METHODS USED FOR ANALYZING THE CUMULATIVE WATERSHED EFFECTS OF FUEL MANAGEMENT ON SEDIMENT IN THE EASTERN UNITED STATES

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Abstract—This paper reviews the methods in use since 2000 to analyze the cumulative watershed effect (CWE) of sediment from fuel management activities within forestlands of the eastern United States, and evaluates how well current methods provide the information needed to meet legal expectations. The two sediment hazard rating models currently being used are the Erosion and Sediment Yield (EASY) and the Aquatic Cumulative Effects (ACE) models. Both are lumped-parameter models based on the USLE that predict sediment yield at the outlet point of a watershed based on the activities and conditions present or proposed. The EASY and ACE models use the same general procedural steps and compute erosion from forest areas using similar data sources and formula. They differ in how the CWE analysis area is determined, how they compute non-forest and road erosion, and how model results are interpreted. Both models can provide users with information needed to address most of the legal expectations for CWE analysis, but both suffer from lack of validation. Comments are offered on helpful features for future models and the need for knowledgeable model users.

INTRODUCTION

Previous chapters in this section have described how various resource systems within a watershed can experience cumulative effects (CEs) from fuel management activities like prescribed burning. As noted previously, a CE is defined as

"[T]he impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time" (40 Code of Federal Regulations 1508.7).

A cumulative watershed effect (CWE) is any CE that involves water movement through a landscape, either because water-related resources are affected or because a change in watershed processes generates the effect (Reid in press). As sediment production and movement is tied to water movement and affects water-related resources, a sediment CE is clearly a CWE.

Reid (in press) has determined the expectations for CE analysis that federal courts have expressed in recent decisions concerning the Forest Service (FS) and Bureau of Land Management. She reviewed 62 district and appellant court decisions issued between 2000 and 2005 to determine these expectations. Some of these expectations are unaffected by which method is chosen to analyze sediment CEs. However, others would be affected by what method is chosen or the content of the documentation for a given method. These latter expectations are listed in Table 1.

For National Forests of the Southern and Eastern Regions (R8/R9), the Eastwide Technical Guide (Tetra Tech 2002) provides the sanctioned strategy for determining if a CWE assessment is needed. The Guide provides a step-by-step decision process (after MacDonald 2000) for conducting a CWE analysis and for determining the "level of effort" to be applied in doing CWE analysis for a given situation. Five effort levels are identified depending on the degree of controversy involved, the linkages between activities and resources of concern, and the risk to those resources, with Level 1 being the lowest effort and Level 5 the highest. The Guide does not specify that any particular analysis method be used at a given level; rather the analyst is expected to select the method most appropriate given the resource concerns and level of effort required.

It is important that the reader understand the difference between a "method" for evaluating a CWE and the CWE analysis itself. The method is a tool used to predict how a specific watershed feature or process (e.g., stream temperature or sediment yield) will respond to a proposed activity; whereas a CWE analysis uses these predictions to assess how a resource of concern (e.g., water quality or a freshwater mussel population) will be affected. The methods are a necessary first step to CWE analysis, but they do not constitute the CWE analysis itself, and the

reader should keep this difference clearly in mind. Our review will focus largely on the methods in use, but we will briefly describe how outputs from these methods have been used in past CWE analyses. The Eastwide Technical Guide (Tetra Tech 2002) is recommended to those readers wishing a more comprehensive discussion of how results from analysis methods should be incorporated into a CWE analysis.

The purpose of this chapter is to describe the methods currently being used to conduct CWE analysis of fuel management projects within forestlands of the eastern United States (US) and to evaluate how well they provide the information needed to meet legal expectations for CE analysis. To determine what methods are being used, we contacted the soil scientists, hydrologists, or other specialists on all National Forests within the eastern US who might be involved with CWE analysis. We also contacted a limited number of resource specialists within environmental agencies of eastern states who were recommended to us as CWE practitioners. While our survey indicates that CWE analysis of fuel-management projects is at present only being done on federal forestlands, the methods we discuss below could be used for any forestlands in the eastern US. Currently, the only CWE issue related to fuel management that is being analyzed is sediment; therefore only methods addressing sediment are covered. Moreover, while many techniques are available for managing forest fuel loading, prescribed fire is the one most commonly used and is the technique -- along with its concomitant fireline construction and use -- that occasions CWE analyses most frequently in the eastern US. We limit our review to those CWE methods that have been employed since 2000.

The remainder of this chapter is organized as follows. First, we review the methods currently being used to assess possible sediment CWEs from fuel management practices. Second, we discuss how well the methods provide the information required to meet the legal expectations identified by Reid (in press). Lastly, we identify several issues that should be considered in developing future models for assessing sediment CWEs.

ANALYSIS METHODS USED IN EASTERN US

Based on our survey of resource specialists, we found several common features to how CWE analyses were being done in R8/R9. The responses from these specialists indicated that sediment is currently the only CWE issue related to fuel management that is being addressed in environmental analysis documents. The fuel-management practices of greatest concern related to sediment production are fireline construction and prescribed burning. The reasons why sediment is a primary CWE concern can be found in Kolka (this volume). Within R8/R9, CWE analysis of sediment related to fuel-management practices has most often been done during the Forest planning process; it has only been done on a very limited basis as part of project assessments. To date, sediment CWE analysis has not been applied to wildfires in R8/R9.

Past CWE applications for fire in R8/R9 seem to fall into just two effort levels (based on the Eastwide Technical Guide [Tetra Tech 2002]) and employ similar methods within each level. Level 2 applications occur most often and result when CWE concerns are low and existing protection or mitigation methods are considered sufficient to address any concerns. Level 4 applications occur when CWE concerns are moderate to high and existing controls may not be sufficient. For Level 2 applications, a "narrative analysis" is used to assess sediment CWEs. A narrative analysis describes the extent and potential severity of sediment CWE, reviews the relevant literature on fire effects on sediment production; and states conclusions as to likelihood of a sediment CWE and the effectiveness of proposed mitigation measures. For Level 4 situations, "hazard rating models" are used to analyze sediment CWEs. Hazard rating models use measured or categorized input variables that are mathematically manipulated (based on some conceptual or empirical model) to compute the combined effect of these variables on a response variable (in this case, sediment). Hazard rating models differ from deterministic models (e.g., the Water Erosion Prediction Project [WEPP] model [Flanagan and Nearing 1995]) in several ways but most importantly in that the rating model output is explicitly recognized as not representing a real amount; rather it is interpreted as an index value which can be used to compare different action scenarios and judge the potential chance for a CWE to occur (e.g., high, moderate, or low). While a number of models, both hazard rating and deterministic, have been developed over the years to assess the CWEs associated with fuel management activities (see Elliot and others [in press] for a recent review), the only two models currently being used in the eastern US are the Erosion and Sediment Yield (EASY) model and the Aquatic Cumulative Effects (ACE) model. While other models have been used in R8/R9 to analyze sediment CWEs, only the EASY and ACE models have been used specifically to address sediment CWEs related to fuel management. Both of these models produce outputs that are labeled as “sediment,” however the documentation for both models states that these values are not to be considered physical quantities, but rather are relative values to be used in comparing alternatives and judging relative risks.

