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USING BARK TO PROTECT AND STABILISE FILL SLOPES

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Figure 1- Runoff plots installed on a newly constructed fill slope

ABSTRACT

A field trial was established to demonstrate the effectiveness of bark in reducing sediment yields from fill slopes. Laboratory analyses were performed to assess some physical properties of the bark. It was found that bark coverage significantly ($P<0.1$) reduced sediment yields from treatment plots. There were no significant differences ($P<0.1$) between sediment yields from slopes treated with 100mm and 200mm of bark.

Since the initial trial, bark has been used successfully in Omataroa Forest to reduce erosion of machine tracks, slips, and fill slopes, and to reduce the visual impacts of elevated landings.

INTRODUCTION

Erosion and sedimentation are major environmental concerns for forest managers. It is well documented that roads, tracks and landings are often major sources of sediment (Swanson and Dyrness 1975; Watson 1979; Pearce and Hodgkiss 1987; Fahey and Coker 1989). In particular, fill slopes associated with the surface of these earthworks can be major sources as they are often uncompacted and exposed to the erosive forces of rainfall.

At present, oversowing or hydro-seeding are common methods of fill slope stabilisation used in New Zealand. However, these methods do have some disadvantages influencing their effectiveness. Oversowing or hydro-seeding do not provide immediate protection of the slopes. Some time is necessary for the vegetation cover to develop. Also, the growth of grasses is impaired by extremes in annual rainfall and temperatures, reducing the period where application is considered viable.

Until this study, bark had not been considered as an alternative for fill slope stabilisation. Typically, bark was either used to rehabilitate landing surfaces and road verges, or it was stockpiled. Bark may provide a viable alternative to oversowing or hydro-seeding as it is likely to reduce erosion by protecting slope materials from rain drop impacts, controlling runoff, and reducing the risk of rill erosion occurring. In addition, the bark could act as a mulch by reducing soil evaporation. Bark coverage is considered a short term solution to the erosion problem, providing a favourable medium for subsequent vegetation growth, which in turn would provide for long term slope stability.

A study was initiated in 1993 to assess the effectiveness of bark for protecting and stabilising a fill slope (Sims, 1993). A field trial was established and sediment yields were monitored. In addition, laboratory analyses of the bark attempted to quantify some of the benefits of bark utilisation.

The amount and composition of leachate derived from the bark cover were not measured in this study. However, the potential impacts of leachate should be considered when spreading bark near waterways.

This report summarises the findings of the study and provides an update on the subsequent use of bark for slope stabilisation within Omataroa Forest.

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METHODS

Field Trial

A sediment trial was established in Omataroa Forest in January, 1993 to test the effectiveness of using radiata pine bark for protecting and stabilising fill slopes. The soils in the forest were derived from either the Kaharoa or more recent Tarawera ashes, and were typically weakly structured and erodible.

Three runoff plots were established on two sides of a newly constructed road, giving a total of six plots. The fill slopes were only four days old at the time of plot establishment. The average fill slope angle was 36°, and the two aspects were north and south.

Two replications of three treatments were imposed on the plots, as follows:

- control (no bark cover)
- 100 mm of bark cover
- 200 mm of bark cover.

The plots were built in a trapezium shape with an approximate area of $15m^2$ (Figure 1). Sediment yielded from the plots was collected in drums at the base of each plot, dried, and weighed. The gravel content of all samples was measured, and where the sample weight exceeded 50g the percentage of remaining sand, silt and clay was assessed using the hydrometer method of Nicholson (1984). The weight of each sample was then divided by the plot area to allow sediment yields to be defined in terms of dry weight per unit area (g/m^2).

The bark used on the plots was the waste product from the Forest King 2318 mobile flail delimber debarker chipper that operates in Omataroa Forest. The bark was put on to the plots with a shovel, and spread with a rake.

Rainfall in the area was monitored using a rain gauge set up beside the plots. Sediment yields and rainfall at the site were monitored for a period of seven months, January to August, 1993.

Laboratory Analyses

Analysis of the bark was performed to determine the mean particle size distribution, and how the bark may react to rainfall, and affect soil water evaporation. The bark was analysed under controlled conditions to determine water absorption and desorption rates, and the rate at which water evaporated from the bark.

Particle Size Distribution

On three occasions during the study, approximately 5kg of bark produced by the chipper was sampled. The particle size distribution for each sample was then determined by dry sieving. The mass of bark retained on each sieve, ranging in sizes from three to 32mm, was determined, and used to calculate the percentage of each class size.

