Tennessee Department of Transportation (TDOT)

Statewide Storm Water Management Program

TDOT Environmental Division
Mitigation Practices

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1 Introduction

This Mitigation Chapter has been developed as a guide for the Ecology Section within the Environmental Division (ED) to use when reviewing projects that require mitigation. The ED conducts various studies (e.g., Ecology Report [Scopes A and N], Environmental Boundaries [Scopes G, J, and N], Biological Assessments [Scope F]) to identify environmental features as well as listed species that may be impacted by a proposed project alignment. These studies are performed to identify natural and constructed features that may dictate alignment location within a project corridor. The Design Phase Ecological Field Study (Scope G) provides the most current natural resource feature location information and tabulates impacts to these features associated with the proposed project alignment.

Natural resource features, such as streams, springs, wetlands, and protected species, are identified and measures are recommended to avoid these sensitive areas to the greatest extent practicable. If these sensitive environmental features cannot be avoided, impacts must be mitigated. TDOT has a standard procedure for mitigating impacts to streams, wetlands, and protected species. Mitigative measures are recommended by the ED in a transmittal to the Design Division via Form J and the Environmental Boundaries and Mitigation Design Memorandum (EBMM) of the ED's procedures manual for conducting Ecological Studies. Form J and the EBMM identify potentially impacted features and provides standard mitigation measures (reprinted later in this chapter) to be placed on the plans by the Design Division, which is to be ultimately carried out by construction. These standard mitigation measures provide instructions in the form of Plan View sketches and Plan Notes, which could include notes to be added to the Erosion Prevention and Sediment Control (EPSC) Plans. Typically, the general EPSC notes are recommended by the developer of the SWPPP (whether consultant or in-house) but the Ecology Section may have specific special EPSC notes to protect special ecological features, such as species. These general EPSC notes were developed to comply with Section C.7 (b) of the Amended Consent Order (the Order) regarding Interim Measures pending approval of the Statewide Storm Water Management Plan (SSWMP). Form J and the EMBB are used for routine mitigation, i.e., relocation of short/small stream reaches, minimization of wetland impacts, and avoidance measures/protection notes for protected species. The ED on a case-by-case basis shall address projects with larger non-routine impacts with special EPSC notes. The following sections of this chapter detail routine on-site and compensatory (In-Lieu Fee) mitigation practices for streams, wetlands and species of concern as well as mitigative measures to lessen impacts associated with construction activities to the aquatic environment as a whole.

2 Routine Compensatory Mitigation Practices

Mitigation practices are for short-term and/or long-term impacts. Mitigative measures / practices for short-term impacts are employed to minimize adverse impacts to an environmental feature (e.g., stream or wetland). These short-term measures can range from temporarily diverting a stream around in-channel construction to returning a temporarily impacted wetland area to pre-project conditions. Long-term or permanent impacts (i.e., loss of stream length, stream function and/or wetland areas) can be mitigated through on-site or off-site restoration or creation activities. The following sections provide routine mitigation practices that can be used by ED staff when reviewing project impacts.

There is a team called the Mitigation Bank Review Team (MBRT) for wetland banks. This team consists of several agencies (EPA, Corps of Engineers, TWRA, TDEC, and Fish and Wildlife Service – TDOT is a non-voting member and FHWA is a non-voting member of some banks). The MBRT determines the service areas of each bank, (with input from/in conjunction with the bank owner, more or less), and determines the mitigation ratios to be used within and outside the banks' service areas. Memorandums of Agreements (MOAs) are signed by the different agencies and permission is granted by the MBRT for us to use these bank credits.

Bank ownership varies across Tennessee. TDOT owns the Madison County Wetland Bank and the Millington Wetland Site in Shelby County that may become a bank once jurisdictional boundaries are approved by the MBRT.

TDOT also owns several wetland sites, which do not have a MOA with the MBRT, but can be used for mitigation, sometimes with limitations. Wetland sites are areas where TDOT has created, restored or preserved a wetland site. These sites do have to have some kind of approval from TDEC and the Corps, but it does not have to go through the formality that the banks do. TDOT owns and maintain these sites. Ratios and service areas are established through the regulatory requirements.

The various private owners of sites and banks are responsible for the development, wetland success, and maintenance of their own properties.

Opportunities for on-site mitigation should be evaluated before making a determination to use the Tennessee Stream Mitigation Program (i.e., TSMP In-Lieu Fee) for stream impacts and MBRT approved mitigation banks or TDOT sites for wetlands. In accordance with Federal Guidance (*TEA-21 and Federal Guidance on the use of In-Lieu Fee Arrangements*), TDOT should follow the protocol for evaluating mitigation planning and opportunities in the following manner:

1. On-site compensatory mitigation of stream and wetland impacts,
2. Use of MBRT approved Wetland Banks or TDOT Wetland Sites, and
3. Use of TSMP In-Lieu Fee Mitigation Program for unavoidable stream impacts.

2.1 Routine Stream Mitigation Practices

2.1.1 Long Culvert Mitigation and Permanent Stream Impacts

The evaluation of potential on-site stream mitigation should be a part of the Ecology Section planning and review process when performing the early site reconnaissance for the NEPA document (Scope A Ecology Report). Potential on-site mitigation areas can be identified early in the process and if needed additional Right-of-Way (ROW) can be acquired as part of the project, if needed. The search for potential stream mitigation sites should be limited to streams adjacent to the ROW or within the immediate vicinity of the project. By requiring lengthy monitoring, large buffer zones, and large mitigation ratios, the Tennessee Stream Mitigation Guidelines actually discourage TDOT from considering on-site stream mitigation for long culvert impacts. However, on-site stream mitigation if identified early in the project planning and design process could include such practices as riparian zone restoration, in-stream habitat replacement, cattle exclusion, and streambank stabilization. These on-site stream mitigation practices would provide beneficial aquatic habitat functions and values as well as improved water quality in the watershed where the impacts will occur.

Upon determination that there is no potential for on-site stream mitigation, TDOT should propose compensatory mitigation for culvert impacts using the Tennessee In-Lieu Fee Stream Mitigation Program (TSMP). All relocated stream channels should be designed such that payment into the TSMP is not required. When the relocated stream channel results in a loss of stream footage, the amount lost should be mitigated using the TSMP. The use of riprap-lined channels should be avoided in all cases unless there is a safety issue related to the creation of a new stream channel.

Placement of greater than 200 feet of stream into a culvert should be mitigated by payment into the TSMP (In-Lieu Fee). Likewise, stream or water body impacts that cannot be mitigated on-site such as springs and seeps that require rock fill to allow for movement of water underneath the roadway should be mitigated off-site by making a comparable payment to the TSMP (In-Lieu Fee).

2.1.2 Stream Relocations

Stream channels requiring relocation should be replaced on-site to the extent possible, using natural channel design techniques that will replace existing stream characteristics such as length, width, gradient, sinuosity (a bending or curving shape, meander wavelength, and curvature) and tree canopy. All relocated streams should be designed such that sufficient on-site credits are given to TDOT to fully mitigation impacts of relocating the stream. The use of riprap-lined channels should be avoided in all cases unless there is a safety issue (e.g. slope destabilization) related to the creation of the new stream channel. Stream or water body impacts that cannot be mitigated on-site such as springs and seeps that require rock fill to allow for movement of water underneath the roadway should be mitigated off-site by making a comparable payment to the TSMP.

Stream relocations less than 50 ft. should not require detailed measurements and design as this is considered a transition zone and is often needed to direct flow into a culvert. The reach of stream immediately upstream of the transition zone should be mimicked to replace a natural and smooth transition into the culvert. Sufficient field data should be collected when performing Scope G (Ecology Field Study for Environmental Boundaries) so a replacement stream channel with the proper plan and cross-section can be designed and constructed. Detailed stream profile data should be collected by the survey group and provided to the Environmental Design Group. Three general cross-sections should be measured for design of the new channel. Cross-section measurements are shown in Figure 4. One cross-section each should be measured upstream of the proposed relocation, near the middle of the relocated stream reach, and downstream of the proposed relocation. Each cross-section should provide the following data:

- Channel Bottom Width
- Top of Bank Width
- Bank Height
- Bankfull Height
- Bankfull Width
- Water Width
- Water Depth
- Side Slopes
- Soil Type

A template such as Figure 5 could be used to facilitate the gathering of the correct information. Other data to be collected for stream relocations includes substrate description and habitat. This data is collected so the existing stream can be duplicated to the extent practical including channel length, bottom width, elevations, sinuosity, and curvature of the existing channel. Each relocated channel should transition smoothly from its beginning elevation to its tie-in elevation in the receiving stream, without profile drops or jump. Sufficient field data or description should be provided to allow for a low flow channel with a vegetated floodplain shelf. A floodplain shelf or bench is typically present along the inside of meander bends; therefore, the bench will transition from left bank to right bank depending on the meander pattern (see figures in Appendix). This will allow the high velocity flood flows to spread out, reducing the shear stress on the stream banks eliminating, in many cases, the need for riprap-lined channels. Riprap lined channels require exorbitant mitigation fees into the TSMP (In-Lieu Fee). General Notes for Design are typically included with Form J.

Locate the new stream channel in as flat an area as possible to avoid unusually high side slopes; this may require additional ROW. Channel side slopes should be 2:1 or less (if possible) and seeded. Plant two alternating rows of trees on 12-foot centers on both sides of new channels. Trees should be quality bare root seedlings between 18” and 24”. Species selected should be commercially available and be those typically observed along the alignment. If tree species are sparse around the project then select trees that grow in the region. The first row should be centered no further than 3 feet from the top edge of the bank on the side slope if possible and the second row of trees 12 feet back from the first row. Riprap, if required, should be limited to prevent erosion at the outlet of culverts only. All relocated channels and their accompanying mitigation features, including trees, shall be placed in permanent ROW rather than easements; this may require acquisition of additional ROW. Use the following tree specifications:

2.1.3 Channel Relocation Sequence and Implementation Notes for Relocated Stream Channels

1. The new channel should be excavated and stabilized during a low-water period. Riprap (only as shown on plans), seeding, and sod should be installed immediately following channel completion. Trees should be installed in the first planting season following channel excavation. Stream flow should only be diverted into the new stream after it is completely stabilized, and only during a low-water period. If required by the permit(s), the old channel must remain for a specified time to allow for emigration of aquatic organisms. Stabilized means that all specified rock, substrate, in-stream habitat, and erosion control blanket or flexible channel liner is in place, and seeding and sod are in place and established.
2. Channel Relocation Sequence
    a. Flag edge of the new channel top bank before clearing. Do not clear large trees outside of the relocation footprint and roadway toe of cut or fill slope, especially if they are in position to shade the new channel. Leave as many trees and shrubs as possible between toe of the new highway slope and the stream.
    b. Excavation of the new channel should be separated from flowing water or expected flow path and performed during low flow conditions by leaving areas of undisturbed earth (diversion berms) in place at both ends. This should be accomplished by the use of sheet piles, flumes, diversion pipe with sand bag dam at pipe inlet, lined diversion channel with sand bag or clean rock berm, jersey barriers, etc.
    c. Shape channel to specifications shown. Remove loose soils and debris.
    d. Place topsoil, erosion control blanket or flexible channel liner, seed, and sod as specified.
    e. Excavate substrate from existing channel (i.e., gravel, cobble, boulders, logs, and woody debris) and place in bottom of new stream channel for habitat (only for use in gravel bed streams. Oversight should be provided by the Ecology Section. Do not use this note for West Tennessee Streams or bedrock streams).
    f. Remove diversion berms, beginning with the downstream end. Banks and bottom elevation of the old channel should transition smoothly into the new channel. The elevations of the new channel bottom at each end of the relocation sequence should match the elevations of the existing channel, and a steady percent slope should be maintained throughout the relocated channel centerline or as specified.
    g. Install trees according to TDOT Standard Specifications Section 802.
3. Only riprap shown on plans should be used in the relocated channel reach. Any other proposed riprap should be coordinated with the ED, Design, and Structures through the TDOT Headquarters Construction Office.

Requests by any agency for field changes that would require the modification of channels, ditches, elevations, riprap or any other stream mitigation items associated with the channel relocations should be referred to the TDOT ED via the Headquarters Construction Office for coordination with all involved agencies and TDOT divisions. Figures 1-3 show examples of relocated channel designs.

2.1.4 Vegetation

No substitutions of tree species or sizes should be allowed without the written approval of the TDOT ED. For stream mitigation, trees should be of the variety requested, bare root seedlings, and first quality. No clones or cultivars will be accepted. Any found to be incorrect species, or improperly planted, at any time prior to termination of the contract should be removed and replaced at the contractor's expense.

Signs should be placed along relocated streams channels where bare root seedling trees have been planted to avoid mowing by TDOT maintenance crews. The signs should read "Do Not Mow" or some similar warning that the area is a protected zone and should not be disturbed.

Table 1: Tree Specifications

Item #	Description	Unit
	TREES (*Scientific name)* bare root	
	TREES (*Scientific name)* bare root	
	TREES (*Scientific name)* bare root	
	TREES (*Scientific name)* bare root	
	TREES (*Scientific name)* bare root	

The contractor should arrange several months ahead of time to obtain the correct tree species, as some may require some time to locate.

Trees should be watered as required through the period of establishment to insure survival.

Use the following grass species for stabilizing the flood storage areas, stream banks, and riparian zone on both sides of the new channel:

- **Rice cutgrass (*Leersia* oryzoides*)***
- **Barnyard grass (*Echinochloa muricata*)**
- **Virginia Wild Rye (*Elymus virginicus*)**
- **Deertongue (*Panicum clandestinum*)**

All species should be mixed with equal ratios (10 pounds per acre each).

Cover Crops

The following species should be used as cover crops in conjunction with the native species since native species require longer time to become established. Use in combination or as single applied cover crop.

- **Winter Rye (*Secale cereale*)**
- **Wheat (*Triticum aestivum*)**

Apply cover crops at a rate of 10 pounds per acre each in a mix or 20 pounds per acre alone.

Use a combination of the following shrub species for the flood storage area on either side of the new channel and on the slope:

- **Buttonbush (*Cephalanthus* occidentalis)**
- **Silky dogwood (*Cornus amomum*)**

- **Brookside alder (*Alnus serrulata*)**
- **Arrowwood (*Viburnum nudum*)**
- **American witchhazel (*Hamamelis virginiana*)**

Shrub species should be 1-gallon container grown stock. Shrubs should be placed on 8-foot centers. Preparation of the seedbed and sowing of the seed mixture should be as specified in the TDOT Standard Specifications manual.

Live stake willows can also be used along the floodplain shelf. Construction Specifications for Live Stake Willows

1. Harvesting:

A. Live stakes may consist of a combination of willows, silky or red-osier dogwood and buttonbush, but the combination must contain at least 50% black willow stakes.

B. Stakes should be harvested and planted when the willows or other chosen species are dormant. This period is generally from late fall to early spring, or before the buds start to break.

C. When harvesting cuttings, select healthy, live wood that is reasonably straight.

D. Use live wood at least 1 year old or older. The best wood is 2 to 5 years old with smooth bark that is not deeply furrowed.

E. Make clean cuts with unsplit ends. Trim branches from cutting as close as possible. Cut the butt end of the cutting at an angle (~45 degrees) and the top end square.

F. Identify the top and bottom of cutting as accomplished by angle cutting the butt end. The top (square cut end) should be painted and sealed by dipping the top 1-inch to 2-inches into a 50-50 mix of light colored latex paint and water. This reduces the possibility of desiccation and disease causing mortality and makes them more visible for subsequent planting evaluations. Assure the stakes are planted with the top up.

G. Cuttings should generally between 0.5-inches to 2-inches in diameter but can be larger depending on the species. Highest survival rates are obtained from using cuttings 2-inches to 3-inches in diameter. Larger diameter cuttings are needed for planting into rock riprap.

H. Cuttings of small diameter (up to 1.5-inches) should be 18 inches long minimum. Thicker cuttings should be longer.

I. No less than ½ of the total length must be buried.

J. Stakes should be cut so a terminal bud scar is within 1-inch to 4-inches of the top. At least two buds and/or bud scars should be above the ground after planting.

2. Installation: (refer to Figures 26 – 30)

A. Stakes must be planted with butt-ends into the ground. Leaf bud scars or emerging buds should always point up.

B. Stakes must not be allowed to dry out. The cuttings not planted the day they are harvested should be soaked in water for a minimum of 24 hours as soaking significantly increases the survival rate of the cuttings.

C. Plant stakes 3 feet apart.

D. Set the stake as deep as possible into the soil, preferably with 80 percent of its length buried.

E. Tamp the soil around the cutting.

Use an iron stake or bar to make a pilot hole in firm soil or between riprap. Drive live stakes into the soil with a rubber mallet or dead-blow hammer.

2.1.5 Mulching of Seeded Areas

All seeded areas are to be covered by straw mulch as specified in Section 801.07 of the TDOT Standard Specifications book.

Figure 1: Special Channel Design for Relocated Stream STR-___

(Channel dimensions may require alteration based on hydraulic needs.)

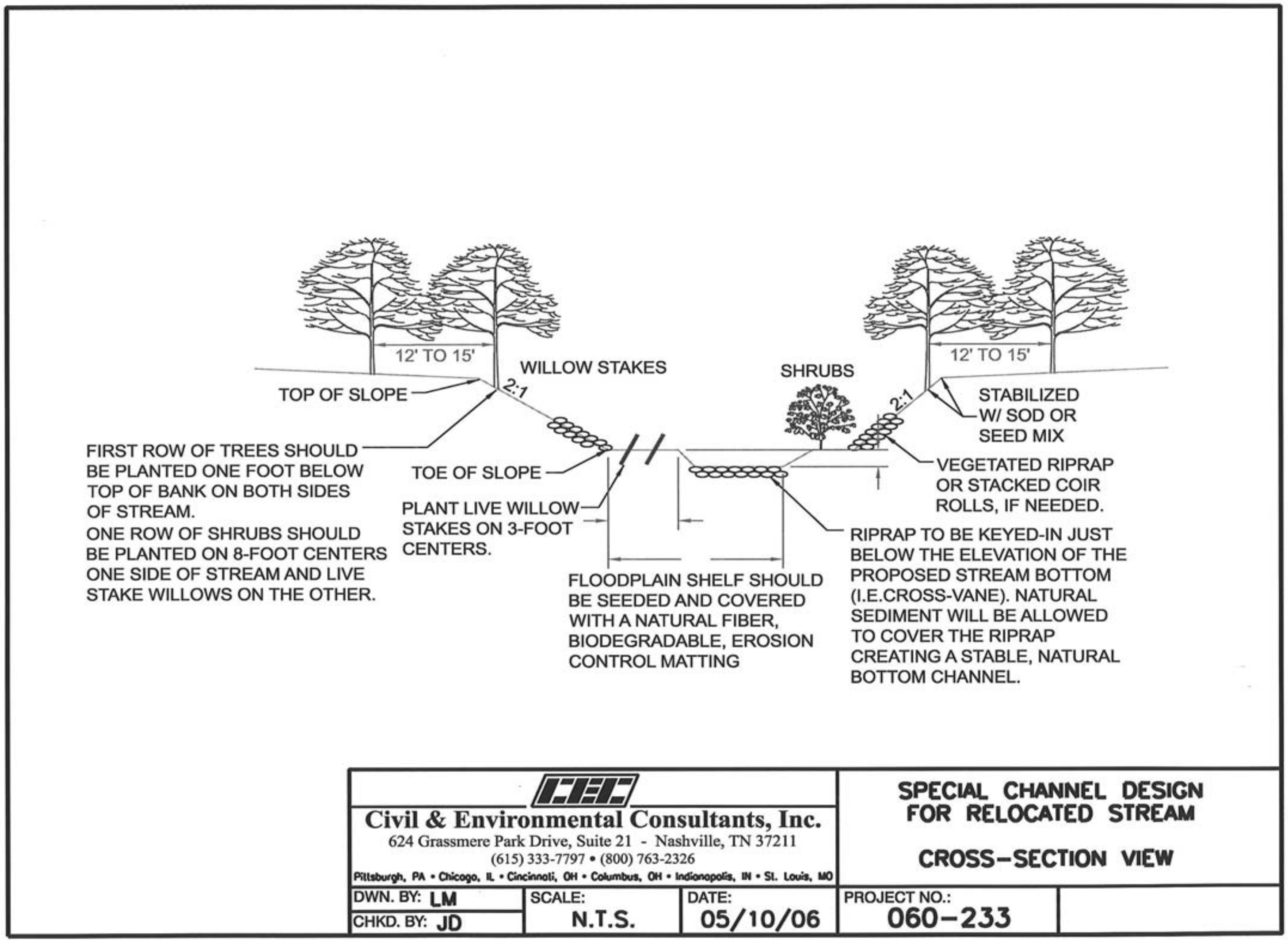


Figure 2: Plan View for Relocated Stream STR-___

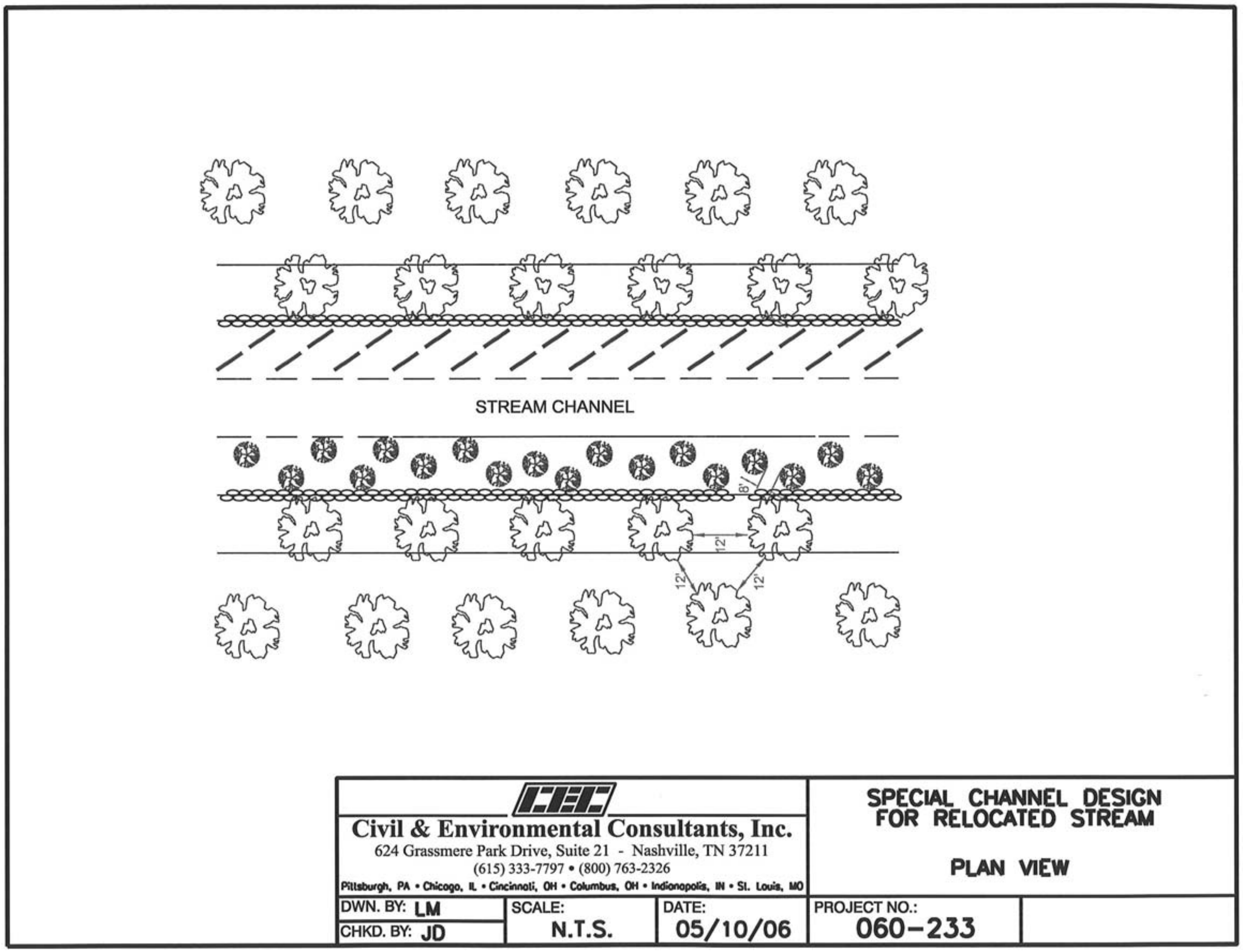


Figure 3: Alternate Special Channel Design for Relocated Stream STR-___

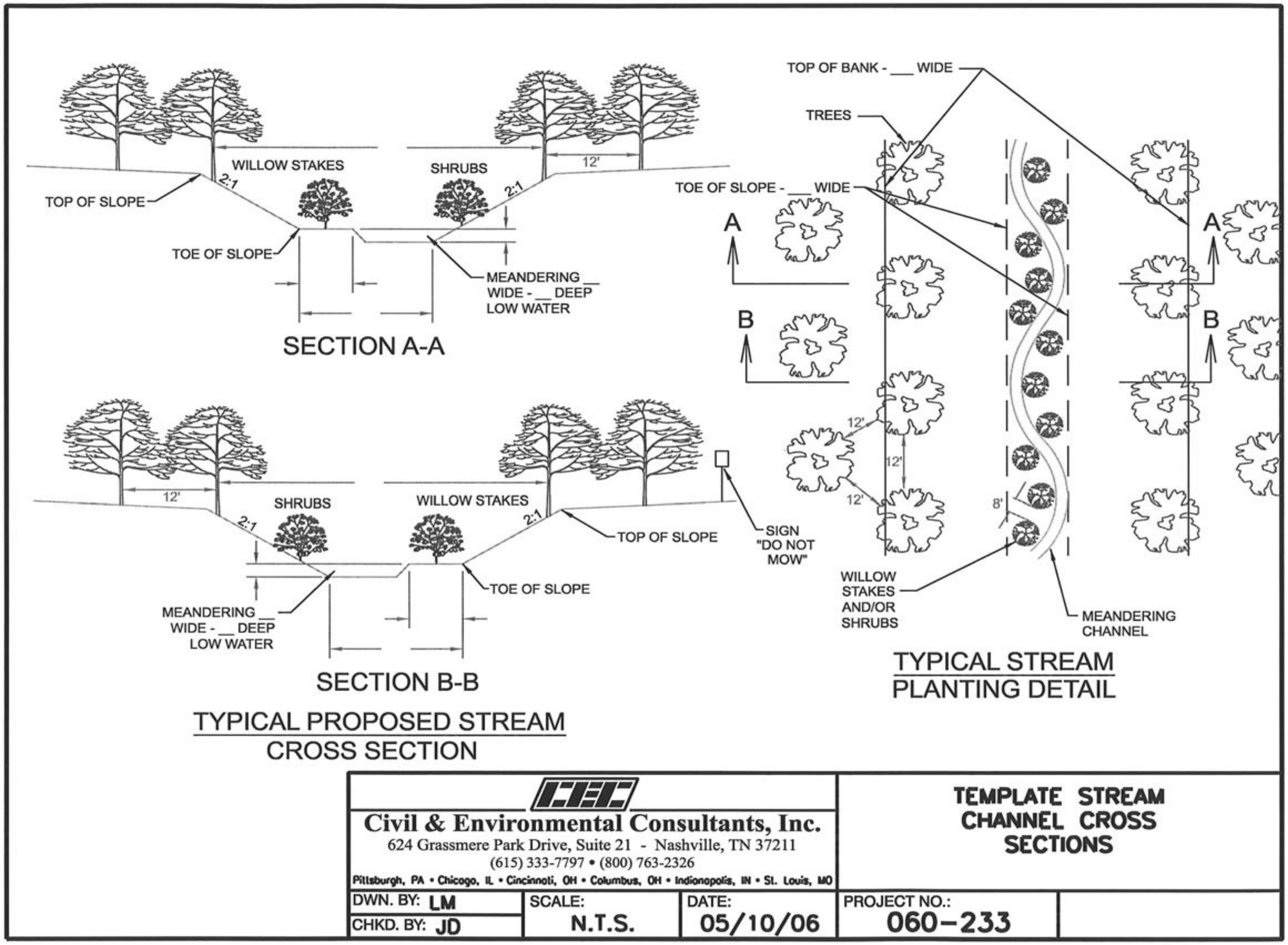
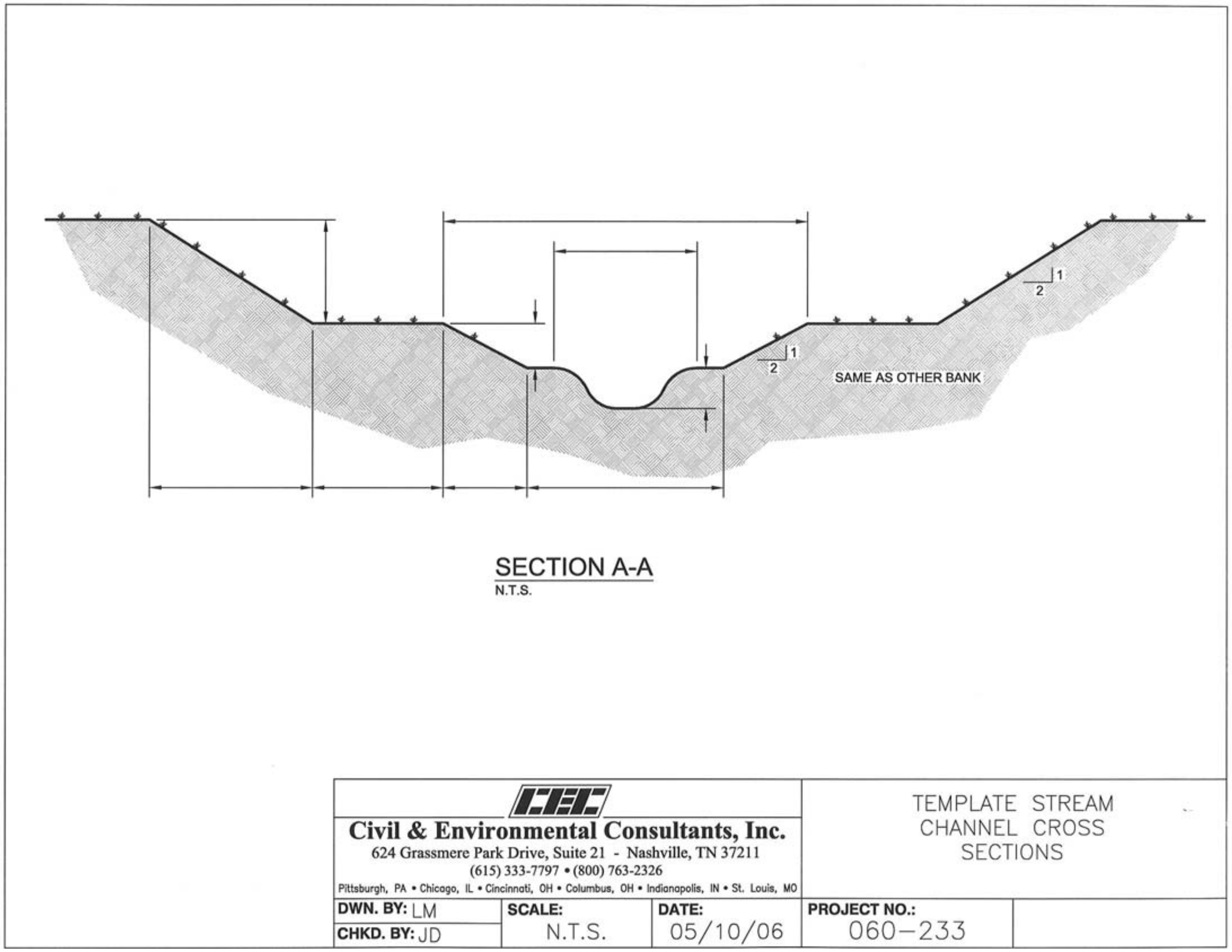


Figure 4: Template for Use When Taking Field Cross-Section Measurements



2.1.6 Long Stream Relocations or High Quality Streams Relocations

The same procedure applies to long stream relocations of but with more cross-section and habitat data. Cross-sections should be measured at the upstream and downstream end of the stream reach with additional cross-sections measured every 100 feet throughout the effected stream. Replacement of habitat should be a focus for stream relocations to avoid payment of mitigation fees. Rarely will streams that reach zero flow (i.e., intermittent) at times due to diversion or natural conditions support a viable fishery. Such streams will not require detailed habitat replacement. Restoration of habitat in highly intermittent streams is not advisable.

The following general notes and procedures should be used for all stream relocations:

- Before installing EPSC, identify permit conditions, environmental boundaries, and impact area limits.
- Install proper BMPs to treat runoff from the work area.
- Typical channel relocation projects shall require EPSC measures around stream channels to be added and removed throughout construction to help prevent sediment and debris from reaching the active stream.
- The existing stream should be maintained as much as practical while the relocated channel section is constructed.
- Temporary stream flow diversion should be employed to isolate the work area using a fabric-lined diversion channel.
- The existing stream flow should be separated from flowing water or expected flow path, performed during low flow conditions and should only be diverted into either a stable temporary flow diversion channel or a completed and stabilized relocated channel reach.
- Inactive work areas should be stabilized by temporary seed and mulch, such that the work performed will not be displaced in the event the area is inundated during a storm event.
- Active areas should be temporarily stabilized prior to an anticipated precipitation event to prevent the work performed from being displaced in the event the active work area is inundated.
- Riprap should only be placed when specifically shown on the plans.
- The stream dimensions and depth shown on the plans are critical to the proper function of the channel relocation. Notify the Project Engineer and ED immediately if these dimensions cannot be maintained.
- The relocated channel and surrounding area should be properly stabilized prior to receiving the normal stream flow. It is important that vegetative plantings occur at the proper time of the year and as soon as possible to help stabilize the stream.
- Remove all temporary EPSC measures and properly dispose of excess spoil in an approved area.

2.1.7 Stream Relocation Considerations (Planning, Design and Construction)

The following sections provides an introduction to habitat replacement and design consideration that should be made to replicate natural streams and was modified from Restoration of Habitat in Relocated Streams, Federal Highways Administration at http://www.fhwa.dot.gov/Environment/fish1.htm. If good hydraulic design and construction practices are followed, a relocated stream, in time can recover its aesthetics and its aquatic habitat value that supports fish and aquatic life. When stream relocations are necessary, they should be as carefully planned and constructed as the highway itself, using the IPPT approach. This means providing a stable channel of adequate hydraulic capacity, and naturalizing the new channel by restoring aquatic habitat and planting trees and vegetation to regenerate the original bank conditions as rapidly as possible.

If the relocated channel is shortened by relocation, the local gradient will be steepened, which may cause the stream to begin headcutting its bed above the relocation. Any significant change to the natural channel has the potential to start a new cycle of erosion, and it must be considered in the hydraulic design of all stream relocations. Stream relocation design should strive to establish the basic conditions that will favor rapid recovery by natural processes.

Natural streams are rarely straight; even where they have steep gradients; they tend to develop bends. In straight streams having beds composed of several sizes of coarse materials, the riffle-pool sequence commonly occurs at intervals of 5 to 7 stream widths. On the average, pools tend to be longer than riffles; riffle-pool sequences will not develop in streams with sand or silt beds (i.e., West Tennessee). Therefore, consideration for development of riffle/pool sequence streams should only be for the middle and eastern part of the state.

Natural or fabricated obstructions in a stream may cause or reinforce meandering in unwanted places. This possibility must be considered when designing and placing habitat improvement structures. Riprap bank protection may be needed in vulnerable erosional areas to help prevent the extension of meanders.

2.1.8 Fish Habitat

Replacement of habitat should be a focus for all stream relocations. Tree roots, logs, fallen trees, rocks, or dense brush that hang out over the water near the surface all provide valuable resting and hiding areas for fishes. Riffles are important food-producing areas for stream fish.

Designing and constructing a stable channel should be the primary goal for relocated channels. A prime cause of channel instability is shortening the length of the stream. This may start a cycle of erosion that can damage the stream both upstream and downstream from the relocated section. The best treatment for stream relocations is to preserve the original gradient throughout the relocation. This can be done by making the new channel the same length as the old one (including culvert length). Do not attempt to create enough new stream length in a relocated channel to offset the culvert length and the relocated length. This artificially lengthens the channel, thereby reducing the gradient. If the channel must be shortened, the effects of gradient change can be mitigated by building cross vanes or weirs to absorb some of the elevation difference.

2.1.9 Natural Appearance

The new channel of a relocated stream should appear as much like the adjoining undisturbed portions of the stream as possible. The new channel should have sinuosity, and should vary in width and depth. Avoid designing and constructing a channel based on a single cross-section. Many constructed relocated stream channels use a continuous cross-section (most efficient - trapezoidal shape) throughout. This results in high velocity flows with virtually no in-stream aquatic habitat. The stream channel side slopes should vary in steepness to simulate the irregular shapes of nature. Typically, this cannot be accomplished by design and construction efforts alone. In many instances, the best thing that can be done is to excavate a large enough channel, and then let the stream do the rest of the work of naturalization, assisted by whatever habitat measures may be appropriate. A selection of drawings and figures for in-stream habitat and stabilization measures are included in Appendix A.

The sides and top of bank of the new channel should be vegetated immediately upon completion with trees, shrubs, and native grasses to provide stabilization, cover, and eventually shade to the new stream. During construction, no original vegetation outside the relocation footprint should be unnecessarily removed or damaged. Large trees to remain should be selected, marked in plans and flagged before grading. Field changes can be made if it is determined that the relocated channel could be shifted to move around trees. By leaving much of the well-established existing vegetation in place, the stream aesthetics and a large degree of bank stability can be preserved without a long wait for new vegetation to grow.

Rocks and structures placed in new channels to develop habitat should have a natural appearance and blend into the new channel (http://www.fhwa.dot.gov/Environment/fsh_p13.gif.) Riprap slopes should be partially covered with soil to provide a toehold for grasses and plants. If riprap must be used, live stakes should be planted in the joints between the rocks.

2.1.10 Habitat Improvement

A newly excavated channel lacks many of the features for good aquatic habitat. However, in time, the annual floods will form the bed materials into pools and riffles, trees and bushes will grow on the banks, and the habitat will gradually improve. This slow process can be hastened by special measures. Seeding and transplanting trees and bushes can help to restore the bank vegetation, which provides shade and cover for the fish and aquatic life. Placing rocks, gravel, or special structures (Figures 5–12) in the channel will help the stream shape its bed in a manner favorable for fish and aquatic habitat more rapidly. Rocks and log structures placed in streams to develop habitat should have a natural appearance and blend into the new channel.

The ideal habitat improvement would be to establish a stable riffle-pool sequence in the relocated channel. Such a sequence will develop naturally if the stream carries enough coarse sediment (i.e., gravel bed dominated streams). If insufficient sediment is available, this may indicate the stream needs some help. The most commonly used habitat improvement measures are large rocks placed in the stream, current deflectors, and log/rock weirs or vanes. The number, size, and location of these will affect the stability and conveyance capacity of the new channel; therefore, they should be considered concurrently with the hydraulic design.

Figures 5 and 6 present details on the use of coconut fiber rolls (coir) that provide rapid stabilization of stream banks in small streams with velocities up to 12 ft./s. Coconut fiber rolls are a good measure to use on small relocations where rapid stabilization of the toe is necessary. Vegetation (shrubs and plant plugs) can be planted directly into the coir rolls and staked in just behind the rolls. The rooted coir roll locks into the natural streambank becoming one unit providing excellent stabilization and habitat along the streambank.

