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FILL SLOPE EROSION FROM FOREST ROADS

by

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SUMMARY:

First year erosion from fill slopes ranged from 5.1 to 9.9 cubic feet per 100 feet of road. Approximately 50 percent of the eroded material was deposited within 20 feet of the toe of the fill slope. However, material was transported as far downslope as 437 feet. The placement of filter windrows on the fill slopes proved effective in minimizing material leaving the fill slope.

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INTRODUCTION

Past research has found that road construction and harvesting in Idaho's forests may substantially increase stream sediment loads. Megahan (1972), in his investigations of forest management activities on selected Idaho Batholith watersheds, found that road related erosion is the most important contributor to stream sedimentation. Additionally, Megahan (1972) found that the largest percentage of eroded material from roads is attributed to fill slope erosion, at least during the first few years following construction.

There is currently a study being conducted in north central Idaho to determine the hydrologic and sedimentation effects of alternate design standards of forest roads. A portion of this research effort involves the quantification of erosion processes from fill slopes, of effects of selected fill slope treatments on erosion, and of transport of eroded material downslope. This research is being supported by funds from the Intermountain Forest and Range Experiment Station, Missoula Forest Science Laboratory.

STUDY AREA

This research is being conducted in the Main Fork of Horse Creek Watershed in the Nezperce National Forest. Horse Creek flows eastwardly into Meadow Creek four miles above its confluence with the Selway River. This area is on the border of the Idaho Batholith, a large igneous intrusion in central Idaho and Montana. The parent material is part of the Belt Super Group (Bennett 1974), composed of sedimentary and metasedimentary rock of primarily gneissic material (Greenwood and Morrison 1967). The deeply weathered soil is sandy but with a substantial portion of silt and clay. Over most of the study area the soil is a well drained, sandy loam to loam with a distinct loess cap (Alvis 1965). In an undisturbed condition there is little evidence of any surface erosion and stream sediment is predominately derived from channel sources. However, following disturbance of the forest floor, there is a high potential for surface erosion. The median side slope in Horse Creek is 31 percent, but slopes in excess of 65 percent are common. Thunderstorm activity during the summers and rapid snowmelt provide conditions conducive to accelerated erosion.

There were 3.8 miles of single lane road constructed at midslope locations in the Main Fork of Horse Creek Watershed during 1978. Roads were constructed with two design standards. Standard 1 was designed for a constant speed of 15 miles per hour, a subgrade width of 16 feet, a minimum curve radius of 110 feet, and travel-way stabilization of 8 inches of rock. Standard 2 represents a design that better fits the road to the topography. It is characterized by a variable design speed of 5 to 25 miles per hour, a subgrade width of 15 feet, a minimum curve radius of 50 feet, and travel-way stabilization of 8 inches of native material stabilized with oil. Cut and fill slopes on both standards were hydroseeded.

Due to the construction time schedule, fill slopes on different roads were subject to varying number of summer thunderstorms (Table 1). Road 9709 did not receive travel-way stabilization until the summer of 1979. However, all exposed soil including the subgrade surface was mulched with straw and an asphalt tack in the fall of 1978.

The soils on the cut and fill slopes are composed primarily of sand size particles (Table 2). The size classes of medium sand, 0.425 to 2.00 mm, and fine sand, 0.075 to 0.425 mm, comprise over 60 percent of the soil. These two size classes are easily detached and transported via raindrop splash and overland flow. Thus, until the fill slopes are stabilized as a result of the hydroseeding, they are easily eroded.

Table 1. Road information for the Horse Creek Watershed.

Road	Standard	Mileage	Beginning of Construction
9704	1	0.94	6/30/78
9708	2	0.28	7/12/78
9709	2	0.30	8/03/78

Table 2. Particle size distribution of cut and fill slope material in the Horse Creek Watershed.

