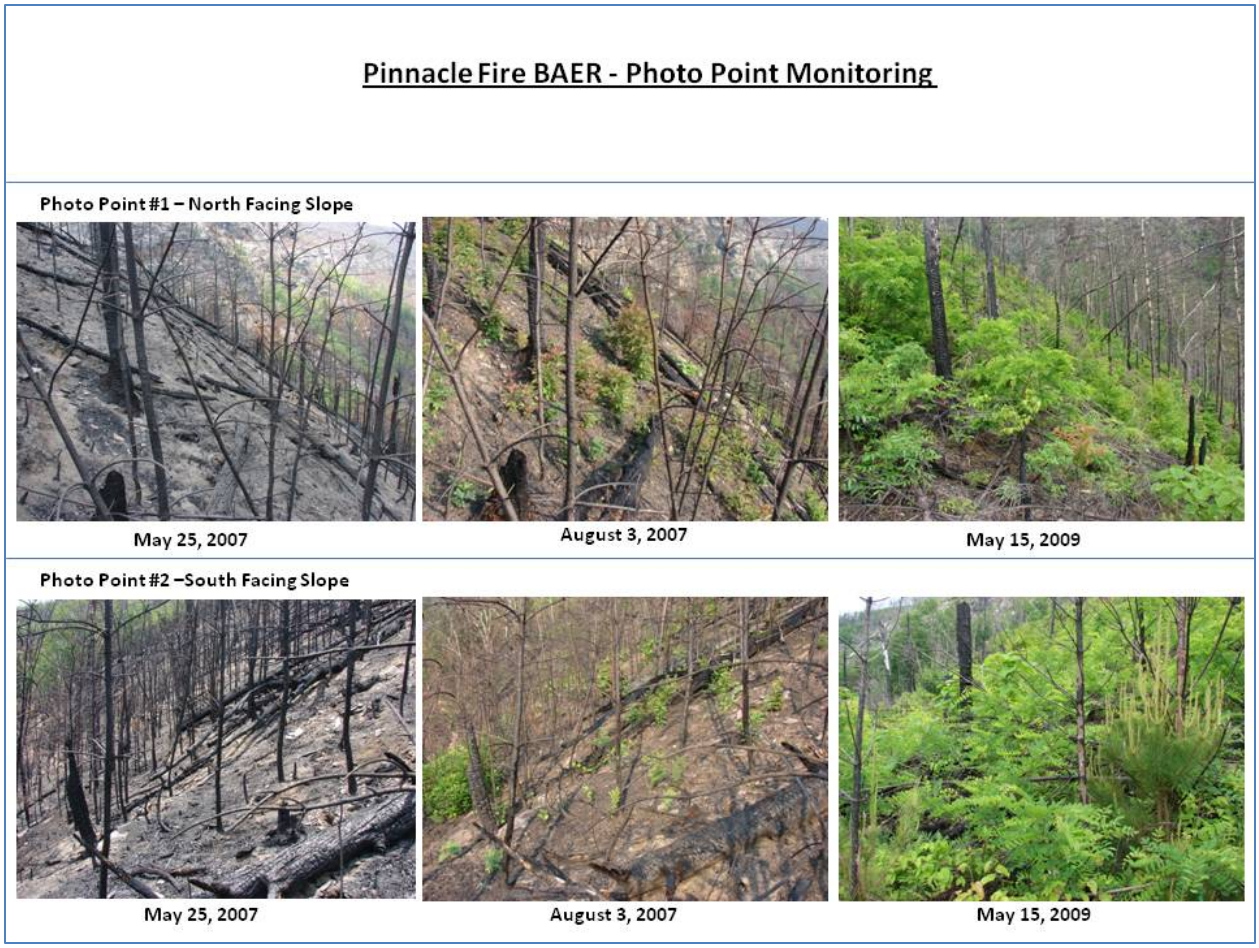

Figure 4. Extreme fire conditions observed in the Linville Gorge during the Pinnacle Fire, spring 2007 on the Grandfather Ranger District, summary of photo monitoring.

Burns with previous soil disturbance may be more at risk than soils that have only been burned. (Swift et al. 1993). Prescribed fire uses fire breaks or firelines to contain the fire. Often, existing roads, old firelines, and natural barriers (riparian areas, waterbodies, and rock outcrops) are used when available. However, new fireline construction by blading or plowing around recently regenerated or privately owned areas may be needed to protect lives and investments from prescribed burning activities. Fireline construction and reconstruction using heavy equipment exposes a relatively wide area of mineral soil by removing vegetation and the organic layer; therefore, it is used only as necessary.

Fireline constructing by hand is often implemented to minimize soil disturbance. Handline construction in the southeast typically involves the scarification of the surface leaf litter layer using fire rakes and leaf blowers. Thus the disturbance of the mineral soil is often minimal when handline is constructed. Often streams are used as fireline and are sometime cleared of woody debris that might carry fire. This clearing and cutting of brush and woody debris rarely would result in increases in sedimentation, but may reduce benefits to streams from woody debris.

Firelines can recover quickly when they accumulate litter from a forest canopy and/or treated with erosion control measures to control concentrated flow and reduce soil exposure through revegetation efforts. Firelines that are needed for frequent or regular burning cycles are best designed and maintained on the landscape to provide for both long-term use and ability to control concentrated flow and erosion, while keeping soil disturbance to a minimum. Designs often employ relatively permanent drainage features such as drainage dips, water bars, reverse grades, out-sloping and lead-off ditches along with reinstalling and maintaining of other erosion control measures.

Fire and Nutrients

Fire can alter the nutrient cycle and have both short- and long-term effects (Knoepp et al. 2004). Nutrient availability of forest soils is often limited and relies on the internal cycling of nutrients to sustain plant growth (Knoepp et al. 2004). Prescribed fire alters the cycle by consuming woody fuels and forest floor, potentially changing the quantity of materials and the patterns of nutrient release. Forest conditions including; community composition, site moisture regime, and fuel loads, influence forest ecosystem responses to burning, and also determine fire intensity and severity (Knoepp et. al. 2009). Fire intensity is defined as the amount of energy or heat release per unit time or area during the consumption of organic matter (Keeley 2009), and is an important factor in determining ecosystem response to prescribed burn.

In the southern Appalachians on the Nantahala NF, Knoepp et al. (2004) and others (Vose et al. 1997, Clinton et al. 1998, Swift et al. 1993, Vose and Swank 1993) studied the effects of a fell (slash) and burn treatment in mixed pine/hardwood ecosystems occupying dry xeric sites. The prescribed burn was designed to restore the pine/hardwood ecosystem, and fire intensities ranged from low to high in the study area. Findings include increased exchangeable calcium and magnesium concentrations, soil pH, and nitrogen availability after treatment. Losses of nutrients via leaching were minimal and were not expected to limit future site productivity or diminish stream water quality (Knoepp et al. 2004 and Clinton et al. 2003).

Elliot et al. (2004) studied the effects of understory burning in a moist mesic mixed-oak stand in the southern Appalachians on the Nantahala NF. A single, dormant-season fire with a low to moderate intensity was conducted in a cove-hardwood forest. Overstory mortality occurred in 55% of the trees, predominantly those <10 cm at diameter breast height (DBH) and no trees >20 cm DBH were killed, and all the understory aboveground stems were killed. This study found that burning significantly reduced the total forest floor mass, carbon, and nitrogen of both the surface litter layer and duff layer. Soil nutrient availability increased after the burn, but diminished to no significant difference after one year compared to the control area. Elliot et al. (2004) concluded that a moderate intensity understory burn may be a useful tool to restore mixed-oak communities without detrimental effects on forest floor mass or nutrient pools.

Knoepp et al. (2009) studied prescribed fires in the same area as Elliot et al. (2004) and found that low intensity prescribed fire generally removes the litter layer, but retains a large portion of the duff layer. The reservoir of plant nutrients was retained on the site and the soil surface was protected from erosion. Knoepp et al. (2009) reported that available soil nitrogen increased and inorganic nitrogen was

lost from the ecosystem through leaching. Still, they concluded that the low intensity, low severity prescribed fires applied to these mesic mixed-oak sites produced beneficial impacts.

