Live and Inert Fascine Streambank Erosion Control

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Complexity	Value as a Planning Tool	Cost
Low Moderate High	Low Moderate High	Low Moderate High

OVERVIEW

Live fascines (LF) and inert fascines (IF) are sausage-shaped bundle structures made from cuttings of living woody plant material. In the LF, the cut branches are expected to grow producing roots and top growth, (performing additional soil reinforcement via the roots and surface protection via the top growth). The LF is used from the baseflow elevation and up along the face of an eroded streambank, acting principally to protect the bank toe and bank face. They are also useful over the crown to improve erosion control, infiltration, and other riparian zone functions. The IF is not intended to grow, but can be used to protect the toe of the streambank while other vegetation becomes established. The LF and IF can also be configured to act as current deflectors and pole drains that collect and transport water. Both have the potential to accumulate sediment.

LF and IF benefit fisheries habitat by providing food and cover when they are used in close proximity to the edge of the stream. Stone used at the base of the LF or IF provides substrate for an array of aquatic organisms. Some of these organisms adapt to living on and within the rocks while others utilize the leaves and stems for habitat or as food. LF or IF can improve water quality and aesthetics. Plants within the LF or IF can be selected to provide color, texture, and other attributes that add a pleasant, natural landscape appearance.

Figure 1. Building a live fascine structure

Figure 2. A fabricated live fascine structure

Plants behind or within the IF bundle, especially emergent aquatic plants that invade and establish over time, such as bulrush (*Scirpus spp*.) and sedges (*Carex spp*), will

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assimilate contaminants within the water column, and reduce non-point pollution by intercepting sediment and attached pollutants coming into the stream from flow and overbank areas.

PLANNING

The first step in the planning process is to determine whether an LF or IF is an appropriate alternative to address the observed and projected mechanisms of bank loss. Both measures are aimed at addressing erosion processes and surficial slope instabilities. They must frequently be combined with other measures to address the full range of instabilities at a site.

The hydrologic character of the stream must support an LF or an IF. Stream velocities and shear stresses must not exceed thresholds for stability of the materials. Banks must retain sufficient moisture to support plant growth. The effect of the plants (typically willows) on water surface elevations due to their resistance must be within acceptable levels if flooding is a concern on the project reach. Risks, and specifically the consequences of failure, should be identified and carefully considered. Costs should be acceptable.

Sediment accumulation potential should be evaluated for its impact on plant establishment and survival. There must be enough sunlight to support the desired system (for an LF), and site conditions during construction must permit installation. LFs should be constructed during the dormant season, so construction schedules outside this period may require the use of an IF or other erosion control devices or materials.

Riparian woody and/or wetland plants in a reference reach or nearby similar system can often be used as a template (and perhaps material source) for building the LF or building and support-planting the IF.

CONSTRUCTION COSTS

Following are Year 2000 cost ranges for LF and IF projects based on the authors' experiences. These include profit margins and contingency factors on contractor bid projects. LF costs range from $10 to $30/ft for 6- to 8-in. bundles. IF costs range from $10 to $26/ft for 12-in. bundles and $14 to $30/ft for 18-in. bundles. These prices include securing devices for installation, twine (for fabrication), harvesting, transportation, handling, fabrication, and storage of the live-cut branch materials, excavation, backfill, and compaction. Costs, however, vary with design, access, time of year, and labor rates. Bundles fabrication is relatively simple and is performed prior to installation. Both LF and IF structures may be fabricated in custom diameters for special needs. Installation is also relatively straightforward because large equipment is not required except to slope the bank.

Figure 3. Installing a live fascine structure

Figure 4. A live fascine during initial growth.

Figure 5. Installing an inert fascine structure

SITE CONSIDERATIONS

A site suited to IF requires a hydrologic regime that 1) keeps the invert of the bundle wet during most of the growing season where the establishment of wetland plants is desirable; and 2) sustains flows sufficient to keep wetland plants growing but not exceeding the plant's flood tolerance. Given these requirements, streams best suited to IFs are perennial, small to moderate in size, with a relatively consistent water surface elevation associated with an extended baseflow. Well-drained soils should be avoided.

