Upper Tellico ORV Area - Water Resource Effects Monitoring Plan

Brady Dodd, NFsNC Hydrologist, December, 2007

The Upper Tellico Off-Road Vehicle Area is located on the Nantahala National Forest of North Carolina within the Upper Tellico River Watershed. The Tellico River flows west northwest out of North Carolina and into Tennessee as part of the larger Tennessee River Basin.

North Carolina waters are classified by the state to protect water quality. Waters of the Tellico River in North Carolina are classified as Class C, trout waters. Protected uses of these waters include aquatic life propagation and survival, fishing, wildlife, secondary recreation, and agriculture. In addition to these protected water uses, water quality in the Tellico River is to be maintained and protected to sustain and allow for natural trout propagation and survival of stocked trout on a year-round basis.

The Tellico River is not listed as "water quality limited" by the N.C. Department of Environment and Natural Resources, Division of Water Quality (NCDENR 2006) as of the latest 303(d) listing of stream channels impaired from meeting State water quality standards. Therefore, all protected water uses are currently identified as "supported" at some level. However, as controversy increases over the sustainablitiy of the off-road vehicle area in the Upper Tellico River Sub-watershed, data is needed to validate management decisions.

Therefore, the objective of this monitoring plan is to determine the effect of erosion from the off-highway vehicle trail system on protected uses of water in the Upper Tellico River Sub-watershed. To satisfy this objective the monitoring plan will focus on erosion of the trail network, transport and delivery of sediment to the stream network, and effects of sedimentation in the channel and aquatic macroinvertebrates. Monitoring shall begin in 2008 and continue for the next six years when an evaluation of data and results will inform the decision to continue the current plan, continue with modification, or discontinue and finalize results. A period of six years is assumed to be adequate for this plan since enough time is given, statistically, to have three bankfull streamflow events. The bankfull event is a channel maintenance discharge occurring every 1.5 to 2 years on average.

Overall Monitoring Question: What is the affect of erosion from the off-highway vehicle trail system on protected uses of water in the Upper Tellico River Sub-watershed?

Trail Best Management Practices

Ties to Water Quality Law: The Clean Water Act was intended by Congress to provide a means to protect and improve the quality of the nations water resources and maintain their beneficial uses. Sections 208 and 319 recognized the need for control strategies for nonpoint source pollution. To provide environmental protection and an improvement emphasis for soil and water resources and their beneficial uses, the National Nonpoint Source Policy (December 12, 1984), the Forest Service Nonpoint Source Strategy (January 29, 1985), and the USDA Nonpoint Source Water Quality Policy (December 5, 1986) were developed. Soil and water conservation practices were recognized as the primary control mechanism for nonpoint sources of pollution on National Forest System lands. This perspective is supported by the Environmental Protection Agency in their guidance, "Nonpoint Source Controls and Water Quality Standards" (August 19, 1987). The National Forests in North Carolina uses soil and water conservation practices (Best

Management Practice or BMP) identified in Forestry Best Management Practices Manual NC Division of Forest Resources (1989) and additional water quality BMPs designed by the Forest in cooperation with Coweeta Reasearch Station. This BMP system is composed of 5 elements:

1) BMP selection and design based upon site specific conditions; technical, economic, and institutional feasibility; and the designated beneficial uses of the stream;
2) BMP application;
3) BMP monitoring to ensure compliance and effectiveness in protecting the beneficial uses;
4) Evaluation of the BMP monitoring results;
5) Feed back the results into current/future activities and BMP design. This portion of our monitoring program is an essential portion of the BMP "feed back loop."

Specific Monitoring Objective & Question: To document the location of trail erosion, delivery of sediment to the stream network, and identify needs for improvement. We will answer the question: Are appropriate BMP’s in place on the trail system and are they working?

Procedures (including a brief description): A baseline assessment will be done in early 2008 of all trails within the Upper Tellico River Sub-watershed, including trails designated for OHV use and trails used illegally. This assessment will identify problem areas or areas that are prone to erosion, and travel distances of trail-derived sediment from trails to stream channels. Thus, sources of sediment and connectivity of trails to streams will be established. These sites will be documented in a contract of work and the corrective BMPs will be applied. To test the effectiveness of the BMPs implemented, inline sediment samplers will be installed at runoff points using borrowed equipment from the Coweeta Lab. Approximately 50 samplers will be installed in designated locations to represent four or five groups of different BMPs implemented. Thus, 10 to 12 samplers will be installed at each BMP. The volume of sediment captured by the samples will be measured following each storm runoff event. A raingage (also borrowed from Coweeta) will be installed early in 2008 to monitor precipitation frequency and amounts.