Clinton et al. (1998) studied the effects of understory burning in a mixed-white pine-hardwood stand in the southern Appalachians on the Nantahala NF. Fire intensity and severity were both moderate. Fifty percent of the small wood and litter mass was consumed, and 20 percent of the humus (duff) layer was consumed. Clinton et al. (1998) concluded that burning conditions that produced a more intense and less severe fire would conserve more of the humus layer and associated nutrients.

Prescribed burns that have low residence time on the forest floor conserve more of the humus or duff layer and associated nutrients, benefiting the site by a slight, transitory release of plant essential nutrients (Clinton et al. 1998). Fire managers recognize the importance of this pool of nutrients when burning, and design prescriptions that minimize consumption of site nutrients and maintain long-term site productivity.

Watershed Improvements

Over the past planning period, thousands of acres of watershed improvements have been accomplished in the planning area. These projects stabilized soil erosion and reduced sources of human-caused sediment in numerous watersheds. It is likely that many tons of soil were stabilized that would have otherwise been eroded away and entered the stream network, where it would have adversely affected water quality and aquatic habitat. Watershed Improvement (WI) projects in the planning area have stabilized old eroding roads and trails by decommissioning and closing access to illegal motor vehicle traffic. Forest System roads and trails were also closed including the Upper Tellico Off-Highway Vehicle Area that was closed and rehabilitated in 2009 and 2010. Benefits from this work are still being assessed, but sediment yields to streams have been dramatically reduced (Jones 2010 and USFS 2011b). The hurricanes of 2004 (hurricanes Frances and Ivan) were the catalyst for numerous WI projects across the planning area including landslide stabilization, road and trail improvements and decommissioning, and stream bank stabilization mostly in recreation areas and along road corridors.

Storm damage from 2004 flooding resulted in 12 stream locations and about 4,000 feet of stream channel requiring rehabilitation work. These stream reaches were estimated to produce 464 tons of sediment per year because of bank erosion (USFS 2011a). Relative to natural rates of erosion, this rate was high and increased the risk of adverse impacts to protected existing uses. Following the rehabilitation of those sites, the rate of erosion and sediment delivered to streams decreased by an order of magnitude to an estimated 41 tons per year, a more natural rate of erosion. These larger projects along with the annual WI program of work (totaling from 200 to 500 acres per year of improvements) have taken great strides to improve water quality on Forest Service lands and cumulatively downstream.

Current Forest Plan guidance, in reference to stream rehabilitation, is to “Provide structural habitat improvements” and “Give priority to use of native materials and mimic naturally occurring structures”. This guidance is generally consistent with the latest stream channel design techniques that employ using reference stream conditions to reestablish natural function. The Nantahala and Pisgah NFs has designed

and implemented numerous stream rehabilitation projects using natural channel design techniques. Such techniques design structures and channels that simulate the natural function of boulders and logs, and restore the dimension, pattern, and profile of stable, reference streams of the same stream type, defined by Rosgen (1996). Structures have been installed in streams using boulders and trees to mimic flow deflectors and pool creators (Figure 5). Tall eroded stream banks have been laid back to stable slopes and vegetated with transplants and native grasses and trees and shrubs (Figure 6). Water quality, aquatic habitat, and riparian areas have been improved largely in stream reaches adversely impacted by roads and recreation. Over the past planning period we have done well to meet the existing standard to "Use habitat restoration, improvement, and reintroduction to re-establish or expand native species populations and diversity" (USFS 1994).

Figure 5. Example of stream rehabilitation project at Bent Creek, Pisgah Ranger District using natural channel design techniques that simulate natural function. Photos of before and after construction.

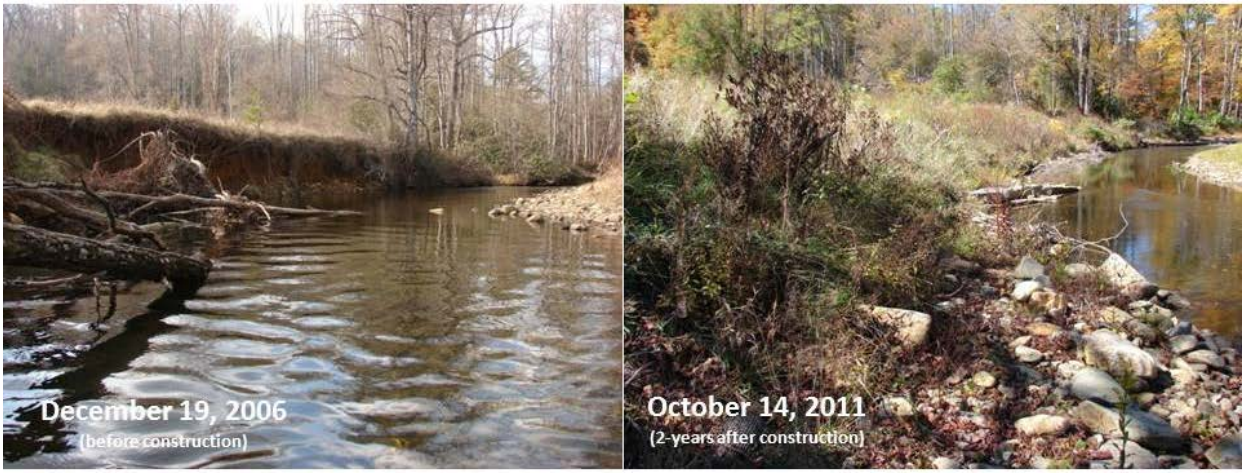

Figure 6. Example of stream rehabilitation project at North Fork Mills River, Pisgah Ranger District using natural channel design techniques to stabilize a long eroded stream bank and create a high quality pool habitat. Photos of before and after construction.

Riparian Areas

Since implementation of the existing Forest Plan, riparian and adjacent areas of influence (streamside zones) are removed from the harvestable timber base as a Riparian Management Area (MA-18) where "…timber management can only occur in this area if needed to maintain or enhance riparian habitat values." Thus, activities are to benefit the form and function of the riparian area. Such activities have included the harvest of plantations of white pine and the subsequent planting of a diverse species composition, and the cutting and herbicide treatment of rhododendron, e.g., Baldwin Gap Timber Sale, Pisgah Ranger District, to improve vegetation diversity of the riparian area.

Over the years, Forest Plan monitoring has evaluated the implementation and effectiveness of forestry practices to meet the Forest Plan standards to enhance riparian values, e.g., preventing sediment and maintaining stream temperatures. Table 6 summarizes forestry BMPs monitoring from the past 20 years (with some data gaps). Specifically, six of 44 reviewed BMPs were selected as a sub-set to characterize the protection of riparian areas (Table 6) and address the Forest Plan Monitoring Question "Are directions and standards being met for riparian areas?" The past five years of monitoring from 2009–2013 shows a 97.9 percent implementation of BMPs and a 98.1 percent effectiveness rating of meeting riparian area standards and directions. Comparing the 1992-2000 and 2009-2013 monitoring data seems to reveal an improving trend in the implementation and effectiveness of BMPs; a testimony to improved pre-harvest planning and administration of contracts during logging operations. Additionally, sediment delivery to streams has been notably reduced.

Table 6. Number of harvest units by category of "Implementation", "Effectiveness", and "Visible Sediment" for selected Forestry BMPs used to characterize the protection of riparian areas relative to forestry activities surveyed in 1992-2000 (in parenthesis) and 2009-2013.

