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USACE / NAVFAC / AFCESA / NASA **UFGS-31 32 39 (April 2006)**

Preparing Activity: USACE (CW) **Replacing without change UFGS-02665 (February 2005)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 1 April 2006

Latest change indicated by CHG tags
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DIVISION 31 - EARTHWORK

SECTION 31 32 39

BIOENGINEERING PRACTICES FOR STREAM BANK AND SHORELINE STABILIZATION

04/06

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SECTION 31 32 39

BIOENGINEERING PRACTICES FOR STREAM BANK AND SHORELINE STABILIZATION
04/06

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NOTE: This guide specification covers the requirements for bioengineering practices for stream bank and shoreline stabilization.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.
****

PART 1 GENERAL

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NOTE: This guide specification covers bioengineering practices as related to stabilizing stream banks and shorelines using natural vegetation by itself or in conjunction with stone, rock, dead vegetation structures, or organic erosion control matting. The methods may also be applied to small tributaries, gullies, canals, and drainage channels. The use of the term bioengineering refers to soil bioengineering in this specification. Soil bioengineering is a method of stabilizing soils using living and dead plant material and biodegradable manufactured products. Bioengineered structures should not at anytime be constructed on embankments, levees, or flood control structures where there is a risk of failure of the project from

a single event or a storm with a recurrence interval of 10 years.

This specification focuses only on stream banks and shorelines at or near the edge of water. This specification is not for coastal protection. This specification does not include requirements for hard or dead vegetation structures that are for erosion control or habitat restoration. This specification does not include the use of geosynthetic materials, metal, or requirements for traditional stone or rock hardened structures for bank protection. The designer should be cognizant that the structures described in this specification often must be augmented with the establishment or enhancement of vegetative zones on the landward portions of the banks or shores. Refer to TR-EL-97-8 Bioengineering for Stream Bank Erosion Control Report 1 Guidelines for guidance.

The designer should use caution in the selection of bioengineering methods for bank stabilization. Many bioengineering methods provide improved erosion resistance to stream banks or shorelines. However, bioengineering methods are not designed to repair inherently unstable stream banks or shorelines, which require engineering design, soil improvement, or extensive soil removal prior to vegetation efforts. Bioengineering methods will not prevent bank failures due to poor soil conditions, over steepened or undercut slopes, rapid draw down or drop of water levels, or where flow velocities exceed bioengineering established tolerances. Improved stability due to the development of root mats in the soil may take two or more years to be realized. Therefore, the desired bioengineering methods or bioengineered structures must be selected based on-site specific conditions, realistic expectations of performance, and consultation with soil, hydraulic, and structural engineers and environmental resource personnel.

The designer should compare bioengineered structures to more traditional stabilization methods, such as stone revetments or concrete channel lining, in terms of cost and performance before final selection of stabilization methods. Traditional stabilization methods may be better suited and more economical and provide greater protection at lower costs than bioengineered structures. The designer should review case histories on the performance and maintenance of existing bioengineered structures during selection and design. It is important to anticipate possible future failures of banks due to toppling of large mature vegetation, changes in vegetation species, and impact on the structure and vegetation by animal and human activities. Hard structures may be preferred at locations where the risk of loss of life or property is apparent or where rapid changes in land use may pose such a risk in the future.

This specification is applicable to semiarid and temperate regions. The construction of bioengineered structures in arid regions requires special attention to the selection of appropriate plant species, water supply, irrigation, and maintenance for successful completion and performance. Other bank protection alternatives may be more cost effective than bioengineered structures in arid regions.

The construction of bioengineered structures in cold climates requires additional design efforts to reduce or prevent damage. Structures may be damaged by the impact of ice flows or ice blocks in the stream or river. The development of ice at the stream bank that incorporates the vegetation of the structure may result in vegetation loss or increased forces on the structure. Consult with a hydraulic engineer on methods to minimize damage to the structure. The percent of damage and mortality to vegetation may be higher due to frost or severe cold. Free draining soils should be used to reduce the amount of frost heave on structural components. Structures may not be suitable in climates with deep frost depths where surficial soil may be subject to flow when disturbed during the spring thaw. Bioengineering methods may not be suitable in cold regions where plant development and growth are stunned due to the climate and where root development, which is required for performance of the structure, may require more than 2 years. Consult with regional experts when planning bioengineered structures in these regions.

Planning of the bioengineered structure requires a multidisciplinary team approach. The designer should consult at a minimum with personnel in soil mechanics, structural design, hydraulic engineering, biological sciences, botany, regulatory, cost estimating, contracting, and construction during the initial development of conceptual designs, comparison of alternatives, and throughout project execution as required. Clear objectives for the selection, performance, and risk of the structure must be developed early in the planning phase. Sponsors and the public must be advised about the cost, performance, safety, benefits, and risks of the selected structure during the early stages of design. The designer should be aware of the need for construction oversight during installation to ensure quality.

The designer should include the long-term costs of maintenance in cost estimates and the amount of maintenance required for adequate and safe performance of the structure. Monitoring or after care of the structure may be necessary for 2 to 10 years after the structure is completed to ensure the vegetation becomes established and the structure is meeting performance requirements. The impact of changes to site conditions should be evaluated during planning for safety and maintenance requirements. The effect of loss, damage, and change of vegetation species on structure performance should be discussed. The effect of disease, fire, harvesting, or removal related to plants in the structure and impact on performance must be elevated. Requirements for vegetation replenishment, pruning, selective cutting, and replacement should be included in maintenance planning. Repair to the soil, backfill, or hard materials in the structure must be addresses. The accretion of sediment on stream banks due to the trapping of sediment by vegetation should be evaluated for loss of stream conveyance and decreased slope stability due to the increased weight of accreted sediment. Damage due to wave action from storms, navigation, or boats should be determined.

Clear acceptance criteria should be defined for the project as well as warranty requirements. Acceptance and warranty requirements may be more stringent and require longer periods of time than traditional bank stabilization projects due to the need for vegetation to become established.

The following stream flow velocities are recommended for maximum limits on the selected methods of stream bank or channel stabilization.

Vegetative protection 8 feet per second (fps)
Structural and bioengineering
Woody material, 8 fps
Woody material and herbaceous species, 5 fps
Herbaceous alone, 3 fps
(USDA TN Plant Materials No 23, Technical Notes, September 1993)
Flow velocities greater than 8 fps may require reinforced matting or hard structures.

Bioengineering methods require construction techniques and materials, which are described by other existing specifications. The following specifications should be included with this specification in the bid package depending on site conditions and design objectives.

Minor clearing and grubbing of vegetation is provided in this specification with an emphasis on salvaging cleared or grubbed material for the construction of the bioengineered structure. For extensive clearing and grubbing of vegetation for site construction or access, refer to Section 31 11 00 CLEARING AND GRUBBING.

Minor earthworks may be required for the construction of the bioengineered structure. In addition, select fill or backfill materials may be needed. This specification only includes the requirements for the minimal earthworks necessary for key trench installation and surface roughening. For slope reduction, benching, and material specification, refer to Section 31 00 00 EARTHWORK.

The construction of bioengineered structures often results in the exposure of soils that require protection from erosion. This specification mentions the need for erosion control products but does not provide the specifications or installation methods for these products. For the requirements for soil erosion structures, products, and installation methods, refer to Section 31 32 11 SOIL SURFACE EROSION CONTROL.

Bioengineering methods may incorporate stone or rock. For the requirements for hard armor, refer to Section 35 31 19 STONE, CHANNEL, SHORELINE/COASTAL PROTECTION FOR STRUCTURES.

Seeding is an important component for many bioengineered structures. To specify the requirements for the installation procedures for seeding, refer to Section 32 92 19 SEEDING.

Fencing may be required during and after construction to protect bioengineered structures and associated vegetation from damage due to human and animal activities. For the requirements for fencing, refer to Section 32 31 00.00 10 FENCING.

Bioengineered structures are commonly placed in or adjacent to bodies of water. Best Management Practices for storm water pollution prevention shall be employed in accordance with Section 01 57 23.00 10 STORM WATER POLLUTION PREVENTION MEASURES.

Portions of this specification may not be consistent with sections in the construction contract. The designer will delete unnecessary paragraphs of this specification or provide full requirements to portions in this specification that may conflict with or contradict other sections in the contract. These conflicts, contradictions, or lack of requirements will be resolved between this section and other specifications and the construction contract before the design package is released for review.

For additional information concerning bioengineering practices, methods, structures, construction, and performance, see the following publications:

United States Department of Agriculture, December

1996, Engineering Field Handbook, Chapter 16, Stream Bank and Shoreline Protection.

United States Department of Agriculture, October 1992, Engineering Field Handbook, Chapter 18, Soil Bioengineering for Upland Slope and Erosion Reduction.

Muhlberg, K, Gayh, A, and Moore, Nancy J., 1998, Stream Bank Revegetation and Protection, A Guide for Alaska, Alaska Department of Fish and Game, Technical Report No. 98-3, 75 p.

Schiechtl, H. M., and Stern, R., 1997, Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection; Blackwell Science Ltd, London, 186 p.

TN Plant Materials No. 2, USDA, September 1993, How to Plant Willows and Cottonwoods for Riparian Rehabilitation.

The publications listed above are a small sample of the numerous publications available with related guidance for bioengineering practices. The designer is encouraged to obtain and review local and State publications that are specific to the region of project work. These publications generally contain useful information on suitable plant species, soil and stream conditions, and regulations. Insert project specific references as needed. Numerous guidance and case history publications on bioengineering by the USACE may be reviewed at http://libweb.wes.army.mil.

Publications may contain drawings of proposed structures that are of value for reference and incorporation in design documents. It is strongly recommended that the designer obtain and review drawings of the various bioengineering methods and structures during the preparation of this specification. These drawings lend considerable clarity to the descriptive text about the structures. These drawings should be included in the specification package as attachments to this specification and should be modified to reflect site-specific conditions and restraints.
****

1.1 REFERENCES

****
NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D 6765	(2002) Standard Practice for Live Staking

U.S. ARMY CORPS OF ENGINEERS (USACE)

TR-EL-97-8	(April 1997) Bioengineering for Stream Bank Erosion Control Report 1 Guidelines (and Appendices); US Army Corps of Engineers Environmental Impact Research Program, Waterways Experiment Station, Vicksburg, MS 105 p. (Allen, Hollis H., and Leech, James R.)

1.2 SUBMITTALS

****
NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes

following the "G" typically are not used for Navy, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

The designer should ensure adequate time is allowed for the review of submittals before the start of work. The designer will clearly note the time for submittals, where required. Insert the number of copies required as needed.

The submittals listed below are for general bioengineering projects. The designer will edit this section to tailor the submittals to the project needs and requirements and include submittals not listed below as necessary.

****

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Existing Site Conditions

A detailed description of the existing site conditions prior to construction work including but not limited to literary references, site visits, public or private reports, studies (engineering, ecological, environmental, etc.) and topographic or other maps. The Contractor shall submit [_____] copies of this survey to the Contracting Officer [_____] days before the start of work.

Site Evaluation Plan

The contents of the plan shall be developed by the Contracting Officer and the Contractor. The Contractor shall submit [_____] copies of this plan to the Contracting Officer [_____] days before the start of work.

Permits and Regulations

List and copies of all required and approved permits for site work and of all regulations that pertain to site work. The Contractor shall submit these items to the Contracting Officer [_____] days before the start of work.

Construction Work Sequence Schedule

Construction sequence schedule detailing the work tasks and order of completion.

Seed Establishment Period

Calendar time for seed establishment. When there is more than one seed establishment period, the boundaries of the seeded area specific for each period shall be described.

Dewatering[; G][; G, [_____]]

Submit overall plan for dewatering and any required diversion of water. The plan shall completely address installation and removal of the required systems and features.

SD-02 Shop Drawings

****
NOTE: The Contractor shall submit sufficient drawings to clearly define site layout, structure, details, site conditions, extents of features, and the like to allow adequate planning and cost estimating. The designer will delete or add drawings below that are necessary to meet project needs.
****

Staging area
Structures[; G][; G, [_____]]

Submit design and details of site engineered structures

Structures[; G][; G, [_____]]

Submit cross sections and profiles of site structures

Vegetation

Submit Vegetation type and planting plan

Harvest site restoration

SD-03 Product Data

****
NOTE: Edit this section to include materials that are specific to the project work. Add or delete materials or products as required.
****

Materials

A list of nonvegetative materials to be used in the construction of bioengineered feature or structure. Include manufacturer's literature regarding physical characteristics, limitations, and application or installation instructions.

Stakes
Binders
Fertilizer
Sealing of harvest cuts
Painting of stakes and poles

Lumber
Logs, trunks, and brush
Equipment

A list of all equipment and tools that shall be used for the construction of the bioengineered structure. Include information on products used in equipment such as fuel, hydraulic fluids, and the like.

Harvesting and Soaking Records

SD-04 Samples

****

NOTE: Several different types of samples and tests may be required depending on structure design, construction, and location. Soil samples should be collected for geotechnical analyses for grain size, moisture content, density, Atterberg limits, compaction, shear strength, and pH. Soil at the site and fill that may be imported should also be tested for these parameters. The chemistry of the soil should be tested to ensure the soil will support vegetation growth and is free of contaminates. Soil should be tested for deleterious microorganisms that could increase plant mortality. Surface and groundwater should be sampled for chemistry and quality. Sediment samples should be collected for mechanical and chemical analyses. Rock and stone should be tested for toughness, durability, chemical stability, and freeze and thaw at a minimum. Vegetation to be used in construction should be tested for health and presence of disease. All analyses must be preformed by analytical laboratories that are certified by the USACE. The designer will add or delete sample and testing requirements to this section as needed. Specify the specific tests and methods adjacent to the sample or refer to the accompanying specification in which this information is contained.

****

Soil
Excavated Sediments
Surface water
Groundwater

Samples, as specified.

SD-06 Test Reports

Material Testing

Certified reports of inspections and laboratory tests, prepared by an independent testing agency, including analysis and interpretation of test results. Each report shall be properly identified. Test methods used and compliance with recognized test standards shall be described.

SD-07 Certificates

Prior to delivery of materials, certificates of compliance attesting that materials meet the specified requirements. Certified copies of the material certificates shall include the following for items listed in this section:.

a. Certification of recycled content or,

b. Statement of recycled content.

c. Certification of origin including the name, address and telephone number of manufacturer.

d. Certification for binders showing EPA registered uses, toxicity levels, and application hazards.

Installer's Qualification

The installer's company name and address; training and experience and or certification.

Personnel Qualifications

Provide a list of personnel working on the project including name, title, and statements of their current positions and previous experiences. Selected personnel shall have been involved in bioengineering design and construction efforts similar to the proposed site work within the last 2 years.

Seed

Classification, botanical name, common name, percent pure live seed, minimum percent germination and hard seed, maximum percent weed seed content, and date tested.

Vegetation

Classification, botanical name, common name, harvest location, plant heath, and date tested. (live or dead cuttings, nursery stock, plants).

Binders

Certification for binders showing EPA registered uses, toxicity levels, and application hazards. Prior to delivery of materials, certificates of compliance attesting that materials meet the specified requirements. Certified copies of the material certificates.

SD-10 Operation and Maintenance Data

Maintenance Instructions

Instruction for year-round care of installed products including schedule, materials, and tasks.

SD-11 Closeout Submittals

Maintenance Records

Records on maintenance work performed, detailing the methods and frequency of site monitoring and aftercare of established bioengineered site and plants and of measurements and findings for product failure, recommendations for repair, and products replaced.

Final Project Report

Specify and summarize all construction activities and problems.

1.3 MEASUREMENT AND PAYMENT

****
NOTE: Add or delete products and measurement and payment as require for project specific needs.
****

1.3.1 Binder

The standard binder shall be measured by the linear meter foot placed.

1.3.2 Live or Dead Cuttings

Live or dead cuttings shall be measured by number and type of individual cuttings. No payment shall be made for cuttings not required for use in the structure, defective, or that are trimmed from cuttings. Measurement of payment shall include all harvesting, soaking, transportation, and preparation.

1.3.3 Materials

Soil and rock shall be measured by the [cubic meter yard] [metric 2000 pound ton].

1.4 DESCRIPTION OF WORK

****
NOTE: Provide requirements that are specific to the work and that the Contractor shall be responsible for completing.
****

The work shall consist of the Contractor furnishing and installing bioengineered features and structures to enhance [stream bank] [and] [shoreline] stability within project limits and in areas outside the project limits where the soil surface is disturbed from work under this contract [and as noted on the drawings]. This work shall include all necessary evaluation, design, materials, labor, supervision, and equipment for installation of a complete system and after construction maintenance. This section shall be coordinated with the requirements of Section [31 11 00 CLEARING AND GRUBBING] [and] [31 00 00 EARTHWORK] [and] [31 32 11 SOIL SURFACE EROSION CONTROL] [and] [35 31 19 STONE, CHANNEL, SHORELINE/COASTAL PROTECTION FOR STRUCTURES] [and] [32 31 00.00 10 FENCING] [and] [32 92 19 SEEDING] [and all other specifications or requirements as necessary].

1.5 MATERIAL TESTING REQUIREMENTS

****

NOTE: Edit this section as required. Provide specific methods, procedures, sample numbers, test, and the like.

The Contractor should collect samples of select fill and site soils for physical and chemical analyses to ensure these materials are appropriate for growth of the selected plant species. Refer to specific soil requirements needed for healthy plant growth to complete this section. Imported soil or select fill must be tested to ensure the material is free of seeds or root stocks of non native or invasive species or detrimental biological organisms.

Soil samples from the surface and subsurface of the site should be collected for geotechnical and chemical analyses. Geotechnical test parameters should be at a minimum grain size with hydrometer, moisture content, density, and Atterberg limits as required. Testing of site soils and select fill for permeability, consolidation, and soil strength may also be required depending of site conditions and selected structure. Soil samples should be collected to confirm that soils at the site are not contaminated with hazardous, toxic, or radioactive compounds that would require special handling.

Samples of surface and groundwater should be collected to verify that seepage into the stream or water body at the work site is not contaminated with compounds that will endanger plant survival or pose a hazard to human health and the environment. Water that is not obtained from a public source should be tested for biological and chemical contaminates.

Specify analytical laboratories for analyses, turn around time for samples, and holding times for chemical samples.

The soil and water samples must be collected and analyzed a minimum of 120 days before the start of construction. The analytical results must be reviewed by the Contracting Officer before work continues at the site. If hazardous compounds or chemicals are discovered, then the work will be terminated. All testing must be performed by USACE validated laboratories.

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The Contractor shall collect samples of soil and water at and for use at the site. Samples shall be collected at the locations as shown in the drawings and at source locations for the materials or water. These samples shall be collected and tested as specified below.

Sample	Location	Number	Test Method	Collection Method
[_____]	[_____]	[_____]	[_____]	[_____]

1.6 QUALITY ASSURANCE

All Contractor and subContractor personnel shall be fully qualified to perform the specified work and shall provide the Contracting Officer with such documentation no less than [30] [_____] days before the notice to proceed. Work shall not start until the Contracting Office is satisfied that the Contractor meets or exceeds all required qualifications. The Contractor shall be responsible for all quality control measures. All Contractor records, documents, and work may be inspected by the Contracting Officer or designated representative at any time. Items not meeting quality requirements shall be replaced or repaired immediately by the Contractor at no cost to the Government.

