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Streambank Stabilization Handbook

A Guide for Harris County Landowners

HARRIS COUNTY FLOOD CONTROL DISTRICT

The mission of the Harris County Flood Control District is to:

Provide flood damage reduction projects that work, with appropriate regard for community and natural values.

Harris County Flood Control District
Streambank Stabilization Handbook Disclaimer

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HCFCD does not endorse any particular method of erosion repair or stabilization technique or guarantee their success. The long-term success of any method depends on many factors, including, among many other factors, identifying the real problem, method selection, site specific design, construction, and maintenance.

HARRIS COUNTY FLOOD CONTROL DISTRICT
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"Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land." - Luna Leopold

Overview

There are approximately 1,500 channels within Harris County, totaling more than 2,500 miles in length. Two-thirds (2/3) of those waterways are man-made.

There are more than 2,500 miles of waterways within Harris County, Texas, ranging from natural bayous and creeks to man-made channels. Managing these urban rivers, bayous, creeks, and drainage features while finding a balance between urban development and natural functions presents many unique challenges. Urban expansion impacts water quality, wildlife habitat and the ultimate stability of the channel infrastructure. One indirect result of urbanization can be excessive streambank erosion.

Erosion is a progressive problem that is easiest to correct in its early stages. Taking early action to minimize erosion can save you time and money because if left untreated, the streambanks may continue to deteriorate and become a larger problem. You may avoid undertaking a large, complex restoration project by implementing smaller-scale stabilization measures as soon as you identify a problem.

Buffalo Bayou just downstream of Highway 6

Bioengineering is the combined use of vegetation and structural elements to control erosion by stabilizing and strengthening soil. This streambank stabilization technique is often referred to as biostabilization.

Choosing to undertake a streambank stabilization project can greatly benefit you and your property. Maintaining stable, vegetated slopes helps to prevent erosion and retain topsoil. By keeping topsoil and sediment in place, you are benefiting the water quality within Harris County's creeks and bayous, while also preserving your property. Native vegetation and improved water quality enhances wildlife habitat, which also improves the function of the region's creeks and bayous.

Streambank stabilization techniques are often divided into two general categories of techniques: structural and bioengineering. Structural techniques include articulating concrete blocks, stone rip-rap, sand-cement bags, retaining walls, and sheet piles. Bioengineering combines traditional engineering methods with the use of grasses, trees, or other living plant materials to stabilize and protect the streambank. Bioengineering techniques often cost less than structural techniques, are self-sustaining once established and can become more effective with time.

A perceived drawback to bioengineering is that it requires ongoing maintenance. To a certain degree, this is true. Immediately after installation, bioengineering projects must be carefully watched, weeded and maintained. However, after a few years, the maintenance requirements decrease. Over the long term, maintaining bioengineered areas is less costly than maintaining a traditional lawn.

Instability of Buffalo Bayou streambanks and adjacent structural stabilization project.

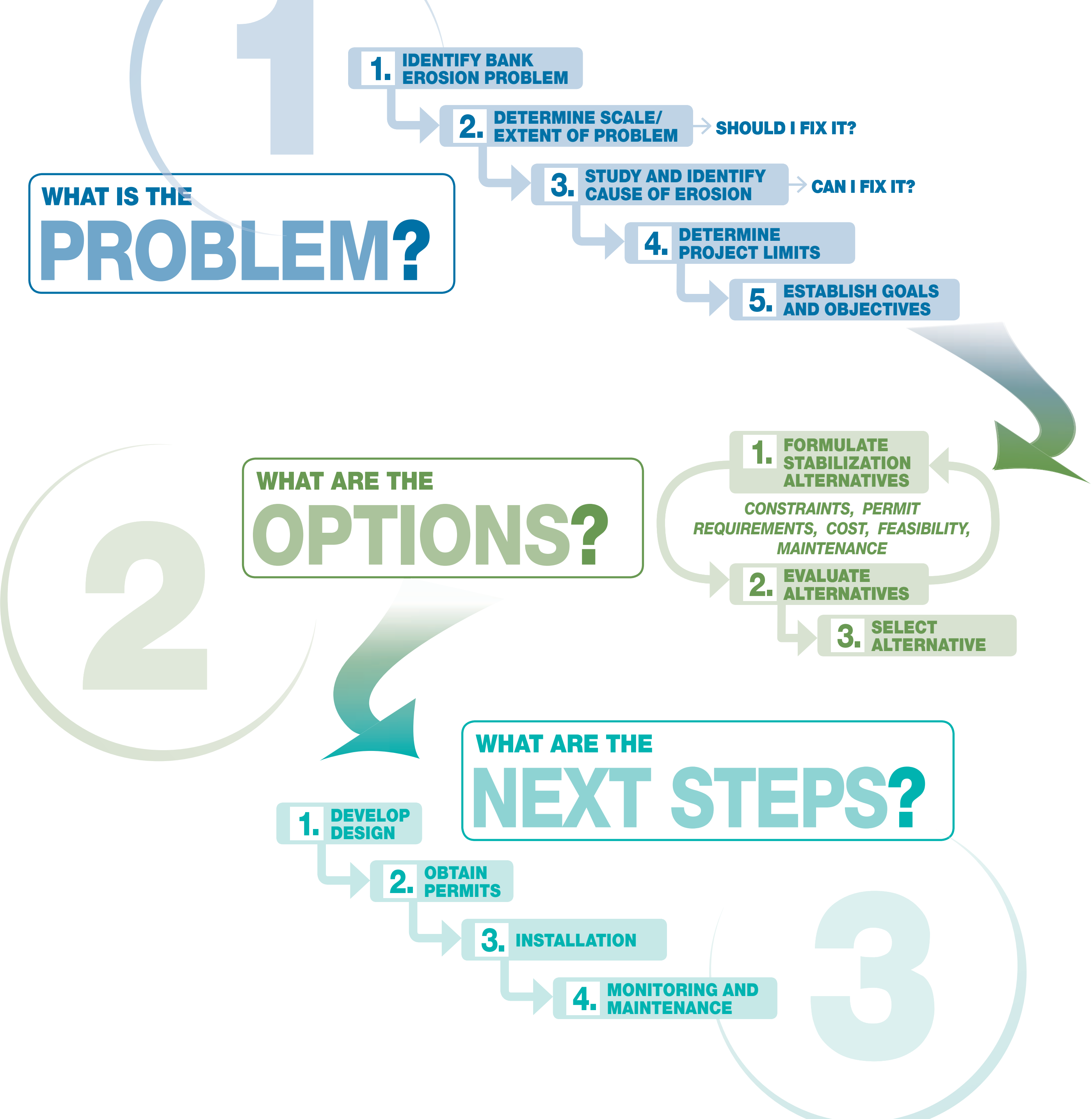
This Streambank Stabilization Handbook (Handbook) was prepared by the Harris County Flood Control District to assist Harris County residents in planning streambank stabilization projects on their property, with an emphasis on bioengineered approaches. It provides information that may be used by landowners to evaluate the potential use of bioengineered stabilization methods on a variety of streambank erosion conditions that exist throughout Harris County. The Handbook is directed towards addressing localized erosion problems and is not intended to provide information regarding full restoration of a stream. Landowners should coordinate their stabilization effort with a design professional and Harris County Flood Control District.

While this Handbook does not provide step-by-step instructions, it does provide information to consider in planning a streambank stabilization project. To make best use of this Handbook, one must have a basic understanding of why erosion is occurring, the physical and legal constraints in correcting the erosion problem, and the actions one can take to correct the problem. In most cases, the solution is to seek professional assistance in the coordination, evaluation, selection, design, and installation of streambank erosion control measures. This Handbook will provide basic information so you can be aware of the many items being considered as your stabilization project takes shape. The following flow chart provides a general guide to assist the property owner in implementing a streambank stabilization project.

This Handbook does not attempt to assume that bioengineering for streambank protection alone will remedy an unstable stream. Streambed stability must first be addressed before banks can be repaired. Causes of erosion should be determined before bioengineering is applied. This document does not address the details of the design involved in streambed stabilization.

Streambank Stabilization Project

This flow chart provides a general road map of the decisions that need to be made and the steps taken in performing a streambank stabilization project. Refer to the Implementation Section for details.



"A river seems a magic thing. A magic, moving, living part of the very earth itself." - Laura Gilpin, The Rio Grande, 1949

Understanding Streambank Erosion

How Streams Work

Streambank erosion and sediment deposition are natural processes. However, accelerated erosion can lead to excess sediment in the stream, affecting water quality and aquatic habitat.

A stream is a complex system. A healthy stream is able to maintain its shape, slope and pattern while carrying the sediment and water produced by its watershed. The condition of its streambanks and floodplains is critical to the stream's health. Stream stabilization techniques that work ***with*** the stream's natural tendency to shape itself according to the watershed and streambank conditions provide a sustainable solution that requires minimum maintenance, prevents land loss, improves water quality, aesthetics and aquatic habitat, and restores native vegetation along streams.

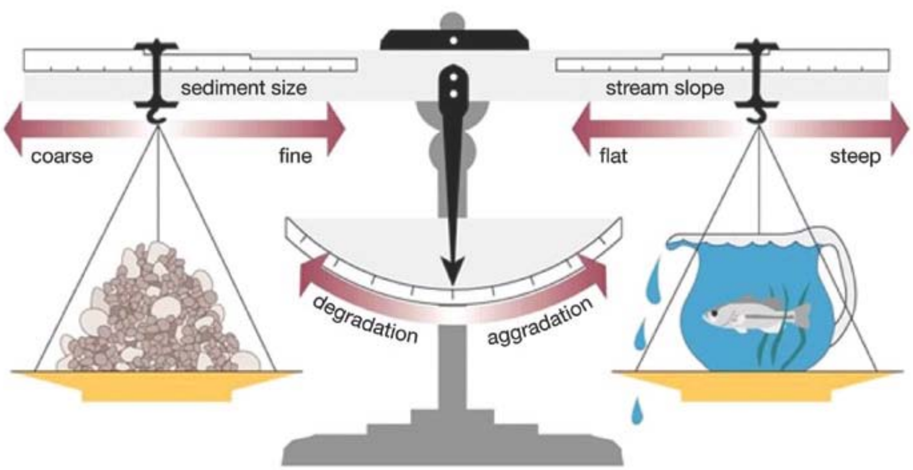
Eroded streambanks on Little White Oak Bayou

A stream's geomorphic floodplain provides an area where flood waters can spread out.

A stream transports water and sediment produced by its watershed and adjusts its shape and slope to seek a dynamic equilibrium. If stream forces change dramatically, the stream may become unstable as it tries to regain equillibrium. This tendency to adjust towards equilibrium can result in severe bank erosion and land loss, especially in urban areas. In designing a stable stream, the stream's form must match what would naturally occur during full adjustment to its watershed condition. In this dynamic state, a stream may experience minor erosion and sediment deposition, but there would be no net change in the shape, slope or meandering pattern of a stream over a period of years.

This dynamic equilibrium is shown in the Lane's Relationship diagram below. If stream flow or slope increases, the balance is tipped to the right resulting in channel degradation. If sediment size or quantity increases, the balance is tipped to the left, resulting in channel aggradation.

Lane's Relationship - Dynamic Equilibrium

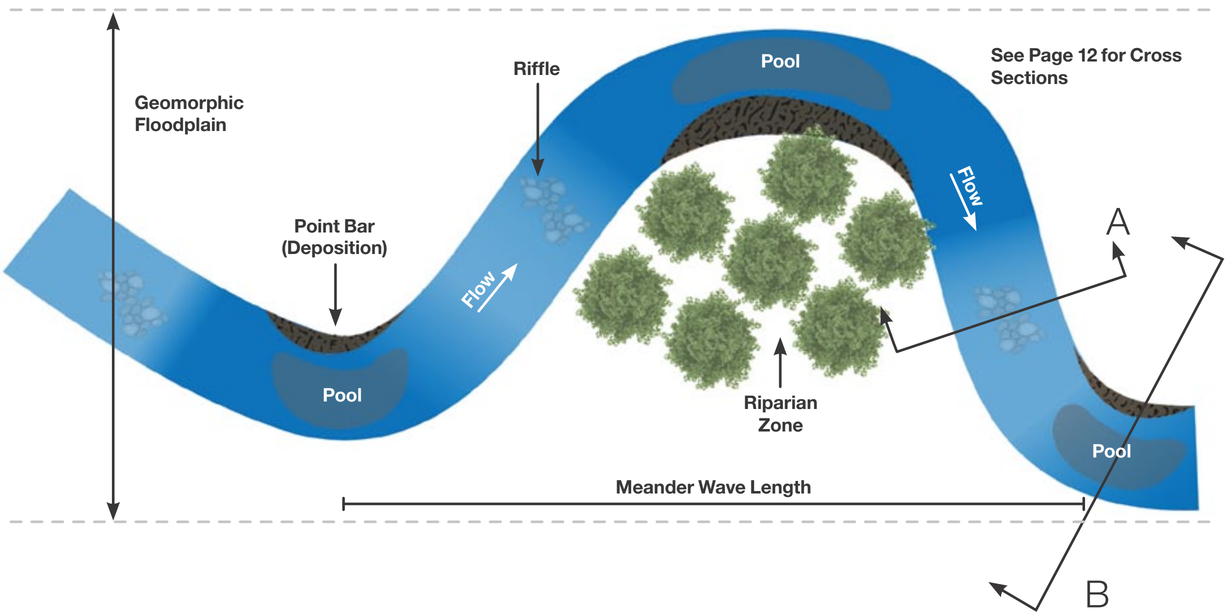


Source: Applied River Morphology, Rosgen 1996, after Lane, 1955

At equilibrium, slope and flow balance the size and quantity of sediment particles the stream moves.