Narrative Analysis
The use of narratives to assess CWEs from fuel management practices is common in R8/R9 forest plans as well as in project level analyses. These narratives vary widely in detail and content, with sediment being the predominant concern. Conclusions are often based on professional opinion and the implementation of mitigation practices. Because of the wide range in detail and content of this method type, we did not attempt to evaluate narratives or assess how well they addressed the expectations listed in Table 1.

Hazard Rating Models
As noted above, the two hazard rating models currently being used in R8/R9 to assess sediment CWEs related to fuel management are the EASY (Hansen and others 1994) and ACE (Clingenpeel and Crump 2005) models. Both models predict the amount of erosion and sediment yield that will occur based upon conditions within an analysis area. Erosion (also called soil loss) is the detachment and displacement of soil material from the ground surface. Sediment yield is the amount of eroded material that moves across the land surface, reaches a stream channel, and is transported as stream sediment to a given outlet point downstream. Erosion is typically expressed as a volume per unit area per unit time (e.g., ton $acre^{-1}$ $year^{-1}$) whereas sediment yield is generally expressed as a total volume per unit time (ton $year^{-1}$).

Analysis Procedure--Both the EASY and ACE models are applied using the same general procedure:

1. Delineate the analysis area.
2. Identify all condition types within the area for the past, present, or future (proposed) scenario being analyzed.
3. Compute the total erosion from all condition types.
4. Compute the total sediment yield at the outlet of the area.
5. Repeat steps 2-4 for all project alternatives.
6. Interpret the sediment hazard associated with all project alternatives.

Analysis Area Definition--The analysis area is the total land area addressed by the CWE analysis. This area includes the area that will be directly affected by the activity prompting the analysis effort, plus all upstream and downstream areas that may contribute to or be affected by the possible CWE being considered. Since both the EASY and ACE models predict sediment yield for entire drainage basins, the analysis area boundary is typically delineated using the one or more basins that encompass all of these land areas. Separate analyses can be done when multiple basins are used.

Condition Type Definition--The condition type is a classification of the land-use activity or site conditions occurring or proposed over a contiguous land area. Examples include undisturbed forest land, forest area with a specific silvicultural practice applied (e.g., clearcut or shelterwood harvest), road area, cropland, orchard, pasture land, urban land, or abandoned land. The classifications used vary somewhat between the models, but both models require an inventory of the existing condition types within the analysis area. Increasingly, this is accomplished using spatial data sets like National Land Cover Data (US Geological Survey 1992) and Topologically Integrated Geographic Encoding and Referencing (TIGER) (US Census Bureau 2006) datasets for non-FS lands, and relevant FS geographic information system (GIS) datasets for FS lands.

Details on how the analysis area is delineated, condition types are identified, erosion and sediment yield are computed, and results are interpreted for both the EASY and ACE models are given in the following sections. Differences between the two models are also noted.

The EASY Model
The EASY model (Hansen and others 1994), in its current or earlier versions, has been used on the Francis Marion and Sumter National Forests (FMSNFs) since the late 1980's to evaluate potential sediment impacts from existing or proposed conditions. A Microsoft Excel spreadsheet program is used to compute the model outputs from input data. To apply the EASY model to any area other than the FMSNFs, the spatial data for all relevant condition types would have to be compiled by the user for this new area. A copy of the spreadsheet is available from William F. Hansen (Francis Marion and Sumter National Forest, 4931 Broad River Road Columbia, SC 29212-3530 phone 803/561-4059 email wfhansen@fs.fed.us).

Analysis area delineation--Analysis areas are determined by the user; the EASY model places no restrictions on how large or small an area may be analyzed. Past applications have used areas up to 50,000 acres. Analysis areas generally correspond to watershed boundaries, but not always. On coastal areas of the FMSNFs, the terrain is very flat and watershed boundaries are difficult to discern with confidence, thus analysis areas there have not always been constrained to match watersheds. Past decisions have been based on what was deemed appropriate for the terrain that will be potentially affected and the project being analyzed.

Condition type determinations--For FS lands, land areas for each existing or proposed condition type are obtained from FS GIS datasets or relevant planning documents. Past applications have estimated the length of new or existing firelines from sample data when GIS data were not available. For non-FS lands, existing conditions are determined by manual measurements from GAP imagery (South Carolina Cooperative Fish and Wildlife Research Unit 1993) or aerial photographs. The EASY model distinguishes several different condition types related to fire. Burned areas are classified as either a site-preparation burn, dormant-season burn, or growing-season burn -- the latter two being used for either fuel reduction or wildlife improvement. Firelines are classified as either hand or bulldozer constructed. Wildfire burns are not included, but could be classified using the existing types that best match the wildfire severity and suppression activities.

Erosion and sediment yield computations-- For each condition type, the soil loss is computed using Equation 1:

$$SL_i = area_i \times A_i \times t_{r_i} \tag{1}$$

where SL_i = soil loss (ton) from the ith condition type for the recovery period; $area_i$ = total area (acre) of the ith condition type in the analysis area; A_i = erosion rate (ton $acre^{-1}$ $year^{-1}$) for the ith condition type with the given soil region; and t_{ri} = recovery period (yr) for the ith condition type..

The EASY erosion rates are calculated for each condition type using Equation 2:

$$A_i = R_{ave} SL_{ave} K_{ave} \left(\frac{C_{low} + C_{ave}}{2} \right) \tag{2}$$

where for the ith condition type, R_{ave} = average rainfall factor; SL_{ave} = average slope length factor; K_{ave} = average erosivity factor; C_{low} = low cover type factor; and C_{ave} = average cover type factor (Hansen, personal communication). Equation 2 is a variation of the USLE model (Wischmeier and Smith 1978) and primarily uses factor values developed by Dissmeyer and Stump (1978) for large soil regions throughout the South. Dissmeyer and Stump (1978) determined Low, High, and Average factor values for a variety of condition types (including burned forestland) in each soil region. The Low, High, and Average values are interpreted by Dissmeyer and Stump (1978) as those that would result from “minimum,” “heavy,” and “average” impacts, respectively, to a given land area. The values given in Dissmeyer and Stump (1978) are mean annual values for the entire recovery period for each condition type. The recovery period was the time (in years) it took for the values to return to pre-disturbance levels. Recovery rates vary from 1-2 years for most vegetation removal practices, to the entire analysis period for roads. Dissmeyer and Stump (1978) provide a map showing the soil regions and tables listing the Low, Average, and High factor values and their related erosion rates. See Dissmeyer and Stump (1978) for additional details on the computation procedures.