In addition to the inline sediment samplers, high priority trail segments will be reviewed annually to determine whether all prescribed BMP's/mitigation measures were fully implemented, and determine if the measure, as applied, was successful in achieving its objective – eliminating sediment transport to stream channels. Sediment travel distances will be measured and compared to previous years. Where implemented BMPs are not successful, new practices will be designed and implemented.

Estimated Annual Cost: See Tables 1.

Table 1: Estimated annual cost of BMP monitoring.

Item	Personnel	Production	Cost
BMP Monitoring	FS District Personnel (2 people @ $250/day)	20 days/person	$10,000
	FS Hydrologist (@ $400/day)	5 days	2,000
Write Report	FS Hydrologist (@ $400/day)	2 day	$800
Total:			$12,800

Person Responsible: Tusquitee Ranger District personnel and NFsNC Hydrologist.

Data Storage: NFsNC Hydrologist will summarize findings in an annual report by February 1 of the following year. This report will be incorporated into the Tellico ORV Area Water Resource Report. These documents will reside at the Tusquitee District office and the NFsNC Supervisors Office, Water Resources Department.

Suspended Sediment & Turbidity

Introduction: One of the greatest potential changes to water quality from a road/trail network is increases in sediment loading on streams. Large increases in the amount of sediment delivered to the stream channel can impair or even eliminate aquatic habitat (MacDonald et. al.1991). North Carolina state standard for turbidity in the Tellico River and its tributaries is 10 Nephlometric Turbidity Units (NTUs). This tie between suspended sediment and protected uses makes it imperative that we monitor suspended particles in the Tellico River OHV area.

Existing Condition: It is appearent that the trail network in the drainage has increased the quantity of fine (< 2 mm) sediment transported, as total suspended sediment (TSS) and turbidity, to the stream network due to an increase in compacted area, erosion, and channel network extension. Although stream energy is high, and much of this sediment is moved downstream, deposition is occurring in the Tellico drainage thereby reducing habitat quality.

Specific Monitoring Objective & Question: To establish trends in suspended sediment and assess the support of protected uses within the Upper Tellico River Sub-watershed. We will answer the question: Is water clarity being improved as measured by TSS and Turbidity.

Procedures:

Multi-sampler:

Four automatic multi-samplers (two borrowed from Coweeta) will be located near the outlet of Tipton Creek, Peckerwood Creek, and Sycamore Creek, and on the Tellico River at the state line. These sites would focus the monitoring effort on cumulative effects from the Upper Tellico ORV Area and provide an appropriate reference site on Sycamore Creek. Samplers would sample at a designated stage to capture water during storm runoff events. Each sampler would also measure water stage (depth) during the sampling period. At several site visits each year, discharge measurements will be taken to establish a stage-discharge curve. Water samples will be analyzed at a lab for TSS and turbidity. Every tenth set of samples (from the four sites) will also be analyzed to determine the ratio of organics to inorganics.

During stream discharge measurements, a sample would be taken by the multi-sampler and a second sample taken with a DH-48 depth-integrated (DI) grab sampler, simultaneously to check for bias in sampling. The DI samples will represent the average total suspended solids from the channel and will be compared to the simultaneously pumped sample. These samples will also be analyzed at a lab for suspended sediment.

Single-stage sampler:

Single stage samplers have been in the Tellico River drainage since 1995, collecting TSS data. These 11 samplers in the Upper Tellico OHV Area will continue to be used to maintain the long-term data set (see Map 1 in Appendix for sample site location). These samplers collect water from a storm runoff event when water rises high enough to enter an opening on the stationary bottle. These samples will be taken to a lab and analyzed for TSS and turbidity.

Data will be summarized using graphic data plots comparing stream discharge to turbidity and TSS concentrations, and discharge and sediment concentration to time for each site for individual storm events (refer to Brooks, et. al. 1991). Statistical analysis will include a two-sample t-test to compare to the reference site and an analysis of covariance (ANCOVA) to estimate trends in each site.

Estimated Cost: See table 2.

Table 2: Estimated annual costs for TSS monitoring .