1.6.1 Regulatory Compliance

The Contractor shall perform the specified work in accordance with all applicable Federal, State, and local regulations.

1.6.2 Pre-Installation Conference

The Contractor shall coordinate and conduct meetings with the USACE and all subContractors prior to the start of any work to ensure all work requirements are fully understood and shall be performed. All of these meetings shall take place in the presence of the Contracting Officer.

1.7 DELIVERIES, INSPECTION, STORAGE, AND HANDLING

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NOTE: Provide specific information on required delivery procedures, inspection requirements and methods, special storage needs, and specific handling methods.

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Materials shall be stored in designated areas as recommended by the manufacturer and that are protected from direct exposure to the elements, moisture, and any potential damage. Containers shall not be dropped from trucks. Material shall be free of defects that would void required performance or warranty. Manufactured items shall be delivered in the manufacturer's original sealed containers and stored in a secure area.

a. Erosion control blankets shall be furnished in rolls with suitable wrapping to protect against moisture and extended ultraviolet exposure prior to placement. Erosion control blanket rolls shall be labeled to provide identification sufficient for inventory and quality control purposes.

b. Seed shall be inspected upon arrival at the job site for conformity to species and quality. Seed that is wet, moldy, or bears a test date five months or older, shall be rejected. Seed shall be stored in a cool dry area protected from moisture.

c. Lumber shall be inspected for straightness and defects. Warped, damaged, or used lumber shall be rejected. Lumber shall not be stored directly on the ground and shall be protected from moisture until the time of installation.

d. Vegetation cuttings, herbaceous plants, and clump plantings shall be inspected for species, size, health, and preparation. Diseased, improperly sized, and incorrect species shall be rejected. Specific requirements for storage and handling are provided below.

e. Select fill, top soil, stone, rock, aggregate, and sand shall meet design specifications. Excavated sediments and fill shall be stored in well drained areas and shall be separated from the ground by a non contaminating isolation barrier. Material not meeting specifications or with contained physical or chemical contaminates shall be rejected.

f. Logs, trunks, and brush shall be of the size and quality specified. Materials shall be placed in organized manner in stock piles near the work site and shall not be damaged during delivery, storage, or installation. Materials shall not rest directly on the ground or be exposed to precipitation if they are to remain at the storage site for longer than [4] week before installation. Coverings or the logs, trunks, or brush shall not promote mold or rotting.

1.8 PROJECT/SITE CONDITIONS

1.8.1 Environmental Requirements

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NOTE: Include information on the physical and environmental characteristics and limitations at the work site e.g. temperature, illumination, slope, water depth and the like.

****

[_____]

1.8.2 Existing Site Conditions

****

NOTE: Include information on site conditions, references to documents and reports about site conditions, and requirements for the Contractor to obtain all literary information available for site planning and design. This paragraph should include the need for surface mapping, subsurface exploration, hydraulic analyses of streams or lakes, and all other information necessary for successful design and construction that is not provided by the Government. Also note that lack of supply of such information by the Government does not relieve the Contractor of any such necessary research or studies.

****

Furnish a detailed description of the existing site conditions prior to construction work including but not limited to literary references, site visits, public or private reports, studies (engineering, ecological, environmental, etc.) and topographic or other maps.

1.8.3 Site Evaluation Plan

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NOTE: Consider the following items during site evaluation and project planning to improve the success of the bioengineered structure. The items below are not all inclusive for every site. Other

evaluation factors may be relevant based on site specific conditions.

Do not construct bioengineered structures:

- where soil or water is contaminated with compounds or elements that may damage live vegetation or where disturbance may result in expansion of the area of contamination,
- at locations with unstable slopes that can not be mitigated as part of construction,
- where robust stabilization structures are required for protection of navigation structures, levees, or embankments,
- where damage of the structure could pose a risk to loss of life or property,
- where long-term maintenance and after care of the structure and vegetation is not desired,
-where climate or hydraulic conditions may threaten establishment of vegetation,
- where the streambed is degrading and where such degradation can not be stopped by altering hydraulic conditions of the stream or by the use of hard armor,
- along stream banks or shorelines subjected to high wave action from storms or watercraft,
- in areas subject to shade from other plant species that may hinder growth of the selected plant species for the structure,
- in areas where the structure may not be secured from undesired animal or human traffic and subsequent damage.

Check with local, State, and Federal agencies to ensure all regulations are understood and followed. Do not alter wetland areas.

Know the mean, mean low, mean high, minimum, and maximum water elevations of the stream, river, or lake. The definitions of water levels may be defined in terms of hydrologic analyses or by observation of stream geomorphic features.

- The maximum water elevation should be the highest water possible at the site due to storm surges, waves, floods, or water storage. The elevation of debris associated with flood events or storm waves on the high bank may be used for recent high water elevations.
- The mean high water elevation is the average high water level over 19 years. This elevation is typically located where trees and brush are established on the high bank of the channel.
- The mean water elevation is the average height of water over 19 years. This elevation typically corresponds to the area where reeds and small shrubs are present on the low bank adjacent to the stream channel or shore.
- The mean low water elevation is the average height of the low water over 19 years. This water level is

characterized by the upper extent of aquatic plants on the bank or swash zone at the toe of the bank or shore.
- The minimum water elevation may correspond to the minimal flow in the stream channel or lowest elevation of a lake due to drought or human activities such as irrigation or water storage. The minimal water elevation may be the bottom of the stream channel or lake if these water bodies may be completely drained.

The designer is advised to modify these definitions and water level elevations based on the growing and dormant seasons for species of vegetation used in construction to ensure establishment, performance, and survivability. Determine the amount and rate of change of water elevations due to natural or human activities.

Determine the possible height of waves, direction, and frequency due to storms or navigation operations.

Determine the changes in current velocities and flow direction due to different stages, seasons, or storm events.

Known the sediment load, composition, size, and rates of deposition or erosion at the site.

Know the climate of the work area. Severe flooding, drought, or cold during construction or in the future may damage the structure.

Determine the requirements for regular monitoring and maintenance of the structure to ensure plant survival and structure performance.

Specify the need for and the role and responsibilities of a multidisciplinary team for design and planning, construction, and after care.

The site evaluation plan may require literary searches; subsurface and surface exploration, sampling, and testing; surface topographic, geological, biological mapping; hydraulic engineering studies; assessment of the of site in relation to residences, commercial property, and biological communities; and impact of navigation or water storage projects on the site. The report should contain sufficient information to determine if the site is viable for the proposed structure and sufficient information for structure deign and planning.
****

Furnish a site evaluation plan stating clear and concise project objectives and assessment criteria of the viability of the proposed structure based on the physical, chemical, biological, political, and social site conditions and aspects. The plan should contain supporting documentation and studies, which include but are not limited to climate, geological, geotechnical, hydraulic, biological, botanical, geomorphic, political, social, project cost estimates, and regulatory and permitting requirements. The site evaluation shall include a review of case histories of bank stabilization methods at other similar sites, reconnaissance report on site conditions and suitability for bioengineering structures or methods, design alternatives, potential problems, and recommendations for the types and methods of bioengineered structures if applicable to site conditions and uses. The plan shall include lists of all applicable permits and regulations and methods of compliance related to construction. The plan shall include a report identifying the species of vegetation and plants that shall be used for construction. Refer to TR-EL-97-8 for site evaluation and planning guidance. The report shall include but not be limited to:

Supply of vegetation,
Harvest area and procedures,
Retention of existing vegetation,
Short and long-term interaction of selected species with existing vegetation,
Interaction of species with existing structures,
Retention or elimination of nonnative or invasive species,
Performance of selected vegetation in the proposed structure,
Maintenance and replacement.

1.9 SUBSTITUTIONS

Substitutions will not be allowed.

1.10 QUALIFICATIONS

1.10.1 Installer's Qualification

The installer shall be certified by the manufacturer for any special training and/or experience required for installation.

1.10.2 Personnel Qualifications

Selected personnel shall have been involved in bioengineering design and construction efforts similar to the proposed site work within the last 2 years.

1.11 SEQUENCING AND SCHEDULING

****

NOTE: Most bioengineered structures must be completed during the period of dormancy of plant growth unless otherwise noted. Structures completed outside of this dormant season will not be accepted by the Government unless provided with specific information on the need for such schedule and survivability of plant species used for construction. Local requirements may limit construction periods and must be fully complied with and adhered to unless granted waiver rights by the appropriate regulatory authorities. See paragraph TIME OF PLANTING in PART 3 for additional information.

****

All work shall be conducted [during the period of plant dormancy] [as stated below] and in accordance with all Federal, State, and local requirements for in-stream or near stream construction. The construction sequence shall result in successful completion of the structure. The Contractor shall submit a construction work sequence schedule to the Contracting Officer for approval a minimum of [90][_____] days prior to the start of construction. Work shall not commence without the approval of the schedule and construction sequence by the Contracting Officer. Construction shall not occur if climatic conditions threaten the survivability of plants or worker safety.

1.12 WARRANTY

****

NOTE: The designer should consult with the manufacturer to ensure proper application and installation techniques for the site specific project conditions. Warranties vary with different materials and may be void if proper technical advice is not obtained. Seed germination is not covered under the warranty.

****

The structure and all manufactured materials shall be under Contractor warranty for a period of [2] years including vegetation and earthworks. Stone and rock shall be under warranty from decomposition for [5] years.

1.13 MAINTENANCE

****

NOTE: Bioengineered structures require observation and maintenance for up to 5 years after installation to ensure the vegetation becomes established. Observation should be done on a weekly basis for the first year and bimonthly thereafter for the second year at a minimum. A minimal level of acceptable survival of plants should be established. The Contractor should be required to replace plants that die above the allotted percentage and area of concentration that may adversely effect structure performance.

****

1.13.1 Maintenance

Maintenance shall include eradicating weeds; protecting embankments and ditches from surface erosion; maintaining the performance of the erosion control materials and mulch; replacement of dead or non-viable plants; repair of soil, stone, rock, or hard structures, and protecting installed structures from human and animal activities.

1.13.2 Maintenance Instructions

Written instructions containing drawings and other necessary information shall be furnished to the Contracting Officer, which describe the care of the installed material; and shall include when and where maintenance should occur and the procedures for material replacement. Instructions shall describe the methods for specific maintenance activities and equipment and tools required for such efforts. Requirements on safety and regulations and permits shall be included.

PART 2 PRODUCTS

****

NOTE: Consult local codes and regulations for additional information that may effect the project before design work begins. The choice of methods and materials will be project specific and will be at the discretion of the designer. Edit the specification choices of products to best suit the needs of the project.

****

2.1 BINDERS

All binders shall be biodegradable and untreated hemp or coir rope or fasteners, which shall be able to withstand 2 years minimum exposure to the environment of placement without significant degradation in strength or quality. Steel or plastic binders or fasteners shall not be used.

2.2 EROSION CONTROL ITEMS

****

NOTE: Several structures require the application or integration of erosion control products. These products include but are not limited to mulch, straw, hay, shredded bark, coir, mulch control netting, and erosion control mats. Products selected for use should be biodegradable and non-damaging to the environment in which they are placed. Sediment retention products may also be required as part of construction efforts. The designer shall refer to and edit the appropriate paragraphs of Section 31 32 11 SOIL SURFACE EROSION CONTROL. Erosion and sediment control products shall be in accordance with Section 31 32 11 SOIL SURFACE EROSION CONTROL. Mention the specific needs and types of products below.

****

The Contractor shall provide [erosion control products] [and] [sediment control structures or products] in accordance with Section 31 32 11 SOIL SURFACE EROSION CONTROL. Materials and structures shall be installed according to manufacturer's recommendations based on [actual site conditions] [and] [as shown in the drawings].

2.3 SEED

****

NOTE: State-certified seed is more stringently monitored than State-approved seed, and therefore, more expensive.

****

All seed shall be in accordance with Section 32 92 19 SEEDING. [State-certified] [State-approved] seed of the latest season's crop shall be provided in original sealed packages bearing the producer's guaranteed analysis for percentages of mixture, purity, germination, hard seed, weed seed content, and inert material. Labels shall be in conformance with AMS Seed Act and applicable State seed laws. The Contractor shall submit the Seed Establishment Period information as specified in the Submittals paragraph. Permanent seed species and mixtures shall be proportioned by weight as follows:

Mixture Percent by Weight	Percent Pure Live Seed	Botanical Name	Common Name
[_____]	[_____]	[_____]	[_____]

2.4 PERMANENT VEGETATION SPECIES AND MIXTURES

****

NOTE: Live or dead cuttings from locally harvested stock should be specified in this section. Nursery stock may also be used for design purposes or in areas with limited supplies of cuttings at or near the work site. Nursery stock has a higher chance of survival due to developed root systems but may add cost to the project.

The selection of the appropriate vegetation species for the site should be made by consultation with a qualified geotechnical engineer, hydraulic engineer, biologist, and botanist based on site conditions, stability requirements, desired habitat creation, and blending ability with surrounding vegetation. The soil types, hydraulic conditions and requirements, and ability of the selected species to survive in the work area must be determined and considered in species selection. Selected species should improve or enhance slope stability and should be flexible and of low height at maturity to allow maximum conveyance of water in the channel.

At some sites, nonnative species may be more appropriate due to changed site conditions or alterations by natural or human activities. Native species may not be able to survive in such alternated settings. For restoration projects, non-native or intrusive species may need to be removed before planting native species to reduce competition for resources and to improve the survivability of the native plants. Plant species should be collected from the same watershed and near the work site to prevent the import of differing genetic stains into the project area.

Woody vegetation that matures to have trunk diameters greater than four inches should not be used. Such species when mature pose a threat of scour to the bank down stream of the trunk during high flow events. In addition, these species may develop extensive root system that may damage the structure when the tree dies and rotates into the stream or lake. In this case, the root wad typically removes a large amount of soil as it is

pulled from the bank. The resulting hole may be subject to scour and result in structure damage or failure during moderate or high flow events.

Sedimentation types and depositional rates should be determined. Some streams may transport sediment that may abrade or break vegetation. Alternatively, large amounts of sediment may be deposited at the site and cover vegetation. The combined effect of the trapping of large amounts of sediment by the selected vegetation species may result in the accretion of sediment onto the bank. While this accretion of material provides additional bank protection in the short term, the long term effects may be large bank failures due to the added weight of the sediment on the bank. The structure may be damaged or destroyed if the failure plane cuts the structure. Therefore the vegetation species in such areas should allow adequate water flow through the vegetation to reduce the amount of sediment that accumulates at the site.

On banks down stream of water storage project, selected vegetation should be able to survive or recover rapidly in the event water levels must remain at elevated levels for an extended period of time due to flood or navigation releases.

Provide specifics on quality requirements.
****

Permanent vegetation species and mixtures for [live and dead cuttings] [and] [nursery stock] [and] [herbaceous plants] shall be as follows:

Mixture Percent by Volume	Percent Live and Dead	Botanical Name	Common Name
[_____]	[_____]	[_____]	[_____]

Weed seed or noxious plants shall be a maximum of 1 percent by weight of the total seed mixture. [Undesired], [non native] [and] [or] invasive vegetation species shall not be allowed. All live cuttings and containerized plantings shall be capable of growth and rooting and free of disease or defects at the time of installation.

2.5 STAKES

Stakes shall be 100 percent biodegradable materials and shall be designed to safely and effectively secure erosion control blankets, coir logs, fascines, and other bioengineered structures for temporary or permanent applications. The biodegradable stakes shall be fully degradable by biological activity [within 2 years]. The stakes must exhibit ample rigidity to enable being driven into hard ground, with sufficient flexibility to resist shattering.

2.6 STAPLES

Metal or plastic staples shall not be used.

2.7 SYNTHETIC GRID AND SHEET SYSTEMS

Synthetic grid and sheet systems shall not be used.

2.8 CRUSHED ROCK, GRAVEL, SAND, STONE, RIPRAP, and BACKFILL

The quality of rock, gravel, sand, stone, riprap, and backfill shall be in accordance with requirements in Section 31 00 00 EARTHWORK and Section 35 31 19 STONE, CHANNEL, SHORELINE/COASTAL PROTECTION FOR STRUCTURES. Materials not meeting specified requirements shall be rejected and immediately replaced by suitable material at no cost to the Government.

2.9 WATER

Water for irrigation, soaking of plants and cuttings, and dust control shall be the responsibility of the Contractor. Water shall be clean, free of contaminates, and have a turbidly of less than 20 NTU. Water shall be from [a public source of know quality] [local surface water source] [groundwater well] near the work site. [Water obtained from non public sources shall be tested for quality in accordance with paragraph MATERIAL TESTING REQUIREMENTS.]

2.10 FENCING

****

NOTE: Permanent or temporary fencing may be required around work sites to prevent vandalism and damage to newly planted vegetation by livestock, animal, or human activities. Fencing may be temporary or permanent. Specify temporary fencing such as plastic construction fence, snow fence, or rental fence below. Use Section 32 31 00.00 10 FENCING to specify permanent wire and chain link fabric fences and gates if required.

****

[All fencing shall be in accordance with Section 32 31 00.00 10 Fencing.] Fencing shall be temporary and consist of [_____] fence. Fencing shall be secured to [wood] [metal T-poles] that are driven 600 mm 2 feet into the ground and extend 1.2 m 4 feet above the finish grade. Fencing shall be installed [at the start of work] [after construction]. Fencing shall remain in place [until vegetation is established] [for 3 years].

2.11 IRRIGATION

****

NOTE: Sites may require extended periods of irrigation to ensure vegetation establishment. Irrigation systems may be on the surface or underground. Water retention in the structure in arid regions may be aided by the use of super absorbent polymers. Edit this specification for products that may be used with open trench irrigation.

Some sites may be remote and may not have electrical or water supplies available. In this case, the designer should include products for solar power, water tanks, or methods such as daily watering by

water truck.
****

[All underground irrigation shall conform to Section 32 84 24 IRRIGATIOUN SPRINKLER SYSTEMS or as approved by the Government.] The Contractor shall provide the following products and materials for irrigation.

Product	Manufacturer	Quantity	Purpose
[_____]	[_____]	[_____]	[_____]

2.12 FERTILIZER, PESTICIDE, HERBICIDE

****
NOTE: Edit this paragraph as required. Fertilizer, pesticide, and herbicide may be required for the construction, establishment, and maintenance of bioengineered structures. The designer will consult with a qualified botanist, biologist, landscape engineer, and regulatory agencies before selecting the use of or type of fertilizer, pesticide, or herbicide for application at the site. Products, if selected for use, should not pose a threat to water quality or the environment. Pesticides and herbicides will only be used when absolutely necessary. Use of biological methods for pest or plant control is encouraged. Provide specific product names, manufacturer, method and concentration of application, and other required product information below.
****

The Contractor shall provide the following products and materials.