When talking about streams, it is common to speak of the stream from three different perspectives: pattern, profile and dimension. Stream pattern refers to the back-and-forth meander of a channel, as viewed from above. Many natural streams tend to follow a sinuous path across a floodplain. The geometry of the meander and spacing of riffles and pools adjust so that the stream performs minimal work. Stream pattern is qualitatively described as straight, meandering or braided (multi-channel).

Channel Planform and Pattern



The profile of a stream is the shape of the bed as viewed from the side. Most natural streams have sequences of riffles and pools that maintain channel slope and stability. The riffle is a bed feature characterized by shallower, faster moving water. The water depth is relatively shallow, and the slope is steeper than the average slope of the channel. Riffles enter and exit meanders and control the streambed elevation. Pools are typically located on the outside of meander bends between riffles. The pool has a flat water surface (with little or no slope) and is much deeper than the stream's average depth. At low flows, pools are depositional features and riffles are scour features. At high flows, however, the pool scours and the bed material deposits on the riffle. On the inside of the meander bend there is often a depositional feature called a point bar, which also helps maintain channel form.

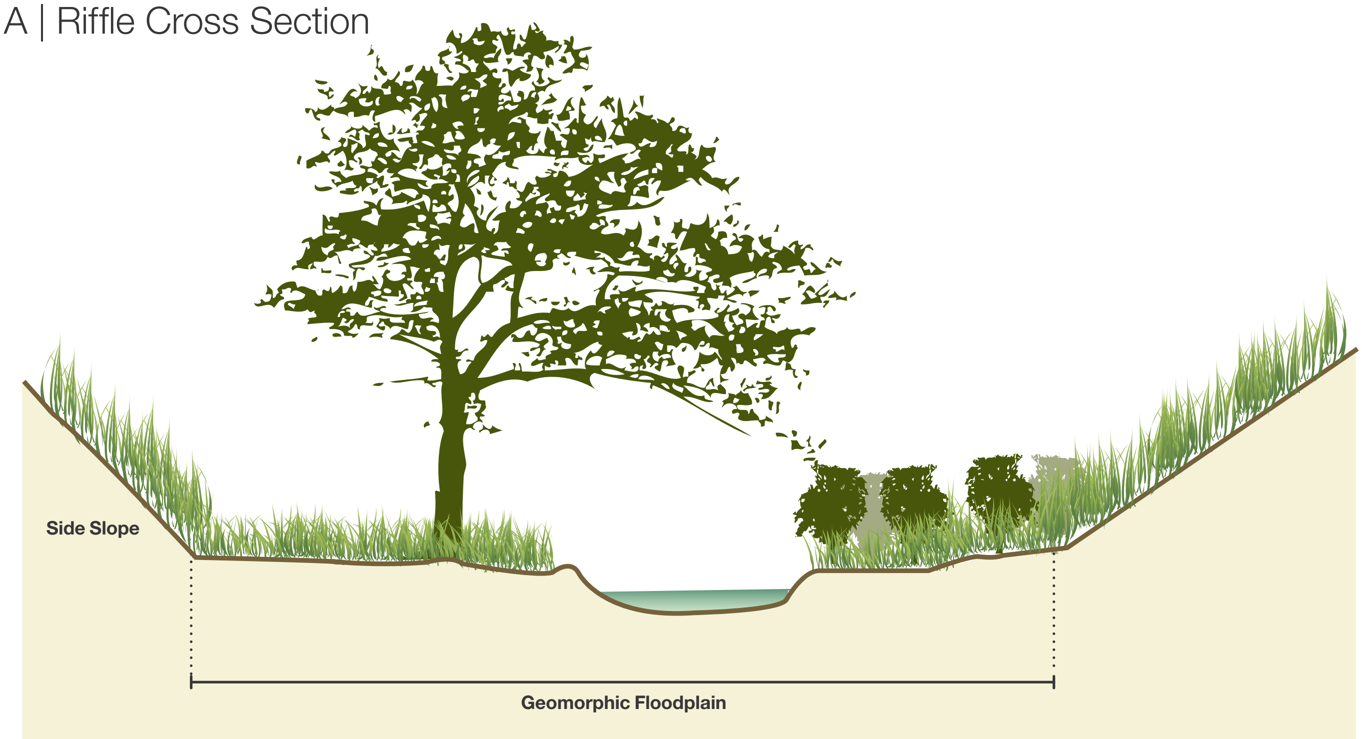
A stream's dimension refers to the shape of a channel looking at a section cut across the channel. The width of a stream generally increases in the downstream direction in proportion to the amount of water discharged from its watershed.

Stream width and depth is a function of discharge (frequency and magnitude), sediment transport (size and amount of material) and the streambed and bank materials.

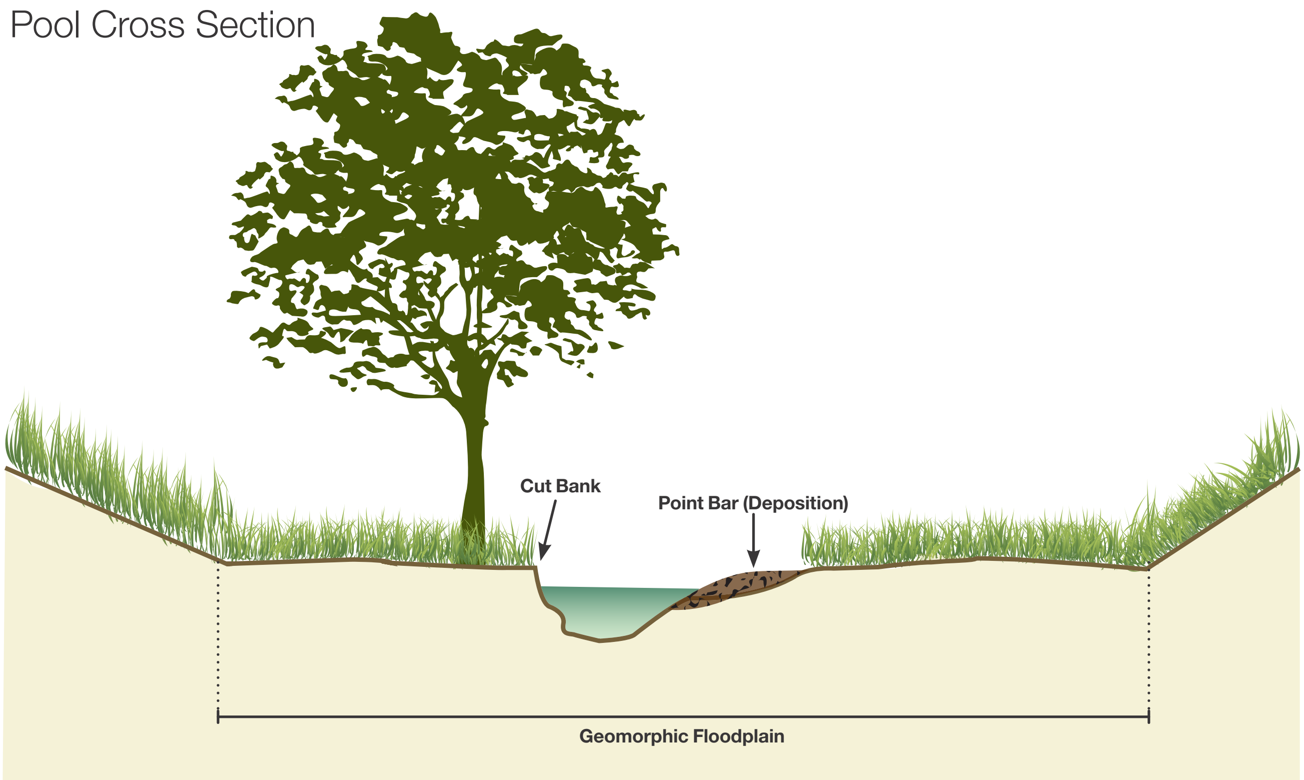
A geomorphic floodplain dissipates energy, reduces streambank erosion, and allows sediment to be deposited.

In summary, a stream and its geomorphic floodplain comprise a dynamic environment where the floodplain and stream evolve through natural processes that erode, transport, sort and deposit sediment. The result is a dynamic equilibrium in which the stream maintains its dimension, pattern and profile over time, neither degrading nor aggrading. Land-use changes in the watershed, channelization, presence of culverts, bridges, removal of streambank vegetation, impoundments and other activities can upset this balance, often resulting in bank erosion or incision of the bed. A new, stable equilibrium may eventually result, but not before the associated aquatic and terrestrial environment are damaged and property lost. Understanding natural stream processes and applying this knowledge to stream restoration and bank stabilization projects will help create a self-sustaining stream with maximum physical and biological potential.

A | Riffle Cross Section



B | Pool Cross Section



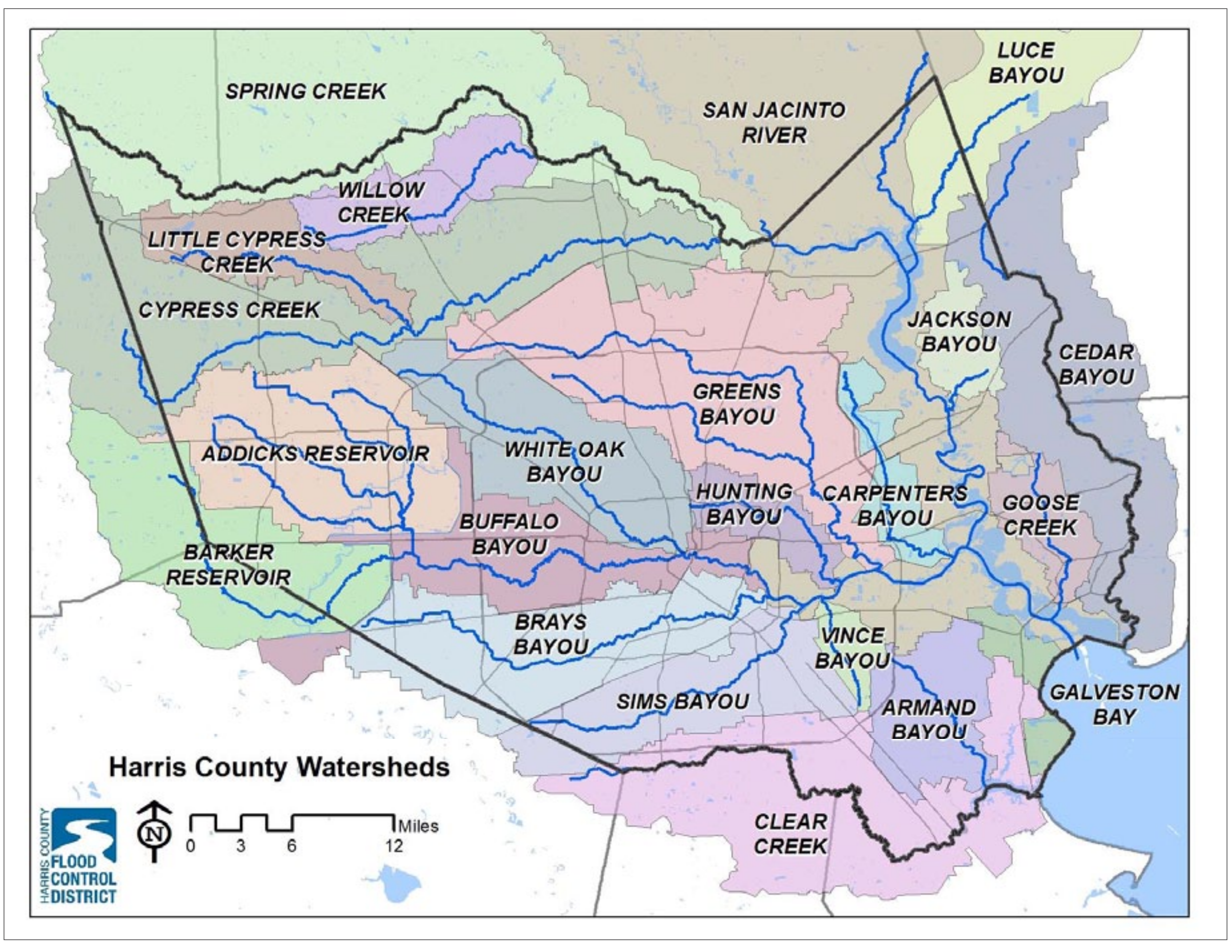
Harris County Streams

Harris County's waterways cut across the coastal prairie and wetlands of western and southern Harris County and the piney woods of northern and eastern Harris County. Urban development and changes in land use have removed most of these historic habitats, leaving isolated remnants. Similarly, many of the region's natural streams have been altered in some way to reduce flooding - through widening, deepening, or changing the shape of the stream, lining the channel with concrete or removing the vegetation that grows on the streambanks. Natural streams are stressed in urban watersheds, causing excessive scour, bank erosion and/or sedimentation.

