SOIL BIOENGINEERING TECHNIQUES FOR RIPARIAN RESTORATION

David F. Polster, M.Sc. R.P.Bio.

Polster Environmental Services Ltd.
5953 Deuchars Drive
Duncan, B.C., V9L 1L5
e-mail d.polster@telus .net

ABSTRACT

Soil bioengineering is the use of living plant materials to perform some engineering function. Soil bioengineering techniques can be used to treat eroding banks, excess gravel and unstable slopes and can provide a finished product that treats the problem as well as providing appropriate riparian vegetation. The natural successional process associated with development of a healthy, functioning riparian vegetation cover is the model that is used to design repair systems that encourage restoration of riparian values. By providing a living, growing system for repair of damaged sites, possibly with wood and rock, the repair can contribute to living riparian area.

Soil bioengineering systems have been used to treat a variety of degraded riparian areas. Live bank protection can be used to form defensive walls of vegetation along the eroding banks of rivers, streams and ponds. Live palisades can be used to re-establish riparian forests quickly. Live gravel bar staking can be used to treat areas where excessive gravel deposits from up-slope erosion threatens downstream channel morphology. Wattle fences, live pole drains, live smiles and a variety of other techniques can be used to treat bank instabilities. This paper presents descriptions of where soil bioengineering treatments have been used for riparian restoration. Examples are drawn from over twenty years of experience by the author.

Paper presented at "High Elevation Mine Reclamation" conference sponsored by the Canadian Land Reclamation Association and the B.C. Technical and Research Committee on Reclamation. September 9-13, 2002, Dawson Creek, B.C.

INTRODUCTION

Soil bioengineering is the use of living plant materials to provide some engineering function. Soil bioengineering is an effective tool for treatment of a variety of unstable and / or eroding sites. Soil bioengineering techniques have been used for many centuries. More recently Schiechtl (1980) has encouraged the use of soil bioengineering with a variety of European examples. Soil bioengineering is now widely practiced throughout the world (Gray and Leiser 1982; Clark and Hellin 1996) for the treatment of erosion and unstable slopes.

This paper presents soil bioengineering techniques that can be used to initiate restoration riparian areas and allow natural processes to provide a sustainable vegetation cover on the treated site. A discussion of plant materials that can be used in soil bioengineering projects is presented initially followed by a discussion of the various different techniques that can be used and the situations in which they are appropriate. Although some of the techniques are common to those practiced in Europe (Schiechtl and Stern 1996 and 1997), many of the soil bioengineering methods that are presented have been developed specifically for situations that are found in British Columbia. The frequent occurrence of marginally stable glacial and glaciofluvial deposits throughout British Columbia combined with areas of high rainfall, frost sensitive soils, saturated soils during snow melt, fast flowing rivers and streams and a host of other circumstances make British Columbia a province where surface stability and erosion problems abound. Soil bioengineering can provide excellent solutions to these problems. Maintenance of completed soil bioengineering work is presented following the discussion of techniques.

PLANT SELECTION, COLLECTION AND HANDLING

Soil bioengineering methods use living plant materials to build structures to stabilize the problem site. As such, the construction materials must be strong enough to withstand the forces acting on them. Li addition, since the intention of building the structures of living materials is that these materials will sprout and grow, the materials must be in a condition that will promote their subsequent growth. The plant materials are typically stem cuttings and must therefore be capable of forming new roots and shoots without special mist tents and bottom heat used in nurseries for plant propagation. Willows *(Salix* spp.), cottonwood *{Populus balsamifera* L.) and red-osier dogwood *(Cornus stolonifera* Michx.) are the only woody native British Columbian species that have been found to reliably root from stem cuttings.

Willows are most commonly used for soil bioengineering projects although cottonwood is becoming more frequently used due to its aggressive growth on disturbed sites. The nomenclature of willows is notoriously difficult and the exact identification of the willows used in a soil bioengineering project is not necessary. Typically common willows such as Scouler's willow *(Salix scouleriana* Barratt in Hooker), Pacific willow *(Salix lucida* Muhlenberg), pussy willow *(Salix discolor* Muhlenberg) and glaucous willow *(Salix glauca* L.) are used. Although the nomenclature of the willows that are used is not important, it is essential that species be selected from habitats that approximate those found on the reclamation site. For instance, treatment of a dry raveling slope composed of sandy gravel would not be very effective with willows that were collected from around a marsh. Red-osier dogwood is particularly useful where the treatment site is under the canopy of other vegetation and not in direct sun.

