OHIO STREAM MANAGEMENT GUIDE

Evergreen Revetments

EVERGREEN REVETMENTS

An evergreen revetment is a protective "wall" made of freshly cut cedars, pines, firs or recycled Christmas trees which are anchored into an eroded streambank. It absorbs stream energy and traps sediments. This buffer system, shown in Figure 1, slows or halts active erosion, creates a place for sediments to deposit and allows vegetation to re-establish on the streambank. An evergreen revetment alone may not be sufficient to hold soils in place after the evergreens decay. For long-term stability, dormant cuttings of willow or other rapidly-rooting species should be planted within the revetment and above it on the bank face to accelerate the re-establishment of root structure (see Guide No. 07 Restoring Streambanks with Vegetation). A buffer strip of native hardwoods should also be planted, if absent, along the top of the bank (see Guides No. 08 Trees for Ditches and No. 13 Forested Buffer Strips).

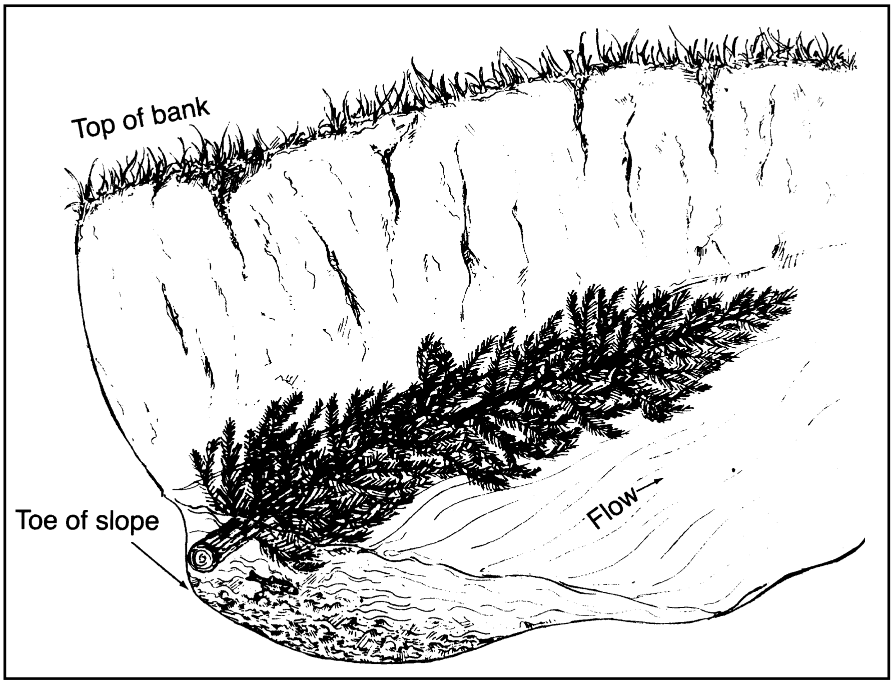

Figure 1. Evergreen Revetment

An evergreen revetment is one of several biotechnical practices described in the Ohio Stream Management Guides. These practices use vegetative or other natural materials to achieve stream management objectives, usually erosion control. One of the chief advantages of biotechnical practices is that they help restore natural stream features, like in-stream habitat and streambank vegetation. Guide No. 10, Biotechnical Projects in Ohio, provides an overview of biotechnical practices. It also maps over 50 project sites and list contacts who can arrange for site visits.

Some site conditions and/or project objectives (such as protecting existing structures on the streambank) will require use of more traditional, structurally-engineered solutions. This is particularly true where high velocity flows can be expected. In other situations, a combination of structural and biotechnical practices may provide both strength and habitat. No project should be undertaken without an understanding of the functions of stream energy and the source of any problems to be corrected. Guide No. 03, Stream Management and the Stream's Natural Processes will provide an overview of stream dynamics and the impacts land and channel management practices have on streams. Technical assistance about stream dynamics can also be obtained at your local Soil and Water Conservation District. Its number is listed under county government in the local phone directory.

The purpose of this Ohio Stream Management Guide is to describe the generally suitable site conditions, design, installation and maintenance steps for evergreen revetments. The guidance provided is based on guidelines from Missouri and on field experience here in Ohio. As with any construction project in a stream, the Ohio Department of Natural Resources recommends you consult with the applicable local, state and federal authorities listed in Guide 06, Permit Checklist for Stream Modification Projects, prior to construction. The extent of permit requirements will depend on the location and design of your project.