Item	Personnel	Production	Cost
TSS – Multi-samplers	TVA Field Technicians (2 @ $215/day each)	4 sites/day (avg. 6 visits/ year)	$2,580
Discharge & depth-integrated sampler	FS Hydrologist (@ $400/day)	4 days	$1,600
TSS – Single-samplers	TVA Field Technicians (2 @ $215/day each)	11 sites/day (avg. 10 visits/ year)	$4,300
Sample Processing by TVA	Lab ($8/sample)	1320 samples	$10,560
Data entry & analysis	TVA Specialist (@ $400/day)	3 days	$1,200
Equipment and materials (TVA)			$850
Total:			$21,090

Person Responsible: TVA would be responsible for monitoring suspended sediment, processing samples, and reporting data to the National Forests in North Carolina Hydrologist.

Data Storage: Electronic database and hard copy files at the National Forests in North Carolina Supervisors Office, Water Resources Department, and at the Tusquitee Ranger District office.

Sediment Deposition

Introduction: In all stream systems there exists a unique balance between many interrelated variables including: sediment quantity and size, stream flow, woody debris, gradient, and channel geometry. A major shift in any of these variables could initiate a series of channel adjustments and affect the streams ability to maintain protected uses. Large amounts of sediment can fill in pools that are important for soucres of fish habitat. The deposition of fine sediments on larger substrate reduces habitat for young fish and aquatic macroinvertebrates, and can adversely affect gravel permeability and the suitability of gravel for spawning (MacDonald, et.al. 1991). This tie between the sediment deposition and protected uses makes it imperative that we monitor sediment deposition in the Upper Tellico River OHV area.

Existing Condition: It is apparent that the trail network in the Upper Tellico River drainage has increased the quantity of fine (<2 mm) sediment transported to the stream network due to an increase in compacted area, erosion, and channel network extension. Since stream energy is high in the Upper Tellico River drainage, much of this sediment can be efficiently moved downstream. However, in several reaches of stream sediment deposition is occurring, filling pools and covering larger substrate. Because of the predominantly large particle sizes (e.g. boulders and bedrock) in the stream bed and banks, channel adjustment due to fine sediment deposition is not a concern. Therefore, monitoring will focus on sediment deposition on the stream bed rather than changes in channel form.

Specific Monitoring Objective & Question: To evaluate and track changes in stream stability and sediment deposition within the Upper Tellico River Sub-watershed to assess the support of protected uses. We will answer the question: Is sediment deposition in pools and riffles decreasing?

Procedures:
Rosgen Stream Channel Classification (RC): Rosgen stream channel classification methodology will be used to establish a basic context for comparison of reaches. Stream reaches are required to have similar geomorphic forms that classify them each in the same Rosgen (1996) stream type. Seven stream reaches will be classified to calculate the Rosgen classification. Sycamore Creek will be established as a reference stream. The Sycamore Creek drainage, although managed in the past 20 years, has few open roads and hiking trails. Data will be presented in table form to compare morphologic features of each stream channel.

Pfankuch Surveys (PS): The Pfankuch Survey is a stream reach inventory and channel stability evaluation designed directly or indirectly to answer three basic questions:

1) What are the magnitudes of the hydraulic forces at work to detach and transport the various organic and inorganic bank and channel components?
2) How resistant are these components to the recent stream flow forces exerted on them?
3) What is the capability of the stream to adjust and recover from changes in flow volume and/or increases in sediment production?

The evaluation portion of the inventory requires judgement based on experience and criteria outlined by the protocol in the booklet, “Stream reach inventory and channel stability evaluation” (Pfankuch 1975). The channel bed and banks are subjectively rated following an on-the-ground inspection. The inspection can occur in either direction of the monitoring site (e.g., pebble count) as long as similar channel conditions do not change (a representative reach). A reach the length of 20 times the channel’s bankfull width is recommended where feasible. The reach should include the other measurement locations on the stream. Where a pool filling (V*) is done, the same reach should be evaluated by the Pfankuch survey. Information will be documented on a survey form and presented in a summary table for comparison of sites. Pfankuch surveys will be completed on seven seperate reaches, identified in Table 4 and in Appendix A – Map 1, during the first year of plan implementation and resurveyed the 6th year when the plan will be reevaluated.