Cuttings used in soil bioengineering projects should follow the "rule of thumb" that is, if it is not as big in diameter as your thumb it is too small. Minimum diameter of the cuttings at the tip end should be at least 2 cm, and larger cuttings tend to work better than smaller ones as long as they are not old and decadent. In terms of length, cuttings should be at least 40 cm long and where structures such as wattle fences are being built, the cuttings should be as long as possible. Cuttings that are 6 or 7 m in length can be used to make very strong structures. Trim all of the small branches and twigs from the cutting before using it in a structure. Where live pole drains are being built, some of the smaller twigs can be left on the cutting as long as they do not have leaf or twig buds on them.

The cuttings that are collected for soil bioengineering projects need to be handled in such as way that they will retain their viability. Keeping the cuttings cool and moist and avoiding excessive damage to the cambium will help to retain viability. In addition, soaking the cuttings in water for up to 10 days has been found (Becker 2002) to stimulate root development in unrooted cuttings. Cuttings should be collected during the dormant period for the plant (late fall to early spring) and where timing does not permit immediate use of the cuttings, they can be stored in a cold storage facility (0 to 1 degree C) for several months as long as they are kept moist. Storage of collected cuttings in snowbanks has been found to be very effective.

SOIL BIOENGINEERING TECHNIQUES

Wattle Fences

Wattle fences are short retaining walls built of living cuttings. Figure 1 shows the typical design for wattle fences. Wattle fences are used on sites where oversteepened slopes are preventing growth of vegetation. As the cuttings are fairly well exposed, wattle fences work best where there is ample moisture available to sustain the growth of the cuttings. Other techniques such as modified brush layers can be used where sites are drier. Wattle fences can be used on very steep slopes as long as the slope itself is globally stable. At the University of British Columbia wattle fences have been effective at revegetating the sand cliffs with an average slope of the in-situ materials of 70 degrees (see www.serbc.org restoration projects section). Wattle fences can be particularly useful where moisture sensitive soils are sliding down the slope as they will hold the soil and allow the moisture to drain, improving the stability of the soil.