WHERE TO USE EVERGREEN REVETMENTS

Evergreen revetments work best on medium to small streams which have erosion problems due to inadequate tree cover on the streambanks. This lack of tree cover usually means there is adequate sunlight to supplement the revetment by planting dormant cuttings and hardwood trees. Always look for the cause of erosion when considering how to solve it. If the stream is just naturally meandering, protective measures should not be installed unless really necessary. A bank that is well covered with trees but still eroding indicates that the channel is undergoing adjustments due to changes in land use or channel configuration in the upper watershed, and an evergreen revetment will probably not stabilize it. Biotechnical practices are not likely to stabilize an eroded area if streambank erosion is very prevalent in your stream, an indication that the stream is undergoing a systematic change (e.g. deepening or widening).

If the water depth at the toe of the slope is less than three feet, a revetment should stabilize the bank. Channel depth at the site needs to be shallow enough to safely stand and work during low flows. Generally, if the target streambank is over 12 feet (ft.) high, an evergreen revetment may not be adequate to stabilize it. However, revetments have been successfully built on higher banks. If the water depth at the toe of the slope is more than three feet, the revetment alone may not be able to protect the toe and stabilize the bank. The toe of the slope is where the bank slope turns and becomes the channel bottom. Consider using a tree kicker upstream to deflect flows if they are undercutting the bank (see Guide No. 11, Tree Kickers).

DESIGN AND CONSTRUCTION GUIDELINES

Enclosed is a reproducible Evergreen Revetment Worksheet which takes you through the calculations needed for designing a revetment and estimating the amount of materials needed for construction. Many hands make constructing a revetment "light" work, but a minimum of 3 to 5 people in good physical condition should be on site to build even a one-row revetment on a small site. Since the revetment itself does not use live vegetation, construction can take place in any season. Construction in late winter or early spring will allow the revetment to catch silt from spring floods while it still has most of its needles and fine branches in tact. In addition, February and early March are good months for planting dormant cuttings to supplement the revetment with new root structure in the bank.

Regrading the slope — Evergreen revetments are generally used as an alternative to expensive regrading, so they are most often used in locations were regrading is not necessary. Providing safe working conditions is a key factor in determining if a revetment should be built at all or if the bank needs regraded before construction. Regrading loosens soil and increases the chance of revetment blow-out, so regrade only if absolutely necessary.

Some eroded banks have a slumped area at the base and a more vertical section toward the top. If the soils in the slump are stable and there is enough area to safely work, regrading the base area may not be necessary, but the top should be regraded after construction. If there is an overhang, for safety's sake it should be taken off first, before construction takes place lower on the bank.

Tree Selection — Freshly cut cedars, firs or pines work best. Cedars resist decay the best, but are not available in all parts of Ohio. It is often possible to work with Christmas tree farms to help cull their stock and put the culled trees to good use. Christmas trees gathered for recycling in January have also been successfully used. But trees which have been dead for some time are more brittle and lose needles and branches during construction.

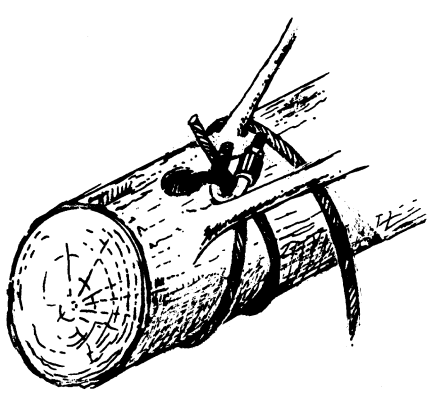

Figure 2 . Wrapping and Clamping Cable to Tree Trunks

The more limbs and fine branches a tree has the more it will continue to slow the stream's current after the needles are gone, allowing sediments to accumulate within the anchored trees. Both time and money can be saved by using the largest trees available as long as they are compatible with the stream's size (see worksheet calculations). Cut the trunk near the lowest limbs; anything below that is excess weight to carry. Trees cut prior to construction and stored on site should be placed above the floodplain. This will prevent them from floating downstream should a storm occur before construction begins.