Riffle Pebble Counts (PC): The riffle pebble count will characterize the bed material in three consecutive riffles in a section representative of each of the seven reaches where Rosgen Classification and the Pfankuch Surveys occur. Thus, 21 pebble counts will occur, measuring at least 2,100 particles annually.

At least 100 pebbles are measured at each of the three transects. The width of the channel bottom at the riffle is measured and divided by 100 to get the distance between sample points. A particle (pebble, rock, stone, etc.) is identified at each of the points by “blindly” lowering a finger to the stream substrate without looking at the pebbles. The particle selected for measurement is the one touched first by the surveyor's finger. Particle sizes can range in size from sand and smaller sizes (<2 mm) to bedrock (>2048 mm), and are identified on the pebble count form. For each sample, the intermediate axis of the particle is measured using a Hand Held Size Analyzer (US SAH-97) or metric caliper, and tallied by size class. Sand size particles measuring less that 2mm are broken down into sand, silt or clay based on the "feel" method (Brady 1990). For large particles, count the same particle as many times as it is encountered. The cumulative percent finer is then calculated for each size class. If at the end of the transects at least 100 particles have not been measured, a random number would be generated to give a number of feet from the beginning of the cross section.

Pebble counts will be conducted annually for the life of this plan at each of the seven reaches identified in Table 4 and Appendix A – Map 1. The first survey will establish a baseline to which we can evaluate trends and conditions. During that period, the probability of having at least one bankfull event (defined as having a 1.5 year recurrence interval) is very likely.

Data will be summarized using a graphic plot of the number of particles as a percent of the total compared to particle size. Plots will be developed for all sites each year and a comparison of each site over a period of years to establish trends in bed material. Statistical analysis will test for a goodness of fit of data using the k-sample Kolmogorov-Smirnov Test.

<u>Pool Filling (V*):</u> This methodology was developed by Hilton and Lisle (1993), and is a procedure to measure the fraction of pool volume filled with fine sediment. The Forest Service Research Note PSW-RN-414, Measuring the Fraction of Pool Volume Filled with Fine Sediment (Hilton & Lisle, 1993) completely outlines this protocol.

The fraction of pool volume filled with fine sediment can be a useful index of sediment supply, and will be used to evaluate and monitor channel condition, and detect and evaluate sediment sources. This fraction (V*) is the ratio of fine sediment volume to the sum of pool water volume and fine sediment volume. All measurements are taken within the residual portion of the pool that lies below the elevation of the downstream riffle crest or pool tailout. The thickness is measure by driving a graduated metal probe into a fine grained deposit until the underlying coarser substrate is felt. Both water depth and fine sediment thickness are measured across transects, and volumes are computed by summing products of cross-sectional area and distances between transects. Since the objective of the monitoring is to monitor changes over time for the stream reaches identified in Table 4 and the pools are structurally stable, 5 to 7 pools will be intensively measured to minimize variability and provide additional information about changes in individual pools. All pools will be measured near an annual low flow discharge each year to compare the reach over time.

Pool filling (V*) will be conducted annually at each of the 7 reaches identified in Table 4. The first survey will establish a baseline to which we can evaluate trends and conditions. Each site will be monitored annually for a period of six years. During that period, the probability of having at least one bankfull event (defined as having a 1.5 year recurrence interval) is very likely.

Data will be summarized in graphic plots showing all sites per year and each site over the period of monitoring. Statistical analysis of the data will include an analysis of varience (ANOVA).

Estimated Annual Cost: See Tables 3.

Table 3: Estimated annual costs for sediment deposition monitoring.

Item	Personnel	Production	Cost
Pebble Counts	FS Hydrologist (@ $400/day) Field Technician (@ $250/day)	3 sites/day for 7 sites	$1,550
Data entry & analysis	FS Hydrologist (@ $400/day)	1 day	$400
Pool Filling (V*)	TVA Field Technicians (2 each @ $350/day/person)	1 site/day for 7 sites	$4,900
Equipment and Materials			$400
Data entry & analysis	TVA Specialist (@ $400/day)	3 days	$1,200
Annual report	FS Hydrologist	2 days	$800
Total:			$9,250

Person Responsible: TVA will be responsible for monitoring Pool Filling (V*), providing raw data, and a summary of data to the National Forests in North Carolina Hydrologist. All other data and reporting will be the responsibility of the NFsNC Hydrologist.

