BANK RESTORATION

Factors in channel form and process

Identifying the cause and solutions for bank instability can be relatively straightforward, or extremely difficult. When in doubt, professional advice is recommended before beginning a project on unstable streams. Basic factors to consider include:

- Channel type.
- Sediment transport.
- Aggrading or degrading conditions.
- Lateral movement (size of depositional bar and vegetation gives good indication of rate of movement).
- Relative condition of upstream and downstream reaches.
- Adjacent land management.
- Condition of woody, riparian vegetation.

Restoring this steep bank with site constraints is challenging, and may require bank sloping and moving the road. Clearly a potential project, but stream process must first be considered before presenting solutions.

Think about channel "process" before channel "project"

Understanding the underlying causes of bank instability is essential to selecting an effective bank treatment. Channel classification, aerial photos, and historical accounts can be helpful for interpreting channel process.

An eroding bank is often the symptom of larger channel instability in the stream system. Stabilizing an eroding bank with natural or engineered materials often does not address the underlying cause of bank erosion. In fact, extensive bank restoration in channels undergoing certain types of change can prevent the channel from making needed adjustments.

Relevant questions to ask (and hopefully answer):

- Is instability systemic or localized?
- Is bank instability only lateral, or is the stream adjusting vertically?
- Is instability accelerated or natural?
- Does land use or disturbance play a role?

Examples of factors commonly associated with localized erosion:

- Weak bank due to lack of vegetation or conversion from shrub to grass.
- Scour associated with channel obstructions (ice, structures, slumping).
- Extreme events (icing, peak flows, blowdown).
- Channel aggradation upstream of undersized structures.
- Bank failure or channel alterations upstream.

Potential causes of large scale, systemic type erosion include:

- Channel straightening.
- Highway and railroad encroachment.
- Extensive diking.
- Inherent, large-scale watershed processes.
- Extensive removal of vegetation in the watershed.

CHANNEL RECONSTRUCTION TECHNIQUES

Modifying channel grade and location

Channel restoration involving major changes to channel gradient, location, or geometry can produce substantial benefits when properly designed.

Applications

- Restoring channelized or diked reaches.
- Removing dams and other structures.
- Relocating away from hazards and infrastructure.
- Relocating due to highway construction.
- Restoring channels impacted by extreme events (debris flows, mass failure).
- Restoring channels impacted by land use (grazing, logging, subdivision).
- Creation of spawning channels or fish passage.
- Restoring a braided channel back to a single channel.

Design considerations

Design on larger projects generally requires input from specialists including hydrologists, geomorphologists, wetland-soil scientists, biologists, and engineers.

Funding may be available to help with channel restoration projects that enhance natural stream function.

CAUTION:

- Major modifications to channel gradient, shape, or location can be destructive if not properly engineered.
- Channel straightening is not generally acceptable.
- Relocating channels may require delineating wetlands, floodplains, and environmental impacts with professional assistance.

Re-establishing meanders in a channelized reach requires substantial hydrology and engineering design expertise.

Restoring natural channel width-to-depth ratio and alignment can improve stream function.

This meander has been restored with channel shaping, grade control structures, root wad/woody debris, and bank sloping sod mats.

SOFT BIOENGINEERING METHODS

SOFT BIOENGINEERING

River stabilization or restoration?

Set clear objectives

When selecting bank treatments consider the level of protection needed, and whether the project is intended to be "restoration" or "stabilization."

Restored banks

For restoration, banks are designed to replicate natural channel stability, and allow some bank movement over time comparable to natural rates. These projects will generally employ biodegradable fabrics and rely on vegetation established for long-term protection.

Stabilized banks

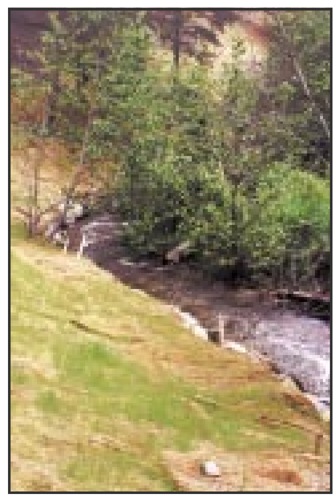
Stabilized banks are designed to withstand erosion irrespective of natural channel migration rates. These projects generally employ permanent fabrics or hard structural techniques such as riprap. Because hard armoring limits natural channel processes, they should be employed carefully to avoid adverse impacts to channel stability.

