ALLUVIAL FAN EROSION AND SEDIMENTATION INVESTIGATIONS USING THE HYDRAULIC MODELING TOOL FLO-2D

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Abstract: FLO-2D offers a useful planning and evaluation tool for addressing sediment related resource concerns by providing information on the spatial distribution of erosion and deposition of sediment. This poster presents an example of how FLO-2D may be used for watershed scale evaluations of erosion and soil loss on alluvial fans. The model has been applied to four scenarios with different soil types and vegetative cover conditions to represent a range of conditions. Each scenario was evaluated using six different storm runoff events. Two-dimensional plots of the model output identify the spatial distribution of overland flow, maximum flow velocities, scour, and deposition. Processing of the model output permits the development of sediment-frequency curves and the determination of average annual soil loss rates. The soil loss rates have been compared to demonstrate the sensitivity of the watershed to differences in vegetative cover conditions and soil type.

INTRODUCTION

The Natural Resources Conservation Service (NRCS) has a long history of using physical process models to estimate erosion and transport of sediment by wind and water. FLO-2D, developed by James S. O'Brien of FLO-2D Software, Inc., continues this tradition by adding to the options available to NRCS and its partners for evaluating the impact of overland flow on erosion and deposition of sediment on alluvial fans.

FLO-2D is a two-dimensional watershed model with a sediment transport component. Model simulations describe the spatial distribution of erosion and deposition within the modeled area. Processing of the model output provides information on the relative severity of erosion in terms of average annual soil loss. O'Brien (2001) defined the sediment transport component in this way:

> FLO-2D can compute sediment transport in channels, streets and overland flow. A multiple regression sediment transport equation for sand bed channels or alluvial floodplains is used in the model. This empirical equation is a computer generated solution of the Meyer-Peter, Muller bed-load equation applied in conjunction with Einstein's suspended load integration (Zeller and Fullerton, 1983). The bed material discharge, q_s, is calculated in cfs per unit width as follows:
>
> $$q_s = 0.0064\, n^{1.77}\, V^{4.32}\, G^{0.45}\, d^{-0.30}\, D_{50}{}^{-0.61}$$
>
> where n is Manning's roughness coefficient, V is mean velocity, G is the gradation coefficient, d is the hydraulic depth and D_{50} is the median sediment diameter. All units in this equation are in the ft-lb-sec system except D_{50}, which is in millimeters.

This poster presents an example that demonstrates how FLO-2D can be applied for watershed-scale sedimentation investigations.

RESOURCE CONCERN

Overland flooding and flood plain scour deliver sediment to a river with a recreational fishery that is important to the local economy.

UNKNOWNS

- Area subject to overland flow.
- Maximum overland flow velocities.
- Location of scour and deposition.
- Rate of soil loss.
- Sensitivity of soil loss rates to land use changes.

APPROACH

NRCS completed an analysis on a sub-part of the watershed (Figure 1) by running FLO-2D for the 100-, 50-, 25-, 10-, 5- and 2-year runoff events with two different soil types and two different cover conditions. The two soils represent the range of soils, from fine (silty sand, SM) to coarse (poorly-graded sand, SP), found in the subwatershed. Cover conditions assume either a fully vegetated state with grasses, shrubs and trees approximating an undisturbed condition (Good) or one with no vegetative cover (Poor).

The two soil types (SM and SP) and cover conditions (Good and Poor) represent extremes of conditions found within the study area. The model could also be modified to compare different vegetative and/or structural land treatment alternatives, but in this case we wanted to evaluate conditions that were most likely and least likely to erode. In this way, watershed planners are provided a basis (i.e. upper and lower limits of soil loss rates) for establishing numerical targets for managing for soil loss.

ANALYSIS

Output from FLO-2D was plotted in ArcView to show the spatial distribution of scour, deposition, overland flow and maximum flow velocities. Examples of output for the 100-year runoff event are shown in Figures 2 and 3. Flow is from the bottom of the page towards the top.

The sediment output files were used to develop sediment-frequency curves (Figure 4) and to calculate average annual soil loss (Figure 5). These numbers give planners representative estimates of the relative volume of soil that may be transported off-site following different storm events and under a range of cover conditions.

These data were also converted to units of tons/acre/year and the values plotted against geologic rates of erosion (Figure 5) to demonstrate the sensitivity of the different soil types to changes in cover conditions.