Water Absorption and Desorption Rates

Tests were performed to determine how quickly the bark could absorb water. This was assessed by determining initial volumetric water contents, then saturating the bark in water for up to 24 hours. Three sub-samples were taken every 10 minutes for the first hour, thereafter at 1½, 2, 2½, and at 24 hours, and the volumetric water contents were assessed for each sub-sample.

To determine the rate at which the bark dried from saturation, saturated bark was packed in a tray to a depth of 90mm, weighed to determine initial volumetric water content, then left to dry in a constant temperature and humidity. The bark was re-weighed during a period of 145 hours to determine changes in water contents. Each test was replicated three times.

Water Evaporation

Bark was layed to a depth of 100mm over wire mesh, below which there was a reservoir of water (Figure 2). Over a period of 60 hours, the bark and reservoir were re-weighed to determine water loss. In addition to the bark treatment, water loss from an unprotected reservoir was measured. Each test was repeated three times.

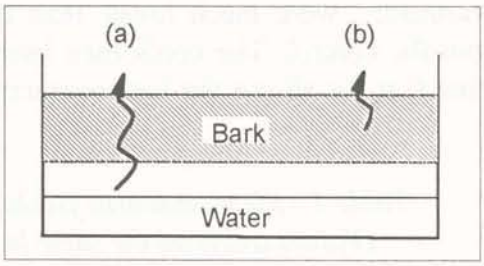

Figure 2 - Set up of evaporation test to measure sum of evaporation from the reservoir (a) and the bark (b).

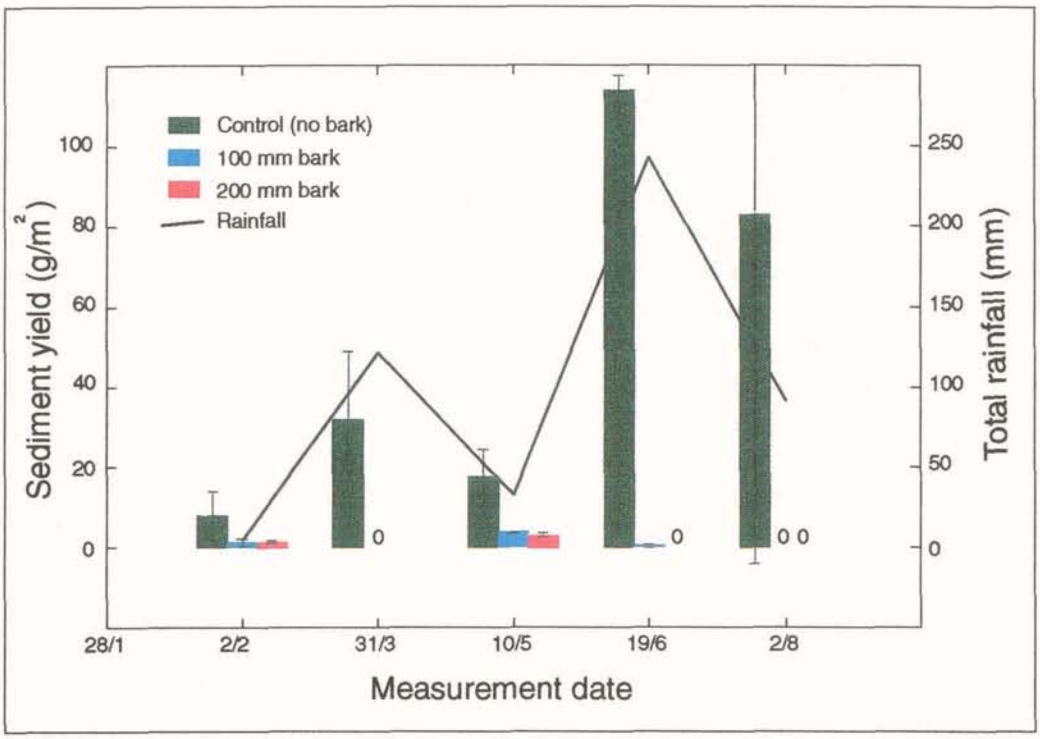

Figure 3 - Mean sediment yields from the three treatments (bars), and total rainfall (line) for each measurement period. Confidence intervals (90%) about the mean sediment yields are also shown. The zeros indicate that no sediment was collected.

RESULTS

Field Trial

Sediment yield was measured on five occasions during the study period. Results of mean treatment sediment yields and total rainfall for the five measurement periods are shown in Figure 3.