Some of those with field experience prefer to drill holes in the butt end of each tree trunk (Figure 2). During construction, cable is threaded through the hole first, then wrapped around the trunk above the bottom limbs. When using this method be sure to size the hole appropriately for the cable you are using (see Equipment, below). Others prefer wrapping cable twice around the trunks above the lower limbs and have found this method adequate for resisting stream flow velocities, especially in lower gradient streams.

Anchoring Methods — Anchoring the trees into the streambank in a manner that will resist the force of water is imperative. There are several different types of anchors available, and they vary in availability, cost, ease of use and effectiveness in different soils.

- Disk anchors (Figure 3-a) are available at most hardware or farm supply stores. They are often used to tie down mobile homes. Use a model with at least a four-foot arm. Since they are screwed into the bank they are used in soils, preferably clays, where there are no rocks. At-

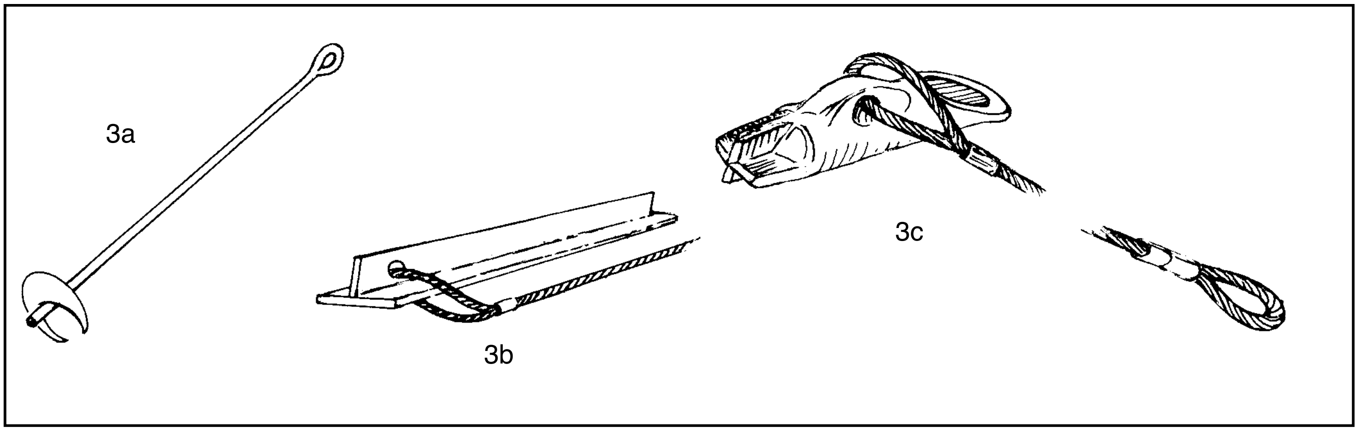

Figure 3. (a, b &c) Types of Anchors

tach the wrapping cable with a saddle clamp after screwing in the anchor.

- T-posts (Figure 3-b) can also be purchased at farm supply stores. These fenceposts are best used on small streams. They can be driven all the way into even rocky banks with a sledge hammer or a T-post driver. Metal caps are available which make driving posts with a sledge hammer easier. Attach a cable to the end below the flange before driving it in.
- Duckbill earth anchors (Figure 3-c) are available from fencing vendors, and nursery and forestry suppliers. Duckbill anchors come in two sizes and are available with or without a cable attachment. The anchors are installed with a drive rod or rebar and can be driven into even rocky soils (see Figure 4). When the anchor is driven most of the way in, thread the wrapping cable through the cable attachment's top loop. Finish driving the anchor far enough into the streambank so that the cable attachment is no longer visible, generally about 2.5 feet. Then jerk the cable with a handyman jack or other type of lever system. This turns the anchor from the vertical to the horizontal underground. Many of the evergreen revetments built in Ohio are anchored with duckbills.

Any of several types of wire or cable can be attached to the anchors and used to tie the trees together. The strength of the materials used should be based on expected stream flows and project size. Choose from cable with saddle clamps, high tensile wire with crimping sleeves (attached with crimping pliers), or use number nine fencing wire which can be twisted tight with pliers. These materials are available at local hardware stores, farm supply stores, and some construction suppliers. The construction suppliers generally keep larger supplies of cable in stock.