This alteration has also led to some streams becoming incised. An incised stream or river is a vertically contained stream that has abandoned its previous geomorphic floodplain and is characterized by high streambanks. An incised channel often results in accelerated streambank erosion, land loss, aquatic habitat loss, lowering of water tables, downstream sedimentation, threats to infrastructure, and flooding from clogged streams.

There are 22 major watersheds in Harris County draining into Galveston Bay. Soils and vegetation vary across these watersheds.

Harris County's Watersheds



Soils

Broad areas of the county have erodable soils. The types of soils that occur along a stream not only affect the type of erosion that occurs but can influence the type of stabilization work that should be performed. The streambank stabilization technique that works the best may differ for clay and silt conditions, as opposed to sandy soils.

Clay soils often expand during wet weather and shrink during dry weather, creating large cracks in the soil. When these tension cracks form parallel to the top of a high steep bank, they may lead to bank failure, especially where the toe of the bank has been eroded, causing a steepening of the bank. Clayey, wet soils drain slowly and are often unsuitable for certain types of bank stabilization techniques, where rapid draining of water is desired. Sandy soils lack cohesion (the ability of the soil particles to stick together), so they erode more easily, often resulting in steep streambanks that are unstable.

Erosion from the flow of water at the base of the streambank further destabilizes the slope. Often sudden and intense storm events cause water to rise quickly, saturating the lower part of the streambank. When the flood waters recede, the saturated soils on the lower slopes often fail. Streams whose flow is controlled by reservoir operations, such as Buffalo Bayou, are particularly susceptible to streambank instability due to frequent and rapid fluctuations in water levels.

Irrigation systems and pools near the top of bank leak and saturate the soil frequently causing streambank failures. Water flowing over the bank from yards, parking lots, and irrigation systems cause erosional failures. Area drains and road ditches that discharge through a pipe on the streambank cause erosional problems as well. Homeowners can alleviate many streambank erosion problems by fixing some of these issues before tackling a biostabilization project.

Streambank erosion in clayey soils on Buffalo Bayou

Sandy soils on Spring Creek exhibit mass streambank failure

Note: Consult with a design professional prior to developing a proposed streambank stabilization project. Expertise should be sought when bank heights exceed 5 feet or when critical infrastructure (buildings, utilities, roads) or other important resources are located on the top of the bank.

Role of Vegetation

Vegetation is a critical component of streambank stability. Trees, shrubs, and grasses growing on the streambank help to dissipate stream flow and energy, protecting the surface from erosion. Root systems also add substantial strength to the streambank. Deep-rooted vegetation provides resistance to slumping and slope failure by mechanically anchoring surface soil to deeper soils. Streambank vegetation can also help direct high energy stream flows towards the center of the stream channel and reduce stream flow velocities and streambank stresses.

Deep-rooted vegetation growing on a streambank physically protects the bank from scour and collapse, providing internal bank strength. When the riparian vegetation is changed from woody species to annual grasses and/or herbaceous forbs, the internal strength of the bank is weakened, which may lead to mass wasting or slumping of the streambank.

Streambank stabilization options and plant selections must be able to withstand intense rainfall as well as periods of drought.

The riparian zone is the vegetated area on both sides of a stream or river and generally consists of trees, shrubs and grasses. Significant changes to the riparian plant communities that border Harris County streams have occurred as stream channels were historically altered. In many areas, native vegetation has been removed and undesirable plant species are now common. Invasive species include Japanese and Chinese privet, Chinese tallow tree, taro, silk tree, kudzu, and Japanese honeysuckle.

When streambank vegetation is removed or altered, instability often occurs. Where a scenic view of the stream may be desired, removal of deep-rooted vegetation to obtain that view may result in severe streambank erosion. Appropriate streambank stabilization or bioengineering methods can balance desired stream access and the need for vegetation that greatly increases the streambanks' overall stability.

Loss of vegetation due to erosion on a tributary to Greens Bayou

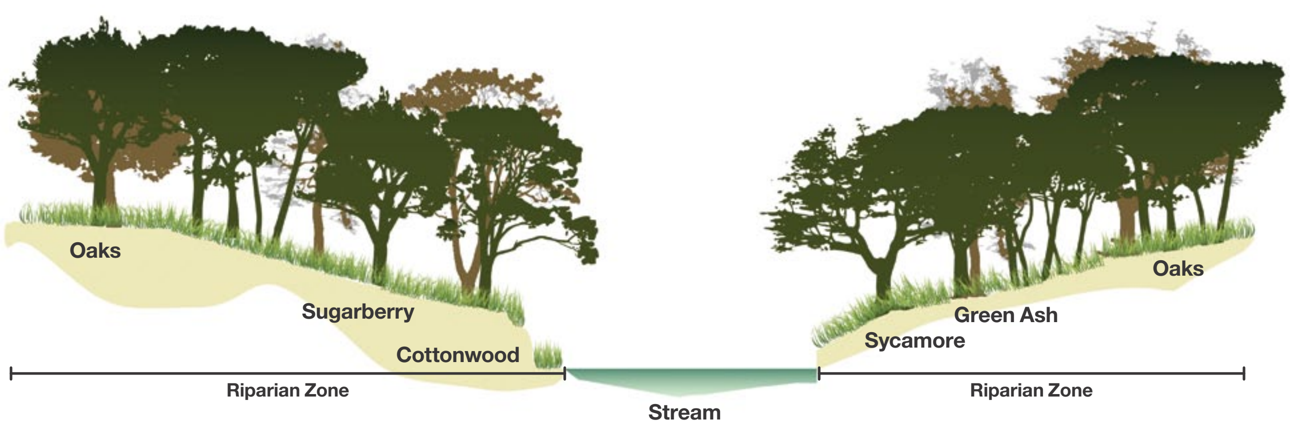
Woody vegetation may increase flood levels and needs to be accounted for in design; projects cannot increase flood levels.

Common native riparian trees found along Harris County streams are willow oak, water oak, green ash, red maple, black willow, sycamore, cottonwood, water tupelo, bald cypress and others. Common understory trees and shrubs include dwarf palmetto, deciduous holly, yaupon, roughleaf dogwood, elderberry, and others. As one moves up the slope away from the stream, trees such as loblolly pine, magnolia, and pecan are found.

Native coastal prairies that surround the riparian corridors commonly have grasses such as big bluestem, gulf muhly, Indiangrass, eastern gamagrass, and species of panicum. These native plant species provide wildlife habitat to numerous birds and mammals.

Riparian vegetation not only stabilizes the streambanks by reducing the amount of sediment that washes into the stream, but also keeps the water cooler by providing shade.

Riparian Vegetation



Typical Streambank Erosion

Harris County's urban development and historic stream modifications have changed the conditions under which natural streams originally formed, often resulting in unstable streambanks. Streambank erosion may be isolated to specific locations or prevalent along the entire stream system. Streambank instability and erosion occur under many conditions and as a result of many factors. It is important to understand the fundamental cause of streambank erosion. Any streambank stabilization method - structural or bioengineered - is susceptible to failure if the designer does not address the underlying instability.

The following descriptions of typical streambank erosion will serve as the starting point for identifying the problem and understanding potential stabilization alternatives. The following describes some typical streambank erosion.

Erosion outside bend on Buffalo Bayou

Erosion at Outside Bends

Erosion often occurs on the outside of a stream bend. As rising water flows through a bend in the river, it typically flows more swiftly and with complex currents along the outside. The tighter the bend, the greater the water's erosional force along the outside streambank. In stable stream systems, the force is relieved when water is able to flow onto a floodplain on the inside of the bend. However, when a stream has degraded, as many in Harris County have, the flows cannot access the floodplain and streambank instability occurs due to the water's increased energy. Increased frequent flows also lead to streambank instability.

Vegetation removal resulting in erosion on Buffalo Bayou

Vegetation Removal

Vegetation plays a key role in minimizing streambank erosion. Streambank erosion can occur if the vegetation on the streambanks has been removed or heavily altered. Often, just changing the vegetation type or reducing the amount can cause severe erosion (e.g., clearing vegetation to provide visual access to the stream, maintaining vegetation on utility crossings or agricultural grazing practices).

Toe Erosion

A "toe" of a streambank is the lowest point on the bank where it meets the bed of the stream. Erosion often occurs along the streambank's toe because periodic water level fluctuations make it difficult for vegetation to become established in this area. Also, the streamflow energy is often directed at the toe. This is particularly noticeable in Buffalo Bayou, where reservoir releases sustain high flows for extended periods, preventing the establishment of vegetation on the lower banks and toe area.

Eroding toe on Buffalo Bayou

Pipe Outfalls

Culverts and pipes discharging stormwater into a stream can erode a stream. Often, a large scour hole is formed at the pipe's outlet, eroding the streambank around the pipe. In some cases, the pipe is undercut and will break off, further exacerbating the problem. Erosion can also occur on the streambank opposite the pipe's discharge point and immediately downstream of the pipe.

Eroding streambank exposing an outfall pipe on Buffalo Bayou

Headcut erosion in Memorial Park - Tributary to Buffalo Bayou

Headcuts

A headcut is an erosional feature of some streams where an abrupt vertical drop in the stream bed occurs. Headcuts resemble a small waterfall or, when not flowing, the headcut will resemble a very short cliff or bluff. A small pool may be present at the base of the headcut due to the high energy of falling water. Groundwater seeps and springs are sometimes found along the face, sides, or base of a headcut. An active headcut erodes or migrates in an upstream direction.

Eroding bank caused by mid channel bar on Little White Oak Bayou

Bank Erosion Caused by Instream Sediment Deposits

Unstable stream systems often become over-widened, or are intentionally enlarged to increase stormwater carrying capacity for bridge construction or flood damage reduction projects. This over-widening can decrease the stream's ability to move sediment, and causes the sediment to deposit on the channel's bed. Over time, the deposits raise the bed's elevation, through a process called aggradation, which can form side bars, mid-channel bars or transverse bars. These bars often redirect water towards a bank causing erosion.

Rill and Gully Erosion from Upland and Overbank Flows

Rills are small, yet well-defined channels formed when surface runoff flows over and down a streambank. If not addressed, a small rill can eventually deepen and turn into a gully. This typically happens in areas where the vegetation protecting the soil surface has been removed or disturbed. Certain soil conditions are also susceptible to rilling and gully formation.

Rilling streambanks on a tributary to Langham Creek

Block Failure

When a streambank's weight is greater than the soil's strength, large block-shaped soil pieces slump or fall from the bank. One name for this type of streambank erosion is called block failure. It often results from increases in the angle or height of a bank due to toe erosion and tension cracks. Block failure often occurs following significant flooding events. Rainfall and a rise in water levels saturate the streambank soils, increasing their weight and decreasing their cohesion. As the water levels recede, the soil remains saturated and heavy. The increased weight, lack of cohesion and sudden change in pressure can trigger block failure. A bank's susceptibility to block failure depends on streambank geometry, soil properties, and vegetation density. This type of erosion is more common in clay soils than sandy soil.