Product	Manufacturer	Quantity/Application	Purpose
[_____]	[_____]	[_____]	[_____]

PART 3 EXECUTION

3.1 CONDITIONS

The work schedule shall coordinate the timing of land disturbing activities with the provision of erosion control measures. An erosion control plan shall be required in accordance with Section 31 32 11 SOIL SURFACE EROSION CONTROL and applicable Federal, State, or local requirements. Erosion control operations shall be performed under favorable weather conditions. When excessive moisture, frozen ground, or other unsatisfactory conditions prevail, the work shall be stopped as directed. When special conditions warrant a variance to earthwork operations, a revised construction schedule shall be submitted for approval. Bioengineering materials shall not be applied in adverse weather conditions, which could affect their performance. The Contractor shall complete all tasks necessary for the required submittals.

3.2 TEMPORARY CONSTRUCTION FACILITIES

****
NOTE: Access roads or paths may need to be

permanent to allow ease in future monitoring and maintenance. If such access is required, provide requirements or references to appropriate specifications below.
****

All temporary construction facilities shall be in accordance with Section 01 50 02.00 10 TEMPORARY CONSTRUCTION FACILITIES. Access to the work site and harvest area shall be provided by [temporary] [permanent] [roads] [and] [paths] designed for [motorized vehicles] [and] [pedestrian access] if acceptable and in accordance with regulations and property owner restrictions and permission. The Contractor shall select access methods that have the least impact on existing site conditions and that may be easily removed and restored upon the completion of work. The Contractor shall provide strict access control to the work and harvesting sites to prevent access by non-authorized personnel. [Access gates] [Barricades] shall be installed at the entrances of temporary [roads] [paths] to the sites. [These gates shall be secured with a keyed lock and shall remain closed at all times when personnel are not present at the gates for access. The Contractor shall provide duplicate keys for the lock to the Contracting Office, landowner, authorized regulatory personnel, and fire and law enforcement as required.] [Appropriate signage shall be placed on the gates that clearly specify site access is restricted.]

3.3 FIRE PREVENTION

All efforts possible shall be taken to prevent fire at the work site and harvest area as a direct result of work efforts. Fire prevention or suppression equipment shall be provided to personnel at the work and harvest sites. All equipment shall be in compliance with applicable regulations and shall be kept in working condition at all times and within no more than 5 m 15 feet distant from the active work areas.

3.4 SANITATION

The Contractor shall provide adequate portable sanitation facilities for persons at the construction and harvest sites that are in compliance with all Federal, State, and local requirements.

3.5 HARVESTING OF VEGETATION

****
NOTE: Most plants for bioengineering structures constructed near water are wetland plants except for species used for the vegetation of high bank areas. Woody plants or herbaceous plants may be used and should be somewhat flood tolerant. Harvesting may include the collection of woody plants, herbaceous plants, or single or clump plantings. Vegetation should be harvested from local sources and native plant species near the construction site. The need to obtain vegetation from distant sources should be evaluated in terms of cost and the risk of introducing foreign genetic material into the watershed in which work occurs. Vegetation should be obtained when at all possible from the same watershed in which the work will occur. Other stabilization methods may be more appropriate for the site due to high transportation and handling

costs.

Site harvesting shall require the cutting of existing vegetation for live and dead stakes, poles, or cuttings, collection of roots or tubers, or excavation of plants with root mats intact. The harvest site must not be over harvested and must be restored as much as reasonably possible after harvest work is completed. The number and location of the vegetation that may be harvested shall be determined before construction by a qualified botanist or forest engineer.
****

3.5.1 Harvesting of Woody Plants

****
NOTE: Woody plants consist of stem cuttings that quickly sprout roots and stems from the parent stem. These plants are typically willow and perhaps some species of dogwood and alder. Nursery stock with established roots may also be used.

The length of the harvested vegetation will vary with site conditions and structure design. In general, stakes and poles should extend at least 300 mm (1-foot) above the top of structure. Cuttings should extend at least 300 mm (1-foot) beyond the edge of a structure or 600 mm (2 feet) above the ground surface. The actual lengths of the stakes or poles shall be based on the depth of soil from the surface to the mid summer capillary zone or water table. For guidance, the minimum length is three feet. The diameters for the base of cuttings and stakes may range from 19 to 38 mm (3/4 to 1.5 inches) and should be of sufficient diameter to resist buckling when driven into the streambed or bank. Live poles may range from 50 to 100 mm (2 to 4 inches). Live or dead logs used for crib walls should be at least 100 mm (4 inches) in diameter for gullies and 200 mm (8 inches) in diameter for use in streams or rivers. To improve survivability, live stakes and poles must be of sufficient length to penetrate the soil 600 mm (2 feet) below the bioengineered structure or to within the capillary zone of moisture in the soil.
****

[Stakes] [,] [poles] [,] [and] [cuttings] shall be harvested from local sources of selected species. Species of plants foreign to the ecosystem environment at the work site shall only be imported if they pose minimal threat to interfering with the native vegetation, are accepted by regulatory and environmental management, and are able to survive at the specific site. Unless otherwise stated below, [cuttings] [and] [stakes] shall be 19 to 38 mm 0.75 to 1.5 inches in diameter and at least 1 m 3 feet in length. [Stakes] [Poles] with a diameter of 50 to 75 mm 2 to 3 inches and minimum length of 1.5 m 5 feet shall be used for insertion into armored stream bank structures. [Stakes] [and] [cuttings] [and] [poles] shall be cut from healthy plants and shall be as straight as possible. Plants for harvest shall be a minimum of one-year-old, preferable 2 to 5 years in age. Suckers or current year growth shall not be used. All cuts shall be clean and free of splits or excessive peeling of bark. At least two bud scars shall be visible on the [cutting] [stake] [pole] above the surface of the ground or structure when installed. [Stakes] [Poles] with deviations or curvatures greater than 13 mm 0.5 inch from vertical per 200 mm 1-foot of length will not be accepted. [All branches emanating from the [stake] [pole] shall be trimmed as close as possible to the surface of the stake without damage to the bark.] [The bottom end of the [stake] [pole] shall be cut at an angle of 60 degrees to the horizontal. The top of the [stake] [pole] shall be cut normal to its length.] [Live cuttings shall be harvested from branches and shall include the growth tips of the branch. The butt of the cutting shall be cut at an angle to the vertical to aid in placing into soil.] If trunks of vegetation remain after cutting, these trucks shall have a sufficient number of healthy branches remaining to allow survival.

3.5.2 Harvesting of Herbaceous Plants

****

NOTE: Edit this section as required. Consult a qualified botanist for harvesting, handling, growing, and transplanting requirements if herbaceous plants are to be used. Herbaceous plants may be emergent aquatic plants such as reeds, rushes, and sedges or may be non aquatic plants such as grasses or other forbs that require moisture during some portion of the year. Harvesting of these plants requires the collection of seeds, roots, or tubers. The roots or tubers may be transplanted directly to the site. Plants from the roots may be grown in a nursery and subsequently transplanted to the site. Plants or roots collected in the field must be placed in containers filled with water and kept cool until being transplanted to growing media at a nursery. Exposure of the harvested plants to wind or dry and hot conditions should be avoided. Consult a wetlands expert for methods for collecting and growing of wetland plants.

****

[_____]

3.5.3 Harvesting of Reeds or Clump Plantings

****

NOTE: Edit this section as required. Consult a qualified botanist for harvesting and transplanting requirements of reed or clump plantings. Single plants or groups of plants may be harvested, which include the root mass in soil plugs. Large clump plantings require the removal of vegetation with the root mass and surrounding soil intact. These larger plantings may be extracted by hand and shovel methods or the use of light or heavy equipment.

****

[_____]

3.5.4 Sealing of Harvest Cuts

All harvest cuts on trunks or branches of the host vegetation shall be trimmed of loose wood or bark and sealed with an approved sealant to prevent desiccation and disease or infestation at the end of the workday without exception.

3.5.5 Harvest Site Restoration

The harvest site shall be restored to preexisting conditions as best as possible after harvesting is completed. Restoration shall include but shall not be limited to removal of aggregate or wood chip roads or access paths, access gates, and ruts or depression, or other items or features related to work activities.

3.5.6 Disposal of Excess Vegetation

Excess cut vegetation from harvesting shall be [thinly distributed on site] [collected and removed from the site] [staked on-site and [burned] [left in place]] [collected and transported to the work site for incorporation in the designed structure].

3.6 TIME OF PLANTING

****

NOTE: Edit this section as needed for site specific conditions. Provide specific dates for the planting window below.

Woody plants and nursery stock should be planted in the dormant season. These plants are dormant when buds are set in the fall after the first hard freeze until the time when the buds begin to swell in the early spring. If planting can not be done during the dormant season, then the cuttings may be stored in a cold environment at -2 degrees C (28 degrees F) until planting is possible.

Herbaceous plants may be planted during the dormant or non dormant seasons. If planted in the non dormant season, these plants should be placed as early as possible in the spring to allow the greatest amount of time for root development and growth. Herbaceous plants should not be planted during hot or dry weather if at all avoidable.

The time of planting is also dependent on site climatic and hydrologic conditions. The best time to plant is when the stream or lake is at mean water level. Planting should occur in the fall at sties where the water levels are expected to be low from the fall to the spring and if the plants may experience some growth and establishment before spring floods. Planting at sites where water levels fluctuate during the winter due to flooding or where frost heaving of soil occurs should be delayed until late spring. Late fall plantings may be preferable at locations subject to winter flooding and summer droughts. Fall planting is not recommended for

areas where late season droughts or frost heaving occurs below the root level. The designer should consult a hydraulic engineer to determine water levels and flow velocities at the site during the planting and initial growth periods. Clump planting of shrubs or reeds should occur in the spring or early summer.
****

Planting shall occur in the [spring] [fall] [summer] starting no earlier than [_____] and shall be completed by no later than [_____].

3.7 TRANSPORTATION OF HARVESTED VEGETATION

a. All freshly harvested and prepared live woody vegetation shall be immediately submerged in clean uncontaminated water and shall not be allowed to dry out. Cut vegetation shall be transported to the work staging area submerged in water. If site conditions prohibit direct access to storage bins filled with water, then the freshly cut live vegetation shall be wrapped in cloth, which is thoroughly saturated with water, and shall be transported to a storage bin filled with water within no more than one hour from the time of cutting.

b. Live vegetation shall be transported from the staging area to the work site in containers fully covered with clean water. Vegetation shall be removed from the containers and immediately placed in the ground. In the event that access to the installation site is limited, vegetation shall be removed from the soaking tanks and wrapped in bundles that are completely covered with at least three layers of saturated highly absorbent cloth or saturated biodegradable paper product with high saturated strength. The cloth and bundles shall be placed in plastic liners for greater ease in transportation to the work site.

c. Cut vegetation shall not be left uninstalled at the work site and exposed to air or heat or excessive cold for any reason. Dead [cuttings] [stakes] [poles] shall not be soaked unless the design requires this vegetation to be flexible. Cut live vegetation that is exposed to air for longer than 15 minutes during harvesting, transportation, installation, or which were not collected or transported as specified above shall not be accepted. Damaged live vegetation shall not be accepted and shall be replaced at no expense to the Government.

d. [[Herbaceous plants] [Nursery stock] shall be transported to the work site in covered vehicles. Plants shall not be subjected to cold or excessive heat or drying during transport. The plants shall be carefully unloaded at the staging area and placed in a shaded area. Plants shall be watered and maintained in healthy condition until the time of installation. The plants shall be transported to the work site [by hand] [push cart] [vehicles] and immediately installed at the site. Damaged, wilted, diseased, or dead [plants] [nursery stock] shall not be accepted and shall be immediately replaced at no expense to the Government.]

3.8 SOAKING AND PAINTING OF LIVE WOODY VEGETATION

****
NOTE: All efforts shall be taken to prevent the harvested live vegetation from losing moisture from the time of cutting to insertion into the ground. Soaking of the live vegetation greatly improves the

ability of the plants to survive transplant into the bioengineered structure.

****

a. All harvested live vegetation shall be soaked in clean water for 3 to 5 days before installation into the ground. The live vegetation shall be placed in clean, leak proof, large plastic storage containers or similar, which are at least 300 mm 12 inches longer in length than the cut vegetation. Reused or new metal drums or drums used for the containment of hazardous wastes or chemicals shall not be used. The containers shall be placed in organized lines in a shaded location separated by a sufficient distance to allow access of a vehicle to the containers for the placement and removal of the vegetation. Each container shall be given a unique identification number or series of numbers and letters that shall be clearly visible at the end of the container that shall be approached for the placement or the removal of vegetation. The identification numbers shall be recorded and referenced in relation to the contained vegetation for quality control and construction purposes.

b. The water levels in the containers shall be checked twice daily and water shall be added as needed to ensure the containers are filled with sufficient water to completely cover the contained vegetation with a minimum of 50 mm 2 inches of water. Rust proof weights or clean cobbles or boulders may be used to weight down the vegetation and retain it under the water surface. These weights shall not crush or damage the vegetation. Water in the containers shall be completely replaced with fresh and clean water every 3 days without exception. Vegetation that remains in water that has not been replaced as required shall be deemed defective and shall not be accepted by the Government. Water replacement schedule may be adjusted to compensate for weekends and holidays with the notification and approval of the Contracting Officer.

3.8.1 Mixing of Live Vegetation

Vegetation of a specific species shall not be commingled with another species during cutting, soaking, or transportation.

3.8.2 Painting of Stakes and Poles

****

NOTE: The painting of the tops of the live stakes and poles will reduce desiccation of the cuttings, potential for disease mortality, and allow ease in locating once installed. All painting shall occur after soaking. Stakes or poles made of lumber may be painted at the option of the designer to improve visibility.

****

The top ends of the [stakes] [and] [poles] shall be painted with a latex paint diluted with water at a ratio of one part paint to one part water. The tops of the [stakes] [and] [poles] shall be [dipped in the dilute paint mixture to a depth of 75 mm 3 inches after soaking] [painted immediately after planting by [brush] [spray applicator]]. The color of the paint shall be [caution yellow] [safety orange]. The top ends of dead [stakes] [and] [poles] shall [not] be painted.

3.8.3 Harvesting and soaking records

Daily logs shall be prepared documenting the activities of plant harvesting, transportation, and soaking. These records shall contain at a minimum: name, date, weather conditions, company, location of harvest area, location of soaking area, site rehabilitation, species harvested, number of cuttings harvested, number of cuttings placed in soaking tanks, damage to cuttings, problems, and solutions to problems encountered. Records shall clearly indicate the health of the primary vegetation from which the cuttings are obtained, diameter of cuttings and primary vegetation, length of cuttings, trimming procedures, time of cutting, time of placement in transportation bins, handling procedures, sealing of harvest cuts, time the live vegetation is delivered and transferred to soaking tanks, and identification label of the tank in which the cuttings are placed. The records shall contain the duration of soaking of the vegetation, water quality and time and amounts of water added to the tank during soaking, time of removal of the cuttings from the tanks, time of planting of the cuttings, and procedures used for removal, transportation, and planting of the vegetation at the construction site. The records shall be signed by the lead harvest person or person in charge of soaking and planting and shall be provided to the on-site manager at the end of each day. Records shall be provided to the Contracting Officer within [24] [_____] hours of completion.

3.9 STAGING AREA

****

NOTE: A staging area for operations may be required. This staging area should be level and of sufficient size for the positioning of numerous bins for the soaking of live vegetation before installation. The staging area should also be of sufficient size to allow parking, storage of equipment, construction of bioengineering components, work trailer, sanitation, and water tanks if necessary.

****

A staging area shall be constructed at the work site for the storage of equipment, work trailer, portable sanitation, water tanks, parking, and all other materials and equipment required to complete the work. The site should have a level portion for the placement of soaking tubs for the live vegetation. [The staging area shall be secured by an eight feet high chain link security fence to prevent vandalism or unauthorized access to the staging area.] Adequate surface preparation shall be performed to prevent excessive settlement, ponding of water, or rutting. The location and design of the staging area shall be shown in the drawings.

3.10 SITE PREPARATION

3.10.1 Access Routes

Access routes to the construction site shall be established prior to the start of work and shall be shown on the drawings.

3.10.2 Clearing and Grubbing

The access route and construction site shall be cleared of vegetation necessary for the construction of the bioengineered structure or staging area in accordance with Section 31 11 00 CLEARING AND GRUBBING. Efforts will be made to salvage vegetation suitable for use in the bioengineered structure.

3.10.3 Erosion and Sediment Control

Erosion and sediment control measures shall be installed prior to active construction efforts to prevent erosion of soil and off site releases of sediment. Specific requirements are in Section 31 32 11 SOIL SURFACE EROSION CONTROL.

3.10.4 Earthwork

****

NOTE: Minor or extensive earthwork may be required as part of the construction of the bioengineered structure. This specification only includes the requirements for minor earthworks for trench excavations and soil roughening. Dimensions for minor earthworks are provided in the specific bioengineering method sections below. Site grading, shaping, or trenching for drains and utilities, and material types and gradations should be included in Section 31 00 00 EARTHWORK.

****

The [stream bank] [shoreline] shall be sloped and graded [in accordance to Section 31 00 00 EARTHWORK] [and] [as shown on the drawings].

3.10.4.1 Trenches

Unless otherwise stated, trenches shall be to the depth, width, and line as shown on the drawings. Side slopes, unless otherwise indicated, shall be at the angle of repose. Material removed from the trench shall be [used as backfill] [removed from the site]. [Trenches shall be backfilled with select fill]. [The floor of the trench shall be compacted to 90 percent maximum dry density and smooth.] Backfill shall be placed in 150 mm 6 inch lifts compacted [to 80 to 90 percent maximum dry density] [sufficiently to improve soil density but not impede vegetation root growth]. [Trenches shall be keyed into the stream bank for a distance of 3 feet]. [Shoring shall be installed [if the trench exceeds 1 m 3 feet in depth] [as required by regulations]]. [The Contractor shall be responsible for dewatering of trenches for construction purposes.]

3.10.4.2 Finished Grade

Finish grade shall be smooth and as shown on the drawings and in accordance with Section 31 00 00 EARTHWORK.