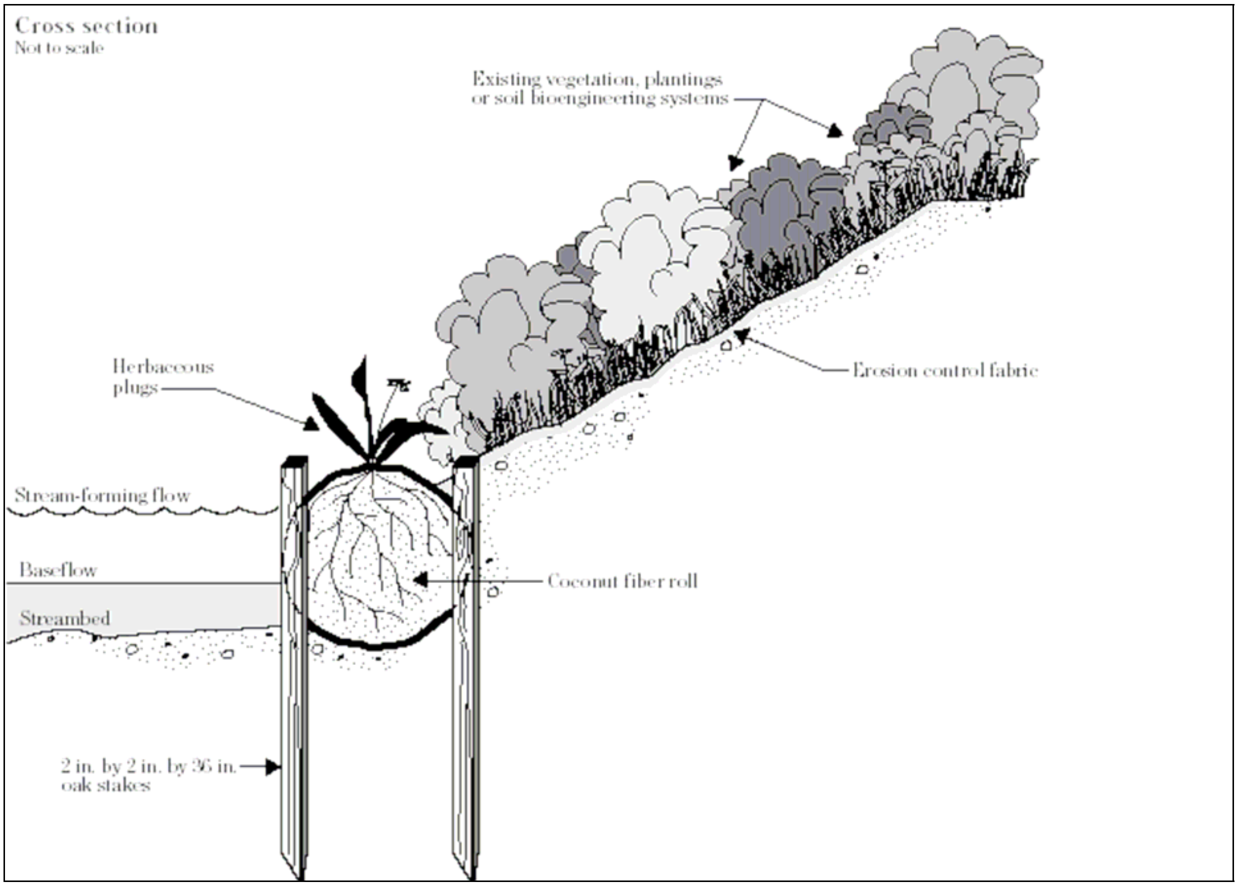


Figure 5: Engineering Field Handbook – Chapter 16 Streambank and Shoreline Protection
(Source: United States Department of Agriculture, December 1996.)

Construction Guidelines for Coconut Fiber (COIR) Rolls

- Excavate a shallow trench at the toe of the slope to a depth slightly below channel grade and place the COIR in the trench.
- Drive 2 in. x 2 in. x 36 in. live willow stakes (or dead stakes if this is not possible) between the binding twine and COIR. Stakes should be placed on both sides of the roll on 2 to 4 ft centers depending upon anticipated velocities with tops of the stakes

not extending above the top of the COIR. Optional anchor method is with the use of duckbill anchors.

- Secure with 16-gauge wire in areas that experience ice or wave action.
- Backfill soil behind the COIR and install an appropriate vegetation or soil bioengineering systems upslope from COIR.
- If conditions permit, rooted herbaceous plants suited for direct streamside planting may be installed in the COIR.

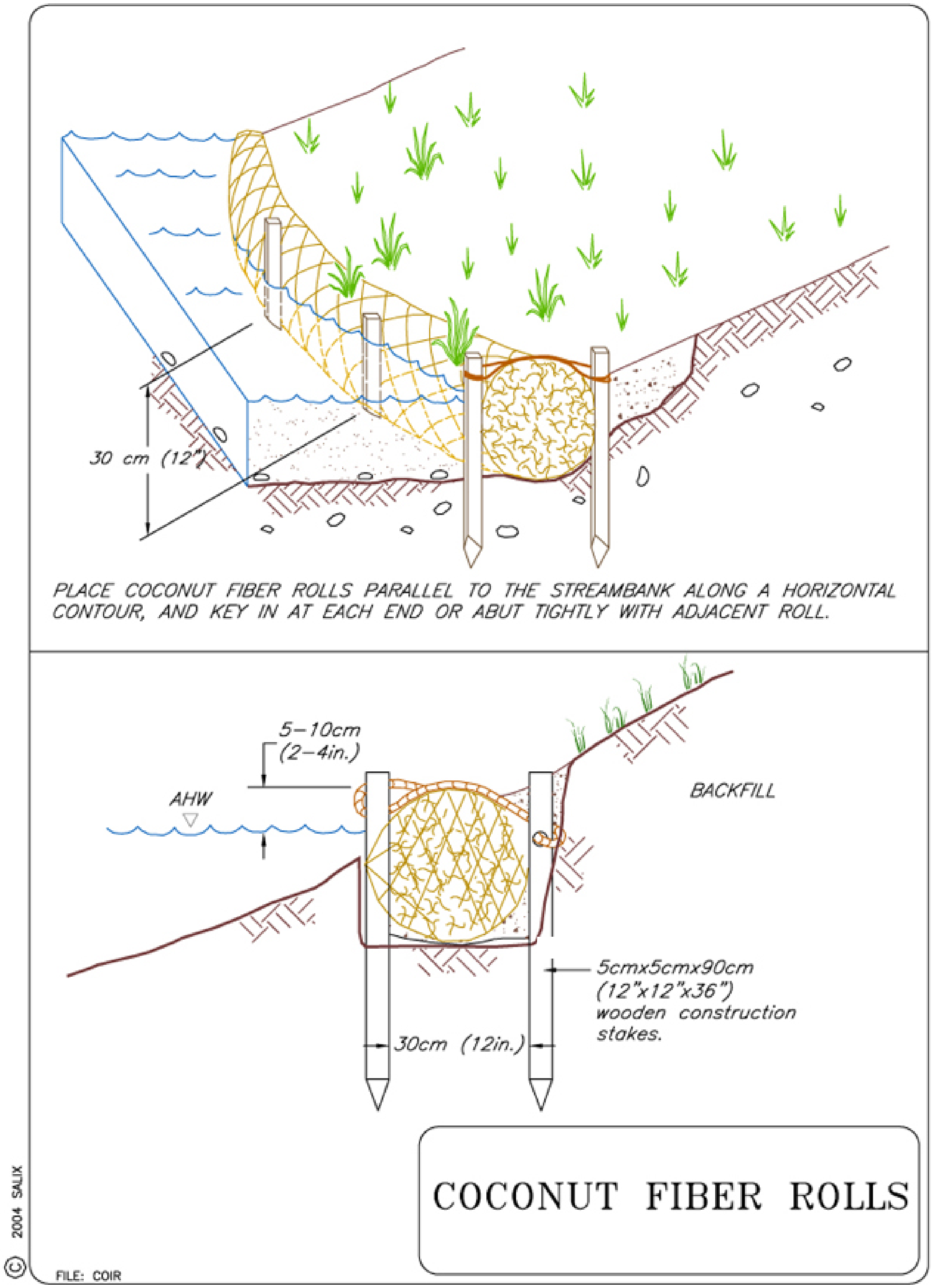


Figure 6: Coconut Fiber Rolls (COIR) Installation Guidelines

Figures 7 – 12 are various rock and log structures that can be applied and used in stream relocations to provide in-stream aquatic habitat.

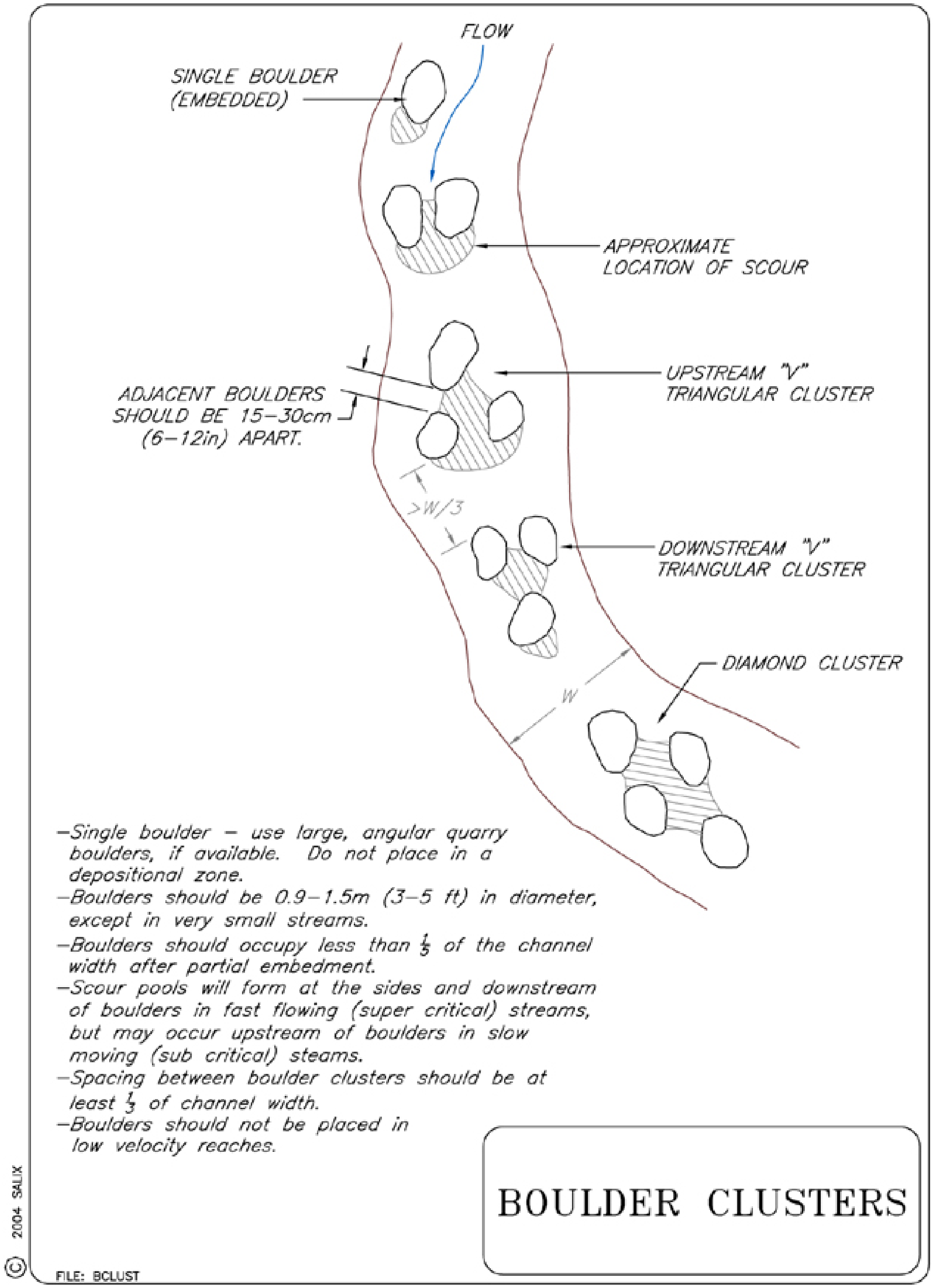


Figure 7: Boulder Clusters

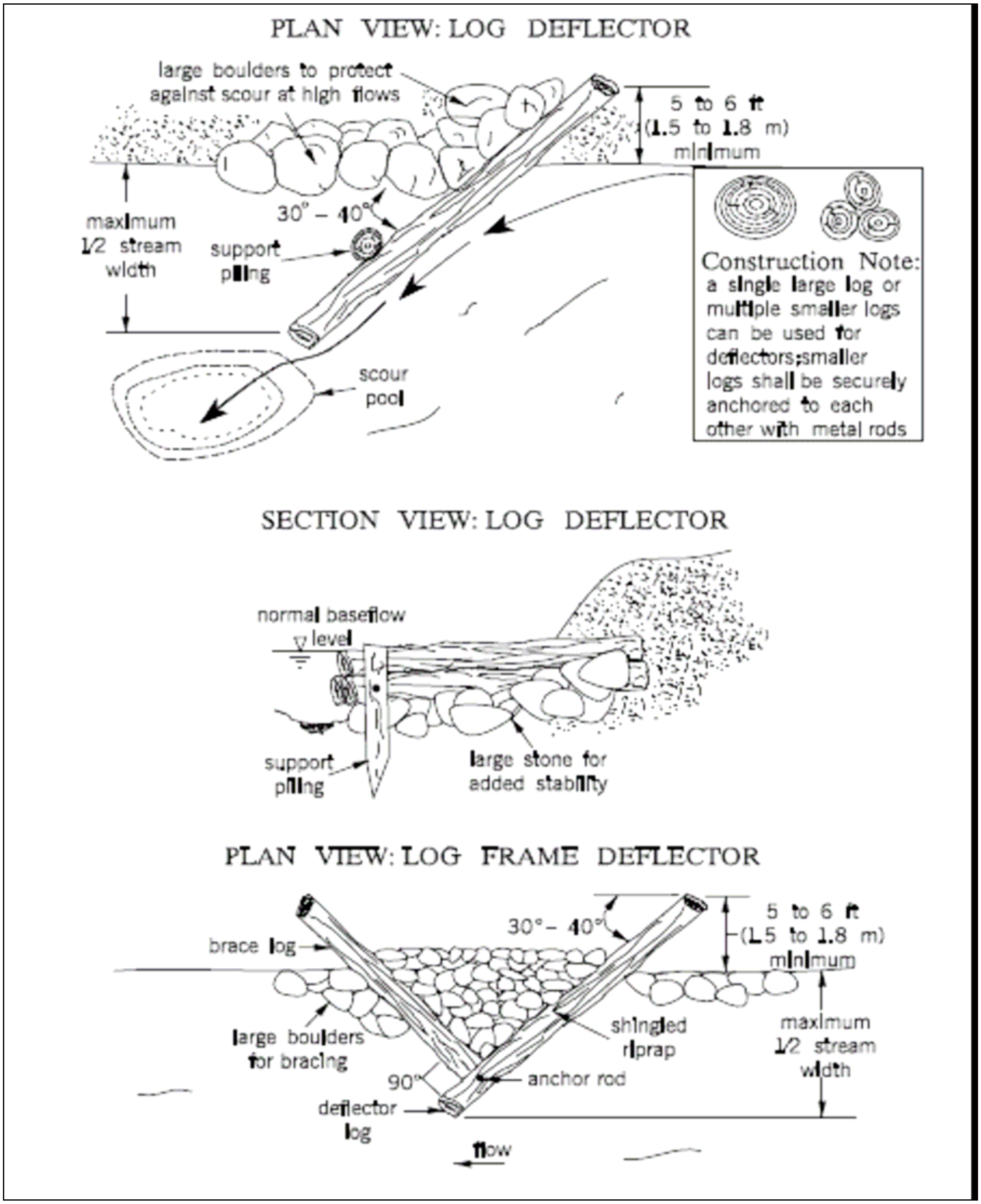


Figure 8: Log Structures and Deflectors

Source: Maryland's Water Construction Guidelines, 1999.)

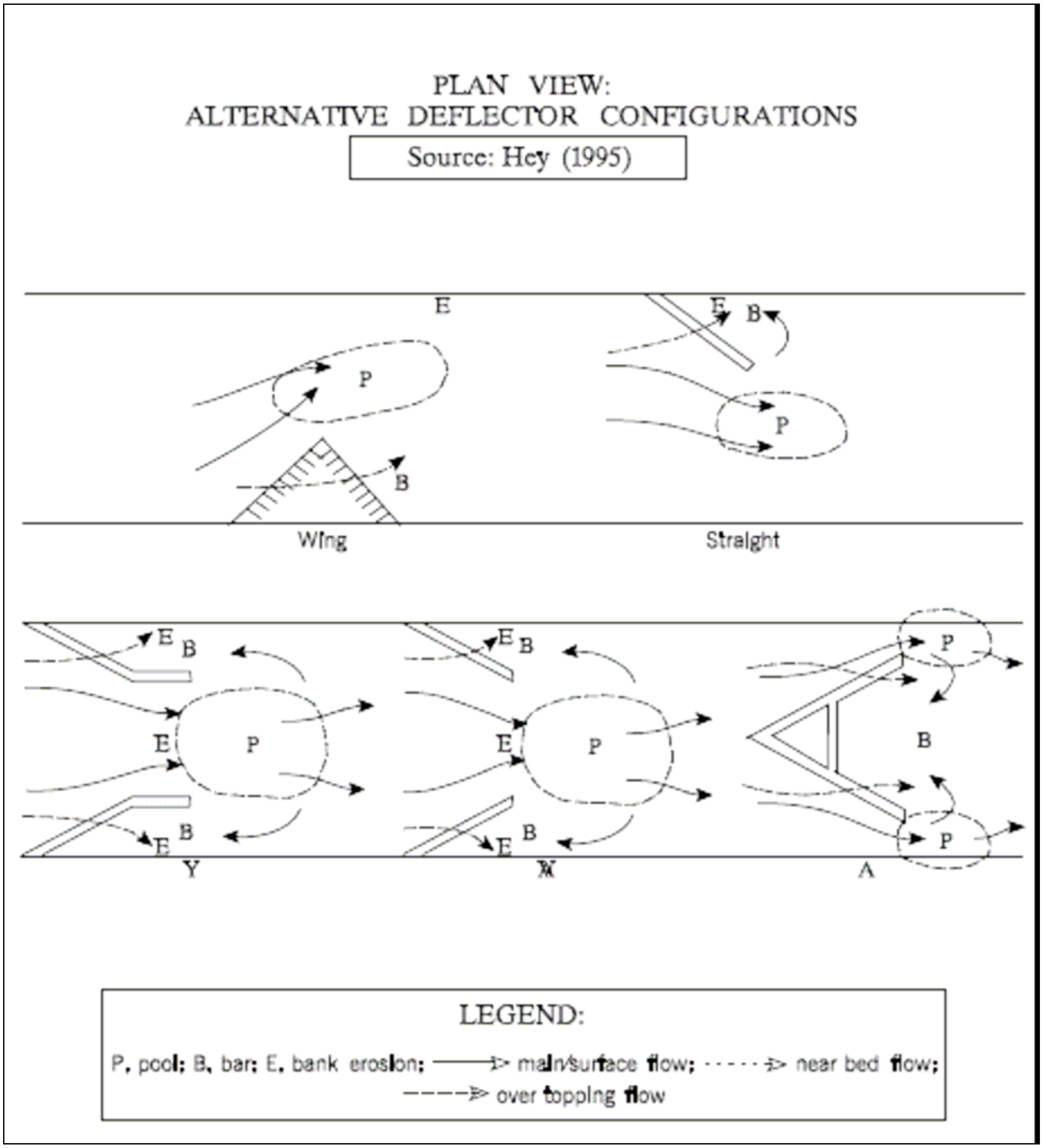


Figure 9: Log Structures and Deflectors

(Source: Maryland's Water Construction Guidelines, 1999.)

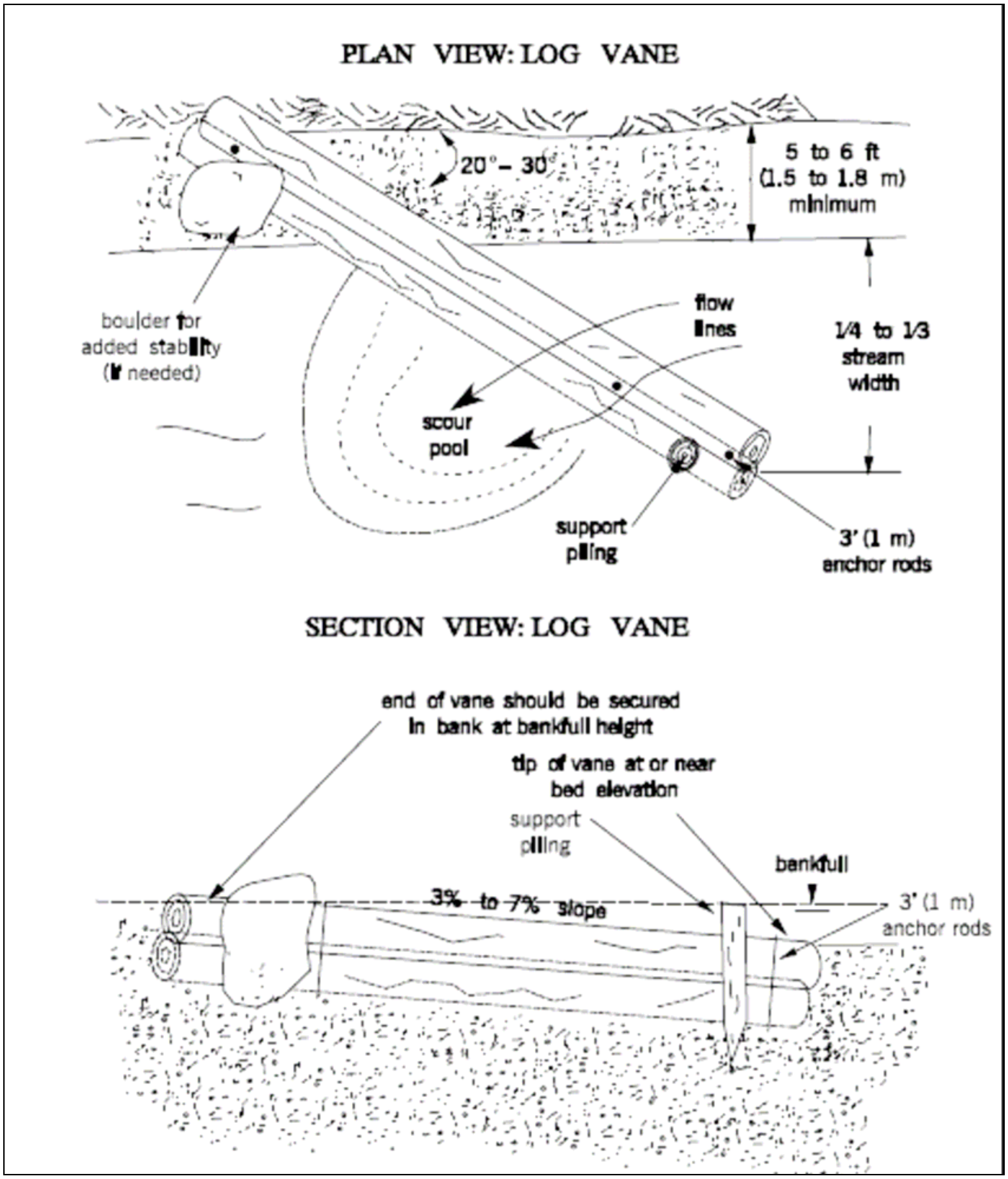


Figure 10: Log Vanes (Source: Maryland Water Construction Guidelines, 1999.)

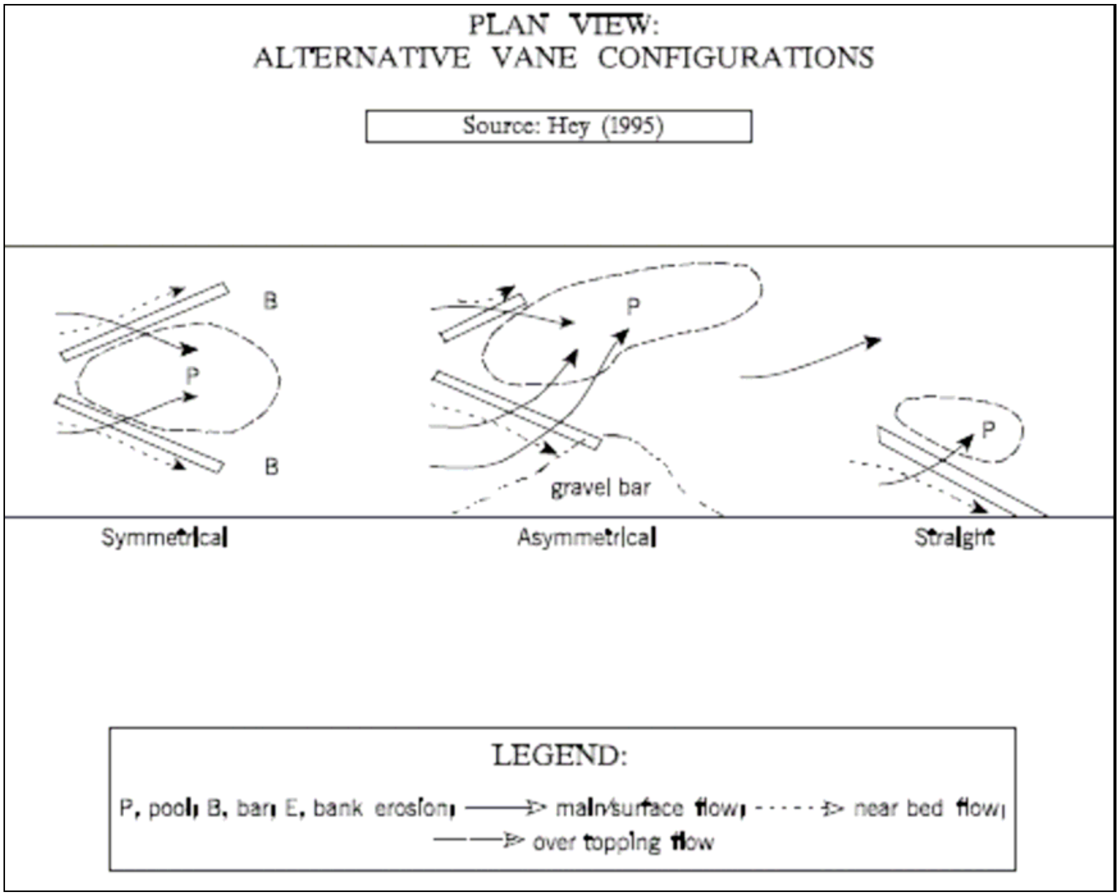
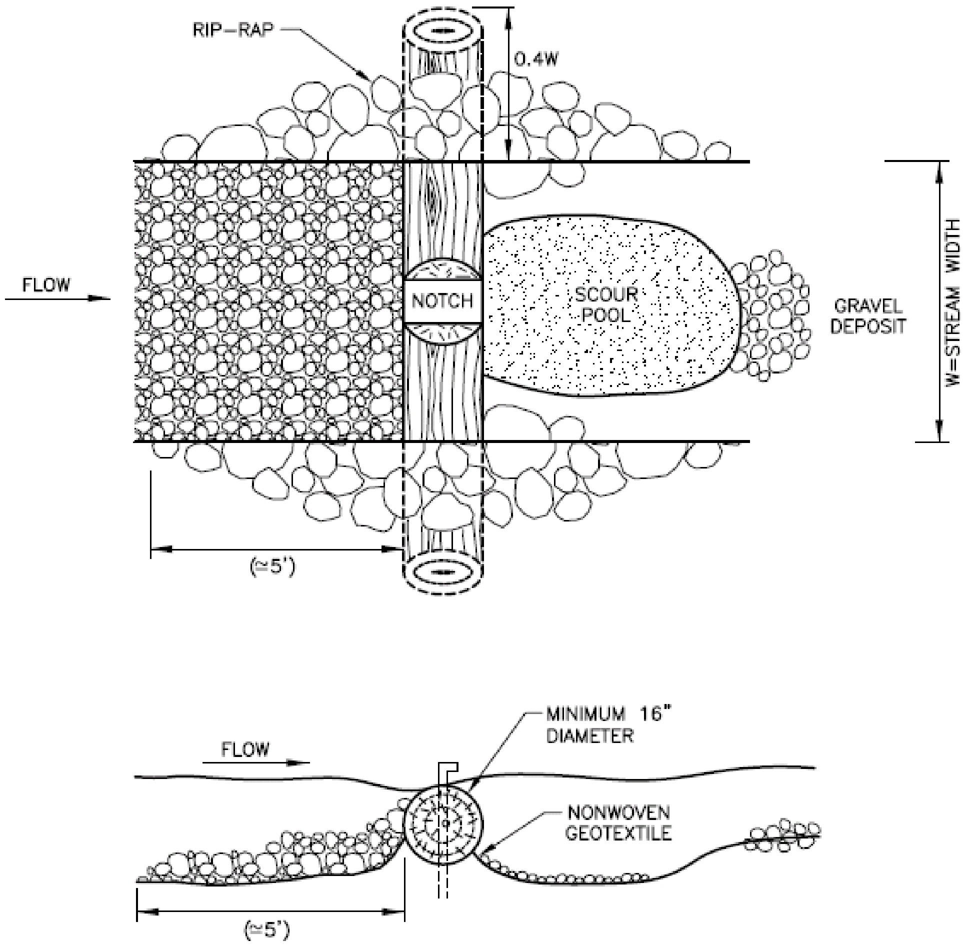


Figure 11: Log Vanes

(Source: Maryland Water Construction Guidelines, 1999)



LOG DROP

1. IF POSSIBLE, SYCAMORE OR OTHER ROT RESISTANT LOG, MINIMUM 16" IN DIAMETER.
2. THE LOGS SHOULD BE ANCHORED AT LEAST 0.4x STREAM WIDTH INTO THE STREAMBANK. IF THE STREAM WIDT IS LESS THAN THAN 2.4m (8ft.), EACH LOG SHOULD BE ANCHORED 1–1.5m (3.3–5ft.) INTO THE BANK.
3. THE END SHOULD BE BACKFILLED WITH ROCK AND PREVIOUSLY EXCAVATED MATERIAL. THE BACKFILL MUST BE ARMORED WITH APPROPRIATELY SIZED ROCK TO PREVENT EROSION.
4. A NOTCH SHOULD BE CUT INTO THE TOP CENTER OF THE LOG TO CONCENTRATE LOW FLOW.
5. LOG DROP STRUCTURES PLACED IN SERIES IN THE SAME STREAM REACH SHOULD BE CONSTRUCTED SUCH THAT THE TOP OF THE DOWNSTREAM LOG IS PLACED AT THE SAME LEVEL OR LOWER THAN THE BOTTOM OF THE UPSTREAM LOG.
6. DROP STRUCTURES ARE TO BE LOCATED IN NON–RIFFLE AREAS WHERE BANK HEIGHT IS AT LEAST 18".

Figure 12: Log Drop Structure

2.2 Planning and Design

A relocated stream channel should be designed to carry about the same discharge as the original natural channel it replaces. Usually, this will be a discharge (Q) in the range of the 2-year (50% chance in any year) flood (Q_2), to the 10-year (10% chance in any year) flood, (Q_{10}). Greater flows than these should be accommodated by overflow on the flood plain. A relocated channel should also approximate the hydraulic gradient of the original stream.

The length and slope of the original stream can be measured in the field, or scaled from the plan sheets, if contours are provided. The average dimensions of the old channel should be determined from field cross sections. With this information, the biologist and designer can sketch a preliminary channel on the plans. Where possible, this channel should have the same average gradient and approximate the curvature of the original stream. However, if constraints exist, such as excessive excavation or the need to preserve valuable land, the designer may have to accept a shorter channel with less curvature.

The IPPT should examine this preliminary channel location on the ground. The inspection group or IPPT should include a stream ecologist or fisheries biologist who can estimate the amount of habitat, cover, and other features that determine the habitat quality of the original stream. The geotechnical engineer can estimate the types of materials that might be encountered in the new channel, and their probable stability against erosion, and identify rock outcrops and other conditions that may affect the cost of channel excavation. The IPPT should consider changes in the channel alignment that would minimize damage to large trees and other vegetation.

The field reconnaissance will indicate where the preliminary channel may be improved. After these changes are made, the new channel should be analyzed for hydraulic capacity, water velocity and high water elevations. The soils in the new channel may also be tested as possible highway embankment materials.

Unlike canals and ditches, natural streams are inefficient carriers of water. Stream channels are undulating, with steep and flat reaches. Widths are variable, and the channels are filled with obstructions that impede flow. A relocated stream should approximate this natural condition. The size of channel required will depend upon the assumed design discharge, (usually Q_2 or Q_{10}), slope, hydraulic roughness and shape (whether wide and shallow or narrow and deep). For design purposes, the hydraulic engineer can divide the proposed channel into reaches of similar gradient. Knowing the proposed gradient, channel shape and roughness, the engineer can compute a water surface profile, and determine the probable water depths and velocities in each reach.

The soil survey should establish the types of materials likely to be encountered in the new channel, especially the range of particle sizes. Knowing the velocities in each reach, the designer can estimate the probable erosion that might take place in these materials. If this erosion seems excessive, the designer may change the shape of the channel, reduce the gradient, or increase roughness to reduce the velocity.

A stream must have adequate depth at low flows to be considered as good habitat. Therefore, wide channels with shallow depths at medium and low stages should be avoided. Over-widening of channels should be avoided to reduce undesirable destruction of bank vegetation.

Hydraulic roughness is an important factor in the hydraulic computations. For a given discharge, an increase in roughness reduces the velocity and increases the depth of flow. In the Manning formula for flow in channels, roughness is represented by an empirical roughness coefficient (n), which may vary from 0.012 for concrete-lined canals to 0.025 or more for unlined earth channels. The roughness coefficient for natural streams may range from 0.03 up to about 0.08, depending on the coarseness of the bed materials, and the vegetation growing in the bed and banks.

Large rocks placed in a new channel to improve habitat conditions increase channel roughness. The total effect depends on the number and size of the rocks, the width of channel in which they are placed, the depth of flow, and the initial roughness of the channel. For example, if $n \geq 0.045$, adding large rocks at the rate of about 1 rock per 300 sq. ft. of the stream bed will not significantly increase the value of n; therefore, the effect of the rocks can be ignored.

Rocks may be used to reduce velocities in steep channels and to create step pools and cascades. If the number used is large enough to be effective, these rocks will materially increase the roughness of an excavated channel. The roughness coefficient for such a channel would be comparable to that of mountain streams with beds of cobbles and large boulders, which commonly range from 0.05 to 0.07, or higher.

In a stable channel, the bottom and sides remain essentially the same from year to year. All new channels undergo some rearrangement of the bed and bank materials, but will gradually and naturally stabilize as the finer materials wash away leaving the coarser materials behind. A reasonable degree of stability can be achieved in vulnerable erosional places such as sharp bends, or where the banks are of new fill of easily eroded materials by supplying some type of natural habitat bank protection.

When suitable rock is available, riprap with live stake willows and dogwoods will provide the most economical bank protection. Protective riprap blankets must be individually designed for the sites they are to protect. The rocks composing the riprap should be large enough that they will not be moved by the design flood. Riprap on the outside banks of bends should be composed of larger rocks than for straight reaches. The riprap should extend up the bank as high as the water surface of the design flood, and the bank above that level should be vegetated. It is good practice to place soil in the crevices of the riprap to encourage the growth of vegetation. This helps to stabilize the riprap and improves its appearance and habitat qualities.

For long-range stability, it is important to establish vegetation on the banks as soon as possible. All exposed earth banks should be top soiled and seeded concurrently with the excavation. In places, it may be desirable to plant willows or other quick-growing native woody vegetation, rather than wait for the bank vegetation to be reestablished naturally.

The preliminary studies for proposed channel relocations will establish the approximate amount of habitat existing in the original stream. An equal amount of habitat should be provided in the new channel. The number, type, and location of habitat structures will affect the stability and conveyance capacity of the new channel, and they should be considered during the original design.

Where cross vanes and weirs are needed to control the gradient, their locations can be determined from the profile and plotted on the plans. Additional vanes and weirs may be used to provide fish habitat. Generally, these should be located where the current at medium stages is generally swift (2 ft/sec to 3 ft/sec); otherwise, the downstream plunge pool may fill with sediment.

The limits of the stream relocation should be shown on the construction plans in sufficient detail for the project engineer to mark the channel for the contractor and measure the excavation involved. The project engineer should have some flexibility to make minor changes in alignment, depth and channel side slopes to take advantage of favorable excavation. The specifications shall require the contractor to save and stockpile logs from the clearing and large rocks from the road and channel excavation for later use as habitat structures. Vegetation suitable for transplanting should also be saved.

2.3 Construction of Relocated Channels with Habitat Structures

New channels for stream locations should be excavated separated from flowing water or expected flow path. Where work must be done in the existing channel, (i.e., when starting a retaining wall or riprap) it should be scheduled during low water periods, and the stream diverted around the work zone (refer to section on temporary diversion for details).

Existing streamside vegetation should be left undisturbed to the extent practicable, and clearing should not unnecessarily destroy vegetation that could be used along the relocated stream channel to establish stabilization of the new stream channel. The project engineer should mark the construction limits for the highway, any necessary channel relocations, and all permissible haul roads. The contractor should confine his operations within these limits. Trees that are to be saved should be clearly marked and protected from damage. A buffer zone equal to drip line from the tree canopy should be established to protect the root zone. Small trees and other usable plant material within construction limits can often be removed in advance of excavation and saved for revegetating the new channel slopes and disturbed areas. Where the toes of embankments are near streams, care should be taken to avoid damage to bank-side vegetation.

The stakeout of a channel should be a flexible process, and the project engineer should have freedom to make minor changes in the field to incorporate natural habitat features such as large trees, rootwads, and natural boulders. For example, where the new channel will be in hard materials such as boulders or large gravel, the side slopes may be staked vertical. Also, where the banks will be of finer materials, flatter slopes may be used for stability. The gradient may be varied slightly from the average gradient for short distances without seriously affecting discharge capacity.

Vanes, weirs, deflectors, log structures, and root wads must be embedded in the bed and banks of the channel. They must therefore be constructed before the stream flow is diverted into the new channel. The designer should estimate a suitable number of large habitat rocks in each reach of the new channel, and leave their placement to the discretion of the field forces. These rocks can most easily be placed before the stream is admitted to the channel, when the channel bed is available as a haul road.

2.3.1 Special Circumstances

On a case-by-case basis, there may be circumstances that require a more in depth approach to stream relocation. Streams such as naturally reproducing trout streams and larger rivers and creeks may require the TDOT ED to use a fluvial geomorphic approach to relocation. This approach will require collection of detailed stream morphology data (e.g., dimension, pattern, longitudinal profile, etc.) from a reference location, a duplication of the reference conditions at the relocation site, and an implementation of a monitoring plan to gauge success of the project. Only trained professionals should perform this procedure. There are many sources, including textbooks, available for detailed procedures on fluvial geomorphology of streams; therefore, this routine mitigation chapter will not cover the step-by-step methods.

2.3.2 Relocation of High Gradient Streams

When high gradient channel relocations are required (i.e., greater than 3%), the design and construction of a "step pools" channel can provide a natural stream habitat and therefore avoid high payment into the TSMP In-Lieu Fee. Step pools generally function as grade control structures and aquatic habitat features by reducing channel gradients and promoting flow diversity. At slopes greater than 6.5%, steeper cascades can be developed that still provide natural habitat for aquatic organisms (See Figures 13, 14, and 15 for representative standard drawings for step pool streams, source: *Maryland's Waterway Construction Guidelines, 1999*).

