The Challenges in Developing the WEPP Cumulative Effects Model

William J. Elliot and Randy B. Foltz
Project Leader and Research Engineer
Rocky Mountain Research Station
Moscow, Idaho, USA

Presented at the 2nd Forest Engineering Conference
12-15 May, 2003
Vaxjö, Sweden

Summary

Many of the forests in the U.S. and elsewhere in the world are source areas for water. The quantity and quality of this water are major public concerns. In a forested watershed, any road segment, harvesting operation, or other management activity can adversely impact forest streams. These disturbances are distributed in both time and space. The disturbance in the first year may have minimal impact on the hydrologic integrity of the watershed, but if the disturbance in the following year is added to the first, and the disturbance in year 3 added to those in years 1 and 2, the net effect may be detrimental to the beneficial uses of the stream. A model to address this cumulative impact is sometimes referred to as a cumulative effects model. This paper presents the application of the GeoWEPP Geographic Information System (GIS) tool to evaluating cumulative effects in forests due to fuel management activities. An example is given to demonstrate the utility and limitations of the current tool.

Key Words: Watershed Analysis, Soil Erosion

Introduction

Forests provide society with numerous resources including fiber, food, recreation, and water. Activities associated with obtaining some of these resources may adversely affect others. One conflict, in particular, is that any disturbance associated with obtaining fiber or food, and many recreational activities, can adversely impact forest water quality.

A single disturbance in a given year is seldom a problem. Forest watersheds are able to recover within a few years from most single disturbance events, including disturbances as extreme as wildfire. As more disturbances are added during a year, and additional disturbances in the years that follow, the forest is less likely to recover to an undisturbed condition. The cumulative effects of numerous disturbances over a number of years must be considered to be able to manage forests for multiple uses.

The Water Erosion Prediction Project (WEPP) (Flanagan and Livingston, 1995) was developed by a number of United States Department of Agriculture research and management agencies. Scientists at the Rocky Mountain Research Station and elsewhere parameterised the model for forests (Elliot and Hall, 1997). The WEPP model was released with both a "hillslope" and a "watershed" version. Developing topographic input files for the watershed version was not easily achieved until 2001, when a Geographic Information System (GIS) tool was developed to assist in spatial analysis and visualization of erosion distribution (Renschler et al., 2002).

Application of GeoWEPP to Watershed Analysis

To evaluate the suitability of the GeoWEPP tool, an example study was carried out on a 1490 ha watershed about 25 km north of Moscow, Idaho (Figure 1). The GeoWEPP tool divided the watershed into 33 hillslopes, and 13 channel segments. The watershed is currently under consideration for significant fuel reduction activities, including small diameter logging in year one, prescribed fire in year 2, and recovery of hydrologic stability and vegetative cover during the next five years. Table 1 shows the sequence of vegetation and soil properties necessary to sequentially describe these disturbances and recovery years.

Table 1.
WEPP vegetation and soil template values used for the analysis, assuming a silt loam soil

Year	Vegetation	Hydraulic Conductivity (mm/h)	Rill Erodibility (s/m)
1	Established Forest	28	0.0004
2	Harvest: 80 percent cover, Young forest	23	0.0004
3	Burn: 80 percent cover, Low severity fire	13	0.0005
4	90 percent cover, Short grass	11	0.0004
5	95 percent cover, Tall grass	23	0.0004
6	95 percent cover, Young forest	23	0.0004
7	100 percent cover, Young forest	23	0.0004
8	Established Forest	28	0.0004

To demonstrate the application of GeoWEPP, each year a hillslope was selected, starting with hillslopes at the bottom of the watershed, to initiate the fuel reduction sequence. We assumed that all other hillslopes were covered in forest at the start of the simulations. Figure 2 shows the sediment yields for the first 12 years of analysis, for both the disturbed hillslopes and the road network. Note that the first year assumed that all hillslopes were undisturbed, and the majority of the soil erosion was from the road. During the years of this example, the sediment yields varied between 40 and 90 tonnes, depending on the size and location of the disturbed hillslopes.