Size Classification	Particle Diameter (mm)	Percent Composition	
Gravel	4.75 - 75.00		12.85
coarse	19.05 - 75.00	8.75	
fine	4.75 - 19.05	4.10	
Sand	0.075 - 4.75		70.40
coarse	2.00 - 4.75	9.00	
medium	0.425 - 2.00	29.15	
fine	0.075 - 0.425	32.25	
Silt and Clay	< 0.075		16.75

METHODS

The fill slopes were stratified into four vertical height classes; 0-10 feet, 10-20 feet, 20-30 feet, and greater than 30 feet. These classes will be referred to as Class I, II, III and IV, respectively. Troughs were located at the toe of the fill slopes. Sampling intensity was determined on the length of road in each fill height class. Two sizes of traps were installed, both are four feet in length but can hold volumes of one or four cubic feet. The percentage of the total length of road that received troughs is small, a shortcoming in this technique.

Fill slopes on selected lengths of road received special treatments. One such treatment was the placement of filter windrows on the lower portions of fill slopes. These were constructed by "keying in" cull logs along the toe of the fill slope and placement of slash, remaining from clearing the right of way, on the fill slopes above the logs. Troughs were also installed below filter windrows to determine their effectiveness in preventing fill material from being transported downslope.

Along the entire length of roads inventories of rills and gullies were made in the fall of 1978 and the spring of 1979. Measurements include the void volumes on the fill slopes, the travel distance below the toe of the fill, and the percent slope of the side slopes over which the material was transported. In the spring of 1979 similar inventories were made along selected lengths of roads to quantify volumes of fill material displaced via slumping. The volumetric measurements made on slumps quantify the void volumes only and do not reflect volumes of material transported below the toe of the fill.

RESULTS

Visual observation has revealed that three erosional processes are evident on these fill slopes. Sheet erosion occurs primarily as a result of raindrop splash during the summer and fall months. It moves relatively small amounts of material from the fill slopes and is not transported an appreciable distance below the toe. Rill and gully erosion moves large volumes of material from the fills and downslope. Transport distance is a function of the microtopography and forest floor obstructions. Rill and gully erosion is most pronounced during summer thunderstorm activity. Slumping occurred during periods when fill slopes have high moisture contents, primarily the result of snowmelt. In many instances slumped material does not leave the fill slope. However, subsequent rilling of slumped material often transports this material downslope.

Rill and Gully Erosion - Road 9704

Quantification of rill and gully erosion on the road constructed to standard 1 specifications was done in September, 1978 and in June, 1979 (Table 3). Thunderstorms in the summer of 1978 eroded an average of 7 cubic feet of material per 100 feet of road length. The net change during the two measurement dates was 2.9 cubic feet of material per 100 feet of road. This volume is attributed to the effects of snowmelt in the spring of 1979.

Table 3. Volumes of fill erosion in rills and gullies on road 9704 (standard 1).

Date	Volume $ft^3/100$ ft	Number no./100 ft
9/9/78	7.02	1.45
6/6/79	9.91	1.54

The number of rills and the eroded volumes in each fill slope height class are proportional to the length of road represented by each height class (Figure 1). For example, the 0-10 foot height class (Class I) had 55 percent of the number of rills which accounted for 52 percent of the eroded material. This height class occurred along 57 percent of road 9704. This trend was evident on both standards of roads.

Actual eroded volumes per 100 feet of road length by fill slope height class ranged from 8.4 $ft^3/100$ ft to 18.1 $ft^3/100$ ft for road 9704 (Figure 2). For both standards of road the 20-30 foot height class (Class III) represented the largest eroded volumes per 100 feet of road length. If data are combined for all roads, a trend of increasing eroded volumes per 100 feet of road length with increasing fill slope height was evident.