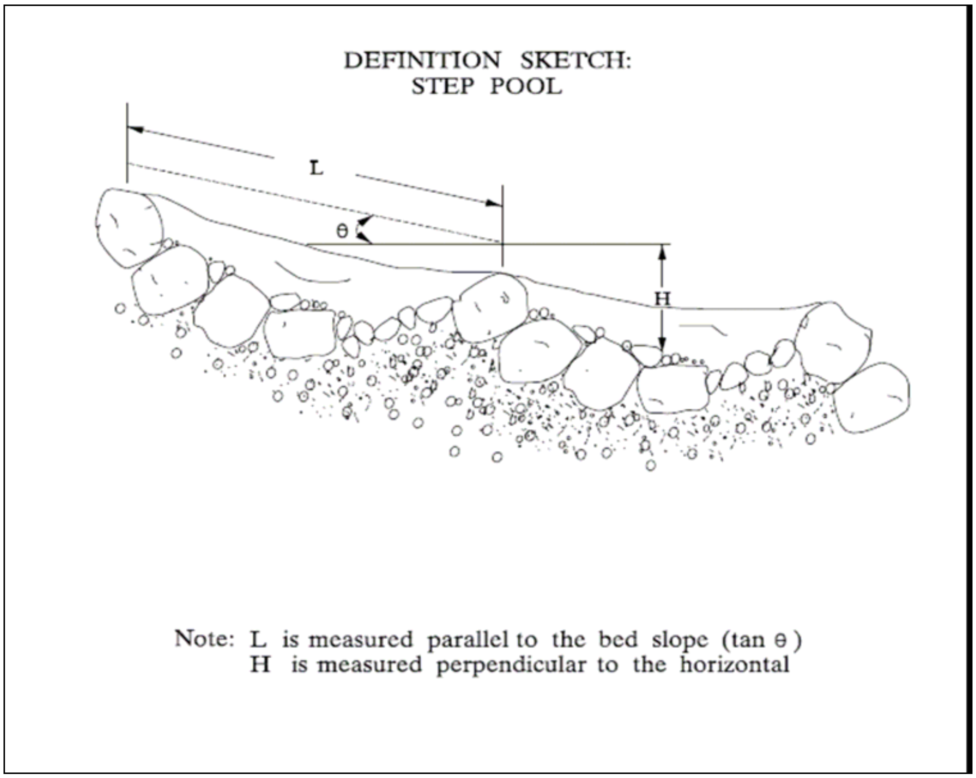


Figure 13: Step Pool

(Source: Maryland Water Construction Guidelines, 1999)

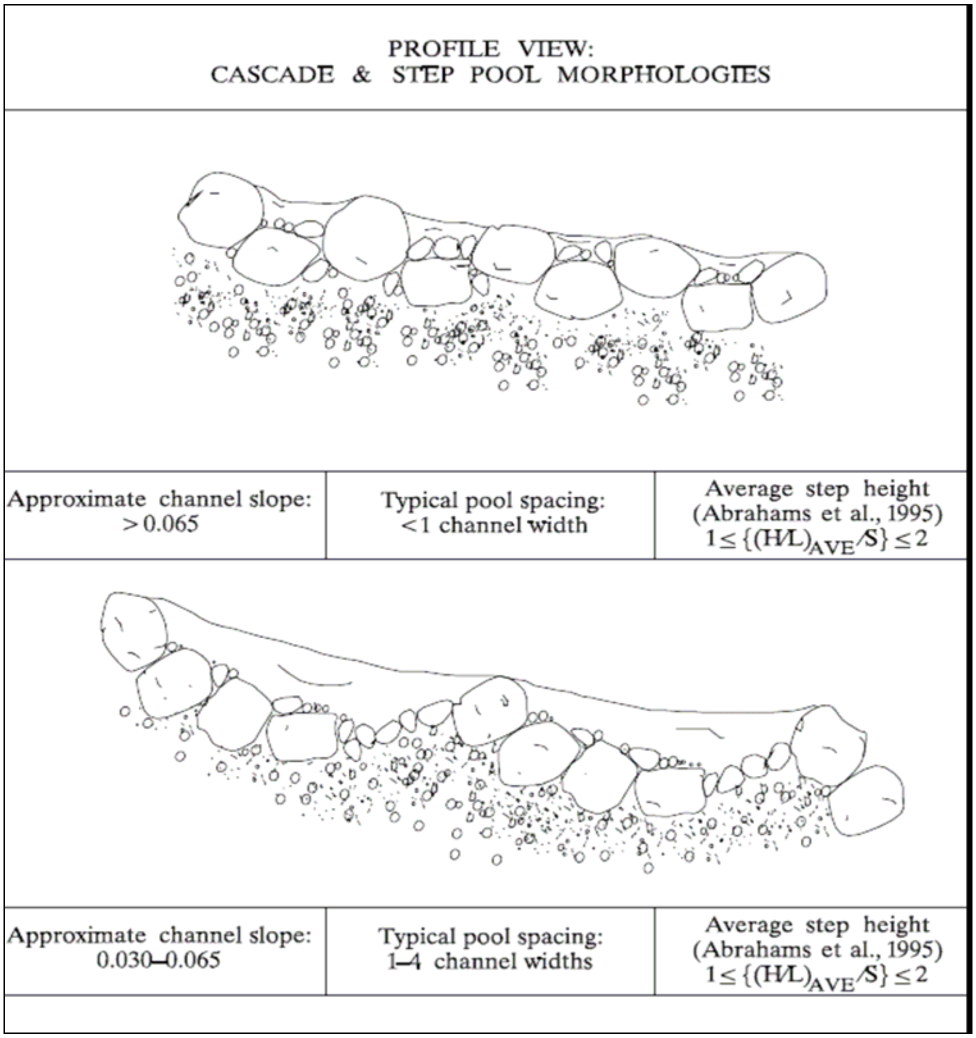


Figure 14: Step Pool Cascade and Morphology

(Source: Maryland Water Construction Guidelines, 1999)

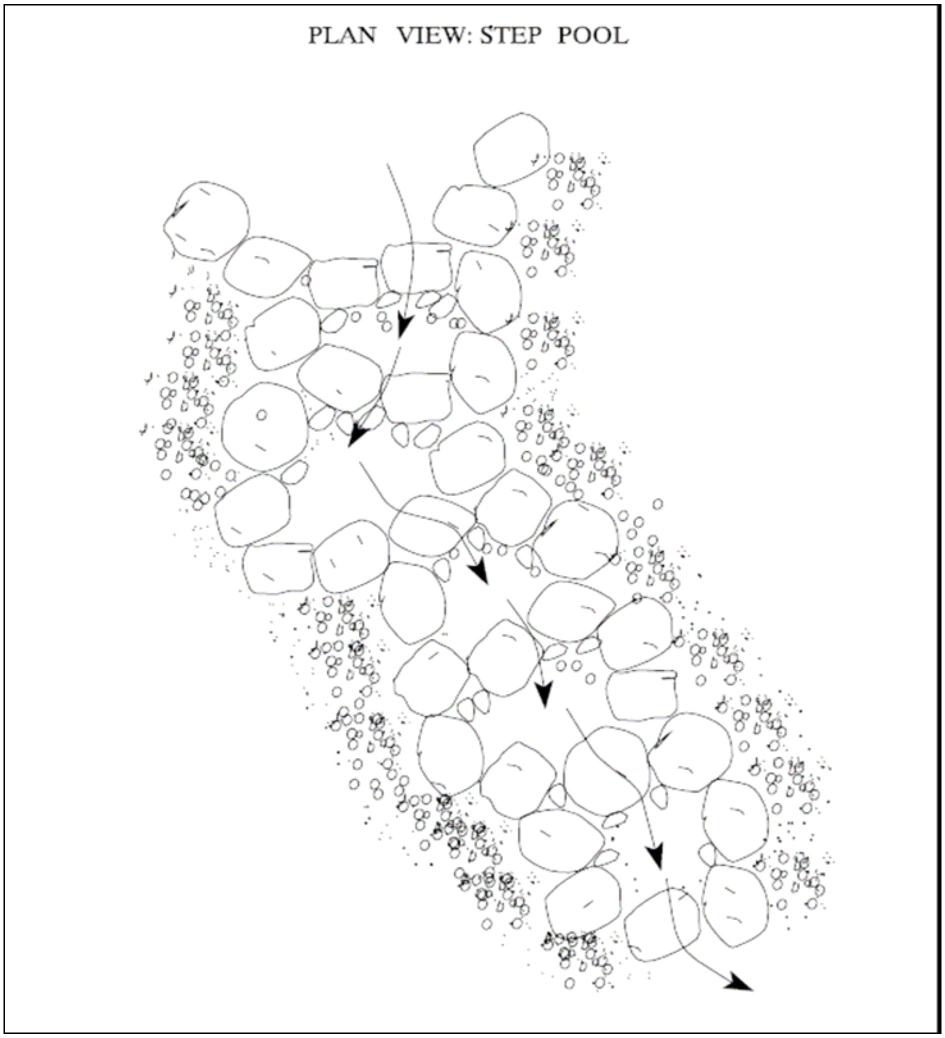


Figure 15: Step Pool Plan View

(Source: Maryland Water Construction Guidelines, 1999)

2.4 Wetland Mitigation Practices

2.4.1 Mitigation for Permanent Wetland Impacts

In accordance with the Federal Guidance on the "*Use of the TEA-21 Preference for Mitigation Banking to fulfill Mitigation Requirements under Section 404 of the Clean Water Act, July 11, 2003*", preference should be given, to the maximum extent practicable, to the use of the mitigation bank. The 1995 Federal Guidance for the Establishment, Use and Operation of Mitigation Banks states, "In general, use of a mitigation bank to compensate for minor aquatic resource impacts (e.g., numerous small impacts associated with linear projects) is preferable to on-site mitigation"; however, opportunities should be evaluated for the potential to conduct compensatory wetland mitigation on-site. Potential wetland mitigation sites along the proposed alignment should be identified early in the project planning process by the IPPT. Wetland mitigation may be in the form of restoration, creation, enhancement, or preservation as outlined in the "*Mitigation Guidelines for the Nashville District Regulatory Program, August 2004*" and the "*Mitigation Guidelines and Monitoring Requirements for the Memphis District Regulatory Program, September 2004*".

For the majority of projects, the use of established wetland mitigation banks should be the preferred method for mitigating permanent impacts to wetlands. If there is a large wetland impact identified along an alignment and potential mitigation sites have been identified, then on-site mitigation must be considered. Site-specific wetland restoration, creation, enhancement, or preservation plans can be developed for specific projects. Barry et al. (1996) presents a method for duplicating the mound and pool topography of forested wetlands. This type of wetland creation provides a diverse microtopography and habitat for wetland mitigation sites. When creating on-site wetland mitigation sites, a diverse array of habitat types should be considered.

2.4.2 Mitigative Measures for Temporary Wetland Impacts

Temporary wetland impacts associated with construction most often involve construction of haul roads and ROW fence, and filling a portion of a larger wetland that extends beyond the project ROW. The following mitigation measures can be applied to reduce temporary impacts to wetlands and reduce impacts to wetlands that extend off site.

- Temporary wetland impacts should be avoided if possible.
- When temporary impacts must occur, remove and stockpile the top 12” of topsoil from the affected area within the ROW prior to construction.
- Upon completion of construction activities, all temporary wetland impact areas are to be restored to pre-construction contours and the stockpiled wetland topsoil spread to restore the area to pre-construction elevation. Wetland tree species are planted on 10’ centers in the affected area.
- Clay berms may be required along the ROW to protect wetlands located adjacent to the ROW or that are part of a wetland filled as part of the project that extends beyond the ROW. These berms protect the wetland from filling, draining, or other impacts.

Figure 16: Standard Notes for Design are typically included with Form J

(Reprinted from TDOT ED's *Scopes of Work for Consultant Ecological Studies*.)

Apply these measures to all applicable temporary wetland impact areas listed in Form J. For temporary wetland impact areas, remove the top six to 12 inches of topsoil and stockpile it until construction is complete. Once construction activities are completed, restore all temporary wetland impact areas to pre-construction conditions. This includes removing haul roads, restoring the site to the original (pre-construction) elevation and spreading stockpiled topsoil back over the wetland site. The area of temporary impacts will then be seeded, covered with straw and planted with tree seedlings to stabilize the site. Seedlings will be planted on 10-foot centers. Place a note on the present and proposed layout sheets to protect wetland areas located beyond the limits of the fill slope and proposed right-of-way. Use the following tree and shrub specifications:

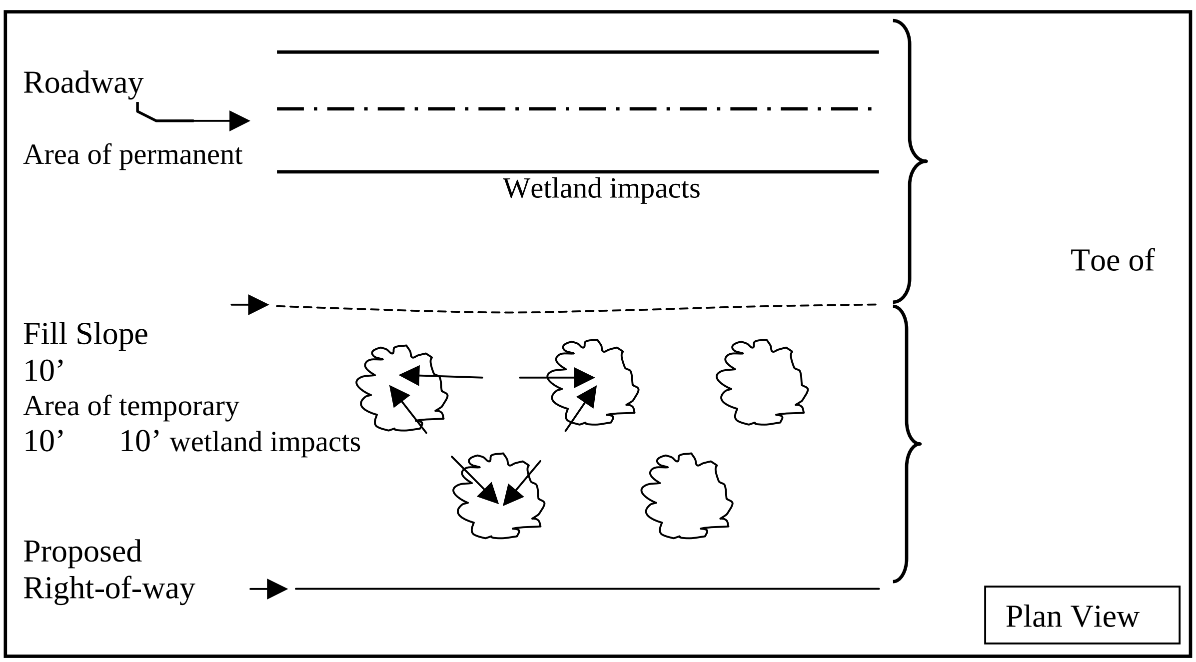
Table 2: Tree and Shrub Specifications

Item #	Description	Quantity	Unit
	Seedling (*Scientific name*) 18”-24" Ht, BR)		Each
	Seedling (*Scientific name*) 18”-24" Ht, BR)		Each
	Seedling (*Scientific name*) 18”-24" Ht, BR)		Each
	Seedling (*Scientific name*) 18”-24" Ht, BR)		Each
	Seedling (*Scientific name*) 18”-24” Ht, BR)		Each

Ht = Height; BR = Bare Root

*(A tree list is not required for emergent, grass, or open water wetlands. If no trees existed in the wetland prior to roadway construction, then no tree list and no replanting are necessary.)

Tree Planting Scheme for Temporary Wetland Impact Areas



Temporary work in wetlands to facilitate construction should be subject to the following requirements:

1. Temporary work in wetlands should be accomplished by using temporary structures, timber, soil with geotextile fabric, or other suitable matting.
2. Soil matting help prevent erosion in accordance with the Specifications.
3. Whenever temporary work is required in wetlands, all temporary structures and/or matting (exclusive of soil matting to be retained in the final roadway section) should be removed in their entirety prior to Final Acceptance of the Project.
4. The Contractor should notify the Project Engineer so a field inspection may be conducted to certify that the temporary materials were properly removed and that the area was properly restored. The Contractor should be responsible for any corrective action required to complete this work.

2.5 Protected Species Mitigation Practices

TDOT currently has access to TDEC Division of Natural Areas (DNA) rare species database. During the early planning stage of all projects, this database should be reviewed and any species within the project area identified. All species present within a four mile radius should be noted and become part of the planning and decision making process of alignment selection. Gray bats (*Myotis grisescens*) and Indiana bats (*Myotis sodalis*) are likewise noted within four miles of the project. Additionally, a letter is sent to the U. S. Fish and Wildlife Service (USFWS) requesting information regarding federally listed threatened and endangered (T&E) species near a proposed project. The USFWS typically responds to TDOT with a letter indicating no known species occur in the project area, or they provide a list of federally protected species that must be addressed in accordance with Section 7 of the Endangered Species Act. The USFWS will also report whether their database indicates the presence of wetlands in the project vicinity. They may also comment on stream crossings or relocations and need for BMPs.

The GIS dataset will include a layer for state and federally listed species and maps documenting the location of the species of concern. This map layer should also become part of the project documentation running with the project from planning to completion of construction.

2.5.1 Federally Listed Species – Informal Consultation

Informal Consultation is a process between the USFWS and the lead agency or representative to determine whether a formal consultation is needed. Also includes discussions or suggestions by USFWS for mitigation measures to negate adverse effects to threatened and endangered species. Typically, TDOT, through the Federal Highway Administration (FHA) will informally consult with USFWS asking whether there are any proposed or listed threatened or endangered species or critical habitat in the project area. If the answer is "yes", then the consulting agency (also know as the "action agency") must do a biological assessment (BA) to assess what impact its action might have on the species or habitat. The contents of the BA are left to the discretion of the action agency, but USFWS regulations suggest the following:

- The results of an on-site inspection of the affected area;
- The views of recognized experts on the species at issue;
- A review of the literature and other information;
- An analysis of the effects of the action on the species and habitat;
- An analysis of alternate actions considered by the action agency.

If the assessment indicates that there will be no impact, and the USFWS agrees, then informal consultation is over and the project can go forward. If the BA indicates that the action is likely to have an effect, then informal consultation is over and "formal consultation" begins. During the informal consultation, the USFWS may suggest project modifications that the action agency could take to avoid the likelihood of adverse impacts.

A Biological Assessment (BA) must be prepared for all species listed in the FWS letter for fulfillment of Section 7 of the Endangered Species Act. The BA provides information to the resource agencies on possible effects to federally listed species and/or designated critical habitat and to the design and construction team to be protective of sensitive species. This document, as well as the USFWS concurrence letter, provides direction, construction sequencing, and notes that will protect the species of concern. Special protection notes are designed to effectively minimize or avoid significant impacts to the protected species.

The BA and concurrence letter should become part of all project documents and run with the project from planning to completion of construction. The species location and any special notes should be placed on the Design plans, including the EPSC plans and notes so measures are in place to be protective of the species of concern. The BA and concurrence letter will also become part of the permit application package submitted to TDEC and the USACE. Likewise, the construction contract language should have specific instructions concerning the presence of protected species.

The BA will become part of the "Environmental Commitments" tracking process. The following special protection notes are designed to effectively minimize or avoid significant impacts to the protected species and can be used in preparation of the BA.

2.5.2 Formal Consultation

The consultation process conducted when a Federal agency determines its action may affect a listed species or its critical habitat, and is used to determine whether the proposed action may jeopardize the continued existence of listed species or adversely modify critical habitat. The formal consultation commences with a federal agency's written request for consultation under Section 7 (a)(2) of the Federal Endangered Species Act (FESA), and concludes with the USFWS issuing a biological opinion under Section 7 (b)(3) of the FESA. A formal consultation is needed if an agency has determined, through a biological assessment or through an informal consultation, that the action will affect either an endangered species or critical habitat. This determination is stated in the USFWS' biological opinion. The BA finding triggers the Biological Opinion by the USFWS.

In this process, the USFWS prepares the biological opinion (BO)—a detailed evaluation of the impacts on the species and critical habitat—based on the BA produced by the action agency. The BO thoroughly explains the current status of the species and describes how the proposed action would affect the species. The USFWS can come to one of three conclusions in its BO:

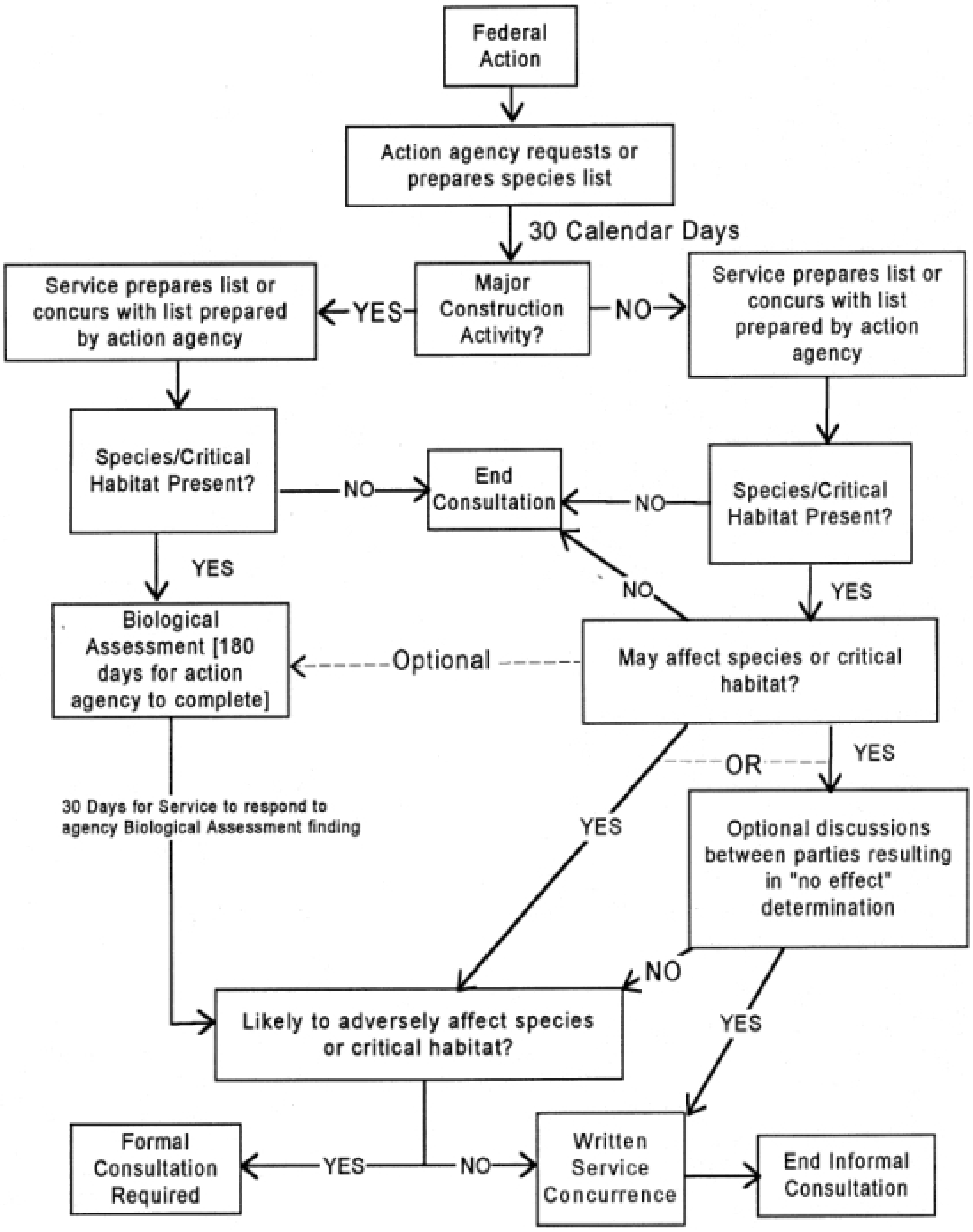
- Jeopardy with reasonable and prudent alternatives;
- Jeopardy without such alternative;
- No jeopardy.

The agency then has to explain how it concluded that the action would, or would not, jeopardize the species that is the subject of the opinion.

If the opinion concludes the action will not adversely affect the species (i.e., a "no jeopardy" opinion), the action can go forward.

If the BO concludes the action could harm the species, the USFWS or NMFS typically proposes a set of mitigation measures ("reasonable and prudent" alternatives) that would allow the activity to proceed.

Reasonable and prudent measures must be incorporated into specifications and contract documents to provide direction, construction sequencing, and notes that will protect the species of concern. The following flow chart explains the steps taken for dealing with E&T species identification stage through informal and formal consultation.



Flowchart courtesy of [the U.S. Fish and Wildlife Service]

2.5.3 State Listed Species

As part of the project evaluation, TDOT biologists review the database maintained by the TDEC Division of Natural Areas' Natural Heritage Program (TDEC-NHP) for the presence of state and/or federally listed species. All species present within a four mile radius. If a state or federally listed species is noted within the project review limits, TDOT biologists coordinate with the appropriate agency—Tennessee Wildlife Resources Agency (TWRA)—for animals and TDEC-NHP for plant species. TDOT biologists provide TWRA with the list of species that were noted during the database review as well as a brief project description; TWRA personnel review this information and provide comments regarding the potential project impacts to the listed species. In situations where TDOT biologists need clarification on whether a project will impact state or federally listed plants, TDOT will also forward a species list and project description to TDEC-NHP. TDEC-NHP may provide comments on potential project impacts if it has further site-specific knowledge available. The TWRA and TDEC-NHP may also provide direction and notes that will protect the listed species.

State listed species documented as occurring within the distance requirements as noted above are also reported and become part of the environmental boundaries studies presented on Form N. Special considerations are given to state listed species on a case by case basis; however a formal biological assessment (BA) similar to the USFWS guidelines is not required for state listed species.

2.5.4. Special Conditions/Protection Guidelines for Various State and Federally Listed Aquatic Species (Fishes and Mussels)

The following notes are intended as a minimum to protect these species and habitat during activities that are in proximity to the known location(s) of aquatic species and should be considered for use in preparing a BA for any given aquatic species. (Please refer to Instruction Bulletin No. 06-14 (or current version) for specific language on EPSC notes).

1. The Contractor should advise project personnel employed to work on this project about the potential presence and appearance of state or federally listed aquatic species and that there are civil and criminal penalties for harming, harassing, or killing the known species which are protected under the Federal Endangered Species Act of 1973, as amended. The Contractor will be provided pictures and habitat information at the preconstruction conference.
2. Haul roads, work pads, and temporary crossings in streams containing state and federally listed species should be avoided, unless previously approved by the USFWS.
3. The designated ED Ecology Section staff member will be given notice two weeks prior to the pre-construction meeting.
4. Prior to beginning any work in the vicinity of the stream, there will be an on-site meeting between the TDOT Project Supervisor, the Contractor, and the ED Biologist. The Contractor will review the procedures and measures taken to reduce impacts to the aquatic listed species. These procedures/measures must then be approved by the ED Ecology Section staff member before in-stream work or work along the stream can begin.

5. The contractor should review applicable Individual and General ARAP (Section 401), Section 404, and TVA permits, including the Coverage under the NPDES CGP and should take measures to comply with each.
6. If any environmental note on the plans conflicts with any other environmental note, or with conditions of a General or Individual ARAP (Section 401), Section 404, or TVA permits, including the Coverage under the NPDES CGP, the more stringent should apply, as determined by the Project Supervisor after consultation with the TDOT ED Ecology Section staff member.
7. An ED Ecology Section staff member should periodically inspect the project. If the ED Ecology Section staff member observes project related activities to have adverse impacts to the state or federally listed aquatic species, the ED Ecology Section staff member should cause these activities to cease and not resume until appropriate corrective measures are implemented.
8. No work will be allowed in the water. No equipment, concrete debris, paving materials, litter, bridge falsework, demolition debris or any other materials should be allowed to fall into or be placed in the waterway.
9. Best management practices will be stringently implemented throughout the construction period to minimize the potential of sediments, oils, or other project related pollutants from entering the waterway. EPSC measures should be in place prior to any earthwork and should be maintained in good condition throughout the project construction. The EPSC measures should be maintained and cleaned on a regular basis.
10. The Contractor should schedule his activities to ensure the installation of permanent EPSC features prior to beginning work.
11. The Contractor will be required to grade an area to completion once the area is disturbed to minimize the time the area is exposed to potential erosion. Disturbed soil, excavation spoil, and stockpiled materials should be mulched daily or covered with approved erosion control mats. Stockpiled materials should be placed to prevent rain runoff from washing the materials into the waterway.
12. Silt fence with backing should be installed at all designated locations as shown on the EPSC Plans.
13. All surface water runoff from undisturbed areas should be diverted to prevent flow across disturbed areas. This may be accomplished through the use of permanent pipes, temporary pipes, or slope drains. The Contractor may propose alternate methods provided prior approval of the Engineer is obtained.
14. In-stream work must be separated from flowing water and conducted in the dry. Any water pumped from construction area must be directed through a settling basin or a filter bag. If sediment is observed in the waterway because of the construction, the work should cease until EPSC measures are repaired.
15. EPSC measures should be closely monitored. When one-half of the capacity of any device has been reached, the device should be immediately cleaned out. As maintenance is performed on silt fences, slope drains, sediment ponds and other

erosion control devices, the materials removed should be placed in such a manner as to minimize the potential entry into the stream.

16. Tree, shrub, and vegetation removal along the waterway should be kept to the absolute minimum to perform the work.
17. All parts of the superstructure to be removed from existing bridges should be cut and lifted during the removal. No material should be allowed to enter the creeks during removal or demolition.
18. Collector/platform barriers approved by the Project Supervisor should be installed beneath the existing bridges during removal of any portions of the bridges to ensure that no debris falls into the stream. These platforms should be maintained through completion of any work that creates the potential for debris or concrete to drop into the stream.
19. Construction equipment should not operate in the streams. Excavation should be conducted from a stable stream bank or road surface, if practical. The use of haul roads into designated critical habitat for federal listed species or waters that contain known state or federally listed species should be addressed in the BA.
20. Staging areas and equipment maintenance areas (particularly for oil changes) should be located at least 200 feet from the stream banks to minimize the potential for wash water, petroleum products, or other contaminants from construction equipment to enter the stream. Additionally, the staging area should not be located along a drainage conveyance that flows directly to the stream.
21. Where applicable, work in the river will be performed from barges. Barges will be launched into the river from an established boat ramp so as not to disturb the riverbanks. Barges will not be allowed to drag or rest on the river bottom.
22. Log/wooden mats will be used on the riverbanks as construction platforms and access beds rather than compacted gravel. The mats will be removed upon completion of the bridge construction. This will minimize the potential of sediment entering the river system and reduce the impact to the riverbed and banks.
23. Where possible, bioengineering of stream banks will be implemented wherever earth disturbance from project construction has occurred. As soon as grading activity allows, geo-tech fabric should be laid down and vegetation planted on stream banks for a width of approximately 25 feet for the full length of the earth disturbance along each bank. Erosion control mats will be placed on slopes greater than 2:1.
24. Riprap should not be placed in streambeds.
25. The Contractor's worksite Erosion Control Supervisor (ECS) should monitor all EPSC measures on a daily basis. When a visible increase in turbidity is observed in the waterway, construction should be stopped until the source can be determined. Immediate corrective measures should be taken before work will be allowed to continue.

26. The Contractor will be expected to immediately modify the EPSC plan to correct any circumstances that may cause or allow pollutants from the worksite to enter the waterway or damage the waterway's habitat.
27. The Contractor should conduct work activities from a stable stream bank or reinforced platform that does not cause degradation or destabilization of the stream banks.
28. The Contractor should not use pesticides, herbicides (including those for ROW maintenance), or fertilizers within 100 feet of the waterway.
29. In the event any incident occurs that causes harm to a listed species or that could be detrimental to the continued existence of that species along the project corridor, the Contractor should report the incident immediately to the Project Engineer who in turn will notify TDOT ED. Construction activity should cease pending Section 7 consultation by the TDOT ED with the USFWS and the lead Federal Agency.
30. All of the notes pertaining to a state or federally listed species should be supplied to all utilities and sub-contractors operating within TDOT project limits. All personnel working within the project limits should be advised of the possible presence of endangered or threatened species and that they should not be harassed, handled, harmed, or subjected to pollutants.
31. The TDOT ED Ecology Section staff member should coordinate any other communication with permit or resource agencies regulating state or federally listed species.
32. Full implementation of the above measures, before, during, and after project construction will minimize the chances of incidental take from this project. However, in the event incidental take occurs, the local USFWS Field Office will be contacted immediately. Upon locating a dead, injured, or sick listed species, initial notification will be made to the USFWS to receive specific instructions regarding the care of an injured specimen or the preservation of a dead specimen. Care will be taken in handling sick or injured specimens to ensure effective treatment and care and in handling dead specimens to preserve biological materials in the best possible state for later analysis. Dead specimens will be collected, properly preserved, and immediately deposited with a detailed incident report (including name of collector, date, time, location, photograph, and probable cause of death) at the local Field Office of the USFWS.

Various other notes and specifications are species specific and will be part of the BA prepared in accordance with Section 7 of the Endangered Species Act of 1973, as amended. These may include, but are not limited to, restricting construction activities to certain times to avoid impacts to breeding, spawning, or seasonal habitat requirements, and collection / relocation efforts to protect less mobile species (e.g., mussels, crayfish).

All costs pertaining to any requirement contained herein should be included in the overall bid submitted unless such requirement is designated as a separate Pay Item in the Proposal.

2.5.5. Special Conditions/Protection Guidelines for Various State and Federally Listed Terrestrial Species (Plants, Bats, and Migratory Birds)

These general protection guidelines are to be used for terrestrial state and federally listed species (e.g., birds, bats, plants). As with the aquatic species, notes that are more detailed may be required for inclusion in the BA. The following conditions are intended as a minimum to protect these species and their habitats during any activities that are in close proximity to the known location(s) of these species.

1. The Contractor should advise all project personnel of the potential presence and appearance of state or federally listed species and that there are civil and criminal penalties for harming, harassing, or killing said species which are protected under the Endangered Species Act of 1973, as amended. Migratory birds are also protected under the Migratory Bird Treaty Act 1918. The BA will be provided to the Contractor at the preconstruction conference.
2. Construction should be done outside the breeding or flowering season.
3. In the event any incident occurs that causes harm or that could be detrimental to the continued existence of the listed species along the project corridor, the Contractor should report the incident immediately to the Project Engineer who in turn will notify TDOT ED staff.
4. The Contractor or Project Engineer should keep a log detailing any sightings or injury to the listed species in or adjacent to the project until such time that Final Acceptance of the project is made. Following project completion, the log and a report summarizing any incidents with and/or sightings of the species of concern should be submitted by the Contractor.

3 Practices for Routine Construction Activities

TDOT performs numerous routine construction activities related to its roadway projects, including the following: culvert staking and installation, test holes for box/slab culvert determinations, ditches and utilities in and around wetlands, haul road installation and removal, and bridge construction and removal. All these activities can adversely impact the environment. General mitigative measures for these activities are usually addressed in the EPSC measures within the Storm Water Pollution Prevention Plan (SWPPP)/EPSC Plan prepared for each project.

Guidelines for most routine construction activities are in the standard specifications and in the catalogues of Standard Drawings and general notes that TDOT maintains. Many of these activities may not have specific step-by-step instructions covered in the general standard specifications but rather have their various components covered in general sections (e.g., clearing and grubbing, excavation, removal of structures).

General EPSC practices currently used by TDOT for their construction projects adequately protect/mitigate environmental impacts when properly installed and maintained. Many of the guidelines previously described in the "Planning" and "General Project Construction Practices/Operations" sections of NCDOT's *Best Management Practices for Construction and Maintenance Activities (2003)* are included in TDOT standard practices. The NCDOT guidelines provide an organized, systematic approach to projects that may impact jurisdictional water. Much of the following information will also be part of *Product 3 – Construction / Maintenance Manual*. The following are sections taken from the NCDOT guidelines that can apply to all the routine construction practices identified in the scope of work.

3.1 Managing the Watercourse

The work area must be separate from the normal flow of a stream or the expected stream path as well as the flow in the stream that occurs during minor rainfall events. When the stream must be diverted on a project, the watercourse should be managed to minimize adverse impacts to the jurisdictional waters.

All projects should minimize the time that the watercourse will be diverted. The following general measures should be employed on all projects as appropriate:

- The stream's normal flow and flow during minor rainfall events should be maintained near normal downstream flow conditions without mixing with untreated water from the work area. This can be accomplished by diverting the stream around or through the work area.
- Where the construction time is anticipated to be less than one day, and where no normal flow occurs in the channel, the watercourse can be managed by keeping equipment and materials from entering the expected flow path within the stream channel and maintaining appropriate EPSC measures. Since these steam channels are intermittent, the timing of construction should be during times of no stream flow.

- Where the construction time is anticipated to be less than one day and little or no base flow occurs in the channel, an impervious dike may be utilized to create an impoundment upstream of the work area.
- The watercourse should be managed to minimize any flooding of the work area.

3.2 Managing the Buffer Areas (Refer to the CGP)

Buffers are legally protected areas along jurisdictional waters such as wetlands, streams, and lakes. Specific areas within the state have specific buffer requirements along streams and floodways (e.g., average of 25 feet to 60 feet, respectively). Buffer zone requirements may also be dictated by water quality (i.e., average of 60-foot buffer or BMPs providing equivalent protection adjacent to impaired and high quality waters from the NPDES CGP).

The following sections provide detailed information on specific construction practices/operations that are performed in or adjacent to jurisdictional waters. Specific construction projects are identified along with the steps to be taken to complete the project in an environmentally responsible manner. It is assumed that the proper permits have been acquired and notifications sent before any work begins in the jurisdictional areas. For each practice/operation, appropriate BMPs are identified and specific conditions highlighted to comply with TDOT, State, and Federal regulations.

3.3 Water Quality Permit and Sensitive Areas Field Boundaries

Violations occur for work or discharges to wetlands, streams, and other environmentally sensitive areas when TDOT fails to acquire regulatory permits. To lessen the risk of an equipment operator unknowingly impacting areas with a valid water quality permit, high visibility safety fence should be placed around all permitted and sensitive areas prior to initiating the clearing and grubbing phase of construction. The identification of these areas with high visibility fencing is a means to minimize the chance for violation. Resource agencies in other states (i.e., Washington, Georgia, and North Carolina) have mandated that this recommendation of fencing be implemented on all projects where wetlands and streams occur.

The intent of the high visibility fencing is to provide positive identification of wetlands, streams, water quality permit boundaries and sensitive areas where equipment is not allowed to work, material may not be placed, except as allowed by regulatory permits, or normal activity is otherwise restricted by permit conditions. Installation of high visibility fence as the first order of work is expected to keep encroachment into sensitive areas to a minimum.

During the design phase, wetlands, streams, and other sensitive areas are identified and located. As the plans are developed, the sensitive areas should be shown on the contract plans along with locations where construction fencing will be installed. High visibility construction fencing will be used as follows:

- Where partial takes of wetlands are anticipated and clearly allowed by the appropriate valid water quality permits, the remainder will be fenced to be avoided.
- Where stream crossings occur and when stream reaches parallel the project alignment.

- Where T&E species protection areas occur.
- Where buffer zone protection is required.
- Other sensitive areas as deemed appropriate by the Project Engineer or ED staff member.

3.4 Temporary Stream Diversions

Refer to TDOT standard drawings EC-STR-31, EC-STR-31A, EC-STR-32, EC-STR-33, and EC-STR-33A for guidance on properly constructing temporary stream diversions. The normal flow of a stream must be diverted and the work area isolated. The watercourse should be managed to minimize adverse impacts to the jurisdictional waters. All projects should be planned to minimize the time that the watercourse will be diverted. Several methods of diverting a watercourse are provided in this section. There may be certain seasonal components to consider when attempting flow diversion of a stream, such as spawning times of individual fish species. Several other methods can be used to temporarily divert stream flows around an active work area. The following sections are modified for TDOT's use from North Carolina DOT's Best Management Practice manual (*Best Management Practices for Construction and Maintenance Activities*, North Carolina Department of Transportation, August 2003.)

3.4.1 Bypass Pumping

A bypass pump and an impervious dike divert the flow of the watercourse from the inlet of the pipe to the outlet of the pipe (Figure 17). This is a water-to-water operation and care should be taken that the discharge is at a low flow rate to minimize turbidity and/or potential erosion of the stream channel at the outlet of the bypass pipe or hose.

3.4.1.1 Conditions where Practice Applies

- When another type of diversion is not physically possible or practical.
- When the construction activities will not require pumping for an extended period.

3.4.1.2 Conditions where Practice Does Not Apply

- When the discharge location cannot be adequately stabilized.
- When ponding of the stream to adequately submerge the pump suction line is not allowed or not practical.
- When the normal flow of the stream cannot be handled by the typical bypass pump.

3.4.1.3 Construction

Step 1 – Set up bypass pump and temporary piping. Place outlet of temporary pipe to minimize erosion at discharge site or provide temporary energy dissipation measures. Firmly anchor pump and piping.

Step 2 – Construct outlet protection if needed.

Step 3 – Construct impervious dike upstream of work area to impound water for bypass pump intake. Use a floating intake for pumps where possible.

Step 4 – Construct an impervious dike downstream, if necessary, to isolate work area.

Step 5 – Check operation of pump and piping system.

Step 6 – Upon completion of construction, remove impervious dike, bypass pump, and temporary pipe and stabilize disturbed area.

