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allows a dense lattice of willow to be constructed. The length of the cuttings depends on the channel to be spanned; however, where cuttings are greater than about 4 m long, their flexibility becomes a problem. If active, beavers may limit the success.

Conclusions

Soil bioengineering can be an effective tool for the treatment of unstable slopes and riparian areas. Treatments are relatively inexpensive and can provide significant benefits in terms of reduced maintenance, reduced erosion and enhanced stability. As living systems, soil bioengineering systems need little or no maintenance and continue to strengthen over the years. Soil bioengineering can provide a bridge between traditional engineering treatments and normal seeding work, and can be useful in the reclamation of difficult sites.

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Hillslope Restoration - Biotechnical Soil Stabilization Demonstration Sites

Pierre Rossouw and Ernie Carson

The Ministry of Forests (MOF) and the Ministry of Environment Land and Parks (MELP) have in recent years developed demonstration sites in Kingfisher Creek and Cooke Creek, south east of Salmon Arm (Figure 1). Kingfisher and Cooke Creeks are tributaries to the Shuswap River, which in turn flows into Mara Lake, Shuswap Lake, and into the South Thompson River. Demonstration values developed by MELP at four sites in the Kingfisher watershed include off-channel, instream, and bank stabilization techniques.

The Ministry of Forests has focused on upslope bio-technical soil stabilization techniques at three demonstration sites in the Cooke Creek watershed. Work and monitoring in the three sites has been ongoing since 1997. Various innovative techniques have been tried at the sites, and lessons have been learned through informal monitoring and evaluation.

The first site involves the restoration of a landslide downslope from the Cooke Creek Forest Service Road (FSR) at 4km. This landslide occurred in the spring of 1997 and covered approximately one and one half hectares. The initial failure was on 60% unstable slopes, approximately 200 meters above the creek. The slide path continued down to, and into, the creek.

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Figure 1. The location of the Kingfisher Creek and Cooke Creek demonstration sites.

Secondary failure of the sidewalls of the transport zone occurred again in 1998. Biotechnical soil stabilization techniques in the form of modified brush layers, wattle fences, and live pole drains were installed in the fall of 1997. The sidewalls of the transport zone were treated with wattle fences in the fall of 1998. Because the site is wet, biotechnical soil stabilization techniques have been fairly successful in spite of a very dry summer in 1998.

One aspect of the work completed at this particular demonstration site bears mention: the selection of fall rather than the spring work windows at this location. For some time, the best work window for restoration work has been the subject of vigorous debate amongst practitioners of biotechnical soil stabilization techniques. Most agree that the spring work window (using cuttings collected in the winter) produces the best results. Unfortunately, landslide-prone terrain such as the site at 4km is unpredictable during the breakup period. Crews working in these areas during the spring may be exposed to an unacceptable level of risk. Therefore, it is to our advantage to consider both fall and spring work windows, here, and in landslide-prone terrain.

The second demonstration site involved restoration of a cutslope in raveling sand. This site was treated with modified brushlayers in the fall of 1997. The very dry summer of 1998 resulted in failure of 80% of the cuttings planted in 1997. Monitoring of the site during this hot, dry summer revealed that cottonwood cuttings were more robust than willow in dry conditions. In addition, thicker cuttings survived longer than thinner cuttings taken from second year growth. This site was replanted in the fall of 1998. The summer of 1999 was wet and the site is now relatively well established.

Shading and establishment of leaf mould on top of the sand should aid in arresting the drying and raveling of the sand. Under these conditions, it is likely that conifers will eventually populate the site, so that over time its condition will be similar to that of the surrounding forest.

The third demonstration site was a deeply incised gully formed by ditch water flow off a switchback on the Cooke Creek FSR at 1.7 km. The ditchline above the switchback carries water for some 400 meters to flow out onto unstable, 60% slopes. The result has been the formation of a deep gully in the unstable till material of the slope. The sidewalls of the gully have become unstable, and on the adjacent hillslope are extensive tension cracks, associated with a loss of toe support at the gully. The most obvious solution in a case such as this is the introduction of cross culverts above the switchback to lessen flow and lead ditch water onto the flatter terrain below this part of the road. Unfortunately, cross culverts on this section of road would discharge ditch water directly above private property. As this could cause damage to the private property, forest road managers have not been able to install culverts in this section of road.

The tension cracks and other obvious signs of instability and eminent failure in the gully led to the decision to proceed with treatment of the gully before additional culverts could be introduced, and without lessening of the flow. This deeply incised gully is approximately 6 meters deep with steep sidewalls. Restoration objectives in this instance were to arrest down-cutting and loss of toe support, and to treat the sidewalls. To achieve these objectives, wattle fences were constructed on the sidewalls. These have a 2% fall to the center of the gully, and were configured in the form of "arrow heads." In this treatment, the wattle fences meet in the center of the gully forming appropriate gully breaks to dissipate energy and to arrest down-cutting (Figure 2). Work at this site was undertaken in the fall of 1998. Because the site is fairly wet, there has been vigorous growth and the treatment is successful at this stage.

