Stream Bank Stabilization Technical Manual

Using

Soil Bioengineering Techniques

As Demonstrated on

Willow Creek
Ingham County, Michigan

STREAM BANK STABILIZATION
TECHNICAL MANUAL
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SOIL BIOENGINEERING TECHNIQUES

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WILLOW CREEK
Ingham County, Michigan

Prepared by:

PATRICK E. LINDEMANN
INGHAM COUNTY DRAIN COMMISSIONER
707 Buhl; P.O. Box 220
Mason, Michigan 48854-0220
(517) 676-8395

FISHBECK, THOMPSON, CARR & HUBER, INC.
6090 East Fulton, P.O. Box 211
Ada, Michigan 49301-0211
(616) 676-2666

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  6075 Jackson Road
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  P.O. Box 157
  St. Charles, MI 48655

- Shellenbarger Engineering & Surveying, P.C. (1995 only)
  5910 North Hagodorn Road
  East Lansing, MI 48823

- City of Mason
  345 North Jefferson
  Mason, MI 48854

- Aurelius Township
  1939 South Aurelius Road
  Mason, MI 48854

- Vevay Township
  780 South Eden
  Mason, MI 48854

- Ingham County Road Commission
  301 Bush
  P.O. Box 38
  Mason, MI 48854

- Ingham Soil Conservation District
  312 North Street
  P.O. Box 236
  Mason, MI 48854

- Natural Resources Conservation Service
  1405 South Harrison
  Room 101
  East Lansing, MI 48823

- Michigan Department of Agriculture
  611 West Ottawa
  P.O. Box 30017
  Lansing, MI 48909

- Michigan Department of Environmental Quality
  Surface Water Quality Division
  10650 South Bennett Drive
  Morrice, MI 48857

DISCLAIMER

These techniques were utilized along Willow Creek in Ingham County, Michigan, and are not guaranteed to be successful elsewhere. The expertise of an engineer or biologist may be necessary to determine which techniques are applicable for specific sites.

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GLOSSARY

Acceptable Species	Plants which have the ability to root easily from cuttings.
Biolunker	A system of fascines used for the stabilization of vertical slopes.
Brush	Vegetation with trunks or stalks less than or equal to 4 inches in diameter as measured at breast height.
Brush Mattress	A system of fascines, brush, and live stakes used for the stabilization of bare slopes.
Clearing	Cutting and removal of trees, brush, and shrubs.
CONTRACTOR	The person, firm, or corporation installing the soil bioengineering techniques.
Cut Section	A section of the site in which soil needs to be removed.
Disposal	Burning, burial, or removal from site of all debris and woody material that is removed during the clearing, grubbing, and snagging operations.
ENGINEER	The person, firm, or corporation hired by the OWNER to design and inspect the project.
Fascine	A sausage-like bundle of brush tied with twine. May be composed of acceptable or unacceptable species. Live fascines are 100% acceptable species. Mixed live/dead wood fascines are 50% acceptable species and 50% unacceptable species. Dead wood fascines are 100% unacceptable species.
Fill Section	A section of the site in which soil needs to added.

Grubbing	Removal of tree stumps and roots from below ground.
Live Stake	A stake made from acceptable species; live, rootable, vegetative cuttings inserted into the ground.
Lunker	A structure made of lumber, used for stream bank stabilization and fish habitat.
Mercantile Timber	Trees having a stump diameter of 6 inches or more.
OWNER	The person, firm, or governmental agency that has jurisdiction over the project site.
Property Owner	The landowner of record for the project site.
Relocating	Removal and replanting of live trees and shrubs.
Salvaging	Saving of mercantile timber resulting from the clearing and snagging operation for use by property owner.
Site	The location at which the work is to be performed.
Snagging	Removal of loose and fallen trees, limbs, logs, debris, and stumps.
Soil Bioengineering	The combination of structural, biological, and ecological concepts to construct both living and non-living structures used to prevent shallow slope failures and erosion.
Tree/Branch Revetment	Securing of trees and branches to prevent erosion of channel banks and encourage the deposit of sediment in the area; also helps deflect current into midstream.

Trees	Vegetation with trunks or stalks exceeding 4 inches in diameter as measured at breast height. A stump with numerous branches, trunks, or sprouts shall be considered one tree.
Wood Stake	Triangular stakes made from untreated 2" x 4" timbers.

OVERVIEW

Manual Layout

Each of the following sections in this manual is generally organized as follows:

Description of Technique
Application and Effectiveness
Equipment and Tools Required
Illustration of Technique
Specifications
Details

Specifications are written assuming a PROJECT OWNER, ENGINEER, and CONTRACTOR will be the entities involved in the project. In some sections, imperative or direct language is used without identifying who is to perform the work. In these cases, the statement is directed at the CONTRACTOR unless noted otherwise.

Purpose of this Manual

The purpose of this manual is to provide a practical field guide for the user to be able to reasonably apply, specify, and install soil bioengineering systems. The specifications and details provided may also be used when contracting out the work.

Definition

Soil bioengineering combines structural, biological, and ecological concepts to construct both living and non-living structures that may be used to prevent shallow slope failures and erosion. Woody vegetation is used alone or in combination with simple structures, such as armoring, retaining walls, or buttresses. Vegetative plantings may be used to enhance the structure or provide surface erosion resistance, but offers no structural reinforcement.

General Application of Soil Bioengineering Systems

The soil bioengineering systems presented in this manual were used for the primary purpose of stream bank stabilization, but they may be used in a variety of applications, including:

- Slope protection against surface erosion.
- Slope stabilization.
- Stream bank and shoreline stabilization.
- Dune stabilization.
- Small gulley repair.
- Shallow slope failures (mass slides).
- Wetland buffers.

The advantages of soil bioengineering over conventional slope stabilization techniques (riprap, slope paving, sheet piling, etc.) include:

- More easily installed where access is a problem.
- Utilize inexpensive materials and tools.
- Can be installed by trained volunteer labor.
- More natural and aesthetically pleasing.
- May present a better long-term solution than rigid "engineered" structures.

Engineering expertise may be required to determine appropriate applications at specific sites. These techniques alone may not be sufficient to address massive erosion problems or complex slope failures.

Considerations When Applying Soil Bioengineering Systems

The following factors should be considered before applying soil bioengineering techniques presented in this manual.

Preconstruction

- Schedule work for appropriate time of year (early spring or late fall).
- Select plant species for conformance to requirements (Refer to Table 1).
- Locate and secure source sites for harvesting.
- Define construction work area limits.
- Provide fencing for sites requiring special protection.
- Plan protection for downstream sites.
- Complete and inspect the following preparations:
  - Layout.
  - Clearing, grading, and shaping of banks or slopes.
  - Slope and bench size, shape, angle.
  - Excavation.
  - Disposal of excess gravel, soil, debris.
  - Vegetation to be preserved/removed.
  - Stockpiling of suitable soil and/or rock.

During Construction

- Inspect the plant for quality control:
  - Check all cuttings, remove unacceptable material.
  - Inspect the plant material storage area when in use.

- Inspect each system component, at every stage, for the following:
  - Angle of placement and orientation of the live cuttings.
  - Backfill material.
  - Fertilizer: Type, method, and quantity applied.
  - Lime: Type, method, and quantity applied.
  - Preparation of trenches or benches in cut and fill slopes.
  - Staking.
  - Pruning.

- Ensure that proper maintenance occurs during and after installation.
- Protect downstream sites.

Establishment Period

- Inspect bi-weekly for the first two months. Inspections should note infestations, soil moisture, and plant growth.

- Inspect monthly for the next six months. Systems not in acceptable growing conditions should be noted.

- Necessary reestablishment work should be performed every six months during the initial two- to five-year establishment period.

- Extra inspections should always be made during periods of drought or heavy rains.

Final Inspection

A final inspection should be held two to five years after installation is completed. Vigorous, healthy growing conditions should exist by that time. Satisfactory performance can be gauged as follows:

- Healthy growing conditions in all areas refer to overall leaf development and rooted stems defined as follows:

Live stake	70% to 100% growing
Live fascine	20% to 50% growing
Brush mattress	40% to 70% growing
Biolunker	20% to 50% growing
Live cribwall*	30% to 60% growing
Brush layer*	40% to 70% growing
Branchpacking*	40% to 70% growing
Live gully repair*	30% to 50% growing
Vegetated rock wall*	50% to 80% growing

Vegetated gabion* . . . . . 40% to 60% growing

Joint plantings* . . . . . 50% to 70% growing

* Not included in this manual at this time.

- Growth should be continuous with no open spaces greater than 2 feet in linear systems. Spaces 2 feet or less will fill in without hampering the integrity of the installed living system.[1]

Applicable Vegetation

Many species of trees and shrubs may be used for soil bioengineering systems. Plant species must be suitable for the intended use and adapted to the site's climate and soil conditions. The National Resources Conservation District may be able to assist in selecting plants for a specific site.

Table 2 lists many of the most applicable species for soil bioengineering due to their ability to root easily from cuttings and their long, straight branches.

TABLE 1
Plant Tolerance

Name	Location within U.S.	Availability	Tolerance to Flooding[1]	Tolerance to Drought[2]	Rooting Ability from Cuttings
Cornus amomum Silky dogwood	N, SE	Very Common	Medium	Medium	Very Good
Cornus racemosa Gray dogwood	NE	Common	Medium	High	Good
Cornus rugosa Roundleaf dogwood	NE	Common	---	---	Fair - Good
Cornus sericea ssp. stolonifera Red osier dogwood	N, NE, & NW	Very Common	High	Medium	Very Good

[1] Gray, Donald H and Robbin B. Sotir, *Biotechnical and Soil Bioengineering Slope Stabilization—A Practical Guide for Erosion Control*, John Wiley & Sons, Inc., U.S.A., 1996, pp. 210-211.

[2] USDA-NRCS, *Chapter 18 Engineering Field Handbook*, October 1992, pp. 39-40.

TABLE 1
Plant Tolerance

Name	Location within U.S.	Availability	Tolerance to Flooding[1]	Tolerance to Drought[2]	Rooting Ability from Cuttings
Elaeagnus commutata Silverberry	North Central	Very Common	Low	High	Fair - Good
Physocarpus opulifolius Common ninebark	NE	Common	Medium	Medium	Fair - Good
Robinia pseudoacacia Black locust	NE	Common	Low	High	Good
Rubus allegheniensis Allegheny blackberry	NE	Very Common	Medium	Medium	Good
Rubus strigosus Red raspberry	N, NE, & W	Very Common	Low	Medium	Good
ssp. interior Sandbar willow	N, SE	Common	High	Low	Fair - Good
Salix amygdaloides Peachleaf willow	N, S	Common	High	Low	Very Good
Salix humilis Prairie willow	N, NE	Very Common	Medium	High	Good
Salix lucida Shining willow	N, NE	Very Common	Medium	Medium	Very Good
Salix nigra Black willow	N, SE	Very Common	High	Medium	Excellent
Salix purpurea Streamco Willow	N, S, E, & W	Very Common	High	Medium	Very Good
Salix scouleriana Scoulers willow	NE	Very common	High	Medium	Very Good
Salix X cotteti Bankers willow	N, S, E, & W	Uncommon	High	Medium	Very Good
Salix discolor Red willow	N, NE	Very Common	High	High	Very Good
Sambucus canadensis American elderberry	NE, SE	Very Common	Medium	Medium	Good

TABLE 1
Plant Tolerance

Name	Location within U.S.	Availability	Tolerance to Flooding[1]	Tolerance to Drought[2]	Rooting Ability from Cuttings
ssp. pubens Scarlet elder	NE	Common	Medium	Medium	Fair - Good
Spiraea alba Meadowsweet spirea	N, E	Common	Medium	Medium	Fair - Good
Spiraea tomentosa Hardhack spirea	NE	Common	Medium	Medium	Fair
Symphoricarpos albus Snowberry	N, NW, & E	Common	Low	High	Good
Viburnum alnifolium Hubbiebush viburnum	NE	Fairly Common	---	---	Good

[1] Tolerance to flooding:
- High—severely damaged after 10 to 30 days of flooding.
- Medium—severely damaged after 6 to 10 days of flooding.
- Low—severely damaged after 1 to 5 days of flooding.

[2] Tolerance to drought—Resistance to drought (relative to native vegetation on similar sites) is High, Medium, or Low.

Stream Bank Before Installation of Soil Bioengineering Systems

Stream Bank After Installation of Soil Bioengineering Systems

SPECIFICATIONS

AND

DETAILS

SOIL BIOENGINEERING SYSTEMS

General

1. The measures described in this section are generally referred to as soil bioengineering systems.

Materials

1. Live Materials:
   a. Seasonal limitations: These materials will be harvested and handled during the dormant season between November 1 and May 1 of the following year.
   b. Live cut material shall be collected from sources that have been provided by ENGINEER (see Source Inspections, Live Cut Materials).
   c. Only healthy, well-branched, and disease-free stock shall be acceptable.
   d. The use of equipment such as chain saws, bush axes, loppers, and pruners shall be permitted, provided that they are used in such a manner that they leave clean cuts. Bark stripping shall be avoided. Dead blow hammers or rubber mallets shall be used to tamp the live stakes into the ground, provided that they are used in such a manner that they do not cause wood splitting. Sledge hammers may be used to drive wood stakes into the ground, but may not be used to tamp live stakes into the ground.

2. Dead Materials:
   a. Baling twine: Baling twine may be used to tie the fascines. The twine shall be natural and undyed.
   b. Wood stakes: Wood stakes shall be a minimum of 30 inches long when used in cut sections, and a minimum of 36 inches long when used in fill sections. They are cut to the appropriate length from untreated 2 by 4 timbers. Each length shall be cut again diagonally across the 4-inch face, to make two stakes from each length. The diagonal cut will begin and end ⅛ to ¼ inch from the edge of the piece so the finished stake will have a ⅛- to ¼-inch tip. Only new, sound, unused material shall be used. These stakes shall be used to secure the fascines, brush mattress, or biolunkers.

c. Water: Water used for storage of the live plants during construction shall contain no toxic elements that could be harmful to plant growth. A nearby shaded pond or the creek may be utilized for storage purposes. (See Storage).

d. Wire: Wire used for the purposes of holding down the brush mattress shall be 20 gauge steel wire (i.e., electrical fencing wire).

Source Inspections

1. Live Cut Materials: Live cut native plant materials not provided through a nursery shall be taken from approved, existing, natural, native growing sites. These sites may be located on government and private lands. Written permission must be obtained from all landowners (private or government) two weeks prior to harvesting operations.

Storage

1. The collector shall schedule their cutting and delivery to the site so that the materials can be installed on the day they arrive. Live cuttings or branches not installed on the day of arrival at the job site shall be stored and protected. They may be stored for a maximum of two days. Outside storage locations shall be continually shaded and protected from the wind. Live cut plant material shall be heeled-in moist soils, or kept in water. Live cut materials shall be protected from drying at all times. When the temperature is 50°F or above, the live cut branches shall not be stored, but shall be installed on the day of harvesting. When the live cut branches have been fabricated into building units, such as live stake or similar systems, they shall be used that day. This prepared material may not be stored.