Block failure on Buffalo Bayou

Failing hardened streambank on Buffalo Bayou

Hardened/Engineered Structure Failure

Many streambanks throughout Harris County have been hardened with a traditional stabilizing technique, such as concrete revetments, sheet piles, articulating concrete blocks and retaining walls. For various reasons, many structures have failed over time and, in some cases, are contributing to further streambank erosion upstream and more frequently downstream.

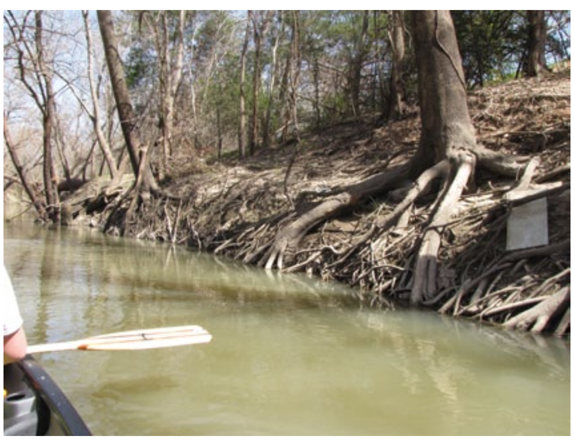
Eroding streambank downstream of rip rap and concrete lined segment on Turkey Creek

Downstream of a Hardened Structure

Numerous engineered, smooth-surfaced, hardened structures can be found along streambanks throughout Harris County. A smooth structure is made from materials with little roughness and few irregularities (e.g. concrete). These structures include bridge abutments or harder stabilization structures, such as sheet piling, concrete lining, mortared rubble, and articulating concrete blocks. Smooth structures provide little resistance to water flow, allowing flows to accelerate along the structure during higher flow events. There can be an increase in erosion after flow exits this hard/smooth boundary.

"The best time to plant a tree is twenty years ago. The second best time is now." - Anonymous

Streambank Stabilization Methods



Tree roots protecting bank on Buffalo Bayou

Streambank stabilization techniques work by either reducing the force of water against a streambank or increasing a streambank's resistance to the force of water. Any streambank stabilization method - structural or bioengineered - is susceptible to failure if the designer does not address the underlying instability.

Bioengineering techniques are often preferred for streambank stabilization. They use natural materials and riparian vegetation to control streambank erosion and promote long-term stability of the stream channel and banks. Locally preferred methods use a combination of buried rock or tree root material and vegetation to stabilize streambanks. Choice of materials depends largely on the slope of the streambank and the desired vegetation density.

Geogrid on Buffalo Bayou, after recent construction, prior to full planting

Biostabilization alone may not be able to address areas of severe erosion. A larger scale stream restoration project that addresses channel alignment or in-channel processes may be necessary to address areas of severe erosion. This would require working collaboratively with adjacent landowners and, possibly, a local government agency, such as the Harris County Flood Control District or City of Houston.

Techniques designed to increase a streambank's resistance to the force of water provide an armoring of the streambank with materials that are less likely to erode than bare soil. Vegetation and other materials (coir/coconut fiber, buried rock, geogrid, or gabion baskets), used in conjunction with plantings, provide flow resistance. Plants slow the flow of water along the streambank and reduce shear stress. As the plants grow and mature, their roots provide protection from streambank erosion and collapse and increase the internal streambank stability.

Some of the bioengineering bank stabilization techniques rely on the use of geotextile fabrics to help stabilize or contain the soils while the vegetation becomes established and matures. Geotextiles are permeable textile materials that are used with soil, rock, fill, etc. to increase stability and decrease erosion. A geotextile may be made of synthetic or natural fibers and are designed to be permeable to allow the flow of water through it.

Modern geotextiles are usually made from a synthetic material (such as polypropylene, polyester, polyethylene, and polyamides) or a composite of natural and synthetic material. Geotextiles can be woven, knitted or non-woven. Different fabric composition and construction are suitable for different applications. Consideration should be given when selecting a geotextile fabric to ensure that it functions properly for the selected bank stabilization method.

Natural fiber geotextiles degrade to form an organic mulch and help quickly establish vegetation. Different fibers will degrade at different rates. For example, coir geotextiles degrade in 4-6 years while jute degrades in 1-3 years; coir is therefore useful in situations where vegetation will take longer to establish.

Rummel Creek before stabilization

Rummel Creek after revegetation

A variety of stabilization techniques are available for use. Each have specific applications, benefits and costs. This table summarizes bioengineered streambank stabilization techniques that may be applied locally. An overview of each technique follows this table.

Comparison of Bioengineered Streambank Stabilization Techniques*

STABILIZATION TECHNIQUE	APPLICATION	INSTALLATION METHOD	CONSTRUCTION COST	MAINTENANCE COST	COMMENTS
Coir Matting	Gently sloping banks	Hand	Low	Low	Used by itself or as part of many other techniques.
Live Stakes	Moderately steep banks	Hand	Low	Medium	Works best at base of streambank when bottom of stake can intersect the water table.
Joint Planting	Moderately steep banks	Hand	High	Low	Rip rap will provide immediate protection while vegetation becomes established.
Live Fascine	Moderately steep banks, at toe of bank	Hand	Medium	Low	Fascine can help trap sediment
Brush Mattress	Moderately steep banks	Hand	Medium	High	Works well when banks are only 2 to 4 feet in height.
Coir Fiber Rolls	Moderately steep banks, at toe of bank	Hand	Medium	Medium	The fiber rolls can also be planted with vegetation.
Buried Rip Rap	Moderately steep banks	Heavy Equipment	Medium	Low	Typically used in conjunction with other techniques.
Bankfull Bench	Moderately steep banks	Heavy Equipment	High	Low	Helps relieve stress on the bank.
Branch Packing	Steep banks, localized erosion	Hand/Equipment	Medium	High	Rapidly establishes vegetation.
Live Cribwall	Steep banks	Heavy Equipment	High	Low	Useful where space is limited.
Vegetated Geogrids	Steep banks	Heavy Equipment	High	High	Useful on the outside of meander bends.
Rootwad Revetment	Steep banks	Heavy Equipment	High	Low	Provides in stream habitat for fish.

* Landowner should consult with an experienced design engineer to determine appropriate application.

Coir Matting

- Erosion control matting constructed of coconut fibers.
- Matting protects the streambanks while plants become established and then biodegrades in about five years.
- Fabric is woven, so it has open space in the weave that allows seeds to sprout and grow up through the matting.
- May be cut and restarted to create holes so that trees and shrubs can be planted directly into the soil through the matting.
- While sometimes used by itself, it is commonly combined with other techniques and used to construct a number of other bioengineering systems, including prevegetated mats, coir fiber rolls (coir logs) and vegetated geogrid.

Applications: Streambanks that have been sloped back and need protection while vegetation develops.

Pros: Biodegrades allowing vegetation to provide a natural appearance. High tensile strength; has open space to plant trees, shrubs and plugs.

Cons: Biodegrades in five years: in some applications this may not be desirable. Not as strong as some synthetic fabrics. Problems can occur if installation is not done correctly. These include rilling under the material, lifting up and rolling at the edges, and erosion of backfill material used in the turn down areas.

Coir matting on Warren Creek, prior to full vegitation

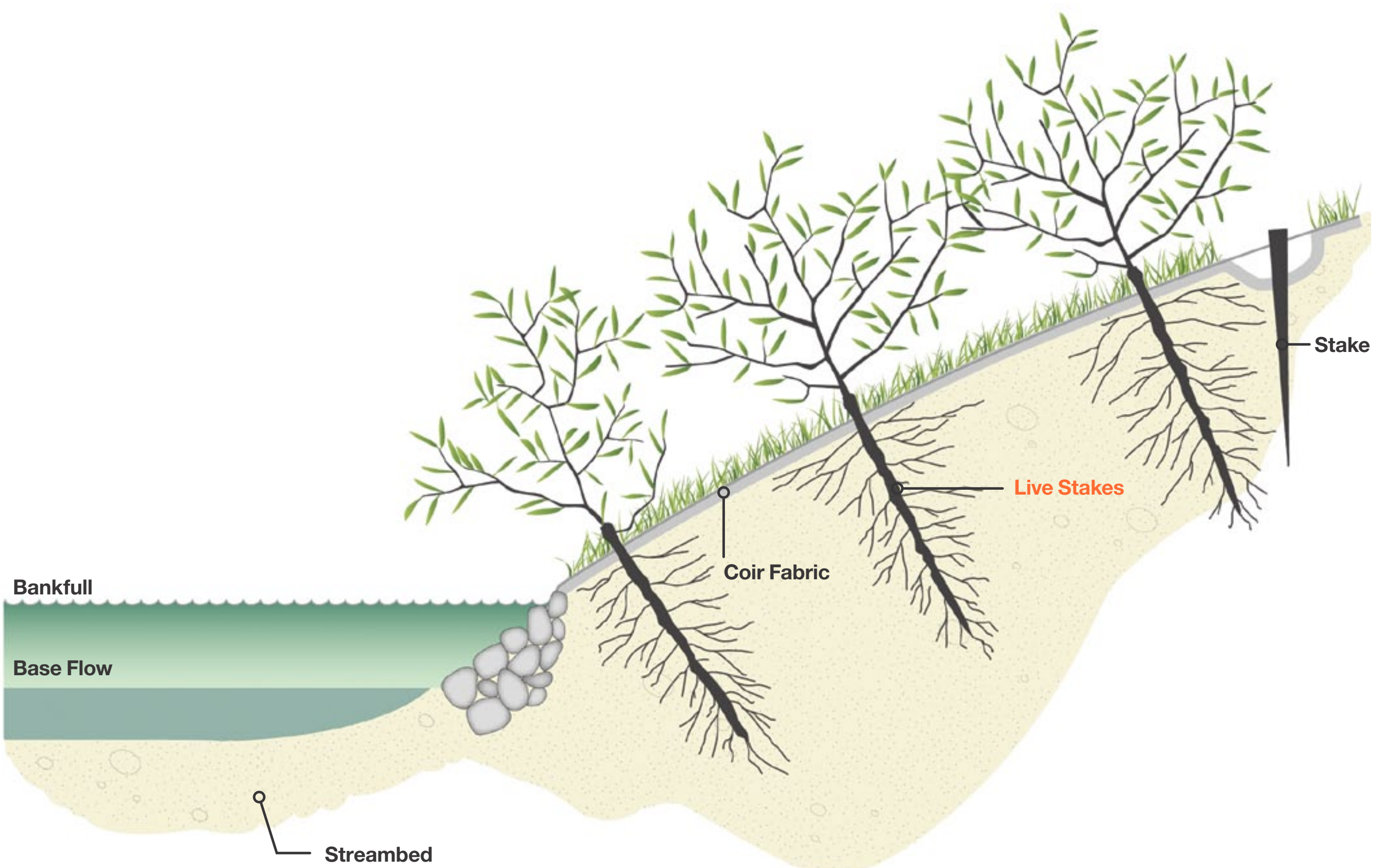
Live Stakes

- Dormant cuttings or branches typically 2 to 3 feet long that are pushed or driven into the soil deep enough to reach saturated or moist soil. If correctly prepared, handled, and placed, the live stake will root and grow.
- Only a few species in the Harris County region are capable of rooting from live stakes and include black willows (*Salix nigra*) and eastern cottonwoods (*Populus deltoides*).
- Can be used in conjunction with other techniques, including erosion control matting.

Applications: Where site conditions are uncomplicated and construction time is limited. Repair of small slumps that are frequently wet.

Pros: Provides immediate stability to a streambank; Growth is quick and successful if placed in a suitable area.

Cons: Can only be used on lower areas of streambank where moisture levels are more constant. Can increase the roughness of the channel and thus increase flood elevations.