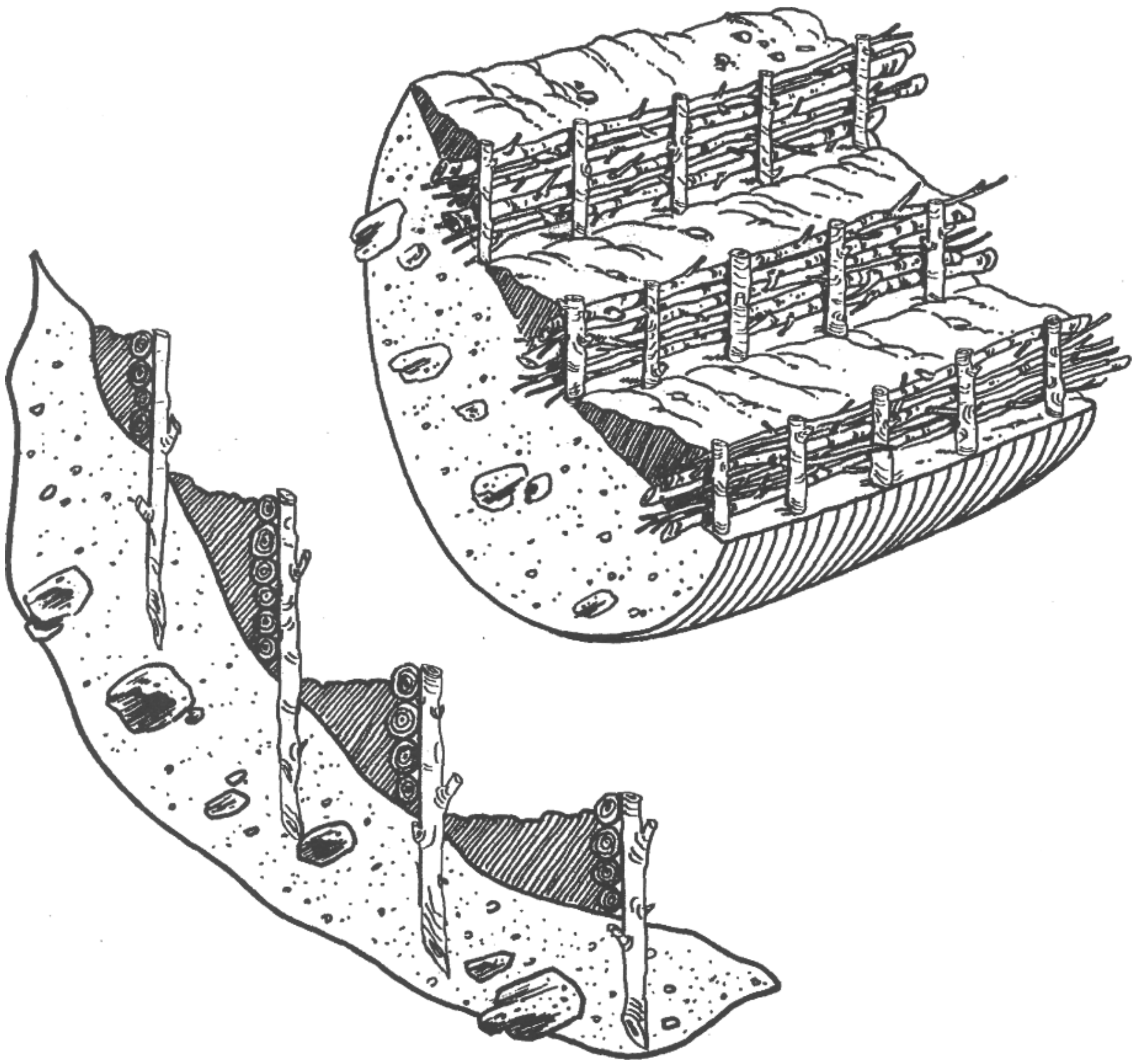


Figure 1. Wattle fences can be used to treat oversteepened slopes. The terracing created by the wattle fences reduces erosion while the growth of the cuttings provides *a* dense cover of pioneering woody species on the slope.

The support for wattle fences can be either stout cuttings as shown in Figure 1 or 15 mm steel concrete reinforcing bars (rebar). Where rebar is used care must be taken to avoid the hazard created with steel bars protruding from the slope. Where cuttings are used, care must be taken while installing the cuttings to ensure they are not damaged too much. Creation of pilot holes and the use of steel caps to drive the cuttings in with can prevent excessive damage. When cuttings are used the cuttings as well as the cross pieces grow and contribute to the vegetation on the slope.

Live Bank Protection

Live bank protection consist of wattle fences along the bank of the stream to create a woody buffer against further erosion. The construction of the live bank protection must be sufficiently dense so that erosion is avoided. Sometimes twigs and trimmings from the cuttings can be used to fill in gaps between the cuttings and thus avoid erosion. Once the cuttings used in the live bank protection sprout and grow, the resulting vegetation provides good protection against erosion. Live bank protection can be particularly effective along the edges of newly constructed ditches. Brush mats (see Schiechtl and Stern 1997) can be used with live bank protection where erosion is excessive.