Soft bioengineering methods

Soft bioengineering methods may be preferred where:

- Adequate vegetation can be established within several years.
- Restoration has precedence over immobilizing bank.
- Costs are competitive with hard engineering due to material costs (usually the case).
- Risk associated with natural methods is acceptable.
- Hard methods are unacceptable due to potential channel impacts.

In combination with vegetation, synthetic and natural materials can provide excellent bank stability.



Stabilized bank using coconut fabric (same location as above) four months later.

Geotextiles such as jute, coconut fabric, and wood fiber are biodegradable and can last 2 to 4 years while vegetation becomes established.

GEOTEXTILE EROSION CONTROL FABRICS

Geotextile fabrics

Erosion control fabrics are made out of many different fibers. Some are completely biodegradable, and others include a plastic mesh matrix. Heavier weight fabrics are commonly referred to as Turf Reinforcement Mats (TRMs).

Natural Fabrics

- Coconut blankets
- Jute mesh
- Excelsior blankets
- Straw

Natural materials break down over several years (typically 2 to 4 years), and vegetation must provide long-term erosion resistance.

Synthetic Fabrics

- High-density polyethylene blanket
- Women polypropylene
- Geoweb

Synthetic fabrics are permanent and break down slowly over decades if exposed to sunlight.

Soft bioengineering can be strong

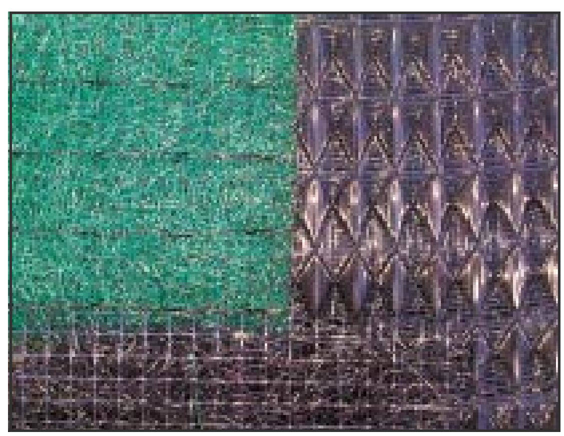
Turf reinforcement mats can provide the equivalent protection of 2-foot rip-rap with good vegetation.

Coconut or jute blankets typically last 2 to 4 years depending on conditions, at which time vegetation is most important for maintaining stability.

Plastic mesh can last 5 years or longer, providing continuing bank protection even in the absence of good plant cover. Synthetic fabrics provide a high level of long-term protection, but can pose a hazard for fish and wildlife.

Natural fiber erosion fabrics are commonly made with coconut or jute.

Hybrid natural and synthetic fabrics combine natural fiber with long-lasting synthetic grids to increase longevity and strength.



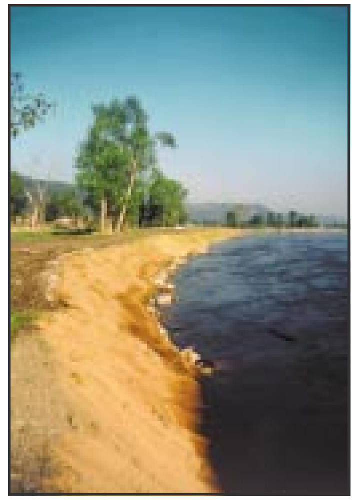
Synthetic fabrics are long lasting, but can pose a nuisance to anglers and wildlife.

FABRIC-WRAPPED BANKS

Geotextile fabric-wrapped banks are an excellent alternative to rip-rap for stabilization of eroding banks with natural vegetation.

Applications

- Restoring eroding banks with low to moderate erosive forces.
- Alternative to rip-rap and other hard treatments.
- In conjunction with woody debris, brush layering, or tree revetment techniques.



A single wrap of jute mesh fabric with a rock toe provides immediate protection following construction.

Design and construction techniques

- Banks are sloped at 2:1 or less when possible. Steeper 1.5:1 slopes can be vegetated, but are more vulnerable to failure.
- The toe is stabilized as required (often with rock, large cobble, or woody debris).
- Geotextile fabric is wrapped over smooth slope with topsoil plus seed, or salvaged sod.
- Raw fill materials alone may limit seed or cutting establishment.
- Staples, wood stakes, rebar, and willow cuttings are used to help hold fabric in place.
- Cuttings or plantings can be incorporated into fabric banks, either through fabric, or in lifts.