Tree Placement — Depending on the bank height and tree size, the trees may be manually lowered over the bank crest for placement. If using large trees on a tall bank, it may be best to lower the cut trees using cable or push them over the bank with a vehicle and front-end loader. All vehicles should stay as far away from the bank crest as possible to prevent soil damage or collapse. Workers in the stream should stay clear of cables and trees as they come down the bank.

In order to adequately protect the area of active erosion, an evergreen revetment needs to extend beyond the area of exposed soils on the streambank. Start downstream of the exposed soil anchoring each tree in place with the butt end of the trunk pointing upstream. Work upstream laying each tree so that it overlaps the previously laid tree until the revetment extends beyond the exposed soils. This usually means the entire length of the outside bend must be covered by the revetment. The first row of trees needs to be placed so that the tree crown (the widest part of the tree, i.e., the bottom of the foliage area for evergreens) rests on the toe of the bank slope as shown in Figure 1.

Anchor the trees near the toe of the slope (where the bank slope turns and becomes the channel bottom), which is usually below the water line. Banks often become unstable when stream energy cuts into the bank toe and undermines the strength of the bank. Protecting the toe of the slope is a primary objective in revetment construction. The branches underwater must be located where they will stop the undercutting action of the water around the curve. In the process they provide excellent cover for fish and other aquatic life.

Figure 4. Driving a Duckbill Earth Anchor

It is very important to wrap the cable more than once around each trunk and to pull the cable together as tight as you can before you clamp the ends firmly. If cables are loose or too much cable is stretched between the anchors and the trees, flood waters will cause the trees to move violently and either break free or allow the bank behind them to erode. Loose cable and not setting the anchors properly are two major reasons for revetment failure.

Construction procedures — The following construction steps are

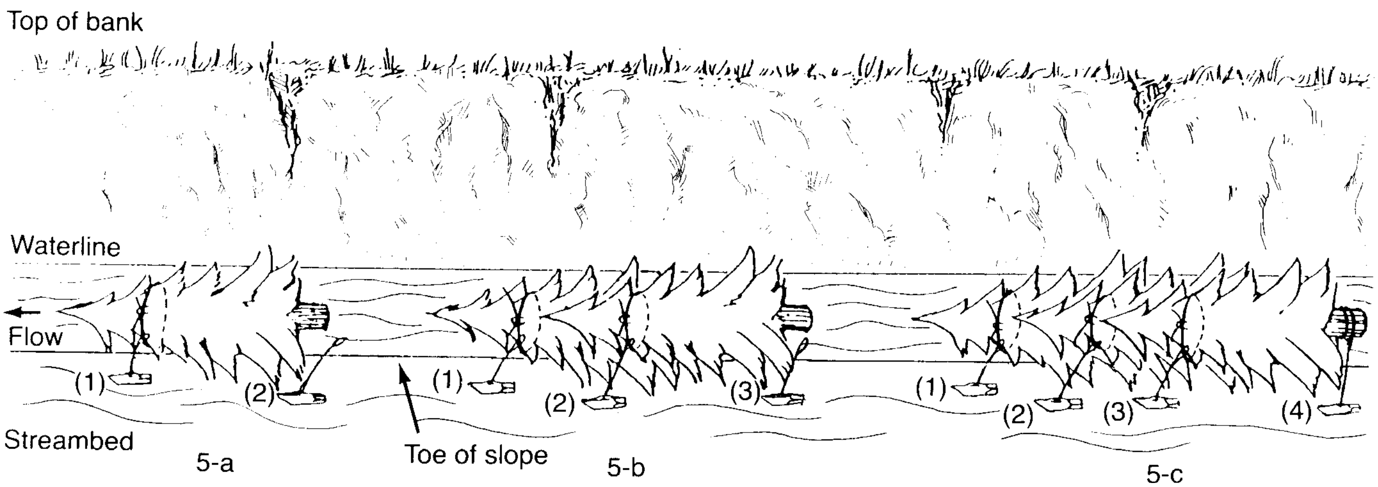

Figure 5. Constructing a One-Row Revetment - Figure shows the general placement of cable. Cable should be wrapped around trunks only and not the outside branches. Pull cable together as tight as possible and clamp tightly.

provided in a logical order to give you a concept of how each element fits together. Once you understand the concept, you will establish a sequence of steps which suits you best. The description assumes holes are drilled in the trunks and that duckbill anchors with pre-assembled cable attachments and cable with clamps are used. Directions are found on the worksheet for estimating the length of cable needed in total and for wrapping each tree or set of trees.