Massive amounts of sediment movement could smother plants that establish within and behind the IF bundle. However, when IFs have been effectively used to trap soils from both stream flows and upper bank sloughing, they establish conditions for subsequent colonization or planting. When IFs are used, planting should not be attempted until the upper bank has stabilized. Frequently the upper bank stabilization is accomplished with LFs.

A site suited to an LF requires a hydrologic regime that 1) allows the roots to reach the water table during most of the growing season; and 2) where enough soil (growing medium) is available to allow for root penetration. Depending upon the site- specific conditions, plant species that have the required tolerances, such as flooding, sediment cover, drought and shade, are selected. The LF structures have a wide variation to these tolerances due to a broad range of species that can be used in their construction.

Other important considerations in site selections are shade conditions, type of substrate in which they will be placed, and their relation to the channel thalweg. Most wetland plants that are desired for establishment within an IF are shade- intolerant and require some sunlight. The same is generally true for LF. Though sunlight is generally desired, there are shade-tolerant plants that can be used for the IF, such as Baltic rush (*Juncus balticus*) or some species of burreed (*Sparganium spp*.) and *Viburnum*.

Substrate conditions are also important in site selection because, aside from growth expected in the LF structure, both IFs and LFs must be securely anchored. If the substrate is non-cohesive material, such as sand or silt, anchoring may be problematic due to lack of friction. Longer dead stout stake anchor systems are typically used and installed at closer intervals. Conversely, a substrate laden with interspersed rock or having an underlying rock layer, can require special equipment or materials to achieve anchor penetration. Dead stout stakes, 2.5 to 4 ft long, are typically successful (Figure 6). When installing an LF or IF adjacent to the thalweg, ensure it is protected with a stone toe buttress to prevent scour and undercutting.

Figure 6. Dead stout stakes

DESIGN

Design of IF and LF stabilization measures usually involves the integration of other materials and methods to address the full range of bank loss mechanisms active at a site, and to prevent structure loss from erosion at the toe or by flanking. Riprap or other materials are often used to provide a stable toe and to construct refusals to prevent flanking. These measures are addressed in more detail in companion technical notes. Important design steps include defining the limits of protection and developing the layout.

Limits of Protection

The spatial extent of fascine treatments is a function of both the project objectives and the site conditions. Depth of erosion must be in the range of 6 to 8 in. for the LF to be an effective immediate erosion control device when used alone. Elevation of the LF and IF must be suited to the hydrologic requirements and limitations of the vegetation. In general, the IF must be at an elevation that permits absorption of water to prevent desiccation of the vegetation. However, it must not be placed so low as to inundate the vegetation beyond its flood tolerance. If stacked bundles are used, they must be in a position to be wetted quite often or to absorb groundwater seepage from the bank. When willow branches or other woody plants are used with LFs or IFs as brushlayers or live siltation constructions, their basal ends are inserted well into a moist zone within the lower bank. There is no requirement for periodic wetting. In these cases, IFs are intended primarily to provide temporary sediment and erosion control until the woody vegetation has become established.

Installed measures must withstand anticipated sustained velocity and shear stress conditions on the bank. Limited data that have been collected for shear or velocity tolerances of LF and IF structures (largely empirical information collected from constructed projects), are summarized in Tables 1 and 2 (from Fischenich 2001, Gerstgasser 1998, Schiechtl and Stern 1996, and Schoklitsch, 1937, augmented with data from Robbin B. Sotir and Associates, Inc.). Designers should exercise caution in considering limiting velocity or shear stress criteria. Failure of LF or IF structures can be attributed to several mechanisms, notably flanking, undercutting, and anchor failure.