Riparian Rule (BMP)	Implementation				Effectiveness					Visible Sediment		
	Meets or Exceeds	Minor Departure	Major Departure	Gross Departure	Improvement Over Past	Adequate Protection	Minor/Temp. Impact	Major Short-Term Impact	Major Long-Term Impact	No Visible Sediment	Non-Critical Visible	Critical Visible
HARVEST AREA INCLUDING SKID TRAILS/LOG DECK												
3. Barriers Used if W/I 300ft P/I Channel	(31) 85	(24) 2	(4) 0			(42) 86	(11) 1	(6) 0		(50) 87	(5) 0	(2) 0
4. Drainage not to Stream Channel	(114) 100	(11) 2	(3) 0			(115) 100	(8) 2	(5) 0		(121) 101	(5) 1	(2) 0
5. No Skidding in Ephemeral Channel	(6) 99	(4) 1	(1) 0			(6) 99	(2) 1	(3) 0		(7) 100	(1) 0	(1) 0
6. Shade Strips in Place	(15) 86	(5) 3	(4) 1			(15) 86	(6) 3	(3) 1				
7. No Logging Debris in P/I Channel	(3) 95	(4) 0	(2) 0	(1) 0		(3) 95	(4) 0	(2) 0	(1) 0			
9. Violation W/I MA-18 (SMZ)	(3) 94	(10) 2	(1) 1			(5) 94	(8) 2	(1) 1		(9) 97	(5) 0	
Total	**(172) 559**	**(58) 10**	**(15) 2**	**(1) 0**	**(0) 0**	**(186) 560**	**(39) 9**	**(20) 2**	**(1) 0**	**(187) 385**	**(16) 1**	**(5) 0**
Percent in Class	**(69.9%) 97.9%**	**(23.6%) 1.8%**	**(6.1%) 0.4%**	**(0.4%) 0.0%**	**(0.0%) 0.0%**	**(75.6%) 98.1%**	**(15.9%) 1.6%**	**(8.1%) 0.4%**	**(0.4%) 0.0%**	**(89.9%) 99.7%**	**(7.7%) 0.3%**	**(2.4%) 0.0%**

A study by Clinton et al. (2010) on the Nantahala Ranger District suggests that at a distance of 33-66 feet from the stream, transitions occur that separate riparian from upland conditions. In the Ray Branch Study on the Nantahala Ranger District where skyline or cable-yarding technology was used, Clinton (2011) studied the effectiveness of stream side buffers. He found that soil Nitrogen (N) availability had increased in the two-age harvest areas, and stream side buffers as small as 30 feet wide were effective at preventing N movement to streams compared with pre-harvest levels. Where the harvest did not leave a buffer width an increase in stream N did occur, although amounts were well below EPA drinking water standards. Stream nitrate concentration (NO3 –N) increased two-fold during both base and stormflow following harvest, and all base cations, like calcium and magnesium, increased in concentration. Stream nitrate concentrations on the no-buffer site showed steady decline with time following the initial post-harvest increase (Clinton 2011). A small increase was noted in suspended sediment, and stream temperatures were slightly elevated in the no buffer stream. Consequently, where cable-yarding techniques are used, 30 feet wide buffers may afford effective protection from timber harvesting activities with respect to stream water chemistry, sediment, and temperature.

Trends in riparian area diversity are improving where a diversity of tree and understory species exists. These areas have been mostly excluded from harvest over the past planning period because of Management Area 18 designation and thus are maturing and providing natural riparian function. In

many areas experiencing the loss of hemlock to wooly adelgid infestation, hemlock will be replaced by a mix of hardwood species (maple, oak, birch, and beech) where establishment is not limited by rhododendron (Ford et al. 2011). However in areas where vegetation composition is predominantly hemlock with an understory of rhododendron, trends in riparian habitat diversity are likely to decline. The remaining rhododendron would dominant vegetation composition in these stands because of the exclusive nature of the rhododendron (Clinton 2003).

Trends in large woody debris in stream channels are improving where a diversity of tree and understory species exists in the streamside area. However, in areas where vegetation composition is predominantly hemlock with an understory of rhododendron, trends in large woody debris are likely to have a short-term improvement, followed by a long-term decline. As the dead hemlocks decompose there would be an influx of new wood into the channel, thus a short-term improvement, but when these trees are gone the remaining rhododendron would thereafter dominant vegetation composition.

Cutting and treatment of rhododendron, where it dominates the riparian area, has occurred in a few areas in the planning area, such as the approximately quarter-acre plot on Baldwin Field Branch, Pisgah Ranger District. Treatment was followed by the planting of a mix of native riparian species, e.g., tag alder, sweetshrub, clethra, etc., to supplement the existing tree species. No adverse effects to available nutrients are expected from these treatments since rhododendron thickets play a relatively minor role in controlling nutrient export to headwater streams (Yeakley et al. 2003). However, potential stream temperature changes and bank stability must be considered in the design of these projects since rhododendron provide shading and root holding strength to a bank.

What geology and soil resources occur across Nantahala and Pisgah NFs?

Geology

The Nantahala and Pisgah NFs are within the mountain belt of the Blue Ridge physiographic province. This belt consists mostly of igneous and metamorphic rocks, and small areas of sedimentary rock on the western margins (Trapp and Horn 1997). These rocks are crystalline, high in mica content, crystalline rocks low in mica content, and metasedimentary rocks (Sherrill, Unknown year).

Crystalline rocks, e.g. mica schist and mica gneiss, high in mica content typically produce soils and weathered rock (saprolite) high in mica content. Such soils erode easily and are difficult to compact when used as earthen foundation material. Micaceous rock tends to weather deeply, commonly extending tens of feet below the soil surface (Sherrill, Unknown year).

Metasedimentary rocks generally are composed of thin beds that dip at some angle from the horizontal. When slopes parallel the bedding dip, soils are very susceptible to landslides (Sherrill, Unknown year). Numerous landslides occurred across the planning area within the last decade, including those from the 2004 hurricane storm events (e.g. Peaks Creek landslide and debris flow, Macon County) and during the abnormally wet year of 2013.

Some thin beds of metasedimentary rocks contain sulfur compounds and produce a yellowish acid leachate when exposed to weathering. These areas are considered to have a high potential to produce acidic runoff when sulfidic rocks are exposed to weathering. The soil and highly weathered rock derived

from the sulfidic rock is generally not a hazard because iron sulfide minerals like pyrite and pyrrhotite have long been leached out through the natural weathering process. In fresh rock however, the degree of potential acid runoff depends on the concentrations of sulfide minerals present, and the amount of surface area exposed in the excavated area and used in embankments or stockpiled in waste areas (Email from Rick Wooten, NCGS, 2008). When this leachate enters nearby streams, damage to aquatic communities can occur (Sherrill, Unknown year).

Guidelines for handling acid producing material were developed by the North Carolina Division of Water Quality and the North Carolina Geological Survey (NCDWQ 2007). This guidance is adhered to during project development and the layout of skid roads, system roads, temporary roads and the reconstruction of system roads to avoid any exposure of iron sulfide rock and reduce the risk of road cut and fill slope failures of this material.

Soils

Soils within the planning area can be grouped by landscape position. On high mountains above 4,000 feet on north aspects and 5,000 feet on south aspects, the soils are loamy with thick, black topsoils that have high organic matter content, with brownish and yellowish subsoils containing less than 20 percent clay. On the north and east sides of intermediate mountains between 3,000 and 4,000 feet, the soils are loamy with thick, dark surfaces influenced by organic matter, with brownish to yellowish subsoils containing less than about 20 percent clay. On the south and west sides of intermediate mountains, between 2,500 and 4,500 feet, the soils are loamy with thin brown topsoils, and reddish to brownish subsoils containing about 20 to 30 percent clay. On intermountain hills and low mountains, the soils are loamy to clayey with some thin brown topsoils, and reddish subsoils containing about 25 to 50 percent clay.

In coves at the higher elevations, the soils are loamy with thick, black topsoils that have a high organic matter content with brownish to yellowish subsoils containing about 15 to 25 percent clay and 20 to 50 percent (by volume) rock fragments. In coves at the lower elevations, the soils are loamy, with dark surfaces of varying thicknesses influenced by organic matter, with brownish, yellowish, or reddish subsoils containing about 25 to 50 percent clay and 10 to 50 percent (by volume) rock fragments. Moving downstream, the first floodplains that appear in a watershed have soils that are loamy with thick, black organic matter rich surfaces, and brownish to yellowish subsoils containing about 10 to 20 percent clay; they are underlain with sand and rock fragment layers that start within 20 inches of the surface. In general, the organic matter content of the surface decreases, and the sand and rock fragment layers occur deeper as the floodplain extends lower into the watershed.