While values for most of these factors are taken from Dissmeyer and Stump (1978), some were estimated based on available research and consultation with relevant specialists (Hansen and others 1994). Users can readily change the erosion rates provided by the EASY model if they have more specific data for their analysis area.

In applying the EASY model, it is assumed that all cover type values fall somewhere between the Low (C_{low}) and Average (C_{ave}) values given by Dissmeyer and Stump (1978); therefore the model uses the simple average of these two values in computing a representative erosion rate for each condition type (see Equation 2). This assumption is based on the reasoning that current practices are not as disruptive to the ground cover as those measured by Dissmeyer and Stump (1978); thus the typical response should fall within the lower part of the range determined by Dissmeyer and Stump (1978) (Hansen, personal communication.).

Soil losses from non-FS lands are included in the analysis, but are assumed to be constant over the analysis period and the same for all planning alternatives.

The total sediment yield is the product of the total predicted erosion and the sediment delivery ratio (DR) for the analysis area (Equation 3).

$$Yield = DR \times \sum_i SL_i \tag{3}$$

Sediment delivery is the integrated result of the various processes between on-site erosion and downstream sediment yield; whereas the DR is the ratio of total yield at the basin outlet to total erosion within the basin (Walling 1983). DR values have been determined two different ways in the past, depending on the spatial scale of the model application. For coarse spatial scales, a single DR value has been determined for each of the three physiographic regions that encompass the FMSNFs (listed below).

	Mountain	Piedmont	Coastal Plain
Sediment delivery ratio	0.38	0.34	0.1

The DR values for the Mountain and Piedmont regions were determined by Goddard (as cited in Hansen and others 1994), while the DR value for the Coastal Plain is assumed to be 10 percent. This assumption is based on the estimated DR for third- and fourth-order basins in the mountain and piedmont regions that is reduced by 30 percent for the lower drainage density in the lower Coastal Plain (USDA Forest Service 2006). For finer spatial scales (e.g., individual projects or timber sales), individual DR values are determined from Roehl's (1962) model using basin area.

Results interpretation--The EASY analysis produces estimates of total soil loss and sediment yield for each condition type and a total sediment yield for each analysis area and planning alternative (Figure 1). The spreadsheet can be modified by the user in any way desired to show how sediment yields vary between alternatives, condition type, land ownership, time period, or other categories of interest. The model does not include explicit direction on how to interpret the sediment yields; it is expected that the results will be presented and interpreted in whatever form the analyst deems most appropriate for the problem at hand. Past applications on the FMSNFs have presented EASY model results in a number of ways. One common approach has been to compute sediment yields for similar analysis units and to then judge the potential impacts between alternatives by the relative differences in their predicted sediment totals. A second method has been to compare the magnitude of sediment concentrations between alternatives. Sediment concentration is computed for the analysis area over the entire recovery period using an assumed mean water yield (based on local data) and the predicted sediment yield value for each alternative. A third method has been to determine the sediment yield value for the analysis area that is judged to be the worst case, and assume that impacts in other areas will be less than the worst-case value.

One concern with the EASY model is the way DR values are often applied. Sediment yields are generally computed for each condition type within an analysis area (e.g., Figure 1). While this produces mathematically accurate results, it is nonetheless conceptually incorrect. DR values provided by Roehl (1962) and others are based both on the *total* erosion produced within the entire catchment (i.e., $\sum_i SL_i$ in Equation 3) and the *total* drainage area for the catchment. Applying DR values to the erosion produced from an area that covers only a portion of a drainage basin implies accuracy that is unsupported by Roehl (1962). This problem in no way invalidates the past analyses using the EASY model since

$$DR \times \sum_i^n SL_i = DR[SL_1] + \cdots + DR[SL_n], \tag{4}$$

however we recommend that sediment yields only be listed for entire watersheds in future applications.

The ACE Model

The ACE model for the Ouachita and Ozark National Forests (OONFs) (Clingenpeel and Crump 2005) is the most current version of a CWE model which has evolved since 1990. Previous versions (e.g., Clingenpeel 2003, Clingenpeel and Mersmann 1999, USDA Forest Service 1990) differ in certain components of the model, but the overall methodology has remained fairly constant. The model runs through a Microsoft Excel workbook file. Spatial data for current conditions (the compilation date varies by area) have been compiled for all 5th-level Hydrologic Units (HUs) on the NFs in Alabama, Chattahoochee-Oconee NF, Cherokee NF, Daniel Boone NF, Sumter NF, NFs in Mississippi, OONFs, and Jefferson NF, and for all 6th-level HUs on the OONFs. Both the model and all relevant spatial data for the OONFs are available on a CD-ROM from Alan Clingenpeel.

Analysis area delineation--The ACE model is designed to be applied at the 5th-level HU (10^2-10^3 km^2) for forest planning efforts and 6th-level HU (10-10^2 km^2) for project level analysis (Clingenpeel 2003, Clingenpeel and Crump 2005). Unlike the EASY model where users can bound the analysis area however they choose, the ACE model currently computes sediment yields for these two scales only. At the project level the user simply selects the 6th-level HU or HUs that contain the project areas and the model analyzes the entire area within each selected HU.

Condition type determinations--The data sources used to compile condition types for the ACE model are described in Clingenpeel and Crump (2005: 27-28). FS GIS data were used to determine condition type, road, land ownership, and ecoregion type for FS lands within each 5th- or 6th- level HU. 1995 TIGER data (US Census Bureau 2006) were used to determine non-FS road types and lengths. Condition types outside FS lands were classified using 1992 data from the National Land Cover Data (US Geological Survey 1992). The slope class that each condition type fell within was determined by deriving slope class polygons using ArcView's GIS Spatial Analysis 2.0a extension (ESRI 2001) and 30-m digital elevation models. Ecoregion, condition type, slope class, and ownership layers were then overlaid and rasterized on a 30-m grid using ESRI's ArcView 3.2 so that each grid cell was assigned a single value based on the combined layers present in the cell. Total areas for each combination type were then computed using the grid cells for each 5th- or 6th-level HU. A similar overlay analysis was done to determine total length of road types by ecoregion and ownership by HU.