To consider the sediment from roads, sediment delivery was modelled assuming a road erosion rate of 1.33 t/km on roads with heavy traffic, and 0.67 t/km for roads with light traffic. These values were estimated with the WEPP model for multiple 60-m long road segments with gradients of 4 percent, distances of 20 m between the road and the stream, and with buffers covered in forest. The rill erodibility value was reduced from 0.0003 s/m for the road with traffic to 0.000075 s/m for the road with low traffic, to reflect the observed surface armouring on roads without traffic (Foltz, 1998). It is apparent from figure 2 that the sediment from the road accounts for about a fourth of the sediment generated from human disturbances during active years, and 96 percent of the sediment in the absence of disturbances. The road sediment delivery values are approximate estimates in this study, as a detailed road map was not available. The relative importance of roads in the analysis, however is unlikely to change with greater detail.

These sediment yield rates need to be compared to the expected sediment yield from natural disturbances. When the entire watershed was described as wildfire, the predicted sediment yield was 4832 tonnes in the year of the fire. If the frequency of fire in this area is assumed to be about 48 years, then the average annual sediment generated in the year following the wildfire averages about 100 tonnes per year. If fuel management operations reduce the likelihood of fire, or the severity of the fire, as has been observed in recent studies, then the average annual sediment production due to the operations is less than sediment from wildfire.

To complete the analysis, some users may wish to add in sediment from landslides. McClelland et al. (1997) found that typical sediment yields averaged over the 20 year return period associated with such events was around 10 t/ha. Operations are unlikely to decrease this value, but a more dense road network could increase it.

Currently, the WEPP model only predicts surface runoff. Observations in many steep forest watersheds have shown that over 99 percent of all runoff is subsurface flow. Work is ongoing to incorporate subsurface flow into the WEPP model (Wu et al., 2000).

In summary, we have presented the application of the new GeoWEPP spatial analysis tool to cumulative watershed effects analysis. At this time, the tool is run for each year of disturbance. If desired, users can then add the sediment impact due to roads, wildfire, or landslides.

References

Elliot, W. J. and D. E. Hall. 1997. Water Erosion Prediction Project (WEPP) forest applications. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. Gen. Tech. Rep. INT-GTR-365. 11 p.

Flanagan, D. C. and S. J. Livingston. 1995. *WEPP User Summary, USDA-Water Erosion Prediction Project (WEPP).* W. Lafayette, IN: USDA-ARS National Soil Erosion Research Laboratory. 123 p.

Foltz, R. B. 1998. Traffic and no-traffic on an aggregate surfaced road: Sediment production differences. *Proceedings of the seminar on environmentally sound forest roads and wood transport.* Sunnia, Romania, 17-22 June, 1996. Rome: FAO.

McClelland, D. E., R. B. Foltz, W. D. Wilson, T. Cundy, R. Heinemann, J. Saurbier, and R. Schuster. 1997. Assessment of the 1995 and 1996 floods and landslides on the Clearwater National Forest. Part I: Landslide assessment. Missoula, MT: USDA Forest Service, Region 1. 52 p

Renschler, C. S., D. C. Flanagan, B. A. Engel, J. R. Frankenberger, T. A. Cochrane and R. C. Vining. 2002. GeoWEPP - The Geo-spatial interface for the Water Erosion Prediction Project (WEPP). Online at: <http://www.geog.buffalo.edu/~rensch/geowepp>. Accessed 4 December 2002.

Wu, J. Q., A. C. Xu,. and W. J. Elliot. 2000. Adapting WEPP for forest watershed erosion modeling. Paper No. 002069. Presented at the 2000 International ASAE Meeting, 9-12 July, Milwaukee, WI. St. Joseph, MI: ASAE. 9 p.