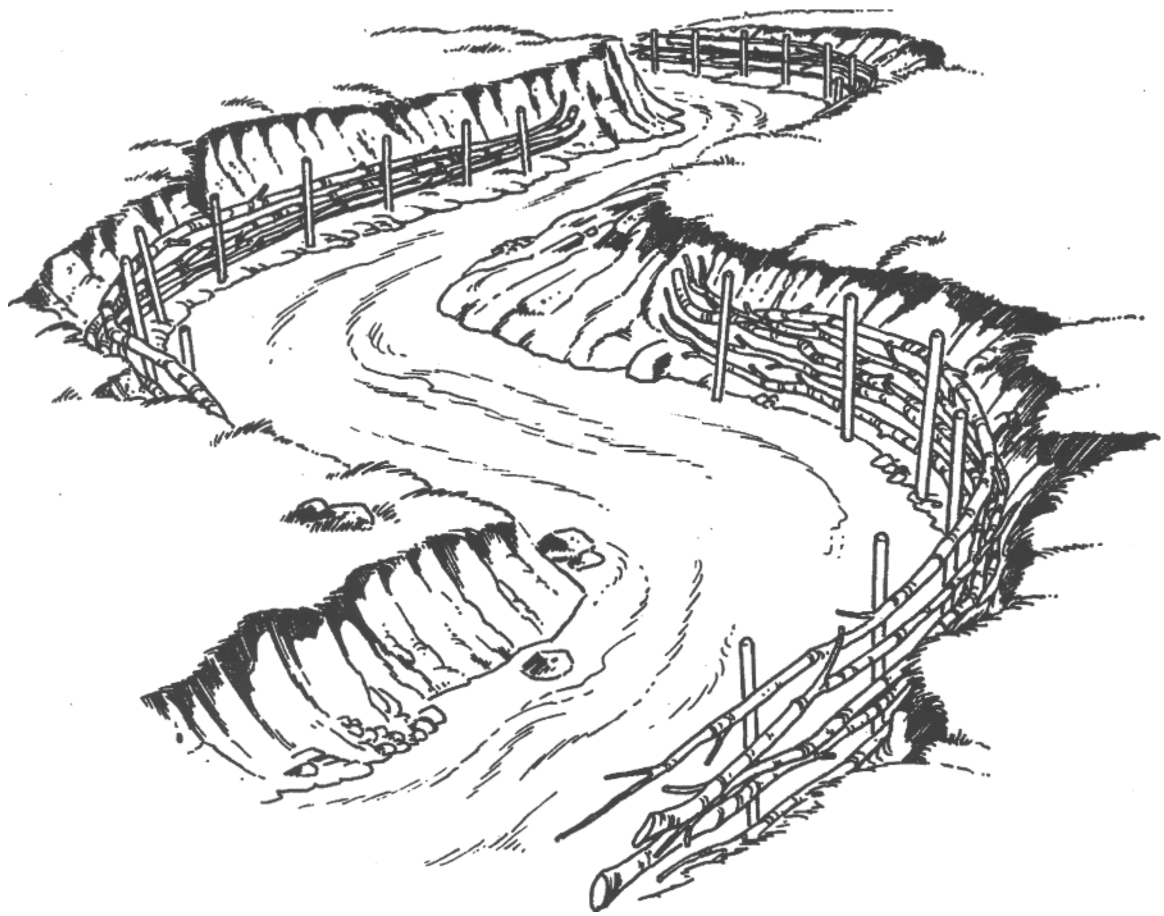


Figure 2. Live bank protection shown here without backfill. Note that the ends of the structures are carefully placed to avoid areas where the current is actively eroding the bank.

Live Palisades

Live palisades are large cottonwood posts installed in trenches adjacent to the eroding stream or river where the natural riparian vegetation has been lost due to clearing or erosion. Figure 3 shows the typical design for live palisades. The key is to get the cottonwood posts down into the water table so that the trees will grow even during dry weather. Large cottonwood posts (15 to 20 cm diameter by 3 to 4 m long) are inserted into a trench dug by an excavator a few meters away from the actively eroding bank. The cottonwood post is expected to root along its entire below ground length and thus produce a dense cylinder of roots that will protect the bank from erosion as the steam encroaches on the palisade. The large cottonwood posts are placed about 50 cm apart so that the growth of the roots will overlap within one growing season. Cottonwood roots can grow as much a 1 cm per day during the growing season (Braatne and Rood 1998). Riparian cottonwood trees provide significant riparian benefit when they mature.