The ACE model uses four condition types related to fire: fuel reduction and site preparation burns (for areas); fireline constructed; and fireline reconstructed. No distinction is made for burned areas concerning type (controlled vs. wildfire), preburn vegetation cover, or vegetation growing period.

Erosion and sediment yield computations--The ACE model uses an overall computational process that is similar to the EASY model (Equation 1), however there are several important differences in how erosion rates are determined and applied. Whereas the EASY model uses the factor values, the ACE model uses the actual erosion rates for each condition type provided by Dissmeyer and Stump (1978). More precisely, the ACE model uses the "Average" rate determined by Dissmeyer and Stump (1978) for slopes less than or equal to 35 percent, and the "High" rate for slopes greater than 35 percent. Although it is recognized that this probably overestimates erosion related to FS activities, the higher erosion rates compensate for steeper slopes and management practices on other lands "that may not have the same standards as FS lands" (Clingenpeel 2003) -- i.e., where erosion rates are presumed to be higher. The basis for erosion rates from burned areas is a second difference: Where measured rates are lacking (e.g., the Ouachita Mountains), the ACE model assumes burned areas erode at twice the rate of comparable undisturbed forest areas (Clingenpeel, personal communication). The length of the recovery period and how erosion rates vary during this period is still a third difference. For forested areas, the ACE model assumes that all burned areas recover fully after one year and all harvested areas recover after three years. The decrease in erosion rates during the second and third years after harvest is based upon past research and field observations within the Ouachita NF (Clingenpeel and Crump 2005).

Soil loss from sample agricultural and urban condition types (SL_{nf}) (e.g., pasture land or cultivated cropland) was determined using the WEPP model (Flanagan and Nearing 1995). Representative soil characteristics from the WEPP database were applied to morphologic data (e.g., ecoregion, area, and slope) for each area of agricultural and urban condition types with a given HU to compute the soil loss from each area (Clingenpeel and Crump 2005).

Total sediment yield from non-road areas (SY_{nr}) within a HU is computed by summing the soil loss values computed for all forest and non-forest condition types, and multiplying this value by the sediment delivery ratio given by Roehl (1962) for the basin area (Equation 5).

$$SY_{nr} = DR \times \left(SL_f + SL_{nf}\right) \tag{5}$$

Still another important difference with the ACE model is how sediment from road areas was determined. The WEPP model (Elliot 2004) was used to compute representative sediment yield values (ton/mile) for roads, firelines, and ATV trails within each ecoregion occurring within the OONFs based on sample data from each ecoregion (Clingenpeel and Crump 2005). Separate yields were computed for each combination of usage type (road, ATV trail, or fireline), surface type, and maintenance level that occurs. Note that these are sediment yields, not soil loss values. The WEPP model includes a channel routing algorithm for estimating how much eroded sediment is delivered to and moves through the channel to the mouth. Total sediment yield from roads (SY_r) for an analysis area is determined by multiplying the appropriate unit yield value (SL_{ri}) times the length of road by surface type and maintenance level (l_i), and summing these for all road types/maintenance levels within the HU (Equation 6).

$$SY_r = \sum_i l_i \times SL_{r_i} \tag{6}$$

where i = the given road type and maintenance level. A more detailed explanation of how road sediment yields were modeled is given in Clingenpeel (2003).

Total sediment yield from the analysis area is the sum of road and non-road sediment yields (Equation 7).

$$SY = SY_{nr} + SY_r \tag{7}$$

The ACE model is designed to require a minimum of user input. Areas for all condition types and existing roads are already determined for each 6th-level HU within the OONFs. Erosion rates for all condition types have also been computed and compiled for each HU. The user is only required to input any road types not previously captured, the various areas and condition types associated with the project alternatives being analyzed, and an assumed rotation age for private forestlands. Once these data are entered, the ACE model computes sediment yields for past, present, and proposed future conditions within each HU. To compute the past condition sediment yield, the model assumes undisturbed forest cover over the entire basin. Present sediment yield is based on conditions existing as of when the spatial data were compiled (1992 for the OONFs), plus any updates for roads. The condition types for nonforest lands are assumed to remain constant between the compilation date and the analysis date; whereas forestland condition types have their erosion rates adjusted based on recovery or new harvest disturbances during this intervening period. The future sediment yield is based on conditions proposed in each alternative plus assumptions about harvesting on private forestlands. The ACE model also provides a routine where erosion mitigation efforts on roads that reduce soil losses (e.g., through road obliteration or closure) can be accounted for in the analysis.

Unlike the EASY model, the ACE model only computes the total sediment yield of the past, present, and future scenarios for just one year -- the first year of implementation of the proposed project. For condition types with erosion rates that decrease over time (i.e., "recover"), the model uses the rates appropriate to the implementation year in computing the present sediment yield. For the future scenario, all proposed activities are assumed to occur during the first year of implementation. For example, a proposed project with new road construction, harvesting, and burning is modeled in ACE as if all of these activities occur in Year 1. While recognized as inaccurate in most cases, this assumption eliminates the need to know which year each activity will occur and provides something of a “worst case scenario” by forcing all effects into a single year (Clingenpeel and Crump 2005).

Results interpretation--The ACE model presents its results in a standard format which the user cannot modify. An example of the summary page which displays the model results is given in Figure 2. The summary displays the total areas for each condition type under FS or non-FS ownership, road lengths and densities, and the total sediment yield from road and non-road areas under the past, present, and future scenarios. Lastly, the model displays ratings of relative risk to aquatic biota from sediment for each alternative.

The risk ratings show the significance of sediment CWEs relative to the beneficial use common to all streams draining FS lands – providing aquatic habitat. These risk ratings (also called watershed condition ranks) are based on the percent increase in sediment yield over what is predicted for the past (undisturbed forest) condition (see

Figure 2). Percent increases are listed for the current combination of condition types, and the combinations associated with each proposed alternative. In addition, the risk ratings for the current condition and all alternatives are also listed. These ratings were determined for each Arkansas ecoregion from bivariate analysis of various fish community metrics and predicted sediment increases using the ACE model (Clingenpeel and Crump 2005). Based upon the rationale of Terrell and others (1996), this analysis identifies when sediment increase – despite the influence of other habitat factors – becomes a limiting factor on fish numbers. This analysis was used to establish criteria for rating the condition of fish communities given current sediment levels, and the hazard posed by potential sediment increases from proposed projects. A similar analysis was used to develop risk ratings for four ecoregions outside of Arkansas: the Coastal Plain; the Central Appalachian/Western Allegheny; the Piedmont; the Blue Ridge; and the Ridge and Valley (Clingenpeel 2003).