The results in Figure 3 show that the mean sediment yields from the two bark treatments were much lower than those from the control. The confidence intervals show that for all but the last measurement period, the differences between treated and untreated plots were significant at the $P<0.1$ level. However, there were no significant differences between the mean sediment yields from the 100mm and 200mm bark treatments. For several of the measurement periods, no sediment was yielded by one or both of these treatments. These are indicated by the zero values in Figure 3. The mean sediment yields for the three treatments on a per unit area basis are shown in Table 1. These values represent the total yield over the seven month study period. Total rainfall for the same period was 495mm.

Table 1 - Mean sediment yields per unit area for the seven month study period. (Values assigned the same letter were not significantly ($P<0.1$) different.)

Treatment	Mean sediment yield (g/m^2)
Control	17.0 ± 7 a
100 mm bark	0.3 ± 0.1 b
200 mm bark	0.4 ± 0.1 b

The yield from the control plots was approximately 60 times greater than the two bark treatments, which were essentially the same as each other. This finding demonstrated that greater benefit was not derived from the thicker coverage of bark.

The particle size distribution of sediment yielded from the control plots over the study period was dominated by sand (mean = 69% of total yield), with mean gravel content and mean silt and clay contents combined being 14% and 17%, respectively. Sediment from the treated plots had higher gravel contents (mean = 31%), largely comprising bark fragments.

Laboratory Analyses

Particle Size Distribution

The mean particle size distribution for the three bark samples is summarised in Table 2.

Table 2 - Summary of the mean particle size distribution for the bark.

Particle size class (mm)	Percentage
> 32	26
13 - 32	69
3 - 13	5
< 3	0

Water Absorption and Desorption

Results from the water absorption tests showed that mean bark water contents increased markedly in the first 10 minutes of saturation (Figure 4a), after which the rate slowed achieving a maximum of 157% after 3600 minutes (not shown in Figure 4a). This response reflected rapid filling of the larger pores, followed by slower filling of the smaller pores.

The mean desorption rate for the 90mm thick layer of bark is shown in Figure 4(b). Water desorption was much slower than absorption, taking approximately 140 hours for the initial water content to be achieved.

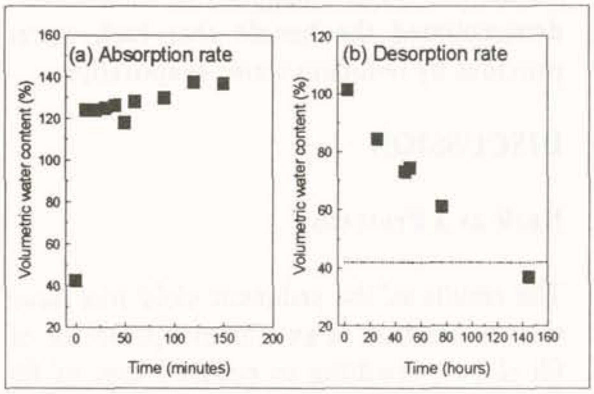

Figure 4 - Results of (a) water absorption rate test, and (b) the desorption rate test for a 90mm thickness of bark. The dashed line in (b) indicates the initial water content of the bark.

Evaporation Losses

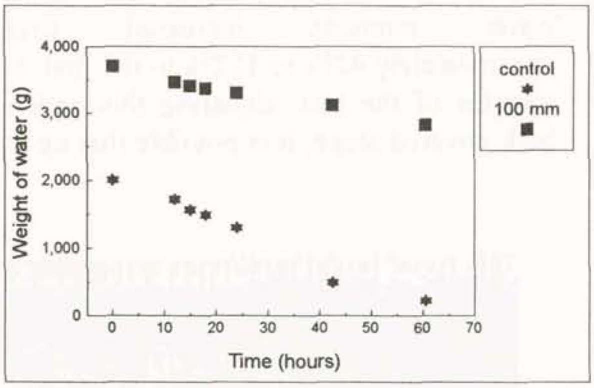

Figure 5 - Results showing the rates of water loss from an uncovered water reservoir (control), and from a reservoir and the 100mm layer of covering bark.

Results from the evaporation tests are summarised in Figure 5. The rate of water loss was greater for the uncovered (control) reservoir than for the bark covered reservoir. The difference in initial weights of water reflected water stored within the bark, which was at an initial mean volumetric water content of 42%. Comparing the two treatments, approximately 88% of the water in the uncovered reservoir was lost to the atmosphere, whereas only 24% was lost from the bark and covered reservoir combined. The results of this test demonstrated the benefit that bark cover provides by reducing water evaporation.

DISCUSSION

Bark as a Protector

The results of the sediment yield trial have shown that bark is an effective protector of fill slopes, resulting in reduced loss of fill materials through surface erosion. The bark provides protection and stability through several processes.