Handling

1. Cutting: Live growing plant material at the harvesting site shall be handled with care to avoid bark stripping and trunk wood splitting. Cuts shall be made 8 to 10 inches from the ground when cutting from the approved, natural growing, source sites. Cuts shall be made flat or at a blunt angle. This ensures that the source sites will regenerate rapidly. The harvesting sites shall be left clean and tidy. At the desire of the landowner, the unused brush and logs may be piled and used for habitat enhancement.

A permission letter must be signed by the landowner allowing access to the site, and removal of vegetation, and stating the condition that the site shall be left. This letter must be signed and given to ENGINEER. All conditions for use and cleanup must be included.

2. Transportation: During transportation, the live cut branch groups shall be placed on the transport vehicles in an orderly fashion, with the growing tips toward the cab of the vehicle (if it is a dump truck type system) to prevent damage and to facilitate handling. The live cut plant materials shall be covered with a tarp or burlap material during transportation.

3. Fabrication: All live system fabrication and preparation is to be done on the project site. It may not be done at the harvesting/source area or other offsite locations.

Construction Requirements

1. Installation of the live structures shall be started when the general excavation and backfill operations are being accomplished. It is intended that each installation be smoothly and securely transitioned into the existing land and the adjacent installations. Sedimentation control shall be considered in all areas prior to bank excavations. Major excavations or lower toe activities will require such controls. These specific activities shall be controlled from damaging downstream sites. The downstream sites shall be protected by the use of local sediment traps, such as rock check dams. Damage may also be greatly reduced by organized fast construction practices. Final top-of-bank grading must ensure that drainage is not occurring indiscriminately over the bank. Water must be properly collected and drained. Final determination of such erosion control measures will be decided onsite by ENGINEER to satisfy local ordinances and state regulations. As onsite changes occur, exact configurations, locations, and quantities of all soil bioengineering and conventional installations shall be determined by ENGINEER.

Compaction

1. Slope compaction: Suitable native fill material around the soil bioengineering systems shall be compacted to the density of the adjacent natural soils.

2. Live construction compaction: Fill placed over and around live cut branches shall be compacted through the use of hand tools, foot tamping, and machine compaction as designated in the Specifications and as directed by ENGINEER. Water compaction shall not be acceptable.

Cleanup, Restoration, and Repairs

1. Debris and vegetation removal: Tree and shrub debris, abandoned silt fencing, concrete, and other debris which shall occur during construction shall be removed and disposed by the CONTRACTOR in accordance with local ordinances.

2. Upper bank disturbance and drainage: All upper bank areas and areas between soil bioengineering systems that have been disturbed by construction activities shall be left smoothly graded and shall have raked in seed with a layer of long straw mulch covering. If necessary, fertilizer lime shall be applied before the mulch covering. They shall also drain properly and shall not drain over the bank indiscriminately.

3. Washouts: Washouts which occur within the onsite construction time period shall be repaired within 48 hours after the occurrence, subject to approval by ENGINEER. All soil or live system losses shall be repaired.

Maintenance

1. Maintenance shall be provided by the CONTRACTOR for a period of one year following final completion and acceptance.

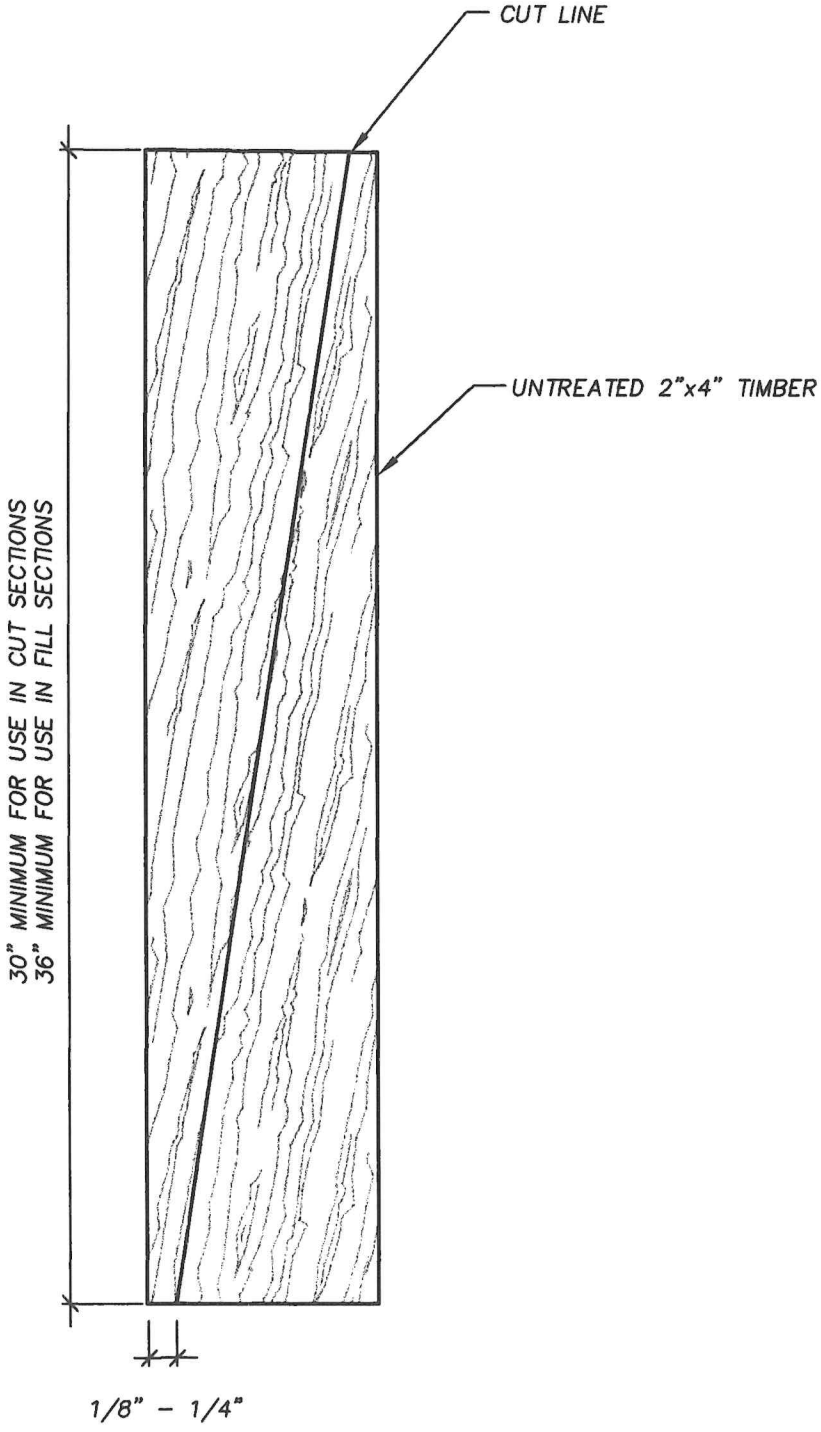
2. Maintenance of new installations shall consist of replacing, weeding, spraying, and repairing of gully erosion or washouts, and keeping installation free of insects and diseases.

3. Stream bank installations shall be reasonably protected against trespassing and damage for the duration of the maintenance period. If any areas become damaged or injured, they shall be repaired or replaced by the CONTRACTOR during the maintenance period and by the OWNER thereafter. No work shall be done within, adjacent to, or over any installed areas without proper safeguards

and protection of the installations. Existing trees and vegetation shall also be protected during construction activities.

4. The CONTRACTOR shall be responsible for keeping all installations and work incidental thereto in good condition by performing all other necessary operations to care for promotion of root growth and plant life so that all Work is in satisfactory and acceptable condition during the first year.

5. The project site, harvesting site, and surrounding areas shall be continuously kept clean when construction installation and maintenance operations are in progress. The entire work area shall be cleaned at the end of each day's work.



WOOD STAKE DETAIL

NO SCALE

fishbeck, thompson, carr & huber
engineers • scientists • architects
Grand Rapids • Lansing • Kalamazoo
Michigan

ftc&h

WILLOW CREEK WATERSHED
STREAM BANK STABILIZATION PROJECT

IMPLEMENTATION PLAN

PROJECT NO.
F95116

FIGURE NO.
1

SITE PREPARATION

Description

Minimal site preparation may be necessary before installation of soil bioengineering techniques. Site preparation may include, but is not limited to:

- Clearing, grubbing, and snagging.
- Channel cleanout.
- Channel side slope reduction.

Application and Effectiveness

Canopy trimming and selective tree removal in heavily shaded areas may increase the success rate of establishing brushy and grassy vegetation as ground cover by allowing sunlight to penetrate through the leaf canopy.

The assistance of an engineer may be necessary to determine the existing capacity of the channel and the need for a channel cleanout.

Where it is possible for heavy equipment to access a site, shaping of a slope or channel bank can facilitate the installation of the soil bioengineering systems.

Equipment and Tools Required

- Chain saw
- Hydrohoe (if access permits)
- Bulldozer (if access permits)
- Shovel

SPECIFICATIONS

AND

DETAILS

SITE PREPARATION

Staking and Identification

1. A preliminary site visit will be conducted by OWNER, CONTRACTOR, and ENGINEER. Trees to be cut shall be marked.

2. The limits of each section of work will be identified prior to commencing work in the vicinity.

Access Road

1. An access road shall be constructed within the drain right-of-way in a manner that will minimize the quantity of trees to be removed and minimize disturbance to the stream bank.

2. Where access to the Work must take place outside of the drain right-of-way, written permission shall be obtained from the affected property owner.

Existing Tile Inlets

1. The location and elevation of existing buried tile inlets shall be verified prior to commencing Work.

Preservation and Protection

1. Facilities such as gas lines, meters, and fences to be preserved shall be protected throughout the construction. Existing trees and vegetation not interfering with the Work shall be protected during the construction period. Those that require removal shall be determined during the preliminary site visit or onsite by ENGINEER.

2. Temporary protection devices such as straw bales and fencing shall be utilized as necessary. They shall be maintained and removed, and the specific and overall areas cleaned up when the construction activities have been completed and the area is stabilized.

CLEARING, GRUBBING, AND SNAGGING

Summary

1. Section includes:
   a. This Section includes, but is not necessarily limited to, the major items listed below as indicated on the Drawings, as specified herein, and as necessary for the proper and complete performance of the Work.
   b. Major items:
      1) Clearing.
      2) Grubbing.
      3) Snagging.
      4) Disposal.
      5) Salvaging.
      6) Relocating.

Definitions

1. Terms:
   a. Clearing: Cutting and removal of trees, brush, and shrubs.
   b. Grubbing: Removal of tree stumps and roots from below ground.
   c. Snagging: Removal of loose and fallen trees, limbs, logs, debris, and stumps.
   d. Disposal: Burning, burial, or removal from site of all debris and woody material that is removed during the clearing, grubbing, and snagging operations.
   e. Salvaging: Saving of mercantile timber resulting from the clearing and snagging operation for use by property owner.
   f. Relocating: Removal and replanting of live trees and shrubs.
   g. Trees:
      1) Vegetation with trunks or stalks exceeding 4 inches in diameter as measured at breast height (DBH).
      2) A stump with numerous branches, trunks, or sprouts shall be considered one tree.

h. Brush: Vegetation with trunks or stalks less than or equal to 4 inches in diameter as measured at breast height (DBH).

I. Mercantile Timber: Trees having a stump diameter of 6 inches or more.

General

1. Limits of Work:
   a. Clear within drain right-of-way for access lane on one side only. Remove only those trees that interfere with execution of the Work.
   b. Clear and snag both sides of channel to top of bank. Trees are to remain if they do not interfere with the flow or the construction process and are not in danger of falling into the drain.
   c. Grubbing is not required except where tree roots interfere with construction.

2. Precautions: Avoid damage to stable, vegetated channel banks, or to trees and shrubs that are not designated for excavation or removal during completion of the clearing, grubbing, and snagging operations.

3. Selective Clearing and Grubbing: In areas where called for on the Drawings. Remove only those trees as designated by ENGINEER.

4. Ownership:
   a. The property owner shall have the option of retaining ownership of any trees that are removed on their property.
   b. The OWNER shall notify the property owner of the schedule for clearing, grubbing, and snagging in order to allow a reasonable amount of time for removal of material by the property owner.
   c. Any trees, stumps, etc., that are not removed by the property owner after a reasonable amount of time will be disposed in accordance with the Specifications.

Clearing

1. Cutting:
   a. General:
      1) Cut trees and brush a maximum of 18 inches above the ground.
      2) Remove tree tops and limbs prior to cutting the entire tree if necessary to avoid damage to adjacent structures or trees that are not designated for removal.
      3) The final cut shall be an even cut, parallel with the ground.
   b. Identification for canopy trimming:
      1) The trees that are specified for cutting shall be marked by ENGINEER.
      2) Cut only marked trees.
      3) Cut trees at height indicated on marked tree.

2. Fruit Trees: Clear only when authorized by ENGINEER.

Grubbing

1. Stump Removal: Unless stumps are specifically designated for chipping, pull the entire stump and roots out from below ground.

2. Utilities:
   a. Notify ENGINEER of all instances in which stump removal may result in damage to existing utilities or culverts.
   b. Be responsible for any damage to utilities that may result from stump removal.

3. Chipping: Where authorized by ENGINEER, stumps may be chipped to a minimum depth of 1 foot below ground in lieu of pulling the stump and roots.

Snagging

1. Access:
   a. Restrict equipment access for snagging operations to areas indicated on the Drawings as designated by ENGINEER.
   b. Equipment shall remain outside of the channel limits unless authorized by ENGINEER.

Disposal

1. General:
   a. Trash and other non-woody material that are removed during the snagging operation: Sort out and dispose in a licensed landfill.

2. Burial:
   a. Trees, brush, stumps, and other woody material may be disposed by burial where authorized by ENGINEER and in areas that do not conflict with present land use.
   b. Bury material in compacted trenches with a minimum of 2 feet of compacted earth cover.
   c. Locate buried trenches a minimum of 10 feet (horizontal) beyond the top edge of the proposed channel bank.

3. Burning:
   a. Woody material may be disposed by burning where authorized by local ordinances and ENGINEER.
   b. Maintain a minimum 200 feet horizontal isolation distance between overhead public utilities or wooded areas and all burning piles.
   c. Bury material that remains following burning or remove from the site.
   d. Burning will not be permitted in areas with combustible organic soils.

4. Debris piles:
   a. Woody material may be placed in debris piles as authorized by ENGINEER and in locations that do not conflict with present land use.
   b. Neatly windrowed debris piles beyond the spoil piles or place in debris piles at intervals of not less than 100 feet.

c. Maintain a minimum clearance of 200 feet (horizontal) between debris piles and overhead public utilities.

d. Floodplains: Secure debris piles to prevent movement of debris during flooding events.