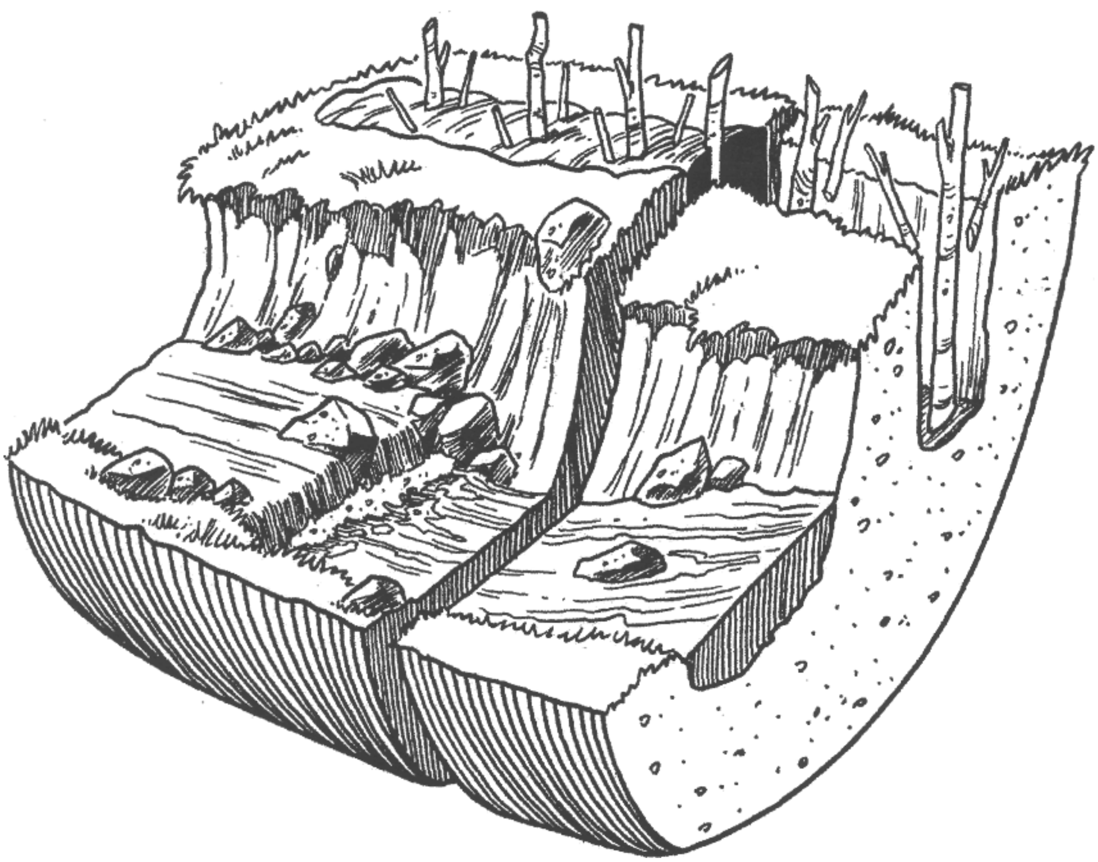


Figure 3. Live palisades consist of a row (or rows) of large cottonwood posts sunk into the water table. Smaller cuttings of willow and red-osier dogwood are inserted in the trench as it is backfilled to provide some diversity to the riparian stand as it develops.

Live Gravel Bar Staking

Excess gravel deposits in streams and rivers can occur in areas of resource development from erosion of upslope areas. These in turn cause avulsions in the stream that results in greater accumulations of sediments downstream. This cycle continues until the stream ends up as a broad expanse of bare gravel with a braided channel and no fish habitat. Live gravel bar staking is designed to establish the natural successional processes that would revegetate the gravel bars and eventually lead to a single channel with well-vegetated banks. The key to live gravel bar staking is to get the cuttings well into the substrate. Use of an excavator is essential (Figure 4). Cuttings should be a minimum of 1 m long and should not protrude from the gravel bar surface more than 20 cm. Large diameter cuttings (4 to 10 cm) appear to work better than smaller stock.