Same bank as above 14 months later. This is essentially a hard stabilization approach because the rock toe makes the stabilized bank stronger than a natural bank.

CAUTION:

- Biodegradable fabrics eventually break down and rely on vegetation for bank strength.
- Unless stabilized, the toe of the bank can scour and undermine fabric.
- A mature geotextile bank can be nearly as solid as rip-rap, and can impair channel dynamics.
- Rock toes act as rip-rap and should be used only when absolutely necessary.
- Fabric may be vulnerable to damage from ice and drifting woody debris before vegetation matures.

Proper installation of fabric mats is essential to success, including adequate foldover of the toe, overlap of the mats, anchoring with staples, live stakes, etc.

WATTLES / FASCINES

Willow fascines, or wattles, are dormant branch cuttings bound together into long, cylindrical bundles. Fascines are placed in shallow trenches to reduce surface erosion on slopes.

Applications

- Wattles are commonly used as slope reinforcement methods above the high water line.
- Use on slopes gentler than 1.5:1.
- Ensure adequate soil moisture for rooting cuttings.
- Ensure adequate live plant material is available.
- Requires a minimum amount of site disturbance.
- Where appropriate, wattles should be used with other soil bioengineering systems and vegetative plantings.

Willow fascines are being staked at the toe of the bank prior to wrapping the slope with geotextile fabric.

Two years later, the geotextile bank is predominantly grass, but willows are becoming established at the toe.

Design and construction techniques

- Bundles are prepared from live shrubby material such as willow or cottonwood.
- Bundles are bound with heavy twine and staked with 2 to 3 foot construction stakes.
- Bundles must be kept wet, and can be prepared up to one week before placement.
- Bundles are typically 8 inches in diameter and 6 to 10 feet long.
- Bundles are set in shallow trenches, placed on the contour, and partially covered with fine soil tamped into voids.
- Fascines can be placed in multiple rows, or used as a single row at the toe of a bank.
- Use dormant material (late winter, early spring, or fall) cuttings.

CAUTION:

- Can be vulnerable to erosion when installed below the bankfull level.
- Not effective to control large mass movement on slopes.
- May require watering on arid sites for good establishment and survival.

BRUSH LAYERING

Alternating layers of live branches and compacted backfill can be used to stabilize a slope. This produces a filter barrier that prevents erosion and scouring from streambank or overbank flows, and provides immediate soil reinforcement. Geotextile or a rock toe is often used to ensure stability while vegetation becomes established.

Applications

- Stream banks with light to moderate lateral erosion and good vertical stability.
- Small patches of bank that have been scoured out or have slumped leaving a void.
- Appropriate after stresses causing the slump have been removed.
- Eroded slopes or terraces where excavation is required to install the branches.

Design and construction techniques

- Brush layers may be incorporated into many types of slope and bank reconstruction.
- Use live willows, cottonwood, or other plant material, preferably a species that will root.
- Shape the streambank to a grade of less than 1.5:1. Lay plant material on the successive "lifts" of a fill or in trenches cut successively from the bottom to the top. Soil removed from each successively higher cut is used for fill over the brush below.
- The cut material will vary in length depending on slope dimensions. Brush may be 6 feet or longer.
- Cut branches should be laid in a criss-cross pattern for greater stability.
- Use dormant plant material (late winter, early spring, or fall) cuttings.

Brush layer technique is used here in combination with coconut fabric to restore the bank and enhance habitat.

Four years later bank remains stable at this site. Three short low profile barbs were used to reduce near-bank velocities.

CAUTION:

- Typically not effective in large slump areas.
- Droughty soils may limit establishment of cuttings.
- Toe protection is required where toe scour is anticipated.