5. Removal: Material that is required to be removed from the site shall become the property of the CONTRACTOR.

Salvaging

1. Mercantile timber:

a. Cut mercantile timber that is designated for salvaging into 8-foot lengths or lengths as designated by ENGINEER.

b. Avoid damage to materials designated for salvaging during clearing, grubbing, and snagging operations.

2. Material for tree revetments and soil bioengineering systems: Branches used for current deflectors and in soil bioengineering systems shall be salvaged from live trees designated for cutting.

Maintenance

1. Clear, grub, and snag trees that become unstable (lean) or fall into the drain between completion of the work and final completion.

2. OWNER: Perform inspection annually to remove deadfalls and grub woody vegetation in the centerline of the channel. Additional trimming shall be performed as necessary to maintain partial sun conditions on the stream banks.

OPEN CHANNEL EXCAVATION AND SLOPE REDUCTION

Summary

1. Section Includes: This Section includes, but is not necessarily limited to, the excavation of open channel drains as indicated on the Drawings, as specified herein, and as necessary for the proper and complete performance of the Work.

Definitions

1. Excavated materials:
    a. Earth:
        1) All materials which can be excavated with equal facility by equipment used for normal earth excavation. Examples include, but are not limited to:
            a) Common materials such as sand, clay, loam, gravel, silt, and stones less than ½ cubic yard in volume.
            b) Organic materials such as muck, peat, and marl.
            c) Rock-like material that is fragile, friable, or fragmented.
    b. Other:
        1) Natural items, such as trees, stumps, logs, brush, shrubs, and other vegetation.
        2) Man-made items, including but not limited to:
            a) Surface items, such as bituminous and concrete paving, curb, headwalls, and the like.
            b) Underground items, such as pipes, culverts, manholes, catch basins, foundations, walls, chambers, refuse, and the like.

Open Channel Excavation

1. Location: Excavate existing channels from one side only with the intent to incur minimal disturbance to the opposite bank.

2. Tolerance:
   a. Excavation of the open channel drain shall conform to the horizontal and vertical alignment indicated on the Drawings.
   b. The completed cross-section shall not be more than 0.2 foot above or 1.0 foot below the plan elevation without the prior approval of ENGINEER.
   c. The finished bottom grade shall not be greater than 0.5 foot below the plan elevation within 300 feet upstream or downstream of structures or enclosures.

3. Spoil banks:
   a. Spoil material not used elsewhere on the project shall be placed within the right-of-way and leveled.
   b. Location:
      1) On one side of channel only unless indicated otherwise on the Drawings.
      2) Away from existing tributary water courses or drains.
      3) Away from landscaped areas.
      4) Away from the trunks of trees.
      5) Maintain a 12-foot buffer strip between the top of the channel bank and the edge of the spoil pile unless indicated otherwise on the Drawings.
   c. Grading:
      1) Grade spoil banks to a minimum 4 on 1 side slopes away from the drain in open areas and a minimum 2 on 1 side slopes in wooded areas unless indicated otherwise on the Drawings.
      2) Level spoil to allow broad, flat drainage ways to enter the drain without the ponding of surface water behind the spoil banks.

4. Side inlets: Required where concentrated surface runoff enters the drain.

5. Tributaries:
   a. Grade tributaries at a constant slope away from the drain excavation throughout the limit of the available right-of-way or 75 feet, whichever is less.
   b. Begin tributary grading at the proposed drain elevation and meet the existing grade at the limit of the regrading.

c. Regrade the tributary to a bottom width equal to the existing bottom width. Regraded channel side slopes shall be a minimum of 2 on 1.

VEGETATIVE PLANTING

Description

Vegetation creates a living root system that stabilizes the soil by reinforcing and binding soil particles together.

Application and Effectiveness

Although vegetative plantings are not soil bioengineering systems, when placed along the top of stream banks, they may be very effective at binding the soil together.

Vegetation can also be used in conjunction with structures to provide additional surface cover. The Natural Resources Conservation Service or the Soil Conservation District in the area can help you select appropriate species of plants.

Equipment and Tools Required

- Shovel
- Tree planting tool
- Gloves
- Fertilizer (if required)
- Mulch
- Stakes
- Cable

Volunteers Planting Vegetation Along the Top of Bank

Planted Stream Banks with Mulch

SPECIFICATIONS

AND

DETAILS

VEGETATIVE PLANTING

Trees

1. Materials:
   a. Container-grown plants shall have grown in the container for not more than one growing season. If plants have been in the container too long they will show "pot-bound" root ends.
   b. Balled and burlapped plants shall be planted prior to "bud break". If planted in the fall, balling operations shall not begin until after the plants have begun to "harden off". All plants shall be dug and transported so that the ball is moist, and protected from rain or sudden changes in the weather.
   c. Bare-root plants shall only be handled in early spring, late fall, or late winter. These plants shall meet the following criteria to prevent a high rate of mortality.
      1) Seedlings shall be fresh smelling. Sour odor indicates that the seedlings have been stored too long and have begun to rot. Trees stored at correct temperatures will be free of mold.
      2) The roots shall be moist and glistening white when stripped of bark. Using a knife or fingernail, strip the bark off the root, working from base to tip. If the roots appear yellow, brown, or have brown spots, the stock is badly damaged and has little chance of survival. Check the roots of several seedlings.
      3) Buds shall be firm, with no evidence of new growth.
      4) Seedlings shall be packed and shipped in wet moss or other medium, and kept cool (less than 34°F) and moist prior to and throughout the planting process. Moss-packed seedlings shall be kept in their container and kept moist. Clay-packed seedlings shall not be watered, but shall be covered with burlap if they are not to be planted soon after they are purchased.
      5) Packages of seedlings shall be stored in a shaded location out of the wind.
      6) Seedlings shall be planted as soon as possible after they are received. If planting is delayed longer than four days after seedlings are received, "heel" the seedlings in a shaded area and keep moist. To heel in seedlings, dig a trench in soil that is shaded or in a well-ventilated enclosure. Place seedlings in the trench and cover the roots with soil. Replanting shall occur when planting conditions allow.

2. Site Preparation: A hole shall be dug at least deep enough and wide enough to hold the entire root ball. The final level of the root ball's top shall be level with the ground surface. Topsoil shall be kept separate from the subsoil. If the soils are clay, a deeper hole shall be dug and backfilled with some of the topsoil.

3. Trees in containers and burlap shall be planted individually. Follow the steps below:
   a. Trees in containers shall be removed carefully so that all roots and soil remain attached. It may be easiest to cut the container. On balled and burlapped trees, loosen the twine and burlap at the top and check to make sure no other wrapping is present before planting.
   b. Depending on the type of subsoil, it may be beneficial to mix a little peat moss into the soil.
   c. The dug hole shall be such that the plant is planted at the same depth as the original container.
   d. Water shall be added to settle the soil and eliminate air pockets. Once the water is drained off, the tree shall be lowered into the hole, backfilled half way, and patted firm. Water again. Once the water is drained again, the burlap shall be removed from ball and burlapped trees from around the trunk and the upper half of the ball. The hole shall be filled so that it is even with the ground line.
   e. The hole shall be backfilled and the soil shall be compacted firm. A small depression shall be left around the tree so that water can run into the depression.
   f. A fertilizer shall be used when planting trees:
      1) Fertilizer: Osmocote 18-5-11, 12- to 14-month release; or Agriform 20-10-5, 2-year release.
      2) The fertilizer shall be in 10-gram tablets.
   g. Mulch shall be added around the tree to reduce competition from unwanted vegetation and to help prevent roots from drying out. Mulch will also prevent soil erosion from occurring around or between trees.
   h. Bare-root seedlings shall not be pruned prior to planting, except for broken or damaged roots. Plants will be planted by hand.
   I. Plants shall be set at a depth equal to the depth in their original location. The exposed roots shall be held firmly in the proper position, with the roots spread out. The prepared soil shall be watered around the roots and thoroughly firmed at intervals during the process of backfilling. Sufficient water shall be used to ensure the soil is thoroughly saturated.

4. Spacing: Trees shall be spaced at 10-foot intervals unless indicated otherwise on the Drawings.

5. Plants located on slopes: For plants located on slopes, a berm of prepared soil shall be constructed halfway around each plant on the down-slope side. The berm of prepared soil shall have an inside diameter equal to that of the planting hole, and a maximum height of 6 inches. Soils shall not spill down-slope more than 18 inches.

6. Wrapping trees: Trees shall be wrapped within one week following planting. Trunks shall be carefully wrapped beginning at the base of the trunk just above the roots and below the normal ground line, and shall extend upward in a spiral with an overlap of one-half the width of the strip. The portion of the wrapping below the finished grade shall be covered with soil. The paper shall be held securely in place with masking tape.

7. Staking trees: Newly planted trees often need to be staked for support. Trees which need to be staked shall be secured with stakes and guy wires. The tree shall be cushioned against the wire by placing old garden hose or equivalent between the tree and wire.

Shrubs

1. Site preparation and planting:
   a. Follow the tree planting procedures for "Trees in containers and burlap", above.
   b. Mulch the entire area to keep other plants from competing with the desired plant and to cover exposed soil.

2. Spacing: Shrubs shall be spaced approximately 5 feet apart unless indicated otherwise on the drawings.

Ground Covers

1. Site preparation: The dense growth of ground covers requires that they have good soil. Well-drained soils high in organic matter work best. On steep slopes, individual holes shall be dug for each plant.

2. A fertilizer shall be used when planting ground covers:
   a. Fertilizer: Osmocote 18-5-11, 12- to 14-month release; or Agriform; or 20-10-5, 2-year release.
   b. The fertilizer shall be in 10-gram tablets.

3. Planting:
   a. Most ground covers are planted from container-grown nursery stock. Transplanting to the prepared soil bed can be done using a small trowel or spade. A hole shall be dug large enough to accommodate the roots and soil. The soil shall be backfilled and firmed around the plant. Water immediately.
   b. Mulching around ground cover is necessary to better protect the ground cover from competitive species.

4. The plants shall be spaced 18 inches apart unless indicated otherwise on the Drawings.

Maintenance

1. Maintenance shall be provided by the CONTRACTOR for a period of one year following final completion and acceptance.

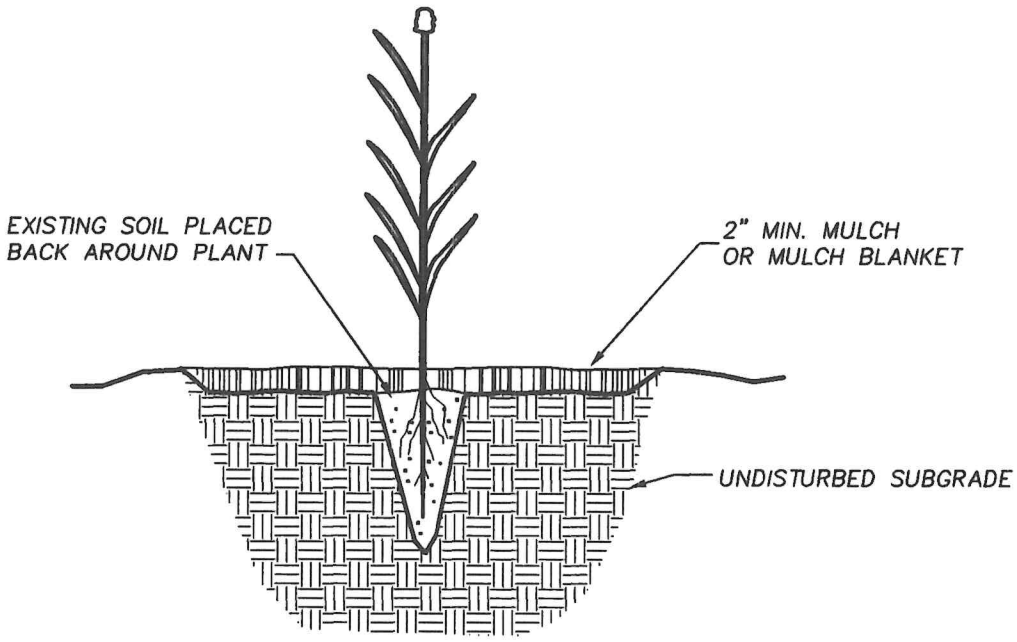
2. New plantings:
   a. Survival shall be checked the first year and replanting shall occur where survival is poor.
   b. Competing vegetation shall be controlled as needed.
   c. Livestock shall be excluded from all plantings.

2. Trees: Seedlings are subject to competition with invading grasses and other vegetation. Mulch to prevent competition, or mow or clip competitive vegetation, where possible. Herbicides shall be used only where mulching has failed and mowing and clipping are not possible.

3. Shrubs: Mulch shall be maintained around the base of each plant to reduce weed competition and retain moisture. Pruning shall be done as needed to remove dead limbs.

4. Ground covers: Most ground covers need yearly trimming to promote growth. Trim back from trees, flower beds, fences, and buildings. Additional mulch shall be added as needed until the area is completely stabilized.

5. Organic debris disposal: Any organic debris which results from pruning, trimming, or any other vegetative maintenance shall be disposed within drain right-of-way so that no interference with the channel occurs.



VEGETATIVE PLANTING DETAIL

NO SCALE

BARE ROOT STOCK

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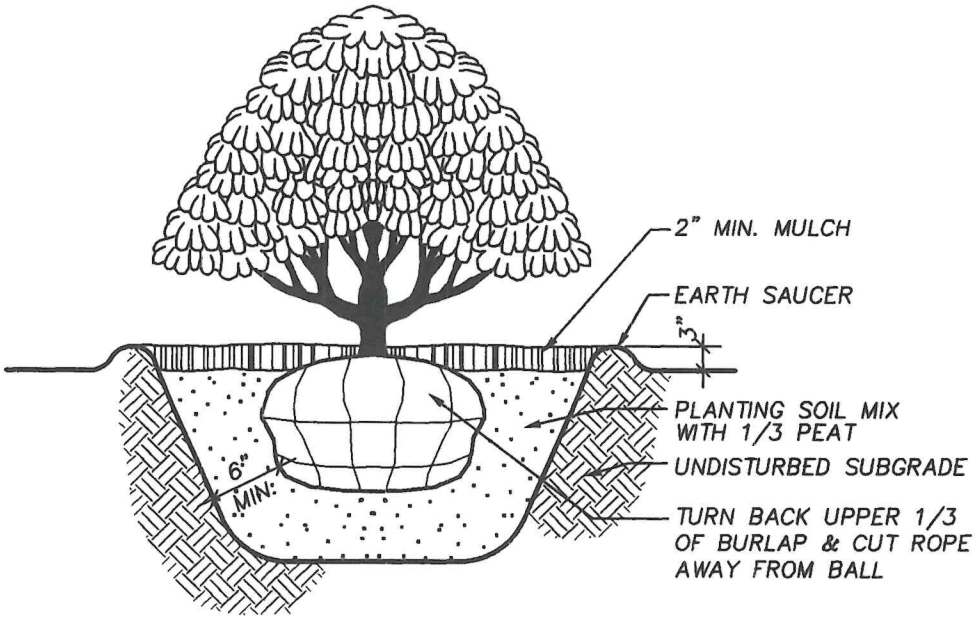
WILLOW CREEK WATERSHED
STREAM BANK STABILIZATION PROJECT

IMPLEMENTATION PLAN

PROJECT NO.
F95116

FIGURE NO.
1



VEGETATIVE PLANTING DETAIL

NO SCALE

BALLED STOCK

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engineers • scientists • architects
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Michigan

fc&h

WILLOW CREEK WATERSHED
STREAM BANK STABILIZATION PROJECT

IMPLEMENTATION PLAN

PROJECT NO.
F95116

FIGURE NO.
2

SEEDING

Site Preparation

1. Areas to be seeded shall be protected from pedestrian access.

2. Concentrated flows shall be diverted away from the area to be seeded at least until the vegetation is established.

3. A 3- to 5-inch-deep seed bed shall be prepared. The top 3 to 4 inches shall consist of native topsoil. Note that the earth bed upon which the native topsoil is to be placed shall be at the required grade.