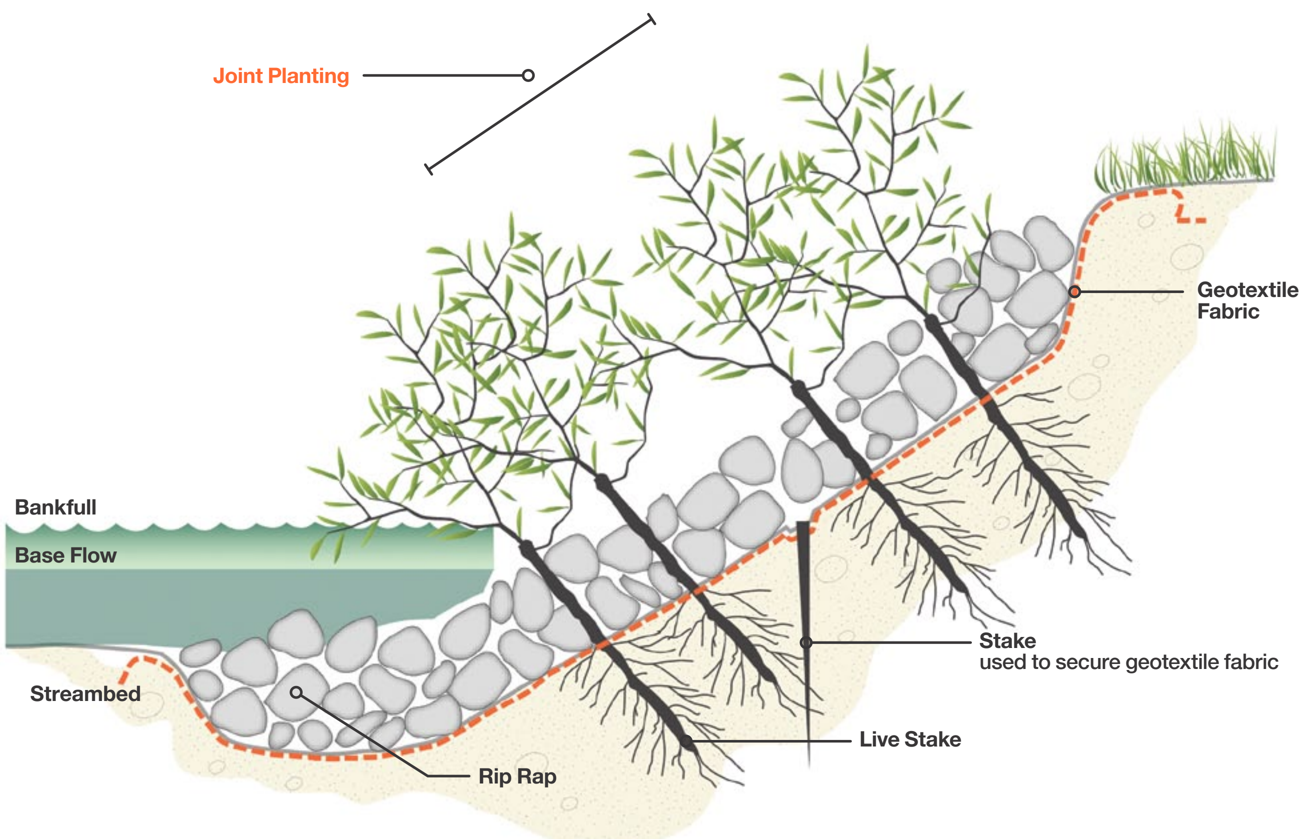
Joint Planting

- Planting of plugs and/or live stakes between rip rap or other structural material to promote the growth of vegetation.
- Exposed or buried rip rap is installed to provide immediate stabilization to the bank, while deep rooted plantings help increase long term stability once the vegetation is established.

Applications: Banks where immediate stabilization is needed.

Pros: Immediate protection of rip rap is combined with the long-term protection of vegetation.

Cons: Rip rap will limit the density of and types of plants that can become established. Installing live stakes through rip rap may be labor intensive or require specialized installation equipment. Can increase the roughness of the channel and thus increase flood elevations.



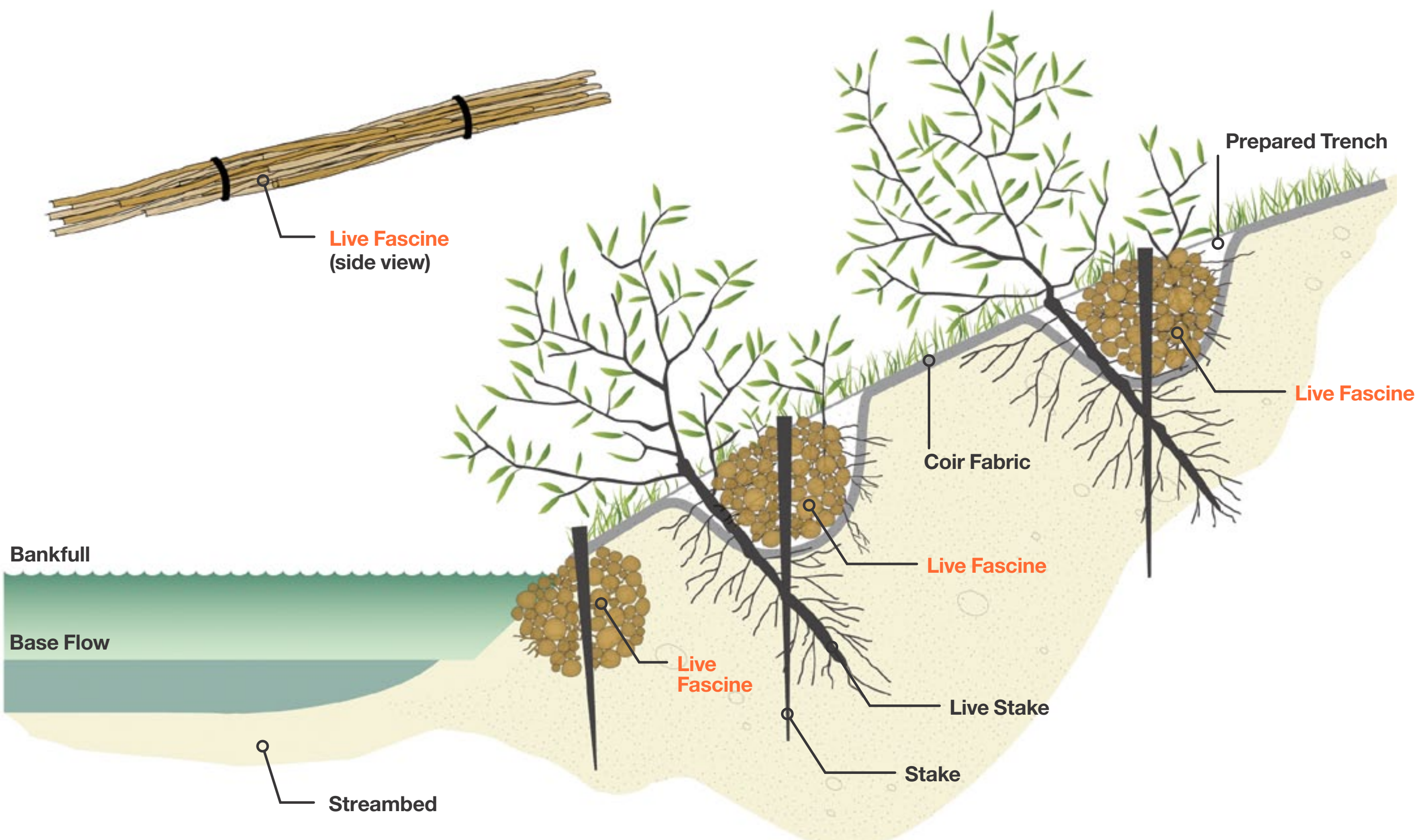
Live Fascine

- Consists of long bundles of live woody plants (primarily willow).
- Cuttings are bound together in bundles that are typically 6-8 inches in diameter and 4-20 feet long.
- Bundles are buried in shallow trenches placed parallel to the flow of the stream.
- The plant bundles sprout and develop a root mass that will hold the soil in place and protect the streambank from erosion.

Applications: Areas where the streambank toe is eroding, or in conjunction with other stabilization techniques where toe protection is needed.

Pros: Helps establish vegetation on the toe of the bank. Material can be collected on-site and is free.

Cons: May be labor intensive to install, especially where access is limited. Can increase the roughness of the channel and thus increase flood elevations.



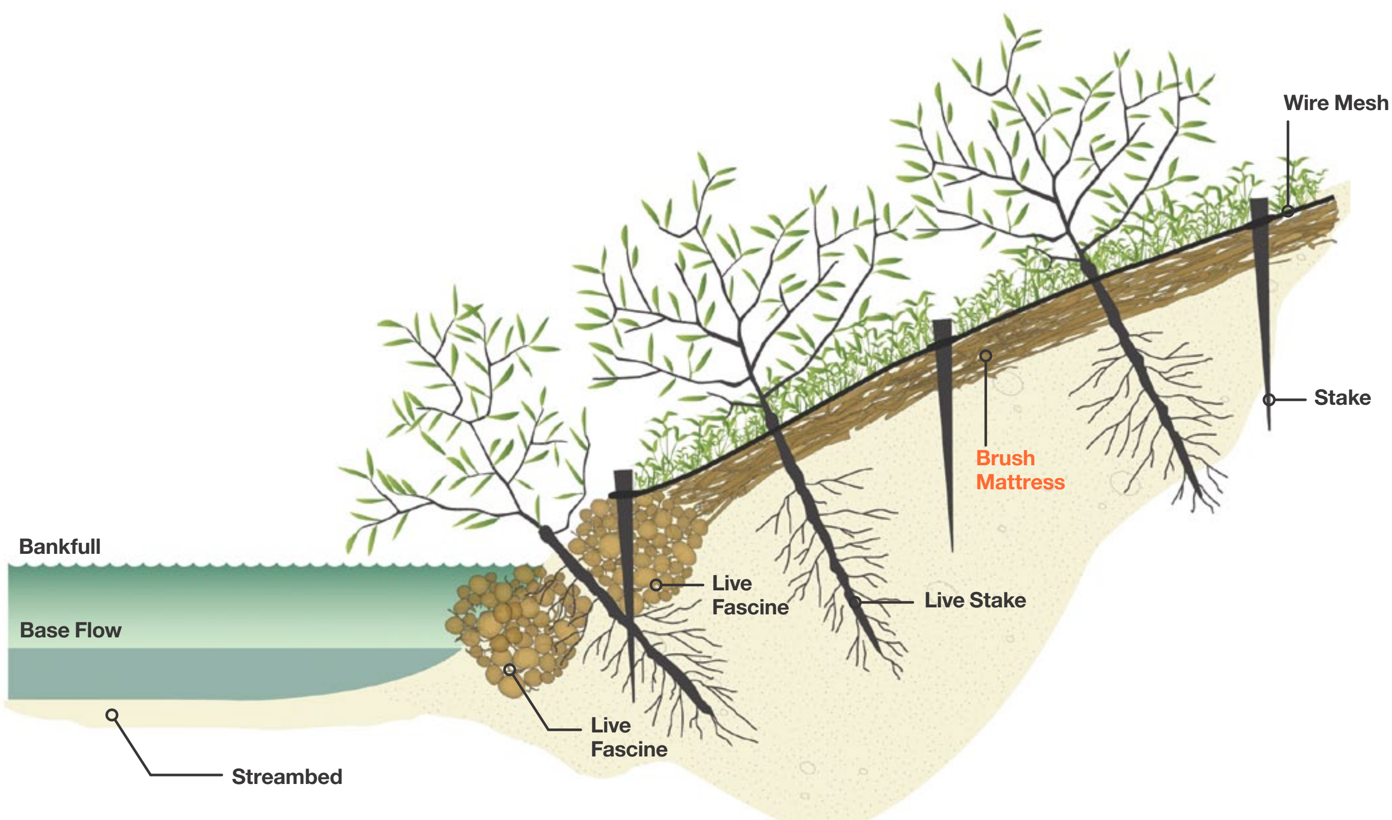
Brush Mattress

- A layer of live branch cuttings placed on the streambank perpendicular to the flow of the stream and held in place with light gauge wire mesh to form a mattress of woody material.
- Live stakes are often placed in between the layers of brush, and a live fascine is placed at the toe of the streambank for added protection.
- The live cuttings and stakes sprout and quickly grow, helping vegetation establish rapidly on streambanks.
- The mattress covers the bank and provides high resistance to shear stress and increased roughness, helping to slow the erosive forces on the bank.
- One of several techniques that are appropriate for outer meander bends or where space for excavation is limited by high banks or relatively deep pools near the streambanks.

Applications: Outer meanders, especially where constraints prevent heavy equipment from accessing the streambanks.