The soils vary widely in productivity, behavior, and response to management. While natural fertility and mineralogy are influenced by the type of materials from which the soils developed, site quality for the growth of native tree species often is more closely related to landscape position and elevation than to parent material. However, the soils derived from granites and gneisses generally are more productive than soils from metasedimentary rocks on similar landscape positions. Within a given area, the most productive soils generally are those in the coves and at the toe of slopes. Such sites are characterized by very deep, colluvial soils, which can support high quality cove hardwoods.

Soil productivity is also linked to landscape. Residual soils on side slopes and ridgetops, which constitute the majority of any given area, vary widely in productivity. Below an elevation of approximately 4,800 feet, productivity is greatly influenced by soil depth (rooting depth) and moisture supply. Soils commonly range from shallow to deep, with moderately deep soils predominating. Within a local area, slopes that face north or east or that are sheltered by higher mountains are cooler, moister, and more productive than south- and west-facing slopes. Cool slopes generally sustain high-quality cove and upland hardwoods, except on some very steep slopes where shallow or outcropping bedrock limits rooting depth and/or growing space. Warm slopes vary widely, ranging from sites with moderately deep to deep soils capable of sustaining good growth of upland hardwoods and pines to droughty sites with shallow soils and very low productivity. Generally, within a local area, broad ridgetops have deeper soils with more available water for vegetation, and thus are more productive than narrow ridgetops.

Above 4,800 feet, productivity is limited by the short growing season and severe climate. Soil formation is limited by cold temperatures, resulting in less developed soil profiles with minimal microbial activity. Frigid soils occur in these areas, occupying 55,270 acres of the planning area. They are characterized by organic, rich soils, and cool, moist microclimates. Sheltered positions can support good growth of northern hardwoods and, at the higher elevations, spruce fir as well as heath and grassy balds. Tree growth on positions that are exposed to the strong prevailing wind is limited by ice and wind damage.

Hydric soils are defined by the National Technical Committee for Hydric Soils (NTCHS) as soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part (59 Federal Register 35680, 7/13/94). These soils are either saturated or inundated long enough during the growing season to support the growth and reproduction of hydrophytic (water-loving) vegetation. Hydric soils occur across the landscape in areas along stream channels, on floodplains, and in isolated springs and seeps. Based on data from NRCS, hydric soils occupy 594 acres in the planning area, and there are an additional 74,205 acres of partially hydric soils. Hydric soils are a primary indicator of wetlands and are used in the assessment of Forest Service compliance with Executive Orders 11988 and 11990, directives relative to the management and disposition of floodplains and wetlands.

Prime Farmland Soils Listing

There are 3,498 acres of prime farmland soils in the planning area. Farmland of local and statewide importance and potential prime farmland also occur.

As identified by Subtitle I - Farmland Protection Policy Act, Section 2 [7 USC 4201]

(a) Congress finds that:

(7) the Department of Agriculture and other Federal agencies should take steps to assure that the actions of the Federal Government do not cause United States farmland to be irreversibly converted to nonagricultural uses in cases in which other national interest do not override the importance of the protection of farmland nor otherwise outweigh the benefits of maintaining farmland resources.

(b) The purpose of this subtitle is to minimize the extent to which Federal programs contribute to the unnecessary and irreversible conversion of farmland to nonagricultural uses, and to assure that Federal programs are administered in a manner that, to the extent practicable, will be compatible with State, unit of local government, and private programs and policies to protect farmland.

Therefore, the Forest Service is to avoided activities that would contribute to unnecessary and irreversible conversion of these farmland areas to nonagricultural uses. Such development could include roads, buildings, and campgrounds.

How have roads impacted stream channels and what are the general trends?

Roads generally pose the greatest risk to streams, both stream channels and water quality. Roads can affect stream channels by intercepting, concentrating, and diverting flows from natural flow paths. These changes in routing can result in increases in peak flows by both a volumetric increase and changes in timing of storm runoff to streams (Wemple et al. 1996). A stream channel susceptible to erosion, such as one without sufficient bank protection, could scour under an elevated flow regime. The most notable example of this is occurring on the Cherohala Skyway on the Cheoah Ranger District. This State road is a paved two-lane highway with long distances between ditch relief culverts and open drainages. The result is in many instances, excessive energy and deeply scoured channels on steep slopes (Figure 7) interrupted by extensive areas of sediment deposition where stream gradient lessens downslope.

Forest roads can produce similar impacts where road drainage is inadequate and soils are prone to erosion. The Forest Service and local groups, such as the French Broad River Keepers, keep a close watch on road conditions and are efficient at identifying issues. Following high rainfall events, district personnel often review the open road system and other areas of concern. Solving issues of erosion and sedimentation can at times be slow however due to declining personnel and budgets.

Figure 7. Photo from NCDOT condition survey of Cherohala Skyway (May 2011), road drainage and subsequent erosion of fill slope. Cheoah Ranger District.

Erosion hazard ratings for unsurfaced roads and trails, as defined by the National Resource Conservation Service (NRCS), National Cooperative Soil Survey, are presented in Appendix A for roads and trails within 100 feet of a stream channel, by Forest Service ownership in 6th- level Watersheds. There exist 137 miles of road and 105 miles of trail in the planning area within 100 feet of a stream channel having a "severe" erosion hazard from unsurfaced roads and trails (Table 7). These road and trail segments are expected to require more frequent maintenance and implementation of erosion control measures than other segments.

Table 7. Summary of miles of road and trail within and outside 100 feet of a stream for each of the Erosion Hazard Ratings.

Erosion Hazard	Miles of Road within 100ft Stream	Miles of Road outside 100ft Stream	Miles of Trails within 100ft Stream	Miles of Trails outside 100ft Stream	Total
Severe	137	1,793	105	1,093	**3,128**
Moderate	76	212	51	101	**440**
Slight	20	31	27	16	**94**
Unknown/Not Rated	3	111	3	15	**132**
Total	**236**	**2,147**	**186**	**1,225**	**3,794**

Monitoring of road BMPs, conducted at the time of the Forestry BMP monitoring, found that Roads BMPs were properly implemented and effective at controlling sedimentation at 93.1 and 94.7 percent of the sites surveyed, respectively (Table 8). Non-critical visible and critical visible sediment was observed 4.3 and 1.1 percent of the time, respectively. Sediment delivery to streams was primarily due to legacy system roads located along a stream channel, within the Management Area 18 (Streamside Management Zone).

Table 8. Summary of Roads and Road Stream Crossings Best Management Practices for 2009-2013 monitoring data, subset of Table 4.

BMP Category	Implementation %				Effectiveness %					Visible Sediment %		
	Meets or Exceeds	Minor Departure	Major Departure	Gross Departure	Improvement Over Past	Adequate Protection	Minor/Temp. Impact	Major Short-Term Impact	Major Long-Term Impact	No Visible Sediment	Non-Critical Visible	Critical Visible
Roads	93.1%	5.0%	1.2%	0.7%	0.7%	94.0%	3.3%	1.2%	0.7%	94.6%	4.3%	1.1%
Road Stream Crossings	88.5%	5.1%	5.9%	0.5%	0.0%	89.5%	3.8%	4.3%	2.4%	92.6%	6.6%	0.8%
Total Percent	94.8%	3.2%	1.8%	0.3%	0.5%	94.8%	2.7%	1.4%	0.6%	96.6%	3.0%	0.4%

Road Stream Crossings were also monitored during Forestry BMP monitoring. In the planning area there are approximately 2,178 locations where roads cross streams (Appendix A). These monitoring results are a small sampling of the total, but are assumed to give a good indication of current conditions and effectiveness at protecting water quality across the area. Implementation and effectiveness rates were 88.5 and 89.5 percent, respectively (Table 7). Sediment from the road crossings was controlled at 93 percent of the sites. The remaining seven percent of the crossings had some level of sediment entering the stream channel, but only one crossing was found to be a major concern, needing immediate attention. These implementation and effectiveness ratings could be improved over time by correcting road grade declines over stream channels (Figure 8) and correcting fish migration blockages (Figure 9).

Figure 8. Example of road grade sag over stream crossing during a storm runoff event, Tusquitee Ranger District.