4. The seed bed shall be firm but not compact. The top 3 inches of soils shall be loose, moist, and free of large clods and stones. For most applications, all stones larger than 2 inches in diameter, roots, litter, and any foreign matter shall be raked and removed.

5. Slopes steeper than 3:1 shall be roughened.

Materials

1. Seed:
   a. Uniform mixtures composed of seed of the following proportions by weight
      1) Loamy Soils:
         USDA NRCS Seeding Mix No. 8
         34% Creeping Red Fescue
         10% Kentucky Bluegrass
         2% Redtop
         34% Tall Fescue
         3% Timothy
         17% Birds Foot Trefoil

2) Sandy soils:

USDA NRCS Seeding Mix No. 15

40% Creeping Red Fescue

8% Perennial Rye Grass

2% Redtop

20% Smooth Bromegrass

30% Tall Fescue

b. All legumes shall be inoculated with the proper nitrogen fixing bacteria within 24 hours prior to seeding.

c. Germination of all seeds shall be 80% minimum.

d. Purity of all seeds shall be 90% minimum.

Planting

1. Seed shall be applied after seed bed preparation when the soil is loose and moist. If the seed bed has been idle long enough for the soil to become compact, the topsoil shall be harrowed with a hoe by hand. Harrowing shall be done horizontally across the face of the slope.

2. Seed shall be applied before mulch.

3. Seed shall be applied at a minimum rate of 100 pounds per acre. If seed is planted after October 1, seed rate should be increased by 10% to 25%.

4. Broadcast seed shall be incorporated into the soil by raking or chain dragging, or otherwise floated, then lightly compacted to provide good seed-soil contact.

5. All newly seeded areas shall be protected from erosive forces by mulch.

6. Species of grasses which cannot be planted with seed shall be planted by sprigging or sodding.

7. Excess native topsoil shall be used as needed in other stream bank areas. The unusable native top soil will be disposed in drain right-of-way and leveled.

Maintenance

1. Newly seeded areas need to be inspected frequently for the first few months to ensure the grass is growing. If the seeded area is damaged due to runoff, additional storm water measures may be needed. Spot seeding can be done on small areas to fill in bare spots where grass did not grow properly.

MULCHING

General

1. Mulch shall be applied immediately after seeding or vegetative planting has occurred.

Materials

1. All seeded or vegetative planted areas shall be mulched using one of the mulching techniques below.

2. Organic mulches are more effective and less likely to impact the environment than manufactured mulches, and are therefore recommended for most uses.

3. Choose from the following types of mulch. Application rates are given for each type of mulch.
   a. Straw: Straw is the most commonly used type of mulch, is readily available in most areas, and is effective when applied properly. Use small grain straw (wheat or oat) that is reasonably free of grain and weed seeds or mold. Straw of winter rye is preferable to spring-seeded grains, since fewer weed seeds generally are present. On critically eroding areas, spread uniformly at the rate of 2.5 to 3 tons per acre (2 to 3 bales per 1,000 square feet). Under normal applications, use 1.5 to 2 tons per acre. Hay shall only be used if straw is not available.
   b. Long Straw Mulch: Long straw shall be spread evenly by hand 1.5 to 2 inches deep. The straw or hay shall not be chopped up, nor will it be "blown" on. This shall be hand spread and used on all construction disturbed upper bank sections where soil bioengineering systems end. Long straw shall not be utilized alone in the lower elevation river areas, but on the upper banks. It shall be performed as designated on the Drawings, and as directed by ENGINEER. These areas shall be fertilized, limed, seeded, and lightly raked in ¼ inch prior to long straw application.
   c. Mulch Blankets: Mulch blankets shall be made of a uniform layer of straw or other material (i.e., coconut fibers) and shall have a net covering on only one side. The straw and net shall be securely stitched together to create a uniform mat. The straw shall be clean

wheat straw free of weeds and weed seeds. All components, including the stitching, shall break down within the first growing season after placement.

d. Excelsior Blankets: Excelsior blankets are made up of coarse wood fibers reinforced by netting. They are most commonly used in drainage ways and other critical areas which will be exposed to concentrated flows during storms. The excelsior shall consist of evenly distributed wood fibers. The top of the blanket shall be covered with netting.

e. Compost: Compost (humus) can be used as mulch.

4. The mulching application rates given above can be increased for dormant seeding.

5. Anchoring shall be done at the time of or immediately following the application of the mulch. The appropriate type is dependent upon the type of mulch selected.

a. Mulch Blankets: Below are some generic types of mulch blankets, also called nets and mats, which are effective in preventing erosion on both raw and seeded areas. Their specific applications differ depending on the soil type and the slope of the area being protected.

1) Mulch netting: This is a light-weight, fibrous material used to secure straw mulch where heavy flow is expected. Use bio- or photo-degradable products.

2) Mulch with netting in combination (mulch blanket): This is a roll of mulch with netting bound on either side. Because the mulch and netting are in one roll, installation is much easier than applying mulch and then securing a netting in a separate step. These must be anchored with staples or wooden pegs.

3) Mulch, netting, and seed in combination. This is a roll of mulch bound on either side by netting, with seed mixed in. This allows the user to merely prepare the seed bed and install the blanket. These must also be anchored with staples or wooden pegs.

b. All mulch nettings shall be made of a polypropylene or jute mesh that will gradually decompose with exposure to sunlight.

Implementation

1. Seed bed preparation shall be in accordance with the section on seeding.

2. The seed shall be applied before mulching except for mulch blankets which already contain seed.

3. The mulch shall be applied uniformly according to the rates determined above.

4. Mulch blankets:
   a. Mulch blanket type shall be selected by ENGINEER.
   b. Mulch blankets shall be applied with the netting side of the blanket on the top side. Lay the downstream or down-slope blankets first, working upstream or upslope. Follow manufacturer's Specifications.

5. Where more than one width is required, and on ends, provide a minimum 4-inch overlap (or more based on the manufacturer's recommendations). Blankets shall be secured with U-shaped wire staples of a size and length suited to the soil condition. Follow the manufacturer's Specifications.

Maintenance

1. Mulched areas shall be checked following each rain to ensure the mulch is staying in place. Additional tacking materials or netting may need to be applied to hold the mulch in place.

2. Maintenance procedures shall also be followed for the best management practices (BMPs) which are implemented to keep eroded soil or concentrated runoff away from the mulched area. Follow maintenance procedures for the appropriate BMPs.

LIVE STAKE

Description

Live staking involves the insertion and tamping of live, rootable vegetative cuttings into the ground. If correctly prepared and placed, the live stake will root and grow.

A system of stakes creates a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. Most acceptable species root rapidly and begin to take up moisture from a slope soon after installation.

Applications and Effectiveness

- A technique for relatively uncomplicated site conditions when construction time is limited and an inexpensive method is necessary.
- An appropriate technique for repair of small earth slips and slumps that are frequently wet.
- May be used for pegging down surface erosion control materials.
- Enhances conditions for natural invasion and the establishment of other plants from the surrounding plant community.
- Can be used to stabilize intervening area between other soil bioengineering techniques, such as live fascines.[2]

Equipment and Tools Required

- Chain saw
- Rubber mallet
- 0.5-inch-diameter metal rod

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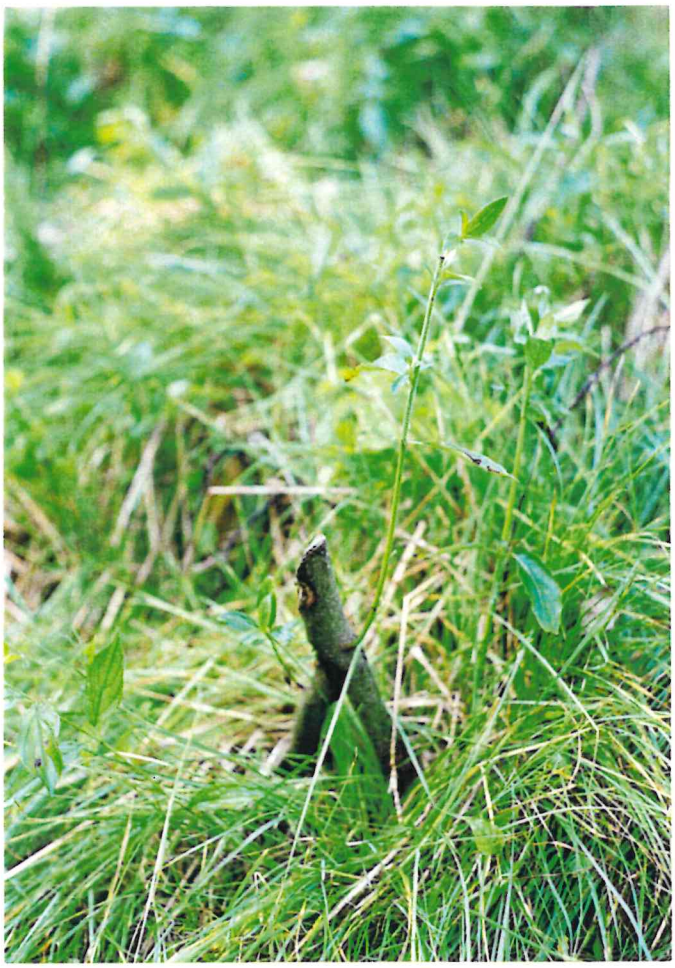
[2]USDA-NRCS, *Chapter 18—Engineering Field Handbook*, October 1992, p. 15-16.

Live Stakes Before Installation

Installation of Live Stake
(Note rubber mallet being used to tamp stake into place.)



Sprouting Live Stake

SPECIFICATIONS

AND

DETAILS

LIVE STAKE

Installation

1. Live stakes shall be used alone or as part of live fascines, long straw mulch, brush mattress, biolunkers, and fiber rolls.

2. Live staking shall be performed as designated on the Drawings and Specifications and as directed by ENGINEER.

Materials

1. Live stakes shall be made from acceptable vegetative species.

Sizes

1. The live branches or sticks which shall be trimmed and cut to length for this construction technique, shall be 2.5 feet long on all sections. The stake shall be 0.5 to 1.5 inches in trunk diameter.

Fabrication

1. All side branches shall be cleanly removed from the live branch stakes. They shall be cut flat on top and at an approximate 45-degree angle on the bottom end for easy tamping into the ground.

2. They shall be from species indicated on the site Drawing or by the ENGINEER.

Placement

1. Live stakes shall be installed directly into the ground. They are tamped into the ground, with the growing tip directed downstream. They shall protrude approximately 3 inches from the finished ground elevation. Immediately after each live stake has been tamped into the ground to the final depth, it shall be foot compacted around the stake. On the sloped areas they should be placed at right angles to the slope face. Live staked areas on top of the slope over the crown, shall be long

straw mulched 1.5 to 2 inches deep, behind the brush mattress installations. In between the brush mattress, the long straw mulch shall be 1.5 inches deep, covered with jute mesh, and the area shall be live staked. In cases where the ground is hard or when designated by ENGINEER, a pilot hole using an 0.5- inch metal rod may be made to assist in inserting the live stake. This rod may not be larger than 0.5 inch outside diameter. The rod must be removed carefully and may not be used to engage the hole.

Density

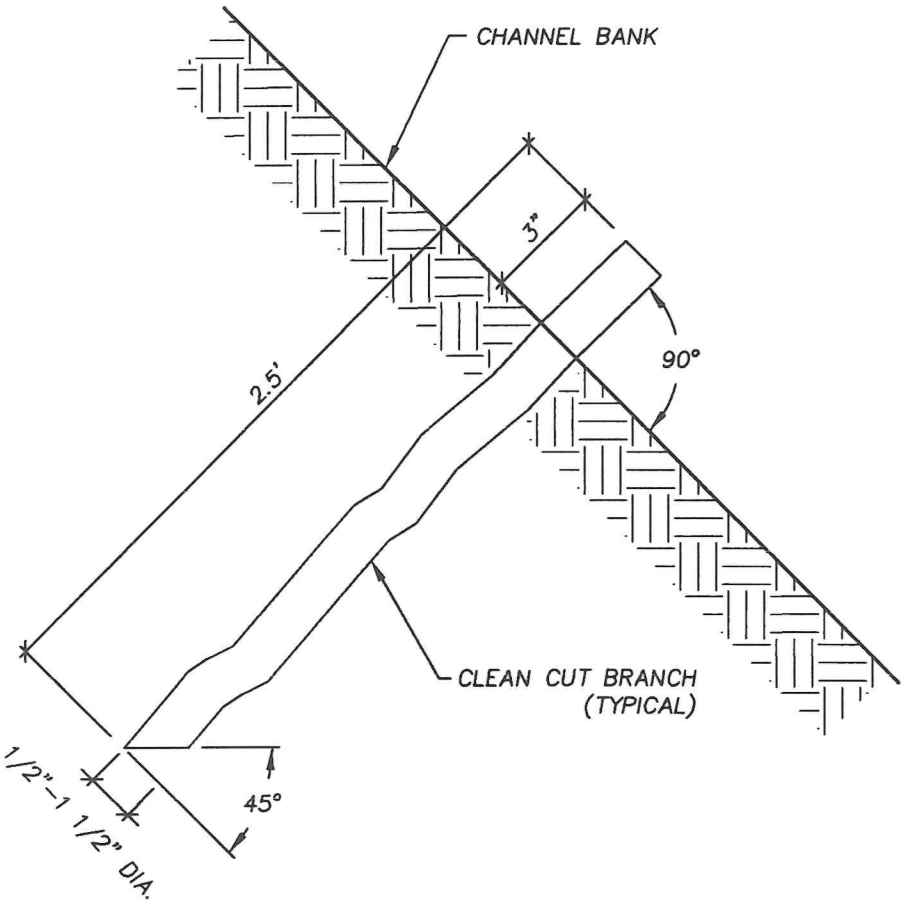
1. The stakes shall be placed on 2- to 3-foot centers, or as determined by ENGINEER.