3.10.4.3 Surface Roughening

****

NOTE: Surface roughening should be performed on all slopes with exposed earth that are greater than 3H:1V. Surface roughening reduces surface runoff velocities and provides depressions that collect sediment, seed, and water, thereby improving vegetation establishment on the slope. Roughening may be accomplished by traversing the surface with

track-mounted equipment, manual efforts such as hand raking, or terracing of the slope during excavation or the placement of fill. The method of roughening may vary depending if the slope is a new cut or fill surface or an existing or graded slope. Surface roughening should not create ridges or depression that hinder the mowing of slopes that are 3H:1V or less.
****

The surfaces of all barren slopes related to work efforts shall be roughened by [equipment] [and] [manual efforts] to reduce erosion and promote trapping of seed, water, and sediment. All lifts shall be compacted as specified in Section 31 00 00 EARTHWORK. [The surfaces of the lifts shall be covered with loosely compacted soil to a depth of 100 mm 4 inches.] [Track-mounted equipment shall traverse the slope from the toe to the crest to place track imprints parallel to the contours of the slope.]

a. [Slopes on new cut faces greater than 3H:1V shall be roughened by stair-step cuts installed during construction. The faces of the steps shall not exceed 600 mm 2 feet in height in soft material or 900 mm 3 feet in height in hard material. The horizontal spacing between the vertical faces shall not be less than the vertical height of the step.]

b. [Slopes on new fill greater than 3H:1V shall be roughened by the installation of lifts of compacted soil that shall not exceed 200 mm 8 inches in thickness.]

c. [The existing slope of graded areas shall be roughened by tilling, disking, harrowing and seeding, or other suitable method or equipment to produce ridges and depressions in the surface of the slope, which are parallel to the contours of the slope. These ridges and depressions shall not exceed 25 mm 1 inch in depth or height above the grade surface and shall be spaced no more than 250 mm 10 inches apart.]

d. The final roughened surface shall not be smoothed by blading or scraping. All large soil clumps shall be broken into small clumps not more than 50 mm 2 inches in diameter and dispersed on the immediate surface. Mounds or depressions of soil that are greater in height or depth than those produced by the method of roughening shall be cut or filled with suitable material to grade and shall be roughened to match the adjacent surface. Depressions of depth greater than 150 mm 6 inches shall be backfilled with compacted suitable material until reaching the design grade of the slope and roughened. Sand or silty sand shall not be compacted to a density that may prevent vegetation planting and growth. Roughened areas shall be seeded, planted, or covered with erosion control products [immediately after roughening] [within [_____] days after completion of roughening].

3.11 SITE DRAINAGE

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NOTE: The designer should specify the site specific requirements for temporary and permanent drainage in this section. Work and harvest sites should be well drained at all times to prevent the ponding of water. Runoff water may need to be stored in retention or settling ponds before release to surface water bodies or channels. All temporary

drainage features and structures shall be removed and restored to preexisting or design conditions at the end of work. Drainage may be a requirement for structure stability and for final grade of the work site. Some structure may require internal drainage of groundwater to improve stability. The requirements for internal drainage design should be stated in the requirement paragraph of the selected structure. Best Management Practices shall be employed in accordance with Section 01 57 23.00 10 STORM WATER POLLUTION PREVENTION MEASURES.

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[______]

3.12 DEWATERING

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NOTE: Excavations may need to be dewatered to allow construction. Failure to due necessary site investigation or characterization may result in construction delays, unsafe working conditions, and cost claims.

It is important to understand the subsurface groundwater conditions, surface drainage, and precipitation in the area of the work during the selection and design of a structure. Water in excavations may delay work efforts, interfere with proper soil placement and compaction, and damage vegetation. Structures that incorporate large amounts of woody vegetation may be damaged due to buoyant forces if these excavations fill with water before sufficient material or binders have been placed to hold the vegetation in place. Water removed from excavations may require treatment before release.

Excavations adjacent to tidally influenced water bodies offer challenges in water control and drainage of excavation in terms of construction timing. Time of construction and dewatering may need to be adjusted to match tidal events and require work during time periods other than normal working hours. Similarly, work schedule and dewatering of excavations may need special attention adjacent to rivers or streams that fluctuate seasonally or daily due to water releases from water storage or hydropower projects. In areas where water levels fluctuate, precautions should be taken to ensure the structure will not be damaged by buoyant forces or by currents.

Dewatering of excavations can be expensive due to planning, equipment, labor, and disposal efforts. Alternative designs, locations, or foundations should be considered to reduce project costs if required. Groundwater should be tested for chemical contamination before the start of work. The cost of

dewatering and treatment of such water may be high.
****

The Contractor shall be fully responsible for all dewatering efforts for construction and for obtaining and reviewing all necessary information to ensure dewatering efforts are in compliance with regulations. The Contractor shall be fully responsible to ensure the designed dewatering efforts are adequate based on site conditions and climate other variables that may effect dewatering efforts. [The Contractor shall submit a technical memorandum detailing all dewatering requirements, locations, methods, and disposal procedures to the Contacting Officer at least [60] days before the start of work.] Information provided by the Government regarding dewatering requirements and site conditions shall in no way relieve the Contractor of full responsibility for all dewater planning, efforts, and costs. The Contractor shall ensure the structure shall not be damaged by buoyant forces or by currents should water enter the excavation or during the removal of this water. The Contractor shall be responsible for ensuring dewatering efforts do not impact adjacent structures or property, result in instability of the excavation floor or slopes, produce unsafe working conditions, or damage to animals or the environment.

3.13 BIOENGINEERED STRUCTURES

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NOTE: The most common types of bioengineered structures are described below. These structures may be categorized as common, transverse, deflector, or longitudinal. Common structures are generic bioengineered structures applicable to gullies, stream banks, and lake shores. Transverse structures are constructed across stream channels that are less than 4.5 meters (15 feet) wide and 3 meters (10 feet) deep. Deflector structures are constructed from the bank into a stream or river to deflect flow away from the bank. Longitudinal structures are constructed parallel to stream banks or lake shores. Bioengineered structures may be used separately or in combination for bank protection and stabilization depending on the geotechnical and hydraulic site conditions, physical setting, desired habitat, and supply of construction materials. Structures not pertinent to the proposed design shall be deleted from this specification. Structures described below are:

Common Structures
Permanent seeding
Live Staking
Joint planting
Pole planting
Live fascine
Siltation structures
Brush mat
Clump planting
Transverse Structures (streams less than 4.5 meters (15 feet) wide, gullies, small tributaries)
Palisade
Brush and stone sill
Wattle fence sill

Vegetated crib wall or wood sill
Vegetated dry stone barrier
Brush works or brush packing
Live fascine sill
Deflectors (Streams wider than 9 meters (30 feet), stream bank protection)
Vegetated deflector (groins, dikes, spurs)
Live brush sill
Brush transverse
Brush grid
Longitudinal Structures
Single or clump reed planting
Live stone revetment
Brush layered revetment
Longitudinal live fascine
Longitudinal brush packing
Live crib wall

The specific names for bioengineered structures have not been standardized. The names of the structures listed above are not inclusive of all structures mentioned in literary sources and only represent a general compilation of the most commonly referenced names assigned to the structures. Therefore, individuals may have a different understanding of the function and deign of a structure when provided with only a name. A diagram of the proposed structure is recommended for inclusion in this specification to provide clarity in the description and intent of the requirements. The designer may obtain these drawings from numerous literary sources, private venders, or State resource agencies. It is recommended that the designer review these drawings during the selection of the structures for use and that the designer should provide these drawings to other personnel involved in the deign and planning of the project to reduce confusion in design objectives and requirements. These drawings may be edited for site specific conditions as needed and should be included in or attached to this specification.

The following paragraphs provide the general types of information that are required for the description of requirements for the structures. The designer must edit the selected requirements to meet project objectives and performance criteria based on actual site conditions.
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3.13.1 Common Structures

3.13.1.1 Permanent Seeding

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NOTE: Permanent seeding is a simple method of stream bank stabilization that may be used along low velocity streams or channels with peak flows less than 3 cubic feet per second. Seeding must be

combined with erosion control stabilization methods to prevent or reduce soil erosion during germination and the first several years of vegetation growth. Selected species of grasses and/or plants should be native to the area, resilient, provide a dense root mat, and be able to withstand being submerged in water for extended periods. The placement of rock or woody debris may be required at the toe of the bank to reduce undercutting.

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Selected seed shall conform to all required regulations and requirements and all seeding shall be performed in accordance with Sectio 32 92 19 SEEDING. Seed shall be placed before installation of erosion control mats or the application of other erosion control materials or products.

3.13.1.2 Live Staking

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NOTE: Live staking is the insertion of living stakes of vegetation into the ground. Live staking may be used to cover large areas of stream banks and to infill areas between other bioengineered structures. Live poles may also be used in lieu of stakes if deeper ground penetration is required. In this event, the method should be referred to as live pole staking. Combining live stakes with dead stakes may be feasible where the trapping of debris on the bank is desired or where there is a limited supply of local live vegetation.

****

Live stakes shall be driven into the ground in a row parallel to the stream bank with the stakes spaced 1 meter 3 feet apart. Rows of stakes shall be installed starting from the toe of the bank and progressing landward and shall be spaced 1 meter 3 feet apart. Successive rows of stakes shall be offset from the preceding row by one half the spacing distance between the stakes. Construction shall be performed in accordance with ASTM D 6765 Standard Practice for Live Staking.

3.13.1.3 Joint Planting

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NOTE: Joint planting is a variation of live staking in which live stakes or poles are driven between the joints of large natural stone, rip rap, or other forms of bank armor. This method may be used to add vegetation to stretches of stream bank, which are protected by barren armor to improve habitat and add areas of shade. Vegetation will improve bank stability due to the development of root mats. The vegetation will also decrease the velocity of water adjacent to the bank during high flow events. Caution is advised to check the stability and condition of the armor before using these methods on existing protected banks. The amount of sediment that may accumulate on the back as a result of the vegetation should be considered in long term design performance since the deposition of large amounts of

sediment may overload the bank and result in failure.
****

Live [stakes] [poles] shall be installed in rows parallel to the stream bank with the [stakes] [poles] driven into joints between the [stones] [rocks] of the bank armor. [Stakes] [Poles] shall be driven a minimum of 600 mm 2 feet into the soil behind the armor and shall be spaced 1 meter 3 feet apart. The [stakes] [poles] shall be inclined at 15 to 45 degrees from horizontal. Rows shall be installed starting at the toe of the bank and progressing landward and shall be spaced 1 meter 3 feet apart. [Stakes] [Poles] in successive rows shall be offset from the [stakes] [poles] in the preceding row by half the spacing distance. The tops of the [stakes] [poles] shall extend at least 0.5 m 1.5 feet but not more than 1 meter 3 feet above the top of the armor.

3.13.1.4 Pole Planting

****
NOTE: Pole planting is the placement of vertical live or dead poles in multiple rows along the toe of a stream bank. The poles may trap debris between the poles and between the poles and the bank. The accumulation of debris should reduce the flow velocity adjacent to the bank and encourage the deposition of sediment and thus promote the aggradation of the bank over time. The structures will not provide immediate erosion protection, habitat, or bank stability. Erosion protection and habitat should develop as debris is trapped and the vegetation begins to grow. The stability of the bank should improve over time as new bank is formed and vegetation and root mats become established in the new bank material. Pole planting may be used in areas with steep or vertical banks or in areas with a limited supply of the vegetation that is necessary for the construction of other types of bioengineered structures. Pole plantings may be combined with brush mats or brush grids. Pilot holes may need to be drilled to allow the installation of the poles in coarse alluvial streambeds. Pole planting is not recommended for use in stream channels that contain large boulders or where bedrock may be within a few feet of the channel bottom. The depth to scour must be known to ensure the poles will not be lost due to degradation of the stream bottom during a flood event.
****

Live poles shall be driven vertically into the stream bed to a minimum depth of 1 m 3 feet. [No more than one-half the length of the pole below grade shall extend above the ground.] [The poles shall be driven to refusal.] [Pilot holes shall be drilled at the locations where the poles shall be installed using a steel rod or mechanized drilling machine. The poles shall be placed into the holes and loose sediment around the poles shall be compacted in place. Additional sediment shall be added as need to fill any space between the pole and the inner wall of the pilot hole until the hole is filled to the existing surface.]

a. Poles shall be straight and at least 100 mm 4 inches in diameter. The driving tip shall be shaped to a point to aid in installation. Branches shall [not] be stripped from the pole [where exposed above grade after installation]. The top of each pole shall be cut normal to its length.

b. Poles shall be installed in rows parallel to the stream bank at a nominal spacing of 1 m 3 feet. Rows shall be installed starting at the toe of the bank and progressing towards the stream channel to the mean low water level. Poles in successive rows shall be offset from the poles in preceding rows by one half the spacing distance. The tops of the poles shall be at a uniform elevation [of 1 m 3 feet] above the mean low water level along the bank.

3.13.1.5 Live Fascine

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NOTE: Live fascines are long bundles of live or dead branch cuttings tied together in tubular sections from 1 to 10 meter (4 to 30 feet) in length and up to 300 mm (1-foot) in diameter. Smaller diameters and lengths of fascines are advantageous in areas where access by vehicles is not possible and materials must be provided to the site by manual labor. Fascines are recommended for sites close to large supplies of vegetation. Fascines are advantageous in stabilizing slopes of long length and for protecting the toes of banks. The structures are effective in reducing erosion on sloped banks that are subjected to bank scour or high surface runoff. The horizontal arrangement of fascines will reduce erosion and trap sediment and seed on the slope. The structures will deflect and insulate the bank from the stream current.

The stability of the bank will improve as the live vegetation develops root systems. Steep or undercut banks must be reduced in slope to provide a stable slope for construction and installation of the fascines. Banks that have experienced sloughing or rotational failures must be repaired by the removal of the failed material and the reconstruction of a stable surface before the installation of the fascine structures.

Fascines require large amounts of live vegetation for construction. Therefore, these structures are best suited for temperate regions where there is a significant supply of available and suitable vegetation near the work site. Staggered fascine structures are recommended in areas with limited supplies of vegetation or as a means to reduce project costs. Fascines are suitable to protect the toes of banks when used in combination with other bioengineering methods on the slopes. Fascines may be used at transition areas between different types of erosion or stabilization structures such as between erosion control mats and live siltation structures at the toe of a stream bank, or with brush mats or layered structures.

Fascines may be refereed to as horizontal or vertical structures. Horizontal fascines are placed parallel to the stream channel. These fascines will reduce bank erosion by scour and surface runoff. The recommended spacing between horizontal fascines based on bank slope are:

Slope	Slope Distance Between trenches (ft)	Maximum Slope length (ft)
1H:1V to 1.5H:1V	3-4	15
1.5H:1V to 2H:1V	4-5	20
2H:1V to 2.5H:1V	5-6	30
2.5H:1V to 3H:1V	6-8	40
3H:1V to 4H:1V	8-9	50
4H:1V to 5H:1V	9-10	60

Vertical fascines are placed normal to the stream channel. These fascines may be used to serve as drainage conduits between the key trenches of horizontal fascines and are recommended in temperate regions and banks composed of poorly drained soils. Vertical fascines may be used to protect the bank from scour. The spacing of the vertical fascines shall be determined by site conditions, but should be close enough to prevent scour of the bank between the vertical bundles.

The trenches for the horizontal fascines may extend the full width of the work area or may be of shorter length and staggered to reduce the amount of material and labor required for the project. Key trenches must be installed at the toes of banks for horizontal fascine structures. The key trenches may be filled with natural stone and live and/or dead fascines up to three bundles in height. The ends of all trenches should be keyed into the bank or protected with large natural stone to prevent scour.

The trenches for vertical fascines should extend from the crest to the toe of the bank if these fascines are used without other structures on the slope. The trenches for the vertical fascines may extend between the trenches of horizontal fascines if used in combination. In this case, the vertical fascine trenches should connect the lowest portions of the horizontal fascine trenches to allow drainage. Trenches for both horizontal and vertical fascines may be installed landward of the crest of the bank if additional protection is desired and sufficient room for these trenches is available.

Fascines composed of live cuttings may be placed on bank slopes to the mean high water level of the stream. Live cuttings capable of growth under saturated conditions may be placed in the stream and in key trenches to elevations below the mean water level. Dead cuttings may be used for fascines placed in saturated conditions or may be interwoven

with live cuttings to provide added resiliency to live fascines. Fascines composed of dead cuttings may also be used separately at the toe or on the bank slopes where erosion and scour protection are desired and other bioengineered or hard structures are used for bank stability. Fascines should be wrapped with erosion control matting when installed in fine-grained cohesionless soil to reduce erosion of backfill.

Fascines should not be constructed on the ground. Elevated tables or braces should be used for assembly. All fascines bundles should be constructed by laying live cuttings parallel to one another with all growth tips oriented in the same direction. The cuttings should have a minimum of 300 mm (1-foot) of overlap on successive layers. The live vegetation cuttings should be secured into a bundle using biodegradable binders spaced every 450 to 600 mm (1.5 to 2 feet) along the length of the bundle. The fascines should be carried to the installation site in a manner that prevents excessive bending or breakage. Fascines with broken or loose cuttings due to excessive bending or the failure of binders must be repaired or replaced at no expense to the Government.

****

a. Horizontal Fascines. All trenches shall be installed parallel to the direction of the bank contours. All trenches shall be 450 mm 18 inches wide and not more than 50 mm 2 inches deeper than the diameter of the fascine bundles.

1) A key trench shall be excavated [at the toe of the bank] [at the mean [high] water level] [at the location shown on the drawings] [to a depth of 1 m 3 feet below the mean high water level] and shall extend the full length of the working area. Trenches up slope of the key trench shall be [the same length as the key trench] [3 m 10 feet in length and separated by a spacing of 3 m 10 feet longitudinally. The midpoints of the trenches placed up slope shall coincide with the midpoints of the spaces between the down slope trenches]. Trenches shall be spaced 1.2 m 4 feet apart. A trench shall be installed at the toe and at two feet below the crest of the bank regardless of spacing interval. These trenches shall extend the full length of the work site. [At least [2] [_____] trenches shall be placed landward of the crest of the slope at a spacing of 1.2 m 4 feet.] All trenches shall be [keyed into the bank slope] [and] [filled for a distance of 1 m 3 feet with large natural stone at the up stream and down stream ends of the trenches].

2) The fascine bundle shall be placed in the center of the trench with at least 50 mm 2 inches of the bundle exposed above the top of the existing grade of the stream bank. The junction between the ends of adjacent fascine bundles in the same trench shall be [offset side-by-side] [interwoven with each other] for a distance of 300 mm 1-foot. The fascine bundle shall be anchored in the trench with [live] [and] [dead] [stakes] [and] [poles] that are at least 50 mm 2 inches [square] [in diameter] at the top, 700 mm 2.5

feet in length, and tapered from the top to the base. The [stakes] [poles] shall be driven vertically through the fascine until flush with the top of the bundle starting 1-foot from the end of each fascine and spaced every 1 m 3 feet thereafter. A terminal [stake] [pole] shall be driven 300 mm one-foot from the end of the fascine regardless of spacing interval. [Stakes] [Poles] shall not be driven through or within 150 mm 6 inches of the binders. Live [stakes] [poles] shall be driven into the slope on the downhill side of the fascine bundle at an angle not to exceed 45 degree from vertical. The [stakes] [poles] shall be placed at the midpoint between the anchor [stakes] [poles] and shall contact the underside of the fascine, but shall not penetrate the fascine. At least 75 mm 3 inches of these downhill live [stakes] [poles] shall extend above the ground surface. Soil shall be placed and lightly tamped into place around the fascine and brushed into the voids in the fascine until only the top of the bundle is partially exposed. The top of the backfill shall slope towards the back of the fascine trench to prevent overtopping by runoff and to retain water and sediment.