Constructing Revetment — When complete, a revetment made with one row of overlapping trees has anchors with cable wrapped around the trunks of both trees on the ends. In the middle section, anchors with wrapping-cable attach the top of each of the middle trees to the trunk of the previously laid tree. Depending on the size of the trees used, it is sometimes possible to construct a revetment with two rows of trees using one row of anchors like a one-row revetment. The following construction steps are illustrated in Figure 5.

- Start at the downstream stable point and position the first tree tight against the bank, with the butt end of the trunk upstream and low enough for the tree crown to rest on the bank toe. Drive and set anchor #1 near the top end of the tree leaving at least 1/5 of the tree height beyond the anchor, and drive anchor #2 by the butt end of the trunk. Set each anchor as described in "Anchoring Methods - Duckbill earth anchors", above.
- Thread a length of cable through anchor #1's cable attachment and wrap it around the trunk near the top of the tree. Pull the two ends of the cable together as tight as you can and clamp the ends of the "loop" together firmly (Figure 5-a).
- Place the second tree slightly upstream with its top overlapping the butt end of the first tree so that no gap exists between them. Drive anchor #3 at the butt end of the second tree.
- Thread a length of wrapping-cable through anchor #2's cable attachment and through the hole drilled in the first tree's trunk; then wrap it around the trunk. (If no holes are drilled, wrap it more than once around the trunk above the bottom branches.) Wrap the same cable around the top end of the second tree's trunk. Pull the cable tight and clamp the loop of cable together near the first tree's trunk (Figure 5-b) linking the top of the second tree to the butt end of the first.
- Thread cable through anchor #3's attachment and the hole in the trunk of the second tree. Position the third tree to overlap the second and repeat the process of threading, wrapping and clamping cable to attach the top of the third tree to the butt end of the second (Figure 5-c).
- Follow this overlapping process until trees cover beyond the eroded area. Anchor the butt of the last tree on the upstream end very tightly and low against the bank to prevent it from breaking loose when flows hit it.

Constructing Revetment — A revetment with more than one row is made of "sets" with each set of trees anchored and cabled together as a unit up the bank slope. The sets of trees overlap each other as in a one-row revetment. Each set has an anchor at the bottom (near the toe of the slope) and at Each set has an anchor at the bottom (near the toe of the slope) and at the the top (on the bank). Cable is threaded through both anchor assemblies and wrapped around each trunk in the stack of trees, making a loop of cable with the ends clamped together. The number of trees in a set is equal to the number of rows in the revetment. Use the worksheet to calculate the number of rows needed. The rows of trees should cover the eroded area of the bank about 1-2 feet higher than the elevation where storm flows will spread out across the low bank into

EVERGREEN REVETMENT WORKSHEET

For use with Ohio Stream Management Guide No. 12

1. Determine water depth at toe of bank slope under normal water level conditions:
   A. If more than 3 feet, then revetments may not stabilize bank.
   B. If 3 feet or less, then revetments should work.

2. Determine streambank soil type and anchoring method by using 3/4" steel rod (scrap rebar) to probe at least 4 feet into channel bottom and streambank:
   A. If bedrock is less than 4 feet below streambank, anchors won't hold.
   B. If bedrock is more than 4 feet below surface, and soils are rocky, use T-post or duckbill anchor.
   C. If bedrock more than 4 feet below surface, and soils are sand, silt, or clay, use T-post, duckbill, or screw-in anchors.

3. Determine size of channel constriction the revetment will cause, and optional approaches:
   A. Difference in elevation (in feet) from top of eroded bank to toe of bank slope = _____ ("3A").
   B. Tree crown diameter (in feet) needed = answer to 3A x 0.67 = _____ (3B).
   C. Tree crown radius = answer to 3B x 0.5 = _____ (3C).
   D. Measure stream width (average) in feet at revetment site = _____ feet (3D).
   E. Percent constriction caused by revetment = (3C ÷ 3D) x 100 = _____ % (3E).
   F. If answer to 3E is less than 15%, then one row of anchored trees should work. Use of at least two rows is recommended if bank height will accommodate it.
   G. If 3E is greater than 15%, a second row is needed, but with smaller diameter tree crowns. Also, the narrower the stream width, the greater the likelihood water will overtop one row.