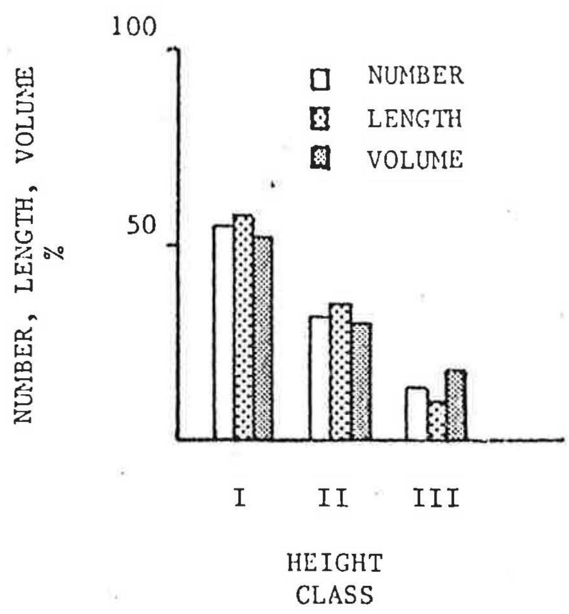

Figure 1. Percentage of number of rills, length of road, and eroded volumes on fill slopes on road 9704 (standard 1).

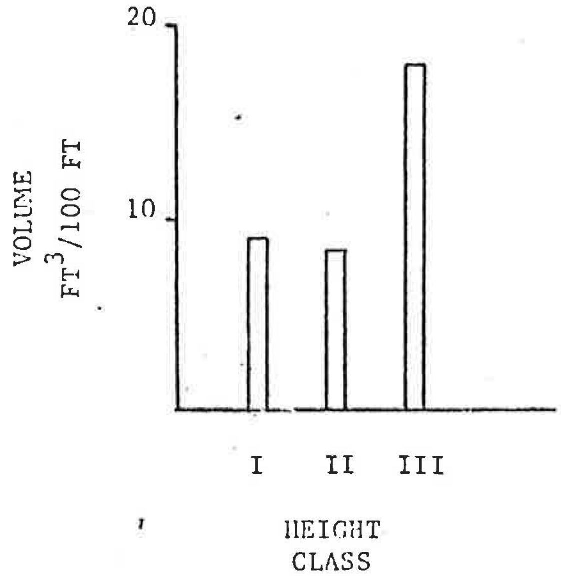

Figure 2. Eroded volumes per 100 feet of road length by fill slope height class.

Transport Distance

The eroded volumes for each rill or gully were classified by the length of downslope transport on road 9704. The average volume per rill was calculated for transport distance categories of 0-5 feet, 5-10 feet, 10-20 feet, 20-50 feet, 50-100 feet and greater than 100 feet (Figure 3). There is a definite trend in the data revealing that those gullies that displace larger volumes move a farther distance downslope. This trend was evident on all Horse Creek roads. The largest average volume per rill or gully was found to occur on fill slopes in the 20-30 foot height class (Figure 4). However, the number of large gullies, greater than 10 ft^3 of eroded material, occurs in the 0-10 foot fill slope height class (Figure 5). The occurrence of larger gullies appears to be related to contributions from the road surface. In most instances wheel ruts or other irregularities near the top of the fill slope caused concentration of surface runoff. When this volume of water was diverted onto the fill slope large volumes of material were displaced. Thus, the occurrence of the larger gullies in the 0-10 foot fill slope height class is primarily due to the fact that the majority of the road length is in this height class. These trends were evident on all of the Horse Creek roads.

To determine the downslope transport distance for volumes of fill material it was necessary to make one assumption. It was assumed that eroded material was uniformly deposited over the transport distance. In reality, deposition is not uniform but related to the microtopography and obstructions of the forest floor.

The relationship between downslope transport distance and the percent of eroded volumes (Figures 6 and 7) is curvilinear. The majority of the eroded