Data Storage: Electronic database and hard copy files at the National Forests in North Carolina Supervisors Office, Water Resources Department, and at the Tusquitee Ranger District office.

Table 4. Summary of Water Resource Effects Monitoring Reach locations for the Upper Tellico Off-Road Vehicle Area, Sycamore Creek, and Citico Creek.

	Monitoring Parameter						
Site Name	*TSS multi-sampler*	*TSS single-sampler*	*Pfankuch Survey**	*3-Riffle Pebble Count*	*Macro-inverts*	*Pool filling (V*)*	*OHV trails in drainage*
Tellico River Sub-watershed sites							
Tellico River TR#2 & 3 (Stateline)	X	X	X	X	X	X	all trails
Tellico River TR#4 (abv Tipton)		X					all except trails #s 1 & 2
Tellico River TR#5 (abv Ruff Xing)		X	X	X	X	X	all except trails #s 1, 2 & 6
Tellico River TR#6 (blw F.Ford)		X					3, 4, 8, 9, 10, 10a, & 11
Tellico River TR#7 (abv Bob Cr.)		X					3, 8, 10, & 10a
Tipton Crk TC#1 (blw Jenks Br.)	X	X					1, 2, & 4 plus private development
Tipton Crk TC#2 (abv Jenks Br.)		X	X	X	X	X	1 & 4 plus private development
Tipton Crk TC#3 (blw Bearpen Br.)		X	X	X		X	none (may have old roads)
Jenks Branch JB#1 (near mouth)		X	X	X	X	X	2
Peckerwood Crk PC#1 (near mouth)	X	X	X	X	X	X	4, 6, 7, & 8
Bob Br. BB #1 (near mouth)		X					8
Sycamore Creek site (less disturbed, reference)							
Sycamore Creek SC # 1 (near mouth)	X		X	X	X	X	FR 163 decommissioned around 1992
Citico Creek site (wilderness, reference)							
Citico Creek CC#3 (in wilderness)					X		

** fill out the Pfankuch Channel Stability Evaluation form for the reach including and upstream and/or downstream of the site, a length 20 times bankfull width.*

Notes:
1) At all sites establish Rosgen channel type at first measurement.
2) Pebble Count, Macro-invertebrate Sampling, Pool Filling (V*) measurements made once every year.
3) Pfankuch Survey completed during the first year to establish a baseline, then at the end of the monitoring period.
4) Pool filling (V*) methodology per Hilton & Lisle, 1993, Measuring the Fraction of Pool Volume Filled with Fine Sediment, PSW-RN-414-WEB

Aquatic Macroinvertebrates

Introduction: Macroinvertebrates are the primary food-base for fish and important indicators of water quality (Davis et al. 2001). Macroinvertebrates have several characteristics that make them useful indicators of stream quality. First, many macroinvertebrates have either limited migration patterns or a sessile mode of life that allows monitoring of local conditions (MacDonald et. al. 1991), in addition to the integration of watershed-level disturbances. Second, macroinvertebrates have relatively short life spans that are indicative of water quality in the recent past (Platts et al., 1983). Third, macroinvertebrates are naturally abundant in most streams (MacDonald et. al. 1991). Finally, the sensitivity of macroinvertebrates to changes in channel conditions and water quality often make them more effective indicators of stream impairment than chemical measurements (EPA 1990). Therefore, a major shift in macroinvertebrate communities could affect our ability to maintain protected uses.

Existing Condition: Limited macroinvertebrate monitoring from the Tellico River reveals a somewhat suppressed community structure. Bedload transport, along with accelerated sediment deposition, can negatively affect habitat quality and quantity, and therefore suppress macroinvertebrate community structure and function. Community health and biodiversity can be reduced from prolonged suppression.

It is appearent that the trail network in the drainage has increased the quantity of fine (< 2 mm) sediment transported to the stream network due to an increase in compacted area, erosion, and channel network extension. Without extensive monitoring in the area, it is reasonable to assume that aquatic macroinvertebrate communities have suffered.

Specific Monitoring Objective & Question: To evaluate and track trends in water quality using macroinvertebrates within the Upper Tellico River Sub-watershed to assess the support of protected uses. We will answer the question: Does the population demographics of macroinvertebrates indicate improvement of water quality?

