USDA National Agroforestry Center

AGROFORESTRY NOTES

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Planning Biotechnical Streambank Protection

Purpose

This note is designed to help planners determine the appropriateness of biotechnical alternatives for streambank stabilization. Biotechnical approaches utilize plants as the primary structural components to provide an alternative or complement to concrete, rock and other materials. Even though various biotechnical techniques have been developed to utilize the ability of plants to stabilize slopes, there are situations where these techniques are not an appropriate choice.

Stream Dynamics

Streambanks are part of a larger dynamic and constantly changing stream corridor system. A stream corridor attempts to maintain a dynamic equilibrium as it interacts with water and sediment moving through the system. When a disturbance occurs (either natural or human induced) the stream system responds to regain this dynamic equilibrium. These adjustments can change both the width and the depth of the channel, which in turn affects the stability of the streambanks. Given enough time the stream corridor will re-establish a dynamic equilibrium with stable streambanks. The stabilization process may involve erosion of large quantities of soil from the floodplain and negatively affect water quality, aquatic habitat, cultural features, land values and other resource conditions that society values. The natural stabilization process can often be accelerated by the use of biotechnical alternatives.

Benefits of biotechnical techniques

Streambank erosion is a natural process. Generally, erosion occurs at an acceptable rate in a stream that is at or near equilibrium. When the system is disturbed, the stream may experience accelerated streambank erosion. The acceptable erosion rate will vary with each situation. Adjacent land uses and environmental impacts will weigh heavily on the decision to intervene and treat the streambank.

Erosion occurs when the hydraulic forces in a channel exceed the capability of the channel boundary to resist those forces. The forces and resistive capability of a protective technique are typically characterized by either a maximum permissible velocity or a maximum shear. Bare streambank soils can typically only withstand a low shear (<0.25 pounds/feet^2), whereas streambanks covered with vegetation can withstand considerably more (0.5 to 8 pounds/feet^2 depending on the technique - see Table 1).

Measuring stream dimensions helps to understand the stream's dynamics.

Lb/ft^2	Type of vegetation/material
0.33	one-inch gravel
0.35	Dense sod in cohesive soil
0.61	Reed plantings
0.67	two-inch gravel
1.22	Reed roll
1.40	Grass and legume plot
2.00	six-inch rock riprap
2.10	Ideal dense sod
2.25	Live stakes
2.45	Live Fascine
2.84	Willow brush layer
4.00	12 inch rock riprap
5.08	Coarse gravel with live stakes
6.10	Brush mattress
6.10	Riprap with live stakes

Table 1 - Estimated shear strength.

Unstable streambanks can often be characterized by nearly vertical banks, large areas of exposed roots, lack of vegetation, vegetated clumps in the channel, slumps and streambank cracking.

Understanding why a streambank is unstable and the in-channel forces at work are critical to developing a solution. Streambank instability either occurs from hydraulic forces removing bank material, geotechnical instabilities, or a combination of the two forces.

Hydraulic Bank Failure

Hydraulic failures occur when the energy (tractive force) of flowing water exceeds the resistance (critical shear stress) of the bank material and plant material. The erosion process is related to depth of flow, flow velocities, and flow direction. It usually occurs at the base of the slope, eventually creating meandering curves. The rate of erosion depends on the cohesiveness of the soil, the size of soil particles, and the amount and type of vegetation present on the bank. It also depends on the quantity of flowing water and the amount of sediment load in the water. Removing streambank vegetation, straightening or widening a channel, or a change in sediment input can result in severe hydraulic streambank erosion.

Geotechnical Bank Failure

Geotechnical failures can occur that are unrelated to hydraulic failures. Generally these types of failures are a result of soil moisture conditions and uneven distribution of weight in the bank. Bank failures typically occur when weight is removed from the base of the slope (toe) or if weight is added to the top. Piping of noncohesive soil can destabilize banks. Piping failures occur when water erodes finer soil particles internally and washes them out of a less cohesive soil layer of the slope. Fine-grained soil material can also become saturated when inundated by floodwater. The heavier saturated soil combined with a rapid draw down in the water level can cause bank failure. Shrinking and swelling of clay soils can cause tension cracks and weaken soil shear strength. Freezing and thawing can also weaken the soil and cause bank failure. Most geotechnical failures will require more in-depth analysis to determine the appropriateness of biotechnical solutions.

Other types of Bank Failure

In some situations the channel bed is unstable and actively downcutting. As the bed drops the relative height of the banks increase making them unstable. Knick points and vertical banks on both sides of the channel are indicators of an unstable bed. Biotechnical solutions are not recommended unless the down cutting can first be stopped.

Streambank instability may also be caused by local flow obstruction and channel irregularities. Fallen trees, log jams, and other obstructions may cause currents to scour into streambanks. Culverts, bridges, and other structures may also cause local scour. Runoff from adjacent land can concentrate and create gullies on the streambank. Vegetation removal can also be the cause of bank erosion. Poor grazing management and some human activities, like foot traffic, can inhibit vegetation and cause bank failure. Floating debris and ice can also gouge and remove vegetation from streambanks.

What is the objective?

Streambank erosion is a natural process and clear objectives are needed before an alternative can be developed. The first decision is to determine if the objective is to slow the process to an acceptable rate or to attempt to halt the stream migration across the valley floor. This decision is based on the value of adjacent land uses and the risk to human life and safety. The purpose for stabilizing a streambank can range from protection of property, protection or creation of habitat, improved water quality, to improved aesthetics. The objectives will dictate the type and magnitude of streambank protection. In high value situations (public health, property damage, etc.) the solutions will probably need to be more intense, immediate, and durable than in lower value situations (habitat restoration, aesthetics, etc.) All streambank erosion control practices will be subject to maintenance requirements. However, biotechnical treatments have the potential to self-repair under some conditions since they are living systems.