DISCUSSION OF CURRENT CWE METHODS

The EASY and ACE models are both based upon specific analytical procedures, compute a variety of outputs, and provide supporting documentation. Next we compare and contrast how well these procedures, outputs, and documentation provide the information needed to meet the legal expectations for CWE analysis as identified by Reid (in press) and summarized in Table 1.

Analysis Area Identification

The EASY and ACE models are very different in how the area that may be affected by a sediment CWE is identified. The EASY model imposes no constraints on the user; the analysis area can be whatever size the user deems appropriate. One advantage of this approach is that the user can model the sediment CWE at a series of catchment sizes to better determine at what scale the CWE becomes insignificant. A disadvantage is that the user would also have to compile the spatial data at each analysis scale, as the model itself does not provide these data. While this approach does provide maximum flexibility, it also provides no guidance as to what spatial scale may be too small or too large for accurate results. The ACE model limits the analysis area to either 5th- or 6th-level HUs; scales that were thought to be appropriate for forest (Clingenpeel 2003) and project planning (Clingenpeel and Crump 2005), respectively. The user has no ability to vary from these two options; however most of the spatial data have already been compiled and the user only has to compile data for updates to the current condition types and the proposed actions. Thus, the EASY and ACE models provide different advantages and disadvantages regarding analysis flexibility and data compilation requirements.

Identification of Impacts from Proposed Action

Both models identify the sediment impact from proposed actions, and present these results in similar ways. The ACE model uses a separate sheet within the Excel workbook for each alternative to list the areas associated with each proposed action (e.g., seedtree harvest, fuel reduction burn, fireline construction) and predicted soil losses associated with each action. The EASY model produces the same results, but the format is dependent on how the user chooses to present the data. The main difference between the two models is that the ACE model only computes sediment for the first year and assumes all actions are implemented during that one year; whereas the EASY model computes sediment over multiple years after project implementation. The length of time modeled with EASY typically depends on the longest recovery period associated with the condition types involved.

Identification of Past, Present, and Future Impacts

Both models have the ability to predict sediment impacts from past, present, and future actions; however only the ACE model currently does so explicitly. The ACE model computes sediment yields for past, present, and proposed future scenarios, and displays the results on separate sheets within the workbook. The EASY model typically uses the present scenario as a no-action alternative, and it displays this alternative along with all proposed future scenarios in separate tables or sheets. The EASY model does not currently compute sediment values for an assumed past situation that would represent natural sediment production. However, it would be a relatively simple matter to revise the model to do this based, for example, on the assumption of uniform natural forest cover. Both models also provide ways for predicting sediment from areas burned during past wildfires, site preparation, or fuel reduction burns, though they differ in the erosion rates used and recovery period lengths.

Identification of CWE from Individual Actions

The two models identify sediment CWEs in very similar ways. They both list the relevant condition types either occurring within or proposed for the analysis area, compute the total erosion associated with each type, and the total

sediment yield for present and proposed future scenarios. Both models include the ability to model expected changes in sediment yield from assumed actions on private lands in assessing future scenarios.

Interpretation of Impacts Relative to Naturally Occurring Conditions

The ACE model provides an explicit comparison of sediment CWEs to natural conditions, whereas the EASY model does not. The ACE model estimates natural (past) sediment yield by assuming a uniform forest cover, computes the percent increase in sediment yield for the present and each proposed future scenario, and lists the relative risk ratings based on these predicted increases. The EASY model does not as yet provide an estimate of natural sediment yields. Past applications of the EASY model have compared future to present – not past – sediment yields, and based risk interpretations on this comparison. As noted earlier, it would not be difficult to revise the EASY model to produce predictions for an assumed natural scenario and thus satisfy this expectation.

Demonstration of Model Validity

No direct validation of the EASY model output has been done. Such a direct test might be accomplished by comparing measured sediment yields prior to and after some activity like prescribed burning in a basin, and determining how well the relative change compares with that predicted by the model. Another approach would be a treatment/control design wherein two basins are used that are similar in every way except one experiences the activity (e.g., is burned), and their relative differences in sediment yields are compared to model predictions.

A less direct approach to model validation would be to validate the model components (soil loss, sediment yield). To our knowledge, no direct validation of the erosion rates given in Dissmeyer and Stump (1978) has been done, nor have the sediment delivery ratios of Roehl (1962) been validated. A later modification of the USLE by Dissmeyer and Foster (1984) was validated against observed sediment yield data from four plots (0.09-0.13 ha) and 35 small basins (0.2-1.0 ha) located in the Coastal Plain and Piedmont regions of the South (Dissmeyer and Foster 1984). This later model was similar to that used by Dissmeyer and Stump (1978) except for how the combined C and P factors were determined, and produced sediment yields very close to those observed ($R^2 = 0.90$). However, the EASY model is typically applied over much larger areas than those used in validating the Dissmeyer and Foster (1984) model.

Like the EASY model, the ACE model output has not been directly validated, nor has the soil loss component based on Dissmeyer and Stump (1978), or the sediment delivery component based on Roehl's (1962) sediment delivery ratios. Soil loss predictions based on WEPP have been validated for several types of forest (Elliot 2001, Elliot and Foltz 2001,), non-forest (Laflen and others 2004, Soto and Díaz-Fierros 1998), and road (Elliot and Tysdal 1999, Grace 2005, 2007) conditions, but not for areas within the OONFs. While the risk ratings have not been independently tested, they are based on actual fish collections from 178 different locations within the Arkansas ecoregions that encompass the OONFs (Clingenpeel and Crump 2005). The size of this sample and the fact that these data were collected within the same ecoregions as those being assessed lends support to the assumption that the functional relationship between the relative abundance of fish assemblages and predicted sediment yields is real.

Disclosure of Model Shortcomings

The available documentation for both models lacks a thorough discussion of the shortcomings of the data sources, computation processes, and assumptions used to evaluate sediment CWEs. The current documentation of both models focuses on providing sufficient information to users so that they can understand how the model works and how to use it. Users are left to determine for themselves how well the reasoning behind the model stands up to current scientific knowledge, how complete are the data sources, and what counter-arguments could be made to challenge the validity of each model.