3.4.1.4 Maintenance

- Inspect bypass pump and temporary piping daily to ensure proper operation.
- Inspect impervious dike for leaks and repair any damage.
- Inspect discharge point for potential erosion.
- Ensure flow is adequately diverted through pipe

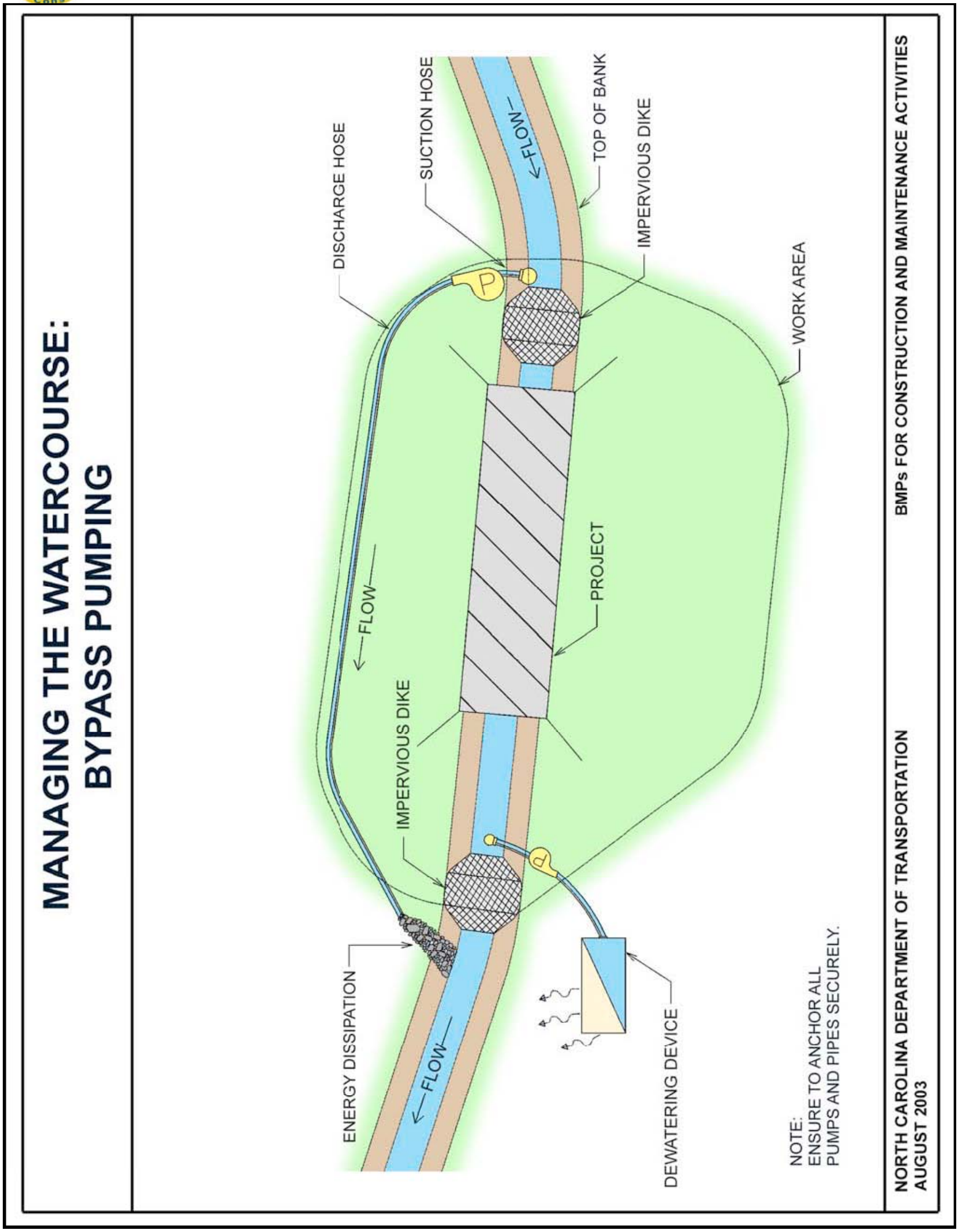


Figure 17: Diagram of Temporary Stream Diversion Using a Bypass Pump

3.4.2 Suspended Bypass Pipe

Refer to TDOT standard drawing EC-STR-33 and EC-STR-33A for specific methods on constructing a suspended bypass pipe diversion. The suspended bypass pipe is used where an existing pipe or culvert is extended. This bypass pipe is constructed inside the existing pipe or culvert to divert the watercourse through the work area while allowing the work area to remain dry (Figure 18).

3.4.2.1 Conditions where Practice Applies

- When a pipe or culvert is being extended and is large enough to accommodate the bypass pipe.
- When space limitations do not allow for a fabric lined diversion channel (for example, widening grade and drain projects)

3.4.2.2 Conditions where Practice Does Not Apply

- When the upstream ponding required to enter the suspended pipe inlet is unacceptable.

3.4.2.3 Construction

Step 1 – Install sediment controls.

Step 2 – Install temporary pipe through the existing pipe or culvert to be extended. Place outlet of temporary pipe to minimize erosion at discharge site or provide temporary energy dissipation measures.

Step 3 – Construct an impervious dike upstream of the work area to divert flow through the temporary pipe. Anchor and seal temporary pipe securely at inlet.

Step 4 – Construct an impervious dike at the downstream side of the bypass pipe to isolate work area.

Step 5 – Upon completion of the culvert or pipe extension, remove the impervious dike and temporary pipe and stabilize disturbed area.

3.4.2.4 Maintenance

- Inspect the inlet regularly and impervious dike for damage and/or leakage and to ensure flow is adequately diverted through pipe.
- Remove sediment and trash that accumulate behind the dike and at the inlet on a regular basis.
- Inspect the outlet regularly for potential erosion and to ensure flow is adequately diverted through the system.
- Ensure that the inlet is properly anchored and sealed.

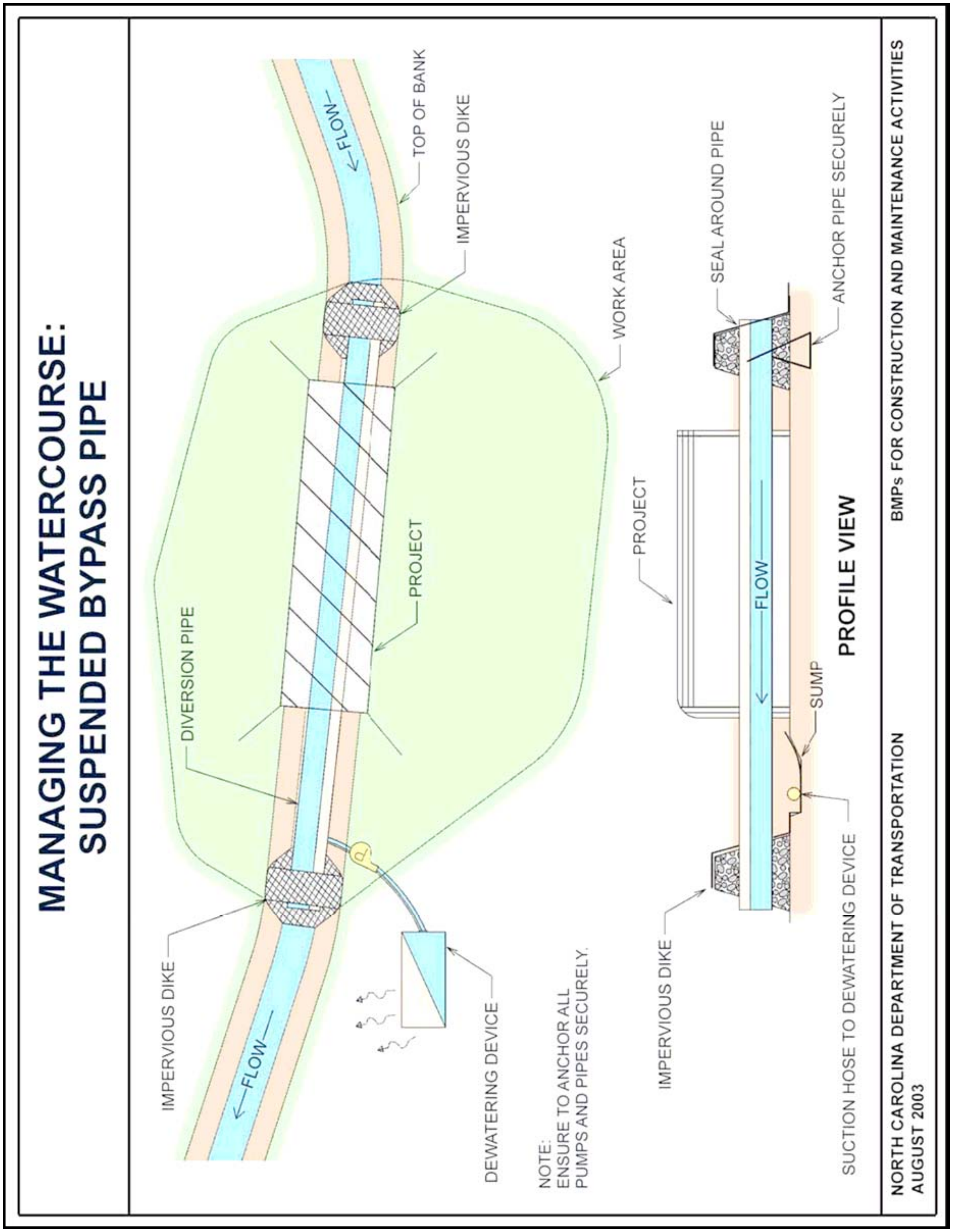


Figure 18: Diagram of Temporary Stream Diversion Using a Suspended Bypass Pump

3.4.3 Piped Diversion

Refer to TDOT standard drawing EC-STR-32 for the specific procedure on constructing a piped diversion. Install a temporary pipe to divert the flow of the watercourse around the work area without the use of pumping operations (Figure 19). While the cost is higher for this operation than an open fabric lined channel, the probability of offsite sediment loss is much lower than with an open diversion channel.

3.4.3.1 Conditions Where Practice Applies

- Where adequate slope and space exist between the upstream and downstream ends of the diversion.

3.4.3.2 Conditions where Practice Does Not Apply

- Pipe extensions, headwall installations and some pipe/culvert replacements where adequate space is unavailable.
- When the pipe would adversely impact the aquatic habitat.

3.4.3.3 Construction

Step 1 – Install sediment controls.

Step 2 – Install temporary pipe adjacent to work area. Excavation may be required to provide a positive drainage slope from the upstream to downstream side.

Step 3 – Connect the downstream temporary pipe into the downstream existing channel. Place outlet of pipe to minimize erosion at the discharge site or provide temporary energy dissipation measures.

Step 4 – Connect the upstream temporary pipe into the upstream existing channel.

Step 5 – Construct an impervious dike at the upstream side of the existing channel to divert the existing channel into the temporary pipe.

Step 6 – Construct an impervious dike at the downstream side of the bypass pipe to isolate work area.

Step 7 – Upon completion of construction, remove the impervious dike and temporary pipe and stabilize the disturbed area**.**

3.4.3.4 Maintenance

- Inspect diversion berm and piping for damage.
- Remove accumulated sediment and debris from berm and inlet.
- Inspect outlet for potential erosion.
- Inspect for diverted flow that bypasses the temporary pipe and causes erosion as surface flow.

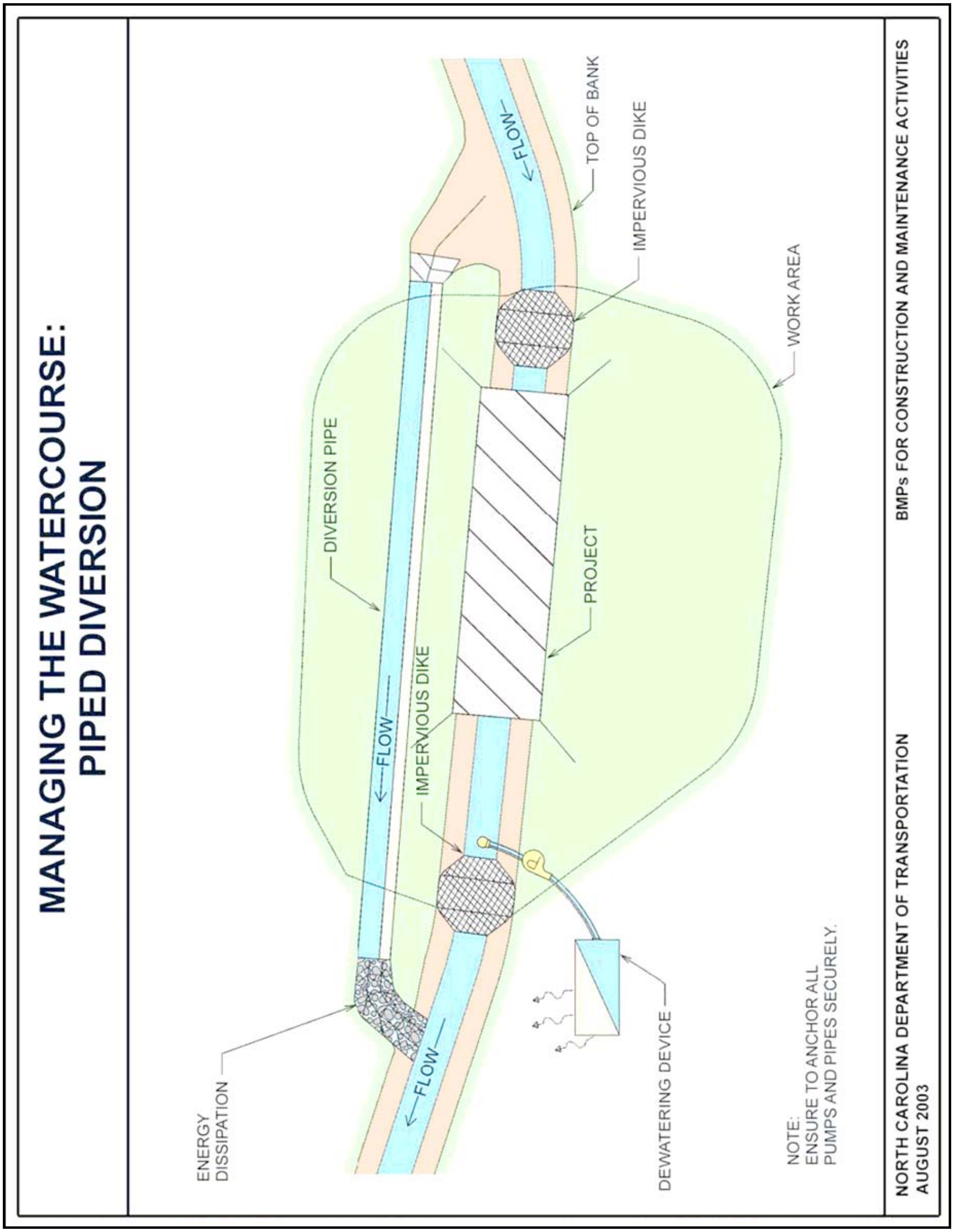


Figure 19: Diagram of Temporary Stream Diversion via Piped Diversion

3.4.4 Fabric Lined Diversion Channel

Refer to TDOT standard drawing EC-STR-31 and EC-STR-31A for specific procedure on constructing a lined diversion. A fabric lined temporary diversion channel is used to divert normal stream flow and small storm events around the work area without the use of pumping operations (Figure 20). The temporary diversion channel is typically constructed adjacent to the work area and is lined with a poly-fabric to minimize the potential for erosion within the temporary diversion channel. The TDOT temporary diversion channel standard drawing is referenced as EC-STR-31.

3.4.4.1 Conditions Where Practice Applies

- When adequate space and slopes exist adjacent to the work area.

3.4.4.2 Conditions where Practice Does Not Apply

- Pipe extensions, headwall installations and some pipe/culvert replacements where adequate space is unavailable.

3.4.4.3 Construction

Step 1 – Install sediment controls.

Step 2 – Excavate the diversion channel without disturbing the existing channel.

Step 3 –Place poly-fabric liner in diversion channel with a minimum of 4 feet of material overlapping the channel banks. Secure the overlapped material using at least 1 foot of fill material.

Step 4 – Connect the downstream diversion channel into the downstream existing channel and secure the poly-fabric liner at the connection.

Step 5 – Connect the upstream diversion channel into the upstream existing channel and secure the poly fabric liner at the connection.

Step 6 – Construct an impervious dike in the existing channel at the upstream side to divert the flow into the diversion channel.

Step 7 – Construct an impervious dike in the existing channel at the downstream side to isolate the work area.

Step 8 – Upon completion of the culvert construction, remove the impervious dikes and divert the channel back into the culvert.

Step 9 – Remove the poly-fabric liner and fill in the diversion channel.

Step 10 – Establish vegetation on fill section and all other bare areas.

3.4.4.4 Maintenance

- Check the poly-fabric liner for stability during normal flow.
- Check the liner for stability after each rainfall event.
- Do not allow earthen material to contact the water body.

There may be certain times of the year, especially in the summer, when fabric-lined diversion channels may cause thermal pollution.

The impervious dikes used to divert normal stream flow or expected flow path around a construction site must be constructed of non-erodible material. Acceptable materials for impervious dikes include, but are not limited to, sheet piles, sandbags, and/or the placement of an acceptable size stone lined with polypropylene, or other impervious fabric. Prefabricated dams are also an option. Earthen material should not be used to construct an impervious dike when it is in direct contact with the stream. Dewatering devices include stilling basins and sediment filter bags.

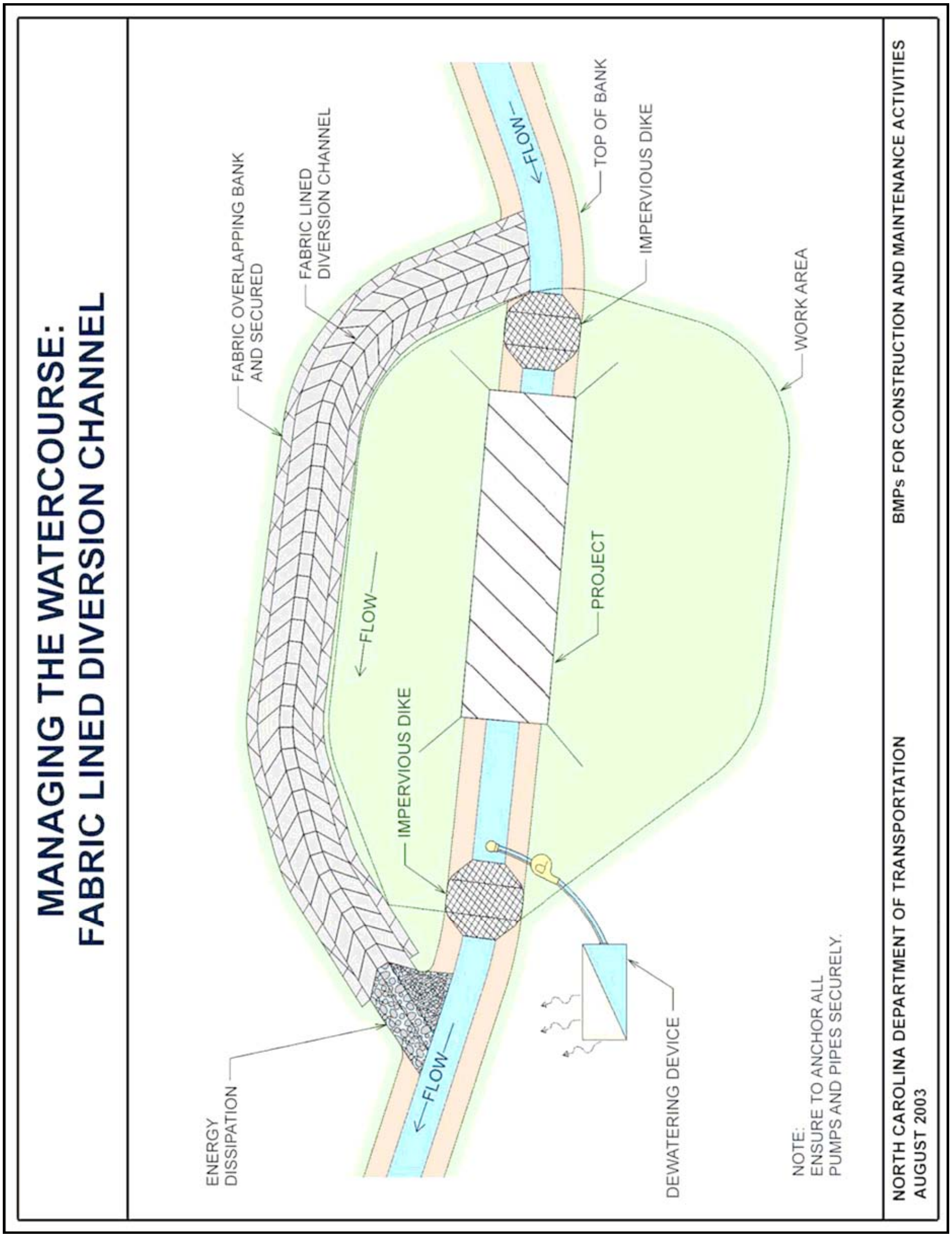


Figure 20: Diagram of Temporary Stream Diversion Using a Fabric Lined Diversion Channel

3.5 Culvert Staking and Installation for Streams

Culvert staking and installation is the act of locating and marking (staking) the exact location of a proposed culvert, and the subsequent installation of that structure. The TDOT Structures Division has catalogues of standard box culvert designs with construction notes (e.g., box culvert standard drawings STD-15-1 through STD 15-150). Culvert staking grades and invert elevations should be checked against the permit sketches for consistency. If the culvert staking reveals improper culvert grade elevations, modifications should be made to ensure that the stream transitions smoothly from upstream to downstream of the culvert. Contact the TDOT ED with field changes as necessary, and when changes are necessary to comply with permit requirements.

For adequate reproduction and fish passage, it is essential that there be no barriers to migration. The man-made barriers that should be considered when designing and constructing linear transportation projects include long culverts with high velocities or short culverts with wide floors, which spread the water thinly. A vertical drop at the end of a culvert will also hinder fish passage.

Culverts should be designed to allow passage of aquatic organisms. Generally, this means that the culvert or pipe invert is buried at least one foot below the natural streambed. This procedure should not be performed on bedrock-dominated streams. Where bedrock streams are encountered, three-sided boxes (bottomless culverts) keyed into the bedrock should be the preferred method of culverting a stream. TDOT will evaluate on a case-by-case basis when bottomless culverts are appropriate. If multiple boxes are required, the second and/or third boxes should be constructed such that they carry only high flow events. These high flow boxes will remain dry during normal flows and will provide the added benefit of wildlife passage. This will also allow sufficient water depth in the primary box or pipe during normal flows to accommodate movement of aquatic organisms. If culverts are long and sufficient slope exists, baffle systems are recommended to trap gravel and provide resting areas for fish and other aquatic organisms. In addition, culverts or pipes should be designed so no channel realignment or widening is required. Widening of the stream channel at the inlet or outlet of structures is not allowed by the regulatory agencies and creates a decrease in water velocity causing sediment deposition that will require future maintenance. Typically there is a need to widen the inlet and outlet for wingwall construction, therefore, a floodplain shelf approximately 1.0 ft. higher than the base low flow stream channel should be established and stabilized with native shrubs and grasses. Finally, riprap should not be placed on the streambed unless it is required for energy dissipation at the culvert outlet or specifically approved in the permits.

3.5.1 Pipe/Culvert Extensions

This section describes the steps to take when performing a pipe or box culvert extension on an existing jurisdictional stream.

1. Prior to installing EPSC, identify permit boundaries/conditions and impact area limits.
2. Install all BMPs required by EPSC plans and SWPPP to treat runoff from the work area or isolate the work area from the jurisdictional areas.

3. Install Temporary Rock Silt Screen (EC-STR-11) or Temporary Rock Sediment Dam (EC-STR-12) in ditch lines to contain sediment prior to discharge into the watercourse.
4. Stream flow diversion is typically used to isolate the work area
5. Use a temporary stream crossing when the stream must be crossed in an area that will not be permanently replaced by the pipe extension. Temporary spans or bridges are preferable to filling and stream and placing temporary culverts, if practical.
6. Dewatering devices such as temporary sediment filter bags (EC-STR-2), stilling basins (dewatering structure, sediment trap, and sediment basin), or temporary rock sediment dam, should be used to manage water from the work area prior to discharge.
7. Install the pipe/culvert per the TDOT standards and specifications.
    - Foundation material should be confined to the pipe extension area and should not be placed in the existing stream channel outside the pipe extension area.
    - Excavation of stream channel should not exceed 10 feet on either end of the new pipe/culvert.
    - No live or fresh concrete should contact jurisdictional waters until the concrete has cured.
8. Install riprap shoulder slope and/or outlet protection on upstream and downstream channels where indicated on permit sketches and plans.
    - Riprap should consist of clean rock or masonry material free of debris or pollutants.
    - If the streambed is subject to high velocity at the outlet of the culvert, engineered outlet protection measures, such as energy dissipaters should be installed. Outlet protection measures should be countersunk approximately one foot below the average streambed elevation.
    - Placement of riprap within jurisdictional waters should be the minimum necessary to protect or ensure the safety of the slopes and must be embedded below the grade of the stream.
    - A low flow channel should be constructed through riprap placement in streambeds Minimal riprap should be used to line stream channel and should not impede aquatic organism passage.

9. Remove flow diversion and allow the stream to flow through the new pipe/culvert extension.
    - The impervious dike used to temporarily divert the stream flow should be completely removed from the existing stream and the affected areas restored to the pre-project conditions.

10. Begin backfill operations. Intermediate EPSC measures should be installed prior to the backfill operation to provide containment between the work area and the watercourse.
11. Upon completion of backfill operations, prepare slopes and other disturbed areas and stabilize.
12. Maintain EPSC measures until groundcover or vegetation is well established.
13. Upon establishment of vegetation, remove any remaining EPSC measures and stabilize disturbed areas.
14. Within jurisdictional waters and wetlands, all temporarily disturbed areas should be restored to the pre-project conditions and planted with appropriate plant species as specified in the temporary wetland impacts Section 2.4.2.

3.5.2 New Pipe/Culvert Installations

In addition to the general mitigation recommendations previously discussed, the following specific recommendations for culvert installation are provided:

1. On larger streams, flow diversion may be used to isolate the work area using bypass pumping, piped diversion or fabric-lined channel. On smaller streams, or at low flow conditions, an impervious dike may be used to temporarily dewater the work area within the stream channel.
2. All temporary in-stream structures must be installed with geotextile fabric beneath them, and removed in their entirety immediately upon completion of in-stream work.
3. Temporary stream crossings may be used to provide equipment access, if underlain by geotextile fabric, so riprap may be entirely removed. Construct Temporary Stream crossing according to TDOT standard specifications. Regulatory agencies should be notified of locations before placement occurs.
4. Dewatering devices are typically needed to keep the work area dry. Every effort should be made to minimize the extent of the area to be dewatered and the length of time the site is dewatered.
5. The pipe/culvert slope should match the streambed slope.
6. Install the pipe/culvert per the TDOT standards and specifications and any specified permit conditions. Note that pipes and culverts should be buried a minimum depth below the existing streambed to allow for aquatic organism passage during low flow conditions (exception to this rule is for bedrock streams).
    - Foundation material should be confined to the pipe/culvert area and should not be placed in the existing stream channel outside of the valid permit impact area.
    - Excavation of the stream channel should not exceed 50 feet on either end of the new pipe or culvert unless the stream is being relocated.

- Culverts 48-inches in diameter or greater, including box culverts, should be buried one foot below the streambed elevation, or as specified on the EPSC plans.
- Pipes/culverts less than 48-inches should be buried a depth equal to 20% of the pipe/culvert diameter or as specified on the plans.
- Examples of culvert embedded depth are as for streams are follows:

Diameter		Embedded Depth
36"	=	*7"*
30"	=	*6"*
24"	=	*5"*
18"	=	*4"*

- Hydraulic capacity loss due to the embedment should be accounted for during design.

7. Stream pattern, dimension and profile should be maintained by pipe/culvert installation.
    - A 4-foot diameter pipe/culvert installed in a stream with a small width (e.g., <5') may require baffles to maintain Aquatic Organism Passage (AOP) during low flow conditions.
    - Multiple pipes installed at one location in a stream would require that one pipe be installed at a lower elevation, and in alignment with the low flow stream channel elevation, so AOP is maintained during low flow conditions. An optional method is to place a sill at the inlet to one of the culverts to allow low flow through one side of the culvert.
    - No "live" or fresh concrete should contact jurisdictional waters until the concrete has cured.
8. Install riprap shoulder slope and/or outlet protection on upstream and downstream channels where indicated on permit sketches and plans.
    - Riprap should consist of clean rock or masonry material free of debris or pollutants (such as asphalt).
    - If the streambed is subject to erosive high velocity at the culvert outlet, engineered outlet protection measures such as energy dissipaters should be installed. Outlet protection measures should be countersunk approximately one foot below the average streambed elevation.
    - Placement of riprap within jurisdictional waters should be the minimum necessary to protect or ensure shoulder slope and streambank stability. All riprap must be embedded below the existing grade of the stream.
    - A low flow channel should be constructed through riprap placement in streambeds. Minimal riprap should be used to line stream channels and should not impeded aquatic organism passage.
9. Remove temporary flow diversion or dewatering devices and accumulated sediment before allowing stream flow to resume through the new pipe or culvert.
10. Stream channel pattern, dimension and profile should be maintained similar to the upstream and downstream reach.
11. Pools should be formed at each end of the culvert to provide a transition from the shape of the pipe (culvert) to the shape of the stream. Pools should ideally be built

in natural rock and be designed to provide conditions for upstream migrants to enter and leave the culvert. The downstream pool should be designed to act as a stilling basin that will minimize the potential for erosion of the banks below and provide quiescent take-off conditions for fish. These pools are not to be plunge pools at the outlet of culvert but should be a smooth transition from the culvert to the downstream pool.

12. Bioengineering techniques (i.e., live willow stakes) should be used to stabilize stream banks.
13. Within jurisdictional waters and wetlands, all temporarily disturbed areas should be restored to pre-project conditions.
14. Begin backfill operations. Intermediate EPSC measures should be installed prior to the backfill operation to provide containment between the work area and the watercourse.
15. Upon completion of backfill operations, prepare slopes and other disturbed areas and stabilize.
16. Maintain EPSC measures until groundcover or vegetation is well established.
17. Upon establishment of vegetation, remove any remaining EPSC measures and stabilize disturbed areas. All temporarily disturbed areas should be restored to the pre-project conditions and planted with appropriate plant species.
18. Hanging or perched culverts are not acceptable in any flow situations.
19. For culvert crossings with multiple pipes at the same location, the lowest pipe should be sized and located to allow passage of fish during low flow periods; size and locate the additional pipe(s) to collectively pass the design peak flows.
20. There are many types, styles, configurations, and materials for culverts. A slab (bottomless) culvert is preferred over a box (with bottom slab) culvert because it helps ensure that a natural stream bottom will be maintained.

3.5.3 Maintaining Normal Flow in New Culverts

Maintaining normal stream flow is critical to aquatic organisms. Multiple barrel culverts or pipes are designed for peak flow conditions, and during low flow conditions, they may distribute normal flow over a large cross-section. Practices such as sills and rock vanes are installed to direct the stream flow through a single culvert or pipe, thereby maintaining a more natural channel condition.

3.5.4 Sills and Baffles

Often a 6- to 12-inch high structure (sill) is placed at the upstream side of a multiple barrel culvert to divert the stream's normal flow into a single barrel (Figure 22). The goal is to maintain a similar depth and velocity of water in the existing stream channel similar to the natural stream geometry. During larger storm events, the sill is overtopped and all of the barrels used. When using multiple barrel culverts, the design of the sill should mimic the stream cross-section. TDOT Ecology Section and Design (Hydraulics) have been discussing this topic and to date there has been no conclusion as to the ultimate use of sills.

Figure 21: Sill Placed at Inlet to Culvert

(Source: NCDOT Best Management Practices for Construction and Maintenance Activities).

Baffles function as large discrete roughness elements in the pipe or box culvert bottom. Baffles raise water levels, slow velocities, and establish resting pools for aquatic life ("Project Share 2004). The between baffle spaces may also fill with sediment, suggesting the possibility of establishing a natural stream bottom in the pipe. As inter-baffle spacing increases, the baffles effectively function as weirs (as opposed to roughness elements) and should be thought of as such. Wood, concrete, or metal can also be used for culvert baffles. Wood provides greater resiliency and is more easily replaced than either concrete or metal. Concrete baffles can be precast and drilled into place while metal baffles are bolted to the culvert floor. Baffles should be designed to just overtop. The height will depend on water depth. Only one barrel of a multi-barrel culvert should be employed for fish passage since the other cells of the culvert should be designed to carry only high flows by either placing a sill in front of the other openings or constructing the other barrels at a higher elevation. In-pipe baffles present several problems that often make them less attractive than other measures.

- Performance may deteriorate over time if between-baffle spaces fill with sediment. The roughness effect of protruding baffles may diminish, with some possible compensation provided by roughness of natural bottom materials.
- Access problems during construction and maintenance limit their use to larger pipes (*e.g.*, $d \geq 6$ ft)
- The baffles may trap debris or may be destroyed during high flows
- They detract from the hydraulic capacity of the pipe.

3.5.4.1 Conditions Where Practice Applies

- Streams that have perennial flow and multiple culvert barrels.

3.5.4.2 Construction

Step 1 – Divert the normal flow into the designated barrel using an approved temporary impervious dike.

Step 2 – Construct the sill (temporary diversion) such that wet concrete does not contact the stream.

Step 3 – Leave the temporary impervious dike in place long enough to allow the concrete to cure.

Step 4 – Remove the temporary impervious dike.

3.5.4.3 Typical Problems

- Debris and sediment accumulation block flow and cause premature overtopping when culvert is not properly sized to accommodate a sill.

3.5.4.4 Use of Sills

In general, the use of sluiceway end treatments and weirs should be investigated before baffles are employed. Project Share (2004) summarizes the hydraulic performance of several baffle configurations. When the baffle extends across the pipe bottom width, it is called a weir baffle. Other configurations use notched (slotted) baffles and baffle sections arranged in an offset fashion (offset baffles). The methods from the Project Share project can be used to estimate depth and velocity under design flow conditions. Typical details for concrete, offset, weir and slotted baffles are shown in Figure 22. In general, minimum baffle height should be approximately 1 ft (300 mm) to achieve desired results. Figure 23 shows a single end-treatment weir baffle.

Reduction of velocity throughout the length of pipe may require frequently spaced baffles, resulting in a large number of baffles at large cost. An alternative design approach uses baffles to establish resting pools for fish within the pipe, relying on their higher burst speed to carry them from baffle to baffle. The baffles effectively function as weirs, accounting for the term "weir and pool", also "baffled and sill" structures. Offset baffles also create resting pools, even though the baffles are not continuous across the culvert. This allows larger spacing between baffles (weirs) and average flow velocity in the pipe higher than the nominal sustainable swimming speed.

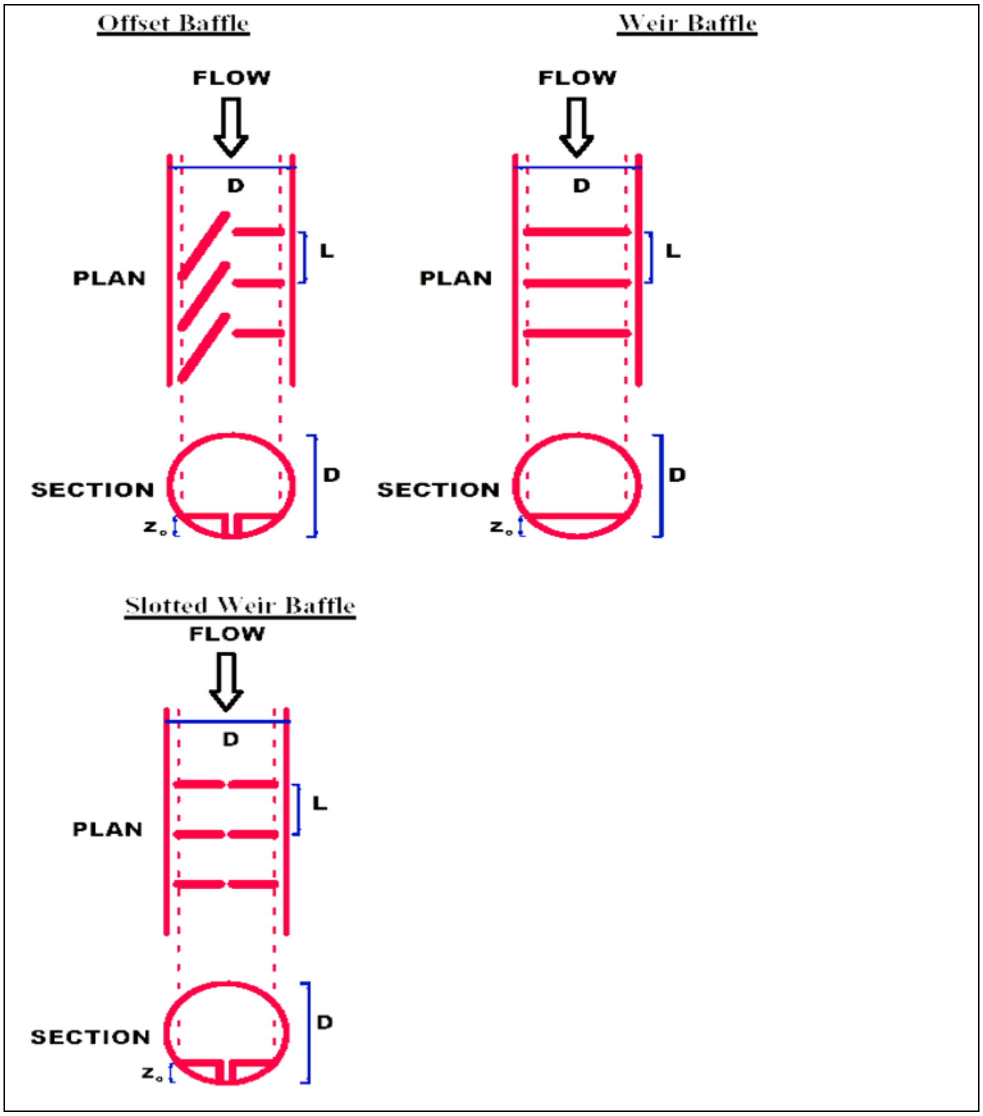


Figure 22: Schematic of Baffle Arrangements

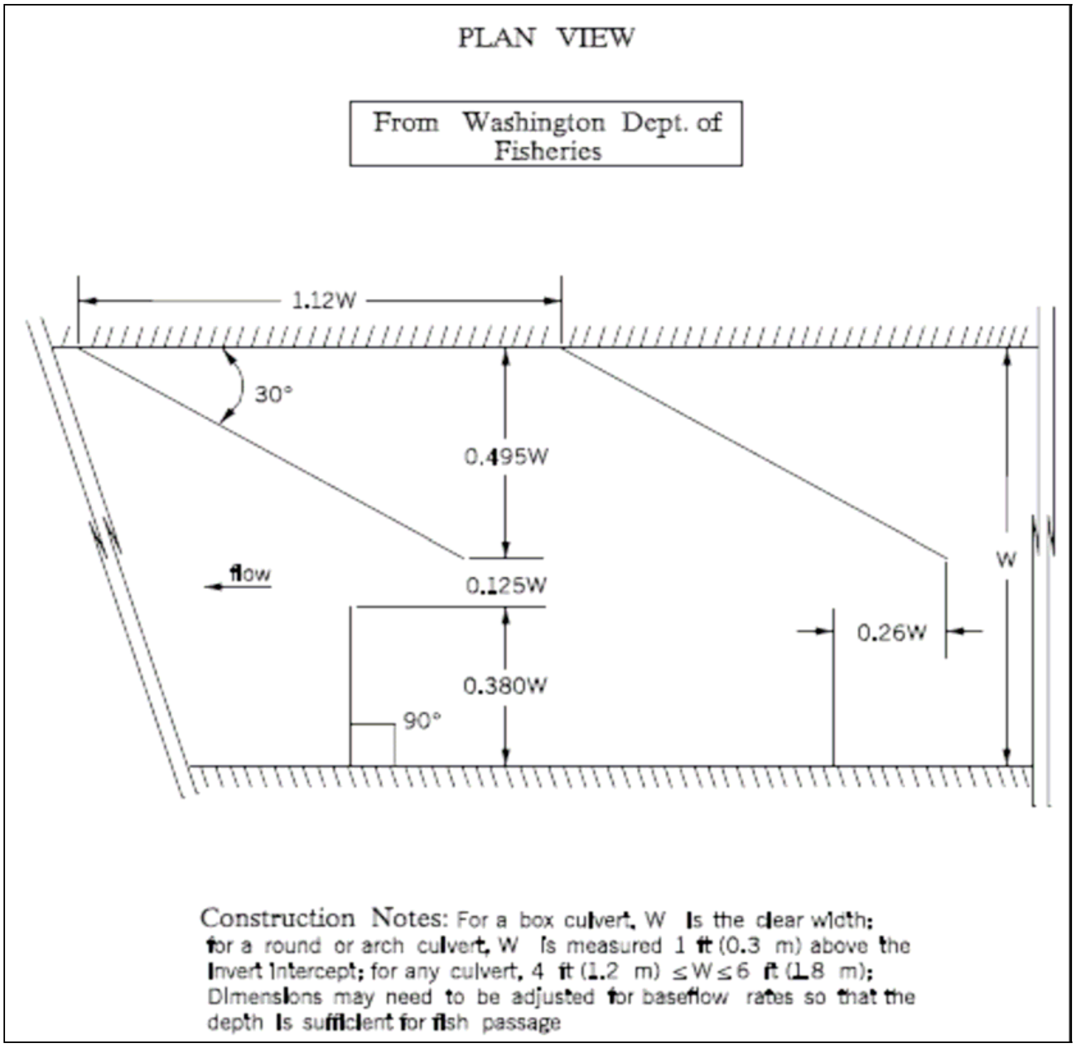


Figure 23: Schematic of Baffle Arrangements

(Source: Maryland's Water Construction Guidelines, 1999).