Figure 9. Fish passage barrier road crossing on Simpson Creek, Grandfather Ranger District.

Much of the road network is a remnant of decades ago and often not designed to current standards. Many system roads would benefit from more frequent and improved drainage features, e.g. rolling dips, properly sized culverts, and provision of aquatic organism passage. During the WCF, roads were identified as not maintained to standard across the planning area, therefore culverts are more prone to plugging and failure, road surfacing is not maintained and replenished and thus more prone to rutting, concentrating runoff and road failure. Aquatic organism passage (AOP) improvements have reduced the risk of larger crossing failures and improved passage of aquatic and riparian organisms. As funding is available, improving trends in AOP would continue. With the growing inability to reconstruct and maintain the existing road network the hazard of erosion is likely to increase. Trends in water quality relative to the current road network overall are expected to decline as a result of an aging road infrastructure and shrinking budgets. Should predictions of increased storm runoff associated with climate change come to fruition risk of road erosion would likely increase.

Where is sulfidic rock a concern and what steps are taken to mitigate its potential effects to water quality?

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The soil and highly weathered rock derived from the rock is generally not a hazard because the iron sulfide minerals like pyrite and pyrrhotite have long been leached out through the natural weathering process. In fresh rock however, the degree of potential acid runoff depends on the concentrations of sulfide minerals present, and the amount of surface area exposed in the excavated area and used in embankments or stockpiled in waste areas (Wooten 2008).

Guidelines for handling acid producing material were developed by the North Carolina Division of Water Quality and the North Carolina Geological Survey (NCDWQ 2007). This guidance will be adhered to during project development and the layout of skid roads, system roads, temporary roads and the reconstruction of system roads to avoid any exposure of iron sulfide rock and reduce the risk of road cut and fill slope failures of this material.

What is the status of ground water resources and what are the potential demands on its use?

Ground water resources are largely intact in the planning area. Ground water extraction from wells and springs occurs in 77 locations; supplying water to individual homes, small businesses, and communities. Information on the quality and quantity of ground water at these locations is not available, but activities that pose a risk to ground water, such as landfills, mining, oil and gas extraction, and associated fracking, are not occurring in the planning area; therefore, water quality is assumed to be good. Where such activities occur on adjacent private lands there is a risk to larger aquifers that may extend below the surface under federal lands. This information is also not available.

Demands on ground water are likely to increase as a result of increasing populations in both rural areas and cities. Cities as far away as Atlanta, Georgia are likely to be in need of water in the mountains of NC as their ground water resources become inadequate. More home sites and developments are likely to occur adjacent to National Forest System land that may desire to tap into surface and ground water sources. With this increasing use looming on the horizon, special attention will need to be given to ground water and ecosystems dependent on ground water.

Ground Water Dependent Ecosystems

Ground water-dependent ecosystems are communities of plants, animals and other organisms whose extent and life processes depend on ground water (USFS 2007b). The following are examples of some ecosystems that may depend on ground water:

- Wetlands in areas of ground water discharge or shallow water table
- Terrestrial vegetation and fauna, in areas with a shallow water table or in riparian zones
- Aquatic ecosystems in ground water-fed streams and lakes
- Cave and karst systems
- Aquifer systems
- Springs and seeps

These areas contain ecological resources that potentially are highly susceptible to permanent or long-term environmental damage from contaminated or depleted ground water. Ground water extraction by humans modifies the pre-existing hydrologic cycle. It can lower ground water levels and alter the natural variability of these levels. The result can be alteration of the timing, availability, and volume of ground water flow to dependent ecosystems. Ground water-dependent ecosystems vary in how extensively

they depend on ground water, from being wholly dependent to having occasional dependence. Unique ecosystems that depend on ground water, fens or bogs for example, can be entirely dependent on ground water, which makes them very susceptible to local changes in ground water conditions (USFS 2007b). Particular threats in the planning area include facility and road development, contamination from roads, clearing of vegetation, and over- extraction of ground water by permitted users.

If predictions of changing climate are to come to fruition these ecosystems will become increasingly important. Ground water-dependent ecosystems are to be managed such that they are protected by (1) maintaining natural patterns of recharge and discharge, and minimizing disruption to ground water levels that are critical for ecosystems; (2) not polluting or causing significant changes in ground water quality; and (3) rehabilitating degraded ground water systems where possible (USFS 2007b).

What soils are sensitive to erosion and where do they occur on the landscape? How has management impacted these soils?

Sensitive Soils

A review of the soil data and interpretations from the NRCS Web Soil Survey Site shows that a majority of the planning area has soils sensitive to erosion should the surface organic layer be removed. Because timber harvest has the greatest potential for disturbing the largest area of soil, the current Management Areas (MA) that promote active harvest of timber were assessed. These include MA 1b, 2a, 3b, 4a, and 4d. Table 9 and Figure 10 summarizes the NRCS Erosion Hazard Rating for soils outside of a road or trail prism; including any other activity that could remove the soil surface organic layer, thus exposing bare mineral soil. A “very severe” hazard exists for 36% of the area that is found in management areas suitable for timber production. However, this risk is mitigated by taking extra precautions that reduce the exposure of bare soil..

***Table 9. Summary of a*cres of Erosion Hazard off Roads & Trails by “Timber Production” Management Areas.**

Sum of Acres of Erosion Hazard Off Roads & Trails by “Timber Production” Management Areas						
	Erosion Hazard Rating - Off Roads & Trails					
Management Area	**Slight**	**Moderate**	**Severe**	**V. Severe**	**Not Rated**	**Grand Total**
1b	1,528.54	8,094.75	14,325.78	12,374.80	319.62	36,643.49
2a	2,799.78	8,351.83	13,013.33	12,220.98	341.00	36,726.91
3b	10,575.96	52,943.29	90,098.75	83,465.44	922.68	238,006.12
4a	2,551.14	13,290.18	22,213.34	17,900.11	346.49	56,301.26
4d	5,202.27	30,230.96	59,985.49	59,972.76	738.38	156,129.86
Grand Total	**22,657.69**	**112,911.01**	**199,636.69**	**185,934.08**	**2,668.17**	**523,807.64**
Percent	**4.33**	**21.56**	**38.11**	**35.50**	**0.51**	

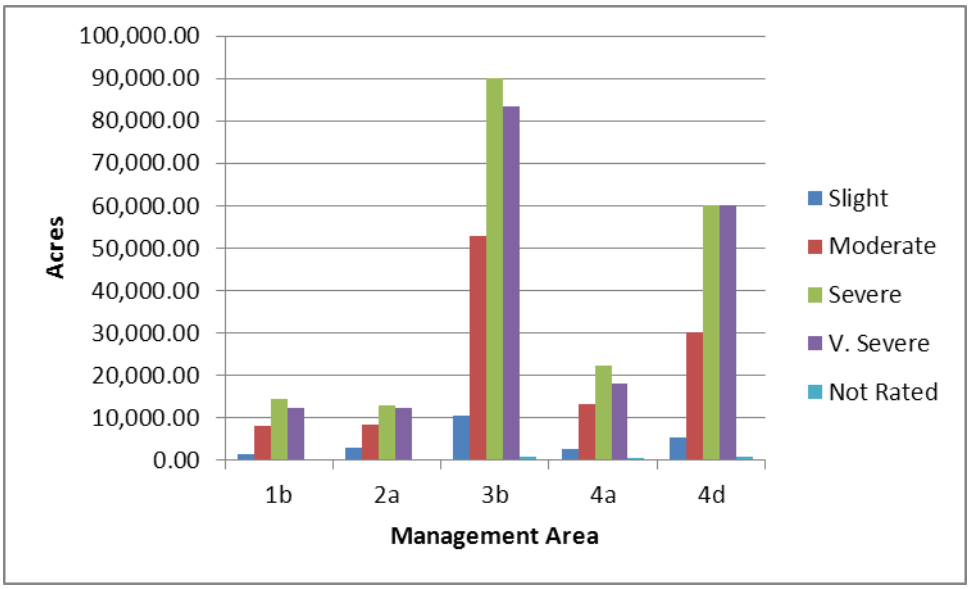

***Figure 10. Summary of a*cres of Erosion Hazard off Roads & Trails by "Timber Production" Management Areas.**

Monitoring indicates very little long-term soil disturbance from activities other than roads and trails over the past planning period. Forestry BMP monitoring from 1992 to 2000 compared to recent years (2009 to 2013) shows a notable improvement in the implementation and effectiveness of management practices (Table 6). This improvement means less soil disturbance including compaction and erosion. Harvest activities are improving in the type of BMP applied, such as the increased use of slash on skid roads and trails, choosing a temporary bridge over installing a culvert at stream crossings, and planning unit boundaries to exclude streamside zones.