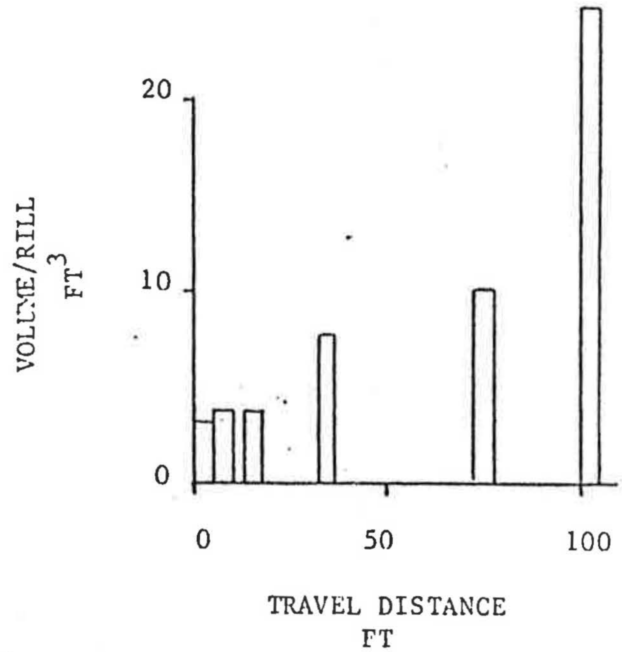

Figure 3. The average eroded volume per rill versus transported distance downslope for road 9704.

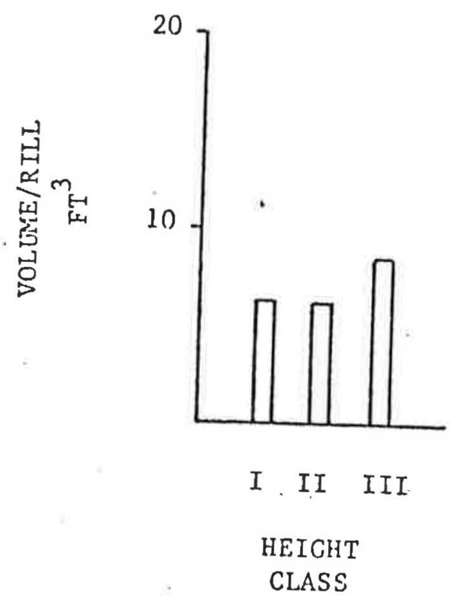

Figure 4. The average eroded volume per rill by fill slope height class for road 9704.

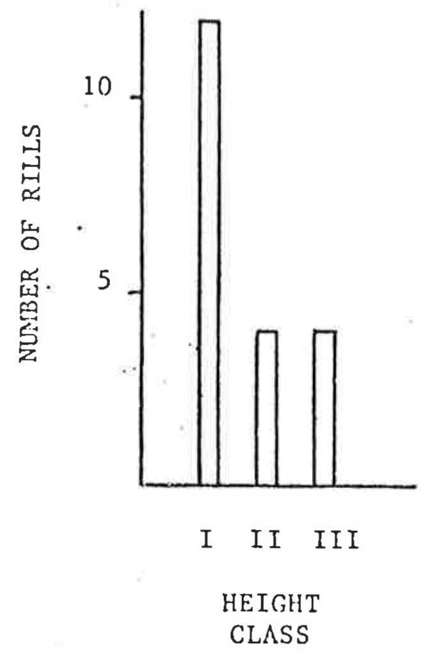

Figure 5. The number of large gullies (> 10 ft^3) by fill slope height class on road 9704.