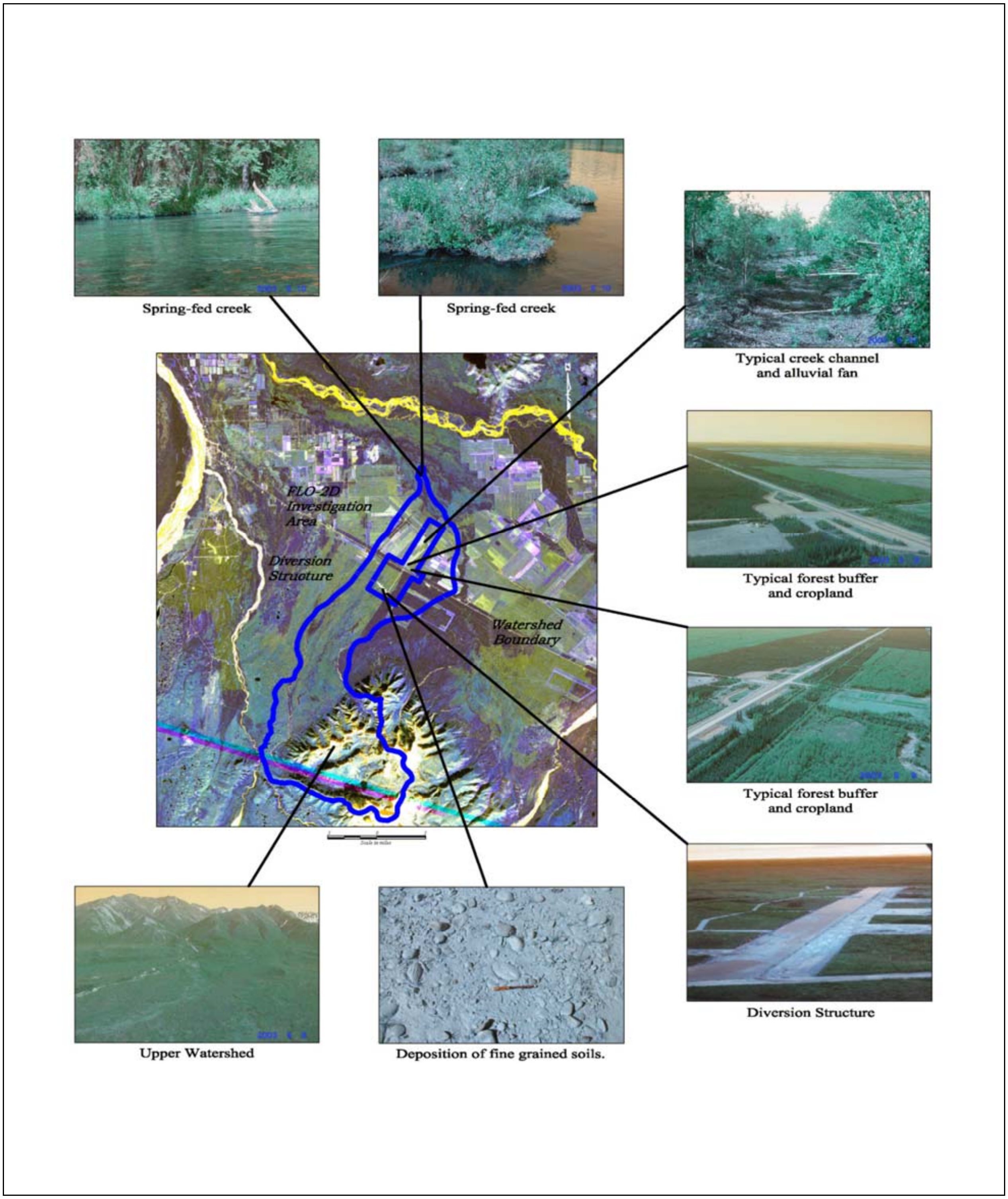

Figure 1. FLO-2D investigation area beginning at a diversion structure in the watershed. Water drains to the north and under a major interstate highway which lies about midway through the study area.