Soil quality monitoring also shows that the level of soil disturbance is minimized during operations and is often well below the 15% guidance. As a result, the majority of the harvested area maintains an organic layer that protects the soil from erosion. Therefore, the high hazard ratings within these management areas have been mitigated through proper application of effective best management practices.

Recreation activities that can expose large areas of bare soil, such as camping, do not typically occur on these sensitive soils because the side slope is often too steep to accommodate such activities. Concentrated use from the public often occurs on flatter areas often located near streams. Exposed soils in these locations can pose often small but chronic erosion and sedimentation.

Roads and trails have been found to be the greatest concern on these erosion sensitive soils since they often cut into the slope exposing soil to weathering and interrupt flow of both surface and groundwater. Appendix A shows the NRCS Erosion Hazard Ratings from roads and trails when surfacing is not reinforced, but left native. On unsurfaced roads and trails soil types with a "severe" hazard of soil loss occur on approximately 58 and 57 percent, respectively, of the planning area (Appendix A). Properly designed and constructed roads and trails often mitigate the hazard of erosion in these and other areas by effectively draining roads and trails using frequent rolling-dips and ditch relief culverts, and the

application of gravel surfacing. As mentioned earlier, much of the road network is a remnant of decades ago and not designed to current standards. The trail network is often located on old roads used for logging decades ago. These old roads were not designed to withstand the use and lack the proper drainage to make them sustainable. With the growing inability to reconstruct and maintain the existing road and trail network the hazard of erosion is likely to increase.

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APPENDIX A - Summary of Road & Trail Length Within 100' of Stream by Erosion Hazard Rating (for Unsurfaced Roads) & Stream Crossings per Watershed

Summary of Road Length (Feet) Within 100' of Stream by Erosion Hazard Rating					
	Erosion Hazard Rating for Unsurfaced Roads				
Watersheds (6th Level HUC)	**Slight**	**Moderate**	**Severe**	**Not Rated**	**Grand Total (Feet)**
030401010102	0.0	0.0	0.0	0.0	0.0
030501010101	1298.0	4599.6	7030.0	442.6	13370.2
030501010102	0.0	1455.0	2110.4	0.0	3565.5
030501010104	1917.1	541.2	8742.5	115.1	11315.9
030501010105	0.0	0.0	5968.1	27.8	5995.9
030501010106	365.5	495.9	1926.0	187.6	2974.9
030501010201	0.0	56.8	1716.8	0.0	1773.6
030501010202	476.7	2043.2	1363.9	0.0	3883.8
030501010302	0.0	95.5	725.7	0.0	821.2
030501010303	0.0	0.0	0.0	0.0	0.0
030501010401	8227.9	2318.5	9016.3	0.0	19562.6
030501010402	1590.3	3042.3	4486.6	93.9	9213.1
030501010403	0.0	0.0	0.0	0.0	0.0
030501010501	0.0	0.0	1162.9	0.0	1162.9
030501010502	1486.8	1427.4	14761.8	0.0	17676.1
030501010503	1534.5	2151.4	11121.8	215.5	15023.2
030501010504	888.1	1588.6	5760.7	37.4	8274.8
030501010505	0.0	0.0	6514.0	0.0	6514.0
030501010506	0.0	348.5	3741.4	0.0	4089.9
030601010101	0.0	0.0	0.0	0.0	0.0
030601010104	0.0	2670.3	2540.2	123.5	5333.9
030601020201	0.0	7023.9	2679.5	0.0	9703.4
030601020202	46.4	2883.4	7985.2	33.2	10948.1
060101050101	3524.9	4562.9	15401.2	0.0	23489.0
060101050102	92.3	0.0	4475.2	67.4	4634.9
060101050104	7479.1	726.1	8839.2	0.0	17044.4
060101050202	16642.9	9695.5	19497.2	0.0	45835.6
060101050203	0.0	0.0	610.5	0.0	610.5
060101050401	0.0	0.0	0.0	0.0	0.0
060101050402	2551.5	2967.8	8519.9	0.0	14039.3
060101050403	916.9	15709.9	13839.7	959.8	31426.3
060101050501	0.0	3594.2	5046.8	395.9	9036.9
060101050503	0.0	268.7	1450.8	17.0	1736.6
060101050603	0.0	1412.3	0.0	0.0	1412.3
060101050704	0.0	0.0	0.0	0.0	0.0
060101050705	10976.2	5741.3	13157.2	0.0	29874.7
060101050801	489.4	6071.8	7170.4	511.5	14243.0
060101050803	0.0	0.0	695.6	0.0	695.6
060101051002	0.0	2535.6	26468.1	178.7	29182.3
060101051003	0.0	0.0	1350.0	0.0	1350.0
060101051004	0.0	0.0	20177.0	0.0	20177.0
060101051103	361.9	0.0	1706.0	313.8	2381.7
060101051201	0.0	2922.6	6970.1	0.0	9892.7
060101051202	0.0	230.2	4449.2	100.1	4779.5
060101051203	256.6	974.4	22632.3	218.0	24081.3
060101060101	0.0	1490.4	6201.4	147.6	7839.4
060101060102	0.0	710.1	276.1	0.0	986.2
060101060103	0.0	0.0	2945.3	0.0	2945.3
060101060201	0.0	0.0	0.0	0.0	0.0
060101060302	0.0	0.0	469.3	0.0	469.3
060101060303	0.0	289.8	3108.8	70.0	3468.6

060101060304	0.0	1060.7	953.7	109.2	2123.6
060101060305	3934.8	10748.5	57619.3	1213.8	73516.4
060101080101	0.0	157.8	253.2	0.0	411.1
060101080105	320.5	357.3	67.4	141.9	887.1
060101080201	2487.3	3541.2	4651.5	0.0	10680.0
060101080301	0.0	0.0	0.0	0.0	0.0
060101080303	0.0	0.0	0.0	166.6	166.6
060101080306	177.1	332.8	3641.9	0.0	4151.7
060101080602	0.0	51.4	162.9	0.0	214.3
060101080603	0.0	181.2	259.5	0.0	440.7
060101080604	221.8	15890.6	12119.1	719.9	28951.3
060102020102	0.0	344.5	1427.4	0.0	1771.9
060102020103	697.2	18905.1	8637.2	0.0	28239.5
060102020104	101.0	4645.4	6264.1	0.0	11010.5
060102020105	239.2	5539.0	8915.8	274.2	14968.2
060102020106	0.0	0.0	307.6	0.0	307.6
060102020201	0.0	1732.5	2128.6	0.0	3861.1
060102020202	0.0	813.0	1356.2	2.6	2171.8
060102020203	0.0	1826.3	1575.6	184.0	3585.8
060102020301	6285.8	19141.7	3373.3	478.5	29279.2
060102020302	4483.0	13972.3	8352.2	0.0	26807.5
060102020303	1112.8	10538.9	6450.6	151.2	18253.6
060102020304	400.6	8658.6	13165.7	1037.4	23262.2
060102020305	187.7	1403.7	4462.8	130.4	6184.6
060102020306	0.0	0.0	1298.2	0.0	1298.2
060102020401	0.0	655.5	4548.4	215.9	5419.8
060102020402	0.0	1047.5	9109.8	371.3	10528.6
060102020403	0.0	1366.7	971.0	0.0	2337.7
060102020404	0.0	2670.4	5275.6	84.2	8030.2
060102020405	0.0	0.0	1019.9	108.7	1128.6
060102020406	369.5	2761.3	2173.7	0.0	5304.4
060102020407	0.0	0.0	8150.3	0.0	8150.3
060102020501	104.8	2788.1	15571.6	0.0	18464.5
060102020502	297.2	2728.7	4877.9	718.3	8622.1
060102020505	704.7	5346.2	3042.3	0.0	9093.3
060102030101	704.1	4186.0	4145.1	69.4	9104.6
060102030104	348.7	1003.1	475.2	0.0	1827.0
060102030105	0.0	12848.8	27208.5	1468.5	41525.8
060102030106	0.0	507.0	16.6	0.0	523.6
060102030107	0.0	689.1	7110.8	0.0	7799.9
060102030301	0.0	1469.6	3149.4	0.0	4619.0
060102030302	0.0	473.2	25.0	0.0	498.1
060102030304	0.0	4365.5	3793.6	172.4	8331.5
060102030405	0.0	0.0	0.0	0.0	0.0
060102040101	386.0	12476.2	16931.8	149.8	29943.8
060102040102	0.0	219.9	932.0	0.0	1151.9
060102040103	6470.1	10006.9	9912.7	200.6	26590.3
060102040104	0.0	662.9	0.0	0.0	662.9
060102040105	4832.5	20261.6	8994.1	0.0	34088.2
060102040106	1838.3	12364.9	10834.8	356.5	25394.5
060102040107	0.0	29179.6	15782.3	64.8	45026.7
060102040401	0.0	1498.2	2898.4	126.5	4523.2
060200020105	106.5	1459.5	2999.7	0.0	4565.7
060200020201	557.0	7370.4	1778.3	0.0	9705.6
060200020202	382.5	6514.5	63545.6	415.0	70857.5
060200020203	0.0	0.0	0.0	0.0	0.0
060200020303	0.0	2013.8	4190.5	0.0	6204.3
060200020401	0.0	912.3	3136.9	0.0	4049.2
060200020402	23.2	3803.9	11212.8	369.2	15409.0