Reasoning behind Significance Interpretations

The two models take very different approaches to how significance is interpreted and justified. The ACE model provides an explicit procedure for interpreting model results by relating predicted sediment yields to relative abundance of fish assemblages. The method by which the relationship between predicted sediment yield and relative abundance, and how the risk levels are determined is explained in the model documentation (Clingenpeel 2003, Clingenpeel and Crump 2005). In contrast, the EASY model does not provide explicit interpretation of model outputs; rather it is expected that the user will decide how best to interpret the results based on each project's circumstances. Past applications of the EASY model have interpreted model results by comparing the relative magnitude of percent increases in sediment yield and by evaluating relative differences in sediment concentration,

but these comparisons are not part of the standard model output. While users bear the responsibility of justifying how they interpret the EASY model results, they have the flexibility to tailor the interpretation process to best meet the needs of each analysis.

Demonstration of Mitigation Effectiveness

This expectation could be addressed outside of whatever method is used to assess sediment CWEs; however a model could provide a very straightforward way of demonstrating mitigation effectiveness. Of course, the same expectation for demonstrated validity would apply to modeling mitigation as applies to all other aspects of a CWE model (see Table 1, items 6 and 9). The ACE model currently incorporates a limited capacity to calculate the effects of mitigation on erosion from proposed alternatives. The lengths of new or existing roads and off-highway vehicle or equestrian trails that are proposed to be closed, obliterated, or have only controlled use can be entered as part of an alternative, and the model will reduce soil losses computed for these areas based on the lower erosion rates. The EASY model also provides for reducing soil losses from temporary roads by specifying them to be closed after the activities requiring them are completed. Past EASY applications have also included additional condition types to assess the effects of closing trails, reconstructing roads to higher standards, and improving road surfacing (Hansen, personal communication), although these refinements are not included in the model documentation.

FUTURE MODELING ISSUES

As our knowledge grows and our technology improves, there will be an ongoing need to periodically revisit and improve whatever models are used to assess sediment CWEs. This need seems self-evident and requires no further comment. What we think is worthy of comment are several issues related to sediment modeling that bear significantly on how future models will work and who will use them. These are often the issues that get set aside or overlooked due to the press of time to develop and implement tools that are needed immediately. There may be other issues that we have overlooked, but what we think is more important is that these issues be considered up front in future modeling efforts.

Determining the Appropriate Spatial and Temporal Scales

In setting out guidance for how to accomplish a CWE analysis, the CEQ (1997) notes that choosing the appropriate geographic scale is critical. The choice of an appropriate temporal scale is, no doubt, of equal importance. The chosen scales should bound the space and time within which a CWE will occur. A number of factors should be considered in choosing the spatiotemporal scales including the spatial magnitude and location of past, present, and future disturbances; how long it takes for ecosystems to recover from disturbances; how individual impacts might accumulate, feedback upon, or negate each other; the location and extent of the resource prompting the CWE analysis; and the processes translating impacts through time and space (Tetra Tech 2002). Given the number and complexity of factors, the choice of the appropriate spatiotemporal scale for sediment CWE analysis will likely be unique for each situation (Bunte and MacDonald 1999). Furthermore, the situation should determine the choice, not the model. Unfortunately, this is often not the case. Practical considerations have in the past lead to a single scale or two being selected and used for all situations. A major consideration behind the single-scale decision is the difficulty in compiling the spatial data for all condition types. Despite the widespread availability of GIS software, we still seem to lack the ability to readily generate the needed spatial data at any chosen spatial scale and output these data into existing sediment models. Another consideration, which affects the time scale selected, is the increased model complexity required to deal with activities scheduled over multiple years. No doubt these are significant challenges; however, they must be addressed if our models are to allow the selection of appropriate temporal and spatial scales based on the situation.

Need to Consider Natural Disturbance

The inclusion of natural disturbance occurrences deserves more attention in future models. Models like EASY and ACE that use mean erosion rates (like those provided by Dissmeyer and Stump [1978]) are very limited in their ability to account for sediment produced by infrequent natural events, especially those affecting extensive areas like hurricanes or wildfires. Moreover, mean erosion rates, while believed to represent erosion produced over long time periods (50 years in the case of Dissmeyer and Stump [1978]), are generally derived from plot studies conducted over a limited number of years. The impact of severe storms is very likely not well represented within these values; thus estimates of sediment yield from undisturbed and disturbed areas may well be too low. Possibly the underestimates from undisturbed and disturbed areas are proportional and thereby do not change interpretation of model results – the point is that we do not know. Future models will hopefully address more accurately the range of erosion amounts and how these are affected by natural disturbance processes.

How to Balance Accuracy vs. Practicality

Future models, like EASY and ACE, will be developed through compromises between model accuracy and application practicality. Such compromises do not invalidate the use of such models for sediment CWE analysis. None of the legal expectations noted by Reid (in press) mandate use of a "perfect" or even "state-of-the-science" model; rather the courts expect that CWE analysis address the concern at relevant spatiotemporal scales, that the analysis and interpretations be reasonably thorough and scientifically defensible, that methodological validity be demonstrated, and that methodological shortcomings be disclosed. Therefore, our objective should be to produce the best model we can given the resources we have available. Resources would go farther if future models could be designed so that when new understanding emerges about erosion processes or sediment routing, we can revise the relevant model components without disrupting the unaffected ones. Such models would require less resource investment over time and reduce the need to start from scratch to just those times when changes in the science or technology make such a decision desirable.

Deterministic vs. Lumped-Parameter Models

While lumped-parameter models like ACE and EASY may serve as satisfactory interim solutions for those regions where they can be validated, the future in sediment CWE models probably lies in deterministic models. Deterministic models like WEPP provide both theoretical credence to the processes being modeled and a structure to the model mechanics that facilitates both computer programming and incremental refinements. In contrast, lumped-parameter models like USLE and its descendants (e.g., ACE and EASY), while being easier to program and having fewer data input requirements, lack a direct theoretical basis and therefore must be validated through numerous empirical trials. The choice between deterministic vs. lumped-parameter models seems to us less a question of model accuracy than investment efficiency. If we have captured the relevant process mechanics correctly in a deterministic model, then scientific theory holds that these processes should function in the same manner at different locations. Testing is necessary to build confidence, but such testing should produce a model that is more broadly applicable because the process mechanics have been improved by making them more robust to input variations. In contrast, when testing shows lumped-parameter models to be inaccurate, all that can generally be done is to apply calibration factors that fine-tune the model to the specific situation being tested, and produce no improvement for model applications elsewhere. As they prove themselves, deterministic models should require less testing over time because we can better evaluate how changing environmental factors might affect model outputs as we better understand which factors most affect model behavior. This is more difficult with lumped-parameter models in which several environmental variables are often combined into a single factor (e.g., cover type) and it remains uncertain how variation in one or more variables might affect the combined influence of the lumped factor. Adopting deterministic models will likely come with a cost, however: It will require that model users have sufficient scientific knowledge to use them effectively.