Table 1. Stress Type and Levels for the LF

Bundle Configuration	Velocity	Shear
Angle only w/o rock bolster protection	<8 ft/sec	1.2 to 2.1 lb/ft²
Angle w/rock bolster protection	<12 ft./sec	>3.1 lb/ft²
On-contour only w/o rock bolster protection	<6 ft./sec	0.1 to 0.6 lb/ft²
On-contour w/rock bolster protection	<8 ft/sec	>2.0 lb/ft²

Table 2. Stress Type and Levels for the IF

Bundle Size	Velocity	Shear
Bundle 12" only w/o rock bolster protection	<5ft/sec	0.2 to 0.8 lb/ft²
Bundle 12" w/rock bolster protection	<8ft/sec	3.0 lb/ft²
Bundle 18" only w/o rock bolster protection	<7ft/sec	0.5 to1.2 lb/ft²
Bundle 18" w/rock bolster protection	<10ft/sec	3.0 lb/ft²

Success requires that a protection guard against undercutting and flanking the treatment be provided. For toe and flank protection, rock protection should be designed for velocities and shear stresses exceeding allowable limited for the soils underlying the LF or IF. Fischenich and Allen (2000) present these limits along with design guidance. Angular rock is recommended and should be sized in accordance with the U.S. Army Corps of Engineers (1994) specifications depending on anticipated velocities and shear stress.

Flank protection can also be aided by keying the ends of the LF or IF into the banks at both ends and protecting the flanks with rock protection. Key ends well into the bank by inserting at least 3 linear feet of bundle into the bank with rock on the upstream side, which is also keyed into the bank. For banks susceptible to significant erosion, keys or refusals extend further into the bank.

Fascine Layout

On moist seeping banks, and especially in outside meanders, the LFs should be installed at an angle on the bank face, parallel to each other, with the growing tips oriented up-slope. The angle ranges between 45 and 60 deg off the horizontal. This assists in bank drainage, prevents rilling, reduces velocities near the bank, disrupts secondary currents, and captures sediment. Typically, the lower end of each LF bundle is in an upstream configuration (Figure 7). In a dry slope environment and along inside meander bends, the LFs are typically installed on contour onto the bank face.

The LFs are typically installed parallel to each other and spaced apart according to slope and soil conditions as shown in Table 1 (adapted from USDA SCS (1992)). Figure 8 is a typical section of stacked live fascines used in conjunction with live siltation.

Table 1 – Live Fascine Spacing (Apart)

	Soils	
Slope Steepness	**Cohesive**	**Noncohesive**
1:1	3ft[1]	NA
1:1 – 2:1	3 to 4 ft[1]	NA
2:1 – 3:1	4 to 5 ft[1]	3 to 4ft[1]
3:1 – 4:1	5 to 6 ft	4 to 5ft[1]
4:1 or flatter	6 to 8 ft	5 to 7ft

[1] Recommended to be used with an erosion control fabric between the LF and the bank