060200020403	0.0	314.7	5790.7	0.0	6105.4
060200020404	0.0	0.0	0.0	0.0	0.0
060200020603	0.0	8686.1	1354.0	0.0	10040.0
060200020701	187.9	3602.9	3625.8	33.6	7450.2
060200020702	678.7	4144.3	2661.7	851.2	8335.9
060200020703	839.9	1593.3	794.6	0.0	3227.8
060200020704	0.0	961.2	3013.1	100.7	4075.1
060200020705	0.0	659.9	1043.8	125.2	1828.9
060200020902	573.7	876.6	1768.9	0.0	3219.2
060200020903	1715.3	12201.6	6638.0	101.6	20656.4
Grand Total (Feet)	**102892.2**	**399179.0**	**722759.3**	**14969.5**	**1239799.9**
Grand Total (Miles)	**19.49**	**75.60**	**136.89**	**2.84**	**234.81**
Percent of Total	**8.30**	**32.20**	**58.30**	**1.21**	

Summary of Trail Length (Feet) Within 100' of Stream by Erosion Hazard Rating

	Erosion Hazard Rating for Unsurfaced Trails				
Watersheds (6th Level HUC)	**Slight**	**Moderate**	**Severe**	**Not Rated**	**Grand Total (Feet)**
030501010101	0.0	1951.7	4528.5	0.0	6480.2
030501010102	0.0	1403.7	3841.6	0.0	5245.3
030501010104	0.0	0.0	541.8	0.0	541.8
030501010105	0.0	0.0	5084.9	0.0	5084.9
030501010106	733.0	0.0	1754.4	0.0	2487.4
030501010201	0.0	2757.8	6328.0	0.0	9085.8
030501010202	0.0	0.0	0.0	0.0	0.0
030501010302	723.7	1894.7	9311.2	1221.6	13151.2
030501010303	162.9	0.0	182.8	0.0	345.7
030501010401	8124.7	0.0	10186.7	0.0	18311.5
030501010402	0.0	0.0	0.0	0.0	0.0
030501010501	0.0	542.5	6922.4	148.2	7613.2
030501010502	21897.5	256.1	24118.3	0.0	46271.9
030501010503	0.0	0.0	0.0	0.0	0.0
030501010504	9617.0	173.7	23902.7	146.2	33839.6
030501010505	0.0	0.0	787.5	0.0	787.5
030501010506	0.0	0.0	3976.7	0.0	3976.7
030601010101	0.0	0.0	0.0	0.0	0.0
030601010104	0.0	837.0	3168.3	0.0	4005.3
030601020201	0.0	4420.7	4481.5	4329.2	13231.3
030601020202	0.0	4667.3	4813.3	0.0	9480.5
060101050101	0.0	36.6	2140.9	0.0	2177.5
060101050102	0.0	0.0	0.0	0.0	0.0
060101050104	0.0	0.0	0.0	0.0	0.0
060101050202	6416.5	11377.3	32851.9	132.2	50778.0
060101050401	0.0	0.0	0.0	0.0	0.0
060101050402	41297.9	25783.3	34933.1	0.0	102014.3
060101050403	11129.2	16279.2	11923.5	114.4	39446.3
060101050501	0.0	0.0	0.0	0.0	0.0
060101050503	0.0	0.0	0.0	0.0	0.0
060101050704	0.0	0.0	0.0	0.0	0.0
060101050705	3473.5	4194.2	7131.8	0.0	14799.5
060101050801	0.0	2312.1	5572.4	92.3	7976.8
060101050803	0.0	0.0	0.0	0.0	0.0
060101051002	0.0	924.1	21236.0	0.0	22160.1
060101051003	0.0	0.0	1652.4	0.0	1652.4
060101051004	1009.1	0.0	20662.3	3521.1	25192.5
060101051201	0.0	3840.3	2570.3	0.0	6410.7
060101051202	0.0	0.0	7532.2	185.3	7717.5
060101051203	110.4	1328.3	47134.6	369.0	48942.3
060101060101	110.9	4979.7	13265.6	0.0	18356.2
060101060102	0.0	5597.4	3440.0	0.0	9037.4
060101060103	0.0	13988.4	16653.0	280.3	30921.6

060101060304	0.0	0.0	0.0	0.0	0.0
060101060305	0.0	0.0	25490.1	438.3	25928.4
060101080101	0.0	206.2	1040.4	0.0	1246.6
060101080201	3420.5	5759.2	2960.3	413.3	12553.3
060101080301	0.0	0.0	0.0	0.0	0.0
060101080303	0.0	0.0	1313.5	0.0	1313.5
060101080306	153.6	969.9	3139.0	0.0	4262.5
060101080602	0.0	0.0	0.0	0.0	0.0
060101080603	0.0	0.0	0.0	0.0	0.0
060101080604	0.0	0.0	2901.2	0.0	2901.2
060102020102	0.0	0.0	0.0	0.0	0.0
060102020103	0.0	331.5	102.4	0.0	433.9
060102020104	0.0	0.0	23.3	0.0	23.3
060102020105	32.9	744.6	2531.3	0.0	3308.8
060102020106	0.0	0.0	0.0	0.0	0.0
060102020201	0.0	2566.3	1385.1	92.1	4043.5
060102020202	0.0	0.0	0.0	0.0	0.0
060102020203	0.0	570.4	384.3	0.0	954.8
060102020301	0.0	417.4	228.9	0.0	646.3
060102020302	9895.8	18602.4	7629.7	0.0	36127.9
060102020303	0.0	0.0	0.0	0.0	0.0
060102020304	0.0	9885.1	10473.1	150.8	20509.0
060102020305	214.0	940.8	16475.0	0.0	17629.8
060102020306	0.0	0.0	61.8	0.0	61.8
060102020401	0.0	0.0	0.0	0.0	0.0
060102020403	0.0	0.0	0.0	0.0	0.0
060102020404	0.0	0.0	0.0	0.0	0.0
060102020406	0.0	85.5	0.0	0.0	85.5
060102020407	0.0	0.0	282.9	0.0	282.9
060102020501	6609.8	5687.5	14383.6	0.0	26680.9
060102020502	0.0	5551.6	3216.5	0.0	8768.1
060102020505	1417.6	3859.7	2542.6	0.0	7820.0
060102030101	2265.6	15192.6	938.3	178.6	18575.1
060102030104	309.9	539.4	9.0	0.0	858.2
060102030105	0.0	442.6	1368.8	0.0	1811.5
060102030106	0.0	113.3	0.0	0.0	113.3
060102030107	147.3	0.0	6572.4	0.0	6719.7
060102030302	0.0	0.0	0.0	0.0	0.0
060102040101	0.0	8526.5	5052.2	0.0	13578.7
060102040102	0.0	0.0	187.8	0.0	187.8
060102040103	7532.3	17189.8	15308.0	0.0	40030.1
060102040104	0.0	1341.1	69.2	0.0	1410.4
060102040105	757.8	18181.3	4938.6	0.0	23877.7
060102040106	0.0	1885.9	872.0	0.0	2757.9
060102040107	0.0	20758.8	8247.1	79.9	29085.8
060102040401	0.0	1776.7	2909.1	0.0	4685.8
060200020105	0.0	1430.9	468.0	0.0	1898.8
060200020201	0.0	2943.6	4459.7	0.0	7403.3
060200020202	472.7	1822.4	56761.8	0.0	59057.0
060200020203	0.0	0.0	0.0	0.0	0.0
060200020303	0.0	0.0	0.0	0.0	0.0
060200020401	0.0	50.9	224.0	0.0	274.9
060200020402	0.0	0.0	0.0	0.0	0.0
060200020403	0.0	0.0	0.0	0.0	0.0
060200020701	0.0	0.0	0.0	0.0	0.0
060200020702	0.0	83.6	595.5	0.0	679.1
060200020703	0.0	0.0	0.0	0.0	0.0
060200020704	0.0	0.0	213.3	0.0	213.3
060200020902	0.0	0.0	88.5	0.0	88.5