4. Determine total length (in feet) of trees needed:
   A. Length of bank needing coverage by the revetment (measure beyond area of exposed soils) = ______ feet (4A).
   B. Total length of trees needed, accounting for tree overlap during construction = 4A x 1.2 = ______ feet (4B).

5. Determine number of **trees** needed:
   A. Number of trees needed for one row = total length of trees needed (4B) ÷ estimated aver age height of trees available = _____ trees for one row (5A).
   B. Height of revetment = height of area needing protection, measured vertically from the toe of the slope up to a point 1-2 feet above where flows will spread out across the low bank into the floodplain = _______ feet (5B).
   C. Number of rows up the bank = 5B ÷ estimated average *compressed* tree crown diameter [cedar & arbor vitae compress more than fir trees] = ____ rows (5C).
   D. The number of rows up the bank is also the number of trees in a "set"; the number of trees needed for one row = the number of sets needed. 5A = ___ sets (5D).
   E. Estimated total number of trees needed for the revetment = 5A x 5C = _____ trees (5E).
   F. *If height or diameter of trees found available is different than the estimate, re-calculate number of trees, anchors, clamps and cable length needed, and adjust purchases.*

6. Determine the number of **anchors** needed
   A. For a one-row revetment, the number of anchors = 1 + number of trees in one row = ____________ anchors.
   B. For a multiple-row revetment, the number of anchors = 2 x the number of sets + 2 = ____________ anchors.

7. Determine the number of **cable clamps** (sized for cable) needed = 2 x number of anchors. Bring extra clamps to replace any lost in the water. Some lost clamps can be retrieved with a *large* magnet.

8. Estimating the amount of **cable or wire** needed, especially for multiple row revetments, is difficult considering the difference between tree species on how much they compact when wrapped with cable. The following are principles to follow:
   A. When using cable, 1/4" steel aircraft cable is flexible and adequate in most circumstances. If in real doubt, double it, but washouts rarely happen due to a 1/4" cable breaking.
   C. When the revetment will have **one row of trees**, the amount of cable/wire needed to wrap around the trees = [4 ft. x the number of anchors (6A)] + 20% = _____ feet of cable or wire (8C).
   D. When the revetment design is for **multiple rows**, the amount of cable needed = [2 x revetment height (5B)] x (the number of sets + 1) + 20% = _____ feet of cable or wire (8D).
   E. *If you are using **anchors without pre-attached cable** for sinking into the soil, you must estimate the depth of your anchor installations, add 0.5 - 1.0 ft. more for a loop to clamp the cable onto the anchor, multiply that sum times the number of anchors, and add that total to your results for 8C or 8D, whichever is applicable.*

Example:

A revetment covering 200 ft. of eroded bank needs 240 ft. of trees to cover the first row [200 x 1.2 = 240] (see worksheet items 4A&B). If using 8 ft. trees, 30 trees are needed for a one-row revetment [240 ÷ 8 = 30] or 30 sets of trees are needed for a multiple row revetment (item 5D). If the revetment needs to cover an eroded area 5 ft. high, and the average tree crown diameter is 2 ft., then the revetment needs to have 3 rows [5 ÷ 2 = 2.5 ‘ 3] (item 5C). Three rows x 30 sets = 90 trees are needed (item 5E). Sixty-two anchors are needed [2 x 30 sets + 2 = 62] (item 6B) and 124 clamps (item 7) are needed. Each set needs 10 ft. of cable for wrapping [2 x 5 ft. eroded area height], so 10 ft./ set x (30 sets + 1) = minimum 310 ft of cable needed (item 8D). Purchase an additional 20% for a margin of error. Cut the cable in lengths of 10 ft. per set at first. If you find less cable is needed for wrapping, reduce that length, saving cable for its next use.

If using anchors without pre-attached cable, and they are to be sunk 3 ft. into the stream-bank, add [3 ft. + 0.5-1.0 ft. for the loop] x [30 sets +1] to the 310 ft. minimum before calculating the 20% extra and cut the cable in 13.5-14 foot lengths at first (item 8E).

The source of the original worksheet, on which this edition is based, is unknown. Its development and availability are appreciated by the authors of Guide No. 12.