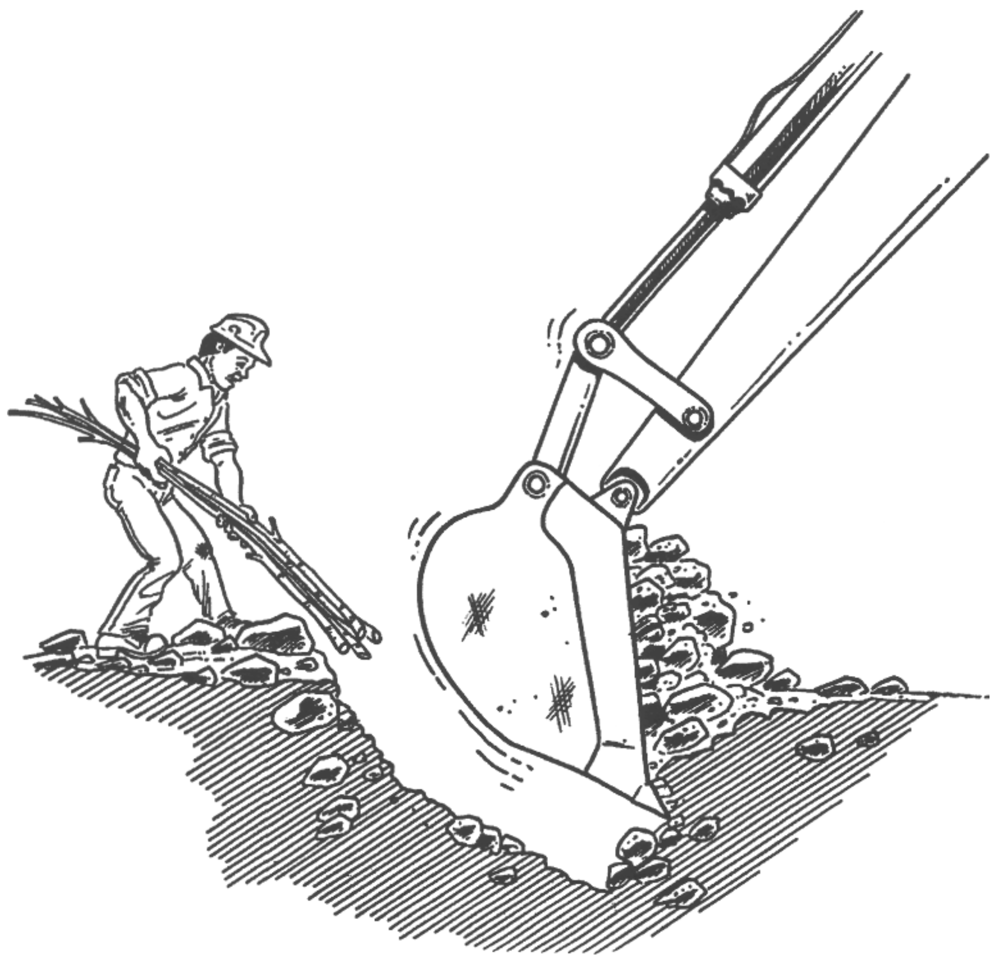
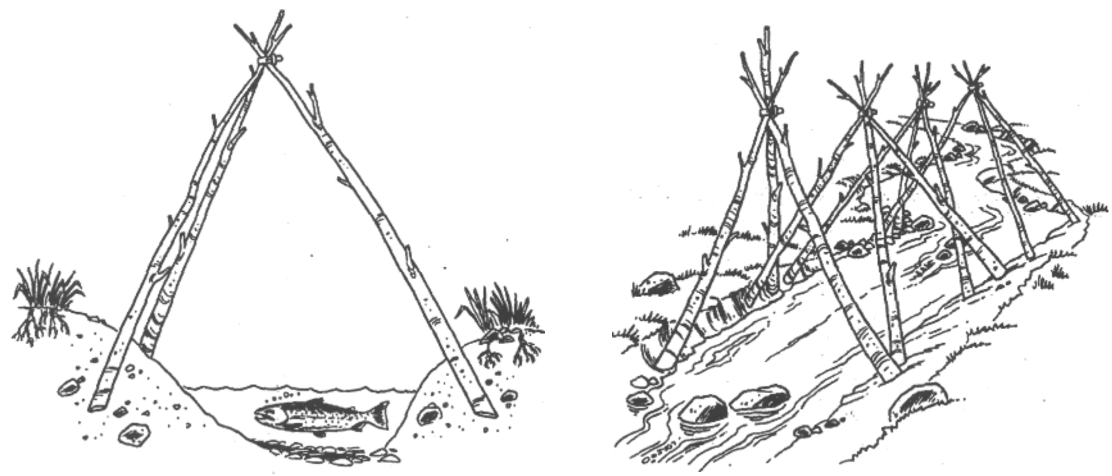


Figure 4. Live gravel bar staking is used to initiate natural succession on bare gravel bars. The sprouted cuttings trap small woody debris that in turn creates a flow disruption that results in deposition of sediment. Once the sediment builds to the point where the sprouts can no longer trap small woody debris there is no more sediment capture until the next year when growth of the sprout again traps woody debris.