Procedures, Selected Streams, & Cost: The Forest Service has a contract with Western Carolina University to provide the services of investigating the effects of the Upper Tellico OHV Area on the aquatic macroinvertebrate communities within the Tellico River watershed. The contract will run from May 2, 2007 through December 31, 2008 and costs $30,000. This contract was completely funded in FY07.

On each of four sample dates (mid-May, mid-August, mid-November, and mid-February) during 2007 and 2008 WCU personnel will visually estimate the proportion of stream bed consisting of particular habitat types (e.g. clay, silt, cobble) and collect 20 kick-net samples proportionally allocated among the observed habitat types (Barbour et al. 1999) at each of the 7 established 100 meter survey reaches. All macroinvertebrates will be picked from the samples in the field and fixed in 5-10% formalin. In the laboratory, all individuals will be transferred to 70% ethanol for preservation and will be identified to the lowest taxon feasible (species for mature larvae of Ephemeroptera, Plecoptera, and Trichoptera, family or genus for other invertebrates).

Descriptive statistics will be calculated for each habitat type within each survey site as well as for the survey site as a whole. Descriptive statistics will include: total number for each taxon; mean number per sample for each taxon; the total number of species in the orders Ephemeroptera, Plecoptera, and Trichoptera; and Shannon-Weiner Diversity and Simpson's Dominance indices.

Beyond the December 31, 2008 contract aquatic macroinvertebrate monitoring will continue for the life of this plan. Annual costs are expected to range from $5,000 to $10,000, depending on recommmendations from Western Carolina University.

Persons Responsible: The Fisheries Biologist, Nantahala National Forest will be responsible for writing an annual summary report that will be given to the NFsNC Hydrologist by Febuary 1 of the following year to be added to the Tellico ORV Water Resources Effects report.

Data Storage: Tusquitee Ranger District, Cheoah Ranger District, National Forests in North Carolina Forest Supervisor's Office.

Overall Program

Feasibility: The accomplishment of this plan is dependant upon funding. An annual monitoring budget of approximately $45,050 is required for full implementation (Table 5).

Table 5: Total estimated annual program personnel costs and fund codes.

Monitoring Type	Cost	Proposed Fund Codes
Trail BMP Monitoring	$12,800	CMRD
Suspended Sediment & Turbidity	$21,090	CMRD / NFIM / NFVW
Sediment Deposition	$9,250	CMRD / NFIM / NFVW
Aquatic Macroinvertebrates	$5,000	CMRD / NFIM / NFWF
Total Program:	$48,140	

Reporting & Responsibilities: An annual monitoring report will be produced by the NFsNC Hydrologist by March 1st presenting the previous years results.

Conclusions: This monitoring plan is intended to be implemented over the next six years. At the end of this monitoring period a determination will be made whether or not to continue such work.

Implementation of the plan will provide the Tusquitee District Ranger with the information needed to evaluate the condition of aquatic resources in the Upper Tellico OHV Area. This monitoring will qualify as the reasonably "hard look" required by the NEPA process for decision making and good resource management in the OHV area.

References

Barbour M.T., J. Gerritsen, B.D. Snyder, J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, Benthic Macroinvertebrates, and Fish. Second Edition, EPA 841-B-99-002. U.S. Environmental Protection Agency. Office of Water, Washington D.C.

Brady, Nyle C. 1990. The nature and properties of soils. Macmillan Publishing Company, New York, NY, Pp. 97-100.

Brooks, K.N., P.F. Ffolliott, H.M. Gregersen, J.L Thames. 1991. Hydrology and the management of watersheds. Iowa State University Press/Ames, 177p.

Davis, Jeffrey C., G.W. Minshall, C.T. Robinson, P. Landres, 2001. Monitoring wilderness stream ecosystems. Gen. Tech. Rep. RMRS-GTR-70. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 52 p.

EPA, 1990. Biological Criteria. U.S. Environmental Protection Agency, Off. Water Regulations and Standards, EPA-440/5-90-004. Washington, D.C., 41 p.

Hilson, Sue and Thomas E. Lisle. 1993. Measuring the fraction of pool volume filled with fine sediment. Research Note PSW-RN-414. Albany, CA. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, 11p.

MacDonald, Lee H., A.W. Smart, R.C. Wissmar, 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. U.S. Environmental Protection Agency, Water Division, EPA/910/9-91/001. Seattle Wa., 147 p.