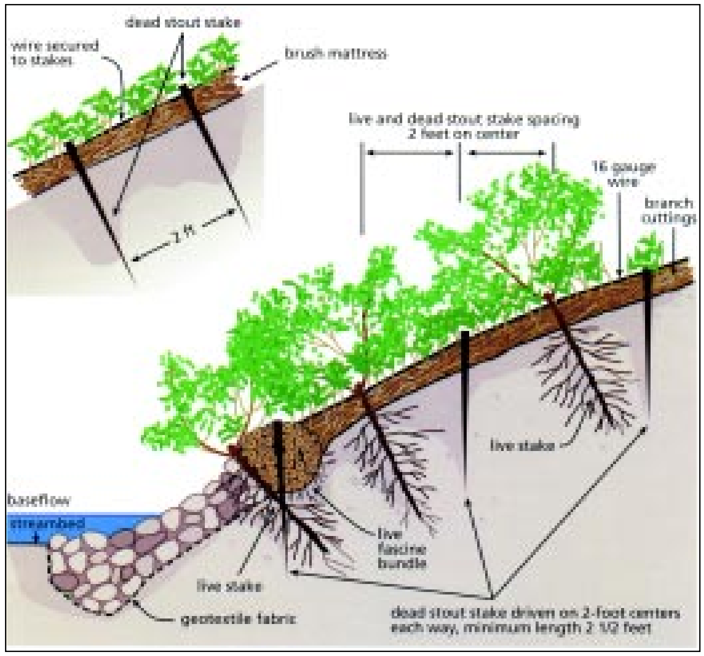
SOFT BIOENGINEERING METHODS

BRUSH MATTRESS

A brush mattress is a combination of live stakes, live fascines, and branch cuttings installed to cover and physically protect streambanks. Eventually, the cuttings sprout and establish solid vegetation. A mattress physically protects the streambank, captures sediment during flood flows, and enhances the establishment and growth of native vegetation.

Applications

- Stream banks with light to moderate lateral erosion and good vertical stability.
- Slopes of 1.5:1 or less.
- Terrace and floodplain areas.
- Appropriate where exposed streambanks are threatened by high flows before vegetation becomes established.
- Can be combined with a geotextile blanket for extra protection.



(At right) Brush mattress methods can be labor intensive, but can provide strong, natural bank stability. Shown is a combination of a rock armored toe, live facine bundles, and live stakes.

SOFT BIOENGINEERING METHODS

Design and construction techniques

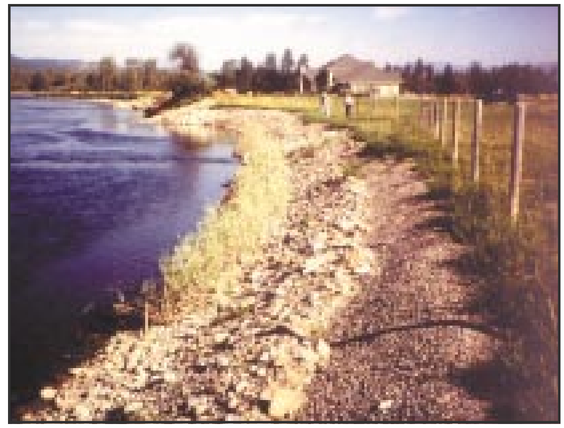
- Layers of live and dead brush are laid in a continuous mattress from 4 inches to 1 foot thick.
- Brush is covered with wire netting or erosion fabric, or is secured with individual stakes and wire.
- Matting must be thoroughly anchored to prevent failure, and it must be protected from undercutting.
- One advantage of brush matting is that no heavy equipment is needed for installation.
- A disadvantage of brush matting is subsequent planting through the matting is difficult.
- Brush species that will root are preferred, such as willow, cottonwood, and dogwood.

CAUTION:

- Limited to the slope located above base flow levels.
- Droughty soils may limit the establishment of cuttings.
- Should not be used on slopes that are experiencing mass movement.
- Toe protection is required where toe scour is anticipated, but should be used only when absolutely necessary.

LIVE CUTTINGS

Live woody cuttings are tamped into the soil to root, grow, and create a dense root mat that stabilizes the bank.



Live willow cuttings seem to survive best when cut and planted in the early spring prior to bud break.

Applications

- To re-vegetate stream banks, slopes, floodplain.
- To repair small earth slips and slumps that are frequently wet.
- Effective where site conditions are uncomplicated.
- Construction time is limited.
- Inexpensive method if material is available.