3.5.5 Cross Vane Rock Weir

The purpose of the rock cross vane at culvert inlets and outlets is to direct flow into the desired location of the culvert and maintain a proper flow path downstream of the culvert to prevent bank erosion as well as to maintain stream stability and stream grade. A rock cross vane is a 6-inch to 12-inch high rock structure keyed into streambank with declining surface plane in center. The goal is to maintain a similar depth and velocity of water as in the existing stream channel. During larger storm events, the cross vane rock weir is overtopped and the other culvert openings are used to convey water. The device size and dimensions are a function of the stream bank full dimension.

3.5.5.1 Conditions Where Practice Applies

- Streams that have a normal flow.
- Existing multiple pipes and culvert barrels.

3.5.5.2 Construction

Step 1 – Divert the normal flow into the designated barrel using an approved temporary impervious dike.

Step 2 – Construct the cross vane rock weir using footer rocks. The rocks should be uniform enough to form a solid barrier to divert the normal flow and minor storm flows

Step 3 – Remove the temporary impervious dike.

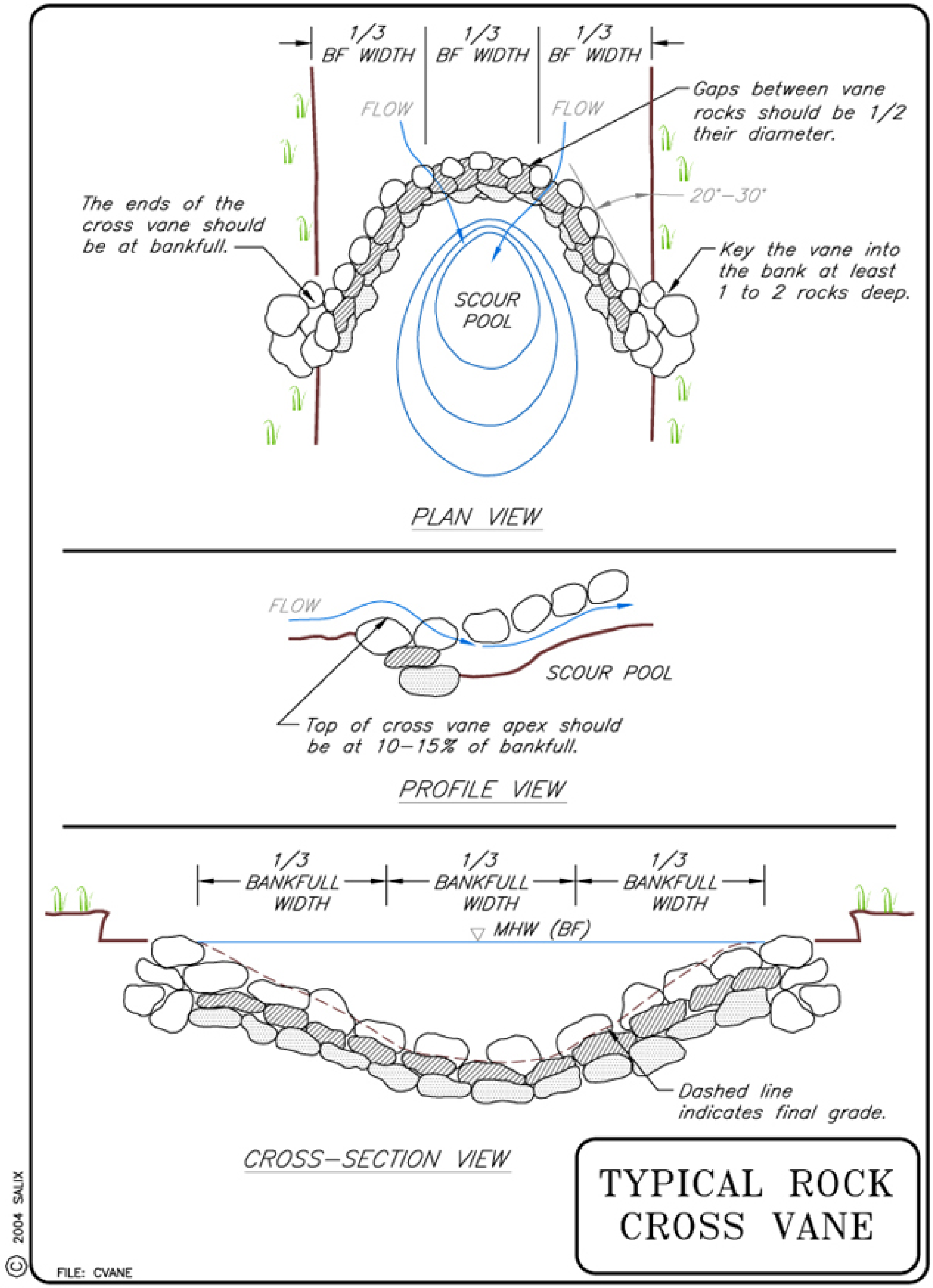


Figure 24: Typical Detail for a Rock Cross-Vane

3.5.6 Riprap Outlet Protection

Where the natural streambed cannot withstand the anticipated outlet velocities, riprap or some other type of streambed stabilization measure or energy dissipater is typically used to absorb energy and reduce velocity from the outlet flow. This prevents outlet scouring and potential erosion, as well as protects the pipe from being undermined.

3.5.6.1 Conditions Where Practice Applies

- At pipe or culvert outlets where scour is present and is endangering the stability of the pipe or culvert.
- At new pipe or culvert outlets where the natural streambed cannot withstand the anticipated outlet velocities and where failure will endanger the stability of the pipe or culvert.

3.5.6.2 Conditions Where Practice Does Not Apply

- When scouring of the natural stream will not endanger the stability of the pipe or culvert.
- When scouring is not present (i.e., bedrock streams).

3.5.6.3 Construction

Step 1 - Riprap should typically be placed for a distance of 4 times the pipe diameter from the outlet but in no instance greater than 50 ft. from the culvert outlet. No widening of the streams base low flow channel should occur at the culvert inlet or outlet.

Step 2 - The area in which to install an energy dissipater should undercut the thickness of the riprap such that the riprap is flush with the channel side slopes and bottom.

Step 3 - Stream flow must be maintained on the surface and not be allowed to flow through or under the riprap.

Step 4 - Clean rock must be used, clean of fines.

Step 5 - Restoration of the streambank should be accomplished with the use of live stake willows within the voids of the riprap (Figure 26 - 30).

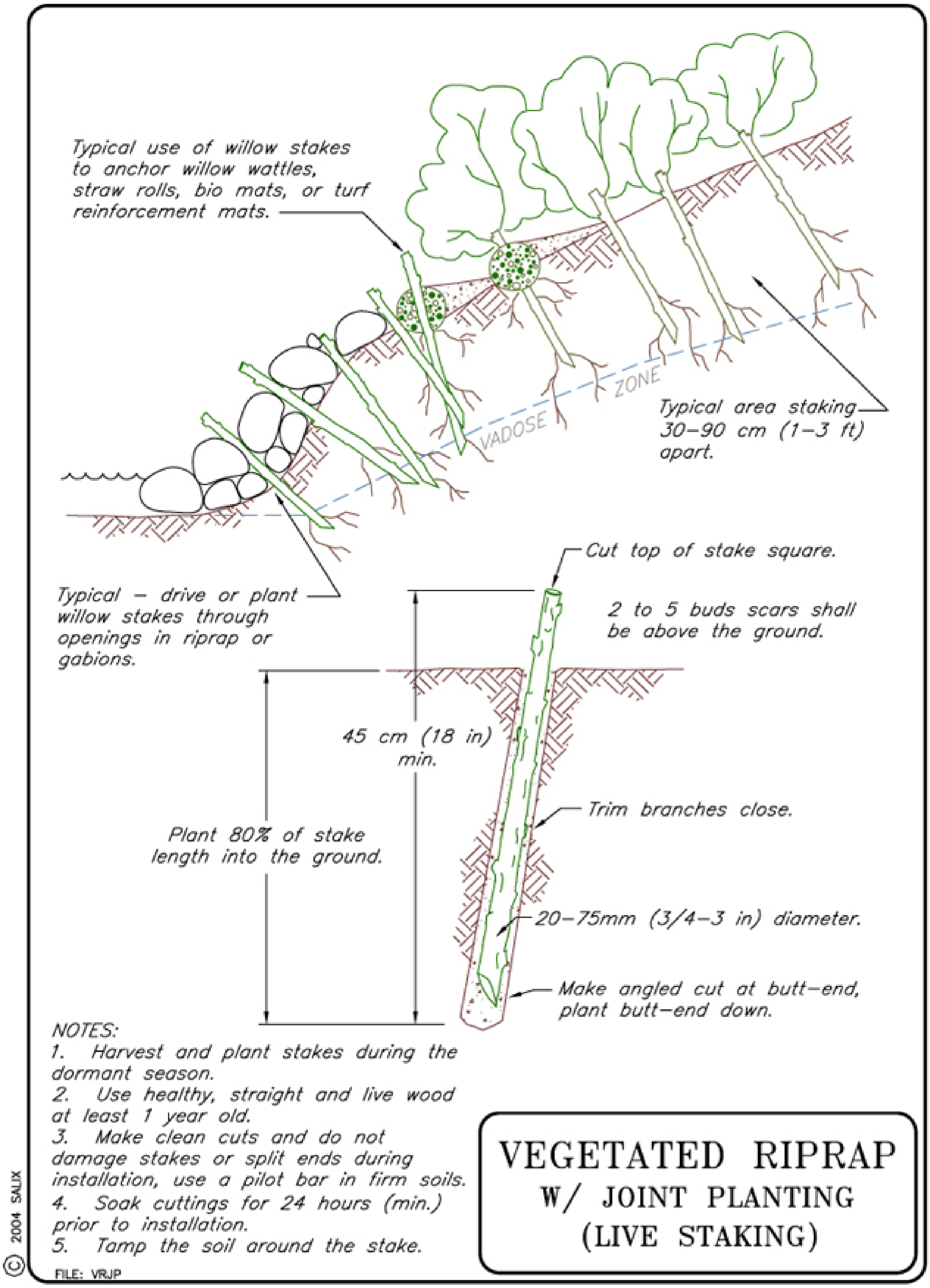


Figure 25: Schematic of Vegetated Riprap with Live Stake Willows Planted within the Voids

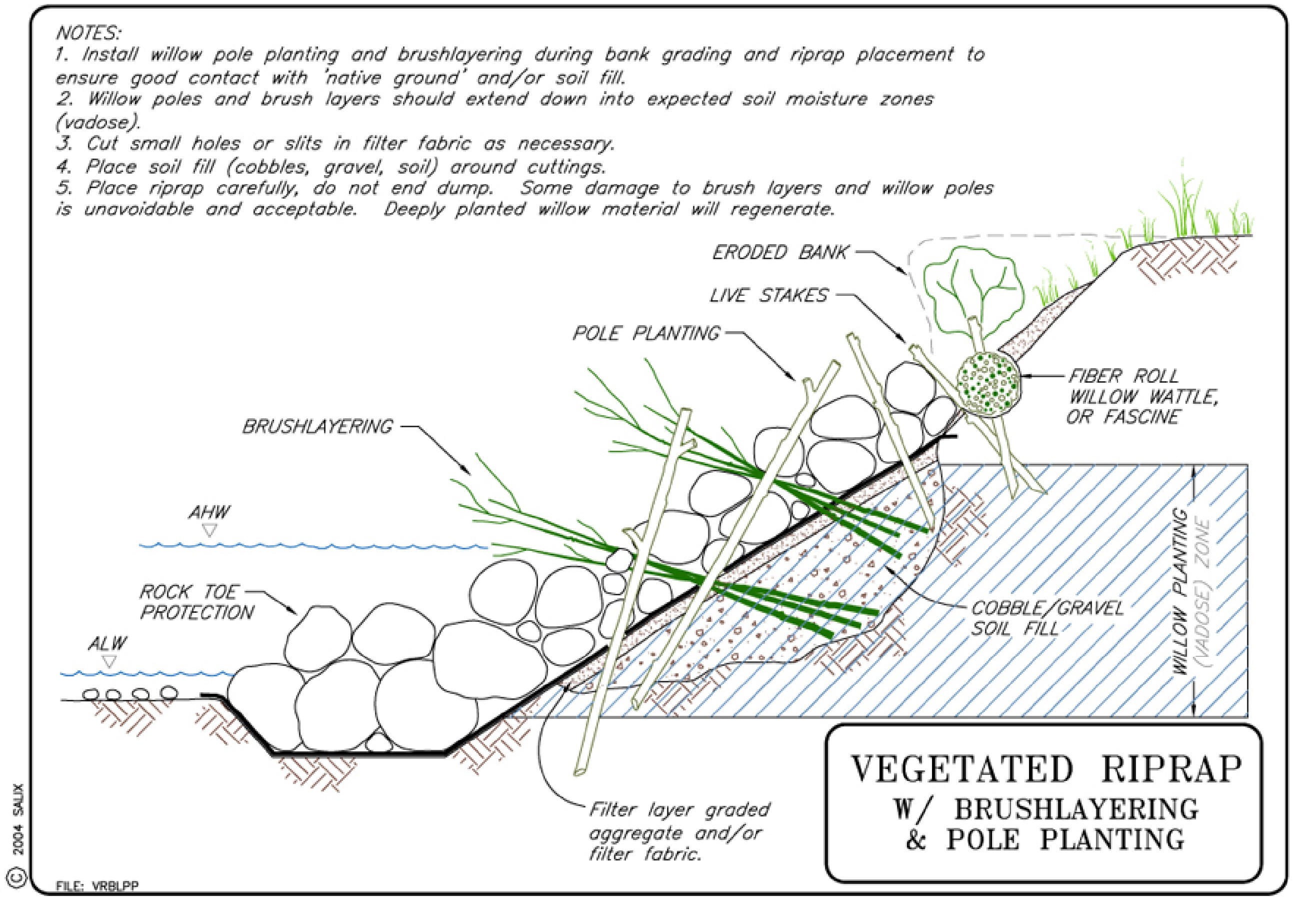


Figure 26: Schematic of Vegetated Riprap with Brush Layering and Pole Planting

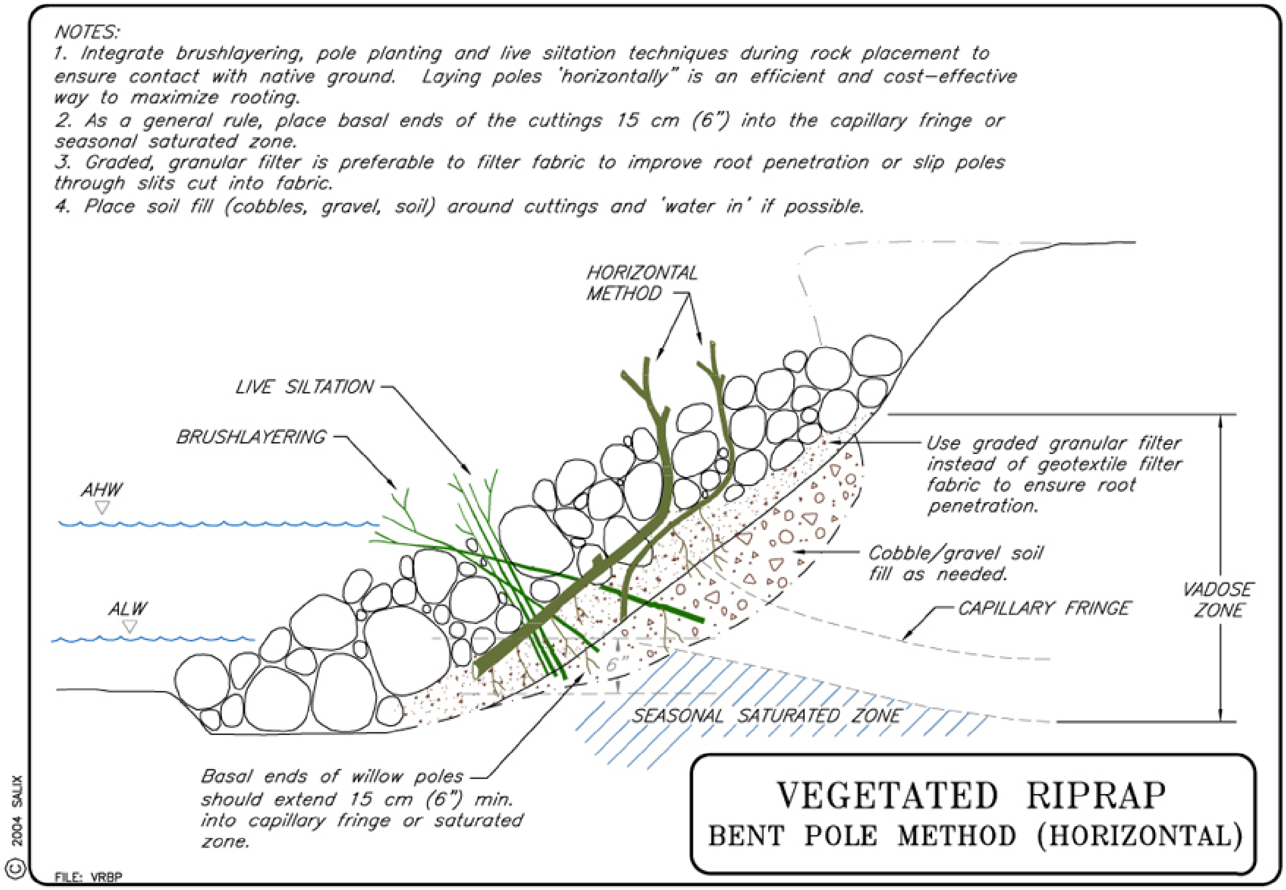


Figure 27: Schematic of Vegetated Riprap, Bent Pole Method (Horizontal).

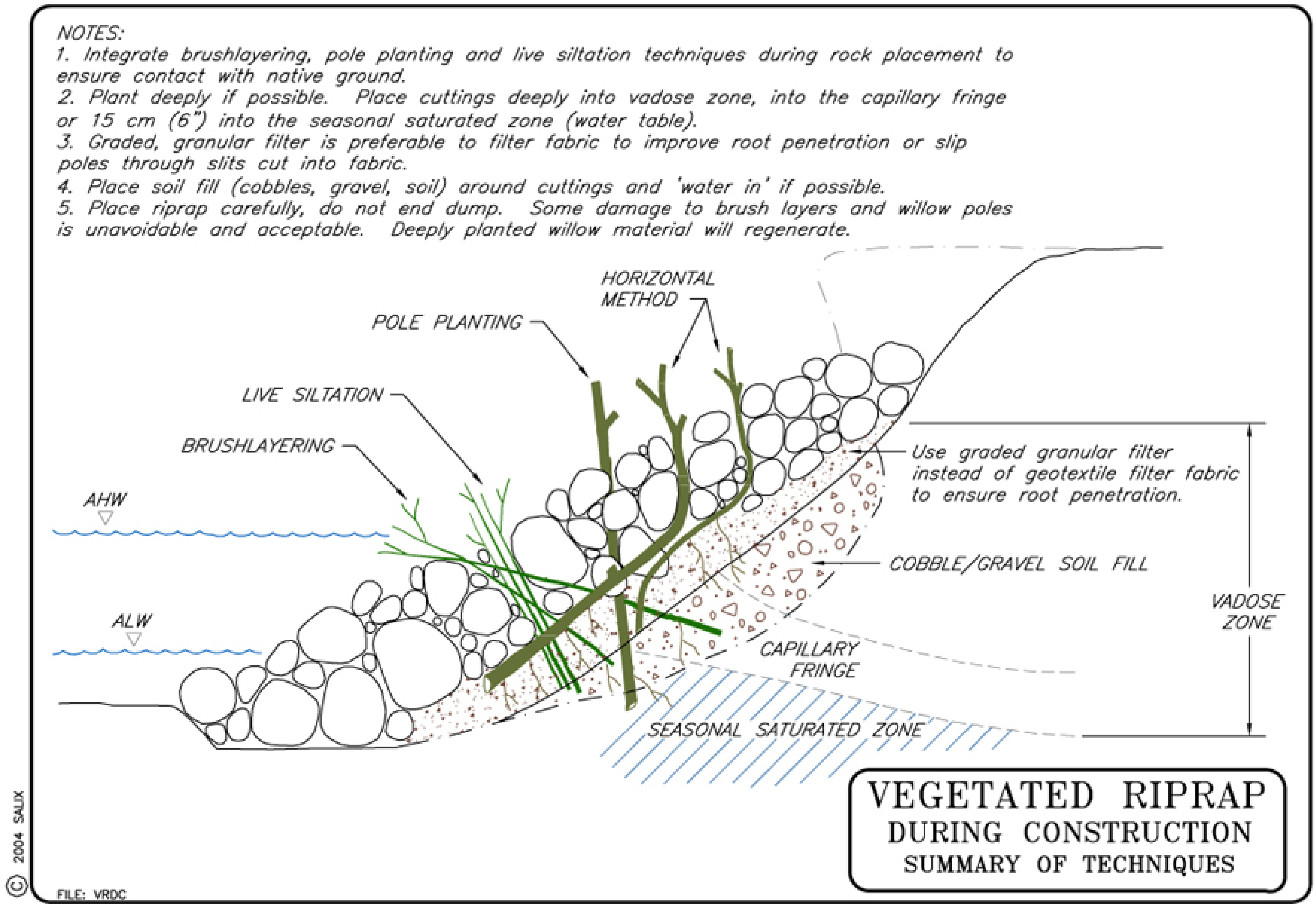


Figure 28: Schematic of Vegetated Riprap Using All of the Above Listed Methods

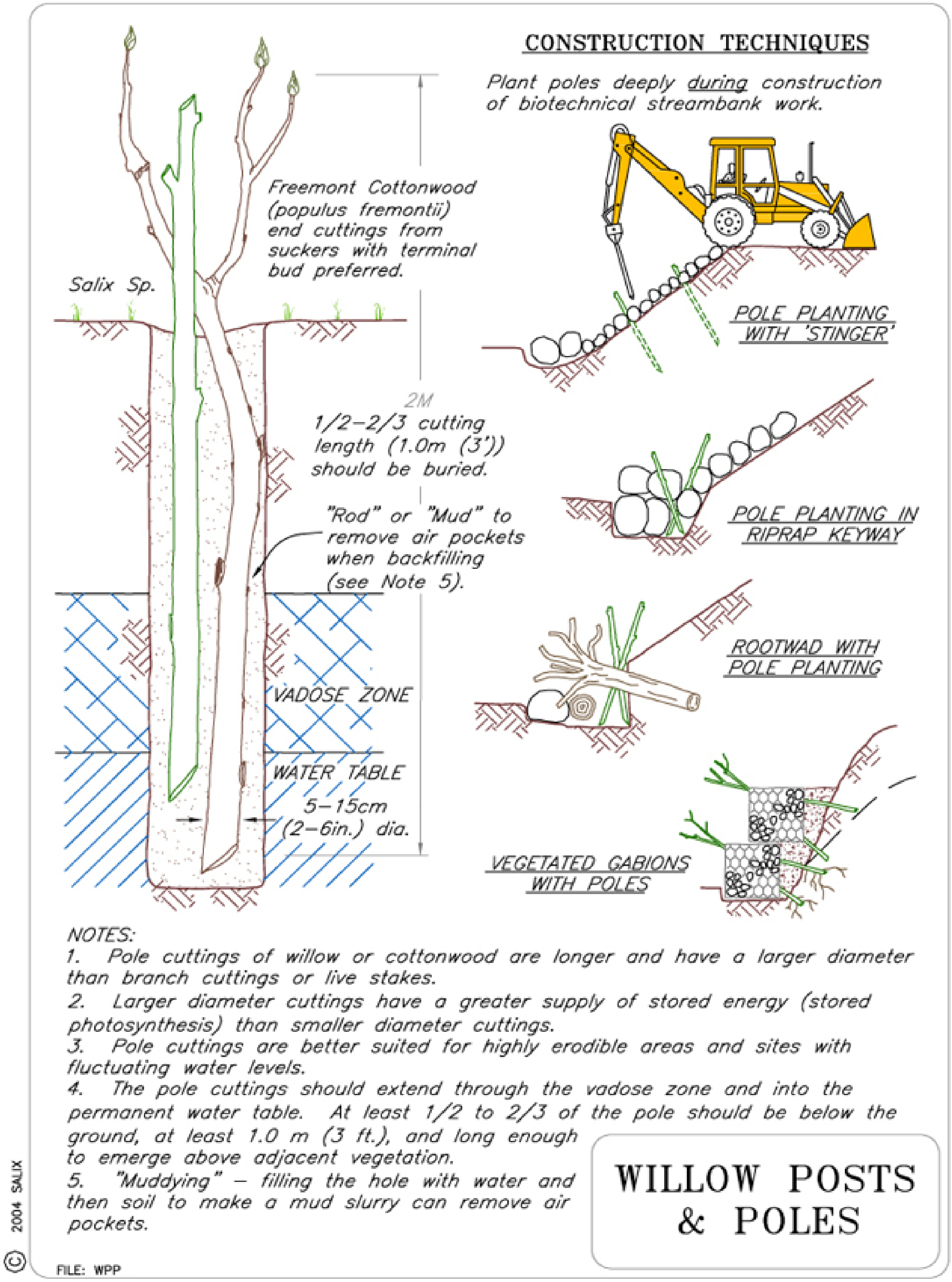
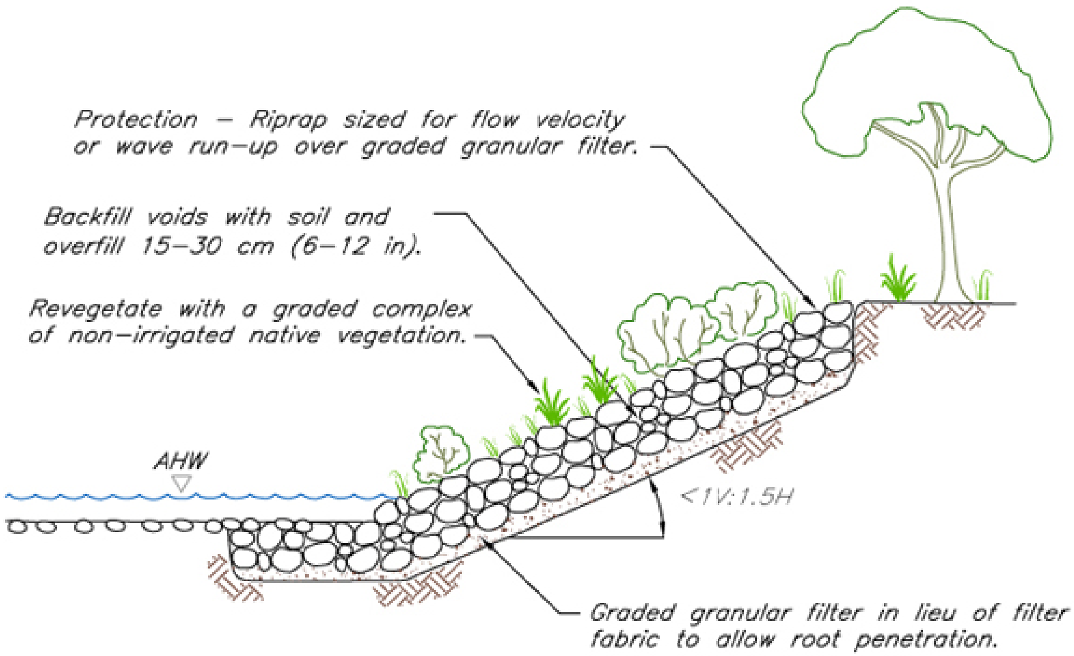


Figure 29: Willow Posts and Poles Method of Installation through Riprap



NOTES: CLASS 2 PERMEABLE MATERIAL

Permeable material for blankets or other subdrainage purposes shall consist of hard, durable, clean sand, gravel or crushed stone and shall be free from organic material, clay balls, or other deleterious substances.

Class 2 permeable material shall have a Durability Index of not less than 40 and a Sand Equivalent value of not less than 75.

SIEVE SIZES	PERCENTAGE PASSING
1–Inch	100
3/4–Inch	90–100
3/8–Inch	40–100
No. 4	25–40
No. 8	18–33
No. 30	5–15
No. 50	0–7
No. 200	0–3

RIPRAP
W/ SOIL AND GRASS
OR GROUND COVER

FILE: RRSG

Figure 30: Schematic of Vegetated Riprap with Soil and Grass Ground Cover

3.6 Test Holes for Box/Slab Culvert Determinations (Geotechnical Drilling)

Current TDOT protocol for test holes is covered under in Section 204 of the TDOT Standard Specifications (see previous discussion). Standard drawings have been developed that depict a typical set-up for geotechnical drilling at two proposed bridge crossings. A standard detail for treating slurry water generated during the drilling process is also developed. Refer to Figures 31 and 32 for general details for EPSC and treating slurry water when conducting geotechnical drilling around streams. The section on Temporary Haul roads should be referred to for the construction of temporary construction roads needed to access drill sites.

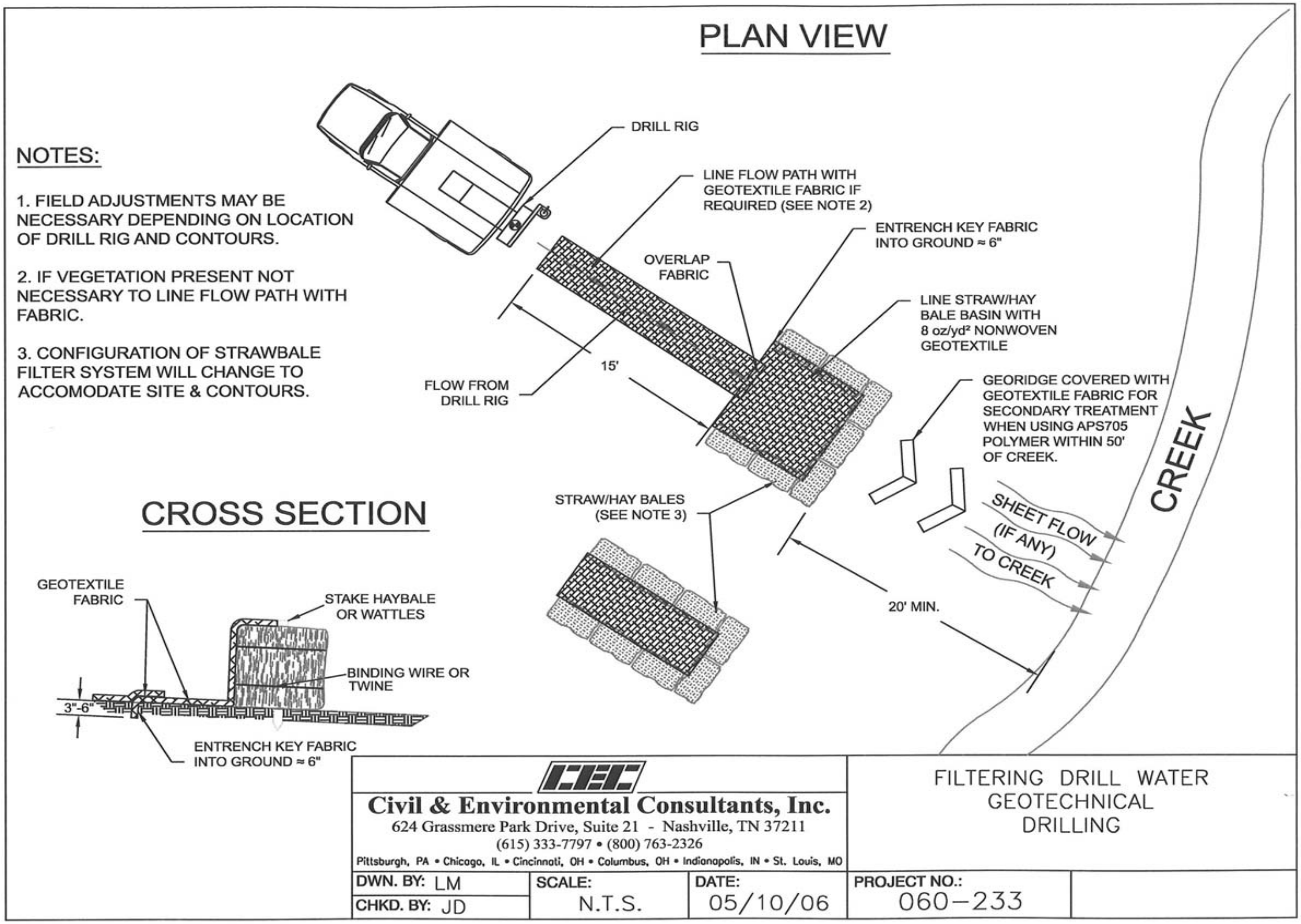


Figure 31: Geotechnical Drill Setup for Drilling Adjacent to Streams

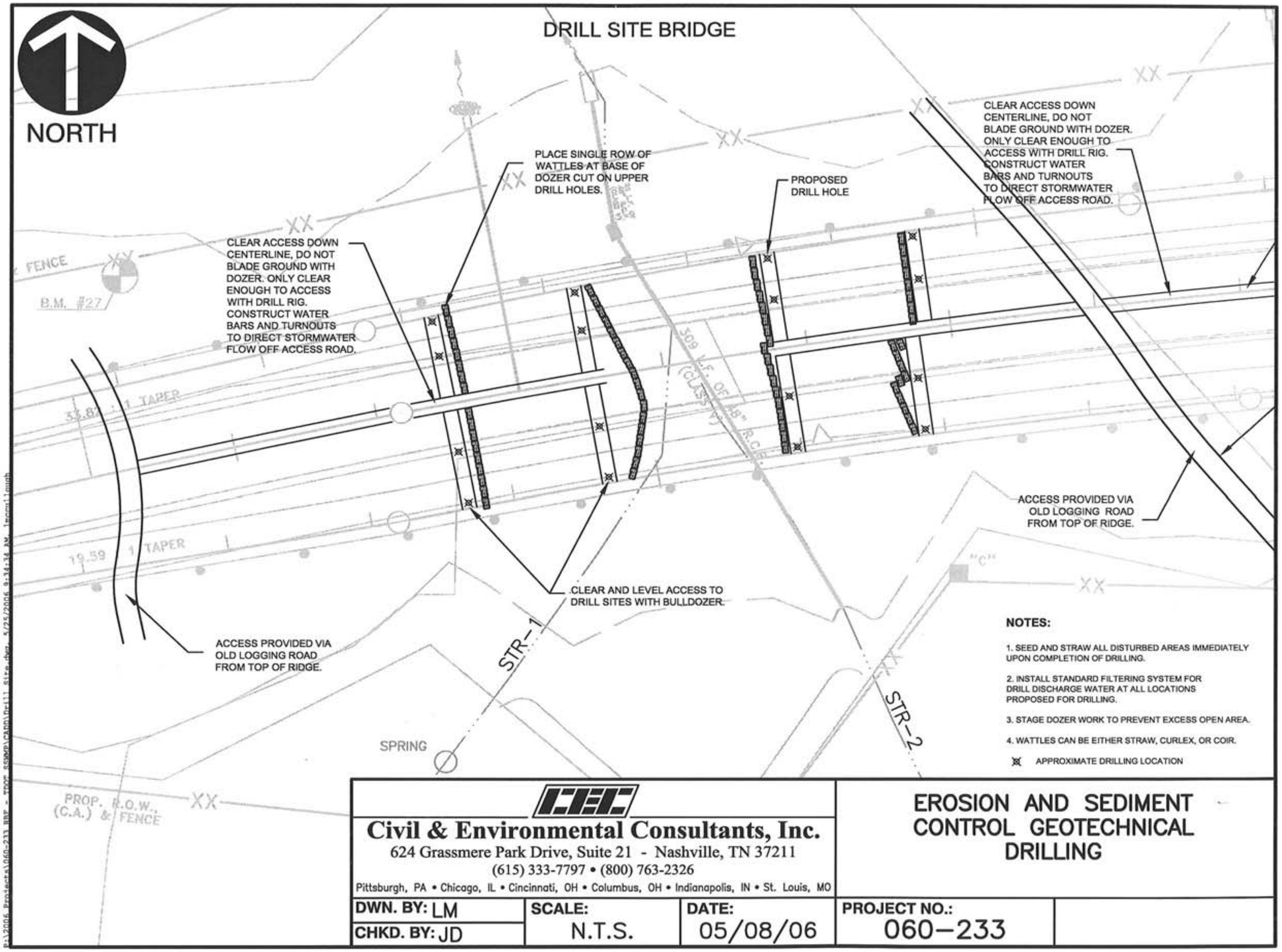


Figure 32: Geotechnical Drill Setup for Drilling Adjacent to Streams

3.7 Ditches and Utilities in and around Wetlands and Streams

Current TDOT mitigative measures for ditches and utilities in and around wetlands are found in the previous descriptions of measures for temporary work in wetlands (e.g., stockpile and protect topsoil, replace to grade) and streams.

Use the current TDOT mitigative measures for temporary work in wetlands, as well as the recommended measures. Additionally, one of the most important issues related to ditches and utility lines, in and around wetlands and streams, is to ensure that the remainder of the aquatic resource is not drained or disturbed. The use and construction of natural earthen berms may need to be considered to prevent draining wetlands. When placing underground utilities through wetlands or across streams, clay plugs should be used when the utility line enters and exits the aquatic resource wetland to prevent subsurface drainage of the wetland (Figure 33 and 34).

The following is a general sequence of procedures for utility line crossings and typically follows much of the same BMP measures for a road crossing:

1. When possible, it is preferred that the stream or wetland area be directionally bored under. Earth and rock in the stream bottom will be excavated in the dry.
2. All flow line length disturbed and stream bottom contours will be replaced to mimic preconstruction conditions.
3. As with bottom contours, stream banks will be restored to preconstruction conditions and seeded and mulched section-by-section when final grades are attained.
4. If hard armoring is required, use vegetated riprap with live stakes method of revegetation.
5. The trench will be filled with limestone gravel bedding material with clay blocks (full anti-seep collars) to ensure that the trench does not create a "French drain" effect and drain waters of the U.S. or state.

Utility crossings should meet the USACE requirements as set forth in ***Nationwide Permit #12, Utility Line Activities*** and TDEC's approved ***General Permit for Utility Line Crossings*** with conditions.