Angles

1. The stakes shall be tamped into the ground at right angles to the slope face, with the protruding end directed downstream.

Maintenance

1. As specified in Section - Soil Bioengineering Systems.



NOTE: PROTRUDING END IS DIRECTED DOWNSTREAM

LIVE STAKE DETAIL

NO SCALE

PROJECT NO. F95116 FIGURE NO. 1	WILLOW CREEK WATERSHED STREAM BANK STABILIZATION PROJECT IMPLEMENTATION PLAN	fishbeck, thompson, carr & huber engineers • scientists • architects Grand Rapids • Lansing • Kalamazoo Michigan

LIVE FASCINE

Description

Live fascines are long bundles of branch cuttings bound together into sausage-like structures.

When cut from appropriate species and properly installed with live stakes and wood stakes, they will root and immediately begin to stabilize slopes. They should be placed in shallow contour trenches on dry slopes; and at an angle on wet slopes to reduce erosion and shallow face sliding.

Application and Effectiveness

- An effective stabilization technique for slopes.
- Protects slopes from shallow slides (1- to 2-foot depth).
- Immediately reduces surface erosion or rilling.
- Suited to steep, rocky slopes, where digging is difficult.
- Capable of trapping and holding soil on the face of the slope, thus reducing a long slope into a series of shorter slopes.
- Enhances vegetative establishment by creating a microclimate conducive to plant growth.[3]

Equipment and Tools Required

- Chain saw
- Rubber mallet
- Sledge hammer
- Shovel
- Twine
- Buck horses
- Wood stakes
- Hydrohoe (if necessary to prepare site and if access permits)

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[3]USDA-NRCS, *Chapter 18, Engineering Field Handbook*, October 1992, p. 18.

Placing Material in Sawbucks

Tying Twine Around Material

Assembled Fascine

Trench for Fascines

Placing Fascines/Wood Stakes

Placing Live Stakes Through Covered Fascine

Sprouting Fascine

SPECIFICATIONS

AND

DETAILS

LIVE FASCINE

Installation

1. Live fascine construction shall be placed on contour and parallel to the creek on prepared slopes as designated on the Plans and Specifications, and as directed by ENGINEER. They shall be installed directly into trenches excavated at the toe of the channel slope above normal flow conditions.

Materials

1. The live fascines shall be composed of branches from acceptable species.

Size Ranges

1. The live branches to be used for the construction of live fascines shall be made from soft branching material and have all growing tips in the same direction. All soft brushy branches shall be retained in the construction. Each branch shall be a minimum of 6 feet long and have a maximum trunk diameter of 1 inch. The live stakes used to secure the fascine are considered part of this construction.

Fabrication

1. The tied live fascine shall be 6 inches in diameter and shall resemble a sausage-like structure. The live fascine shall be tied together securely every 12 inches. The fascine size shall be uniform and tidy in appearance. The fascines should be prepared in lengths of 15 feet or longer.

System Excavation

1. Live fascine trenches shall be dug 7- to 8-inches deep, and 7- to 8-inches wide. The live fascine shall be installed directly in the trench. They are installed so as to leave just the top of the live fascine slightly exposed when native fill material has been tamped in place and the installation has

been completed. The fascine may be completely covered with fill for fall installations to provide added insulation over the winter months

Placement

1. The live fascine shall be placed in the trench and native fill shall be placed in and around the live fascine. The fascine shall be securely staked vertically every 3 feet with a wood stake, directly through the bundle. Additionally, under the fascine on the downslope side, a live stake shall be installed every 3 feet, at an angle to the vertical, in between the previously described wood stakes. The wood stakes shall be installed flush with the top of the fascine. The live stakes shall protrude above the finished ground elevation 3 inches.

System Backfill

1. When backfill operations are completed, the live fascine should be a continuous row of bundled branches just slightly above the ground. Where excessive sediment deposition is expected, the live fascine may be installed more shallowly. This shall be determined onsite by ENGINEER. Special care shall be taken to ensure that the approved native material is filled in around the branches, the fascine, and each wood stake. The backfill shall be well compacted by foot and with wood stakes. Water compaction shall not be acceptable.

Fiber Rolls

1. Fiber rolls may be used in lieu of dead wood fascines at the toe of the channel bank or in other soil-bioengineering system installations.
   a. Manufacturer: *Bon Terra, Biologs*; or equal.
   b. The fiber rolls shall be obtained from the manufacturer and stored onsite until installed.
   c. Installation: Fiber rolls shall be placed on contour and parallel to the creek on prepared slopes as designated on the Drawings and Specification, and as directed by ENGINEER. They shall be installed directly and in native fill material lined trenches over the top of the bank and on the face in the upstream and downstream segments of the project.

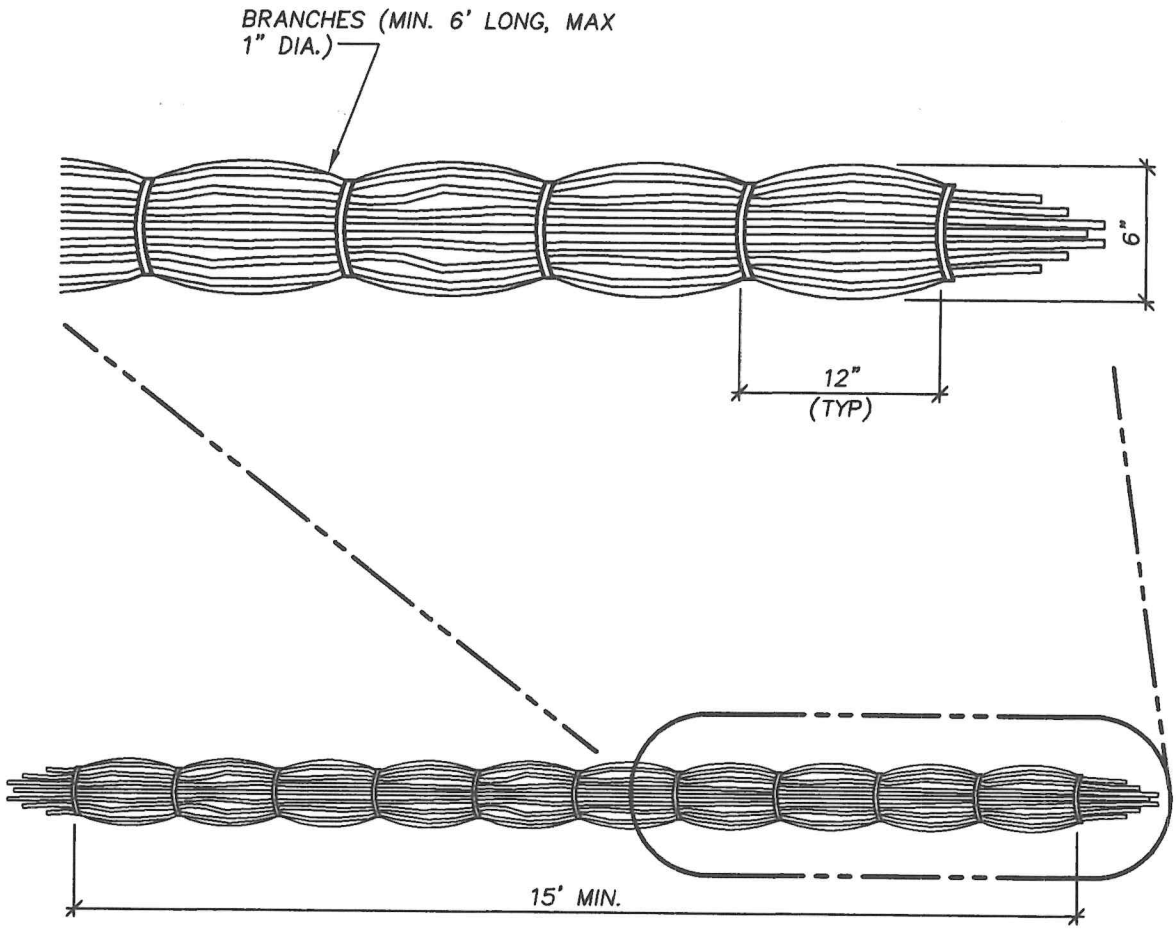
d. System excavation: Fiber roll trenches shall be dug 7 to 8 inches deep, and 7 to 8 inches wide. The fiber rolls shall be installed directly. They shall be installed so as to leave slightly exposed when native fill material has been tamped in place and the installation has been completed.

e. Placement: The fiber roll shall be placed directly in the trench. Native fill shall be placed around the fiber roll. The fiber roll shall be securely staked with wood stakes.

f. System backfill: Depth of installation shall be determined by ENGINEER onsite. Special care shall be taken to ensure that the native fill material is filled in around the fiber roll and wood stakes. The backfill shall be well compacted by foot and with wood stakes. Water compaction shall not be acceptable.

Maintenance

1. As specified in Section - Soil Bioengineering Systems.



FASCINE DETAIL
NO SCALE

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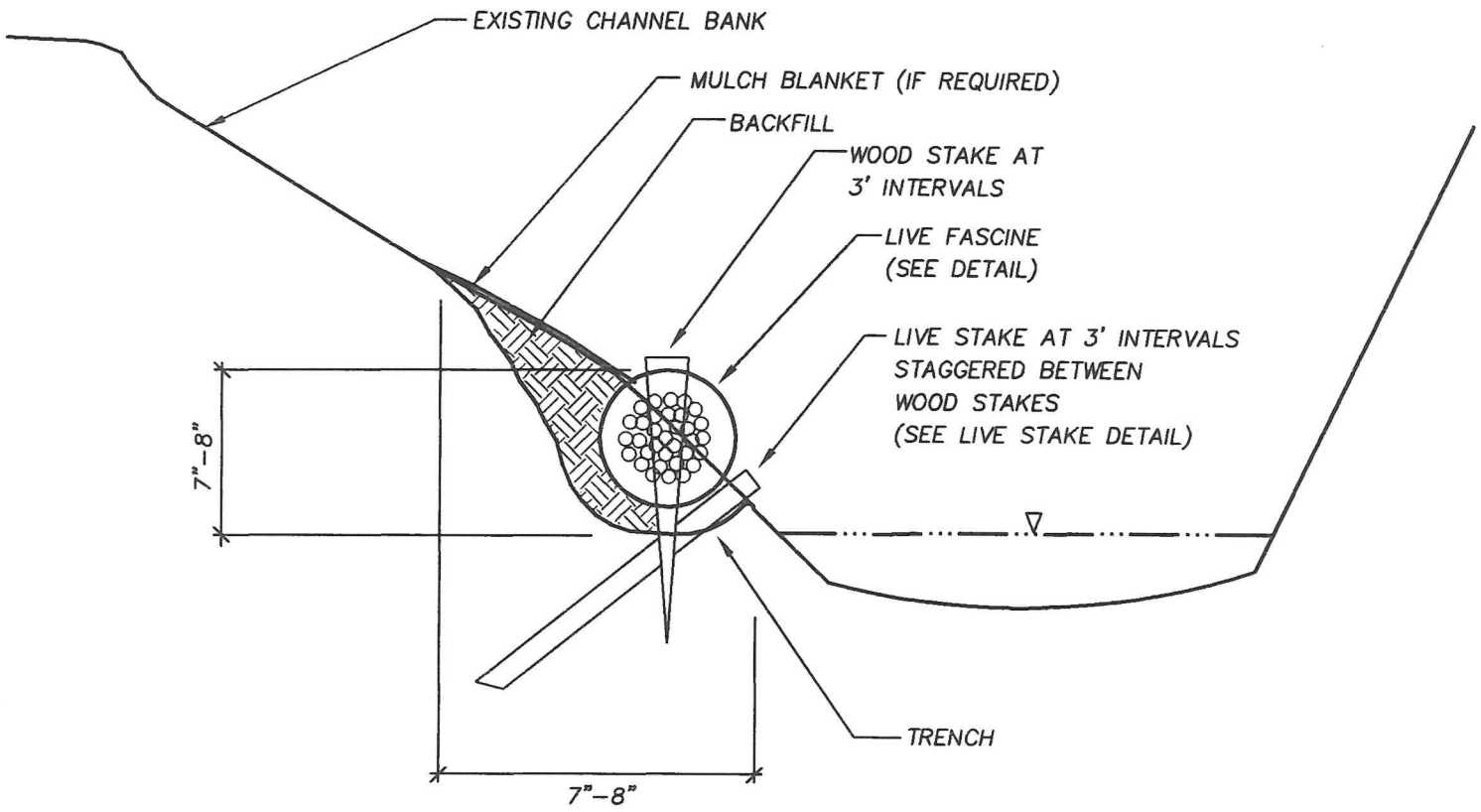
WILLOW CREEK WATERSHED
STREAM BANK STABILIZATION PROJECT