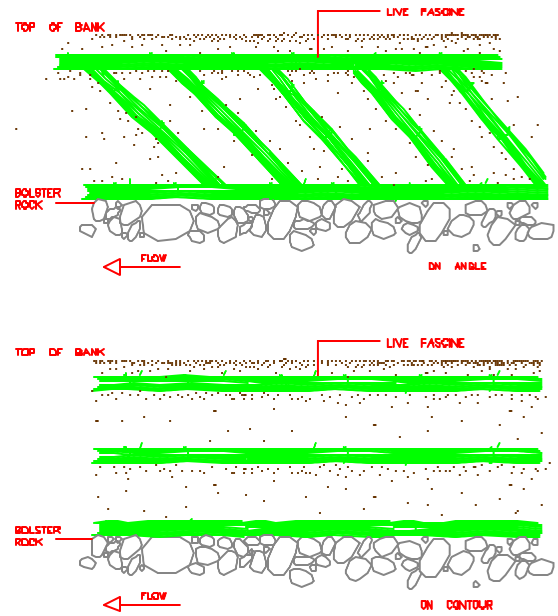

Figure 7. LF configuration showing fascine angle along bank face

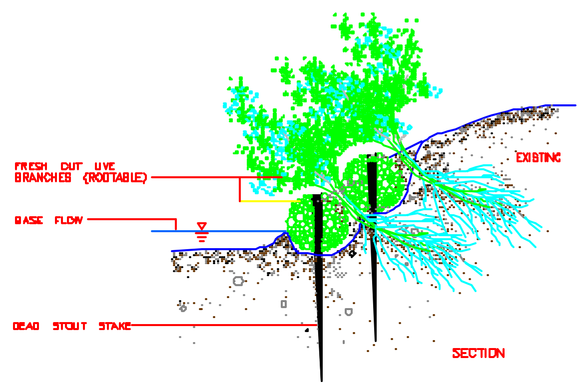

Figure 8. Live siltation construction with stacked LFs

The LFs are typically augmented with the insertion of 2.5- to 3-ft-long live stakes below the bundle and between the previously installed dead stout stakes. The live stakes are inserted into the moist zone within the bank. Typically when tamped in the ground, 3 in. of the live stake is left exposed.

The IF bundles are tied with coir bristle twine every foot. The 12- to 14-in.-diam. bundles are staked every 2- to 3-ft, and the 16 to 18-in.-diam. bundles are staked every 2 ft.

Other design considerations include the type, number, configuration, and diameter of structures needed to protect a streambank. The length of bank reach being eroded will determine the number of structures needed. Configuration of LF's is determined by the location, such as in an outside meander, and soil moisture (e.g., seepage conditions). The LF or IF structures are normally fabricated into 20- to 30-ft lengths but can be custom built to fit almost any situation.

Eroded banks are not always conducive to immediate LF or IF installation and typically require reshaping or filling treatment. If fill is required, rock fill mixed with other substrate suitable for plant growth may be needed for LF. Rock alone is often used to prevent undercutting. Fill will need to be calculated based on cross-sectional area of the bank times the length of reach. Size of rock and appropriate gradation should be determined from U.S. Army Corps of Engineers (1994).

FABRICATION & INSTALLATION

LF bundles are fabricated using fresh, live- cut branch material that roots easily from cuttings, typically harvested from a natural stand, within 40 miles of the project site. Native naturally growing plants such as willow or shrub dogwood species work well and are usually available. All material should be free of splits, rot, disease, and insect infestation.

Live-cut branches from 0.25 to 1 in. in diameter, with a minimum length of 4 ft, are used. The live-cut branches are bundled together with the growing tips oriented in the same direction. The side branches are retained in the LF bundle structure. Age, size, and species should be mixed throughout the bundle structure. The tips and basal ends are mixed throughout the bundle. The live-cut branches are compressed into a 6- to 8-in.-diam. bundle and tied securely every foot with untreated twine. IF bundles are fabricated using freshly cut flexible branches from species that do not root from cuttings. These are harvested from native natural stands near the project site. The cut branches range between 0.25 and 2 in. in diameter, with a minimum branch length of 6 ft. They are bundled together with the growing tips and basal ends evenly mixed in both directions. The side branches are retained in the IF bundle structure. Mix tips, basal ends, and sizes throughout the bundle. Compress the branches into a 12- to 18-in.-diam. bundle, and tie securely every foot with coir bristle twine.

Excavation

Trenches for the LF are typically 1 to 2 in. larger than the fascine size in width and depth, allowing for a few inches of ameliorated soil to be placed in the bottom and along the sides. In certain circumstances, such as steeper slopes, fill soil areas, and/or erosive soils, ECF is also placed in the trench and on the bank face prior to the backfill soil and LF bundle placement.

Trenches for the IF are typically dug with the top of the slope burying approximately half the bundle structure, and with the baseflow water elevation approximately flush or just below the top of the bundle structure to sustain emergent plants (assuming that is the goal). Rock protection may be required to protect toe scour from occurring beneath the IF and LF bundle structure.