060200020903	0.0	0.0	0.0	0.0	0.0
060101030201	0.0	0.0	0.0	0.0	0.0
060101050903	0.0	0.0	0.0	0.0	0.0
060101051001	0.0	0.0	0.0	0.0	0.0
060101080203	0.0	0.0	0.0	0.0	0.0
060101080304	0.0	0.0	0.0	0.0	0.0
060102030102	0.0	0.0	0.0	0.0	0.0
060102040402	3657.1	10154.6	4730.4	3560.3	22102.3
Grand Total (Feet)	**141693.3**	**268158.8**	**553209.8**	**15452.9**	**978514.7**
Grand Total (Miles)	**26.84**	**50.79**	**104.77**	**2.93**	**185.32**
Percent of Total	**14.48**	**27.40**	**56.54**	**1.58**	

Watersheds (6th Level HUC)	**Watershed Name**	**Number of Road/Stream Crossings**
030501010101	Curtis Creek	19
030501010102	Headwaters Catawba River	7
030501010104	Buck Creek	11
030501010105	Mackey Creek-Catawba River	6
030501010106	Toms Creek-Catawba River	7
030501010201	Armstrong Creek	7
030501010202	North Fork Catawba River	7
030501010302	Lower Linville River	3
030501010401	Upper Warrior Fork	17
030501010402	Irish Creek	18
030501010501	Upper Johns River	3
030501010502	Upper Wilson Creek	21
030501010503	Mulberry Creek	25
030501010504	Lower Wilson Creek	9
030501010505	Middle Johns River	12
030501010506	Lower Johns River	6
030601010104	Whitewater River	7
030601020201	Headwaters Chattooga River	9
030601020202	Headwaters West Fork Chattooga River	15
060101050101	North Fork French Broad River	16
060101050102	West Fork French Broad River	3
060101050104	Catheys Creek	16
060101050202	Davidson River	69
060101050203	Williamson Creek-French Broad River	2
060101050401	Boylston Creek	1
060101050402	South Fork Mills River	31
060101050403	Mills River	40
060101050501	South Hominy Creek	20
060101050503	Lower Hominy Creek	4
060101050603	Middle Swannanoa River	2

060101050705	Bent Creek-French Broad River	41
060101050801	Dillingham Creek	25
060101050803	Upper Ivy Creek	3
060101051003	Lower Shelton Laurel Creek	47
060101051004	Lower Big Laurel Creek	44
060101051103	Big Pine Creek-French Broad River	3
060101051201	Meadow Fork	27
060101051202	Spring Creek	9
060101051203	Shut-in Creek-French Broad River	71
060101060101	Lake Logan-West Fork Pigeon River	18
060101060102	Little East Fork Pigeon River-West Fork Pigeon River	3
060101060103	East Fork Pigeon River	4
060101060302	Lower Cataloochee Creek	1
060101060303	Walters Lake-Pigeon River	9
060101060304	Big Creek	6
060101060305	Cold Springs Creek-Pigeon River	138
060101080101	Headwaters North Toe River	2
060101080105	Big Crabtree Creek	4
060101080201	Upper South Toe River	20
060101080303	Upper Cane River	1
060101080306	Lower Cane River	12
060101080602	Little Rock Creek	1
060101080603	Big Rock Creek	1
060101080604	Hollow Poplar Creek-Nolichucky River	71
060102020102	Middle Creek-Little Tennessee River	3
060102020103	Coweeta Creek-Little Tennessee River	30
060102020104	Upper Cartoogechaye Creek	28
060102020105	Lower Cartoogechaye Creek	29
060102020201	Upper Cullasaja River	6
060102020202	Ellijay Creek	3
060102020203	Lower Cullasaja River	9
060102020301	Buck Creek	24
060102020302	Headwaters Nantahala River	55
060102020303	Nantahala Lake-Nantahala River	39
060102020304	Whiteoak Creek-Nantahala River	40
060102020305	Big Creek-Nantahala River	12
060102020306	Fontana Lake-Nantahala River	6
060102020401	Lake Emory-Little Tennessee River	10
060102020402	Cowee Creek	30
060102020403	Burningtown Creek	9
060102020404	Tellico Creek-Little Tennessee River	24

060102020405	Brush Creek-Little Tennessee River	2
060102020406	Alarka Creek	15
060102020407	Upper Fontana Lake-Little Tennessee River	10
060102020501	Panther Creek	43
060102020502	Stecoah Creek	21
060102020505	Lower Fontana Lake-Little Tennessee River	20
060102030101	Wolf Creek-Tuckasegee River	12
060102030104	Cedar Cliff Lake-Tuckasegee River	4
060102030105	Caney Fork	27
060102030106	Cullowhee Creek	1
060102030107	Wayehutta Creek-Tuckasegee River	5
060102030301	Savannah Creek	11
060102030302	Headwaters Scott Creek	1
060102030304	Conley Creek-Tuckasegee River	20
060102040101	Tulula Creek	58
060102040102	Sweetwater Creek	4
060102040103	Snowbird Creek	53
060102040104	West Buffalo Creek	3
060102040105	Santeetlah Creek	77
060102040106	Santeetlah Lake	60
060102040107	Yellow Creek-Cheoah River	66
060102040401	Lake Cheoah-Little Tennessee River	10
060200020105	Shooting Creek	11
060200020106	Chatuge Lake	1
060200020201	Tusquitee Creek	19
060200020202	Fires Creek	85
060200020303	Fall Branch-Hiwassee River	19
060200020401	Headwaters Valley River	12
060200020402	Upper Valley River	40
060200020403	Middle Valley River	15
060200020404	Lower Valley River	3
060200020603	Nottely River	5
060200020701	Hanging Dog Creek	10
060200020702	Grape Creek-Hiwassee Lake	14
060200020703	Lake Cherokee-Persimmon Creek	8
060200020704	Beaverdam Creek	14
060200020705	Hiwassee Lake-Hiwassee River	7
060200020902	Apalachia Lake-Hiwassee River	3
060200020903	Shuler Creek	23
030601020101	Headwaters Tallulah River	1
030601020204	Reed Creek-Chattooga River	4

060101030202	Lower Elk River	2
060101080402	Middle South Indian Creek	14
060102040303	Tellico River Headwaters	12
060200020907	Towee Creek - Hiwassee River	2
	Total:	**2,178**