Design and construction techniques

- Can be used to stake down geotextile erosion control fabric or stabilize areas between other soil bioengineering techniques.
- Where appropriate, should be used with other soil bioengineering and vegetative plantings.
- Enhance conditions for establishment of vegetation from the surrounding plant community.
- Stakes are 2 to 4 feet long, 0.5 to 1.5 inches in diameter, taken from 2 to 4 year old wood, and are inserted with basal end to water table or saturated soil.
- Consider dipping top ends into latex paint to aid in identification of cutting top and prevent drying out.
- Use rebar or dibble to speed installation with a starter hole.
- Most successful if planted in spring prior to leafing out, or in fall while dormant.
- Most native willow species are suitable.
- Beaver, rodents, and livestock can reduce survival of new plantings.
- Locations within the floodplain or where erosive forces are low can be sprigged with cuttings alone.

CAUTION:

- Requires toe protection where excessive toe scour is anticipated.
- Cuttings are most successful if used in conjunction with geotextile, woody debris, or rock treatments within the high water mark.
- Require protection from animals during establishment.
- Do not remove all live material from any one parent shrub or tree.

DORMANT POLE PLANTINGS

Plantings of cottonwood, willow, poplar, or other species are driven into streambanks to increase channel roughness, reduce flow velocities near the slope face, and trap sediment.

Dormant willow poles are effectively placed with a dibble on an excavator or backhoe.

Applications

- Most types of streambeds where poles can be inserted to reach the water table.
- Stabilize rotational failures on streambanks where minor bank sloughing is occurring.
- Establishing riparian trees in arid regions where water tables are deep.
- Will reduce near-bank stream velocities and cause sediment deposition in treated areas.
- Joint plantings in pre-existing rip-rap.
- Generally self-maintaining and will re-stem if damaged by beaver or livestock, but limiting livestock access will speed recovery.
- Best suited to non-gravelly streams and where ice damage potential is low.
- Poles are less likely to be removed by erosion than are live stakes or smaller cuttings.
- Can be used with geotextiles and vegetative plantings to stabilize the upper bank.

Design and construction techniques

- Poles are often used in conjunction with rock or geotextile treatments.
- Robust species such as yellow willow or cottonwood are preferred.
- Generally requires a dibble for effective installation of posts below water table.
- Use 1 inch to 5 inch diameter, dormant material collected in early spring.

CAUTION:

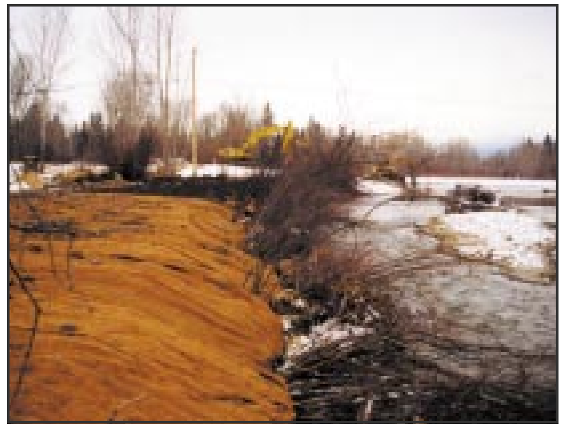
- Unlike smaller cuttings, post harvesting can be very destructive to the donor stand.
- Poles should be gathered as “salvage” from sites designated for clearing, or thinned from dense stands.
- Equipment access should be carefully planned to avoid damaging banks.

ROOT WADS / WOODY DEBRIS

Woody debris is an effective bank treatment in many eroding bank stabilization settings. Several approaches are possible including continuous "root-rap," individual root structures with geotextiles, and/or mature willow transplants.

Root wad protection may be appropriate when:

- Materials can be readily obtained without damage to riparian vegetation.
- Bank materials are cobble/gravel and not erodible sandy textures.
- Fish habitat and restoration is a priority.
- Installation of an effective root wad project is sensitive to careful construction technique.



Root wads and woody debris can provide substantial bank protection while enhancing fish habitat.