Impact of Past Human Activities

One issue that is particularly relevant to modeling sediment CWEs in the eastern US is the impact of past human activities on current sediment dynamics. In many forested areas, the combination of highly erosive soils with abusive land-use practices beginning with European settlement and continuing through the early 1900s produced extensive areas of severely eroded terrain and massive sediment storage within drainage systems (e.g., Trimble 1974). Improved practices and extensive reforestation have reduced soil loss significantly, however a legacy of oversteepened slopes, compacted soils, and stored sediment remains in many areas, and can dramatically affect sediment production. Future models should provide the capability to deal with such historical influences where necessary and model users must be careful to consider and account for these influences when appropriate.

Knowledgeable Practitioners Needed

Our assessment of these two models, plus our discussions with the model developers, leads us to question the ability of non-specialists to adequately use these or other models for any but the most simple and straightforward applications. Both the EASY and ACE models were developed to facilitate evaluating sediment CWEs for a variety of forest management projects that occur at varying spatiotemporal scales. Furthermore, these models were developed in part with the hope that personnel with adequate training – but not necessarily a background in sediment related sciences – could use these models to perform sediment CWE analysis. Most of the legal expectations identified in Table 1 for a CWE analysis do not necessarily require improved skill on the part of the model user; they could be met through revisions to modeling procedures or improvements to model documentation. For example, items 2-5, and 9 in Table 1 could be addressed by revising the current calculations and formats with both EASY and

ACE. Items 7 and 8 could be addressed through more thorough model documentation. Item 6 (demonstrating model validity) would require some rigorous program of testing and analysis to assess model accuracy and to justify the accuracy standards that are chosen as being acceptable; however such work would only have to been done where models have not been validated, standards are elevated, or new knowledge emerges to challenge past assumptions. Conceivably, these improvements could all be made without requiring more knowledge or skill on the part of the user. However, the choice and justification of an appropriate analysis area for sediment CWE analysis (item 1) can only be made by someone who understands the science of sediment processes, how these are affected by past and present land-use practices, how these processes are affected by the spatial and temporal scales at which they are evaluated, and how sediment is linked to other resources. The analyst must also appreciate how well we can actually model sediment and what that accuracy means in terms of our ability to judge the severity of sediment CWEs because they will be the primary person interpreting the model results and defending the conclusions drawn from these results. It is unrealistic to expect that anyone without this knowledge and skill could apply and interpret these models effectively.

SUMMARY

Currently, sediment appears to be the only concern related to CWEs from fuel management that is being addressed in environmental analysis documents prepared by National Forests in R8/R9. Two types of analysis methods have been used to evaluate sediment CWEs: narrative analysis and hazard rating models. Narrative analysis is used when the level of concern is low and a discussion of the given environmental situation, the relevant scientific literature, and why the analyst thinks sediment CWEs are unlikely is deemed sufficient to meet legal expectations. Hazard rating models are employed when the level of concern is high. Two models are currently being used: the EASY (Hansen and others 1994) model and the ACE (Clingenpeel and Crump 2005) model. Both models produce predictions of sediment yield at the outlet point of a watershed based on the condition types present or hypothesized. The EASY and ACE models are employed using the same general procedural steps, compute erosion for forest areas using similar data sources, and provide outputs for comparing alternatives. They primarily differ in how the CWE analysis area is determined, how they compute non-forest and road erosion, and how model results are interpreted. Both models provide much of the information needed to meet the legal expectations identified by Reid (in press), but both suffer from lack of validation.

Future models for evaluating sediment CWEs will have to overcome current operational constraints that limit our ability to tailor analysis area delineation and spatiotemporal scale selection to the particular circumstances of each project. To improve the practicality of future models, they should be designed with updating and revision in mind from the start. While models like EASY and ACE may suffice in the near term for those regions where they can be validated, deterministic models would seem to offer a more efficient way for developing more broadly applicable tools to assess sediment CWEs. Lastly, all CWE analysis methods are merely tools that can only be applied effectively by practitioners who have the necessary scientific training to understand the strengths and limitations of the methods they employ.

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Tables

Table 1--Legal expectations for CE analyses and ways that the analysis method can affect the user's ability to address these expectations. These expectations were among those determined by Reid (in press) from 65 federal appellant or district court decisions issued during 2000-2005 and involving the US Forest Service or Bureau of Land Management. Reference numbers are used in the text.

Reference number	Expectation	Does the analysis method …
1	The area potentially affected by CEs must be identified.	Permit the user to define an analysis area that includes all relevant individual effects, represents the processes and linkages by which a CE could result, and includes the location of resources or entities that could be affected?
2	The impact of the proposed project must be identified.	Consider both direct and indirect impacts to a resource of concern that are caused by the new project activities? Are results for project clearly distinguished from other results and evaluated over a relevant time period?
3	The expected impacts of other individual actions in the past, present, and foreseeable future must be identified.	List past, present, and foreseeable future actions -- and their related impacts -- in sufficient detail that they can be compared to those predicted for the proposed action?
4	The expected CE from the individual actions must be identified.	Determine the aggregate impact resulting from the combined individual impacts of past, present, and future actions?
5	Current and future impacts should be interpreted relative to naturally occurring conditions.	Define a baseline case upon natural conditions that would be expected to exist if no changes had occurred in the past? Can results from this case be compared to those for the past, present, and future conditions, and the proposed project?
6	Model validity for the present applications must be demonstrated.	Have documented tests of CE predictions using conditions similar to those now being analyzed?
7	Model shortcomings must be disclosed.	Have documentation that identifies the scientific reasoning used and any methodological assumptions, data gaps, or other problems that could affect prediction accuracy?
8	Reasoning behind significance interpretations must be stated.	Provide an interpretation of results significance to the resource of concern? If so, is the justification for this interpretation available in the documentation?
9	Effectiveness of mitigation must be evaluated.	Demonstrate how impacts are reduced if mitigation is necessary to lessen impacts to acceptable levels?