IMPLEMENTATION PLAN

PROJECT NO.
F95116

FIGURE NO.
1



LIVE FASCINE INSTALLATION DETAIL

NO SCALE

2	PROJECT NO. F95116 FIGURE NO.	WILLOW CREEK WATERSHED STREAM BANK STABILIZATION PROJECT IMPLEMENTATION PLAN

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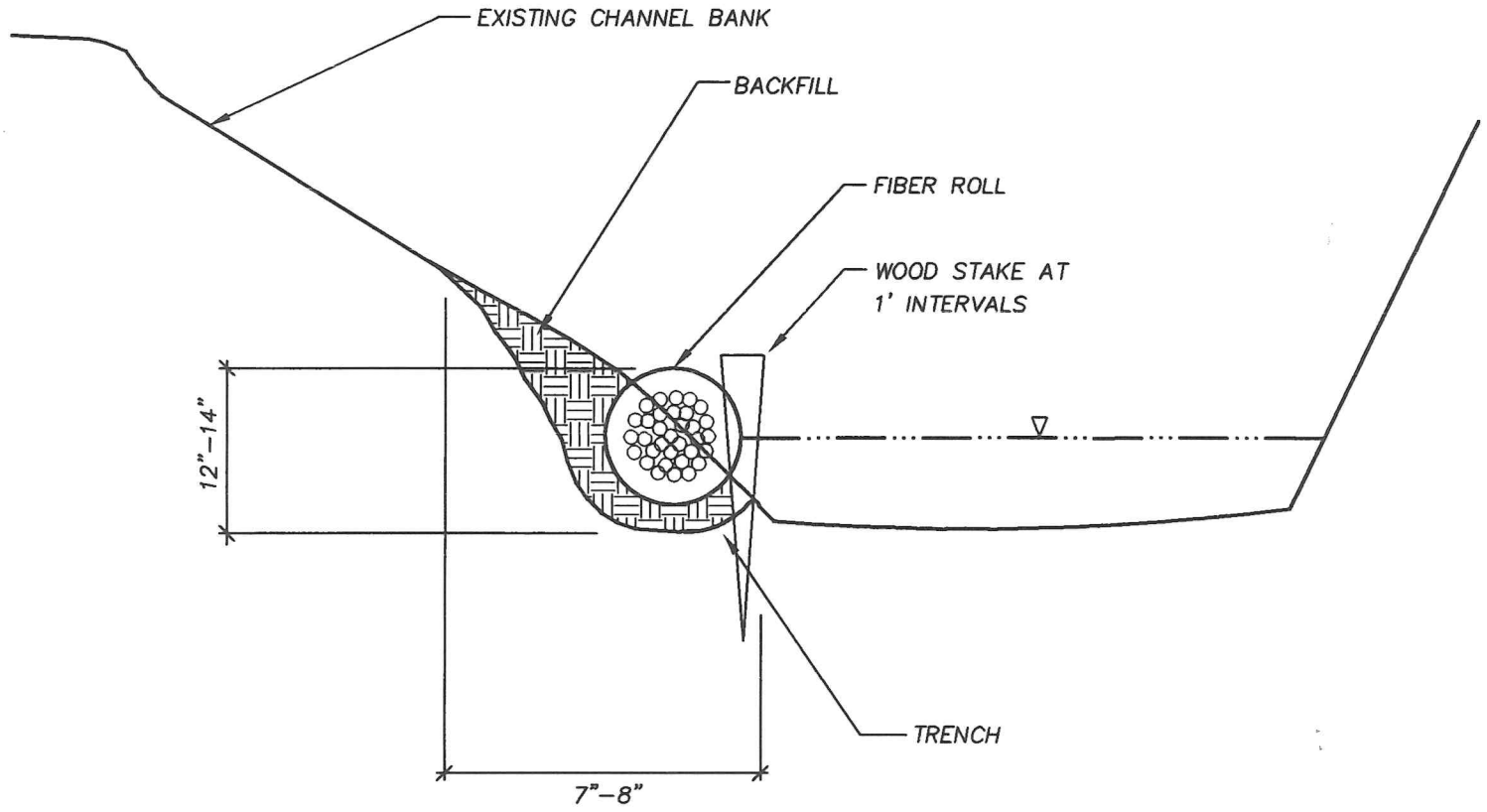
FIBER ROLL INSTALLATION DETAIL

NO SCALE



3

PROJECT NO. F95116
FIGURE NO.

WILLOW CREEK WATERSHED
STREAM BANK STABILIZATION PROJECT

IMPLEMENTATION PLAN

fitch

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BRUSH MATTRESS

Description

Brush mattresses combine live stakes, live fascines, and brush to provide a mattress-like covering of bare banks. The brush mattress aids in reinforcing the soil with the unrooted branch stems, as well as providing slope stability and allowing vegetative cover to become established. The brush mattress may also redirect and mitigate adverse slope seepage by acting as horizontal drains.

Applications and Effectiveness

- An effective stabilization technique for bare banks.
- Reinforces bare banks.
- Redirects and mitigates adverse slope seepage.
- Acts as a horizontal drain.
- Provides slope stability.

Equipment and Tools Required

- Chain saw
- Buck horses
- Twine
- Wood stakes
- Wire
- Rubber mallet
- Sledge hammer
- Shovel
- Hydrohoe (if necessary to prepare slope and if access permits)

Staking Site with Wood Stakes

Placing Fascines

Placing Brush

Wiring Brush in Place

Pounding in Stakes

Covering with Dirt

Finished Product

Sprouting Brush Mattress

SPECIFICATIONS

AND

DETAILS

BRUSH MATTRESS

Installation

1. Installation shall be performed on approved graded and prepared slopes as designated on the Drawings and as determined by ENGINEER.

Materials

1. The brush mattress shall be composed of 50% acceptable species and 50% other branch material. The live stakes used for the brush mattress shall be from acceptable species.

Size Ranges

1. The live branches that shall be used in the brush mattress construction shall be used in three ways:

   a. Live Stakes: Live stakes shall be cut and trimmed, ready to be tamped into the prepared, approved site. Fifty percent of the stakes used in the brush mattress shall be live stakes and 50% shall be wood stakes.

   b. Fascines: See live fascine and size ranges.

   c. Branch work: Branch work or mattress-like covering is placed on the face of the prepared approved slope. These branches shall be 8 to 10 feet long. The branches must be soft and flexible. Brush mattresses require young, flexible material. Old, brittle brush material will not be acceptable.

Fabrication

1. Fascines: See Live Fascines, Fabrication.

2. The brush mattress shall be composed of branches of varying diameter and thickness.

System Excavation

1. The approved, prepared slope shall be smoothly graded so that the live branches that will form the brush mattress will lie flat against the slope. Fascine trenches for the brush mattress installation shall be excavated at the bottom and at the top of slope, as designated on the Drawings and as determined by ENGINEER. Each trench shall be 7 to 8 inches deep, and 7 to 8 inches wide. These trenches shall be parallel to the creek. Exact location shall be determined onsite by ENGINEER.

Placement

1. Construction of the live brush mattress shall be accomplished in the following manner:
   a. Wood stakes shall be tamped into the approved prepared slope. The wood stakes shall be placed 36 inches apart up the slope face, and 36 inches apart across the slope or parallel to the river. The initial bottom row shall be started 12 inches above the dead wood fascine. Initially, the stakes shall be tamped into the ground to a depth that leaves approximately 4 inches protruding from the surface. The wood stakes shall be used when wiring down the branches that will form the mattress of the brush mattress construction. Stakes in the upper section of the mattress shall be installed 6 inches to 1 foot from the live fascine. Extra stakes may be needed at the top and bottom to ensure that the brush mattress branches are tied down securely. The wood stakes shall be placed in a grid pattern on the slope, as previously described. The more uniform the arrangement, the easier it is to tie down and flatten the branches against the slope face.
   b. Excavate the fascine trenches as previously described. The upper section of the trench shall be "shaved off", so as to allow for a smooth transition from the trench up the slope. Care should be taken to ensure that the live branches placed in the trench and up the slope shall not be placed in tension.
   c. Place the fascines in their respective trenches and loosely stake them down with wood stakes every 3 feet.
   d. In the upper mattress area, live branch material shall be placed against the slope, between the stakes. The long live branches shall cover the ground forming a mattress-like cover. They are to be placed flat against the ground, with the growing tips directed up the slope. The basal cut ends of the branches shall be placed in the prepared and approved trench

under the lower fascine. The trench shall be prepared with 1 to 2 inches of select fill material placed in the bottom of the trench.

e. The brush mattress construction shall then be wired down against the slope. The wire is attached to the lower part of the wood stakes and crossed back and forth over the branches.

f. Very carefully, the wood stakes are tamped into the ground a little further, to press the branches as close to the ground as possible. When the stakes in the brush mattress and fascines are tamped into the ground the second time, they shall have 2 to 3 inches protruding above the ground.

g. Tamp live stakes in place between wood stakes. Live stakes shall be tamped in at right angles to the slope, with the protruding end directed downstream.

h. The brush mattress is then lightly covered with native fill material. The size of the area and the number of sections that will have the brush mattress treatment shall be as shown on the Drawings and as designated by ENGINEER.

Soil Covering

1. This procedure shall be to place a light covering of 1 to 2 inches of suitable select fill material over the entire brush mattress; however, the brush mattress shall not be covered completely. This covering procedure shall be done the same day as the brush mattress is constructed. When this procedure is completed, some branches shall be visible. The fascines at the top and base of the mattresses shall also be slightly exposed (see Live Fascines System Backfill).

System Backfill

1. Gravels or clays will not be acceptable soils for covering the brush mattress.

Density

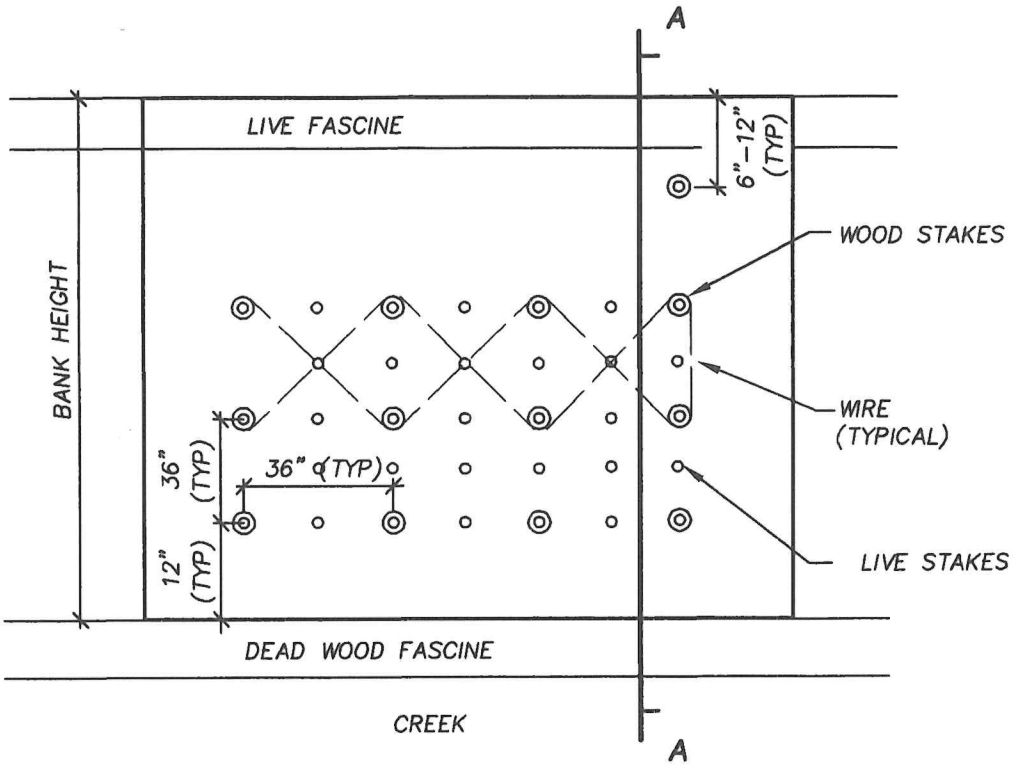
1. The mattress branches shall be placed close together. The density shall be 45 to 55 branches per running lineal yard.

Finished Mattress

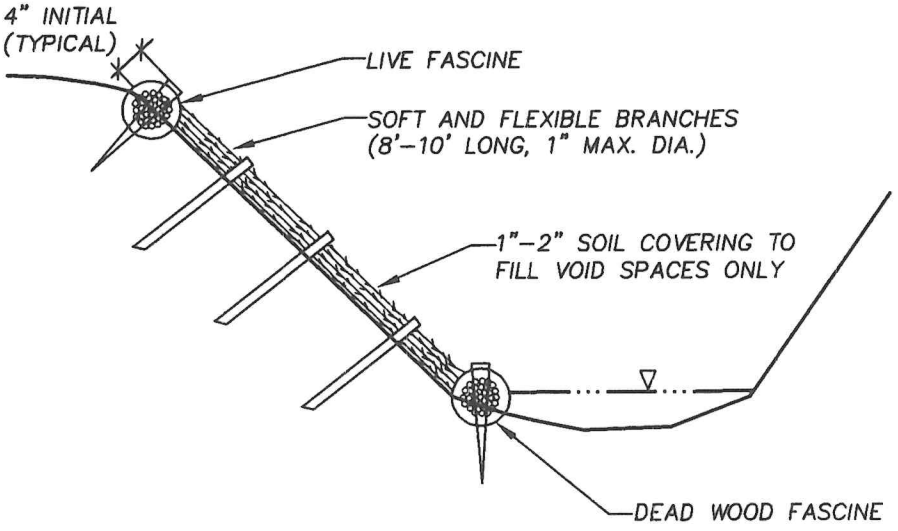
1. The area should look continuous without open spaces, and the branches shall be visible.

Maintenance

1. As specified in Section - Soil Bioengineering Systems.



PLAN VIEW



SECTION A–A

BRUSH MATTRESS DETAIL

NO SCALE

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WILLOW CREEK WATERSHED
STREAM BANK STABILIZATION PROJECT

IMPLEMENTATION PLAN

PROJECT NO.
F95116

FIGURE NO.
1

BIOLUNKER

Description

Biolunkers are made from a combination of live fascines and live stakes. The biolunker forms a wall behind which vegetation can grow. Biolunkers are made by stacking combinations of fascines.

Application and Effectiveness

- Reinforces bare banks.
- Effective for vertical banks with sloughing of the toe.
- Provides habitat for fish and upland organisms.
- Used in areas where slope reduction is not desirable.

Equipment and Tools Required

- Chain saw
- Buck horses
- Rubber mallets
- Sledge hammer
- Twine
- Wood stakes
- Cable
- Duckbill anchors
- Shovels

Stacking Fascines for Biolunker

Installation of Duckbill Anchor System for Biolunker

Biolunker After Installation (with seeding above)

Sprouting Biolunker

SPECIFICATIONS

AND

DETAILS

BIOLUNKER

Materials

1. The biolunker shall consist of three fascines. The bottom fascine (dead wood fascine) shall consist of branch material that has a low probability of reestablishing itself by shoots or suckers. The middle fascine (mixed live/dead wood fascine) shall be composed of 50% acceptable species and 50% other branch material. The top fascine (live fascine) shall be composed of 100% acceptable species.

Size Ranges

1. The live branches to be used for the construction of biolunkers shall be made from soft branching material and have all growing tips in the same direction. All soft brushy branches shall be retained in the construction. Each branch shall be a minimum of 6-feet long and have a maximum trunk diameter of 1 inch. The live stakes used to secure the fascine are considered part of this construction.

Installation

1. Biolunker construction shall be placed on contour and parallel to the creek on prepared slopes as designated on the Drawings and Specifications, and as directed by ENGINEER. The dead wood fascine shall be installed directly into trenches excavated at the toe of the channel slope. The mixed live/dead wood and live fascines will be located on top of the dead wood fascine.

Fabrication

1. See Live Fascines, Fabrication.

System Excavation

1. Dead wood fascine trenches shall be dug 7 to 8 inches deep, and 7 to 8 inches wide. The dead wood fascine shall be installed directly in the trench. They are installed so as to leave just the top of the dead wood fascine slightly exposed when native fill material has been tamped in place and the installation has been completed.

Placement

1. The dead wood fascine shall be placed in the trench and native fill shall be placed in and around the dead wood fascine. The dead wood fascine shall be securely staked with wood stakes, vertically every 3 feet, directly through the bundle. The mixed live and dead wood fascine shall be placed on top of the dead wood fascine. A live stake shall be installed every 3 feet at an angle to the vertical through the mixed live/dead wood fascine on the downslope side. The live stakes shall protrude above the finished ground elevation 3 inches. The live fascine shall be placed on top of the mixed live/dead wood fascine.