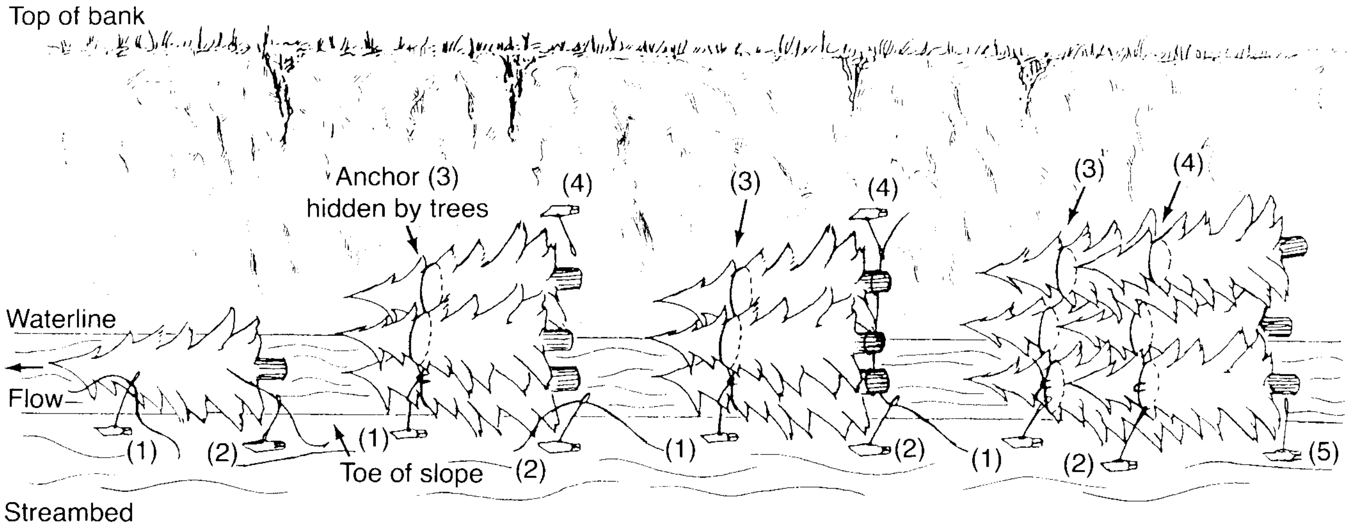

Figure 6. Constructing a Multiple-Row Revetment - Figure shows the general placement of cable. Cable should be wrapped around trunks only and not the outside branches. Compress the trees, pull the cable together as tight as possible and clamp tightly.

the floodplain. Once storm flows are high enough to spread outside of the channel, velocities slow down and the protection of dense branches is no longer needed. The following construction steps are illustrated in Figure 6.

- Start at the downstream stable point and position the first tree tight against the bank, with the butt end of the trunk upstream and low enough for the tree crown to rest on the bank toe. Drive anchor #1 near the top end of the tree, leaving at least 1/5 of the tree height beyond the anchor and drive anchor #2 by the butt end of the trunk. Set each anchor as previously described in "Anchoring Methods - Duckbill earth anchors".
- Thread a length of wrapping-cable through each of the anchors' cable attachments. There should now be a length of wrapping cable threaded through each of the two driven anchor assemblies, one near the trunk and one near the tree top, both placed underwater (See Figure 6-a).
- Lay the trees for the first set up the bank. Drive another two anchors into the bank at the upper end of the set, under where the top tree lies. Keep in mind when you position these upper anchors that you will be compressing the trees in the set together so that they will not shift in high flows. Place anchor #3 near the top end of the trees and #4 in line with the butt ends.
- Take the wrapping-cable from anchor #1 and wrap it around each trunk near the tree tops to link the trees together. Thread the cable through anchor #3's cable attachment. Compress the trees and pull the two ends of the cable together tightly, wrapping and weaving some more as you go. Clamp the two ends of the cable loop together. More than one clamp may be used. As shown in Figure 6-b, the first set of trees is now linked together near their tops.
- Thread the wrapping-cable from anchor #2 through the holes drilled in the first set's trunks. Wrap the cable around the trunk once as you thread it through each hole. Thread the same cable through anchor #4 at the upper end of the set, then let it lie loose (see Figure 6-c).
- Lay the second set of trees in place with the tops of the second set overlapping the butt ends of the first set so that no gap exists between them. At the same time, so you can position it correctly, drive in anchor #5 at the butt end of the second set. Place anchor #5 where the butt end of the second set's bottom tree trunk will lie in the overlapping formation.
- While compressing the trees, weave the cable from the first set (which has been threaded through the trunks then lying loose) around the trunks of the second set's top-end. Pull tightly and clamp the ends of the second cable loop together. As shown in Figure 6-d, the top of the second set is now linked to the butt end of the first set.
- Follow this process, overlapping each set, until trees cover beyond the eroded area. Anchor the butts of the last trees on the upstream end very tightly and low against the bank to prevent them from breaking loose when flows hit them.