Live Shade

Live shade is designed to provide an immediate vegetation cover over newly constructed off-channel fish habitat and small streams where the riparian cover has been lost. Live shade consists of tripods of living cuttings placed over the stream with the feet sunk into the banks about 50 cm so that ample moisture is assured. The cuttings need to be large enough and strong enough to easily span the stream and to support the weight of the new growth plus whatever snowfall might be expected in the region where they are applied. Figure 5 shows the typical design for live shade.



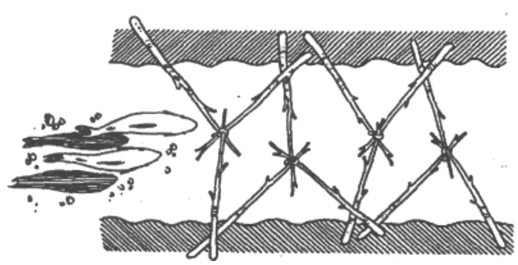


Figure *5*. Live shade provides an immediate vegetation cover on newly constructed fish channels and streams where riparian cover has been lost. The spacing of the legs of the tripods can control the density of the shade.

Other Soil Bioenginecring Techniques

There are a variety of other soil bioengineering techniques that are typically applied to slopes (Figure 6). **Modified brush layers** are used to create small terraces on dry raveling slopes where conditions are too dry for wattle fences. **Live smiles** are used where flowing mud pushes linear structures over. Sites must be relatively moist year-round to sustain live smiles. **Live pole drains** are used to drain excess moisture from seepage zones causing slope problems. They act like living French drains. **Live reinforced earth** walls perform like traditional soil reinforced structures except the construction elements sprout and grow. **Brush layers in a fill** act to prevent circular failures of the fill surface by providing sheer resistance while **brush layers in a cut** create a wall of vegetation to prevent raveling of the cut slope material.