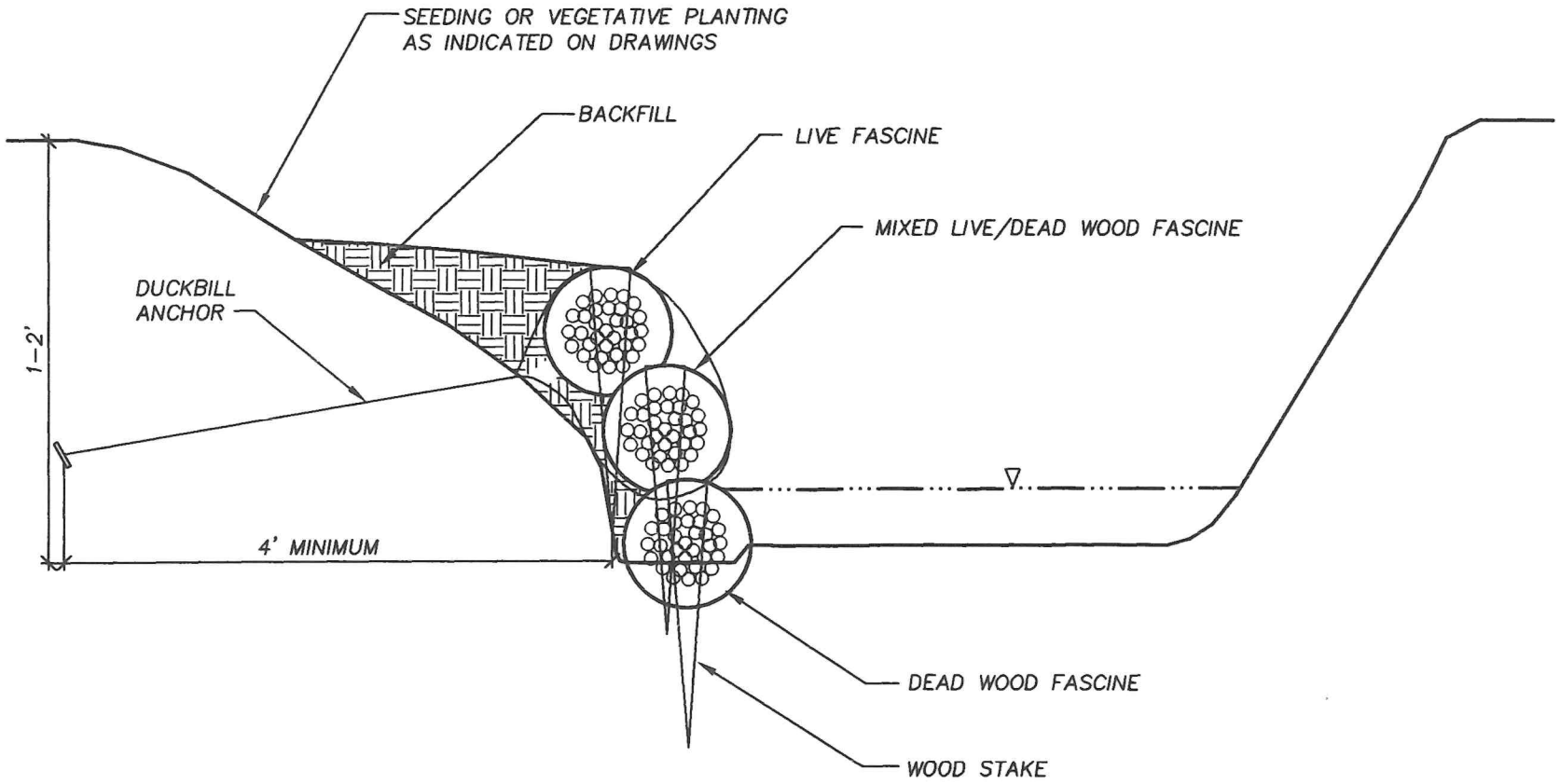
2. Biolunker fascines shall be securely anchored to the stream bank using Duckbill Earth Anchor Systems. The Duckbill anchor shall be driven into the bank using the steel drive rod. Depth of installation shall be a minimum of 4 feet into native materials. After the anchor has been driven to the proper depth, the drive rod shall be removed. The anchor cable shall be pulled on to lock the anchor into the perpendicular (load-locked) position. The anchor hole shall be backfilled and tamped. Duckbill anchors shall be placed every 10 feet. The fascines shall be held to the Duckbill anchor with a $\frac{1}{8}$-inch-diameter steel cable.

System Backfill

1. When backfill operations are complete, the biolunker should be a wall of bundled branches protruding slightly from the bank. Special care shall be taken to ensure that the approved native fill material is filled in around the fascines. The backfill shall be well compacted by foot and with wood stakes. Water compaction shall not be acceptable.

Maintenance

1. As specified in Section - Soil Bioengineering Systems.



INITIAL INSTALLATION

BIOLUNKER DETAIL

NO SCALE

PROJECT NO.	F95116
FIGURE NO.	1

WILLOW CREEK WATERSHED
STREAM BANK STABILIZATION PROJECT

IMPLEMENTATION PLAN

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LUNKER

Description

Lunkers are not considered a soil bioengineering technique by themselves, but used in conjunction with plantings, they may form a stable stream bank and provide for fish habitat.

Application and Effectiveness

- Reinforces bare banks.
- Effective for vertical banks with sloughing of the toe.
- Useful where space is limited and a more vertical structure is required.
- Used in areas where slope reduction is not desirable.
- Provides fish habitat.

Equipment and Tools Required

- Chain saw
- Lumber
- Nails
- Hammer
- Wheel barrow
- Duckbill anchors
- Geotextile fabric
- Mulch blanket
- Riprap
- Sledge hammer

Prepared Banks for Lunkers

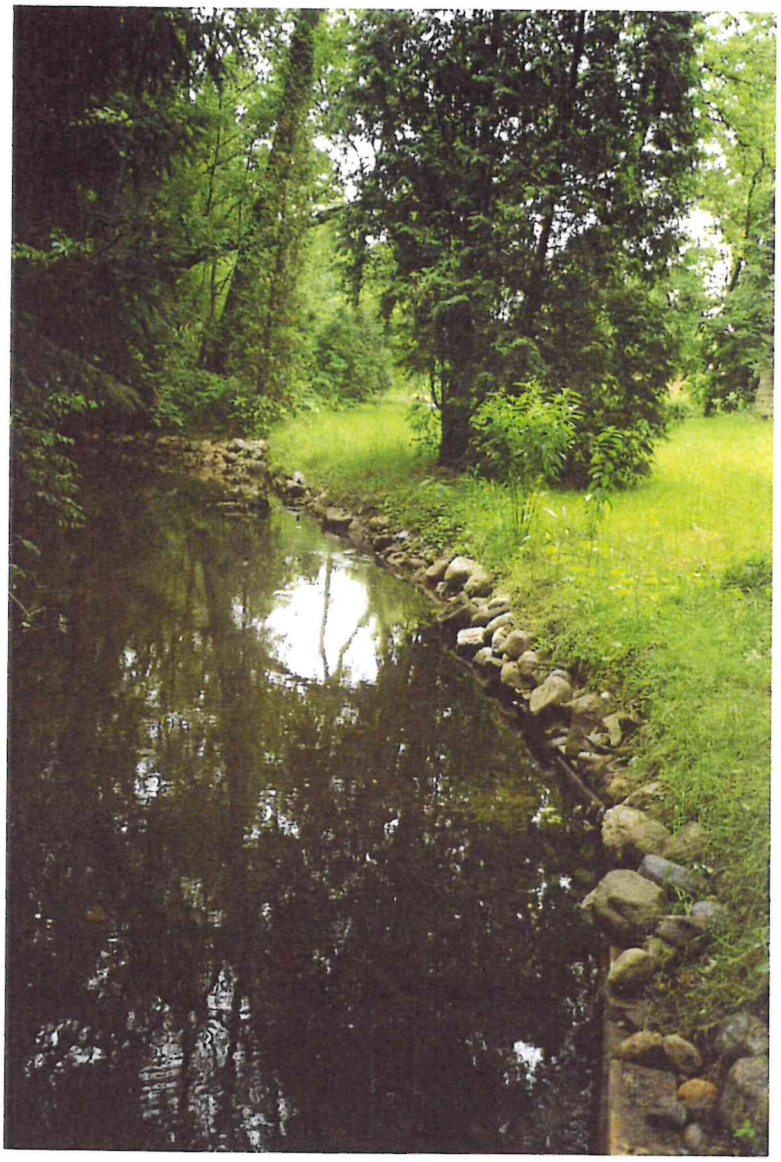
Assembled Lunker Structure

Lunker Structure with Geotextile Fabric and Duckbill Anchors

Installation of Lunker Structure

Placing Rock Riprap on Top of Lunkers

Installed Lunkers



Completed Bank with Grass on Top of Lunkers

SPECIFICATIONS

AND

DETAILS

LUNKER

Materials

1. Lumber: Lunkers shall be made of untreated lumber of the following dimensions:
   Posts: 6" x 6" x 12" long
   Cross Members: 2" x 6" x 3' long
   Long Members: 2" x 6" x 8' long

2. Nails: Lunkers shall be secured with 16-penny galvanized nails on exterior members and with 10-penny galvanized nails on interior members.

3. Geotextile Fabric: Phillips Petroleum Supac 4NP; or equal.

4. Cable:
   a. Galvanized wire rope with a minimum 1/8-inch-diameter meeting Federal Specifications MIL-W-83420.
   b. Construction:
      1) 7 x 7 Strand Core GAC rated at a minimum 1,700 pounds breaking strength; or
      2) 7 x 19 Strand Core GAC rated at a minimum 2,000 pounds breaking strength.
   c. Length: 7-foot lengths.

5. Connections:
   a. Connect cable ends using U-bolt wire rope clip with a minimum of 2 clips per connection; or an oval sleeve.
   b. Clips: Malleable iron saddle with steel U-bolt and nuts meeting Federal Specifications FF-C-450, Type I, Class 2.
   c. Oval sleeve: Zinc-plated, N-type sleeve.

6. Anchors:
   a. Duckbill earth anchor; or equal.
   b. Model 68 (½-inch) with a minimum 1,100 pound anchor strength.

7. Riprap:
   a. Rock:
      1) Sound, tough, and durable rock.
      2) Smaller pieces may be used for filling spaces between riprap rock.
      3) Minimum dimensions:
         a) Small cobblestones: 3 inches.
         b) Cobblestones: 6 inches.
         c) Riprap: 8 inches.

8. Mulch Blanket:
   a. Biodegradable:
      1) Straw: North American Green S-75; or equal.
      2) Coconut: North American Green C-125; or equal.
      3) Straw and Coconut: North American Green SC-150; or equal.
   b. Anchoring staples or pins: Wood pegs at least 6 inches long. Steel wire not permitted.

Installation

1. Lunker construction shall be placed parallel to the creek on prepared slopes as designated on the Drawings and Specifications, and as directed by ENGINEER.

Fabrication

1. Lunkers shall be 8 feet long, 3 feet wide, and 1-foot 8-inches deep. Each lunker shall be made from 6 posts, 6 cross members, and 11 long members.

2. Begin by fabricating post sections. Post sections shall be made from 2 posts and 2 cross members. Posts shall be spaced 3 feet apart and connected with cross members on top and bottom. Cross members shall be attached using 4 - 16-penny nails.

3. Post sections shall be spaced 4 feet apart and connected with 6 long members on top and 4 long members on bottom. Exterior long members shall be attached using 5 - 16 penny nails at each post section. Interior long members shall be attached using 5 - 10 penny nails at each post section.

4. Geotextile fabric shall be secured to the top of the lunker by placing a long member on top of the fabric and attaching with 2 rows, 3 inches apart, of 10-penny nails spaced 1 foot apart along length of the member.

5. Duckbill anchors shall be wrapped around each post on the opposite side of the attached geotextile fabric.

System Excavation

1. Excavation shall start at the lowest point of the slope. Loose material shall be excavated 2 to 2.5 feet below the ground elevation until a stable foundation is reached.

2. The bottom of the excavation shall be flat to provide stability to the lunker.

Placement

1. Geotextile fabric shall be placed along the slope in the excavation.

2. Each lunker shall be placed into the excavation on top of the geotextile fabric with the exposed long member away from the slope.

3. The Duckbill anchors shall be driven into the bank using a steel rod. Depth of installation shall be a minimum of 6 feet into native materials. After the anchor has been driven to the proper depth, the drive rod shall be removed. The anchor cable shall be pulled on to lock the anchor into perpendicular (load-locked) position. Duckbill anchors shall be placed every 4 feet.

4. Riprap shall be placed on top of the lunker until rock is exposed above the water level.

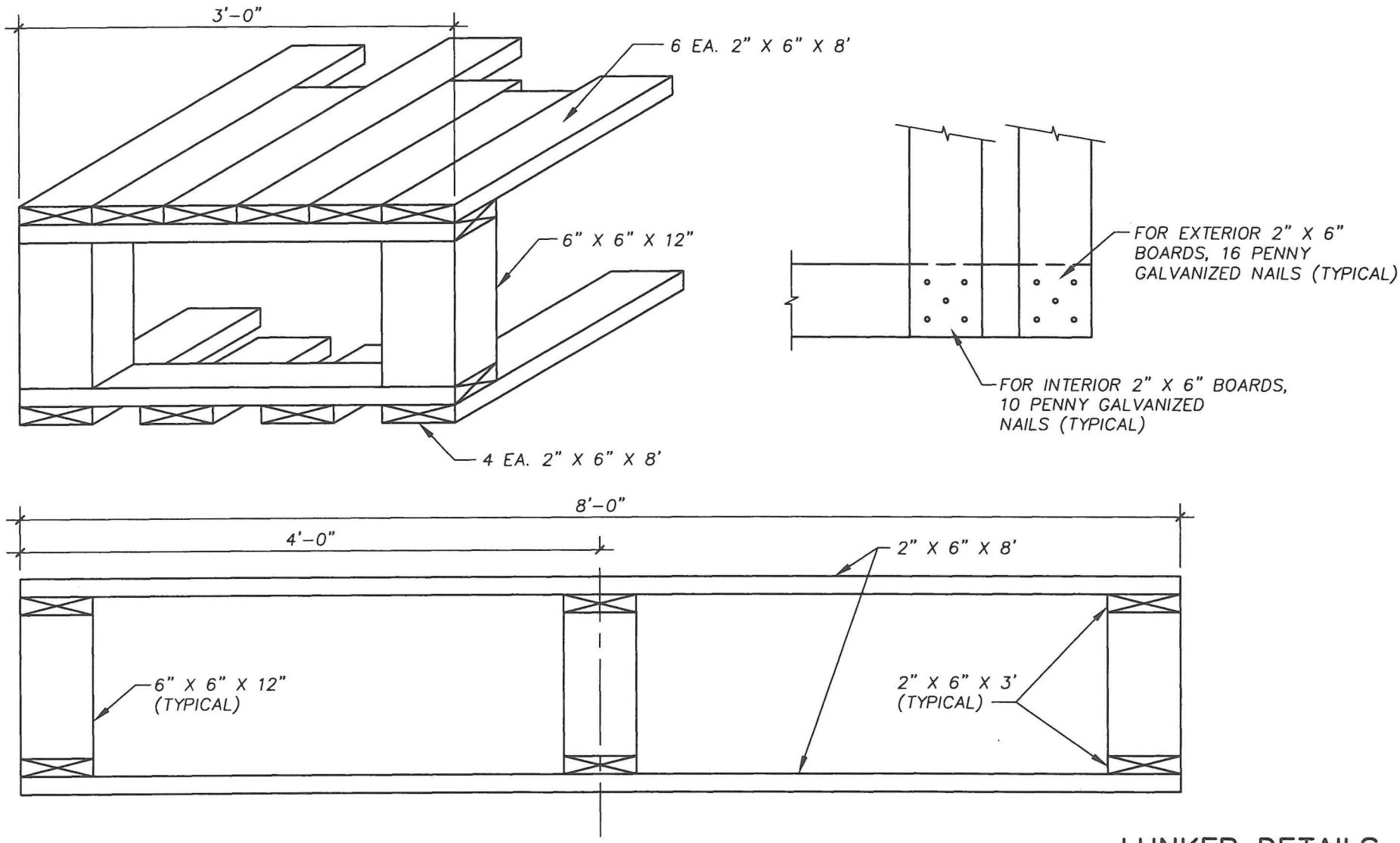
5. Geotextile fabric shall be placed on top of the riprap and covered with native material.