Construction

The primary considerations in construction with an LF and IF are bank preparation, trench excavation, physical handling and placement, securing the bundles in place, backfilling, compaction, and drainage. Securing the LF bundles in place includes overlapping the ends for connections and anchoring them with dead stout stakes, and protecting them from undercutting and flanking as previously mentioned. Securing the IFs in place includes connecting them end to end and anchoring them with dead stout stakes. Additional dead stout stakes are often installed at connections. The LF or IF should be handled with care. A bundle is light in weight, depending on its diameter, and it is easily handled without damage using one person for every 5 ft of length.

The LF ends are fastened together in the excavated trench by overlapping the growing tips over the basal end of the previously installed bundle. The overlap is typically 18 in. and is secured with dead stout stakes driven directly through the bundles. The dead stout stake is typically flush with the bundle when installation is complete.

The LF or IF should be keyed into the bank or abutted to a hard point, preferably a rock refusal that has a rock back into the bank to prevent flanking. Planting IFs is typically accomplished by planting them in place along the streambank behind the bundle structure. A hole is created behind the installed IF in which to place a rooted plant such as a sprig of an emergent aquatic wetland plant (e.g., bulrush, sedge, or rush). The spacing between the holes can vary but usually ranges between 4 and 6 in. The hole can be created by using a dibble or small shovel. After the hole is made, a 6- to 10-in. rooted sprig is inserted into the hole. The hole is backfilled and compacted.

An IF may also be planted with rooted or unrooted cuttings of woody plants such as willow, dogwood, or alder. The planting procedure for the rooted cuttings is the same as for emergent aquatic wetland plants described above except that they are installed 6 to 18 in. apart. At other times, willow and other woody plants that sprout from unrooted cuttings are inserted above and between stacked rows of IFs as live-cut branches that extend back into the soil bank. The live-cut branches are placed in one or more layers for this purpose.

Time of Year

The IFs may be installed throughout the year, but they have the greatest chance of success when the water elevation is at normal baseflow level. Aquatic wetland plants are most successful when installed in the spring, although fall installation is possible. The season of construction may be split if necessary where the IF is installed. Live siltation (LS) construction or brushlayers associated with IF should be installed in the dormant season.

OPERATION AND MAINTENANCE

Operation and maintenance requirements vary depending on the stream system and its associated parameters, such as velocity, flood frequency, flood stage, timing, and future planned use. Repair of the system may be required until the vegetation becomes well-established. Inspection should occur after each of the first few floods and/or at least twice a year the first year, and once a year thereafter (preferably after the predominant flood season).

Undercutting and flanking of the treatment and any other substantial scour should be immediately repaired. Examine the cut branches in the LF for adequate survival and growth and for disease, insect, or other animal damage. Successful plants will grow vigorously and spread their roots into the surrounding substrate.

If animal or human damage is evident, preventative measures, such as exclosures, may be required. Such exclosures, especially for woody plants, may only need to be used until the vegetation is well-established.

APPLICABILITY AND LIMITATIONS

Techniques described in this technical note are generally applicable where primary objectives for streams include habitat diversity, erosion control, water quality improvement, and aesthetics, including a diversity of riparian plants along the streambank. Use of IF where vegetation is expected to establish is limited to streams having fairly constant and consistent base flows. If streams are ephemeral, vegetated IFs will tend to dry out and plants within and possibly behind them will die. If aquatic herbaceous plants are desirable, streams should not have excessive sediment loads that may completely cover and smother plants. Some caution is also needed when selecting the species for LF.

Exercise caution in using IF or LF without rock protection or other hard material when stream velocities at the bank exceed critical thresholds for underlying soils.

Trampling and grazing of LF or vegetated IF can be detrimental from both living and mechanical perspectives. Use may be limited in areas where human traffic is concentrated or where cattle grazing is not restricted.

Consider the time of year when installing LF, brushlayers/live siltation constructions and aquatic wetland vegetation as well as water elevation. Consider consequences of failure if an LF or IF is flanked and washed downstream and if the failure is likely to create hazards that otherwise would not occur (e.g., trapping debris and causing undesired local scour, current deflection, and damming).

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