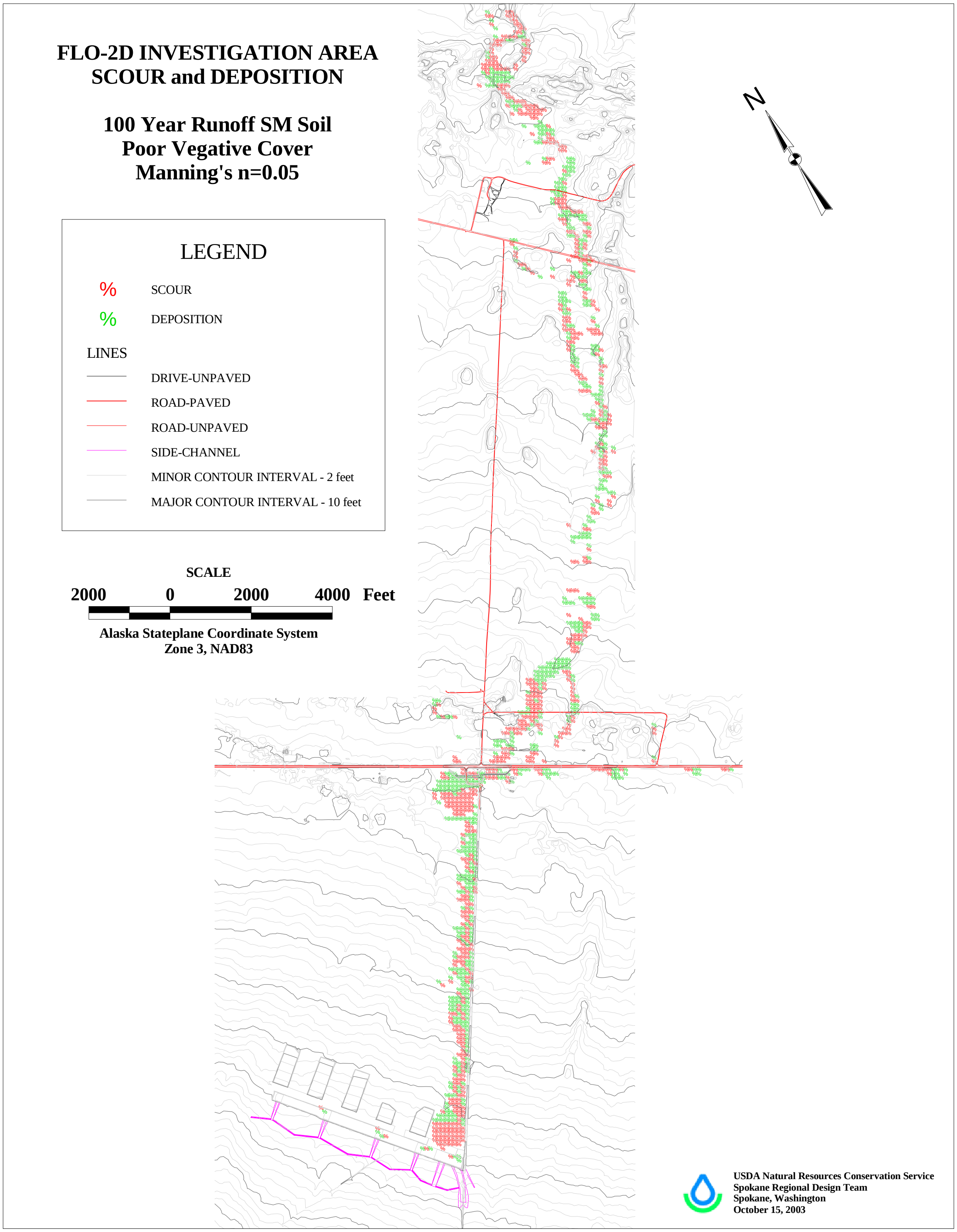

Figure 2 Scour and deposition for the 100-year runoff event; flow is from the bottom of the page towards the top.