FIGURES

1. Example of EASY model output showing the CWE analysis of sediment for one proposed alternative.

Microsoft Excel - EASY RENEW LC final 032105.XLW:5

EROSION AND SEDIMENT YIELD *

Project: Long Cane RENEW

Watershed:

Alternative: Proposed, Alt 2, decade 1

Activity	Recovery Period (years)	Soil Loss Rates (tn/ac/yr)	Acres	Annual Erosion (tons)	Total Erosion (tons)	Annual Sed.Yield (tons)	Total Sed.Yield (tons)
Shelterwood	2	0.393		0.00	0.00	0.00	0.00
OS Removal	2	0.393		0.00	0.00	0.00	0.00
Clearcut with reserves - Conversion	2	0.507	561	284.43	568.85	96.71	193.41
Thin or understory removal (mechanical equip)	2	0.419	1285	538.42	1076.83	183.06	366.12
Precomm. Thin (manual methods)	1	0	132	0.00	0.00	0.00	0.00
Site Preparation:							
Handtools	1	0		0.00	0.00	0.00	0.00
Drum Chop	2	0.183		0.00	0.00	0.00	0.00
Burn	2	0.12	467	56.04	112.08	19.05	38.11
Chop & Burn	3	0.367		0.00	0.00	0.00	0.00
Herbicides	1	0		0.00	0.00	0.00	0.00
Rx Burn (dormant)	2	0.073	12992	948.42	1896.83	322.46	644.92
Rx Burn (growing)	2	0.14	760	106.40	212.80	36.18	72.35
Cultivation (disking) of openings (annual treatment of 50 acres)	1	1.09	532	579.88	579.88	197.16	197.16
Stumping for meadow conversion	4	1.87	16	29.92	119.68	10.17	40.69
TOTAL Activities					4566.96		1552.77

Roads	Periods (years)	Soil Loss Rates (tn/ac/yr)	Miles	Annual Erosion (tons)	Total Erosion (tons)	Annual Sed.Yield (tons)	Total Sed.Yield (tons)
Ex. Perm.,Open	10	4.9	12.0	282.24	2822.40	95.96	959.62
New Perm.,Open	1 to 3	11.9		0.00	0.00	0.00	0.00
	4 to 10	4.9		0.00	0.00	0.00	0.00
New Perm.,Close	1 to 3	11.9		0.00	0.00	0.00	0.00
	4 to 10	4.9		0.00	0.00	0.00	0.00
Syst.,Close/Open	1 to 3	1.1		0.00	0.00	0.00	0.00
	4 to 10	0		0.00	0.00	0.00	0.00
New Temp.,Close	1 to 3	8.9	1.0	17.80	53.40	6.05	18.16
	4 to 10	0		0.00	0.00	0.00	0.00
Ex.Tmp.,Reopen	1 to 3	2.6	14.7	76.44	229.32	25.99	77.97
	4 to 10	0		0.00	0.00	0.00	0.00
Bladed firelines	2	8.9	42.7	380.03	760.06	129.21	258.42
Hand firelines	1	1.1	2.1	2.31	2.31	0.79	0.79
TOTAL Roads				758.82	3867.49	258.00	1314.95
TOTAL PROJECT					8434.45		2867.71

* Piedmont - taken from Table 4-A of Erosion and Sediment Yield Background Information using Sumter NF Forest Plan Process Records prepared by Hansen et. al. (1994). Average sediment delivery ratio calculated was 0.34. Skid roads and skid trails are included in the above coefficients unless modified by the analyst. The period of years needs to be added in some road figures to get totals.

Opening converstion and other treatments are under 4 percent slope. Coefficient presented is for area with 4 percent slope

Temporary roads and firelines estimated based on past activities in Sumter plan (3 mi fireline/1000 acres, 6 miles temporary road/1000 acres)

See spreadsheets for this alternative that summarizes and compiles all the activities estimated for this decade.

Riparian areas left untreated except for 1/2 of riparian area assumed burned during prescribed fire operations.

Alternative assumes there is 819 acres that will be dormant season burning 5 times over the decade or a total of 4095 acres of treatment

calculator | RENEW alt 1-no action | **RENEW alt 2 proposed** | RENEW alt 3 | RENEW alt 4 | dbru 52

Ready NUM

2. Example of ACE model output showing the summary sheet for the sediment CWE analysis for an entire project.

Microsoft Excel - Central revisited 2 8 05

File Edit View Insert Format Tools PopTools Data Window Help

CG Times 10

F43 = =IF(D43<'land use'!$G$109,"Low ",IF(D43<'land use'!$H$109,"Moderate ","High "

	A	B	C	D	E	F	G	H	I	J	M
1	Watershed Number	**111101050201**									
2	Watershed Acres	27,752.74									
3	Sale Date	2004									
4	Alternative A	cut a little									
5	Alternative B	cut some more									
6	Alternative C	cut a lot									
7	Alternative D	cut it out									
11	Analyst	smokey t. bear									
15											
16	Ecoregions	0.00% Arkansas River Valley, 0.00% Costal Plain, 100.00% Ouachtia Mtn.									
17		acres	percent		acres	percent					
18	**Forest Service surface owner**	22,670.17	81.69	**Private**	5,082.58	18.31					
19											
20	Forested	27,047.16	97.46	Forestec	4,401.01	86.59					
21	Urban	17.35	0.06	Urban	6.90	0.14					
22	Cultivated	1.33	0.00	Cultivate	1.33	0.03					
23	Pasture	678.23	2.44	Pasture	672.22	13.23					
24	Quarry	-	-	Quarry	-	-					
25	Water	8.68	0.03	Water	1.11	0.02					
26	Wetland	-	-	Wetland	-	-					
29											
30	Current road density in 6th level wate	INFRA			All Roads						
31		miles	miles/sq mile		miles	miles/sq mile					
32	Forest Service	16.43	0.38		31.73	0.73					
33	Other Roads	46.00	1.06		46.00	1.06					
34	Combined	62.43	1.44		77.73	1.79					
35											
36	Sediment Delivery	0.104898704									
37											
38			Current	Commited	Road uses	Undisturbed					
39	Roads - sediment in tons/year		555.28	64.75	(85.06)	-					
40	Land use - sediment in tons/year		2,268.57	42.59		2,048.94					
41											
42				**Percent**				**FS open road**	**Total open road**		
43	**Current Sediment increase**			139		Low		0.68	1.74		
44			**Proposed (tons)**	**Propose**							
45	Alternative A	cut a little	982.93	195		Low		0.68	1.77		
46	Alternative B	cut some more	1,079.10	200		Low		0.94	2.02		
47	Alternative C	cut a lot	1,480.14	219		Low		1.40	2.49		
48	Alternative D	cut it out	1,083.55	200		Low		0.94	2.02		
49											
50	A low risk indicates minimal adverse effects from sediment to aquatic beneficial uses and only requires the application of forest standards										
51	A moderate risk indicates potential adverse effects from sediment to aquatic beneficial uses. In addition to the application of forest										
52	A high risk indicates significant potential adverse effects from sediment to aquatic beneficial uses. In addition to the application of forest standards and monitoring, a no net increase from proposed activities is required										
53											

Past / Present / Proposed Private / Proposed A / Proposed B / Proposed C / Proposed D / biology sum