3) [A single fascine shall be placed in the key trench.] [Up to [3] [_____] fascines shall be stacked on top of one another in the key trench.] Live poles shall be driven vertically into the ground to a minimum depth of 600 mm 2 feet to secure the [stacked] fascine bundle(s) in the key trench. These poles shall extend at least 600 mm 2 feet above the top of the upper most bundle. Key trenches shall be backfilled with compacted [removed sediment] [select fill] to match the [existing] [final grade of the] surface.

b. Vertical Fascines. Trenches shall be installed normal to the bank contours and shall be spaced 3 m 10 feet apart starting from the up stream end of the work site. A trench shall be placed at the down stream end of the work site regardless of spacing interval. The trenches shall extend [from the [toe of the bank] [key trench]] to [[the crest of the bank] [3 m 10 feet landward of the crest of the bank]] [between the horizontal fascine trenches. Vertical trenches shall be offset by 1.5 m 5 feet between horizontal trenches to prevent through flow of drainage]. All trenches shall be 450 mm 18 inches wide and not more than 50 mm 2 inches deeper than the diameter of the fascine bundles. [A key trench shall be excavated parallel to the bank contours at the [toe of the bank] [mean high water level] and shall extend the full length of the working area. The key trench shall be filled with horizontal fascine bundles as specified above in paragraph a. Horizontal Fascines].

1) The fascine bundle shall be placed in the center of the trench with at least 50 mm 2 inches of the bundle exposed above the top of the existing grade of the stream bank. The junction between the ends of adjacent fascine bundles in the same trench shall be [offset side-by-side] [interwoven with each other] for a distance of 300 mm 1-foot. The fascine bundle shall be anchored in the trench with [live] [and] [dead] [stakes] [and] [poles] that are least 50 mm 2 inches [square] [in diameter] at the top, 700 mm 2.5 feet in length, and tapered from the top to the base.

2) The [stakes] [poles] shall be driven vertically through the fascine until flush with the top of the bundle starting 300 mm 1-foot from the end of each fascine and spaced every 1 m 3 feet thereafter. A terminal [stake] [pole] shall be driven 300 mm

one-foot from the end of the fascine regardless of spacing interval. [Stakes] [Poles] shall not be driven through or within 150 mm 6 inches of the binders. Live [stakes] [poles] shall be driven into the slope on the up stream and down stream sides of the fascine bundle at an angle not to exceed 45 degree from vertical. The [stakes] [poles] shall be placed at the midpoint between the anchor [stakes] [poles] and shall contact the underside of the fascine, but shall not penetrate the fascine. At least 75 mm 3 inches of the up stream and down stream live [stakes] [poles] shall extend above the ground surface.

3) Soil shall be placed and compacted into place around the fascine and brushed into the voids in the fascine until only the top of the bundle is partially exposed. The top of the backfill shall be roughened, seeded, and covered with erosion control matting to prevent the loss of soil.

3.13.1.6 Siltation structures

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NOTE: Siltation structures are composed of live or dead cuttings that are placed parallel to the toe of a stream bank at or below the mean high water elevation of the stream. These structures provide immediate erosion protection, fish habitat during high flow events, and trap sediment that results in bank aggradation. The structures deflect the current in the stream away from the toe of the bank to prevent scour and undercutting. The stability of the bank is improved as root systems develop.

Siltation structures are recommended for sites with low flow velocities such as the insides of meander bends, side channels, and in areas of bank scour behind obstructions. The structures are well suited for locations where the development of new bank is desired. Siltation structures should be combined with large natural stone, coir logs, root wads, or other hard structures if used in areas subject to high flow velocities and scour.

The structures may be constructed of live or dead cuttings. Live cuttings should be 1 to 2 meters (3 to 6 feet) in length, flexible, and from species of plants with do not mature to heights greater than 3 meters (10 feet). Side branches may remain on the cuttings. Live cutting structures should be placed at the mean high water elevation of the stream to allow growth of vegetation unless the selected species is capable of root generation under saturated conditions.

Dead cuttings may be incorporated into a live structure to improve its resiliency and resistance to abrasion by sediment and debris. The dead cuttings may be from any locally available species of vegetation. Structures composed completely of dead cuttings are suitable for areas were temporary bank aggradation and erosion protection are desired.

Dead cutting structures may be placed above or below the mean high water level of the stream. If the dead structure is placed below the mean high water level, it is recommended that large natural stone be placed on the cuttings to reduce floating of the cuttings. More than one row of live or dead siltation structures may be placed along a stream bank to increase the width of coverage.

Siltation structures may be placed on the stream bank normal to the toe of the bank and oriented up to 15 degrees down stream from the perpendicular to the toe. Theses structures are recommended for low slope banks to reduce erosion of low banks, improve bank stability due to root development, and for areas where sedimentation is desired. The spacing between these structures should be determined based on actual field conditions and flow velocities to prevent scour between the structures. Live stakes or poles may be placed between the siltation structures.

****

a. The siltation structure shall [be [parallel] [normal]] [consist of segments parallel and normal] to the contours of the bank. The structure shall be composed of [live] [dead] [live and dead cuttings, comprising [80%] [and] [20%] of the structure, respectively]. Cuttings shall be 1 to 2 m 3 to 6 feet in length [and flexible] with side branches attached.

b. The cuttings shall be placed in a trench that is excavated [at the toe of the bank] [1 m 3 feet from the toe of the bank towards the stream channel] [as shown on the drawings]. The trench shall [be parallel to the bank contours and at the mean high water elevation.] [extend the entire length of the work site.] [[normal] [inclined at 15 degrees down stream to the bank contours.]] [The trench shall extend from the toe of the bank to the mean water elevation of the stream.] All trenches shall be 600 mm 2 feet deep with a 'V' shaped cross section. [Trenches shall be spaced 1 m 3 feet apart.] [All trenches shall be keyed 1 m 3 feet into the stream bank.]

c. The ends of the cuttings shall be pushed vertically into the bottom of the trench along the centerline and shall have the growth tips extending 450 mm 1.5 feet above the top of the trench. The cuttings shall be placed to form a layer that is 150 mm 6 inches thick with at least [15] [_____] cuttings per 300 mm linear foot of trench. Large natural stone shall be placed on either side of the bases of the cuttings and backfill shall be placed to infill between the stones to the top of the existing [design] grade. [The stream side portion of the structure and the toe of the bank shall be protected with [coir logs] [exposed dead fascines] [large natural stone with joint plantings of [live] [and] [dead] [poles] [stakes] [root wads]]]. The ends of the structure shall be protected with large natural stone placed on the up stream side of structure where it ties into the stream bank.

3.13.1.7 Brush Mat

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NOTE: A brush mat is composed of live or dead

cuttings that are placed on the stream bank to form a densely packed layer of cuttings. These structures provide immediate erosion protection, habitat for fish during high flow events, and the rapid establishment of extensive root systems in the bank. Brush mats are well suited for erosion protection of banks damaged by flooding. The growth of the vegetation composing the mat structure may be improved by placing an initial lift of brush and covering it with soil and then placing a second lift of brush to the design surface. The mat is held in place by anchor stakes or poles and further secured to the slope by rope or binding products that are laced between the anchor poles. Erosion control matting may be installed beneath the brush mat to reduce erosion of slope soil, especially if this soil is poorly compacted or easily eroded.

Brush mats require large quantities of vegetation and labor for construction. If an insufficient supply of live cuttings is available, then dead cuttings may be intermixed with the live cuttings in approximately equal portions. Dead cuttings should be flexible to allow construction and interweaving with the live cuttings. The base of the mat at the toe of the bank should be secured with rock or longitudinal bioengineered structures to prevent erosion or damage of the mat. The cuttings for the mat may be placed in small trenches cut into the face of the bank or pushed directly into the slope without the excavation of trenches.
****

a. [Live] [and] [dead] cuttings shall be generally straight, supple, 1.5 m 5 feet long, and shall have lateral branches still attached. The cut ends of the cuttings shall be shaped to sharp tips for penetration into the stream bank. The cuttings shall be placed in rows parallel to the contours of the bank starting 1 m 3 feet below the bank crest. The rows shall be spaced every 600 mm 2 feet thereafter down slope to the toe of the bank. All rows shall extend the full length of the work site.

b. The cut ends of the cuttings shall be pushed into the bank at the same contour elevation for each row with the growth tips toward the top of the bank. The cuttings shall be oriented [normal] [at an angle of 15 degrees down stream from normal] to the bank toe. At least 15 cuttings shall be placed per 300 mm liner foot in each row. A light roller and foot pressure shall be used to push the cuttings of subsequent rows against the bank over the cuttings of preceding rows to achieve a mat thickness of 100 mm 4 inches. [Up to 15 percent of the cuttings shall be placed parallel to the slope of the bank and interwoven with the cuttings that are placed with the growth tips toward the top of the bank. These parallel cuttings shall reinforce the brush mat. The growth tips of the parallel cuttings shall be oriented down stream.] The process of placing and compressing cuttings shall continue down slope until the toe of the bank is reached. A row of cuttings shall be place along the toe of the bank regardless of spacing interval.

c. The toe of the bank shall be protected by [large natural stones] [[live] [dead] fascines] [coir logs] that overlie the base of the cuttings of the row at the toe of the bank. [An erosion control mat shall be installed on the prepared grade of the bank slope before the placement of the cuttings.] [The ends of the mat shall extend 1.2 m 4 feet over unprepared bank.]

d. [Live] [Dead] anchor stakes that are 50 mm 2 inches in diameter shall be driven through the mat and 600 mm 2 feet into the stream bank. The tops of these stakes shall not extend more than 300 mm 1-foot above the top of the mat. The stakes shall be placed in rows parallel to the bank contours starting at the crest of the bank with the stakes spaced 1 m 3 feet apart. Subsequent down slope rows shall be spaced every 1 m 3 feet to the toe of the bank. A row of stakes shall be installed along the toe of the bank regardless of spacing interval to anchor the base of the mat. The top of each anchor stake shall be notched with a 13 mm 1/2-inch deep triangular cut that is normal to the length of the stake and 25 mm 1 inch below the top of the mat when compressed by foot pressure adjacent to the stake.

e. The up stream and down stream ends of the mat shall be secured with anchor stakes that shall be placed with a spacing interval equal to one half the above specified spacing distance of stakes in the rows. The one half distance spacing of stakes shall extend for 1 m 3 feet towards the center of the structure from the up stream and down stream ends of the mat and shall extend from the base to the top of the mat at these locations.

f. The mat shall be secured to the slope using binding ropes. The ropes shall be laced across the mat in a diagonal. A single length of rope shall be secured to a stake in the row of stakes at the toe of the bank. The rope shall be secured to each stake that is oriented diagonally to this stake in a single direction from the toe of the bank to the crest of the bank. Ropes that cross between stakes shall be tied together. Ropes shall be secured parallel and normal to the slope along the rows of stakes and to the stakes that lie in a line from the crest to the toe of the bank. These ropes shall be tied together where they meet between stakes. All ropes shall be secured to the stakes with non raveling knots. No more than 150 mm 6 inches of rope shall remain at the ends of the rope lengths after they are installed.

g. [Removed soil] [Select fill] shall be brushed into the mat to within 50 mm 2 inches of the top of the structure.

3.13.1.8 Clump Planting

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NOTE: Clump planting requires the excavation, transport, and placement of live vegetation with root wads and attached soil. This planting method is recommended for establishing vegetation on steep banks of limited height and on the upper banks or floodplains of a stream where the plants will not be subjected to long periods of inundation by water and where adequate moisture is available. Plantings should not be subjected to erosion, flooding, animal traffic or grazing, dry conditions, or high winds during the first several years after installation. Minor earthwork is recommended to reduce vertical

faces or remove undercut slopes from the bank to limit the loss of plant clumps due to scour or flooding. Selected woody vegetation should not grow to large mature trees, which could induce scour and loss of the bank due to obstruction of the stream flow or the rotation of the tree into the stream channel and creation of a large hole as the root wad is pulled from the bank. Heavy equipment may be required if plant clumps or root wads are too large to be easily moved by manual efforts. The toe of the stream bank should be protected from erosion by the placement of large natural stone, erosion control matting, or construction of longitudinal bioengineered structures. Irrigation and fencing may be required to ensure the survivability of the plants.

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a. The stream bank shall be prepared for clump planting by excavating 600 mm 2 feet deep holes with floors that slope into the bank and that are at least 150 mm 6 inches longer and wider than the same dimensions of the removed clumps. The floors of these holes shall not be within 150 mm 6 inches of the groundwater table. The excavations shall be [spaced at 2 m 6 feet and separated by 1 m 3 feet of existing bank] [1 m 3 feet in width, continuous, and separated by 1 m 3 feet of existing bank] along the extent of the work site. Removed soil shall be used as backfill. Excess soil from the excavations shall be [removed from the site] [thin spread on the upper bank landward of the clump plantings]. The exposed surface of the backfill shall be roughened and seeded [and covered with erosion control products].

b. Suitable species for transplant shall be located in the vicinity of the work site. Plant species shall not mature to heights greater than 4.5 m 15 feet or trunk diameters exceeding 100 mm 4 inches. Clumps of plants shall not exceed the width of the removal equipment. If clumps are removed by hand, these clumps shall not exceed 1 m 3 feet in any dimension. The clumps shall be removed with existing soil and as many shallow roots as possible to aid in growth and survival, and shall be transported immediately to the work site and placed.

c. Prior to placement, the excavation shall be flooded with water to moisten the soil and aid in plant survival. The plant clumps shall be placed with vegetation [standing vertically] [slightly inclined towards the stream] and firmly pushed into the soil at the base of the excavation to prevent rafting. At least [[3] [_____]] [dead stakes] [or] [live poles] shall be driven through each clump to secure it to the bank. Biodegradable coir net with a minimal life of 2 years shall be placed on top of the soil of the clump and shall extend 1 m 3 feet onto the bank beyond the limits of the excavation.

3.13.2 Transverse Structures

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NOTE: Transverse structures consist of live vegetation or a combination of live vegetation and hard material (dead vegetation, logs, rock, and natural stone) that are constructed normal to and across small stream or river channels or narrow gullies. These structures are recommended for

streams with low flow, intermittent streams, or dry gullies subject to flow after precipitation events. The harder structures may be used in narrow channels that experience infrequent or seasonally torrential flows.

The transverse structures function as weirs and drop structures, which reduce the velocity of stream flow, bed degradation, and may result in the transformation of the channel profile to a stepped profile due to the retention of sediment and debris. The reduction in flow velocity aids in reducing bank erosion. In addition, these structures may be placed at the toe and parallel to the stream bank, thus directly improving bank stability and reducing undercutting and erosion especially in areas with banks composed of low cohesive materials. Structures should be placed with key trenches into the banks to improve stability and to prevent the by pass of the structure due to lateral erosion of the bank.

Advantages of transverse structures are ease of construction at remote sites using locally available materials and the establishment of habitat with time. A primary disadvantage of these structures is that they may obstruct fish passage and may reduce the conveyance of the channel resulting in local flooding. Therefore, the structures should be designed to allow fish passage and constructed of supple vegetation that matures to minimal height. Some transverse structures require significant amounts of manual labor and may not be economical in areas of limited vegetation supply. Periodic maintenance may be required to remove excessive amounts of trapped debris to prevent possible flooding, fire dangers, build up of decomposing plant material, or heath hazards caused by habitation of the debris by insects or vermin or trapping of dead fish or animals. These structures may be combined with other forms of live and dead bioengineered structures and hard structures such as gabions, or riprap.

Stagnant water may become present behind transverse structures depending on site conditions. These areas of stagnate water may become breeding grounds for mosquitoes or other insects and undesirable aquatic plants and animals. The designer shall include adequate drainage features in the design to remove water from behind the structure, such as open channels, drainage pipes, or passive subsurface drains.

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3.13.2.1 Palisade

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NOTE: A live palisade is a weir composed of live poles, which develops into a transverse zone of vegetation that crosses the stream channel. These structures may be installed rapidly, are easy to construct, and provide shade to the stream channel as the vegetation matures. Palisades are best suited for small gullies or streams in low-lying areas that are less than 10 meters (30 feet) wide and 4 meters (12 feet) deep. The streambed should consist of loose sand, silt, or soft clay to allow easy installation of the poles used in the construction of the palisade. A steel rod may be required to install pilot holes for the driving of the poles in medium to hard clay, dense sand, sand with fine gravel, and medium dense silt. Palisades may be installed in coarse alluvial streams if placed in a trench excavated in the streambed. These structures in coarse alluvial systems should be viewed as temporary and expendable since they may be damaged by bed load and large debris transported during periods of high flow.

A palisade may be constructed entirely of dead poles if the project objective is the temporary stabilization of the stream channel. These structures will not become reinforced with time by root structures and will deteriorate. However, depending on the site conditions, these structures may be adequate for the retention of sediment on which native grasses and vegetation may take root, thus resulting in the evolution of the dead structure to a live transverse brush sill. Dead palisades may be used in coarse alluvial streams since the establishment of a vegetated structure is not expected and may not be desired.

The live or dead poles should be driven a minimum of 600 mm (2 feet) into the streambed for poles under 1.5 meters (5 feet) in length. Poles over 1.5 meters (5 feet) in length should be driven a minimum of 1 meter (3 feet) into the streambed. The poles should be harvested from local vegetation and should be a minimum of 38 mm (1.5) inches in diameter. The bottoms of the poles should be formed to sharp points to aid in the driving of the poles into the streambed.

The strength of the palisade may be increase by attaching a cross beam to the structure. A cross beam is recommended for palisades with widely spaced or thin poles and that have a height greater than one-foot above the streambed. The cross beams should be at the same height and inclination on both sides of the palisade. The beams are attached to the palisade with binders composed of untreated coir or hemp rope that is capable of withstanding several years of exposure. The binder must be looped and tied around the cross beams and the adjacent poles in a manner that tightly secures the members together. The binders should not unravel if a

portion of the binder or structure is lost or damaged. Cross beams may be composed of untreated dimensional lumber or straight poles of similar diameter as the palisade poles.
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a. Live poles shall be 1 m 3 feet long, 38 to 100 mm 1.5 to 4 inches in diameter, and the bottom ends of the poles shall be cut to form sharp drive points. The poles shall be driven vertically into the streambed to a minimum depth of 600 mm 2 feet and shall be placed across the channel in a [straight row] [row that is deflected down stream by 15 degrees] ['V'-shaped row pointing down stream with the apex at the center of the channel]. Poles shall have a spacing of no less than 50 mm 2 inches but not greater than 150 mm 6 inches. [The center poles of the structure shall extend a maximum of [300] [600] mm [1] [2]-foot above the existing grade of the streambed.] [The center poles shall be dead poles placed for a distance of 1 m 3 feet about the centerline of the structure.] [The central span of the structure shall be composed of large natural stone keyed 600 mm 2 feet into the streambed with a top elevation 300 mm 1 foot above the existing streambed. The stone shall extend 600 mm 2 feet on each side of the centerline of the structure and shall be tightly butted with [live] [dead] poles of the palisade structure.] [The tops of the poles shall increase in height outward from the center of the structure by no more than 15 mm 0.05-foot for each adjacent pole to form a notch at the center of the structure.] [The tops of the poles shall be at the same elevation.] The ends of the structure shall be placed in key trenches that extend 1 m 3 feet into the stream bank.

b. Cross beam members of untreated [straight 25 by 100 mm 1 by 4 inch dimensional lumber] [long straight poles at least 50 mm 2 inches in diameter] shall be attached to the palisade with binding products, which shall be wrapped at least two times around the cross beam and adjacent pole. Binding products shall be installed to prevent raveling of the binder in the event of the loss of a portion of the binder or structure. The cross beam members shall be [horizontal] [inclined] and at the same elevation on each side of the palisade and shall extend the entire width of the structure. The beams shall be 600 mm 2 feet greater in length than the structure and the ends of the beams shall be placed in key trenches in the bank. Key trenches shall be excavated to the depth and width necessary for the placement of the ends of the cross beams and shall be backfilled with soil removed by excavation.

c. The sediment in the streambed shall be compacted around each pole using a tamping bar. [The sediment removed from the streambed for the installation of the poles shall be placed as compacted backfill around the poles.] Dead cuttings and excess live cuttings shall be placed in a criss-cross pattern on the up stream and down stream sides of the structure for a distance of 600 mm 2 feet and shall be tightly packed against the stream bank at the ends of the structure to a thickness of 150 mm 0.5-foot for 600 mm 2 feet beyond the limits of backfill exposed at the key trenches.