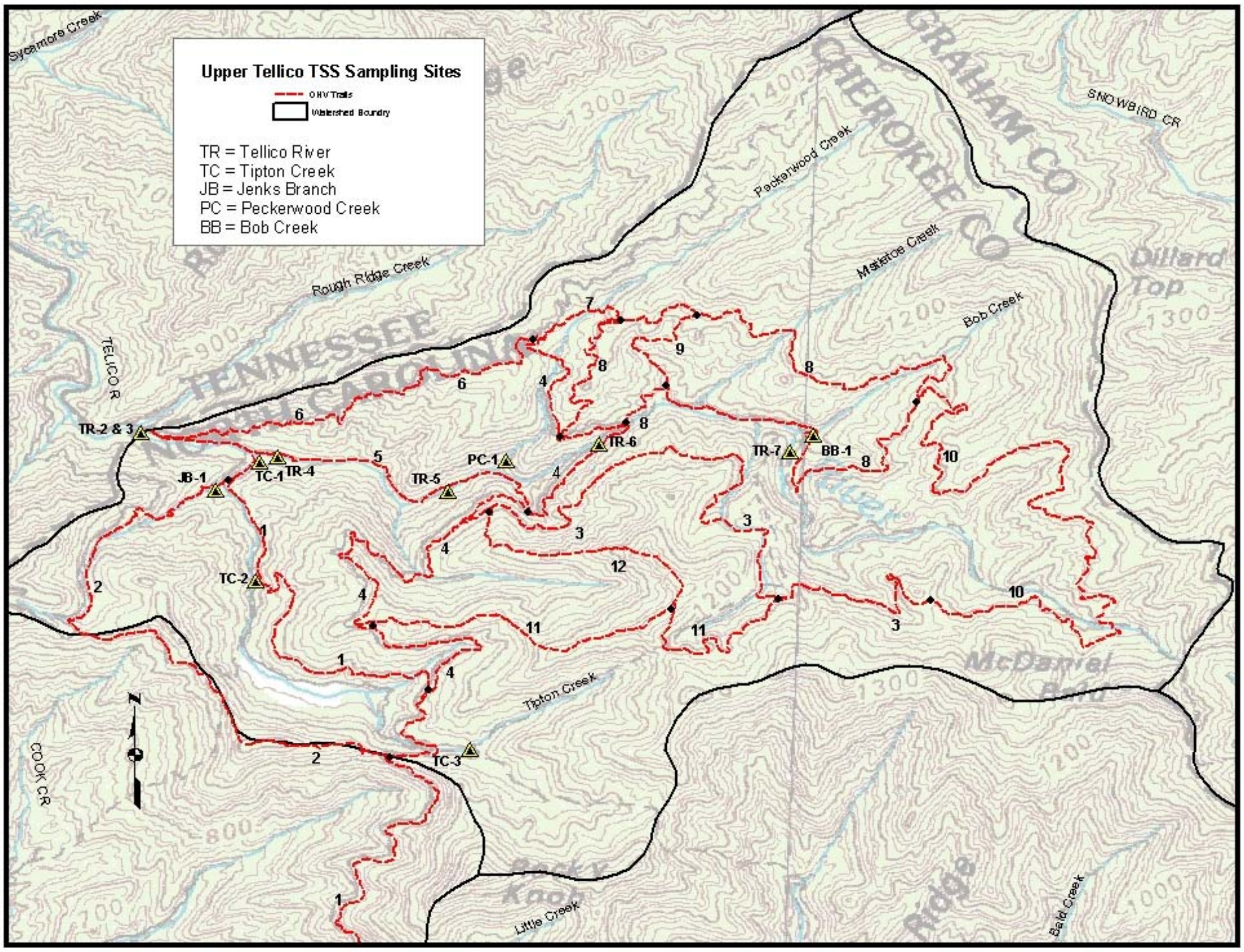
North Carolina Department of Environment and Natural Resources (NCDENR). 2006. http://h2o.enr.state.nc.us/tmdl/documents/303d_Report.pdf

Pfankuch, Dale. 1975. Stream reach inventory and channel stability evaluation. A watershed management procedure. U.S. Forest Service, Northern Region

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA For. Ser., Gen. Tech. Rep. INT-183, 71p.

Rosgen, Dave. 1996. Applied river morphology. Wildland Hydrology.

Appendix A – Map



Map 1. Upper Tellico Subwatershed total suspended sediment sampling sites.