6. Seed shall be sown according to Seeding Specifications.

7. Mulch blanket shall be placed on the seed and secured with wood pegs at 2-foot intervals. Additional wood pegs shall be used as necessary.

Maintenance

1. As specified in Section - Soil Bioengineering Systems.



LUNKER DETAILS

NO SCALE

PROJECT NO. 96342A	WILLOW CREEK WATERSHED
FIGURE NO. 1	STREAM BANK STABILIZATION PROJECT
	IMPLEMENTATION PLAN

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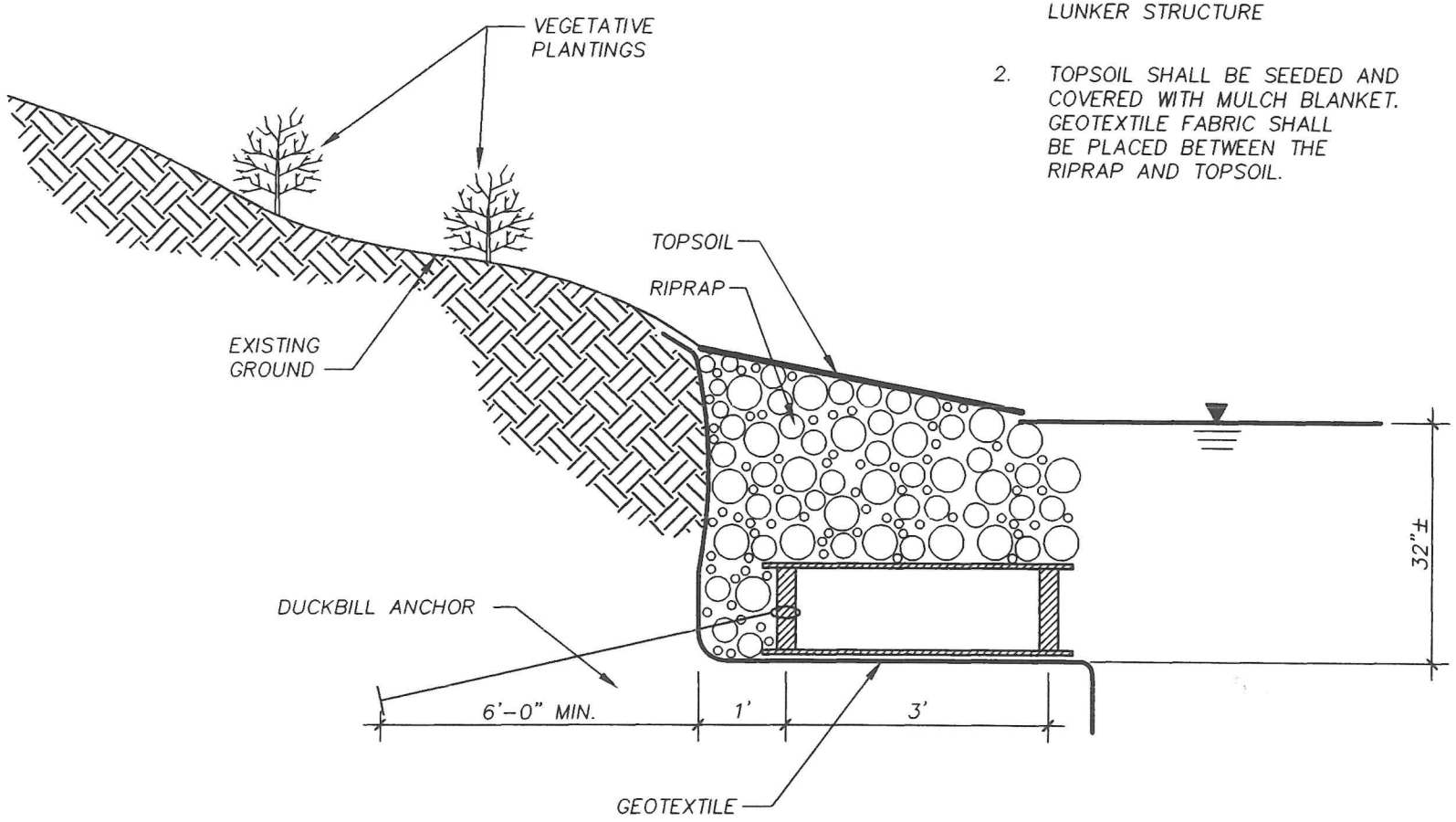
1. ROCK RIPRAP SHALL BE PLACED BEHIND AND ON TOP OF LUNKER STRUCTURE

2. TOPSOIL SHALL BE SEEDED AND COVERED WITH MULCH BLANKET. GEOTEXTILE FABRIC SHALL BE PLACED BETWEEN THE RIPRAP AND TOPSOIL.



LUNKER INSTALLATION

NO SCALE

2 (FIGURE NO.)	PROJECT NO. 96342A	WILLOW CREEK WATERSHED STREAM BANK STABILIZATION PROJECT IMPLEMENTATION PLAN

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TREE/BRANCH REVETMENT

Description

Tree/branch revetments are used to reduce the velocity of the current along the eroded bank, thereby reducing stream bank erosion and causing the stream to deposit sediment in eroded areas needing fortification. A tree/branch revetment has the advantage of being permeable and flexible, thereby using the stream's natural action to reduce erosion and promote sedimentation where it is needed.

Application and Effectiveness

- Slows current along meanders.
- Allows deposition of sediment.
- Deflects current away from eroded banks.
- Easy to install in remote locations.

Equipment and Tools Required

- Cable
- Duckbill anchors
- U-Bolts
- Chain saw

Tree Revetment Installed Along Wheeler Drain*

Cable Holding Tree Revetment in Place*

* Photographs of Newaygo County Drain Commissioner's Project

SPECIFICATIONS

AND

DETAILS

TREE/BRANCH REVETMENT

Summary

1. Section Includes: This Section includes, but is not necessarily limited to the installation of tree/branch revetments as indicated on the Drawings, as specified herein, and as necessary for the proper and complete performance of the Work.

Definitions

1. Terms:
   a. Tree/branch revetment: Securing trees and branches to prevent erosion of channel banks and encourage the deposit of sediment in the area in which bank protection is secured. It is also the intent of this Work to deflect the current into midstream or the opposite bank.
   b. Trees:
      1) Vegetation with trunks or stalks exceeding 4 inches in diameter as measured at diameter breast height (DBH).
      2) A stump with numerous branches, trunks, or sprouts shall be considered one tree.
   c. Branches: Vegetation with trunks or stalks less than or equal to 4 inches in diameter as measured at DBH.

Materials

1. Tree/branch revetment:
   a. Upper tree top material from hardwood trees such as oak and ash. Maple tree branches may be used only when adequate hardwood material is not available.
   b. Material from dead (or diseased) trees shall not be used for tree/branch revetment and must be removed from the site.

2. Cable:
   a. Woven wire cable with a minimum 3/16-inch diameter.
   b. 6 x 19 Fiber Core or 6 x 19 IWRC, rated at a minimum of 3,000 pounds. breaking strength.

3. Connections:
   a. Connect cable ends using U-bolt wire rope clips using a minimum of two clips per connection; or an oval sleeve.
   b. Clips shall be malleable iron saddle with steel U-bolt and nuts, meeting federal Specification FF-C-450, Type 1, Class 2.
   c. Oral sleeve: Zinc-plated, N type sleeve.

4. Anchors:
   a. Duckbill Earth Anchor; or equal.
   b. Model 68 (½-inch) with a minimum 1,100 pound anchor strength.

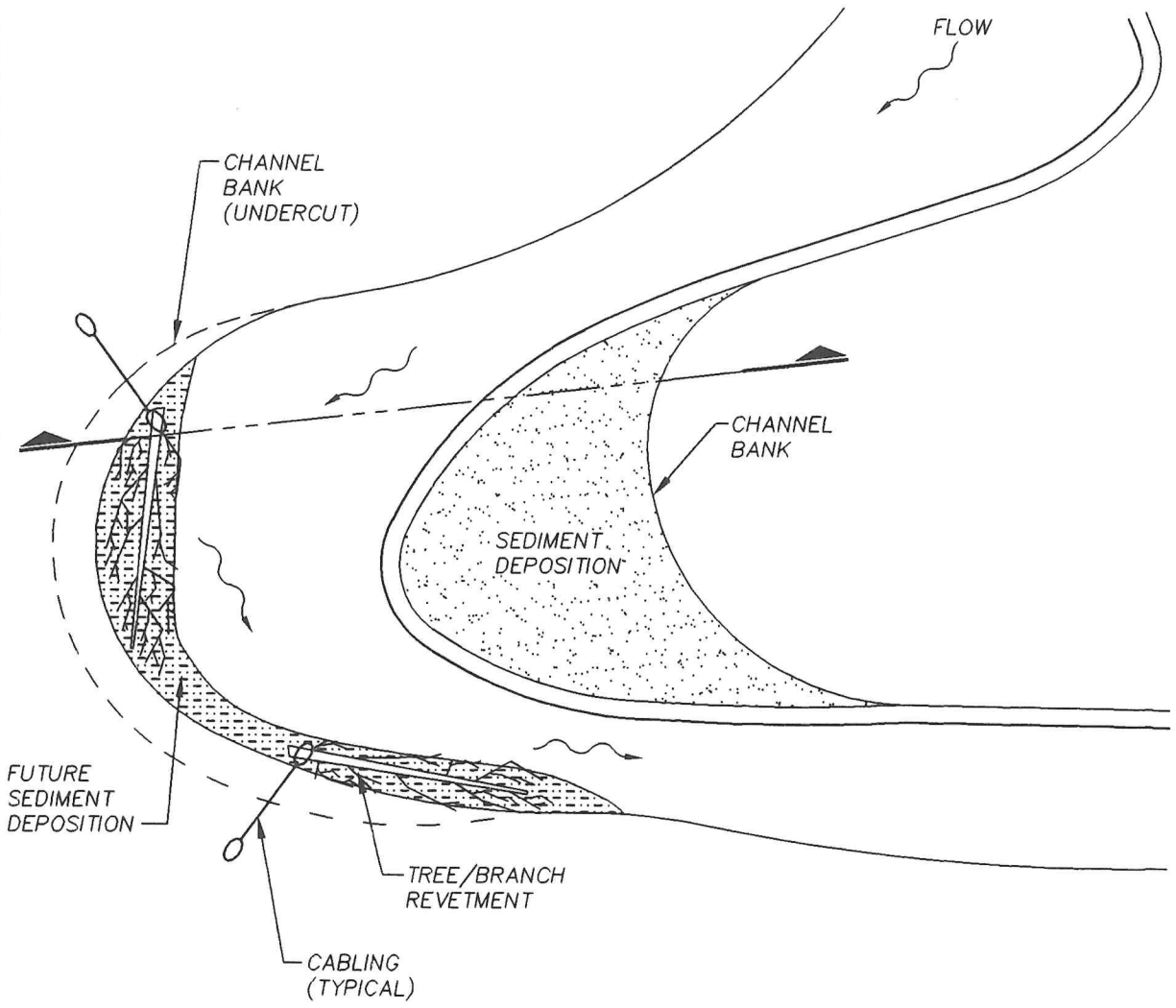
Tree/Branch Revetment

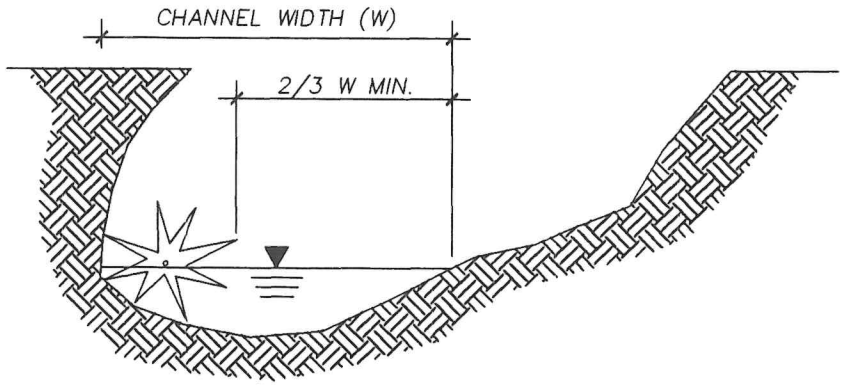
1. Locations: Locations as indicated on the Drawings or as directed by ENGINEER.

2. Procedures:
   a. Tree/branch revetment shall consist of dense piles of tree tops and branch material placed against the bank with the cut ends facing upstream against the bank.
   b. Tree revetments shall extend from the toe of the channel bank to a minimum of 2 feet above the normal water level.
   c. The approximate size of the tree/branch revetment shall be 20 feet along the bank and 5 to 10 feet wide.
   d. Secure the tree tops and branch material cable to anchors, stakes, or trees on the adjacent bank.
   e. Final channel width shall not be less than ⅔ of the existing channel width, unless authorized by ENGINEER.

Maintenance

1. Replace or repair as necessary until final acceptance.





TREE/BRANCH REVETMENT

NO SCALE

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WILLOW CREEK WATERSHED
STREAM BANK STABILIZATION PROJECT

IMPLEMENTATION PLAN

PROJECT NO.
96342A

FIGURE NO.
1

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