3.13.2.2 Brush [and Stone] Sill

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NOTE: Brush sills are transverse structures similar to palisades, but composed of live or dead cuttings. These structures reduce stream channel degradation,

are easy to construct, and may be combined with natural stone to improve performance. Selected vegetation should mature to low height, remain supple with time, and be capable of good root mat development. Live or dead cuttings may be used for the structure and the cuttings may retain small branches and do not need to be straight. Sills may also be placed along the toes of stream banks separately or adjacent to the transverse brush sills. Sills do not trap large amounts of sediment or debris since the vegetation used in construction is pushed against the stream channel during high flow events and does not form an obstruction to flow. Therefore, these structures are suitable for channels where minimal changes to the stream profile are desired. Sills may be constructed in most types of alluvial material and will function in coarse alluvial streams. Backfill and the buried portions of cuttings should be wrapped in several layers of coir mat if the sill is constructed in a stream channel subject to infrequent torrential flows. The width of the construction trench may be increased up stream of the vegetation and filled with large natural stone to reduce damage to the structure by bed load in high flow channels. Live stakes may be planted between the joints of the stone.

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A 600 mm 2 feet deep trench shall be excavated normal to and across the entire width of the stream channel. Live cuttings shall be placed in a criss cross manner with 20 cuttings per 1 meter 3 linear feet of trench on the down stream face of the trench. [Cuttings shall be placed in the same pattern and concentration as in the trench for the sill on the stream side faces of trenches excavated at the toes of the banks for a distance of 4.5 meters 15 feet up stream and down stream of the ends of the sill structure]. The cut ends of the cuttings shall be pushed into the bottom of the trench to [refusal] [150 mm 6 inches] and the growth tips shall extend 600 mm 2 feet above the top of the existing streambed. Large natural stone shall be placed on top of the cut ends of the cuttings [to the top of the existing streambed to fill the entire trench] and shall be tamped into the streambed to secure the stones in place. Removed sediment shall be placed in the voids between the natural stone [and shall be placed over the lower stone work to fill the entire trench]. Excess sediment shall be thin spread up stream of the structure. Large natural stone shall be placed at the ends of the structure against the bank [and at the upstream and down stream ends of the trenches excavated parallel to the banks]. [Live stakes] [and] [dead cuttings] up to 600 mm 2 feet in length shall be driven into the [sediment backfill on 150 mm 6 inch centers] [between the joints in the natural stone] across the entire width of the trench and 1 m 3 feet up each bank from the toe of the bank. Sills shall be spaced [15 m 50 feet apart] [as shown on the drawings].

3.13.2.3 Wattle fence sill

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NOTE: Wattle fence sills are recommended for narrow and slow flowing streams, small gullies, agricultural drainage ditches, or open channel drains. These sills are best suited for streams or

drainage systems with coarse-grained bed load, which will be trapped by the weaves of the fence. The sills may not trap fine-grained sediment or reduce erosion in fine-grained alluvial streams since the fine sediment may pass through the structure. These fence structures may be constructed of live or dead vegetation. The use of live poles and cuttings should result in the establishment of a row of vegetation across the stream channel with time. Cross beams are recommended for structures over two feet in height. These sills may be combined with brush sills and brush layer structures.

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a. A trench 600 mm 2 feet deep and 300 mm 1 foot wide shall be excavated normal to and extend across the entire width of the stream channel. [Live] [Dead] poles shall be 1 m 3 feet long with a minimum and maximum nominal diameters of 38 and 100 mm 1.5 and 4 inches, respectively. The bottom ends of the poles shall be cut to form sharp drive points. The poles shall be driven vertically into the streambed to a minimum depth of 600 mm 2 feet and shall be placed across the channel in a [straight row] ['V'-shaped row pointing down stream with the apex at the center of the channel with the poles] at a spacing of 600 mm 2 feet. The poles shall extend a maximum of [300] [600] mm [1] [2]-foot above the existing grade of the streambed. [The center poles shall be dead poles placed for a distance of 1 m 3 feet about the centerline of the structure.]

b. The wattle fence shall extend from the bottom of the trench to the tops of the poles. The top of the fence shall be [at the same elevation] [sloped to the center of the channel]. The fence shall be constructed of flexible [live] [and] [dead] cuttings that are 2 meters 6 feet in length and from 19 to 38 mm 3/4 to 1.5 inches in diameter. The cuttings shall be [laced horizontally between the poles in an alternating woven pattern with the cuttings being placed on the up stream and down stream sides of adjacent poles across the structure starting from the steam bank] [placed on the up stream side of the poles and shall be tightly packed and interwoven to form a braided vertical structure]. The ends of the cuttings shall overlap 300 mm 1-foot with adjacent cuttings. The cuttings of the fence shall be secured to the poles with binding products. The binders shall be installed to prevent raveling of the binders in the event of the loss of a portion of the binders or structure.

c. [Sediment removed from the trench shall be placed in the excavation as compacted backfill around the poles and lower fence.] [Live stakes shall be placed at 300 mm 1-foot spacings in the backfill.] [Large natural stone shall be placed at the bottom of the trench along the up stream and down stream toes of the fence [and shall extend to the top of the existing streambed]. [The stones shall be tamped into place and sediment shall be used to fill voids between the stones.] [Live stakes shall be placed in the joints between the stones.]] Excess sediment shall be thin spread up stream of the structure.

d. [Cross beam members of untreated [straight 25 by 100 mm 1 by 4 inch dimensional lumber] [long straight poles at least 50 mm 2 inches in diameter] shall be placed on the down stream side of the poles and overlie the fence on the up stream side of the structure. The beams shall be attached to the structure with binding products wrapped at least two times around the cross beam and adjacent pole and laced through the wattle fence cuttings.] [The cross beams shall be horizontal and at the same elevation on each side of the structure and shall extend the entire width of the structure.] Both ends of the structure [shall extend into a key trench that is excavated 600 mm 2 feet in the banks] [extend to the existing stream banks and be covered on both sides with large natural stone placed from the channel bottom to the top of the structure. The stone shall rest on the stream bank, be at least 600 mm 2 feet thick, and extend 1.5 m 5 feet away from the structure in the up stream and down stream directions.]

3.13.2.4 Vegetated Crib Wall or Wood sill

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NOTE: A vegetated crib wall consists of a hollow box-like structure of timber or logs filled with earth and live cuttings. A wood sill is a vertical open wall composed of timber or logs that forms the front header, which is not tied to a similar structure, or rear header, up stream by stretchers as is the case with the crib wall. The crib wall is more stable than the wood sill. These structures may last 20 to 30 years depending on the type of timber used, are quick to construct, and may use locally available materials. The live cuttings take over the function of the crib wall as the cuttings grow and mature and the timber decays. These structures should not exceed 1.5 meters (5 feet) in height and are well suited for gullies with fine-grained sediment bed load and narrow streams less than 4.5 meters (15 feet) wide with steep gradients.

Crib walls or wood sills may be combined with brush sills, brush mats, or large natural stone on the up stream or down stream sides of the structure to reduce erosion. Stability of the structure may be improved using a double crib design composed of front and back rails. Backfill should be free draining material with less than 10 percent fines. However, if such backfill material is not readily available, removed sediment may be placed as compacted backfill. Timber used for the crib wall may be untreated manufactured 100 mm (4-inch) square posts, locally harvested vegetation with trunk diameters greater than 100 mm (4 inches), or a combination of these materials. Treated lumber will not be used.

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a. A trench shall be excavated that is 1.5 m 5 feet wide and 600 mm 2 feet deep and extends normal to and across the entire width of the stream channel. The floor of the trench shall be sloped at 15 degrees up stream and shall be [manually compacted using a tamping bar weighing at least 18 kg 40 pounds] [compacted using a small motorized tamping machine] until the bottom of the trench is dense and provides a solid base for the crib wall [wood sill]. The floor of the trench shall be [as shown in the drawings] [of uniform grade across the trench width]. Depressions in the trench floor shall be filled with compacted material to raise these areas to grade and positive areas above the floor design elevation shall be reduced to grade. The trench shall be keyed into the stream banks for a distance of 1 m 3 feet. Material removed from the key trenches shall be used as compacted backfill in the key trenches. Sediment removed from the trench in the stream channel shall be [removed from site and replaced with select fill] [used as compacted backfill].

b. The [crib wall] [wood sill] shall be framed with [untreated, straight 100 mm 4-inch square by 2.5 m 8 feet long posts] [100 to 150 mm 4 to 6 inch diameter by 2.5 m 8 feet long straight logs harvested from local sources. The logs shall be cut normal to the trunks with all branches stripped from the trucks]. The down stream header shall be placed [parallel to the bottom of the trench and extend the full width of the trench] [along the alignment shown in the drawings]. [The up stream header shall be placed parallel and 1.5 m 5 feet up stream of the down stream header.] Splices between members shall be placed end-to-end and in line. Wood posts that are at least 100 mm 4 inches in diameter shall be driven vertically 150 mm 6 inches from the splices on the up stream and down stream sides of the headers. Wood post shall be driven on both sides of the headers at the midpoints between the splices. The members at the ends of the structure shall be firmly placed against the faces of the key trenches. Wood posts shall be driven on both sides of the headers at the toes of the banks and the toes of the key trenches.

c. Stretchers [for wood sills shall be 1.2 m 4 feet] [for live crib walls shall be 2 m 6 feet] in length. Stretcher shall be placed between the vertical splice poles and normal to the down stream header. The stretchers shall be spaced every 1.2 m 4 feet between the poles and have a minimum of 100 mm 4 inches extending down stream of the header face. The rear butt of the stretcher shall be placed [firmly against the upstream face of the trench] [on top of the up stream header]. The stretcher shall be attached to the header(s) with binding products wrapped three times around the stretcher and header in a criss cross pattern and secured with a non-raveling knot. A 13 mm 1/2-inch diameter hole shall be drilled vertically through the stretcher and header. A 16 mm diameter by 300 mm 5/8 inch diameter by 12 inch long [non-galvanized steel spike] [steel rebar] [hard wood dowel] shall be driven into the hole and set flush to the top of the stretcher.

d. The open area between the down stream header and the upstream [trench face] [header and the portion of the trench upstream of the upstream header] shall be backfilled with compacted [sediment removed from the trench excavation] [select fill] to an elevation that is at the middle of the stretchers. Live cuttings that are 19 to 38 mm 3/4 to 1.5 inch in diameter and 2.4 m 8 feet long shall be placed in a criss cross manner on top of the compacted backfill with the cut ends pushed into the up stream face of the trench. At least 600 mm 2 feet of growth tips of the cuttings shall extend beyond the face of the down stream header. Backfill shall be placed and lightly compacted on top of the cuttings to the top of the stretchers. Additional lifts of headers, stretchers, backfill, and cuttings shall be placed until only the final lift remains. The centerlines of the down stream headers shall be offset 50 mm 2 inches upstream of the lower headers to provide an incline to the down stream face of the structure.

e. The top down stream header shall be 100 mm 4 inches larger in diameter than the headers used for wall construction to reduce sediment loss due to scour. The vertical poles on both sides of the headers shall be cut flush with the top of the final down stream header [and the top rear header]. A header shall be placed at the midpoint between the top down stream and up stream headers and secured with binders and [spikes] [rebar] [dowels] to the underlying stretchers. The lift of backfill immediately below the completion headers shall be filled with a tightly packed brush mat composed of live [and dead] cuttings that are placed in an alternating pattern perpendicular and parallel to the wall. Each layer of cuttings shall be 100 mm 4 inches thick and shall be covered with a thin layer of lightly compacted backfill. [Rounded clean natural stone from 200 to 300 mm 8 to 12 inches in diameter] [Excavated sediment] shall be placed from the top of the packed brush to the top of the down stream header and shall be graded up stream to match the existing slope of the stream channel up gradient of the work site. [Live stakes shall be driven vertically on 600 mm 2 feet centers into the backfill at the top of the structure.] [Large natural stone armor 600 mm 2 feet thick shall be placed at the ends of the structure and on the slopes of the banks for a distance of 2 m 6 feet upstream and down stream from the structure. Live stakes shall be planted in the joints between the stones.] The trench down stream of the structure shall be filled with [large natural stone] [a brush [and stone] sill] [a brush mat].

3.13.2.5 Vegetated Dry Stone Barriers

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NOTE: Vegetated dry stone barriers are constructed of large natural stone with interlayered live cuttings. These structures may be built to heights of 4.5 meters (15 feet) and serve as weirs or drop structures in high gradient streams with torrential flows and heavy coarse bed load. Stone barriers may also be constructed to slightly above the existing elevation of the stream channel to prevent bed degradation. The largest stones that may be moved by manual efforts should be used. Construction of barriers adjacent to existing large boulders may reduce the amount of work required.

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A trench that is 1.2 m 4 feet wide and 1 m 3 feet deep shall be excavated normal to and across the entire width of the stream channel and shall be keyed 1 m 3 feet into the stream banks. The bottom of the trench shall be sloped at 15 percent in the up stream direction and shall be compacted using a manual tamping bar weighing at least 18 kg 40 pounds. Large stone of similar size shall be placed on the entire floor of the trench with a minimum of voids between the stones. The stones shall be covered by [fine sediment] [select fill] that shall be worked into the voids between the stones until only the tops of the stones are visible. Live cuttings that are 2 m 6 feet long and up to 38 mm 1.5 inches in diameter shall be placed on top of the stones in a criss cross pattern with the butts of the cuttings in contact with the up stream face of the trench. The growth tips of the cuttings shall be oriented down stream and shall extend 0.5 m 1.5 feet beyond the farthest down stream placed stones. Addition lifts of stone, fill, and cuttings shall be placed on the lower lifts until the design height of the structure is reached. The stones of each successive lift shall be placed to interlock with the tops of the stones of the lower lift. Live cuttings at the top of the structure shall be placed in between the stones and inclined slightly down stream. [Live stakes that are 600 mm

2 feet long shall be driven between the joints of the stones at the top of the structure on 600 mm 2 feet centers and for a distance of 1 m 3 feet up the stream banks.] The top stones shall be covered with a 100 mm 4 inch thick layer of [fine sediment] [select fill].

3.13.2.6 Brush Work or Brush Packing

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NOTE: Brush work or brush packing uses live and dead cuttings to fill a section of a gully or stream channel to reduce erosion of stream banks. These structures provide erosion protection to the channel by covering the channel with a mat of brush and are recommended for intermittent streams with fine-grained sediment. Brush works refers to brush mats placed across the stream channel with growth tips pointing up stream and which extend up the stream banks. Construction of brush work starts at the upstream limit of the work site and progresses down stream with each new layer of cuttings overlying the immediately up stream layer of cuttings. Brush packing refers to thickly packed layers of brush placed with the growth tips inclined slightly down stream that fill a gully or small stream channel. Brush packing starts at the down stream limit of the work site and progresses upstream with each new layer of cuttings overlying the immediately down stream layer of cuttings. Bank stability is improved as the vegetation grows and develops root systems in the lower bank. The cuttings may be anchored in the channel by cross logs secured to vertical poles driven into the streambed.

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a. [Brush work construction shall start at the upstream end of the work site and progress down stream with each down stream layer of cuttings overlying the layer of cuttings immediately upstream.] [Brush packing construction shall start at the down stream end of the work site and progress upstream with each upstream layer of cuttings overlying the layer of cuttings immediately down stream.]

b. Trenches that are 300 mm 1-foot deep shall be excavated normal to and across the entire stream channel [and shall extend 1.5 m 5 feet up the stream banks]. Trenches shall be spaced 1.5 m 5 feet apart. Live cuttings that are 2 m 6 feet in length shall be placed in the trench in a herringbone pattern at an angle of 30 degrees from the centerline of the channel with the growth tips pointing [upstream] [inclined down stream at an angle of 45 degrees from vertical]. The cuttings shall [not] extend up the stream banks. The cut ends of the cuttings shall be pushed firmly into the streambed. [Removed sediment] [Select fill] shall be placed and compacted over the cut ends of the cuttings to the elevation of the existing channel. This procedure shall be repeated for the specified length of channel at the work site.

c. Cross logs shall be placed normal to the channel and on top of the cuttings every 1 meter 3 feet. The logs shall be 100 mm 4 inches in diameter and shall extend the full width of the channel. [Cross logs shall be placed parallel to the slope of the bank on top of the brush

[work] [pack] layers that extend up the stream banks. The ends of the cross logs at the toes of the banks shall be shaped to sharp tips and the logs shall be driven 500 mm 1.5 feet into the streambed at the angle of the slope of the stream bank.] [Live] [Dead] poles shall be driven vertically into the streambed on the down stream sides of the cross logs. The poles shall be spaced at 600 mm 2 feet intervals and the tops of the poles shall not be greater than 150 mm 6 inches above the tops the cross logs. Poles shall be driven at the toes of the stream banks regardless of spacing interval. The poles and cross logs shall be tied together using binders that shall be wrapped around the logs and poles in a manner that shall prevent raveling.

3.13.2.7 Live Fascine Sill

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NOTE: Live fascine sills are more resilient and less prone to damage by scour than brush sills. However, heavy coarse bed load and large woody debris transported during high flow events may damage the fascines. Fascine sills may be used to form low drop structures to prevent streambed degradation in narrow streams with low flow velocities and minimal coarse bed load. Sills may be combined with other bioengineering methods for channel stabilization of high gradient or torrential flow streams. Fascines have the advantage of being flexible and therefore may be placed to conform to the existing profiles of the stream channel and may be easily extended up the banks of the channel. The diameter and strength of the fascine may be increased by adding dead branches and gravel or cobbles to the fascine. Fascines should be placed in trenches that are normal to the stream channel and that are at least 50 to 75 percent the diameter of the fascine in depth. Live fascines may be placed on top of one another to form step sills. Step sills are constructed by placing a down stream fascine in a trench and positioning a fascine directly up stream of the down stream fascine. The up stream fascine should rest on the upper one quarter of the exposed down stream fascine.
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Each Fascine shall be 300 mm 12 inches in diameter and 3 m 10 feet in length and shall be constructed of live cuttings that are from 19 to 38 mm 3/4 to 1.5 inches in diameter. Up to 35 percent dead branches [and 15 percent rounded gravel or cobbles] shall be interwoven with the live cuttings. A 200 mm 8-inch deep by 0.5 m 1.5 feet wide trench shall be excavated normal to and across the entire width of the stream channel [and at least 1.5 m 5 feet up the faces of the stream banks]. The fascine shall be placed in the trench. The junction between fascine bundles in the same trench shall be [offset side-by-side] [interwoven] for a distance of 300 mm 1-foot. The fascine shall be anchored in the trench with 700 mm 2.5 feet long [live] [dead] stakes that are at least 50 mm 2 inches [in diameter] [square] at the top and tapered from the top to the base. The stakes shall be driven vertically through the fascine until flush with the top of the bundle starting 300 mm 1-foot from the end of the fascine and spaced every 1 meter 3 feet thereafter. A terminal stake shall be driven 300 mm one-foot from the end of the fascine regardless of spacing interval. [Live] [Dead] stakes shall be driven at a 45-degree angle on the down stream side of the fascine but shall not penetrate the bundle. The fascine shall be secured to the stakes with binders that shall be wrapped around the fascine and secured to the stakes. The binders shall be tied to prevent ravel in the event of damage. Removed sediment shall be used as backfill and placed and compacted on the up stream and down stream sides of the fascine and shall be brushed into the fascine structure until only the top of the fascine is visible. Fascine sills shall be [spaced 8 m 25 feet apart starting from the down stream end of the work site] [placed at the locations shown on the drawings].