Pros: Provides a rapidly growing mat of vegetation. Installed by hand (manual labor). Can use on-site material.

Cons: May be labor intensive to install, especially where access is limited. Can increase the roughness of the channel and thus increase flood elevations.



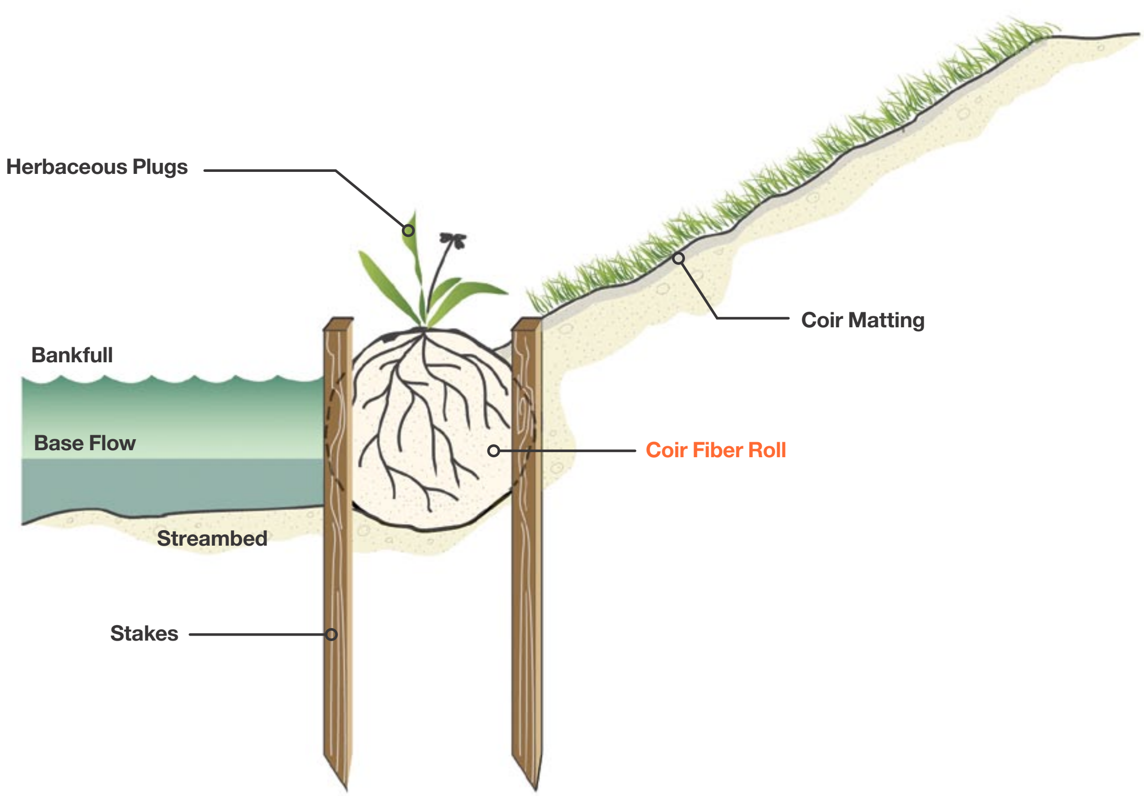
Coir Fiber Rolls

- Technique that uses natural fiber rolls made from coir (coconut) fiber to protect the toe and lower bank.
- Stabilizes and prevents erosion along the toe of the streambank.
- Rolls trap sediment and provides a medium for plants to grow in.
- Often used as a means of protecting the streambank toe, with additional stabilization techniques extending up the bank.

Applications: Toe of eroding streambanks, especially on riffle (straight) sections of smaller channels.

Pros: Easy to install and can also be more aesthetically pleasing.

Cons: Should only be used in areas of low erosion potential, unless combined with a more rigid toe protection technique. Coir fiber roils must be securely staked to the streambank or they can wash away. Method is not appropriate in channels where a large amount of debris (snags and trees) flows down the channel or with high velocity flows.



Buried Rip Rap

- Often a component of many streambank soil bioengineering projects.
- In Harris County, the most common material to use is recycled concrete, due to the scarcity of natural stone.
- Used where velocities are high and/or flood inundation period is long.
- Often used at the toe of the bank to help protect this erosive area where it is difficult to establish vegetation due to continual flows.
- Burying the rip rap under soil allows for turf grasses and other vegitation to be established, further strengthening the streambank.

Applications: Areas of erosion where there is need to have a rigid stabilization method or where it is difficult to grow plants. On many of the larger bayous in Harris County, armor stone may be appropriate for use along the toe of the slope.

Pros: Provides rigid protection of a streambank and its toe. Vegetation can grow through it.

Cons: Some of the rip rap can wash away, requiring more rip rap to prevent further erosion. Not a “natural” material in Harris County streams.

Buried rip rap as toe protection on Cypress Creek

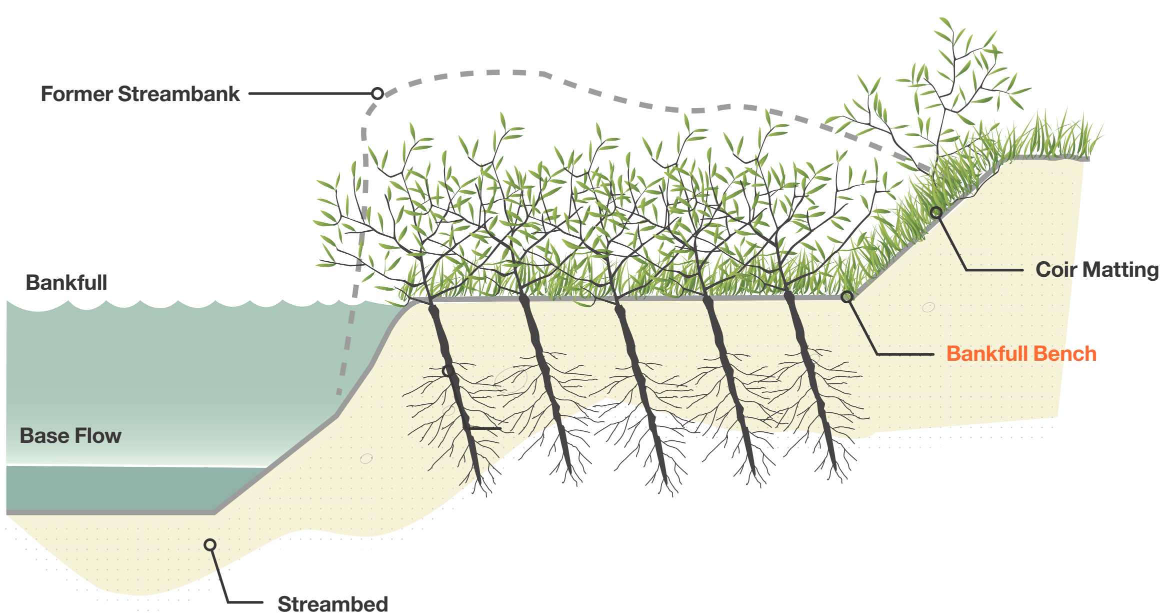
Bankfull Bench

- Is a mostly flat area of variable width (the width of the bench depends on the size of the stream channel's width) created at the elevation of the geomorphic floodplain.
- In an incised stream system, providing a floodplain bench at this critical elevation reduces erosive forces on the streambank by allowing the water to flow out onto the bench and relieve energy.
- Designed not only to stabilize the streambank, but also to improve the overall stability of the channel.
- The ability of the stream channel to transport sediment is increased, while energy (shear stress) to the streambank is decreased.
- Sometimes built out into the channel if the channel is too wide.

Applications: Suitable for use adjacent to all parts of the channel, but especially along straight sections of the channel and inside meanders. Floodplain benches can be combined with any other stabilization method, if room is available.

Pros: Provides overall channel stability by decreasing energy in the channel during flooding.

Cons: Requires additional room to work. In a highly incised channel, it may require removal and disposal of a large amount of soil.



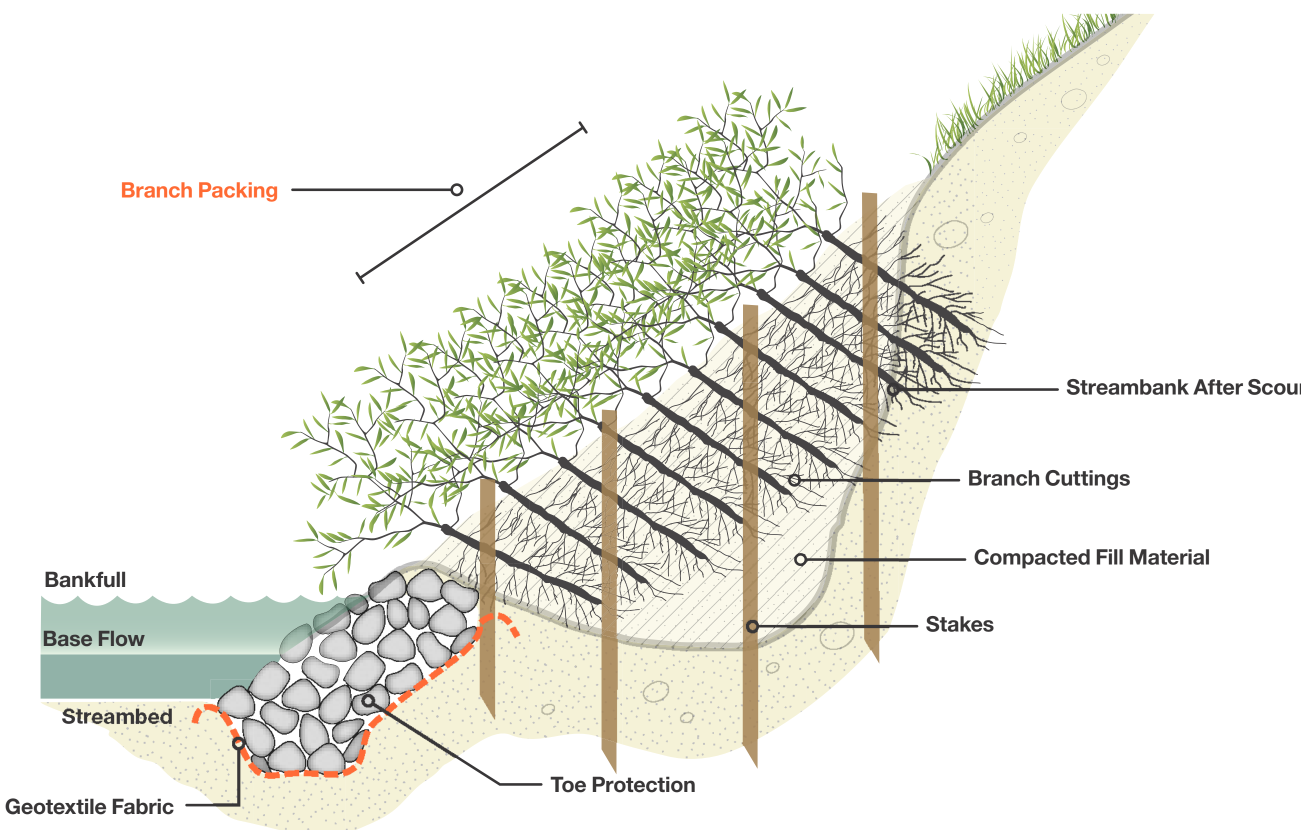
Branch Packing

- Consists of alternating layers of live branch cuttings and soil to fill areas of erosion.
- The branches protrude beyond the face of the slope and wood stakes are used to anchor the material.
- The live cuttings root and provide a permanent reinforcement for the streambank.

Applications: Repair of small streambank slumps and gullies.

Pros: For small streambank repairs, this method can be built with hand labor, and therefore is good for areas where equipment cannot reach.

Cons: Requires a stabilized streambank toe underneath the branch packing. The method is not suitable for areas below baseflow. Can increase the roughness of the channel and thus increase flood elevations.