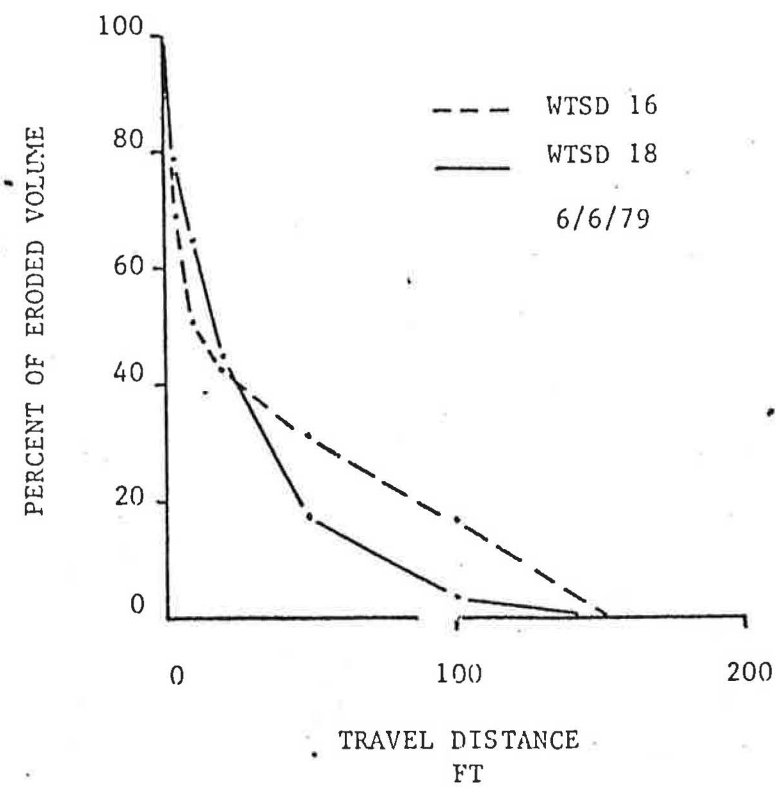

Figure 6. Percent of eroded volumes of fill material passing a given downslope travel distance for road 9704 in two watersheds.

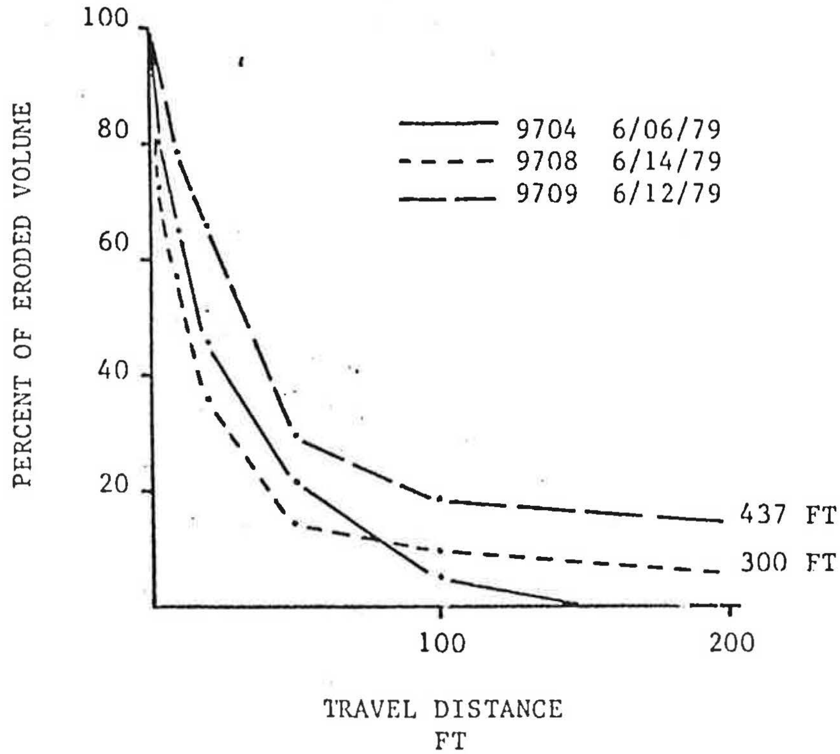

Figure 7. Percent of eroded volumes of fill material passing a given downslope travel distance for three Horse Creek roads.

material is deposited in the first 20 feet below the fill slope. For example, in Figure 6, at a travel distance of 20 feet, 43 percent of the eroded volume is transported farther than 20 feet in watershed 16.

Road 9704 passes through two watersheds, 16 and 18. Along the road the side slopes typically range from 30 to 75 percent in watershed 18. The majority of the side slopes in watershed 18 are 30-45 percent. The side slopes along the road in watershed 16 are steeper, ranging from 60-80 percent. In watershed 16, larger volumes are transported greater distances due to the steeper side slopes (Figure 6).

The transport distances for three roads are shown in Figure 7. Roads 9708 and 9709 are standard 2 roads which represent roads well fitted to the topography. These two roads had maximum transport distances much greater than the maximum for the standard 1 road. From this data it appears that the downslope transport of fill material is not related to a design standard, but influenced by the side slope characteristics below the fills.