3.13.2.8 Vegetated Deflector

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NOTE: Vegetated deflectors are traditional hard structures composed of rock (groins, dikes, spurs) or timber (log or pile revetments) that incorporate live vegetation and which provide excellent long-term bank protection with the added benefits of shade and habitat enhancement. These structures protect the banks of large streams and rivers, which are subjected to high velocity flows, by deflecting the energy of the current away from the banks. The incorporated vegetation improves the strength of the structure and the quality of habitat over time. A key component for the establishment of vegetation on these structures is the retention of fine-grained material and the exposure of the hardened structure above the mean water level of the stream or river. Only vegetation that matures to trees or brush of less than 2 meters (six feet) in height and which remains flexible should be used. Species that may mature to tall tress with extensive root systems may not be used, since these trees may damage the hard structures.

For existing structures, fine-grained material may be placed in open voids and live posts driven into these voids in the structure. For new construction, the interior of the structure may be composed of fine-grained material capable of supporting root growth. This core should be covered with rock of suitable size to resist transport by the stream or river. The cover armor must be anchored along the perimeter of the structure in a key trench below the scour depth of the high flow events. Additional stability of the armor may be gained by inserting dead stakes between stones in areas below the mean water level. Live poles may be driven into the joints of the armor above the mean water level.

Retention of fine-grained material in the core of the structure may be improved by placing this material in untreated sand bags composed of natural fibers. The lifetime of the sand bags should be sufficient to prevent the loss of fines until the roots of the live poles lock this material in place. The surface of the sand bag core may be covered with a coir erosion mat prior to the placement of

armor. To reduce the number of sand bags, the core may be constructed of compacted material overlain by a three-bag thick layer of sand bags, which is in turn overlain by the stone armor. A layer of well-graded fine gravel and coarse sand may be placed beneath the stone armor to form a filter layer and thus further reduce the loss of fines from the core. Other deflector alternatives include the use of logs or wood structures as cores surrounded by fine-grained material with exterior stone armor. These structures may be used to assist in trapping sediment behind rock groins or dikes to in fill large scour areas in a stream or river banks.

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a. Excavate a trench [4.5 m 15 feet wide, 1 m 3 feet in depth below the lowest elevation of expected scour, that extends from the toe of the high bank to 3 m 10 feet into the stream below the mean low water elevation. The trench shall be [keyed 1.5 m 5 feet into the bank.] [as shown on the drawings]. [Live cuttings shall be placed against the face of the trench from the mean water level to the high bank. These cuttings shall extend at least 450 mm 1.5 feet above grade and the cut ends of the cuttings shall be firmly pushed into the bottom of the trench and covered with a thin layer of [sediment] [select fill]]. [Natural stone] [Quarry rock] at least 1 m 3 feet in the minimal dimension shall be placed against the outer perimeter face of the trench and maintain as much contact with adjacent stones as possible. [The [stone] [rock] shall be placed to a height of 600 mm 2 feet above the high mean water level of the stream]. The outer face of the [stone] [rock] shall slope at [2H:1V] while the face towards the center of the trench shall be at the angle of repose. [Sediment removed from the trench] [Select fill] shall be brushed into the voids between the [stones] [rocks] until the soil is even with the tops of the [stones] [rocks]. Live cuttings shall be placed on top of the outer [stones] [rocks] with the cut ends of the cuttings firmly pushed into the bottom of the inside trench. The ends of the cuttings shall be covered with a thin layer of sediment that shall be overlain by [backfill] [sandbags]. [Live poles shall be driven between the [stones] [rocks] to a depth of at least 1.2 m 4 feet.] The core of the structure lying inside the larger outer [stones] [rocks] shall be filled with [removed sediment] [select fill] [in untreated biodegradable sand bags that are placed tightly end to end and in vertical overlapping pattern] [compacted cohesive sediment removed from the trench separated from the outer [stones] [rocks] by a 600 mm 2 feet thick layer of select fill contained in untreated biodegradable sand bags].

b. Successive lifts of armor [stone] [rock] shall be placed on top of the completed lifts to the design slopes and grades of the structure. Live cuttings shall be placed on the top of each lift. The core of the structure shall be raised concurrently with the lifts of armor material. The final lift shall consist of interlocked [stone] [rock] that extends across the entire top of the structure. [Removed sediment][Select fill] shall be brushed into the voids between the [stones] rocks]. Live stakes shall be planted in the joints between the [stones] [rocks] with a spacing of 1 m 3 feet. The top of the rock structure shall be 300 mm 1 foot above the top of the original elevation of the high bank.

3.13.2.9 Live Brush Sill

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NOTE: Live brush sills are structures composed of live vegetation that extend perpendicular from the toe of the bank into the stream channel. These structures may extend landward to the high bank. The sills trap sediment and debris, reduce scour, and are useful in establishing vegetation on point bars of barren flat expanses of low bank. These structures are inexpensive, easy to construct, and may reduce the amount of rock or stone armor required for bank protection. The development of root systems and the growth of vegetation improve bank stability and develop riparian habitat. Dead cuttings may be used in these structures to improve their resistance to erosion and damage due to currents or debris. Sills composed entirely of dead cutting may be placed below the mean high water elevation separately or between harden transverse structures. These dead brush sills trap debris, sediment, and result in bank aggradation. Live sills, or other live bioengineered structures, may be placed on the new bank created by the dead sills at a future date to promote improved stability and habitat development.

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A 600 mm 2 feet deep trench with a 'V' shaped cross section shall be excavated normal to the toe of the stream bank from [the mean high water level] for a distance of [3 m 10 feet into the stream channel [from the mean high water level]] [and] [6 m 20 feet landward of the toe of the bank.] [to the edge of existing vegetation] [as shown on the drawings]. Live cuttings shall be placed in the trench with the cut ends pushed firmly into the bottom of the trench with the growth tips extending at least 600 mm 2 feet above the top of the existing grade. At least 20 cuttings shall be placed per 300 mm linear foot of trench and all cuttings shall rest against the down stream side of the trench. Large stone up to 150 mm 6 inches in diameter shall be placed on the bottom of the trench against the cut ends of the cuttings and shall be covered with loosely compacted [sediment] [soil] [select fill] to the existing surface. [Excess material removed from the trench that is to remain on site shall be mounded around the base of the sill at the surface.] Sills shall be spaced 1.5 m 5 feet apart.

3.13.2.10 Brush Transverse

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NOTE: Brush transverses are stone structures augmented with live or dead brush cuttings that are easy to construct and inexpensive. These structures are useful in deflecting high velocity flows away from stream banks to prevent scour and erosion and may be used to aid in the repair of scoured or failing areas of stream banks. The live vegetation will develop root systems that shall strengthen the structure and provide shade and habit. The stone structure deflects and dissipates the stream velocity away for the bank thereby creating areas of still water down stream of the structures in which

sediment may be deposited. The brush cuttings assist in sediment trapping during periods of high flow. This vegetation matures with time and will eventually completely cover the scour area. Brush transverses may be combined with brush grids to repair areas of bank scour in high flowing rivers.

Brush transverse structures are not suitable for use in streams with torrential flows and heavy clastic bed load. Installation trench depth and width must be based on hydraulic analyses of stream velocities and bed load transport. The structure may be normal to the stream bank or inclined at an acute angle to the stream bank in the down stream direction. The use of subrounded large natural stone from the immediate area of work is preferred for construction. If such material is in limited supply, then the available natural stone may be used as cover stone and the core of the structure may be constructed of angular to subangular quarry rock. In areas that lack natural stone, local durable quarry rock may be used for the entire structure.

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a. A trench 600 mm 2 feet deep by 1.5 m 5 feet wide shall be excavated from [the face of the high bank] [edge of the stream bank] to [3 m 10 feet beyond the low mean water elevation of the stream] [the new bank alignment as shown on the drawings]. [The trench shall be keyed into the stream bank for a distance of 1 m 3 feet.] The base of the trench shall be firmly compacted. Live [and] [dead] cuttings that are at least 1.5 m 5 feet in length and that have side branches attached shall be placed on the down stream side of the trench. The cuttings shall be placed with a concentration of at least 20 cuttings per 300 mm linear foot of trench to form a layer with a thickness of 100 mm 4 inches. The cut ends of the cuttings shall be pushed firmly into the streambed with a minimum of 1 m 3 feet of the growth tips extending above grade and inclined in the down stream direction. The cut ends of the cuttings shall be covered with a 75 mm 3 inch layer of moderately compacted [fine-grained sediment] [select fill] that shall extend from surface grade to the base of the trench at the angle of repose.

b. Durable [large natural stone] [quarry rock] that is 450 mm 1.5 feet in minimal dimension shall be placed along the up stream side of the trench, against the fill covering the cut ends of the cuttings, and completely fill the key trench. [Natural stone] [Quarry rock] ranging from 150 to 450 mm 0.5 to 1.5 feet in minimal diameter shall be placed to cover the floor of the trench and firmly tamped into place to provide the greatest contact with adjacent [stones] [rocks]. [Fine sediment] [Select fill] shall be [brushed] [washed] into the voids between the [stones] [rocks] until only the tops of the [stones] [rocks] remain exposed. Successive layers of [stone] [rock] shall be placed on lower lifts in a pattern that allows the greatest amount of interlocking of [stones] [rocks] and the voids between the [stones] [rocks] shall be filled with [fine sediment] [select fill] to the top of the structure. The end of the structure that projects into the stream shall be constructed of [large stone] [rock] that is 1 m 3 feet in minimal dimension for a distance of 2 m 6 feet. [Excess sediment removed from the trench shall be placed along the up stream and down stream toes of the structure.] The farthest up stream structure in the work area shall be placed at an angle of 30 degrees to the direction of stream flow to deflect the current towards the center of the channel. Subsequent down stream structures shall be constructed at right angles to the stream bank with a spacing of the average length of the structure.

3.13.2.11 Brush Grid

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NOTE: A brush grid consists of layers of brush laid out in a rectilinear pattern with each successive lift being placed normal to the lower lift. The structures are well suited for the repair of severely scoured or sloughing areas on banks in streams with high flow velocities and large range or frequent changes in water level. These structures may be used on portions of the streambed from the toe of the high bank to the edge of the mean low water level of the stream. For large scour areas, a brush grid may be constructed at the up stream end of the scour hole between the stream bank and a brush traverse or vegetated groin or dike. The remaining portion of the scour area may be filled with widely spaced brush transverse structures. The areas between the transverses may be filled with brush sills. A brush grid requires significant manual labor and a large supply of brush. The amount of labor and materials may be reduced by combining the grid with brush sills, vegetated dikes, gabions, or by constructing a widely spaced grid work of brush instead of a complete cover of brush.

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a. [An excavation that is 4.5 m 15 feet wide and 1 m 3 feet deep shall extend from the edge of the high bank 6 m 20 feet into the stream channel. The floor of the excavation shall be sloped towards the bank at 2H:1V and shall be smooth and compacted. The side slopes shall extend beyond the above specified dimensions and shall be at the angle of repose. The trench shall be keyed 1.5 m 5 feet into the stream bank.] [Sediment shall be excavated to form a level floor at the installation area to the grades and dimensions shown on the drawings.] [Live] [Dead] poles composed of [untreated manufactured lumber] [straight sections cut from local trees] shall be driven vertically 1 m 3 feet into the streambed [along the alignment of the proposed bank] [as shown on the drawings] [in a straight row that is 4.5 m 15 feet from the edge of the high bank]. Additional poles shall be placed between the new alignment of poles and the stream bank on 1.5 m 5 feet centers. The poles shall be 100 mm 4 inches in diameter. The length of the poles shall be such to allow 600 mm 2 feet of pole to extend above the mean water level. The bottoms of the poles shall be shaped to sharp tips to facilitate driving them into the streambed. The tops of the poles shall be cut normal to the lengths of the poles. The top elevations of the poles shall be the same for all poles. [Pilot holes, slightly larger in diameter than the poles, shall be drilled into the streambed using a [steel punch rod] [mechanical drill] in coarse alluvial sediment]. The poles shall stand erect without support after installation in the streambed. Loose or nonvertical poles shall be reinstalled. Poles damaged during installation shall be replaced at no expense to the Government.

b. The base layer of the structure shall consist of 150 mm 6 inch diameter by 6 m 20 feet long trunks of trees with their branches still attached. The root wads shall not be attached to the trunk. These trunks shall be tightly packed between the poles with the growth tips extending 600 mm 2 feet into the stream beyond the new bank alignment. The trunks shall be placed horizontally in the excavation with the cut ends placed [in the key trench] [firmly butted against] the stream bank.

c. [Removed sediment] [Select fill] shall be placed over the trunks until only to tops of the trunks are exposed. Live cuttings up to 50 mm 2 inches in diameter shall be placed vertically in rows spaced 1 m 3 feet apart parallel to the base layer of trees with a minimum of 5 cuttings per 300 mm linear foot of row. The cut ends of the cuttings shall be pushed through gaps between the base logs and into the streambed. The top of the growth tips of the cuttings shall be at the same elevation as the top of the vertical poles and inclined at a slight angle down stream. A layer of live cuttings consisting of 1 m 3 feet wide rows that are up to 300 mm 12 inches thick shall be placed horizontal on top of the first lift of trunks and pulled around the upright live cuttings and poles. The growth tips shall extend 600 mm 2 feet beyond the new alignment into the stream. The rows shall be separated from the vertical posts by a distance of 300 mm one-foot. Sediment shall be placed on top of the cuttings to fill all voids until only the top of the rows are exposed. A lift of cuttings shall be placed normal to the first lift of cuttings with the growth tips extending 600 mm 2 feet beyond the down stream edge of the structure. Sediment shall be placed on top of this lift of cuttings the same as the lower lift. Lifts of rows of cuttings shall be placed in this alternating manner until the structure reaches a minimal height of 1 m 3 feet above the mean low water level. Large natural stone shall be placed along the outer perimeter of the structure to protect it from scour. The top of the structure shall be secured with [a layer of natural stone] [sand bags filled with select fill] placed on top of the horizontal cuttings and around the vertical live cuttings and poles.

3.13.3 Longitudinal structures

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NOTE: Longitudinal structures or plantings are placed parallel to stream banks or lake shores and may be used in conjunction with hard engineered structures to provide habitat, shade, and to obscure the hard structures from view thus allowing a more natural appearance to the protected bank.

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3.13.3.1 [Single] [Clump] Reed Planting

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NOTE: Reed planting involves the planting of singe reeds or clumps of reeds along a stream bank or lake shore. This method is well suited for low flowing streams, lakes, canals, and stagnate areas of water that are protected from wave action or strong currents. Such sites may include exposed banks at or slightly below the mean low water level, tidal flats, or areas of low relief shoreline that extends

some distance into a water body. The reeds dissipate energy of the water acting on the shore area and reduce erosion while root structures improve the strength of the bank. Planting should begin at the wet shoreline and progress landward. This planting method is simple to implement and complete, but must be accomplished during the first months of summer to allow the plants to become established.

The method does not provide immediate erosion protection to the bank nor will the plants tolerate shade. The effect of the plantings may not be realized until two to three years after planting. Reed planting will not reduce failure of unstable banks or shorelines. Clump planting refers to the planting of a large group of reeds contained in a large soil and root mat in a hole excavated at the site.

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Reeds shall be planted during the active growing period. The reeds shall be delivered to the site in bundles in saturated cloth. [Single reeds] [Reed clumps] shall be planted on a grid with a spacing of 600 mm 2 feet starting at the shoreline and progressing landward [for a distance of 16 m 50 feet] [to the existing reed line]. The stems of the reeds shall be slightly above grade and vertical. The shoreline edge of the planting area shall be protected by [a line of natural stone] [coir log] [log] [____]. [Reeds placed between stone armor at the water line shall be placed between the stones in narrow trenches backfilled with fine-grained sediment.]

3.13.3.2 Live stone revetment

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NOTE: Live stone revetments are traditional stone or rock armor revetments placed on banks for stabilization and erosion protection with the addition of live cuttings placed in the joints between the armor stones. These structures are well suited for sites where extensive areas of bank must be protected along high flowing streams with heavy bed load or lake shore subject to wave action. Saplings may be placed between the rock joints if topsoil is placed to fill the interstitial voids between the armor stones. Construction must occur in the dormant season for live cutting revetments and in the spring or autumn for transplanted saplings. Expect 30 to 50 percent mortality rate with cuttings, particularly in drier climates. Driving cuttings or live poles deeper into the stream bank and irrigation of the site may improve plant survivability.

The designer is encouraged to review existing references on stone revetment function, performance, and construction. Also, the designer should consider the impact the construction of a hard structure may have to the surrounding banks and channel such as the shifting of erosion to adjacent

or cross stream locations that are not protected.
****

a. The bank shall be prepared by reducing the slope to [2H:1V] [as shown in the drawings]. The surface of the bank shall be smoothed and compacted. A key trench shall be excavated at the toe of the stream bank and shall extend [1 m 3 feet below the mean low water level] [600 mm 2 feet below the lowest elevation of estimated scour]. The bank shall be overlain by a 100 mm 4 inch thick layer of 75 mm 3-inch minus compacted fill that contains less than 5 percent fines that shall serve as a filter blanket between the outer armor stone and the bank soil.

b. Large stone with a nominal diameter of 1 m 3 feet shall be placed in the key trench. Armor stone shall be placed up bank from the key stones to the bank crest [and extend 1.5 m 5 feet landward of the bank crest]. Each stone shall be placed to interlock with down slope stones to form a rock mass that covers 100 percent of the exposed bank. The stones shall be placed by [hand] [heavy equipment with placing bucket]. Stones shall not be dumped in mass from the top of the bank. The stones shall be pushed into the bank once the stone is placed. [Top soil] [Excavated bank material] shall be placed on top of the stone and shall be brushed over the surface of the stone to fill the voids between the stones. Live [cuttings] [stakes] [poles] shall be driven between the joints of the rock at least 600 mm 2 feet into the bank soil below the base of the armor stone. Up to 10 live poles shall be placed per square yard of area. Cuttings shall be placed on the entire structure from the mean low water level to the landward end of the revetment.

c. The ends of the structure shall be keyed into the stream bank. Key trenches shall be excavated 1.5 m 5 feet into the stream bank at the up stream and down stream ends of the structure. These trenches shall be 1.5 mm 5 feet deep and the faces of these trenches shall be the same slope as the face of the prepared bank. The trenches shall be filled with large [stone] [rock] that is pushed into the bottom and sides of the trench. The voids between the [stones] [rocks] shall be filled with soil removed from the trench. The [stone] [rock] shall extend to the surface and wrap in a continuous mass into the armor [stone] [rock] on the face of the bank.