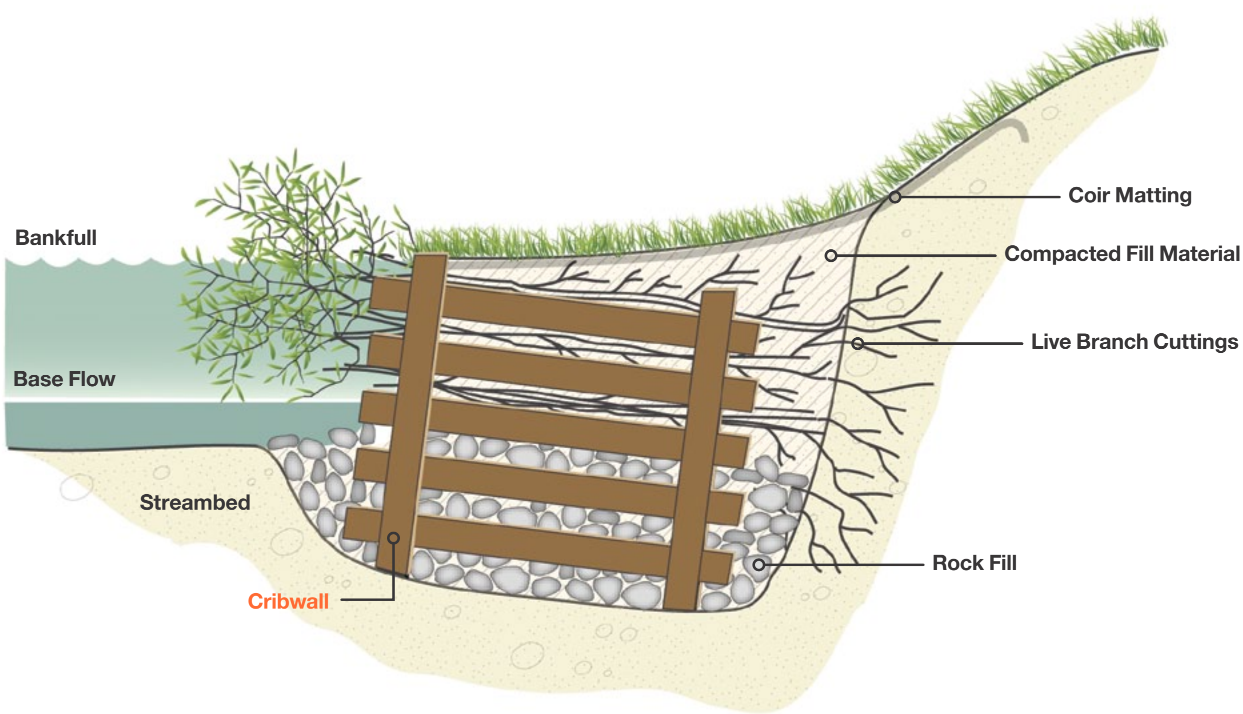
Live Cribwall

- A box-like structure of interlocking logs or timbers.
- The structure is filled with rock, soil and live cuttings of plants, such as black willow (*Salix nigra*).
- Logs provide immediate structural support for the streambank, while the live cuttings grow and provide long-term structural support of the streambank.
- Maximum buildable height is typically less than 6 feet.
- It is important to note that the cribwall structure may not be able to resist pressures from a landslide or slope rotation.
- To work properly, it is critical to estimate the maximum scour depth of the stream next to the cribwall and to securely set the toe below this depth.
- Provide rigid and immediate protection of the lower streambank and toe, as well as long term vegetative stability.

Applications: Suitable on outer meanders of streams where lateral constraints require a steeply sloped streambank and where a more rigid stream toe and streambank are required.

Pros: Allows for stabilization of a steep slope, saving room behind the streambank. The live plants provide long-term protection for the bank.

Cons: The wall has a maximum height limitation of about 6 vertical feet. Labor intensive to install. Larger walls require heavy equipment. Can increase the roughness of the channel and thus increase flood elevations.



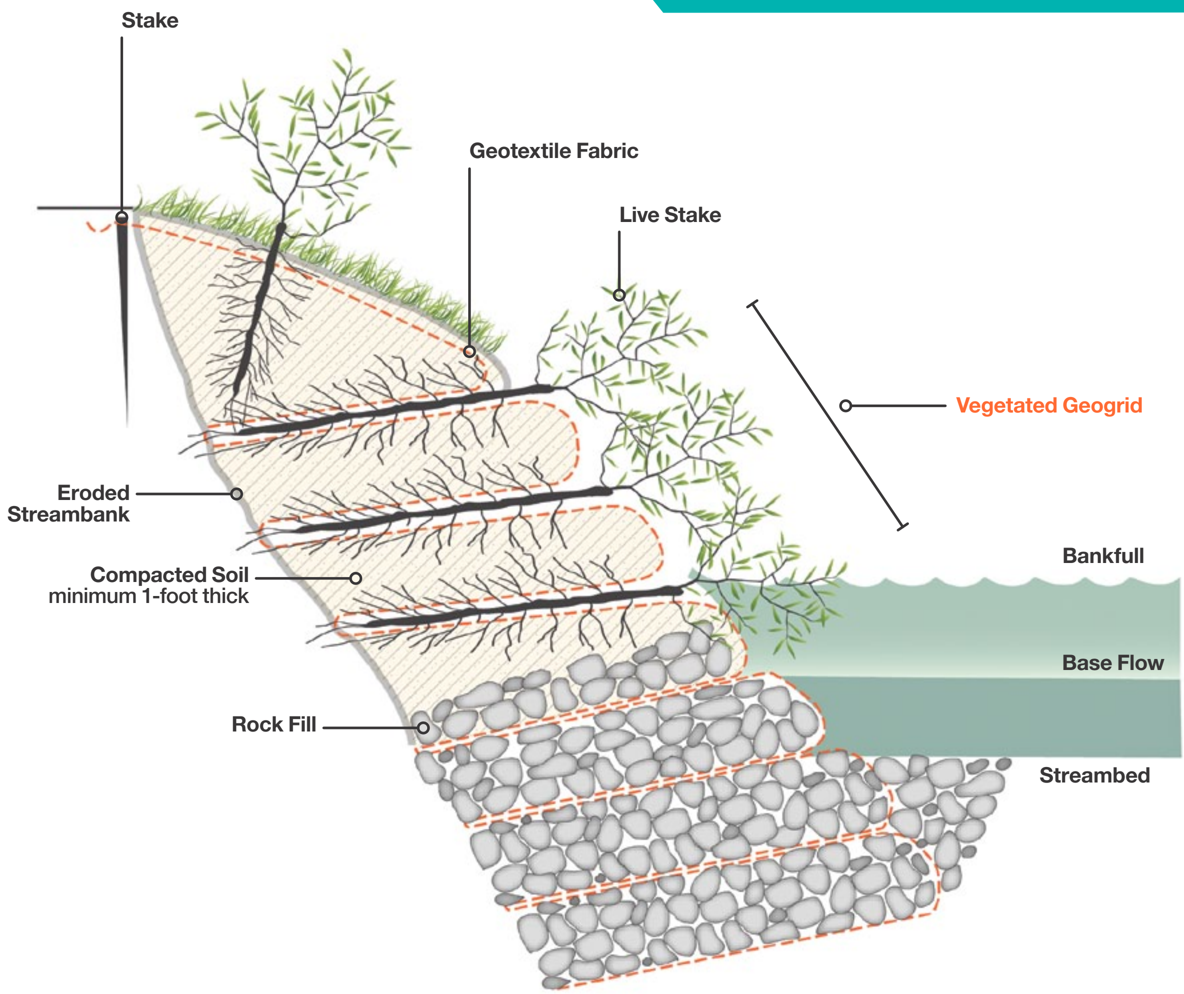
Vegetated Geogrids

- A wall composed of lifts of compacted soil wrapped in coir fabric or geotextile fabric, with grass plugs, live stakes, or other plantings placed between each lift.
- Replaces the eroding streambank with a constructed, reinforced wall that provides resistance to erosive flows, while also promoting plant growth.
- Irregular surface created by the lifts helps to trap sediment during flooding, which encourages further growth and colonization of plants.

Applications: Outside meanders of channels; for protection of fill slopes; where there is little room to work behind the streambank. Best used on tall, steep banks.

Pros: Provides a strong and stable solution for repairing a streambank, especially if a steep slope is required, while also promoting plant growth.

Cons: Can be expensive relative to other bioengineering techniques. May not be suitable on tall, fill slopes. Can increase the roughness of the channel and thus increase flood elevations.



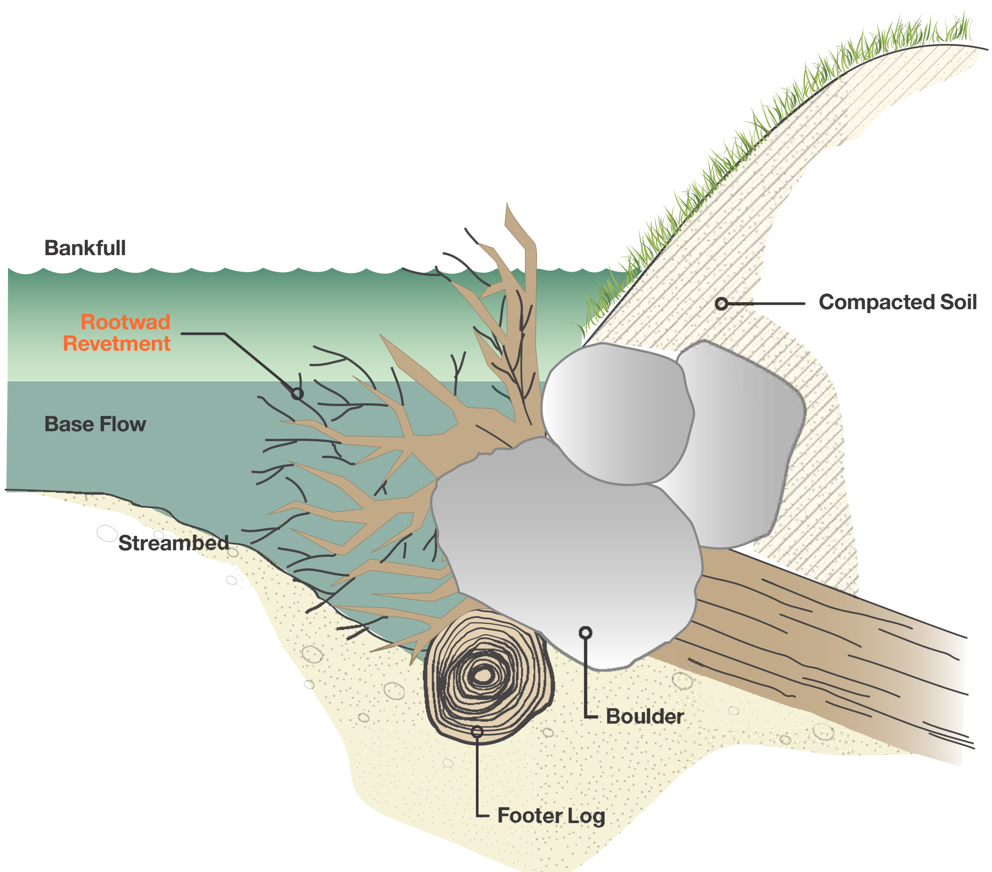
Rootwad Revetment

- Consists of trees buried in a streambank with the root mass exposed to the flow.
- Root mass is generally greater than 3 feet in diameter.
- Often placed in clusters along the outside bank of a meander bend to form a protective layer against high flows impacting the streambank.
- Used in conjunction with logs or boulders to create an integrated revetment.
- Boulders are often placed between the rootwads to minimize erosion or scour around the rootwad, and to anchor the rootwads.
- Plantings, brush layers, or matting around the rootwad help stabilize the upper streambank.
- When properly installed, rootwads can provide a high level of stability in or near high stress bends.

Applications: Outside meanders of channels; for protection of fill slopes.

Pros: Provides a strong and stable solution for protecting the toe of a streambank.

Cons: Can be expensive relative to other bioengineering techniques. May not be suitable on steep fill slopes.



"Rivers know this: there is no hurry. We shall get there some day."
- A. A. Milne, Pooh's Little Instruction Book

Implementation

Rebuilding streambank with geogrid on Buffalo Bayou

The preceding sections provide background information on the need to stabilize streambanks, some of the causes of erosion, and various types of streambank stabilization methods. In most cases, the solution is to seek professional assistance in the coordination, evaluation, selection, design, and installation of streambank erosion control measures. The following section provides additional information to consider as you decide to move forward with a streambank stabilization project.

Rootwad Revetment installation

WHAT IS THE PROBLEM?

1. Identify Bank Erosion Problem

The first step in a stabilization project is to identify the streambank erosion.