Filter Windrows

The filter windrows along road 9704 have been very effective in preventing fill material from leaving the fill slope. Trough data reveal that only 0.22 cubic feet of eroded material per 100 feet of road length was transported through the filter windrow. There were places on other roads where larger volumes of sediment were transported through or over the wondrows. This usually happened where slumping occurred above the windrow during the spring of 1979.

Comparison of Standards

Inventories of rills and gullies provide the most reliable data on fill slope erosion. Based on this data, road 9704 (standard 1) had the highest fill slope erosion from the date of construction to June 6, 1979 (Table 4). The average fill erosion for this road was 9.9 cubic feet per 100 feet of road length, compared with 6.1 and 5.1 for the two standard 2 roads. However, any real difference between standards is obscured since construction was completed on road 9704 approximately a month before roads 9708 and 9709 were completed. During this month, thunderstorm activity initiated substantial gully erosion on road 9704.

The surveys of slumps were confined to only selected sections of roads. Estimates of volumes of fill material displaced ranged from 4.4 to 21.9 cubic feet per 100 feet of road. These volumes do not represent the actual volumes of material leaving the fill slope. Slumping was much more frequent on fill slopes on roads 9708 and 9709, but the author does not believe this can be attributed to differences in design standards.

Estimates of fill erosion from the trough data range from 4.8 to 60.9 cubic feet per 100 feet of road. Again road 9704 had the largest volume of eroded material, most likely due to the additional month that it was susceptible to thunderstorm activity.

Table 4. Comparison of fill slope erosion on three Horse Creek roads based on rill surveys, slump surveys, and trough data. (Based on June 6, 1979 data for rill and slump surveys and August 29, 1979 data for the sediment troughs.)

		Volume (ft^3/100 ft road)		
Road	Standard	Rill Surveys	Slump Surveys	Trough Data
9704	1	9.91	4.36	60.93
9708	2	6.10	21.91	7.82
9709	2	5.10	13.57	4.80

CONCLUSIONS

One purpose of quantifying fill slope erosion and downslope transport in the Horse Creek Watershed is to provide data and relationships useful to road engineers and other land managers. Measurements are continuing so that time trends can be evaluated. Additionally, there are data on rainfall and topography that have an important influence on fill erosion that have not as yet been analyzed.

Based on available data, the eroded volumes of material from fill slopes for approximately one year following construction range from 5.1 to 9.9 cubic feet per 100 feet of road length. The majority of the rill and gully erosion occurs during the first few thunderstorms following construction. During periods of snowmelt rill and gully erosion is substantially less, but slumping occurs as fill slopes approach saturation.

The larger gullies transport material a farther distance downslope. The occurrence of the larger gullies was not related to the height of the fill slope. However, the average volume of eroded material per 100 feet of road increased as the height of fill increased.

The majority of the eroded material is deposited within 20 feet of the toe of the fill slope. Larger percentages of eroded material tend to be transported farther downslope as the slope of the firest floor increases. The relationships between eroded volumes and transport distance can be used to evaluate the effectiveness of buffer strips of native vegetation.

Filter windrows have proven successful in minimizing the movement of material off of the fill slopes during the first year following construction. This may be one means of minimizing entry of fill material into stream channels at locations where roads cross streams. The approximate cost of construction of filter windrows is $1.00 per lineal foot.

LITERATURE CITED

Alvis, R. J. 1965. Horse Creek Soil Survey, Nezperce National Forest. USDA Forest Service, Division of Multiple Use, Soils, and Watershed Management. 14 p.

Bennett, E. H. 1974. The General Geology of that Portion of the Northern Rocky Mountain Province Containing the Idaho Batholith. USDA Forest Service. Contract 1032-R4-74. 228 p.

Greenwood, W. R. and D. A. Morrison. 1973. Reconnaissance Geology of the Selway-Bitterroot Wilderness Area. Idaho Bureau of Mines and Geology. Pamphlet No. 154.

Megahan, W. F. 1972. Logging, Erosion, Sedimentation - Are They Dirty Words? Journal of Forestry 70(7).

Megahan, W. F. and W. J. Kidd. 1972. Effects of Logging and Roads on Erosion and Sediment Deposition from Steep Terrain. Journal of Forestry 70:136-141.