When attempting to fix the streambank location, the solution is either to armor the banks or minimize the hydraulic force on the streambank. Biotechnical solutions may be appropriate if the site conditions are favorable. Hard protection at the streambank toe (rock, walls, concrete, etc.) may still be a critical component in the design.

Biotechnical solutions are well suited when attempting to slow the streambank erosion process to an acceptable rate. Temporary toe protection (tree revetments, coir logs, post plantings, etc.) may be needed in order to get plants established on the streambank. Reestablishing some form of vegetation is the goal of most solutions. However, woody species may not be advisable in stream systems that have been engineered to control floodwater, because they may create flow resistance that will increase floodwater elevation.

Factors to consider

Selecting and developing alternatives can be a complex process. Generally, planners first determine the range of potential solutions that can help meet the stated goals and objectives. These potential alternatives are usually developed on limited data and analysis. The intent is to quickly identify appropriate alternatives that need to be carried through the planning process. The following list is intended to provide early planning guidance to help determine the appropriateness of using biotechnical solutions. The questions are based on the assumption that a more permanent solution utilizing biotechnical practices is desired.

Determine appropriateness of biotechnical solutions by asking yourself the following questions.

What is the land use conversion trend for the drainage area?
Future land use conversion may significantly alter hydrology. Streambank protection measures may not be successful due to increased stresses created by changing hydrologic conditions such as increased flows or sediment load. Biotechnical slope protection may be possible but the risk or frequency of damaging events increases.

Are both sides of channel unstable?
This condition may indicate that the channel is incised or a large-scale adjustment is occurring in the stream channel. Both of these conditions can generate excessive velocity and shear stress making it difficult to establish biotechnical solutions.

Is the channel grade stable?
If the channel bed is down cutting any bank treatment may be ineffective unless toe protection can be provided below the anticipated scour depth. Adding two feet to the deepest depth of water at eroding meander bends will be a rough indication of potential scour depth. Headcuts, overfalls, and nick points are indicators of unstable channel grades.

Is the bank height greater than 6 feet?
When bank heights exceed six feet, slope stability factors can add complexity to the design and need to be analyzed.

What is the slope of the water surface?
The ability of biotechnical measures to protect a streambank will depend on the amount of tractive force of the water. Tractive force can be estimated by determining the slope and depth of water. When the water surface slope exceeds 2 percent (two-foot drop per 100 feet) the tractive stress may be too severe.

What is the depth of the water?
Woody plants don't generally grow in standing water. The level of frequent flooding (every one to two years) will help determine the elevation of toe protection and vegetative components. The level of more severe floods (five- to 10-year storms) will help indicate the amount of tractive force a practice will have to endure. Tractive force may be excessive if the depth of floodwater exceeds five feet.

Is a non-cohesive soil layer present in the slope?
Non-cohesive soil layers may require special design measures. The lower in the slope the weak layer occurs, the more difficult it will be to stabilize the bank.

Is bank instability due to piping or groundwater sapping?
Biotechnical measures are not intended for controlling piping or sapping.

Will mature vegetation adversely affect stream hydraulics?
Changes in flood elevations due to flow resistance on vegetative banks may not be acceptable in some settings.

Is there a stable bank to tie into at each end of the treatment area?
Any streambank protection measure could be flanked if it is not tied into stable points.

Is there bedrock within 12 inches of the surface?
Shallow bedrock will prevent viable woody growth that may compromise the integrity of the biotechnical measure.

Will the soil inhibit plant growth?
Soil tests are recommended to determine the presence of plant growth inhibitors (pH less than 4, iron sulfide, salinity, contaminants, etc.)

Is there anything in the stream water or surface runoff that will inhibit plant growth?
Adverse water quality can inhibit plant growth. Check any stream monitoring records for possible problems and investigate immediate watershed for sources of potential contaminants.

Are there animal or human activities that will inhibit growth?
Overgrazing by livestock and wildlife can make it difficult to establish vegetation. Recreation activities can also hinder establishment. Fencing or other measures may be needed to control these activities.

Will the site be shaded during the growing season?
There are limited plant species that can tolerate dense shade.

Is there significant surface runoff from above the streambank?
A diversion or waterway may need to be installed to control erosion.

Are adequate plant materials available?
Biotechnical techniques may require large quantities of plant materials. Locating an adequate source of plant material is essential to the success of the project.

Are invasive species present in the area?
Aggressive invasive species may out compete biotechnical species and make it difficult for them to get established.

The list of questions is only intended to provide key points when considering a biotechnical solution. Some of the key points can be the basis for design limitations, which can sometimes be overcome by altering the site, but this usually adds significant costs.

Once the decision is made to utilize a biotechnical streambank protection measure, more detailed data collection and analysis are needed to help design specific protection measures. More complex situations will require special expertise and possibly an interdisciplinary approach to design. Contact the appropriate state and/or federal agencies for more guidance and technical assistance.

Additional Information

Streambank and Shoreline Protection." USDA NRCS 1996. Engineering Field Handbook, Part 650, Chapter 16.

"Stream Corridor Restoration: Principles, Processes, and Practices." USDA 1998 Federal Interagency Stream Restoration Working Group.

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"The Practical Streambank Bioengineering Guide." Bentrup,Gary: Hoag, J. Chris: 1998. USDA NRCS Plant Material Center, Aberdeen, Idaho.

"Water Bioengineering techniques for Water Course Bank and Shoreline Protection." Schiechtl and Stern. 1997. Blackwell Science.

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