Figure 1. Output from year 12 of simulations. Areas near outlet have recovered, and areas near the center of the watershed are recovering from forest operations and prescribed fire. The darker the area, the greater the erosion rate. Predicted erosion rate in the white is zero, the lighter shade, 0.1, the medium shade, 0.3, and the dark shade 1.4 t/ha.

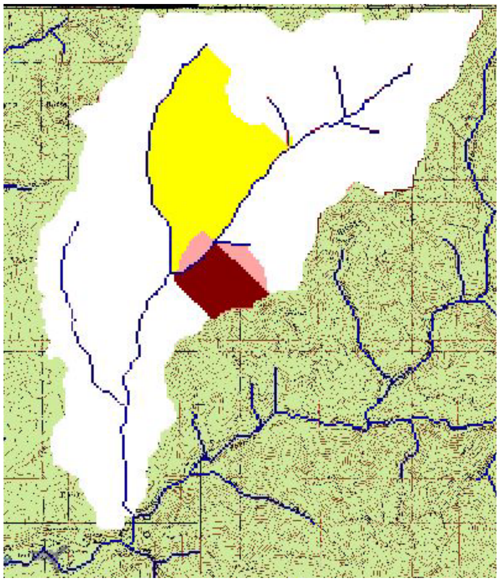
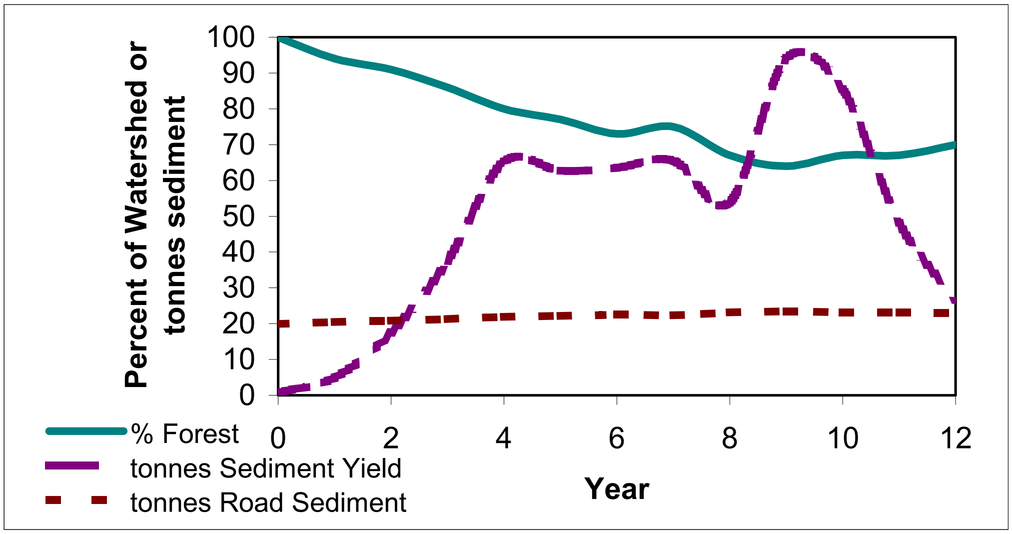


Figure 2. Percent of watershed In forest during the first 12 years of fuel reduction in watershed, and the associated sediment yields from roads and fuel management activities.



Elliot, W.J.; Foltz, R.B. 2003. *The challenges in developing the WEPP cumulative effects model.* In: Wide, M.I.; Hallberg, I., eds. **Proceedings: 2nd Forest Engineering Conference.** Arbetsrapport, Fran Skogforsk NR 540 Maj 2003. Posters. 55-58. Uppsala, Sweden: Skogforsk. www.skogforsk.se

Moscow Forestry Sciences Laboratory
Rocky Mountain Research Station
USDA Forest Service
1221 South Main Street
Moscow, ID 83843

http://forest.moscowfsl.wsu.edu/engr/