2. Determine Scale/Extent of Problem

When stabilizing a streambank, it is important to consider the magnitude and extent of the erosion. Walk along the stream and take note of the existing conditions of the streambanks both upstream and downstream of the reach you want to fix. Determine how much of the streambank is affected by the erosion.

3. Study and Identify Cause of Erosion

Consider possible causes of the streambank erosion. Stabilizing just the streambank on your property may not be practical or worthwhile unless your neighbors are able to stabilize portions of their streambank as well. It may be necessary to team up with your neighbors or other partners to address the instability effectively and have the greatest benefit.

4. Determine Project Limits

Once you have a clear understanding of the magnitude of the erosion problems, it will be important to determine the extent of your project. Consider coordinating with adjacent landowners on both streambanks to develop a comprehensive project.

5. Establish Goals and Objectives

While the overall goal of a stabilization project is to limit the amount or rate of further streambank erosion, specific objectives may include: creating viewscapes, creating aesthetics, improving the landscape, and enhancing habitat.

Considerations in Developing, Evaluating, and Selecting Alternatives

What are the physical conditions of the streambank?

- Where does the streambank of interest fall within the stream's pattern (outside of a bend, middle of a straight section, etc.)?
- How far does the streambank erosion extend upstream and downstream?
- Where on the streambank is the erosion occurring (toe of slope, upper banks)?
- How tall is the streambank?
- How steep is the streambank?

Has the streambank been physically altered in some way?

- Has it previously been stabilized with retaining walls, rip rap, concrete, sheet pile, etc?
- Has the shape of the streambank been changed through excavation?

Additional Considerations

- Is the erosion new or has it been on-going?
- If erosion has been an ongoing issue, has it gotten worse in recent years?
- Has there been recent flooding?
- Are your neighbors also having problems, or is it just on your property?

WHAT ARE THE OPTIONS?

1. Formulate Stabilization Alternatives

Many options may be available to address your streambank instability. Consideration of feasibility, physical and other constraints, permit requirements, costs, and maintenance needs may limit your choices. Develop a full list of possible options based on initial evaluation.

2. Evaluate Alternatives

Your possible streambank stabilization options should then be compared and contrasted for effectiveness, ease of constructability, cost, maintenance, and other factors to help determine which option should be developed and implemented. The table on page 25 provides a comparison of some options.

3. Select Alternative

After you have completed your evaluation of streambank stabilization alternatives, select the option that best meets your objectives.

Urban stream needing stabilization - Little White Oak Bayou

WHAT ARE THE NEXT STEPS?

1. Develop Design

Preliminary design plans are often developed at this time to estimate the project costs and assist in discussions with neighbors, regulatory agencies, and others involved in the project. You are encouraged to include the Harris County Flood Control District early in your design development process. Design changes can easily be made before significant time and costs are invested in developing detailed design plans. Once everyone is in agreement as to how to proceed, then the detailed plans can be developed.

2. Obtain Permits

Local, state, and federal agencies may have jurisdiction over activities that occur in and around streams and waterways. If you do not obtain the proper permits or permissions, your project can be delayed and you may be subject to legal action. Therefore, it is important to determine the permit requirements for a project ahead of time and account for the permitting process in your design, costs, and schedule.

Harris County Flood Control District & Floodplain Administrator – It will be necessary to obtain approval from the Harris County Flood Control District and your local municipality to implement streambank stabilization work. The Flood Control District owns and maintains rights-of-way along most bayous and waterways within Harris County. Work in a regulated floodplain also requires permission from the Floodplain Administrator; Harris County and each local municipality, such as the City of Houston, has a Floodplain Administrator. To obtain approval, you must provide a Drainage Impact Report to verify that there are no impacts to stream flow or water surface elevations resulting from your proposed streambank stabilization project; and then, after your design is complete, submit engineering construction drawings. Both submittals must be signed and sealed by a professional engineer. Consult the Flood Control District's Policy Criteria and Procedures Manual, listed under the Resources section, for additional details.

Texas Commission on Environmental Quality (TCEQ) – The TCEQ issues a general stormwater permit for construction activities and requires that construction projects are designed and implemented in a manner that is protective of surface water quality. A Stormwater Pollution Prevention Plan is required for most construction projects and periodic site inspections are needed to demonstrate compliance with the permit.

U.S. Army Corps of Engineers (USACE) – The USACE regulates activities that occur in "Waters of the U.S." This includes wetlands and streams. Within streams, the Ordinary High Water Mark (OHWM) determines the limit of their jurisdiction. If a portion of a streambank stabilization project occurs below the OHWM, or if adjacent jurisdictional wetlands will be impacted by the project, then a permit may be required from the USACE. USACE permitting options range from streamlined Nationwide Permits to more extensive Individual Permits. Identification of the OHWM is typically performed by a qualified consultant and verified by the USACE. This permit process also includes compliance with regulations of threatened and endangered species, cultural resources, and other water quality concerns.

3. Installation

There are a number of items to consider when installing a streambank stabilization project. A few of these are described below.

Physical Constraints:

- **Site Access** – It must be possible to get the necessary equipment and materials to the project location. Access constraints can include man-made features, such as homes, pools, golf courses, fences, etc. Natural features, such as large trees, native vegetation, and erosional areas may also limit site access.

Adjacent Landowners – Erosional features often cross property lines. The source of the problem may also be upstream or downstream and repairing the erosion would be futile unless the cause of the problem is addressed. Therefore, it is often necessary to work with neighboring landowners to develop solutions that will address the problem.

It is recommended that you contract with a Civil Engineer or qualified engineering and environmental consultant and contact the **Flood Control District** at: 713-684-4000 prior to commencing any streambank stabilization activities or work adjacent to a channel. Plans and proposals for work along streams in Harris County must be reviewed and approved prior to construction. All necessary permits must be obtained prior to commencing site construction.

- **Right-of-Way** – Establish existing property boundaries and be sure that all work to be performed is on your right-of-way.
- **Room to Work** – There needs to be adequate space to stage and maneuver large equipment for some stabilization measures.
- **Infrastructure/Utility Lines** – Many utility corridors follow or cross stream channels. Underground and overhead utilities, such as sewer, water, electrical, gas and fiber optic lines may restrict not only the construction of the project but the type of revegetation that can be allowed.
- **Presence of Significant Resources** – Large trees or other important landscape features that should not be disturbed may influence the stabilization design.

Resource Limitations:

- **Funding** - Streambank stabilization solutions can range greatly in cost. It is important to determine how much funding is available for the project during the planning stages.
- **Materials** – A local supply of the materials needed for a particular type of stabilization method may be limited. Depending upon these limitations, some possible stabilization options may be cost prohibitive.

Revegetation:

Perhaps the most common hesitation of landowners is a fear that a bioengineering project will look weedy or that the project will obscure views of the stream. For those accustomed to the manicured look of a traditional lawn, a natural streambank is a significant change. However, a natural streambank environment can be designed so that it provides both access and views. The use of deep-rooted native grasses provides many of the same benefits that trees and shrubs or other vegetation may provide, while allowing for the maintenance of viewscapes.

A variety of grasses, trees, and shrubs may be planted as part of a streambank stabilization project. Selection of the species to be planted should be based on a variety of factors, such as moisture regime, steepness of bank, amount of shade and landscape requirements.

Not all species of plants are suitable for streambank protection. Aesthetics, such as landscaping and viewscapes, may also play an important role when selecting plants for certain areas. When possible, use locally collected and grown native species. Native species are adapted to live in the area and are likely to have a higher survival rate than non-native species.

The Bayou Preservation Association has published a useful "Bayou Planting Guide" which provides a good listing of plants native to the Houston area. See: *http://www.bayoupreservation.org/html/BPG_2013.pdf*

Planting of live stakes, trees and shrubs should occur during the dormant season (November through February, in Harris County). Grasses can be planted throughout the year. In general, summer plantings should be avoided because of hot temperatures and dry conditions. Check with a local nursery as to the best time to plant the species you have selected. For material planted during the growing season, a significant amount of watering will likely be necessary to protect your investment.

4. Monitoring and Maintenance

Once installation is complete, regular monitoring and maintenance will help make the project successful. During construction, and up to the time when permanent vegetation becomes established, the project should be inspected weekly and after any rain or high flow event. After permanent vegetation becomes established, the time between inspections can be lengthened unless unusual circumstances occur, such as drought conditions.

Watering or irrigation of the site should be performed to help seeds germinate and to maintain plantings. Care should be taken to avoid overwatering, so that soil is not lost to erosion caused by irrigation. Sometimes, it will be necessary to reseed or replant some areas after the first year, if establishing vegetation has been difficult.

Potential revegetation problems to monitor and address early include:

- Undermining (erosion) at the toe of slope,
- Rill formation (small erosion features),
- Poor seed germination or plant survival,
- Invasive species.

Notes:

Resources

The following publications provide information that may be useful in developing and implementing a streambank stabilization project within Harris County. These publications range from very specific information on the geomorphology of streams within Harris County to detailed manuals on bioengineering and streambank stabilization. Many of these publications can be found online or by request from the Flood Control District.

Local Guidance and Manuals

Harris County Flood Control District, 2009. *HCFCD Hydrology and Hydraulics Guideance Manual.*

Harris County Flood Control District, 2010. *HCFCD Policy, Criteria and Proceedures Manual.*

Information on Harris County

AMEC Geomatrix, Inc., 2009. *Fluvial Geomorphological Conditions of Harris County, Texas*. Prepared for Harris County Flood Control District.

Chowdhury, A.H., and Turco, M.J., 2006. Geology of the Gulf Coast Aquifer, Texas. Report 365 - *Aquifers of the Gulf Coast of Texas*, Chapter 2. Texas Water Development Board, Austin, TX.

Hamlin, H.S., 2006. Salt Domes in the Gulf Coast Aquifer. Report 365 - *Aquifers of the Gulf Coast of Texas*, Chapter 2. Texas Water Development Board, Austin, TX.

Larkin, T.J., and Bomar, G.W., 1983. *Climatic Atlas of Texas*. LP 192. Texas Department of Water Resources, Austin, TX.

Streambank Stabilization and Bioengineering Manuals

Allen, H.H. and Leech, J.R., 1997. *Bioengineering for Streambank Erosion Control*. Technical Report EL-97-8. US Army Corps of Engineers Waterways Experiment Station.

Eubanks, E.C. and Meadows, D., 2002. *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization*. US Department of Agriculture Forest Service Technology and Development Program.

Georgia Environmental Protection Division and Georgia Soil and Water Conservation Commission, 1994. *Streambank and Shoreline Stabilization - Techniques to Control Erosion and Protect Property*.

Harman, W., 2004. *Design Improvements of Meander Bend Protection Using Root Wads*. 2004 Stream Restoration Conference, Winston-Salem, NC. http://watershedbmps.com/

Natural Resource Conservation Service (NRCS) Lake County Stormwater Management Commission, 2002. *Streambank and Shoreline Protection Manual*.

NRCS, 2007. National Engineering Handbook. Part 654 - Stream Restoration Design.

Virginia Department of Conservation and Recreation (VDCR), 2004. *The Virginia Stream Restoration and Stabilization Best Management Practices Guide*.

Vegetation Resources

Bowen, M., 2013, *The Bayou Planting Guide*. Bayou Preservation Association. http://bayoupreservation.org/html/BPG_2013.pdf

Harris County Flood Control District. 2013. *Field Guide for Plant Identification* – Volume One: Reforestation: Trees, Shrubs, Vines, and Undesirable Plants Found in our Channels and Basins.

Maywald, P.D. and Doan-Crider, D. *Restoration Manual for Native Habitats of Southwest Texas*. Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville

US Department of Agriculture, Soil Conservation Service, 1976. Harris County Soil Survey. (available online at http://soils.usda.gov/survey/online_surveys/texas/TX201/harris.pdf)

Wynn, T., S. Mostaghimi, J. Burger, A. Harpold, M. Henderson, and L. Henry. 2004. *Ecosystem Restoration Variation in Root Density along Streambanks*. J. Environ. Qual. 33:2030–2039 (2004).

Stream Processes and Geomorphology

Rosgen. D. 2006. *Watershed Assessment of River Stability and Sediment Supply*. Wildland Hydrology, Fort Collins, Colorado.

Thorne, S. D. and D. J. Furbish. 1995. Influences of coarse bank roughness on flow within a sharply curved river bend. Geomorphology. 12(3):241-257

Photo courtesy of SWA Group

Overview of stream corridor design at Cross Creek Ranch Ft. Bend County

HARRIS COUNTY FLOOD CONTROL DISTRICT

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