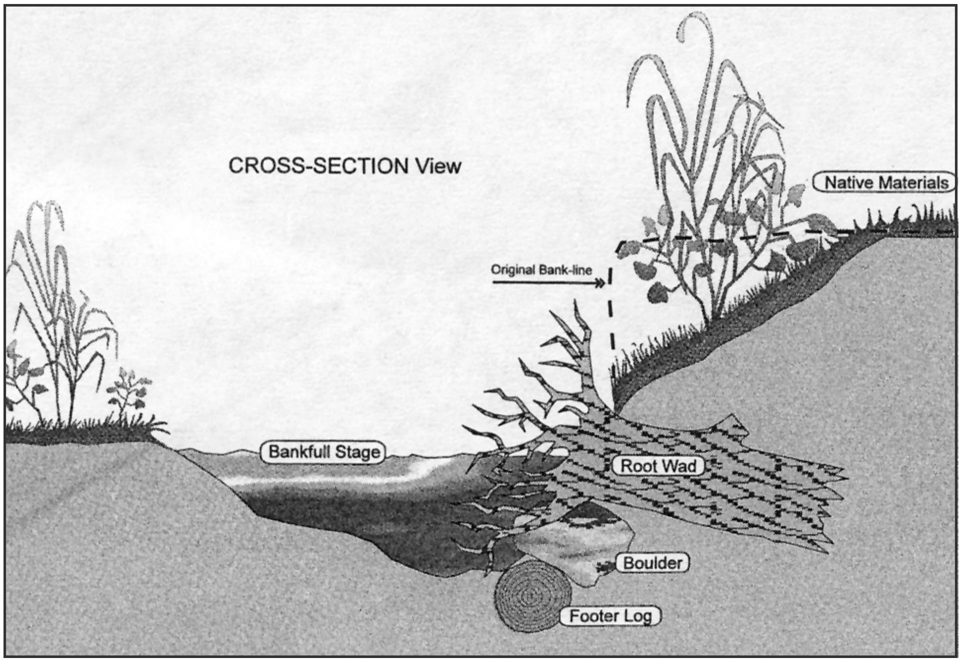
Design and construction techniques

- Will tolerate high velocities (greater than 10 feet per second) and erosive forces if logs and rootwads are well anchored.
- Native materials can trap sediment and woody debris, protect streambanks in high velocity streams, and improve fish habitat.
- Where appropriate, should be used with geotextile and vegetative plantings to stabilize the upper bank.
- Will have limited life depending on climate and tree species used. Some species, such as cottonwood, often sprout and improve stability.
- Site must be accessible to heavy equipment.
- High banks (greater than 6 to 8 feet) may limit successful placement and anchoring of tree trunks.
- Use root wads with 12 to 15 feet of the tree trunk attached. Anchor with a footer log and rocks one-and-one-half the diameter of the trunks. Tree trunk diameters should be greater than 18 inches, larger on large rivers.
- Install so the root ball remains partially submerged during low flows.
- May be used in combination with log or rock vanes.

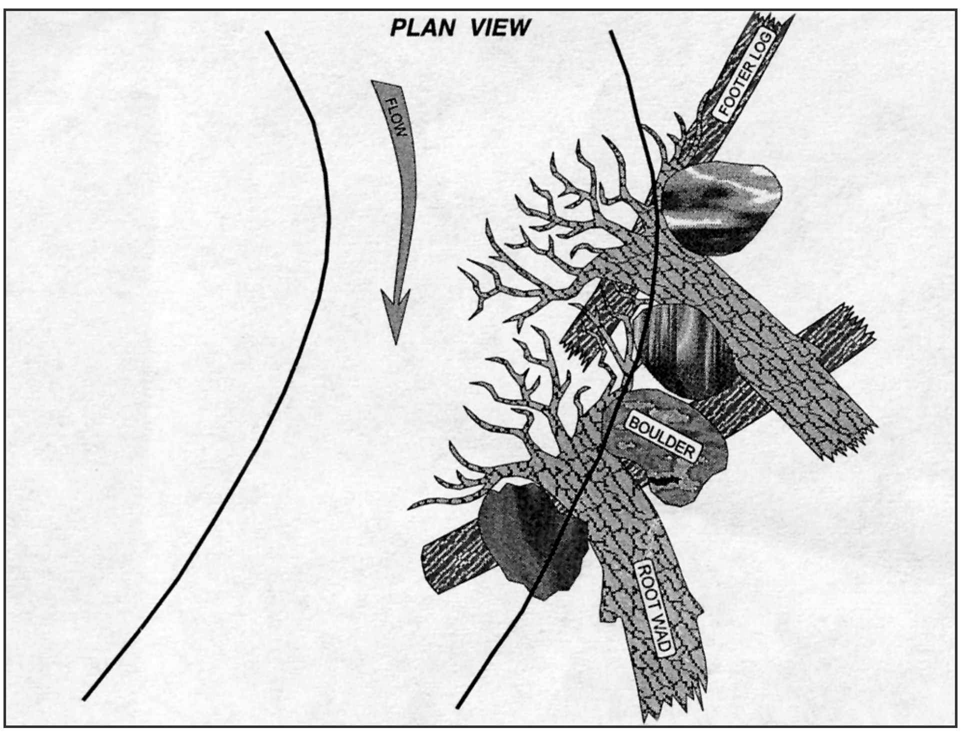
CAUTION:

- Can create scour and erosion with potential loss of structure if not adequately anchored.
- Might need eventual replacement if revegetation is poor or soil bioengineering is not used along with the structure.
- Can be expensive and time consuming to install, especially on high steep banks.
- Excavation for tree trunks and roots can destabilize banks and damage root systems of existing trees.