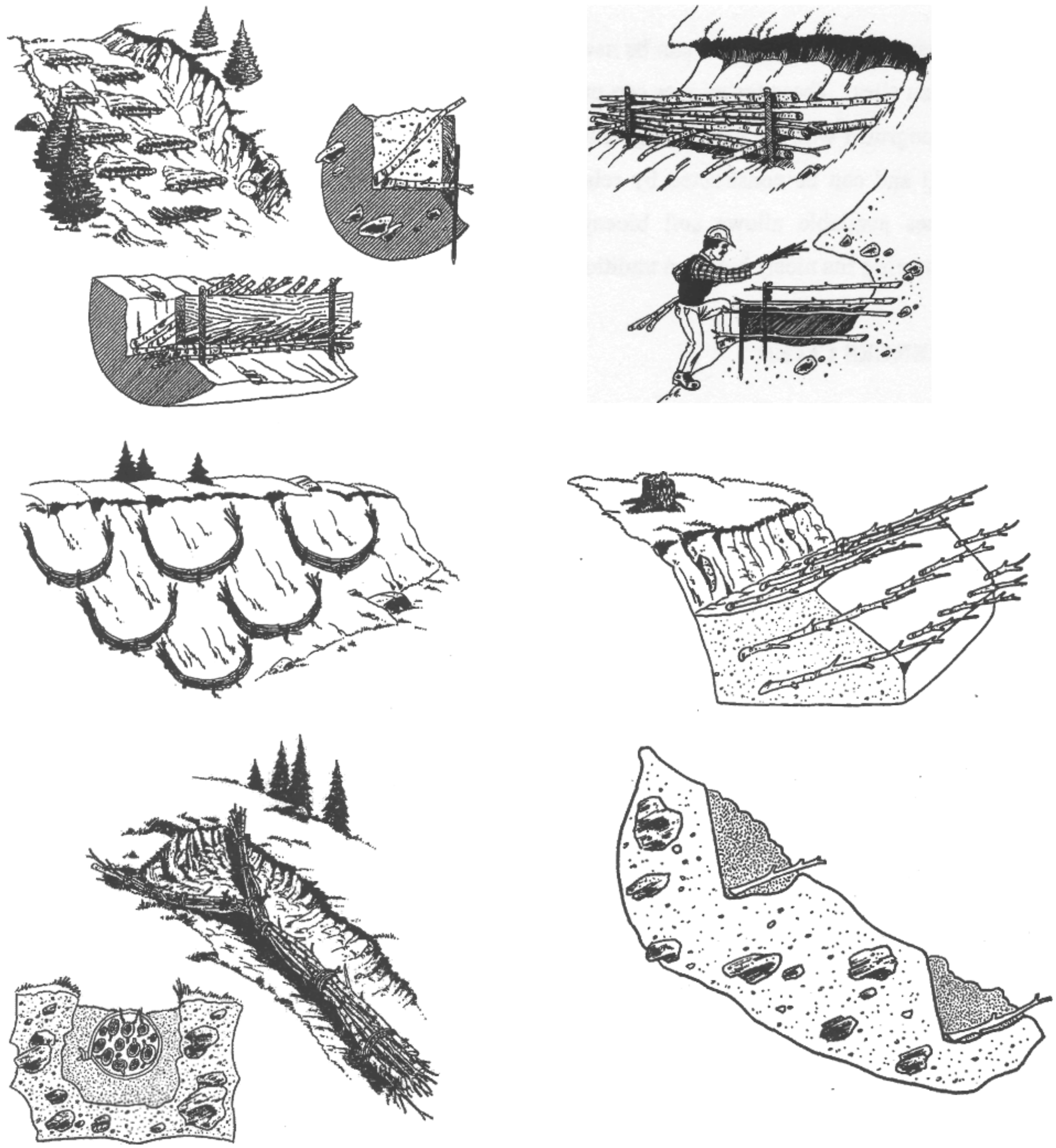


Figure 6. Modified brush layers (upper left), live smiles (middle left), live pole drains (lower left), live reinforced earth walls (upper right), brush layers in a fill (middle right) and brush layers in a cut (lower right) can be used to treat a variety of slope problems.

CONCLUSIONS

Soil bioengineering techniques can be used to treat a variety of problems that may arise in the restoration of riparian sites. These techniques can provide protection from erosion and effective riparian vegetation that is congruent with the natural vegetation in the riparian zone. In most cases these techniques are easy to install and can be constructed by relatively untrained crews or volunteer groups. The diversity of techniques available allows soil bioengineering to address a wide array of problem sites. Soil bioengineering fits nicely between traditional engineering and normal revegetation programs.

REFERENCES CITED

Becker, H. 2002. Soaking willow cuttings helps them protect streambanks. USDA Agricultural Research Service National Sedimentation Laboratory. Oxford, Mississippi (contact person: F. Douglas Shields Jr. shields@sedlab.olemiss.edu).

Braatne, Jeff H. and Stewart B. Rood. 1998. Strategies for promoting natural recruitment and restoration of riparian cottonwoods and willows. Paper presented at Ecosystem Restoration: Turning the Tide. Society for Ecological Restoration Northwest Chapter Conference and Annual Meeting. Tacoma, Washington.

Clark, J. and J. Hellin. 1996. Bio-engineering for Effective Road Maintenance in the Caribbean. Natural Resources Institute. The University of Greenwich. United Kingdom.

Gray, D.H. and A.T. Leiser. 1982. Biotechnical Slope Protection and Erosion Control. Van Nostrand Reinhold Company Inc. Scarborough, Ontario, 271 pp. (reprinted by Krieger Publishing Co. Malabar, Florida).

Schiechtl, H. M. (Trans. N.K. Horstmann, 1980). Bioengineering for Land Reclamation and Conservation. University of Alberta Press. Edmonton. Alberta. 404 pp.

Schiechtl, H.M. and R. Stem. 1996. Ground Bioengineering Techniques for Slope Protection and Erosion Control. Trans. By L. Jaklitsch. Blackwell Scientific. Oxford, U.K. 146 pp.

Schiechtl, H.M. and R. Stem. 1997. Water Bioengineering Techniques for Watercourse, Bank and Shoreline Protection. Trans. By L. Jaklitsch. Blackwell Scientific. Oxford, U.K. 185 pp.