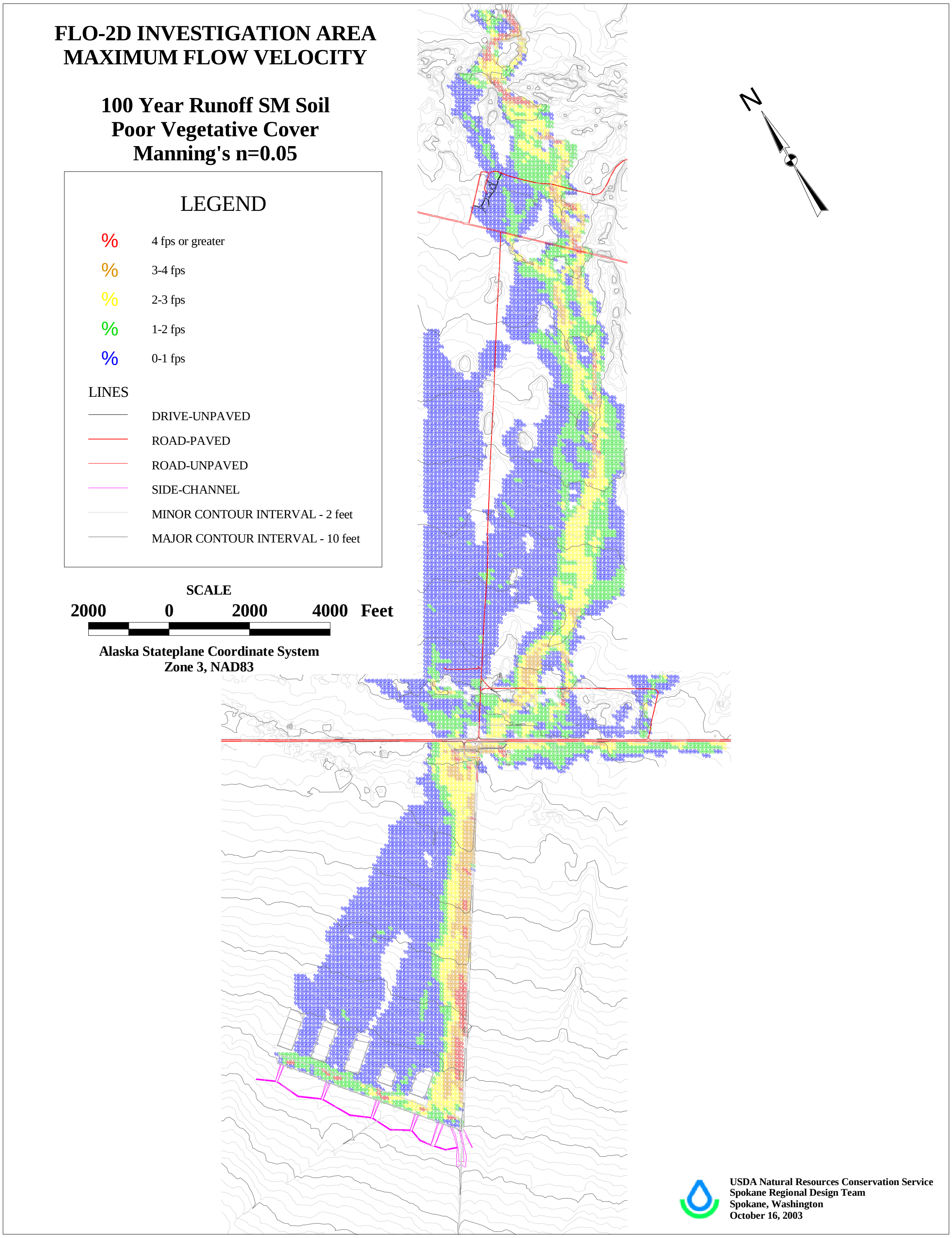

Figure 3 Maximum flow velocity for the 100-year runoff event; flow is from the bottom of the page towards the top.