Acting as lead proponent for restoration work in the Brash Creek Watershed, Spallumcheen Band has subsequently had success using the "arrow head" configuration of wattle fences in a similar circumstance. Brash Creek is a community watershed a few tributaries to the South of Cooke Creek.

The MOF and MELP are presently developing interpretive signs and a brochure to illustrate demonstration values and the locality of sites for both the instream and hillslope components in Kingfisher

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Figure 2. Gully treatment at Cooke Creek FSR 1.7 km. The wattle fences were configured in the form of "arrow heads" to dissipate energy and arrest downcutting.

and Cooke Creeks. This interpretive work has been undertaken in partnerships with Spallumcheen Band and the Kingfisher Interpretive Center (a community-based educational institution). The aim is to fully realize the instructional value of the extensive demonstration work in these watersheds.

Hints and Tips

1. Choose work season according to potential risk at site.
2. Cottonwood cuttings have a better survival rate than willow cuttings in well-drained, drier situations.
3. When constructing wattle fences, additional benefit can be gained by tying horizontal cuttings at 90° to the fence, into the slope. This can be done as the layers of the fence are being constructed. Leave the end of these cuttings sticking out of the fence by 50 mm to 100 mm.

Figure 3. Specialized rebar pounding tool made out of pipe and bars.

4. 20M rebar is far more effective than 15M.
5. A specialized rebar pounding tool can be made out of pipe and bars (Figure 3). With proper design, the pounding of rebar for wattle fences and modified brush layers can be made significantly easier. (Editor's Note: WRP courses are now suggesting the use of wooden stakes (sapling stakes) instead of rebar because rebar is not biodegradable and will not contribute to vegetative growth as stake post/pole sapling cuttings will. Rebar should only be considered if extremely hard soils are encountered.)
6. Use cedar planks (5/8" x 8") for modified brush layers (Figure 4). Individual cedar planks are: (i) easily transported in bundles on site; (ii) light and rot-resistant; and (iii) easily cut with a hand saw, eliminating the need for chain saws and all the regulations associated with their use.

Figure 4. At this site, cedar planks were successfully utilized in modified brush layers.

7. Live pole drains work best when the tops of the bundles are partially exposed.
8. Wattle fences at the toe of the escarpment will catch some of the raveling wall, but may fail or be covered if too much raveling takes place.
9. Leave non-danger trees on the margins of the slide. Such trees are a potential seed source for the successional growth of conifers on the slide. In addition, if they do fall into the slide area they provide a natural stabilizing effect and can bring organic matter down onto the rehabilitating slope (Figure 5).
10. With proper, controlled application of fertilizers, accelerated grass/legume growth can occur. This also assists in the establishment and growth of cuttings.

Figure 5. Non-danger trees remain on the margins of the slide providing a seed source. If they do fall into the slide area they can provide a stabilizing effect and bring additional organic matter onto the slope.

11. In particular cases, wattle fences can be tied back using heavy gauge wire and rebar stakes. This adds to the vertical stability of the wattle fence.
12. "Weaving" of the wattle fences has a benefit over tying only.

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Seeding for Site Rehabilitation

David C. Sahlstrom

The Forest Practices Code (FPC) requires the seeding of disturbed forest areas to prevent impacts from erosion, and this has become a common procedure during watershed rehabilitation as well. Although the benefits of seeding are well documented, a thorough understanding of the science is required to realize these benefits consistently. There are three primary benefits to seeding – erosion control, soil development, and site revegetation or rehabilitation. These three benefits have common components and some aspects of one may limit the benefits of another.

Seeding should always include a mixture of both grasses and legumes. The grass component can include either native species, agronomic species and cultivars, or both. The legume component can include a variety of species from the legume (or pea) family. All legume species have flowers that are similar in shape to the pea flower (although the flowers on some species are so small their similarity may not be noticeable without a magnifying glass). They include clovers, alfalfa, birdsfoot trefoil, lupines, and sainfoin, among others.

Erosion Control

Vegetation is the most effective means of controlling erosion and it protects the environment from the negative impacts of sediment transport and deposition. Grasses and legumes can provide a strong mat that protects the soil surface from erosion caused by precipitation, flowing water and wind. It is possible to use other types of vegetation for erosion control but seeding with grasses and legumes has proven to be very effective in most situations. Initial erosion control during seed germination and establishment can be provided through the use of mulches, tackifiers, erosion control revegetation mats, and other surface protection measures. However, a strong contiguous mat of vegetation provides longer-term erosion control. Research has shown that a cover of 70 to 80% will effectively control erosion and 65% cover is considered a minimum for erosion control (Bergland 1976, Homoky 1996, Sahlstrom 1997).

Soil Development

The role of grasses and legumes in soil development may be the most overlooked aspect of site rehabilitation but it has significant impacts on future success of replanting and reforestation attempts. A healthy, vigorous cover of grasses and legumes can transform barren, infertile subsoils into productive topsoils in an amazingly short time. Under natural grassland conditions, topsoil development has been estimated as requiring 500 years for every 2.5 cm. The establishment and maintenance of a grass and legume cover can accelerate this process and significant contribution to topsoil