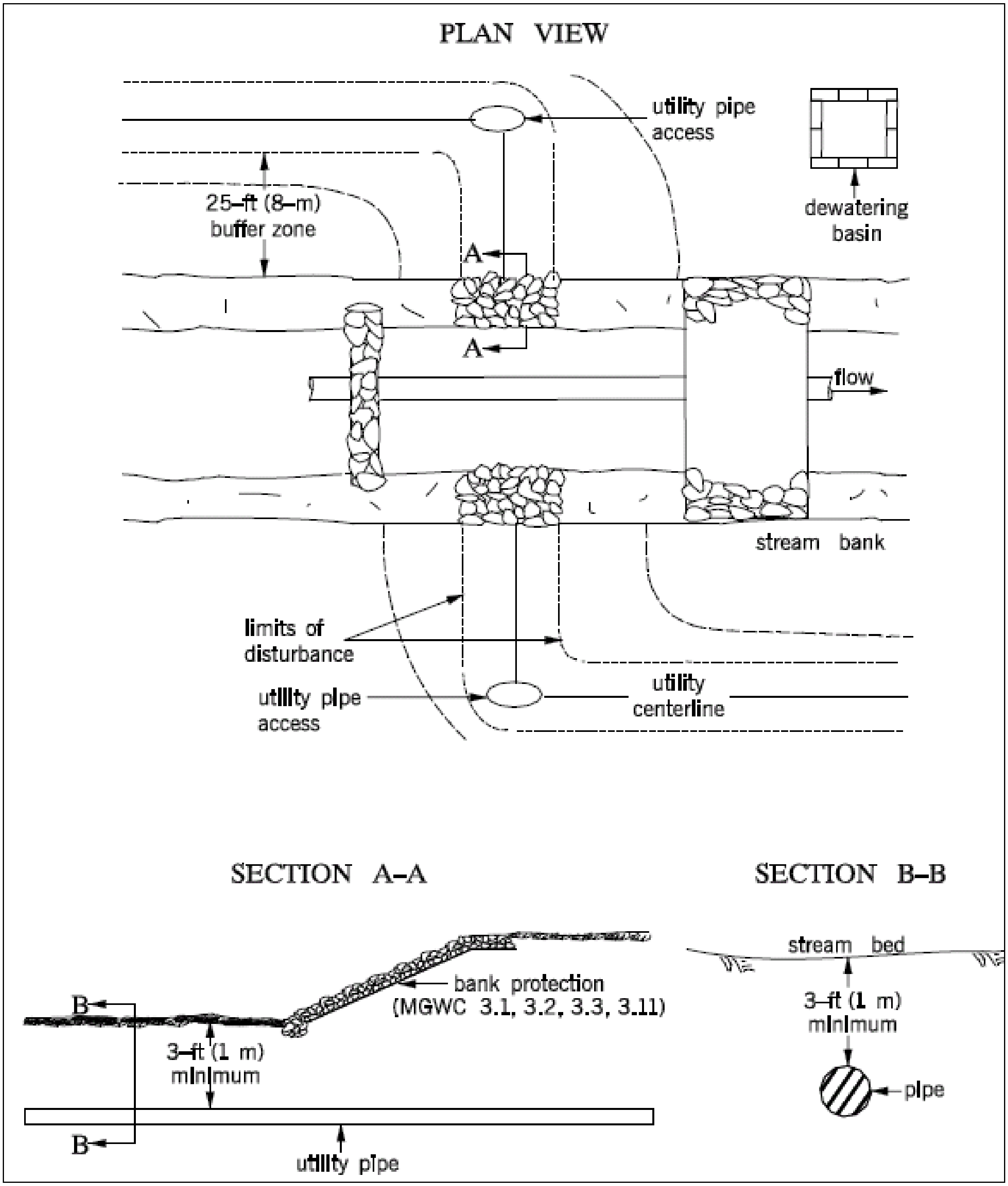


Figure 33: Example Utility Line Crossing

(Source: Maryland's Water Construction Guidelines, 1999).

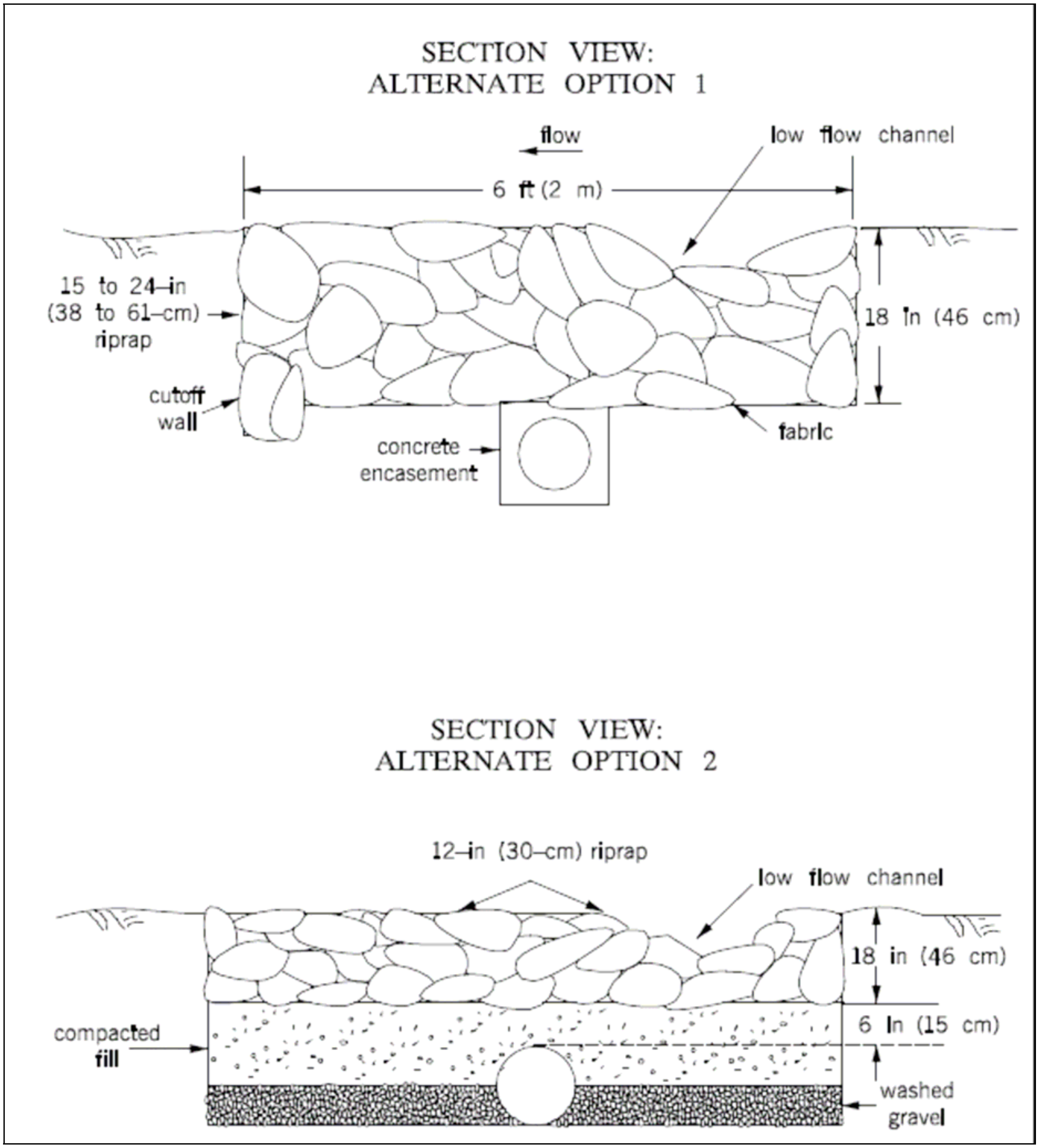


Figure 34: Example Utility Line Crossing, Section View

(Source: Maryland's Water Construction Guidelines, 1999).

3.8 Haul Road Installation and Removal

Some current TDOT mitigative measures for haul road installation and removal are found in the previous descriptions of measures for temporary work in streams and wetlands. Haul roads also are referenced in Section 209 of the TDOT Standard Specifications. Temporary haul roads and construction pads for use when building bridges have historically been an issue with various ARAP's and the restoration that is performed following completion of the work. The TDOT Standard Drawing "Temporary Road Stabilization and Temporary Culvert Crossing" (EC-STR-25) is used to provide temporary crossings of water bodies and in many instances is a haul road from one end of the project to another. Temporary haul roads used in-stream, as working pads for cranes and other heavy equipment must be designed such that flood flows do not wash the pad downstream. When T&E species (e.g., mussels and crayfish) are present haul roads and working pads may not be approved by the regulatory agencies due to the presence of these aquatic species. The Biological Assessment (BA) and water quality permit requirements should be consulted when proposing to build haul roads over a stream.

The construction of Temporary Haul Roads is similar to roads built for forestry operations and should be constructed similarly. The use of water bars, dips, and turnouts are very beneficial to reducing water quality impacts to area streams and wetlands (*Guide to Forestry Best Management Practices in Tennessee*, Tennessee Department of Agriculture, Division of Forestry, 2003). Techniques such as varying the slope of the road, crowning, outsloping, wing ditches, sediment control structures, broad based dips, water bars and/or cross-drain culverts should be used to control runoff from roads (See Section 2.5).

- A water bar is a shallow trench with a mound (or berm), which provides cross drainage and intercepts runoff from temporary haul roads. Constructing a water bar will minimize the potential for erosion and provide conditions for natural or artificial revegetation. Place water bars at a 20 to 30 degree angle with a cross drainage grade of 2%.
- Diversion ditches, or berms, divert water away from roads and side ditches, and channel it into vegetation. These structures are used before stream crossings to ensure that water will be diverted into vegetation and not directly into a stream, lake or wetland. Construct diversion ditches so they intersect the roadside ditch at the same depth and are outsloped 1% to 3%.
- When possible, vary road grade to reduce concentrated flow in road drainage ditches, culverts and on fill slopes and road surfaces.
- Crown roads when located on flat or gently sloping terrain. Crown roads when crossing a ridge.
- Outslope roads 2% to 3% when side slopes are at least 10%.
- Inslope roads 2% to 3% on extremely steep slopes and sharp turns as a safety measure. Inslope roads require drainage ditches, broad-based dips and/or culverts to carry water to downhill sides of road.
- Install water turnouts (wing ditches) to move water quickly away from roads. Water turnouts should route water into undisturbed areas allowing filtration before entering water bodies.
- If soils are highly erodible, armor broad-based dips with clean large crushed rock, gravel or other suitable material. Install riprap or other suitable materials at the outlet of the dip to slow and absorb runoff.

When temporary crossings are required such as when constructing culverts, bridges, or to provide access to other areas of a project, the streambank and streambed should be restored to pre-existing conditions. Upon completion of construction activities, temporary haul roads are to be completely removed. Excavated material from the haul roads should disposed of as directed by the Engineer in an area that will not re-enter waters of the State. Upon completion of excavation on both sides of a stream, close out the temporary haul road across the creek as follows:

1. Removal of temporary haul road crossing must be performed during a period of low flow.
2. Remove temporary haul roadbed material (course riprap) from top surface.
3. Remove temporary pipes.
4. Remove as much of the fine aggregate bedding material as possible.
5. Large riprap may be left in place along the streambank for stabilization.
6. Plant live willow stakes and silky dogwood stakes from the water's edge up to the top of the bank on 3-ft centers (see specification in Section 2.1.4. and Figures 23 – 27).
7. Seed all exposed surfaces with switchgrass (*Panicum virgatum*)(4 lbs/ac), Virginia wild rye (*Elymus virginicus*) (8 lbs/ac), deertongue grass (*Panicum clandestinum*)(4 lbs/ ac), and winter rye or wheat (*Secale cereale* or *Triticum aestivum*)(10 lbs/ac) (or other approved nurse cover crop).
8. Plant bare root seedling trees on 12 ft. centers beginning at the top of bank and extending 50 ft. out from creek bank.

In addition to the current TDOT mitigative measures for temporary work in wetlands and streams, the following are additional specific recommendations:

1. After the area for the haul road is cleared and grubbed, the top 12-inches of topsoil from this area should be removed and stockpiled in an adjacent upland site and protected from potential erosion.
2. The Contractor should be responsible for restoring the area within the limits of the haul road as follows:
    a. Upon completion of the project, all fill material used to construct the haul road should be removed to a depth that will allow matching of the original ground elevation after the topsoil is replaced onto the haul road corridor.
    b. Topsoil stockpiled should be replaced onto the haul road corridor after removal of fill material.
    c. Ditches or berms constructed or filled in conjunction with the haul road and not part of the final project should be filled or removed, as appropriate and such areas should be graded to match the original ground elevations.
    d. Once the area of the haul road and any ditches or berms has been restored to the original ground elevation, they should be tilled to a depth of 12-inches. This area should then be grassed and mulched according to

TDOT Standard Drawings and Specifications. Grass should be established and accepted prior to the removal of BMPs.

e. Once the haul road has been removed and the area restored, the Contractor should notify the Project Supervisor so a field inspection will be conducted to certify that the haul road was properly removed and restored. The Contractor should be responsible for any corrective action required to complete this work.

3.8.1 Bridge Construction and Removal

TDOT has Standard Specifications for Road and Bridge Construction that should be followed when constructing and demolishing bridges in and around waters of the state. In addition, the following general notes and guidelines should be used for new bridge construction and bridge demolition. Many of the BMP actions necessary for construction of bridges has been discussed in previous sections of this chapter (i.e., managing the watercourse, haul roads, temporary diversions).

3.8.2 Bridge Construction

1. Install proper BMPs to manage runoff from the work area required to install the roadway approach fill.
2. Conduct approved clearing and grubbing necessary to construct the roadway approach fill.
3. When stream banks are exposed due to clearing and grubbing operations, banks should be stabilized with indigenous vegetation and/or vegetated riprap.
4. Temporarily seed and mulch roadway approaches and maintain EPSC measures.
5. Install and/or relocate EPSC measures to manage runoff from the work area required for bridge construction.
6. Where fill is too close to the stream bank to allow for adequate EPSC measures, install turbidity curtain when water surface velocity and depth are sufficient to move debris downstream outside of work area in sensitive water bodies.
7. At the end of each workday, remove any debris or sediment deposited outside of the work area because of the bridge construction and replace any temporary measures removed to work that day.
8. Evaluate proposed bridge structure and site for construction methods that will minimize the potential for erosion and construction debris. Steps for sequencing are required on the work plan.
9. Store construction material and equipment within the construction limits of the project and away from flood prone areas. No equipment should be stored in wetlands, surface waters, or protected riparian buffers.
10. Transfer of fuel and vehicle maintenance should occur in a fuel containment area that is at least 50 feet away from any surface water.

11. Locate all equipment on existing roadways or specially constructed work pads.
12. Inspect and repair equipment for possible leakage of liquid or semi-liquid fuels and lubricants. Promptly remove any leaking equipment from the area.
13. Contain fresh concrete in wood or plastic forms and properly clean out areas so no seepage into the adjacent water body occurs, especially with the pouring of foundation work.
14. Install any scour protection measures in accordance with permit conditions.
15. Remove inactive equipment from temporary causeway or floodplain areas.
16. Dispose of construction debris and stockpiles of erodible material properly and stabilize the site.

3.8.3 Bridge Demolition

1. Prior to installing EPSC BMPs, identify permit conditions and impact area boundaries.
2. Install EPSC BMPs around each bridge approach.
3. Install turbidity curtains when water surface velocity and depth are sufficient to move debris outside of work area in sensitive water bodies.
4. Evaluate structure and site for demolition method that will create the least amount of debris and sediment transport.
5. Locate all equipment on existing roadway or specially constructed work pads.
6. Transfer of fuel and vehicle maintenance should occur in a containment area, which is at least 50 feet away from any surface water.
7. Collect and remove all loose debris and asphalt-wearing surfaces from the roadway.
8. Collect and remove all road surface material before removing bridge sections.
9. Remove bridge in the fewest number of sections possible. This limits the amount of loose debris created.
10. Use non-shattering demolition methods.
11. Concrete bridge decks should be removed by sawing full depth or full span length in order to remove deck and beam sections as one unit.
12. Remove any material that falls into the water body. No bridge deck or substructure components should be dropped into the water. If this is not possible, such as the case of concrete arch design, demolition should not occur over more than one-half of the channel width at any one time.
13. Remove loose debris and road surface material piles from the work site promptly to eliminate possible scattering by wind and rain.
14. Remove any debris and sediment resulting from the bridge demolition at the end of each workday.

15. Inspect all equipment used near surface water for possible leakage of liquid or semi-liquid fuels and lubricants daily. Promptly remove any leaking equipment from the area.
16. Stabilize exposed stream banks with indigenous vegetation or riprap (if required).
17. Riprap should consist of clean rock or masonry material free of debris or pollutants.
18. No asphalt or concrete debris recycling is allowed in jurisdictional waters.
19. Placement of riprap within jurisdictional waters must be the minimum necessary to protect or ensure the safety of the slopes. Riprap should be limited to the toe of the slope being stabilized and should be clean rock with no fines or soil.
20. No material is placed which impairs surface water flow into any wetland area.
21. No material is placed in a manner that will be eroded by normal or expected high flows.
22. Plant material should be installed during the proper planting season and as soon as possible to help stabilize the stream.
23. Upon establishment of vegetation cover remove remaining EPSC BMPs and stabilize disturbed areas.
24. Remove inactive equipment from temporary causeway of floodplain areas.

3.9 Riprap Standards and Substitutions

Refer to Section 3.5.d. for use of riprap at outlet and inlets of culverts. The use of riprap lining of stream channels should be prohibited. Various types and manufacturers of turf reinforcement mats (TRM) can be used in place of riprap with the same amount of protection. Refer to Product 1 – BMP Review and Product 3 – Construction Manual on uses and specification for riprap alternatives.

4 TDOT Mitigation Notes and EPSC Notes and Sequencing

Refer to the current TDOT Instructional Bulletins for the most up to date EPSC notes and mitigation notes. The current version as of the date of this draft is IB No. 06-13 (Regarding Notes to be Added to the Erosion Prevention and Sediment Control [EPSC] Plans) and IB No. 06-14. (Regarding English General Notes on Plans). These notes became effective on February 6, 2004 for all projects that require coverage under a NPDES permit. These notes are to be added in the EPSC plans, and they are required to comply with Section C.7 (b) of the Amended Consent Order regarding Interim Measures pending approval of the SSWMP and the requirements of the NPDES CGP as well as some ARAP conditions:

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Glossary

Glossary

ARAP. Aquatic Resource Alteration Permit.

BMP. Best Management Practice. Schedule of activities, technologies, practice, methods, and maintenance procedures to prevent or reduce pollution.

CO. Consent Order

DNA. Division of Natural Areas.

ECS. Erosion Control Supervisor.

ED. (TDOT) Environmental Division.

EPA. (U.S.) Environmental Protection Agency. The federal agency with primary or oversight responsibility for implementing the federal environmental statutes, including the CWA, Clean Air Act, Safe Drinking Water Act and Resource Conservation and Recovery Act. Tennessee is included within EPA Region IV, headquartered in Atlanta.

EPSC. Erosion Prevention and Sediment Control.

FEMA. Federal Emergency Management Agency.

FHWA. Federal Highway Administration.

FWS. Fish and Wildlife Service

GIS. Geographic Information System. Computerized data management system with tools designed to gather, store, retrieve, analyze, transform, and manipulate large amounts of geographic and demographic information to produce color-coded maps, three-dimensional virtual models, tables, and lists.

NPDES. National Pollutant Discharge Elimination System.

SSWMP. Statewide Stormwater Management Plan.

SWPPP. Storm Water Pollution Prevention Plan.

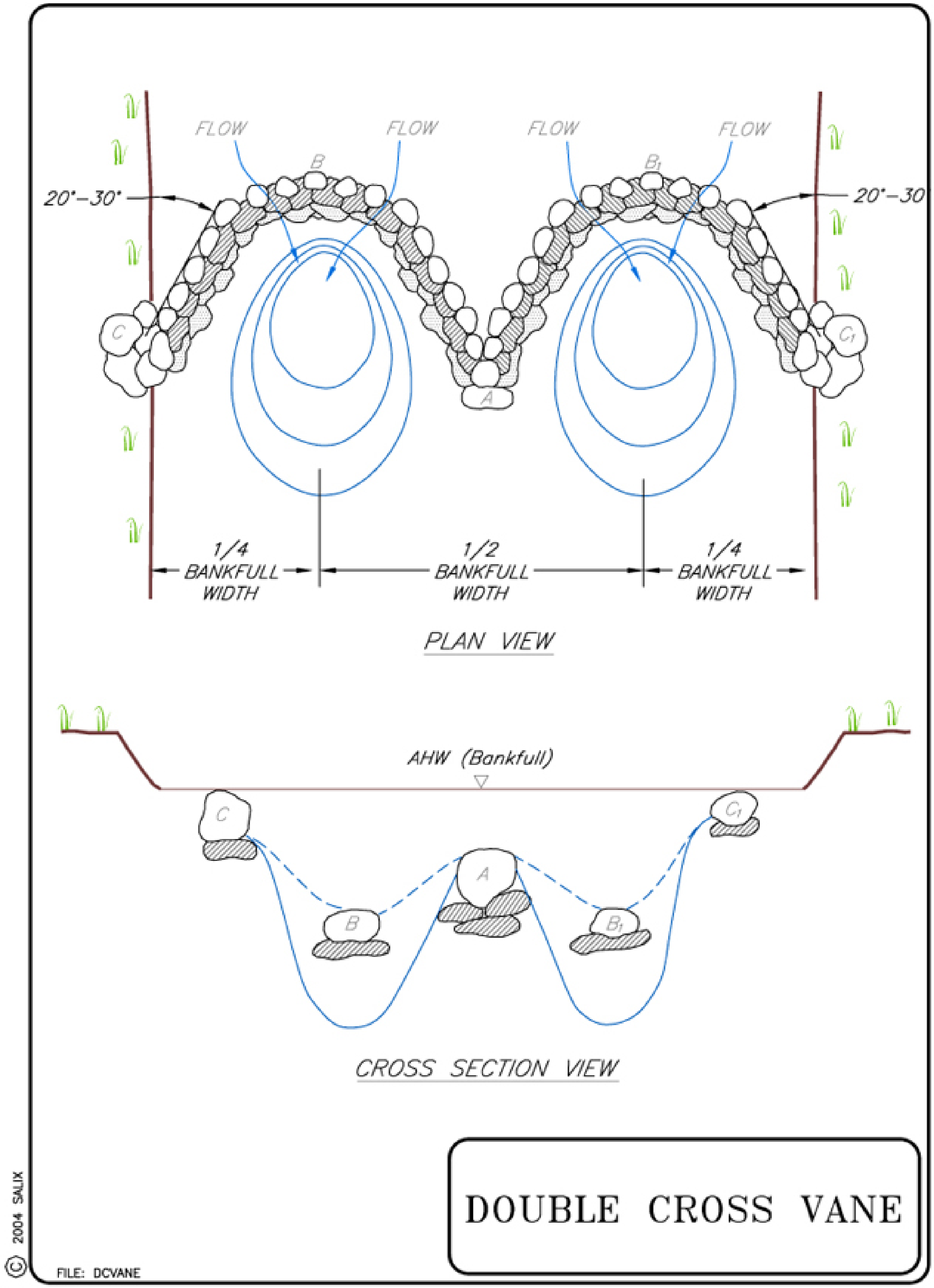
TDEC. Tennessee Department of Environment and Conservation.

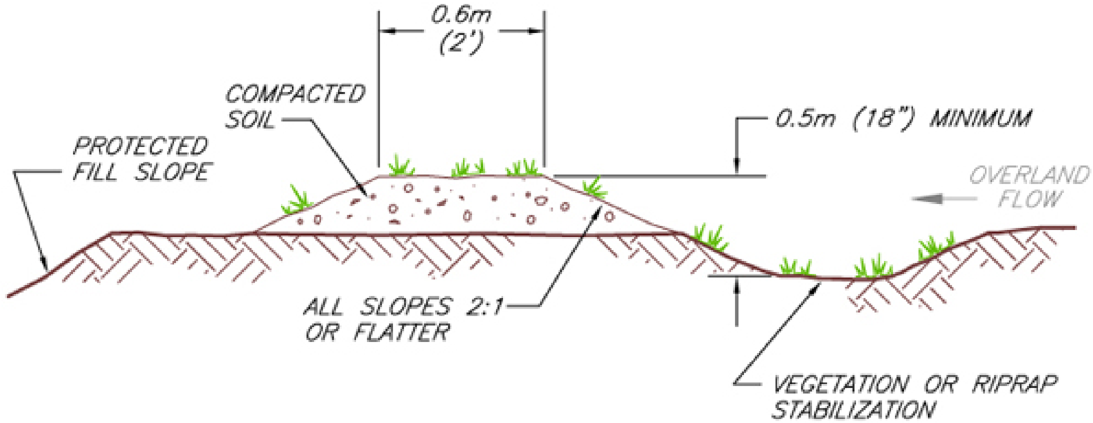
TDOT. Tennessee Department of Transportation.

TSMP. Tennessee Stream Mitigation Program (In-Lieu Fee).

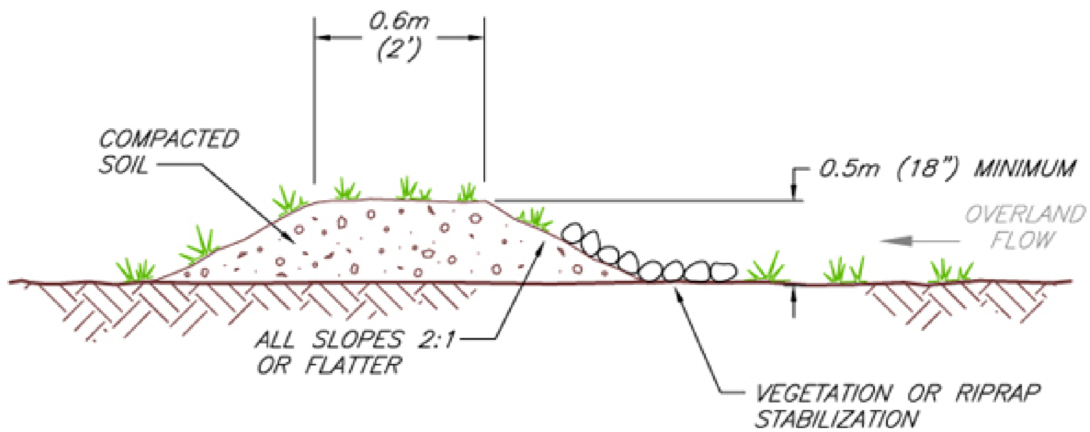
USFWS. United Stated Fish and Wildlife Service

Appendix A: Catalogue of Drawings


FLOW
FLOW
FLOW
FLOW
B
B1
20°–30°
20°–30
C
C1
A
1/4 BANKFULL WIDTH
1/2 BANKFULL WIDTH
1/4 BANKFULL WIDTH
PLAN VIEW
AHW (Bankfull)
C
C1
A
B
B1
CROSS SECTION VIEW
DOUBLE CROSS VANE
© 2004 SALIX
FILE: DCVANE



TYPICAL FILL DIVERSION

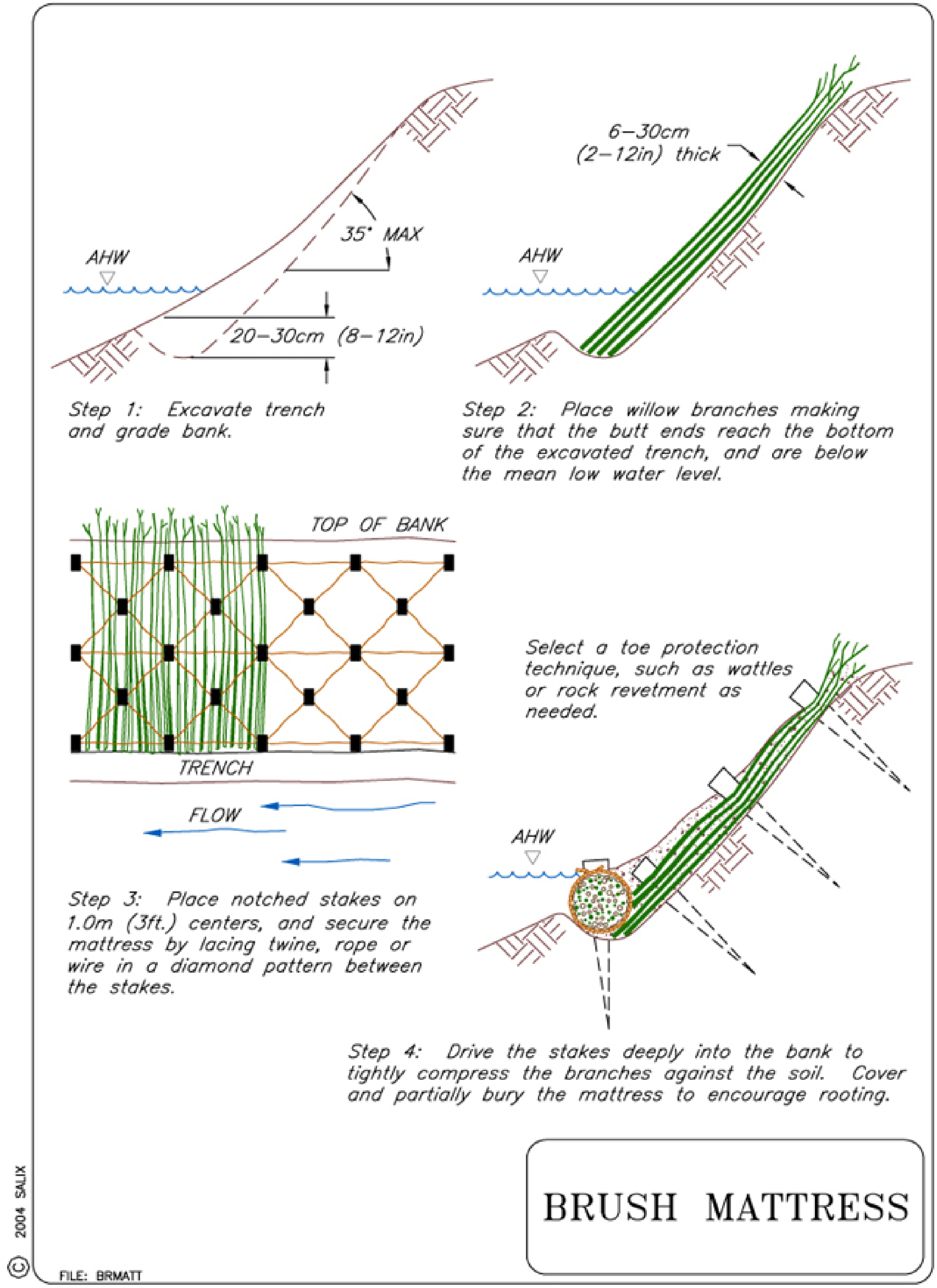


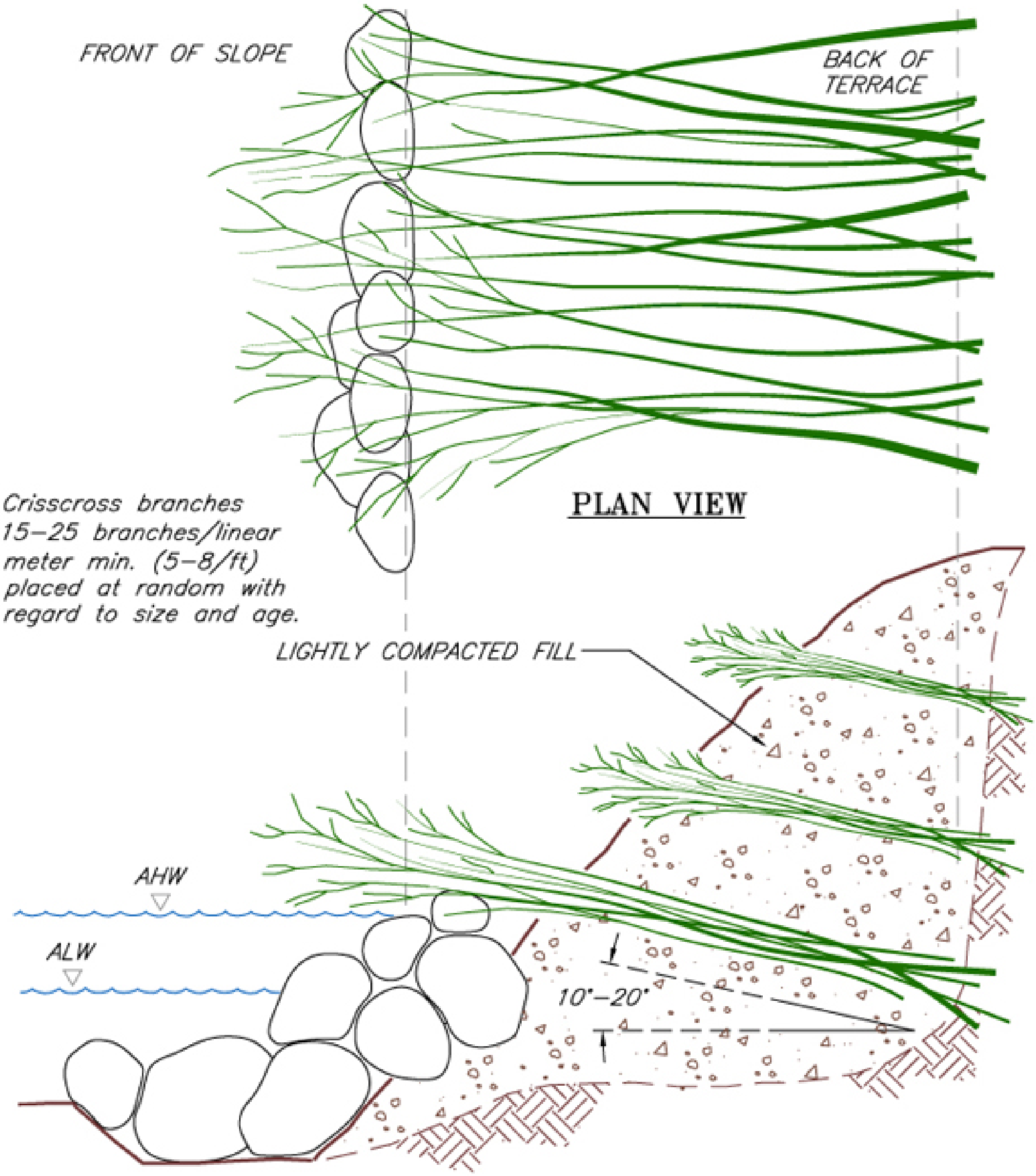
TYPICAL TEMPORARY DIVERSION DIKE

NOTES:
1. THE CHANNEL BEHIND THE DIKE SHOULD HAVE POSITIVE GRADE TO A STABILIZED OUTLET.
2. THE DIKE SHALL BE ADEQUATELY COMPACTED TO PREVENT FAILURE.
3. THE DIKE SHOULD BE STABILIZED WITH TEMPORARY OR PERMANENT SEEDING OR RIPRAP.