Equipment — You will need a first aid kit and the following items.

For harvesting evergreens and dormant cuttings to supplement the revetment:

- Chain saw and appropriate safety equipment: hard hat, goggles, chaps, and gloves
- Tree pruning saw, long handled loppers, hand-held pruners if volunteers help in the harvest
- Pick-up truck, flat-bed truck or

tractor and trailer for transporting vegetation
- A garden tractor or golf cart can be used to drag or maneuver trees if working conditions, (number of workers available, distance from site) warrant it

For drilling holes in the trunks of cut evergreen trees, if desired:
- Drill, 1/2 or 3/4 chuck, variable speed if possible
- Drill bits for wood, appropriate chuck size:
  1/2" diameter bit if using 1/4" cable; 3/4" diameter bit if using 3/8" cable

For cutting wire or cable and tightening clamps:
- Cable cutter (1/2" dia. max) for use with a sledge hammer is a good investment if you will be constructing many revetments; hand-held cable cutters do not have replacement blades
- Electrician's tape may be used to wrap cut ends of cable
- Crimping sleeves and crimping pliers when using high tensile wire
- Wire cutters when using No. 9 fencing wire or high tensile wire
- Standard deep well 3/8 inch drive socket set, including extension, 9/16, 1/2, 5/8 sizes or a five-piece open-end wrench set, including 9/16, 1/2, and 5/8 sizes

For driving various types of anchors into the bank:
- Sledge hammers
- T-post drivers
- If using duck bill earth anchors, use a cold-roll 3/4" steel rod or rebar shaped on the end for the size earth anchor to be used (either # 68 DBI or # 88 DBI). Rods can be purchased and shaped at a local steel supplier.

Maintenance — Inspect the revetment after high water events during the first year and once a year thereafter. Replace any blown out sections. Look for any additional erosion and add more trees as necessary.

Reference: Gough, S., "Tree Revetments for Streambank Stabilization," Missouri Department of Conservation, Fisheries Division.

~

This Guide is one of a series of Ohio Stream Management Guides covering a variety of watershed and stream management issues and methods of addressing stream related problems. The overview Guides listed below, are intended to give the reader an understanding of the functions and values of streams. For more information about stream management programs, issues and methodologies, see Guide 05 Index of Titles or call the ODNR Division of Soil and Water Resources at 614/265-6740. All Guides are available from the Ohio Department of Natural Resources. Single copies are available free of charge and may be reproduced. Please contact:

ODNR Division of Soil and Water Resources
2045 Morse Road, Bldg. B
Columbus, Ohio 43229-6693
614/265-6740

The guides are also available on-line as web pages and PDF files so you may print high quality originals at your location. You will find the guides on-line at:

Prepared by the Ohio Department of Natural Resources, Jim Bishop and Kathy Smith, Division of Forestry, Randy Hoover, Division of Wildlife, and Margo Fulmer, Division of Soil and Water Resources, co-authors. Input from staff of several ODNR divisions, and local, state and federal agencies are used in the development of the Ohio Stream Management Guides.

Guides are available on-line at: http://www.ohiodnr.gov/soilandwater/

Video Available

A copy of the video "How to Build a Stream Revetment" is available at each Division of Wildlife district office. This 20 minute video was developed by the Missouri Department of Conservation and is available by permission. To borrow or view a copy, contact any of the following staff.

District 1	(Central Ohio)	Elmer Heyob	614/644-3925
District 2	(NW Ohio)	Larry Getty	419/424-5000
District 3	(NE Ohio)	John Golz	330/644-2293
District 4	(SE Ohio)	Mike Greenlee	614/594-2211
District 5	(SW Ohio)	Randy Hoover	937/372-9261