ROOT WADS / WOODY DEBRIS (continued)



Native material bank revetment, cross-section view. From Rosgen, 1993a.



Native material bank revetment, plan view. From Rosgen, 1993a.

TREE REVETMENT

A tree revetment is a row of interconnected trees attached to the toe of the streambank or to deadmen in the streambank. Revetment reduces flow velocities along eroding streambanks, traps sediment, and provides a substrate for plant establishment and erosion control.

Tree revetment should include substantial amounts of finely branched material along with trunks overlapping with the treetops facing downstream.

Applications

- Bank heights under 10 feet and bankfull velocities under 6 feet per second.
- Vertical stability is adequate: lateral bank erosion is moderate.
- Can use inexpensive, readily available materials.
- Low-cost, low-tech treatment is desired.
- Captures sediment and enhances conditions for establishment of plants.

Design and construction techniques

- Enhanced protection by incorporating branches and tree tops rather than trunks only.
- Where appropriate, use geotextiles and vegetative plantings to stabilize the upper bank.
- Use uprooted, live trees laid on their sides and secured to the bases of banks along eroded stream segments, tops pointed downstream and overlapped about 30 percent.
- The best species are those with abundant, dense branching to promote sediment trapping, and trees that are decay resistant.
- To determine tree size: the diameter of the tree's crown should be about two-thirds the height of the eroding bank, and trees greater than 20 feet tall are most economical for most applications.

CAUTION:

- An adequate anchoring system is essential. Inadequate anchoring will allow the trees to float and move back and forth against the bank, causing accelerated erosion.
- Revetment has a limited life and must be maintained or replaced periodically.
- Ice flows may damage revetment.
- Do not install directly upstream of bridges and channel constrictions because of the potential for downstream damages if revetment dislodges.
- Should not be used if the revetment would occupy more than 15 percent of the channel's cross-sectional area at bankfull level.
- Requires toe protection where toe scour is anticipated.

COCONUT FIBER ROLLS

Fiber rolls are cylinders of coconut husk fibers bound together with twine woven from coconut material. These can be used to protect the toe of a slope from erosion, while trapping sediment that encourages plant growth within and behind the fiber roll. Fiber rolls are easily installed with wooden stakes and over time will blend in to the natural environment.

Coconut logs may be used with geotextile fiber mats for bank protection. The application above relied on a rip-rap toe to stabilize the streambank.

Applications

- Low to moderate strength toe stabilization is needed in conjunction with restoration of the streambank.
- When the sensitivity of the site allows for only minor disturbance.
- Stream velocities and scouring are low to moderate.
- Can be molded to the existing curvature of the streambank.
- Requires minimal site disturbance.
- Have an effective life of 2 to 3 years.
- Are often used with soil bioengineering systems and vegetative plantings to stabilize the upper bank.
- Are typically staked near the toe of the streambank with dormant cuttings and rooted plants inserted into slits cut into the rolls.

Design and construction techniques

- Most commonly available in 12-inch diameter by 20-foot lengths.
- Place rolls on surface, or sometimes in a shallow trench or bench cut in the bank.
- Stake with 2- to 4-foot stakes on 3-foot centers.
- Use heavy twine to lash down each roll between stakes.
- Submerge roll at a constant depth of one-half to two-thirds of the roll's height to ensure plant survival.
- Plants can be plugged into roll after it has been in the water a short time. To ensure plant roots extend into the soil, plug plants into the sides of the roll or in soil between lifts.
- The recontoured soil behind the roll should be seeded and covered with an erosion control blanket to prevent slope erosion.

CAUTION:

- The rolls are buoyant and require secure anchoring.
- Not appropriate for sites with high velocity flows, high scour potential at the toe, or large ice build-up.
- Can be expensive and labor intensive to provide adequate staking.