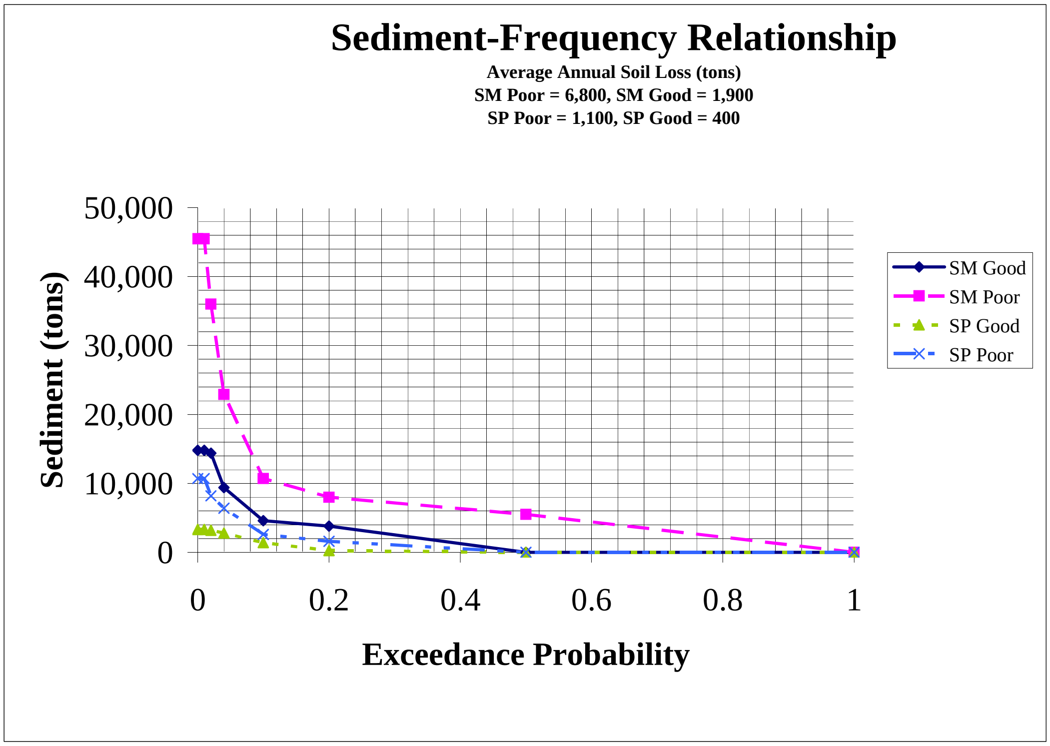

Figure 4 Sediment-frequency curves.

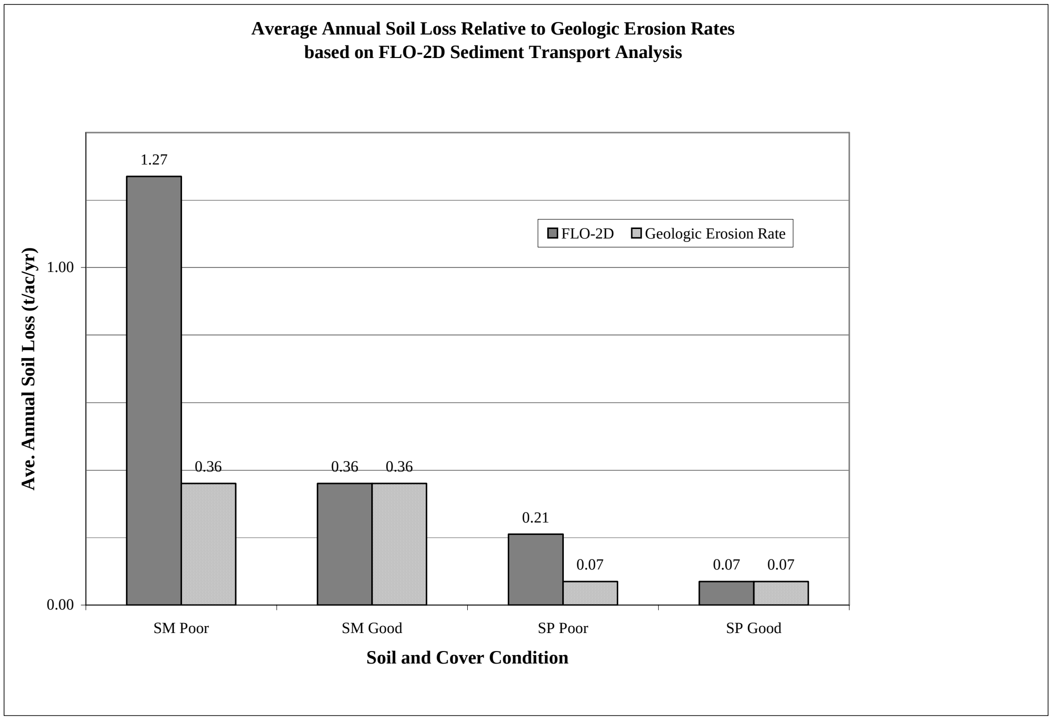

Figure 5 Average annual soil loss vs. geologi rates of erosion.

DISCUSSION

FLO-2D provides valuable information on where erosion and deposition occur and also information on the distribution of overland flows and flow velocities.

Plots of average annual soil loss relative to geologic rates of erosion reinforce the notion that ground cover plays a significant role in slowing overland flow and trapping sediment before it can be transported off-site.

Particle size too is critical to the gross erosion rate. Finer soils are more sensitive to watershed disturbances than coarser soils and are more likely to be scoured than coarser soils under the same runoff conditions.

CONCLUSION

Plots of output can help watershed planners and the public to better understanding the spatial distribution of overland flows and how flow velocities influence where scour and deposition of soils occur.

Processing of the model output and displaying it graphically demonstrates how the size of the runoff event, the coarseness of soil particles and the quality of cover conditions influence the volume of soil transported off-site and the rate of soil loss.

Appropriately designed watershed sensitivity analyses can provide a basis from which to establish numerical targets for the management of soil loss.

REFERENCES

O'Brien, J.S. (2001). "FLO-2D Users' Manual," Version 2001.06, FLO-2D Software, Inc., Nutrioso, Arizona, pp113.

FURTHER INFORMATION

FLO-2D Software, Inc., can be found on the web at: http://www.flo-2d.com/