DIVERSION DIKE

FILE: DIVDK

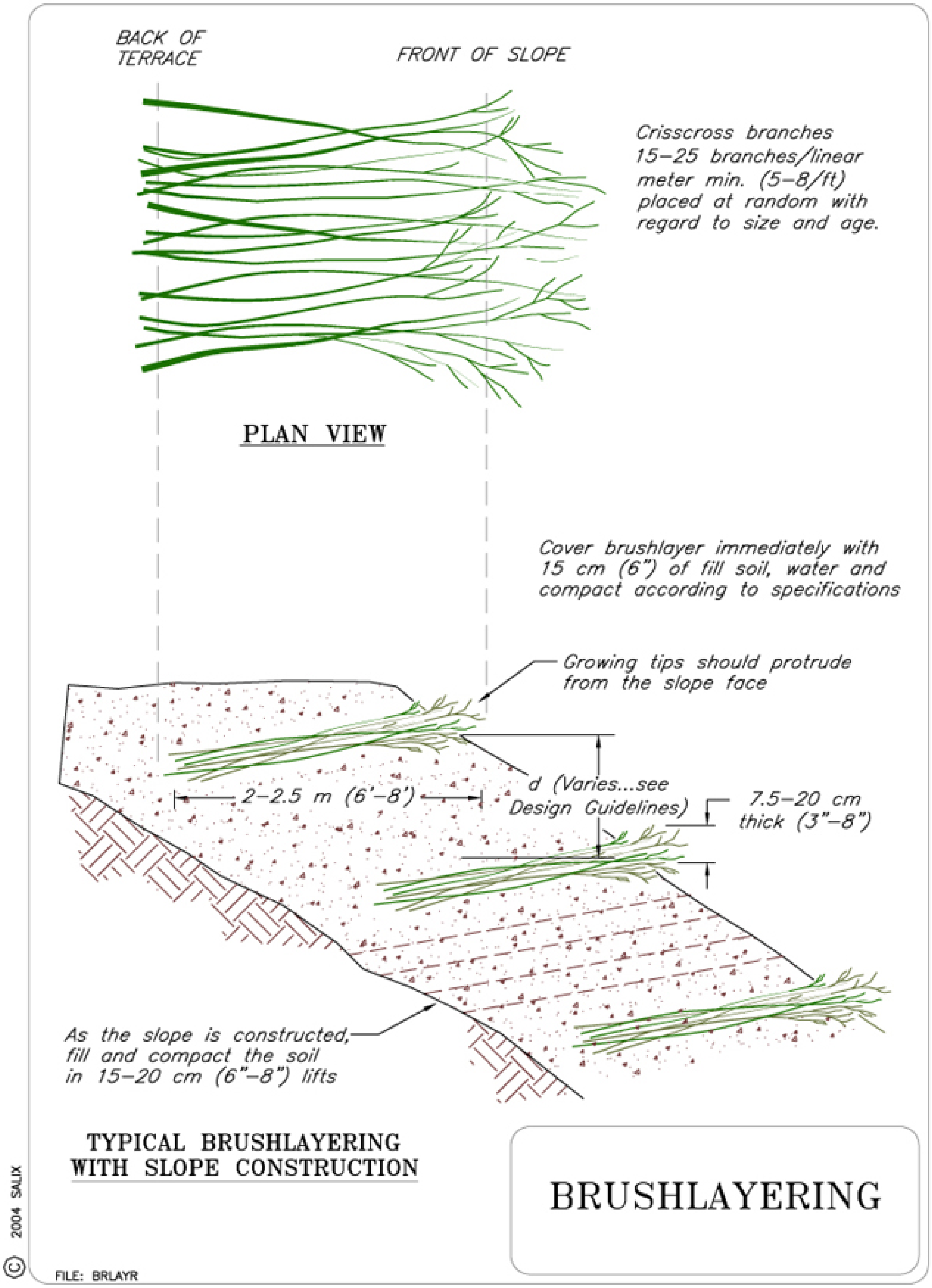

AHW
35° MAX
20–30cm (8–12in)
Step 1: Excavate trench and grade bank.
6–30cm (2–12in) thick
AHW
Step 2: Place willow branches making sure that the butt ends reach the bottom of the excavated trench, and are below the mean low water level.
TOP OF BANK
TRENCH
FLOW
Step 3: Place notched stakes on 1.0m (3ft.) centers, and secure the mattress by lacing twine, rope or wire in a diamond pattern between the stakes.
Select a toe protection technique, such as wattles or rock revetment as needed.
AHW
Step 4: Drive the stakes deeply into the bank to tightly compress the branches against the soil. Cover and partially bury the mattress to encourage rooting.
BRUSH MATTRESS
© 2004 SALIX
FILE: BRMATT

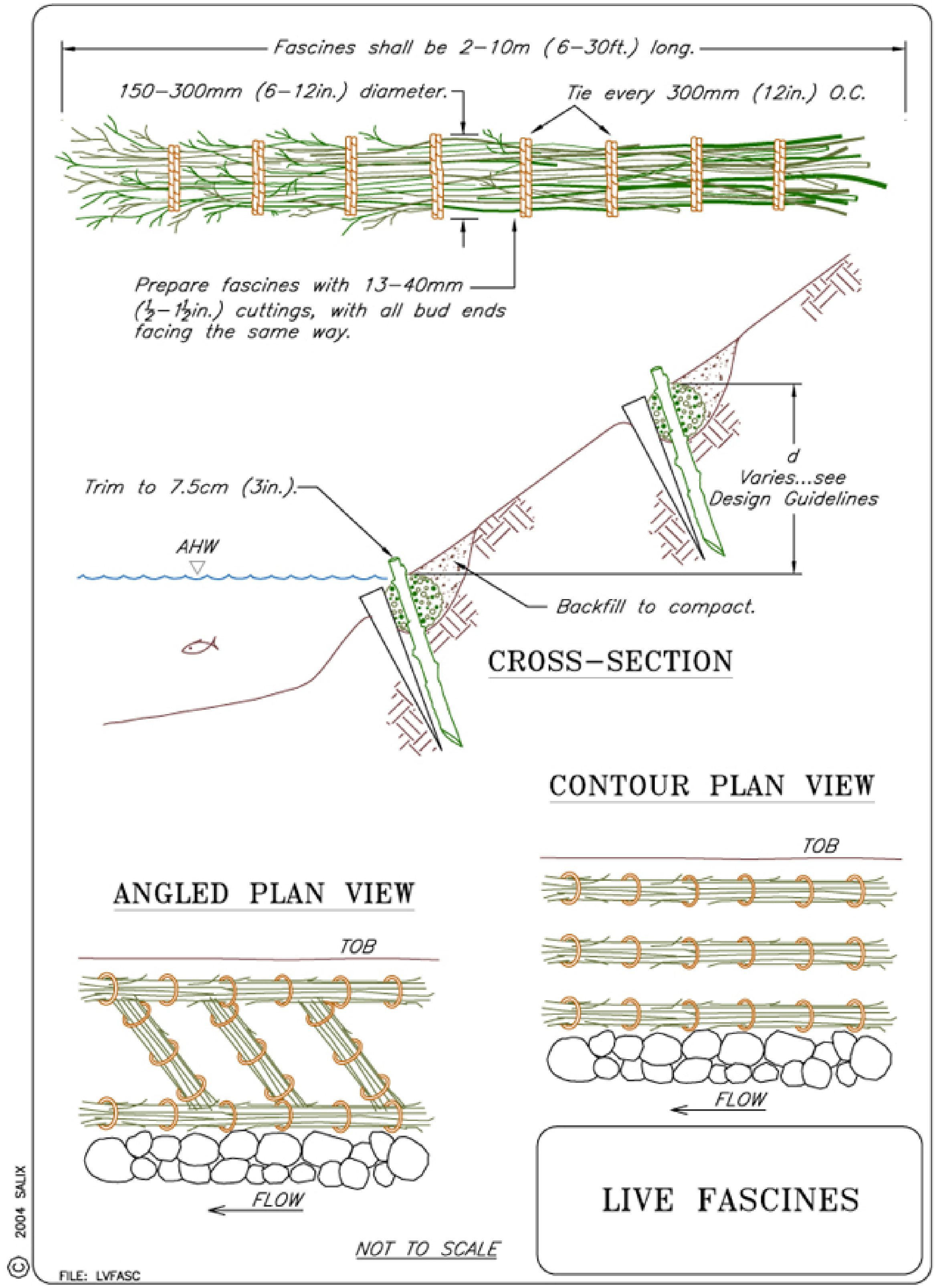


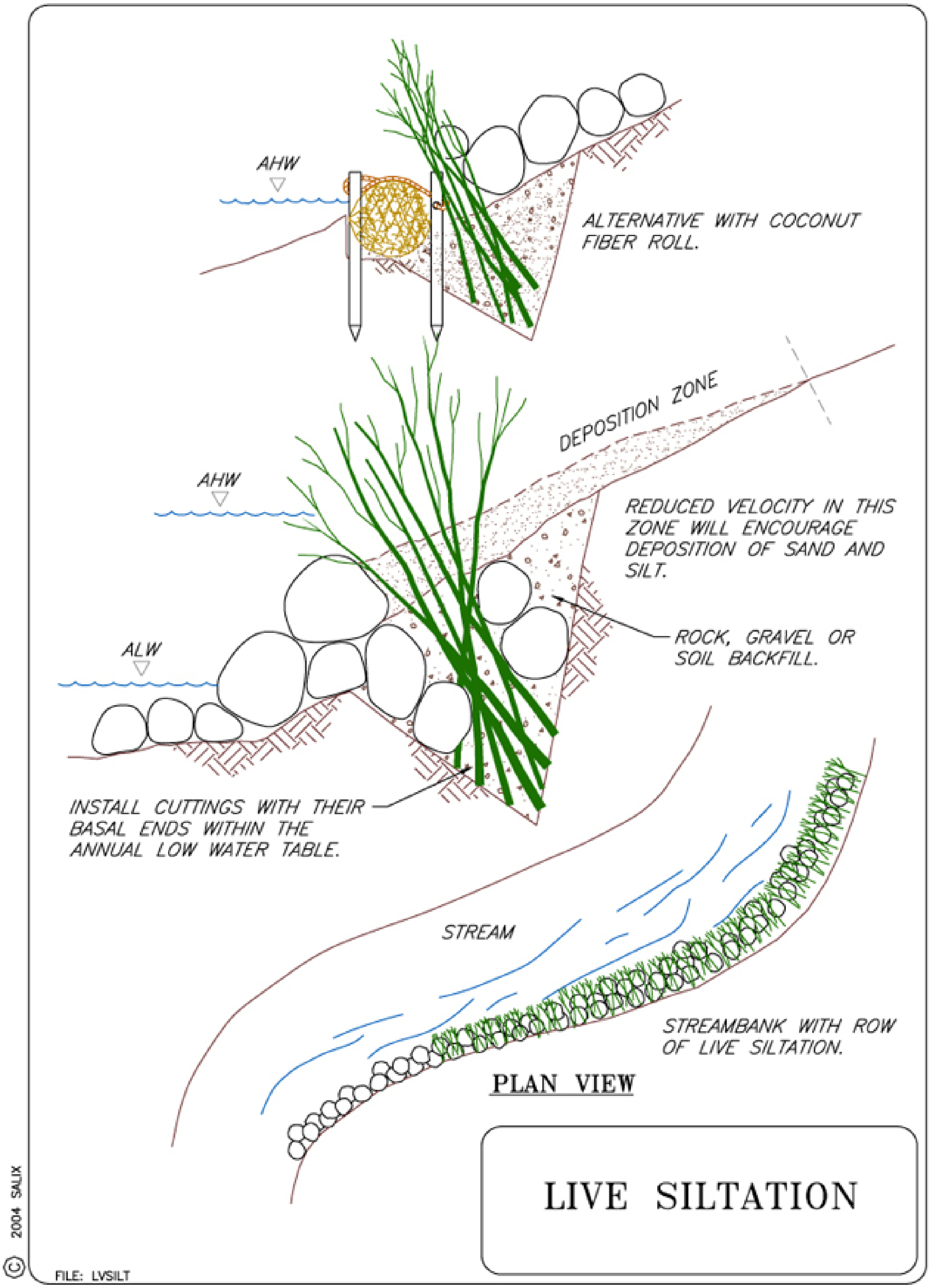
NOTES:
1. Tilt branches down into the slope 10°–20° min.
2. Brushlayering may be constructed with non–compacted or compacted backfill without damage to the brush layer.
3. Branches irrespective of length, should protrude 20–45 cm (8–18in.) beyond the face of the slope.

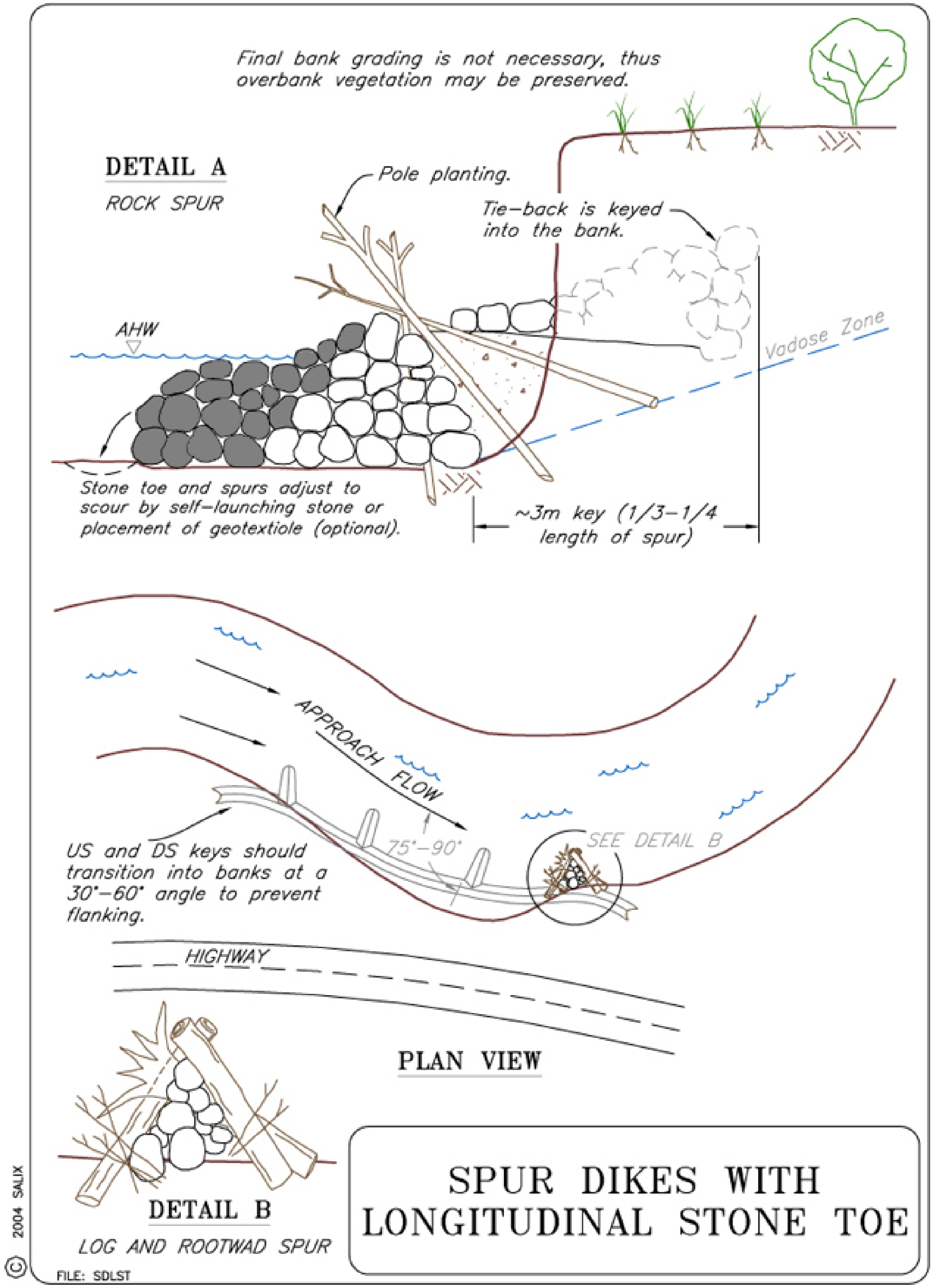
BRUSHLAYERING WITH ROCK TOE PROTECTION

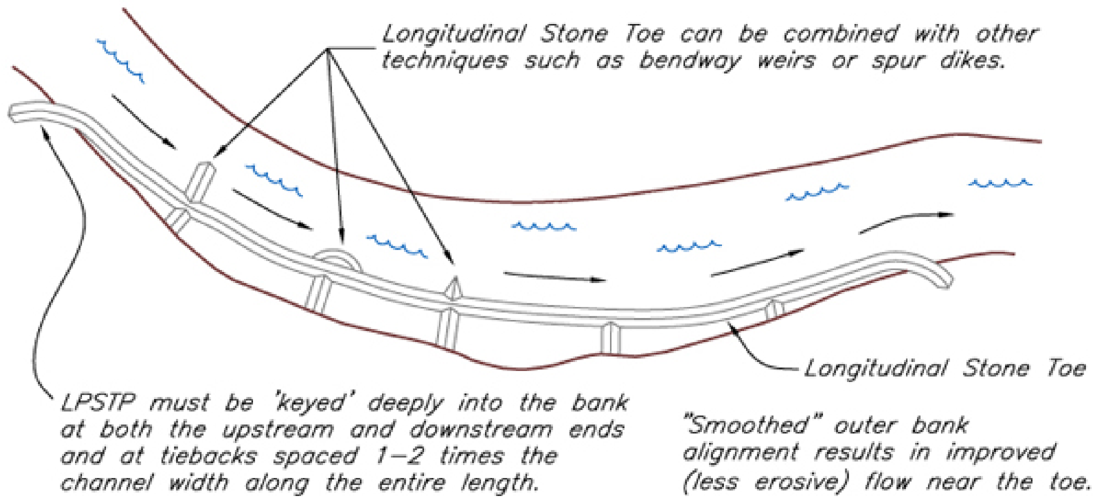
FILE: BLRT


BACK OF
TERRACE
FRONT OF SLOPE
Crisscross branches
15–25 branches/linear
meter min. (5–8/ft)
placed at random with
regard to size and age.
PLAN VIEW
Cover brushlayer immediately with
15 cm (6") of fill soil, water and
compact according to specifications
Growing tips should protrude
from the slope face
d (Varies...see
Design Guidelines)
2–2.5 m (6'–8')
7.5–20 cm
thick (3"–8")
As the slope is constructed,
fill and compact the soil
in 15–20 cm (6"–8") lifts
TYPICAL BRUSHLAYERING
WITH SLOPE CONSTRUCTION
BRUSHLAYERING
© 2004 SALIX
FILE: BRLAYR

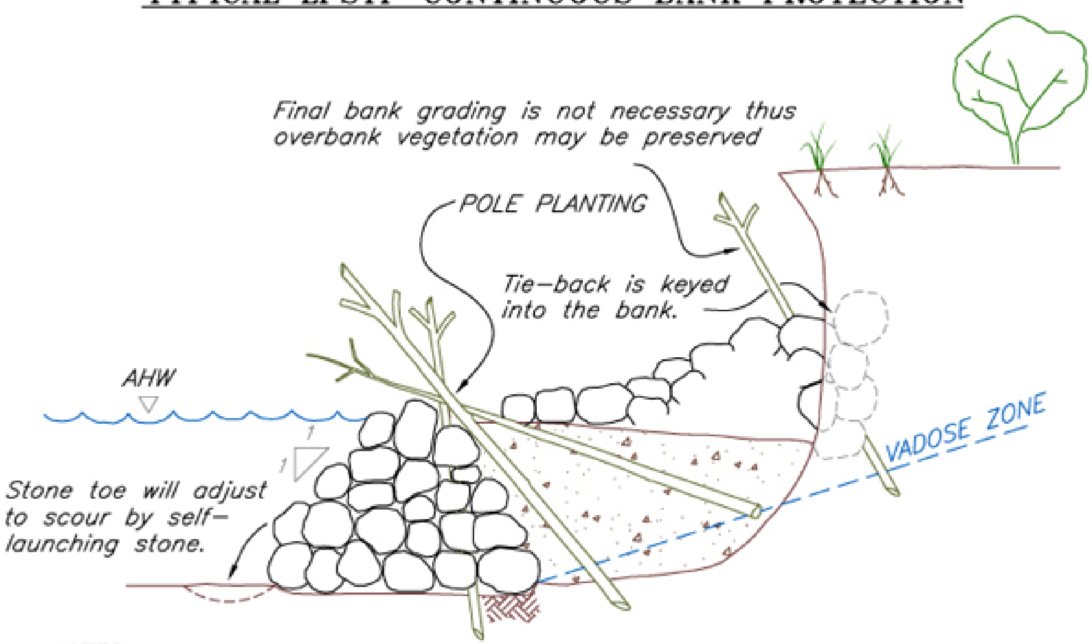

Fascines shall be 2–10m (6–30ft.) long.
150–300mm (6–12in.) diameter.
Tie every 300mm (12in.) O.C.
Prepare fascines with 13–40mm (½–1½in.) cuttings, with all bud ends facing the same way.
d
Varies...see Design Guidelines
Trim to 7.5cm (3in.).
AHW
Backfill to compact.
CROSS–SECTION
CONTOUR PLAN VIEW
TOB
FLOW
ANGLED PLAN VIEW
TOB
FLOW
NOT TO SCALE
LIVE FASCINES
© 2004 SALIX
FILE: LVFASC


AHW
ALTERNATIVE WITH COCONUT FIBER ROLL.
DEPOSITION ZONE
AHW
REDUCED VELOCITY IN THIS ZONE WILL ENCOURAGE DEPOSITION OF SAND AND SILT.
ALW
ROCK, GRAVEL OR SOIL BACKFILL.
INSTALL CUTTINGS WITH THEIR BASAL ENDS WITHIN THE ANNUAL LOW WATER TABLE.
STREAM
STREAMBANK WITH ROW OF LIVE SILTATION.
PLAN VIEW
LIVE SILTATION
© 2004 SALIX
FILE: LVSILT


Final bank grading is not necessary, thus overbank vegetation may be preserved.
DETAIL A
ROCK SPUR
Pole planting.
Tie–back is keyed into the bank.
AHW
Vadose Zone
Stone toe and spurs adjust to scour by self–launching stone or placement of geotextiole (optional).
~3m key (1/3–1/4 length of spur)
APPROACH FLOW
75°–90°
SEE DETAIL B
US and DS keys should transition into banks at a 30°–60° angle to prevent flanking.
HIGHWAY
PLAN VIEW
DETAIL B
LOG AND ROOTWAD SPUR
SPUR DIKES WITH LONGITUDINAL STONE TOE
© 2004 SALIX
FILE: SDLST



TYPICAL LPSTP CONTINUOUS BANK PROTECTION



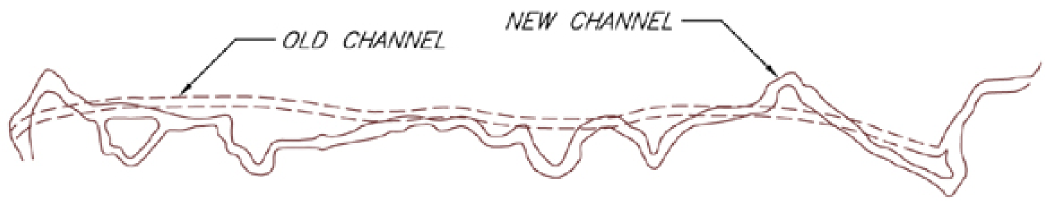
NOTES:

1. Longitudinal stone toe is a good choice when continuous bank protection is needed for the toe, but the mid and upper banks are relatively stable and/or biotechnical practices are suitable.

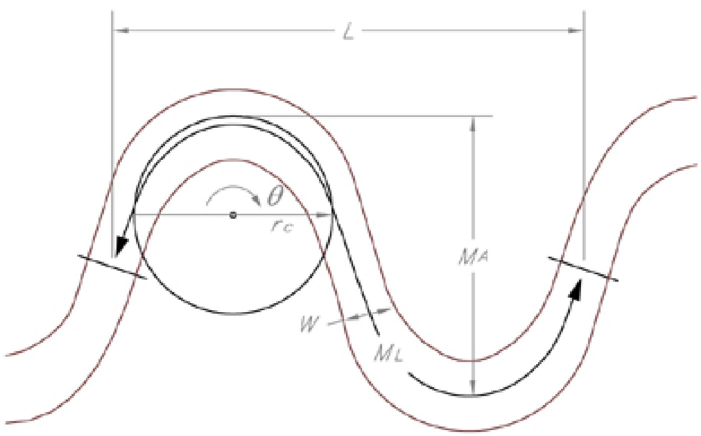
2. The success of Longitudinal Stone Toe depends on the ability of the well–graded stone to self adjust or "launch" into any scour holes formed on the stream side of the stone toe.

LONGITUDINAL STONE TOE

FILE: LST



PLAN VIEW OF AN EXAMPLE MEANDER RESTORATION

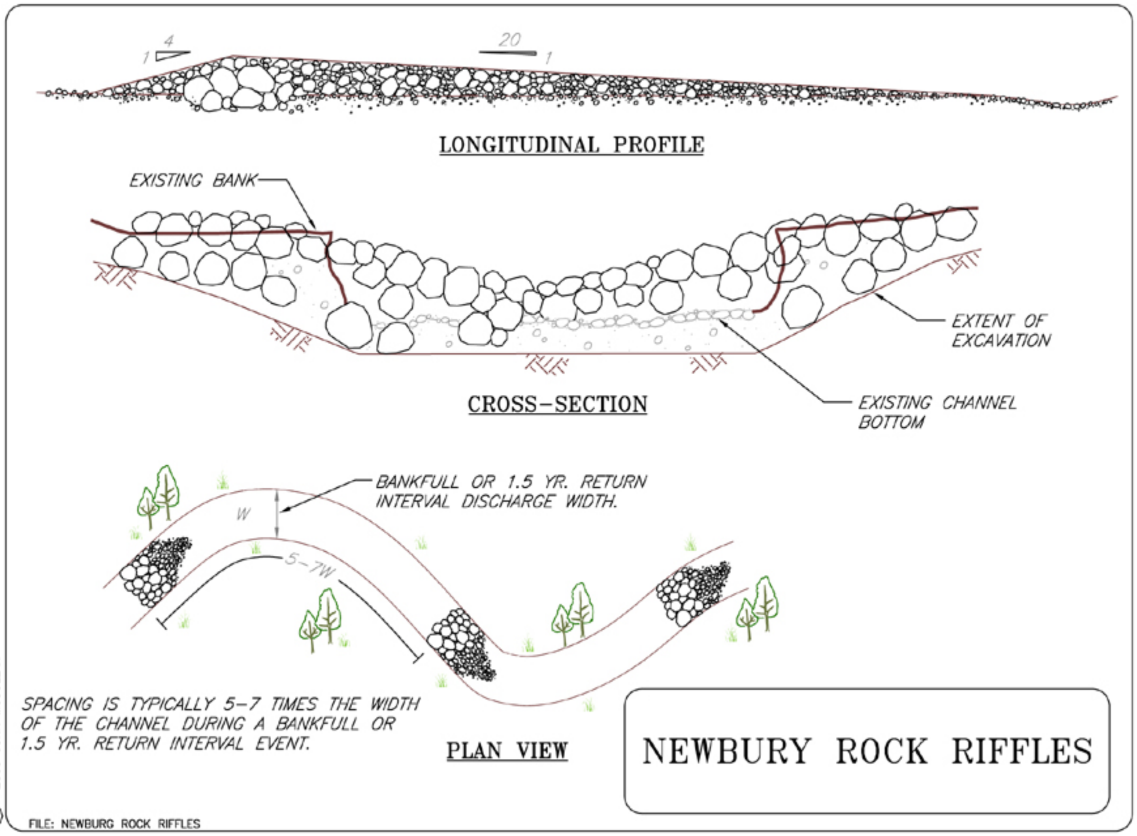


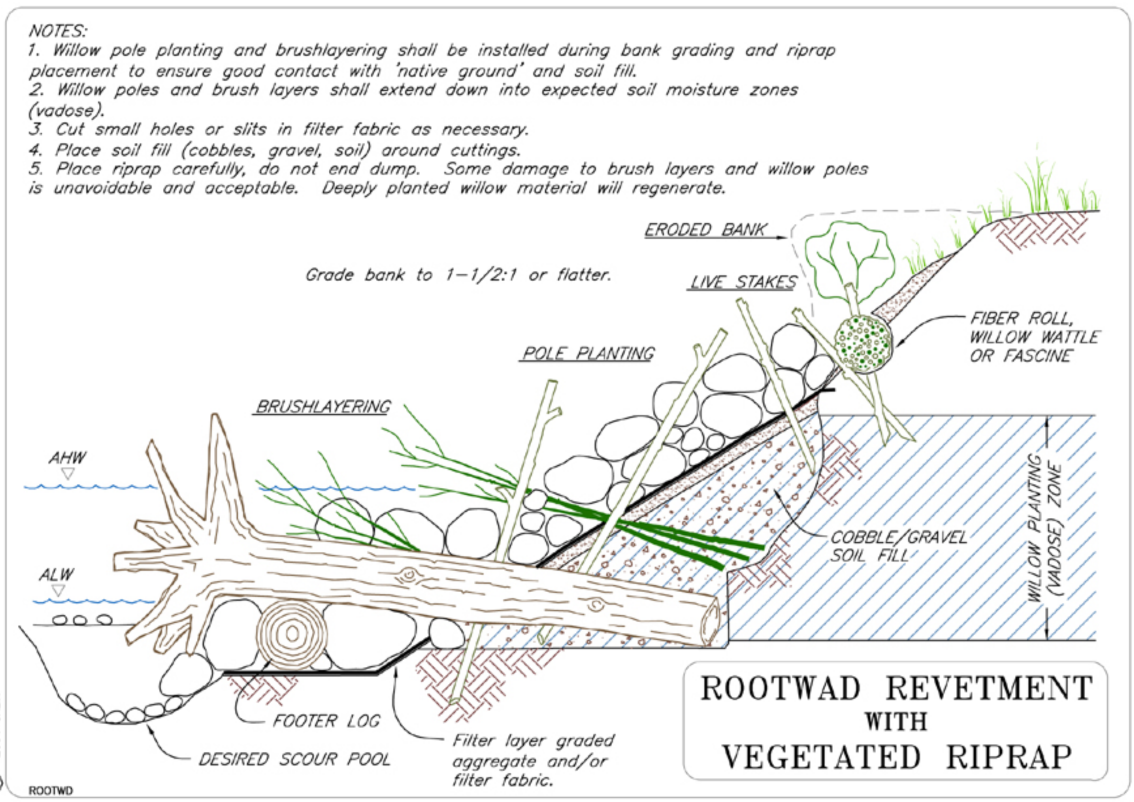
Meander Restoration Design Parameters (adapted from Williams, 1986)

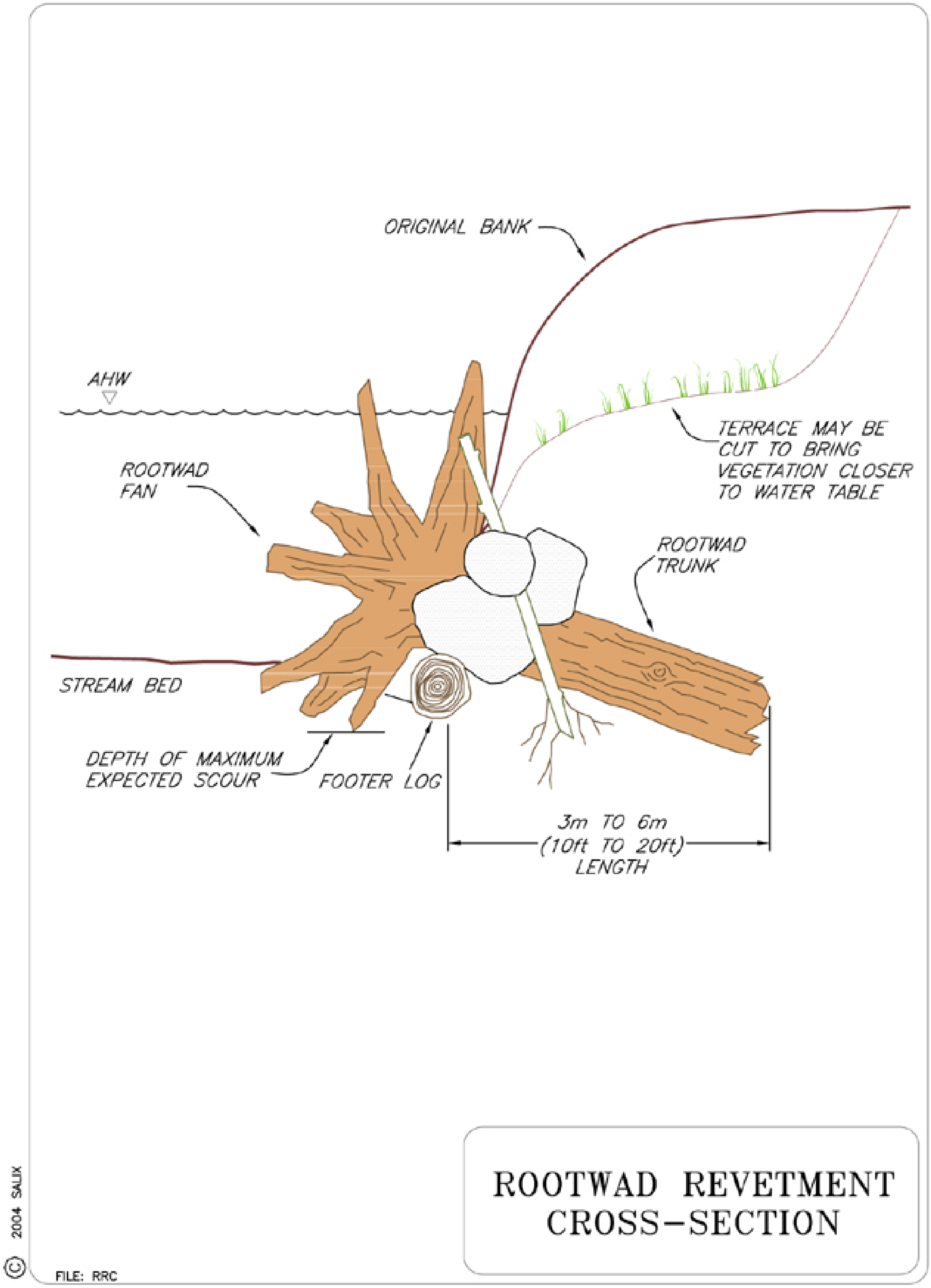
L = meander wavelength
M_L = meander arclength
W = average width at bankfull discharge
M_A = meander amplitude
r_c = radius of curvature
θ = arc angle

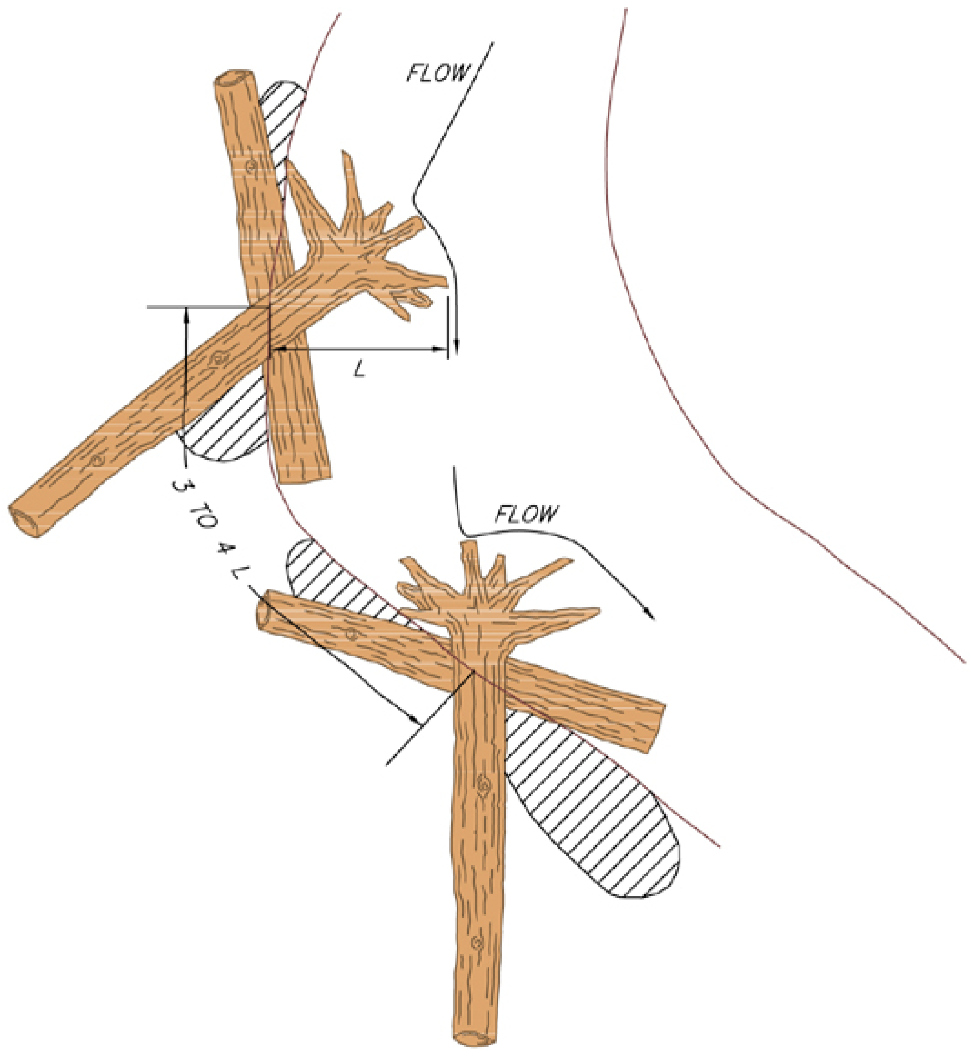
MEANDER RESTORATION

FILE: MNREST


4
1
20
1
LONGITUDINAL PROFILE
EXISTING BANK
EXTENT OF EXCAVATION
CROSS-SECTION
EXISTING CHANNEL BOTTOM
BANKFULL OR 1.5 YR. RETURN INTERVAL DISCHARGE WIDTH.
W
5-7W
SPACING IS TYPICALLY 5-7 TIMES THE WIDTH OF THE CHANNEL DURING A BANKFULL OR 1.5 YR. RETURN INTERVAL EVENT.
PLAN VIEW
NEWBURY ROCK RIFFLES
© 2003 JOHN McCULLAH
FILE: NEWBURG ROCK RIFFLES

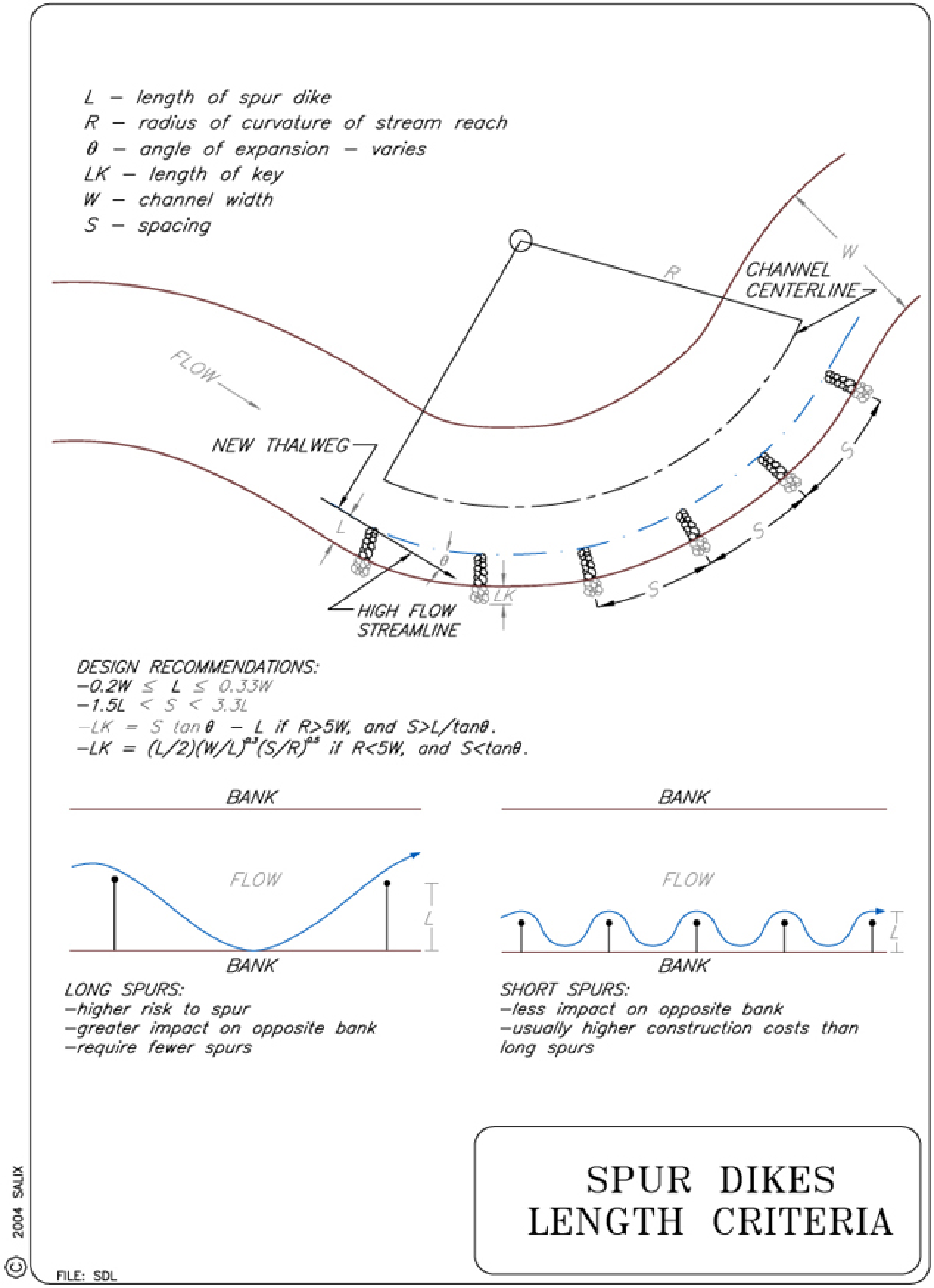

NOTES:
1. Willow pole planting and brushlayering shall be installed during bank grading and riprap placement to ensure good contact with 'native ground' and soil fill.
2. Willow poles and brush layers shall extend down into expected soil moisture zones (vadose).
3. Cut small holes or slits in filter fabric as necessary.
4. Place soil fill (cobbles, gravel, soil) around cuttings.
5. Place riprap carefully, do not end dump. Some damage to brush layers and willow poles is unavoidable and acceptable. Deeply planted willow material will regenerate.
ERODED BANK
Grade bank to 1-1/2:1 or flatter.
LIVE STAKES
FIBER ROLL, WILLOW WATTLE OR FASCINE
POLE PLANTING
BRUSHLAYERING
AHW
ALW
COBBLE/GRAVEL SOIL FILL
WILLOW PLANTING (VADOSE) ZONE
FOOTER LOG
DESIRED SCOUR POOL
Filter layer graded aggregate and/or filter fabric.
ROOTWAD REVETMENT WITH VEGETATED RIPRAP
© 2004 SALIX
ROOTWD

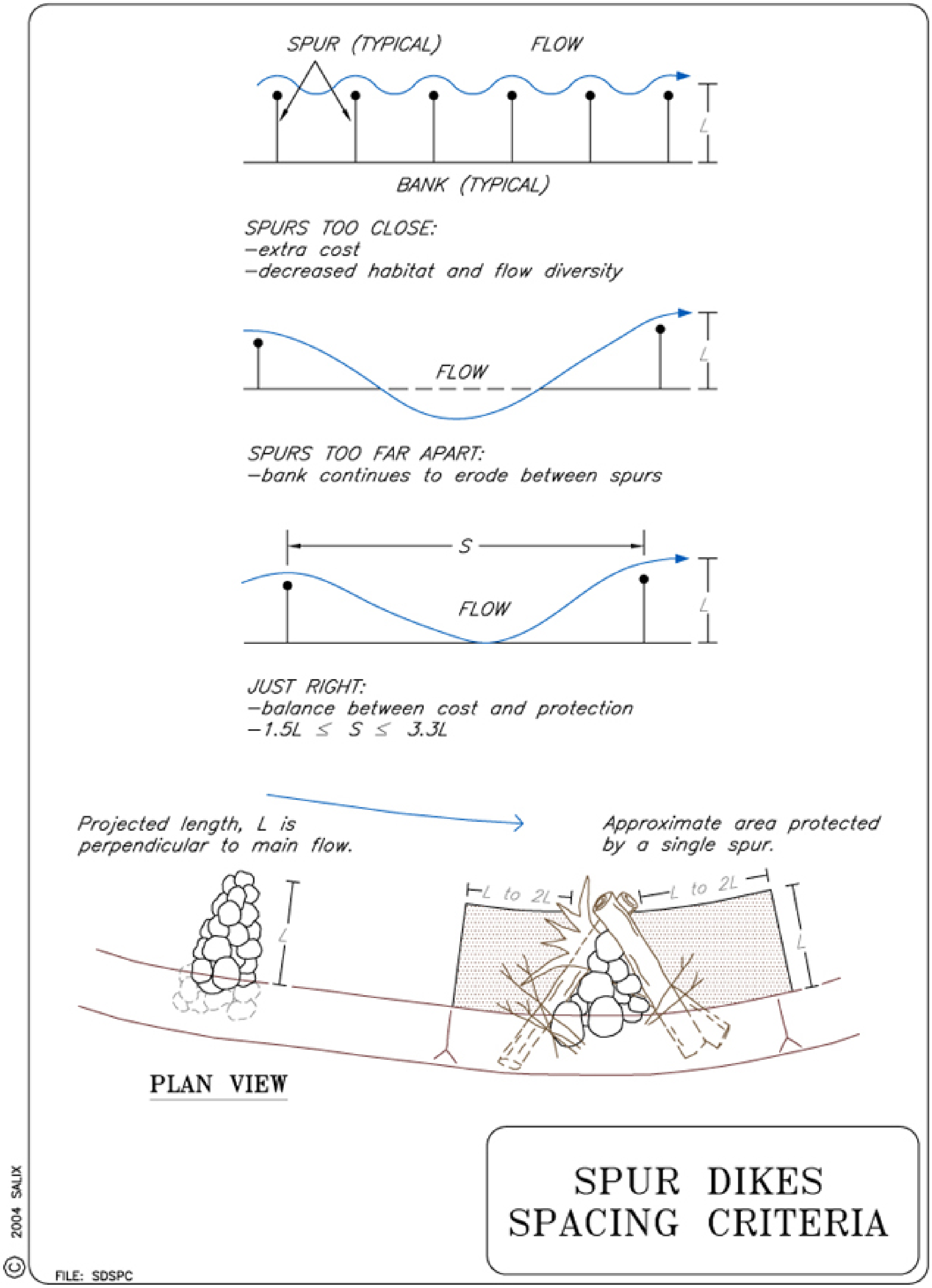

ORIGINAL BANK
AHW
ROOTWAD FAN
TERRACE MAY BE CUT TO BRING VEGETATION CLOSER TO WATER TABLE
ROOTWAD TRUNK
STREAM BED
DEPTH OF MAXIMUM EXPECTED SCOUR
FOOTER LOG
3m TO 6m (10ft TO 20ft) LENGTH
ROOTWAD REVETMENT CROSS–SECTION
© 2004 SALIX
FILE: RRC