The layer of bark protects the fill slope surface from rain drop splash, which causes detachment of the soil particles. Rainfall on to the bark covered slope can be absorbed by the bark. The results from the water absorption test, showed that volumetric water contents increased from approximately 42% to 122% in the first 10 minutes of the test. Equating this with a bark covered slope, it is possible that up to 80mm of rainfall from a single event can be absorbed by a 100mm thick layer of bark before infiltrating into the underlying fill slope. This value is likely to be a substantial overestimation as preferential flow through large voids will result in short circuiting to the fill slope materials. Nevertheless, these results do demonstrate that the absorption properties of the bark will be important for reducing erosion during the initial stages of rainfall.

As rainfall continues, the fill slope will continue to wet up at which time it is the degree of consolidation of the slope and the nature of the slope materials which will control erosion.

The coverage of bark provides other benefits for slope stability by regulating moisture conditions in the underlying material. Once saturated, the bark can take several days to dry, during which time it maintains elevated water contents in the underlying slope materials. This may be important during dry hot periods when bare fill slopes quickly dry, resulting in a lack of plant available moisture. Therefore, maintaining favourable soil water contents will be beneficial for the growth of vegetation on the fill slopes.

Figure 6 - Bark spread on fill slopes below a landing, Omataroa Forest, to reduce visibility from Rangataiki River plain in the background

Bark Utilisation

Since the completion of the field trial in August 1993, the Manager of Omataroa Forest, P.F. Olsen and Company Limited, has used bark for slope stabilisation extensively. Within the forest, there is a ready supply of bark, produced by the chipping operation.

Bark has been used for the rehabilitation of slips and disturbance associated with machine tracking, and to stabilise rock culvert surrounds. As well as reducing erosion, bark coverage of the prominent fill slopes also improves the site aesthetics by reducing colour contrasts with the cutover (Figure 6).

Typically, an average depth of 100mm to 200mm of bark is used to stabilise and protect slopes. Depths of greater than 200mm were not recommended, as there was a potential for the bark to collapse when it got wet and heavy.

Bark has been applied to slopes using either an agricultural tractor, equipped with a bucket, or a hydraulic excavator. Although the excavator is more expensive to operate, it does provide several advantages over the tractor. Using the excavator, bark coverage can be more controlled, and there is considerably more reach available, which is particularly important when working near water courses. In contrast, the tractor tended to concentrate the bark within reach of the bucket and, as a result, was considered more appropriate for flat sites.

In addition to using radiata pine bark, stringy bark from the debarking of eucalypt for chipping has been used as a base on the steeper slopes upon which pine bark has been placed. This provided a well bound together surface covering which has remained stable on slopes of approximately 40° to 45°.

At the field trial site, the plot surrounds had been removed, and bark spread over the whole fill slope. After 1½ years, the bark coverage was still intact on these fill slopes and there was no evidence of bark or fill slope collapse. The re-establishment of vegetation growth on this site has been slow, and as a result there are plans to oversow this site in the near future. Vegetation regrowth has occurred at some of the other younger sites, particularly where fill had originally been spread over vegetated slopes.

Overall, the method has worked very successfully within Omataroa Forest. The use of bark for slope stabilisation has been particularly well-suited to slopes of 40° or less. On steeper slopes, hydro- seeding still remains a more viable option for stabilisation. The other major benefit for the forest manager, is that the bark generated by the chipping operation can be used in a beneficial way, eliminating the need for disposal by stockpiling throughout the forest.

CONCLUSIONS

The report summarises the findings of an investigation (Sims 1993) of the use of bark to protect and stabilise fill slopes, and reports on the use of slope stabilisation within Omataroa Forest.

As part of the investigation, a field trial was established to compare sediment yields from runoff plots treated with two depths of bark (100mm and 200mm) and a control (no bark). Laboratory analyses were also performed to characterise some physical properties of the bark.

The major findings of the field and laboratory investigation were as follows:

- Bark coverage greatly reduced sediment yields from the fill slopes relative to the control

- There were essentially no differences in mean sediment yields for the two bark depths
- The bark quickly absorbed water over a ten minute period, but water desorption occurred over a period of several days
- Bark coverage acted as an effective mulch, by reducing evaporation.

The use of bark for slope stabilisation has been very successful within Omataroa Forest. Slopes of up to approximately 40° have had 100mm to 200mm of bark applied to reduce erosion and improve site aesthetics. Almost two years after initial bark application, bark stabilised slopes were still intact and providing adequate protection of the underlying fill.

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