3.13.3.3 Brush Layered Revetment

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NOTE: Brush layer revetments are constructed of alternating layers of live brush cuttings and rock. These structures are easier to construct and of lower cost than live revetments and are suitable for protecting long stretches of stream banks or lake shores. The live brush will cover the armor rock with time and obscure it from view. Angular quarry stone or rip rap may be used with this method.
****

a. The bank shall be prepared by reducing the slope to [2H:1V] [as shown in the drawings]. The surface of the bank shall be smoothed and compacted. A key trench shall be excavated at the toe of the stream bank and shall extend [600 mm 2 feet below the mean low water level] [600 mm 2 feet below the lowest elevation of estimated scour]. The bank shall be overlain by a 100 mm 4 inch thick layer of 75 mm 3-inch minus compacted fill that contains less than 5 percent fines that shall serve as a filter blanket between the outer armor stone and the bank soil.

b. Live cuttings shall be placed in the trench against the stream side wall of the trench. The cuttings shall be pushed into the streambed and the cut ends shall be covered with a thin layer of [sediment] [select fill]. Large stone with a nominal diameter of 1 m 3 feet shall be placed in the key trench. The large stone shall rest on the ends of the cuttings and anchor them in place. Armor stone shall be placed up the bank from the key stones to the bank crest [and extend 1.5 m 5 feet landward of the bank crest]. Each stone shall be placed to interlock with down slope stones to form a rock mass the covers 100 percent of the exposed bank. The stones shall be placed by [hand] [heavy equipment with a placing bucket]. Stones shall not be dumped in mass from the top of the bank. The stones shall be pushed into the bank using suitable heavy equipment once the stone is placed. [Sediment] [Select fill] shall be [brushed] [washed] into the voids between the rocks as the rocks are placed.

c. Stone shall be placed in lifts not to exceed 1 m 3 feet in height. The top of the lift shall be within 150 mm 0.5-foot of the same elevation across the surface of the lift [and parallel to the water surface of the stream]. A layer of loosely compacted topsoil at least 150 mm 6 inches thick shall be placed on the top of the rock lift. Live cuttings shall be placed in a criss cross manner with 20 cuttings per 1 m 3 linear feet on top of the topsoil layer with the cut ends pushed at least 300 mm 1-foot into the bank beneath the filter layer and with growth tips extending 150 mm 1.5 feet beyond the face of the armor rock. The cuttings shall be covered with 100 mm 4 inches of moderately compacted topsoil. The next lift of rock shall be placed on top of the compacted top soil and these rocks shall be pushed into the topsoil until refusal due to contact with the rocks of the underlying lift. The process of alternating layers of rocks, cuttings, and topsoil shall continue to the [design height] [top of bank].

d. The ends of the structure shall be keyed into the stream bank. Key trenches shall be excavated 1.5 m 5 feet into the stream bank at the up stream and down stream ends of the structure. These trenches shall be 1.5 m 5 feet deep and the faces of these trenches shall be the same slope as the face of the prepared bank. The trenches shall be filled with large [stone] [rock] that is pushed into the bottom and sides of the trench. The voids between the [stones] [rocks] shall be filled with soil removed from the trench. The [stone] [rock] shall extend to the surface and wrap in a continuous mass into the armor [stone] [rock] on the face of the bank.

3.13.3.4 Longitudinal live fascine

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NOTE: Longitudinal live fascines consist of live fascines combined with brush layers and possible bank toe armor stone along the length of a stream bank or lake shore. These structures provide immediate protection of the toe of the bank from current or wave erosion. These structures are inexpensive and easy to construct and suitable for low banks. The method may be used as toe protection for stable high banks if the upper portions of the banks are protected by other bioengineered or hard

structures.
****

The fascines shall be composed of live cuttings and constructed in accordance with paragraph "Live Fascines" in PART 3. [A trench shall be excavated at the mean low water level of the stream with a floor that slopes at 15 degrees towards the bank.] [A key trench shall be excavated between the fascine trench and the mean low water line. This trench shall be 600 mm 2 feet deep and 1 m 3 feet wide. The face of the key trench shall terminate at the lip of the trench for the fascine. The trench shall be filled with [quarry rock] [large natural stone] [rock and brush fascines anchored with dead stakes].] A layer of live cuttings shall be placed in the bottom of the fascine trench in a criss cross manner with the cut ends of the cuttings in contact with the face of the trench and the growth tips extending 150 mm 1.5 feet beyond the lip of the trench. A minimum of 20 cuttings shall be placed per linear foot. The cuttings shall be covered with a layer of compacted soil. The fascine shall be placed in the trench and anchored in place by live poles. The poles shall be 1.2 m 4 feet in length and driven 10 mm 2.5 feet into the bottom of the trench through the fascine. The poles shall be spaced every 1 m 3 feet along the length of the fascine. Backfill shall be placed around the fascine to the [grade of the original bank] [design grade].

3.13.3.5 Longitudinal brush packing

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NOTE: Longitudinal brush packing is a method suited for the repair or protection of near vertical or under cut banks subject to erosion. These structures provide immediate protection to the bank from erosion or wave action. The stability of the bank should improve over time as vegetation becomes established dependent on the properties of the soils that compose the bank. The structures are suited for low to fast flowing streams or active lake shores. They are simple and easy to construct but may require large amounts of fill and vegetation. The structure consists of lifts of soil and brush that are wrapped by erosion control products. Geosynthetic or plastic netting shall not be used unless absolutely necessary and in this case only for the lower lifts of the structure.
****

a. The slope of the bank shall be reduced to [2H:1V] [steps that are 300 mm 12 inches high and 600 mm 24 inches deep from the toe to the crest of the bank] [as shown on the drawings]. A key trench shall be excavated at the toe of the design slope. This slope shall be of the same grade as the adjacent undamaged stream bank. The key trench shall be 1.2 m 4 feet wide and 600 mm 2 feet deep and extend the length of the work site. The trench shall be filled with [large natural stone] [quarry rock] that has a nominal diameter of 600 mm 2 feet and that is well graded with 100 percent greater than 100 mm 4 inches. The [stone] [rock] shall be placed to form a triangular topped dike with side slopes of 2H:1V. The [stone] [rock] shall be tamped into place.

b. A 100 mm 4 inch layer of [select fill] [removed sediment] shall be placed on top of the landward face of the rock dike and compacted. The [fill] [sediment] layer shall be covered with erosion control fabric composed of [coir netting] [_____]. The fabric shall extend from the face of the bank to at least 1.2 m 4 feet beyond the top of the rock dike. The netting shall be secured to the soil layer with [staples] [stones] [stakes]. The fabric shall be free of wrinkles and extend the full length of the rock dike.

c. Live cuttings [with 25 percent dead branches] shall be placed on top of the fabric layer in a herringbone pattern. The cut ends of the cuttings shall be pushed into the streambed to refusal. The cuttings shall be placed at a density of 20 cuttings per 300 mm linear foot to a thickness of 100 mm 4 inches. The growth tips of the cuttings shall extend 150 mm 1.5 feet beyond the top of the crest of the rock dike into the stream channel. [Select fill] [Removed sediment] shall be brushed into the voids between the cuttings. A 100 mm 4 inch layer of [select fill] [removed sediment] shall be placed on top of the cuttings and compacted. The fabric that extends over the rock dike [shall be cut and removed] [tightly rolled and anchored at the base of the cuttings on top of the rock dike].

d. The top of the [fill] [sediment] layer placed on top of the first layer of cuttings shall be covered with a layer of erosion control fabric composed of [coir netting] [_____]. The fabric shall cover the top of the lower lift. At least 1.5 m 5 feet of fabric shall remain above the contact of the lower lift and the slope of the bank. This portion of fabric shall be temporarily staked to the bank slope. At least 2 m 6 feet of fabric shall extend beyond the top of the design slope. A 300 mm 12 inch layer of [select fill] [removed sediment] shall be placed on top of the fabric and compacted to 90 percent dry density. The ends of the fabric shall be placed on top of the compacted material. The fabric near the face of the bank shall be placed on top of the compacted material and pulled free of wrinkles. The portion of fabric towards the stream channel shall be placed across the face of the compacted material and pulled tight and secured to the top of compacted material with staples. The staples shall be installed flush with the top of the lift.

e. Live cuttings shall be placed on top of the lift of compacted material in the same manner as the cuttings on the first lift. These cuttings shall be covered by a 100 mm 4 inch layer of compacted [select fill] [removed sediment]. The process of wrapping lifts of compacted soil with erosion control fabric and the placement of layers of cuttings shall continue to the [design height of the structure] [top of the bank]. The height of the soil lift nearest to the top of the structure shall be adjusted in thickness to meet the design grade. The top of the structure shall not be covered with cuttings. [Live stakes shall be placed across the top of the structure on 600 mm 2 feet centers for a distance of 2 m 6 feet landward of the top of the bank and for 2 m 6 feet upstream and down stream of the ends of the structure on the original stream bank.]

f. The structure shall be keyed into the bank on the up stream and down stream sides of the structure. The key trenches shall be 1.2 m 4 feet deep. The lifts of the structure shall be wrapped into the trenches and the ends of the lifts shall butt against the face of the key trench.

3.13.3.6 Live Crib Wall

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NOTE: Live Crib walls are robust structures suited for stabilization and protection of banks or shores subjected to high flow or moderate wave action. These structures provide immediate erosion protection and possible habitat during high flow events dependent upon design. The structure provides a hard frame that dissipates current or wave energy. Bank stability and habitat improve as the vegetation matures and develops extensive root systems and shade along the bank. These structures typically require earthworks and large equipment for bank preparation and backfilling. Large amounts of vegetation and labor are required. Crib walls may be used to increase the width of a stream by replacing the natural sloped banks with the near vertical walls of the structure. Crib walls may be used to repair severely scoured banks by placing the structure in the stream at the new bank alignment and backfilling the void between the structure and the existing bank.

The structure may be combined with brush sills, brush mats, or large natural stone on the up stream or down stream sides of the structure to reduce erosion. Stability of the structure may be improved using a double crib design composed of front and back headers. Backfill should be free draining material. Timber used for the crib wall may be untreated manufactured 300 mm (12-inch) square posts, locally harvested vegetation with truck diameters greater than 300 mm (12 inches), or combination of these materials.

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a. The stream bank shall be reduced to the required slope and design grade. A trench shall be excavated that is 600 mm 2 feet deep and extends parallel to the toe of the slope. This trench shall extend the full length of the work site and shall extend [for a distance of 4.5 m 15 feet into the stream channel from the toe of the slope] [in the stream channel to the distance and dimensions shown on the drawings]. The floor of the trench shall slope at 15 degrees towards the bank and shall be [manually compacted using a tamping bar weighing at least 18 kg 40 pounds] [compacted using a small motorized tamping machine] until the bottom of the trench is dense and provides a solid base for the crib wall. The floor of the trench shall be [as shown in the drawings] [of uniform grade across the trench width]. The trench shall be keyed into the stream bank for a distance of 2 m 6 feet. Material removed from the key trenches shall be used as compacted backfill in the key trenches. Sediment excavated from the trench shall be [removed from the site and replaced with select fill] [used as compacted backfill]. Depressions in the trench floor shall be filled with compacted material to raise these areas to design grade and areas above grade shall be reduced to the design grade.

b. The crib wall shall be framed with [untreated straight 300 mm 12-inch square by 2.5 m 8 feet long beams] [200 to 300 mm 8 to 12 inch diameter by 2.5 m 8 feet long straight logs harvested from local sources. These logs shall be cut normal to the trunk and the logs shall have all branches stripped from the trucks]. The header adjacent to the stream shall be placed parallel to the toe of the slope at the design alignment of the wall and shall extend the full width of the trench. The header adjacent to the bank shall be placed parallel to and 2 m 6 feet from the stream side header in the direction of the bank. Headers shall be placed end-to-end and in line at splices between the members. Wood posts shall be driven vertically into the streambed 150 mm 6 inches from the splices on both sides of the header.

c. Stretchers shall be 2 m 6 feet in length. Each stretcher shall be placed normal to the headers and between the vertical poles at the splices between the headers. The stretchers shall be spaced [every 1.2 m 4 feet] [mid distance] between the vertical poles and shall extend a minimum of 100 mm 4 inches beyond the outer edge of the stream side header face. The rear butt of the stretcher shall be placed on top of the header near the bank and shall [extend 100 mm 4 inches beyond the outer face of the header] [be firmly placed against the exposed bank]. The stretcher shall be attached to the header with binding products wrapped three times in a criss cross pattern and secured with a non-raveling knot. A 13 mm 1/2-inch diameter hole shall be drilled vertically through the stretcher and header. A 600 mm 24 inch long, 16 mm 5/8-inch diameter [non-galvanized steel spike] [steel rebar] [hard wood dowel] shall be driven into the hole and set flush to the top of the stretcher. The open area between the inner face of the stream side header and the inner face of the landward header shall be backfilled with compacted [sediment removed from the trench excavation] [select fill] to the middle of the stretchers. Live cuttings 19 to 38 mm 3/4 to 1.5 inches in diameter shall be placed in a criss cross manner on the top of the compacted backfill with the cut ends pushed into the backfill near the landward header. The growth tips of the cuttings shall extend 600 mm 2 feet beyond the face of the stream side header. Backfill shall be placed and lightly compacted on top of the cuttings to the top of the stretchers. Additional headers, stretchers, backfill, and cuttings shall be placed until only the final lift remains. The centerlines of stream side headers shall be off set 50 mm 2 inches towards the bank relative to the lower headers to provide an incline to the face of the structure. Select fill shall be placed in the area between the face of the landward header and the slope of the bank. The fill shall be placed in lifts of the same thickness as the lifts on backfill in the interior of the structure. Each lift shall be compacted to at least 90 percent dry density.

d. The top stream side headers shall be 100 mm 4 inches larger in diameter than the headers used for wall construction. The vertical poles shall be cut flush with the top of the final headers. A header shall be placed at the midpoint between the outer headers and secured with binders and [spikes] [rebar] [dowels] to the underlying stretchers. The lift of backfill immediately below the completion headers shall be filled with a tightly packed brush mat composed of live [and dead] cuttings that are placed in an alternating rectilinear grid pattern. Each layer of brush shall be covered with a thin layer of lightly compacted backfill. [Rounded clean natural stone from 300 to 600 mm 12 to 24 inches in diameter] [Excavated sediment] shall be placed from the top of the packed brush to the top of the final headers [to the grade shown in the drawings]. [Live stakes shall be driven vertically on 600 mm 2 feet centers into the backfill at the top of the structure.] [Large natural stone armor 600 mm 2 feet thick shall be placed on the banks and against the ends of the structure for a distance of 3 m 10 feet upstream and down stream from the structure. Live stakes shall be planted in the joints between the stones.] The key trenches shall be filled with [large natural stone] [quarry rock] to the design grade.

3.14 IRRIGATION

Irrigation of the structure shall be started immediately after installing erosion control products and vegetation. Water shall be applied to supplement rainfall at a sufficient rate to ensure moist soil conditions to a minimum 300 mm 12-inch depth. Run-off and puddling shall be prevented. Watering trucks shall not be driven over turf areas, unless otherwise directed. Watering of other adjacent areas or plant material not related to work efforts shall be [prevented] [as specified by the Contracting Officer]. Water shall be applied to trenches immediately before placement of live vegetation. Water shall be placed on the completed structure at the end of each day, as needed to control dust and to prevent excessive drying of vegetation, and at the completion of the structure. [The structure shall be irrigated after installation for 3 months until the end of the first year growing season.] [Structures in arid climates shall be irrigated for a period of 3 years.] [Daily irrigation of the structure and work site shall not exceed 20 minutes [each day] [twice a day] [3 times per week] and shall be sufficient to support the survival and growth of planted vegetation. Irrigation shall never exceed limits that could impair the stability of the structure and shall be adjusted to compensate for additions or deficits to soil moisture caused by precipitation or evaporation.]

3.15 FERTILIZER, PESTICIDE, HERBICIDE

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NOTE: Edit this section as required. Fertilizer, pesticide, and herbicide may be required for the construction, establishment, and maintenance of bioengineered structures. Provide methods for application, frequency of use, safety precautions for humans and the environment in the section below.

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3.16 FIELD QUALITY CONTROL

The work site shall be inspected by the Contracting Officer prior to final acceptance of work. A punch list noting deficiencies shall be compiled by the Contracting Officer and provided to the Contractor. The Contractor shall perform, repair, adjust, align, or otherwise comply with the specified work on the punch list to the satisfaction of the Contracting Officer. The Contractor shall be responsible for notifying the Contracting Officer at least 14 days prior to the inspection that work shall be ready for inspection. Work will not be accepted until all punch list items are resolved and all work meets or exceeds contract requirements. Final acceptance of work shall not be provided by the Contracting Officer until all defects or deficiencies are corrected. Final Acceptance shall occur only after all corrective actions and supplemental viable plantings are complete and the structure meets performance standards and all contract requirements. The Contractor shall comply with necessary repairs to the structure and vegetation as stated in the warranty.

3.17 CLEAN-UP

Excess material, debris, and waste materials shall be disposed of offsite at an approved landfill or recycling center. Adjacent paved areas shall be cleared. The site shall be restored to preexisting conditions to the extent reasonably possible and to the satisfaction of the Contracting Officer.

3.18 PROTECTION

Immediately upon the start of the installation in an area, the area shall be protected against traffic or other use by erecting barricades and providing signage as required, or as directed. Signage shall be [in accordance with Section 10 14 01 EXTERIOR SIGNAGE] [as shown on the drawings]. The Contractor shall protect the work site and vegetation from damage and vandalism and free of trash and debris until final acceptance by the Contracting Officer.

3.19 DOCUMENTATION

The Contractor shall establish and maintain documentation for bioengineering practices to record the desired information and to assure compliance with contract requirements, including, but not limited to, the following:

3.19.1 Maintenance Records

The Contractor shall visit, inspect, and document site conditions after the completion of construction every week for the first year and every two weeks thereafter until the end of the second year. Documentation shall include written reports on site structure and vegetation conditions, damage, plant loss, and the like, to fully describe site conditions at the time of the visits and changes observed since previous visits. Photographs of the site and areas of growth, defects, or damage shall be obtained and included with the records. Records shall be submitted to the Contracting Officer within [48] [_____] hours after the completion of the site visit.

3.19.2 Final Project Report

The Final Project Report shall summarize information included in the construction and maintenance records as submitted throughout the project. The report shall summarize the work rather than repeat the items in the individual reports.

-- End of Section --