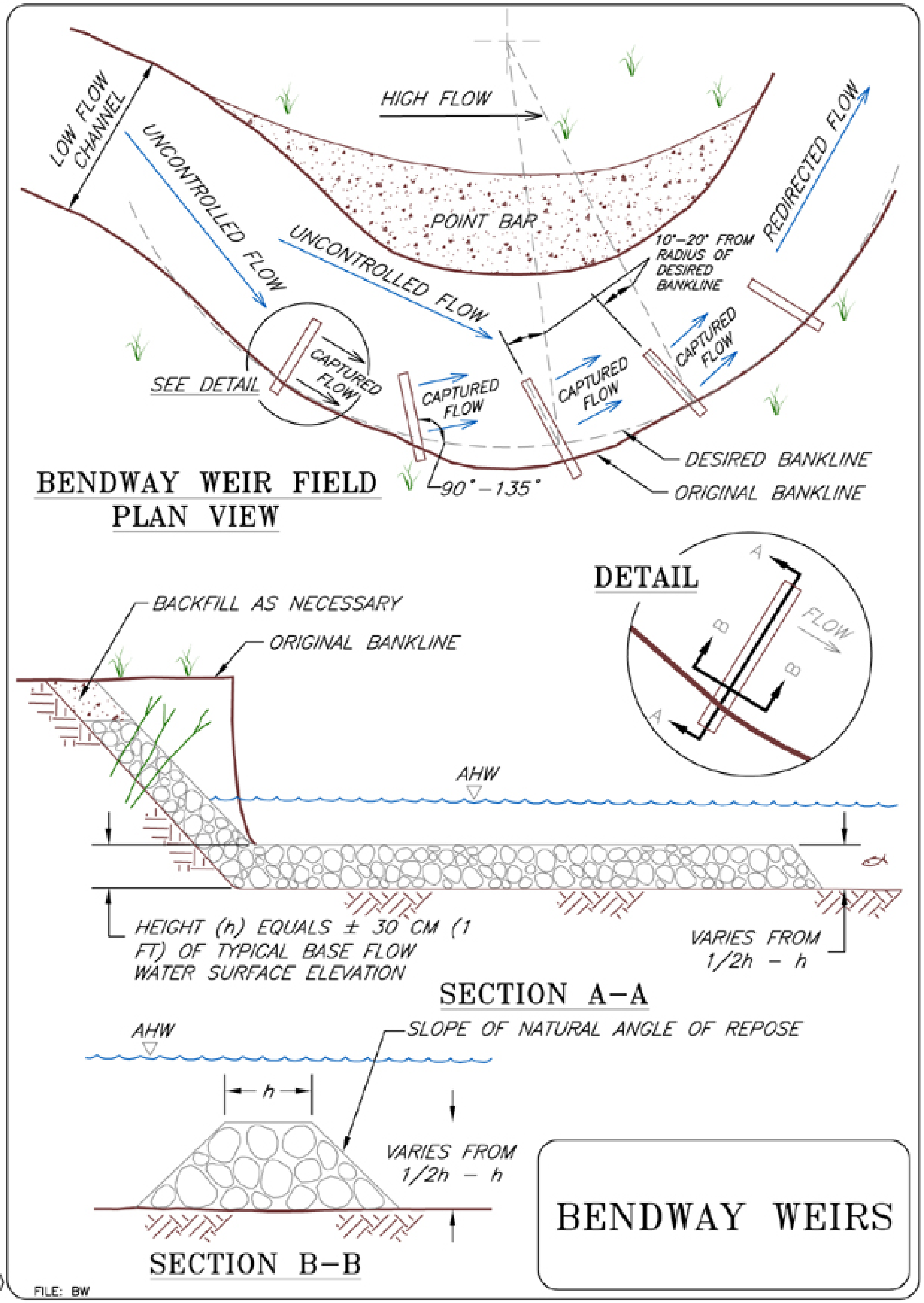


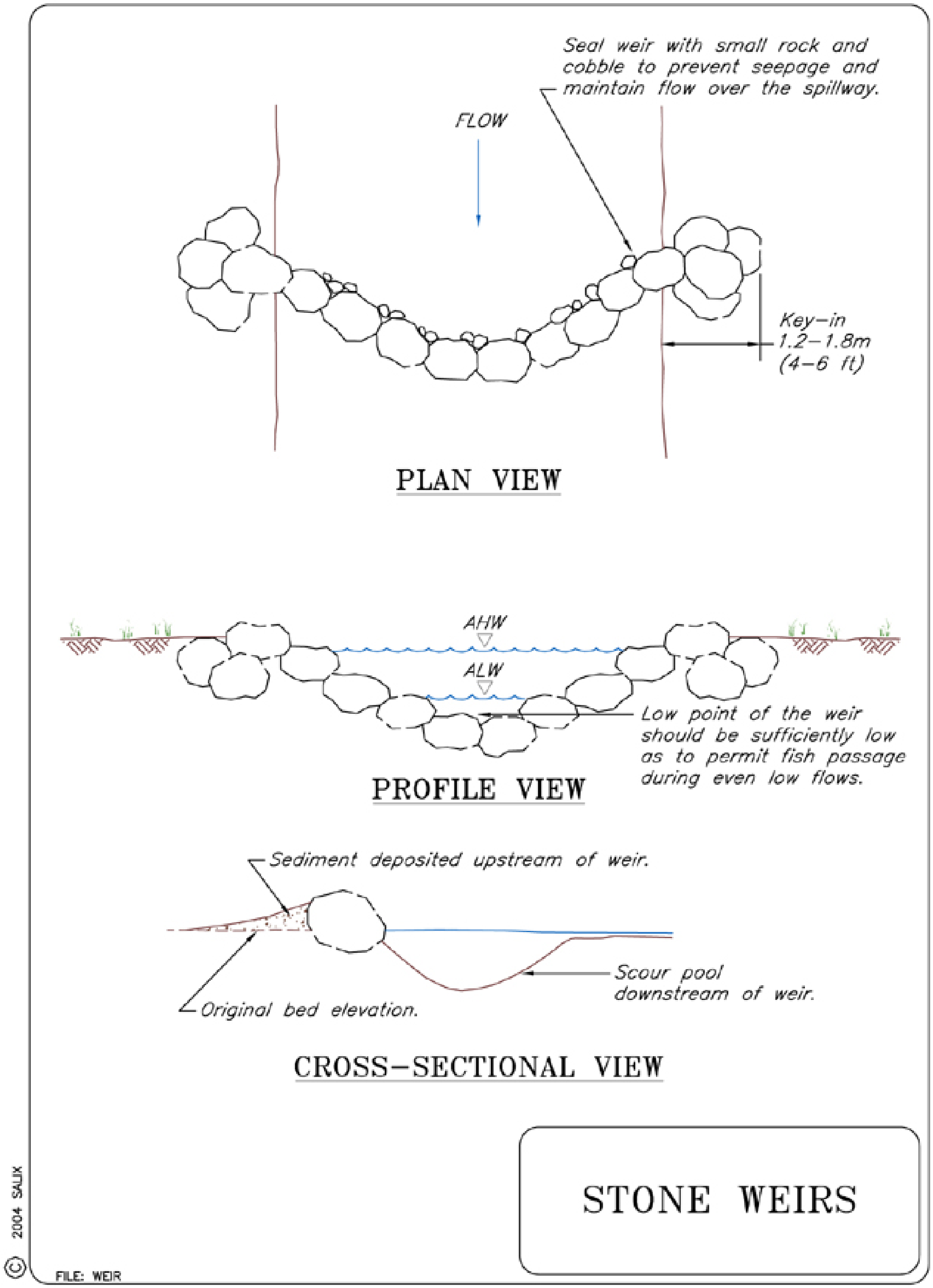
ROOTWAD REVETMENT
PLAN VIEW

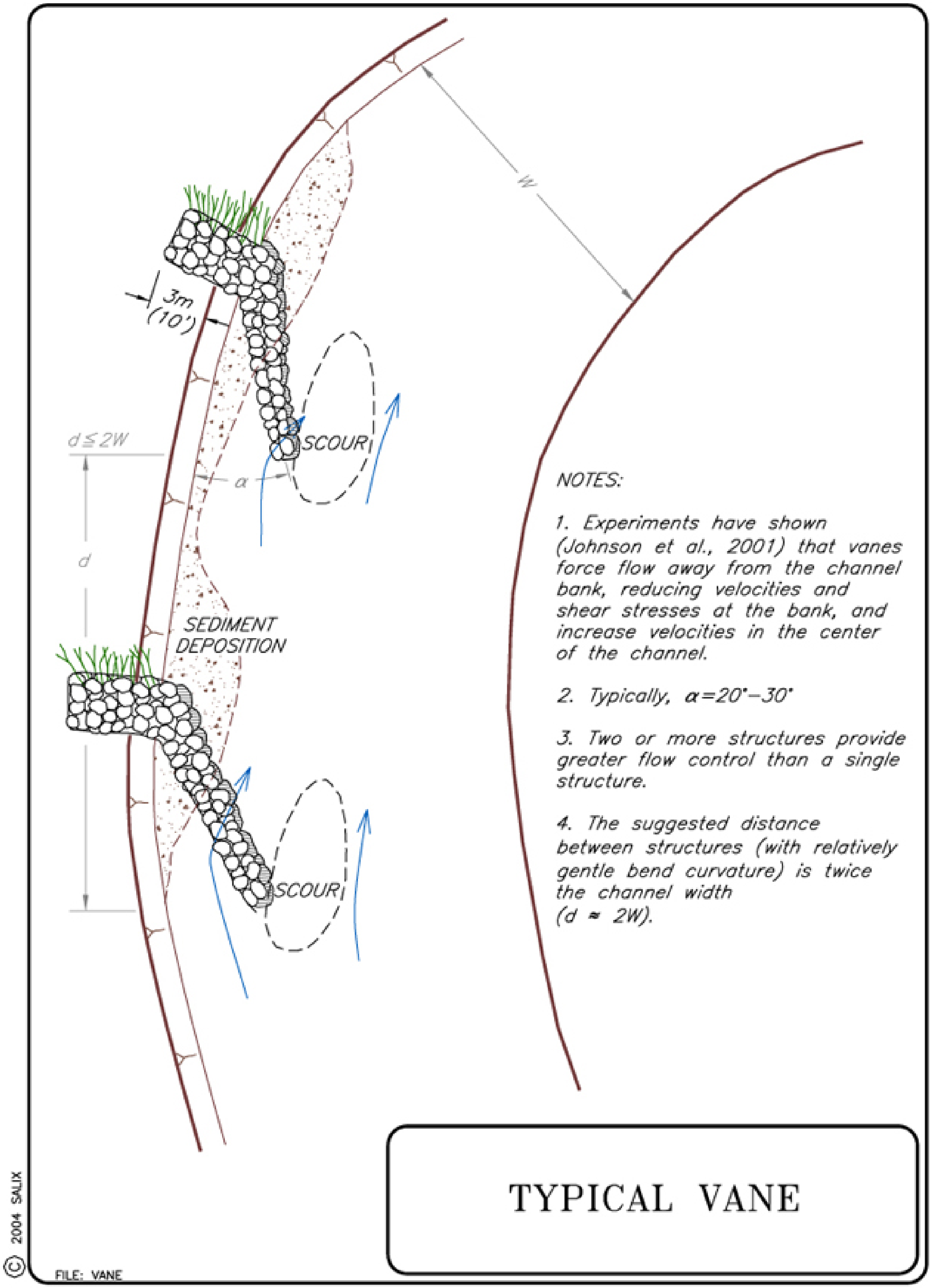
FILE: RRP

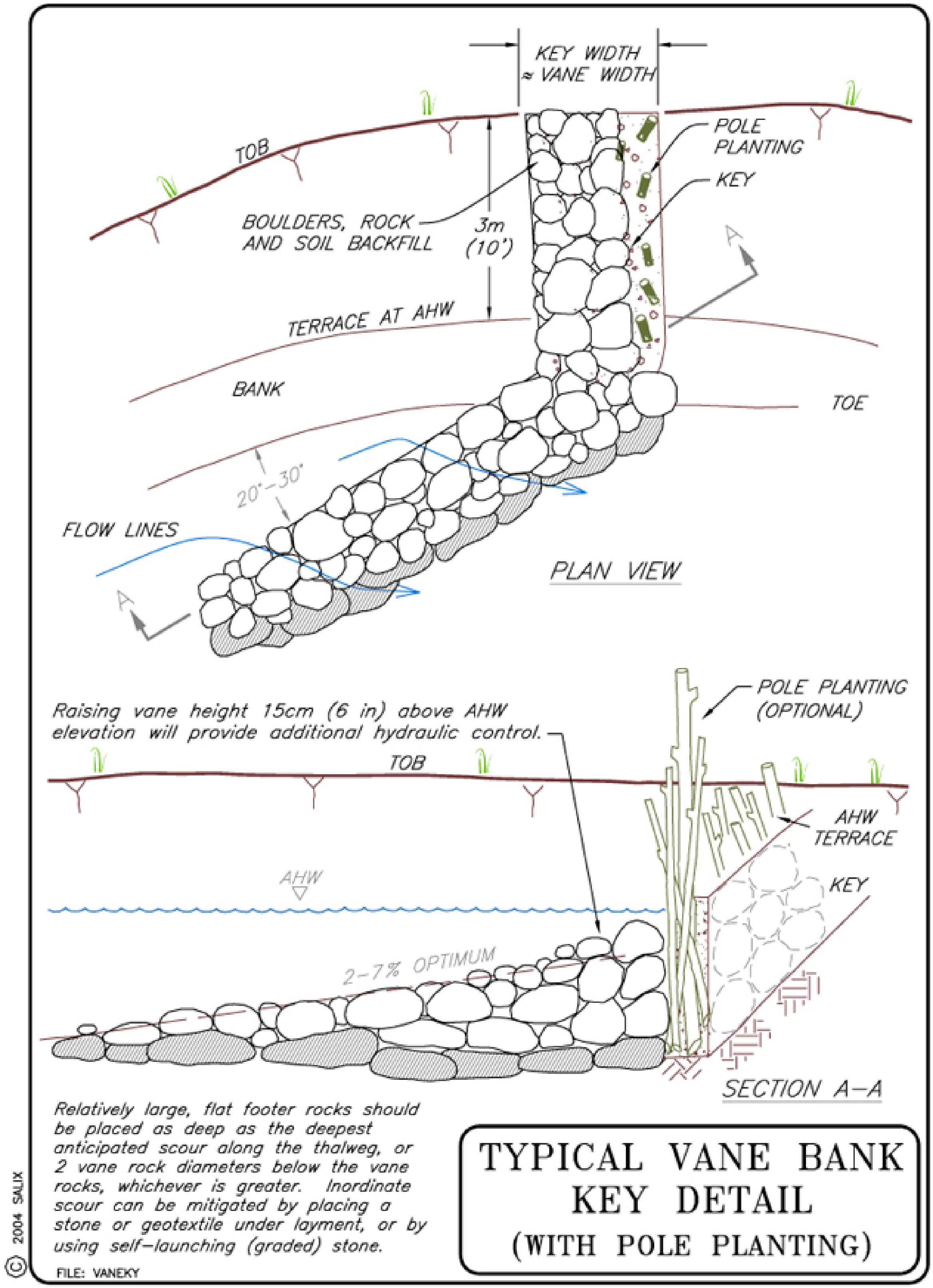

L – length of spur dike
R – radius of curvature of stream reach
θ – angle of expansion – varies
LK – length of key
W – channel width
S – spacing
FLOW
W
R
CHANNEL CENTERLINE
NEW THALWEG
L
θ
LK
S
S
S
HIGH FLOW STREAMLINE
DESIGN RECOMMENDATIONS:
−0.2W ≤ L ≤ 0.33W
−1.5L < S < 3.3L
−LK = S tanθ − L if R>5W, and S>L/tanθ.
−LK = (L/2)(W/L)^0.3(S/R)^0.5 if R<5W, and S<tanθ.
BANK
FLOW
L
BANK
LONG SPURS:
−higher risk to spur
−greater impact on opposite bank
−require fewer spurs
BANK
FLOW
L
BANK
SHORT SPURS:
−less impact on opposite bank
−usually higher construction costs than long spurs
SPUR DIKES
LENGTH CRITERIA
© 2004 SALIX
FILE: SDL

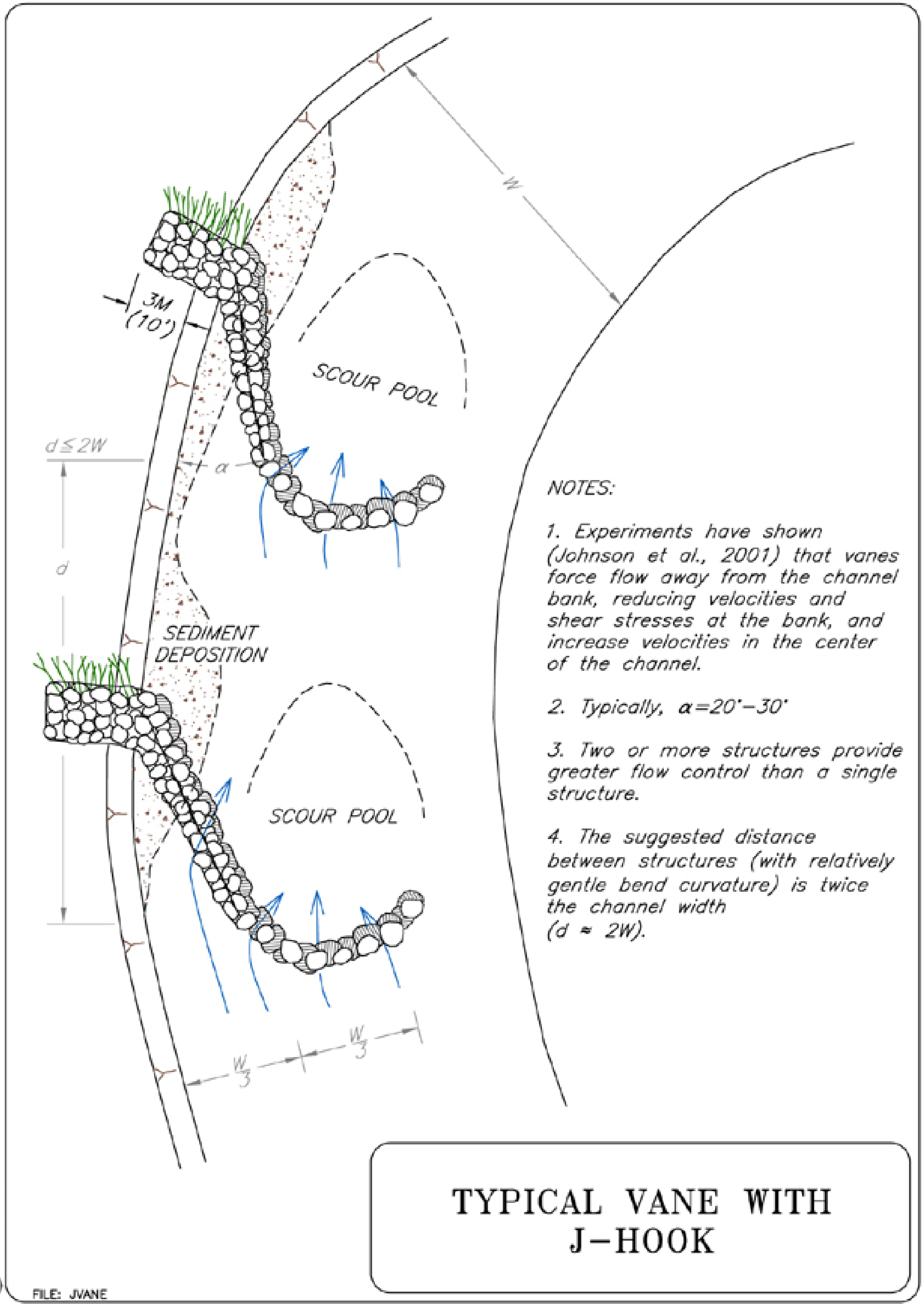

SPUR (TYPICAL)
FLOW
L
BANK (TYPICAL)
SPURS TOO CLOSE:
-extra cost
-decreased habitat and flow diversity
FLOW
L
SPURS TOO FAR APART:
-bank continues to erode between spurs
S
FLOW
L
JUST RIGHT:
-balance between cost and protection
-1.5L ≤ S ≤ 3.3L
Projected length, L is perpendicular to main flow.
Approximate area protected by a single spur.
L to 2L
L to 2L
L
L
PLAN VIEW
SPUR DIKES
SPACING CRITERIA
© 2004 SALIX
FILE: SDSPC


HIGH FLOW
LOW FLOW CHANNEL
UNCONTROLLED FLOW
UNCONTROLLED FLOW
POINT BAR
REDIRECTED FLOW
10°–20° FROM RADIUS OF DESIRED BANKLINE
SEE DETAIL
CAPTURED FLOW
CAPTURED FLOW
CAPTURED FLOW
CAPTURED FLOW
DESIRED BANKLINE
ORIGINAL BANKLINE
90°–135°
BENDWAY WEIR FIELD PLAN VIEW
DETAIL
FLOW
BACKFILL AS NECESSARY
ORIGINAL BANKLINE
AHW
HEIGHT (h) EQUALS ± 30 CM (1 FT) OF TYPICAL BASE FLOW WATER SURFACE ELEVATION
VARIES FROM 1/2h – h
SECTION A–A
AHW
SLOPE OF NATURAL ANGLE OF REPOSE
h
VARIES FROM 1/2h – h
SECTION B–B
BENDWAY WEIRS
© 2004 SALIX
FILE: BW

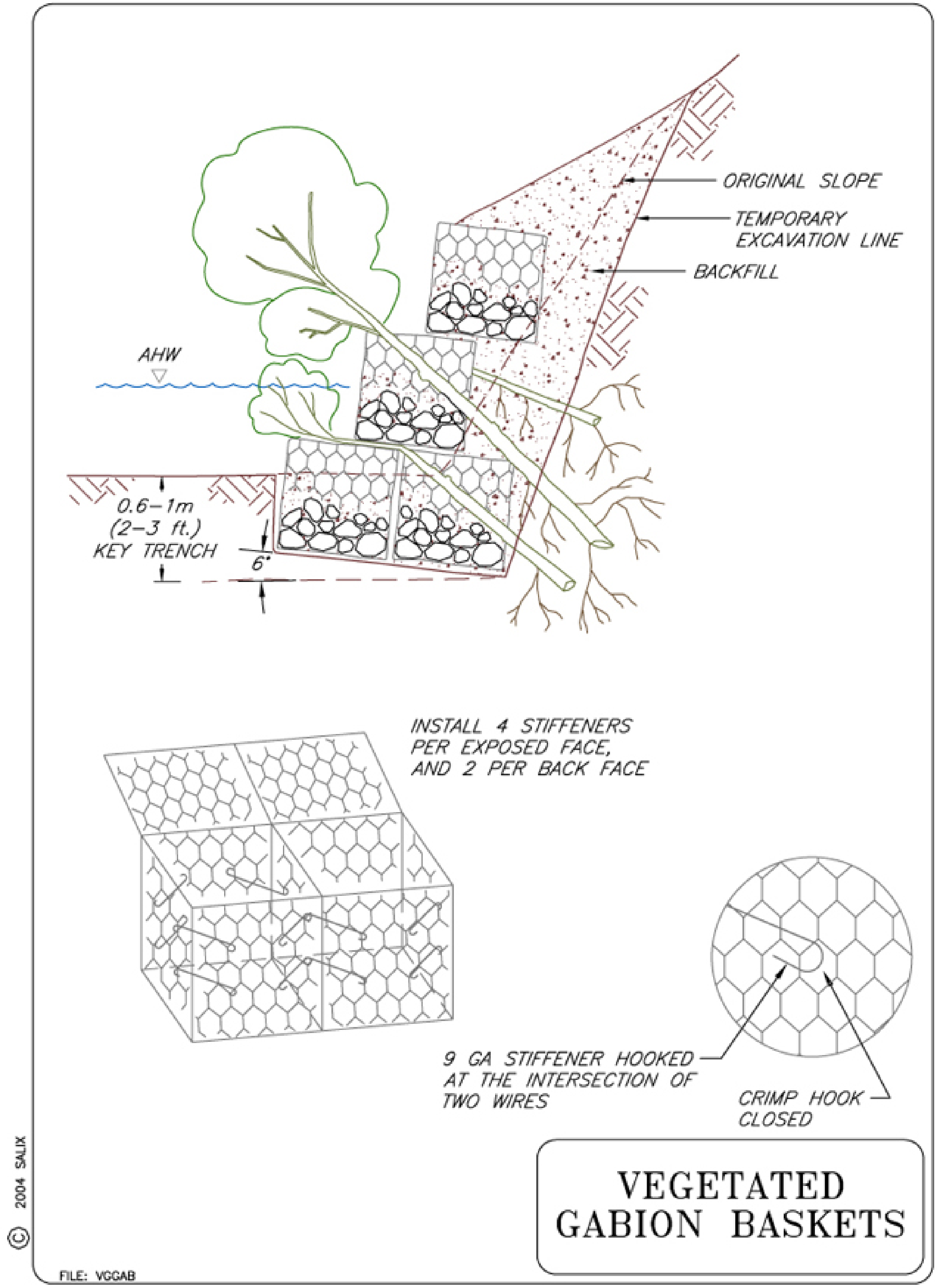

Seal weir with small rock and cobble to prevent seepage and maintain flow over the spillway.
FLOW
Key–in 1.2–1.8m (4–6 ft)
PLAN VIEW
AHW
ALW
Low point of the weir should be sufficiently low as to permit fish passage during even low flows.
PROFILE VIEW
Sediment deposited upstream of weir.
Scour pool downstream of weir.
Original bed elevation.
CROSS–SECTIONAL VIEW
STONE WEIRS
© 2004 SALIX
FILE: WEIR

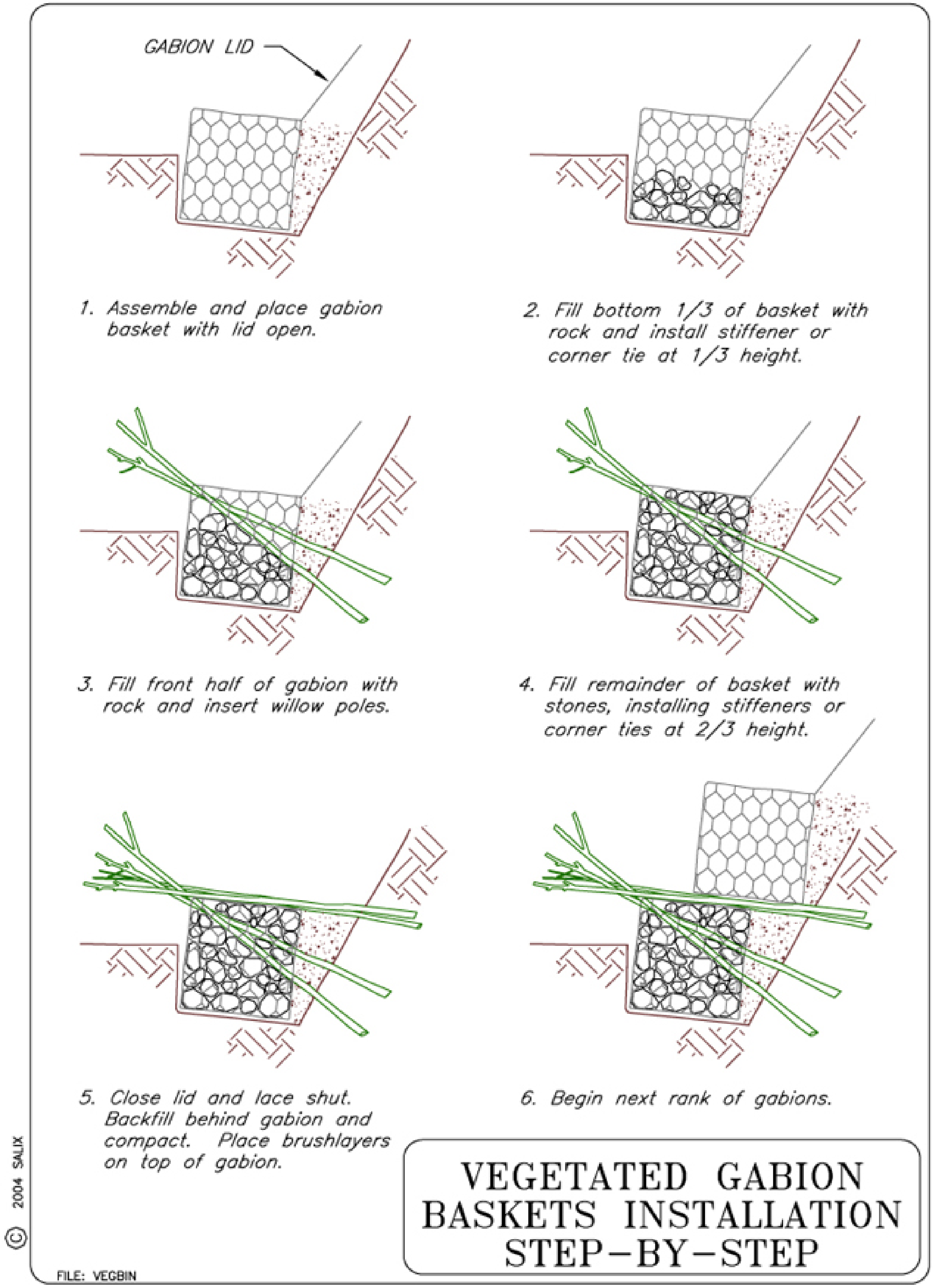

W
3m
(10')
d≦2W
d
α
SCOUR
SEDIMENT
DEPOSITION
SCOUR
NOTES:
1. Experiments have shown (Johnson et al., 2001) that vanes force flow away from the channel bank, reducing velocities and shear stresses at the bank, and increase velocities in the center of the channel.
2. Typically, α=20°–30°
3. Two or more structures provide greater flow control than a single structure.
4. The suggested distance between structures (with relatively gentle bend curvature) is twice the channel width (d ≈ 2W).
TYPICAL VANE
© 2004 SALIX
FILE: VANE

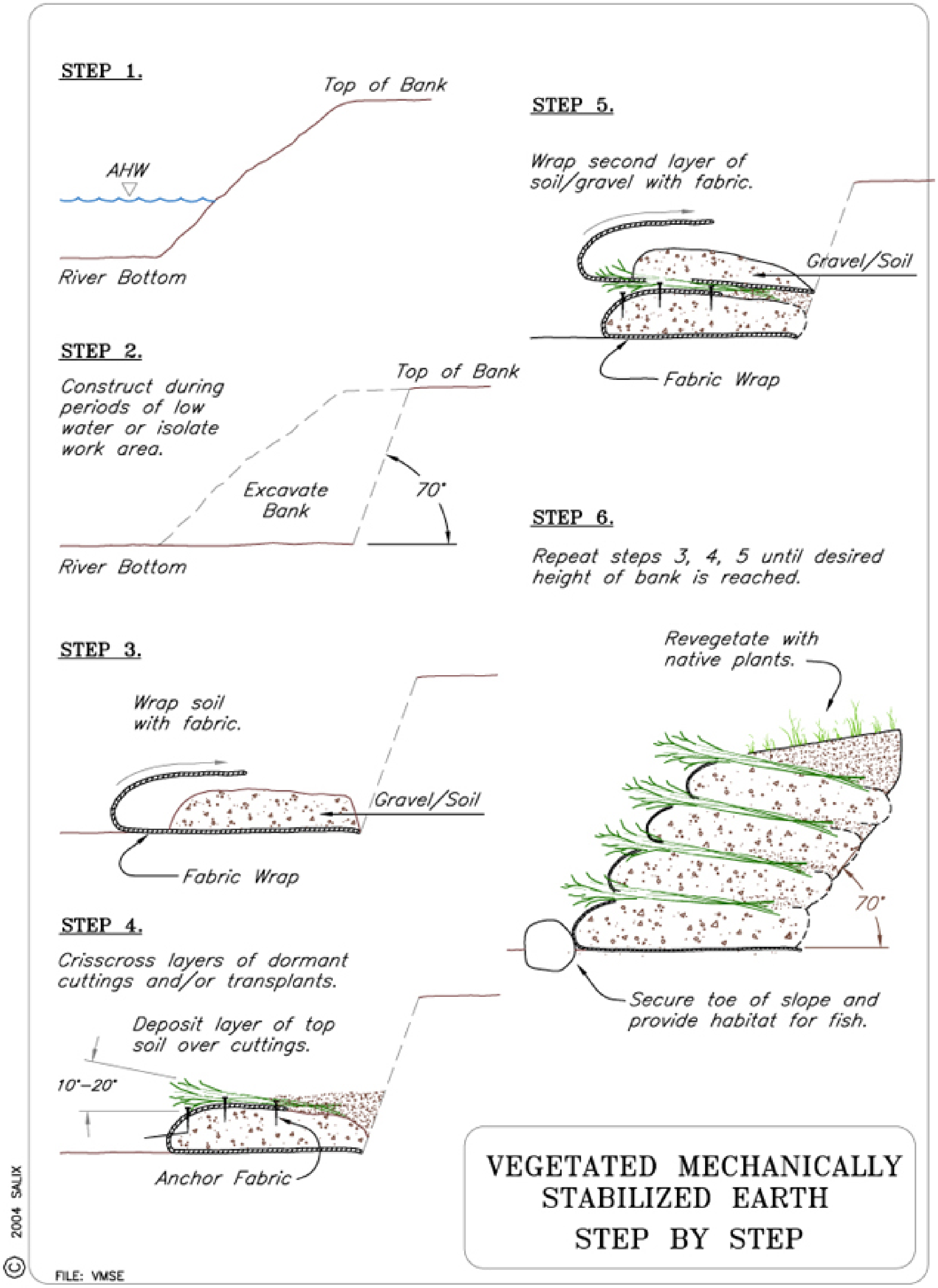

KEY WIDTH
≈ VANE WIDTH
POLE
PLANTING
KEY
TOB
BOULDERS, ROCK
AND SOIL BACKFILL
3m
(10')
TERRACE AT AHW
BANK
TOE
20°–30°
FLOW LINES
PLAN VIEW
A
A
POLE PLANTING
(OPTIONAL)
Raising vane height 15cm (6 in) above AHW
elevation will provide additional hydraulic control.
TOB
AHW
TERRACE
KEY
AHW
2–7% OPTIMUM
SECTION A–A
Relatively large, flat footer rocks should
be placed as deep as the deepest
anticipated scour along the thalweg, or
2 vane rock diameters below the vane
rocks, whichever is greater. Inordinate
scour can be mitigated by placing a
stone or geotextile under layment, or by
using self–launching (graded) stone.
TYPICAL VANE BANK
KEY DETAIL
(WITH POLE PLANTING)
© 2004 SALIX
FILE: VANEKY

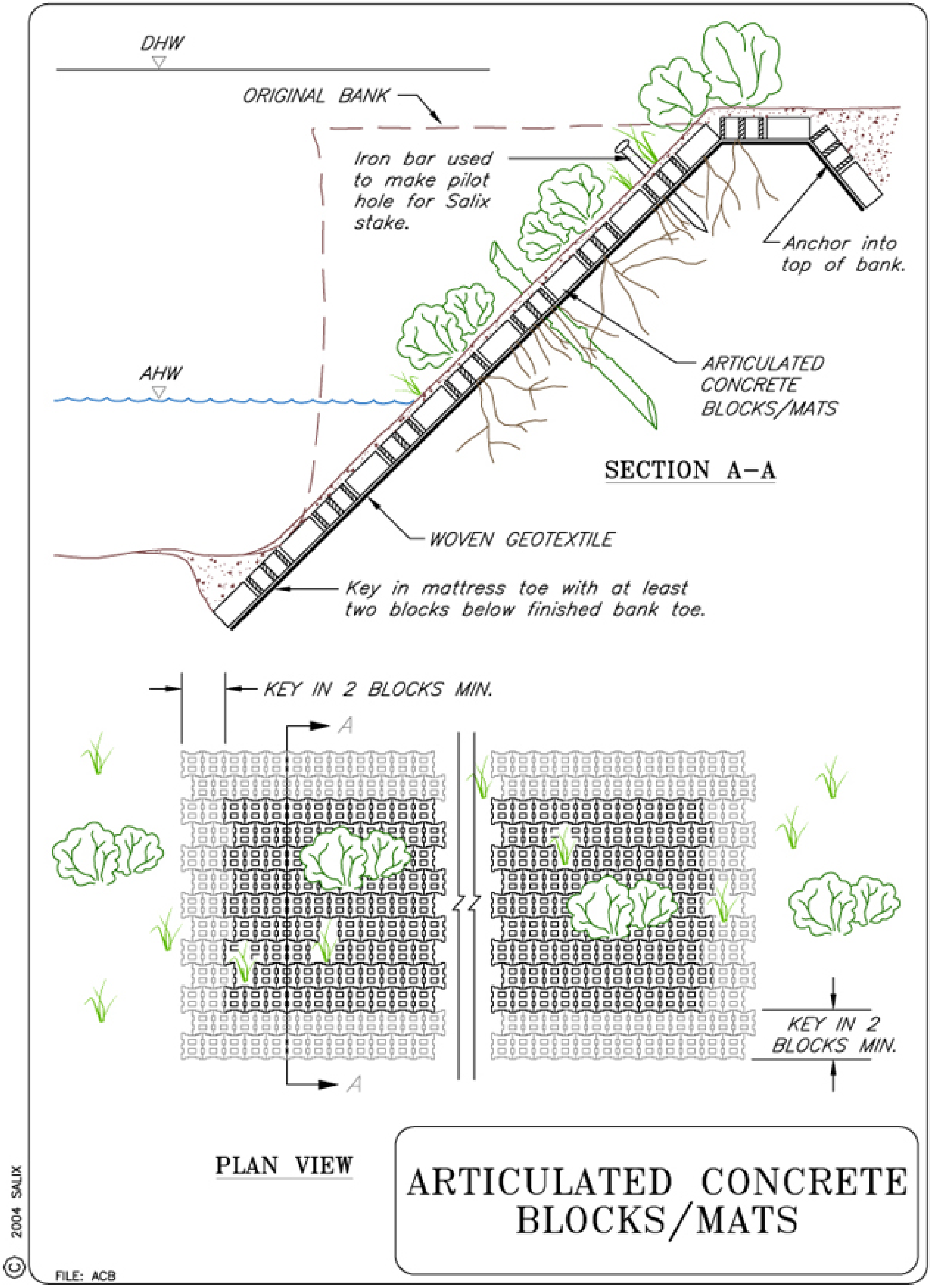


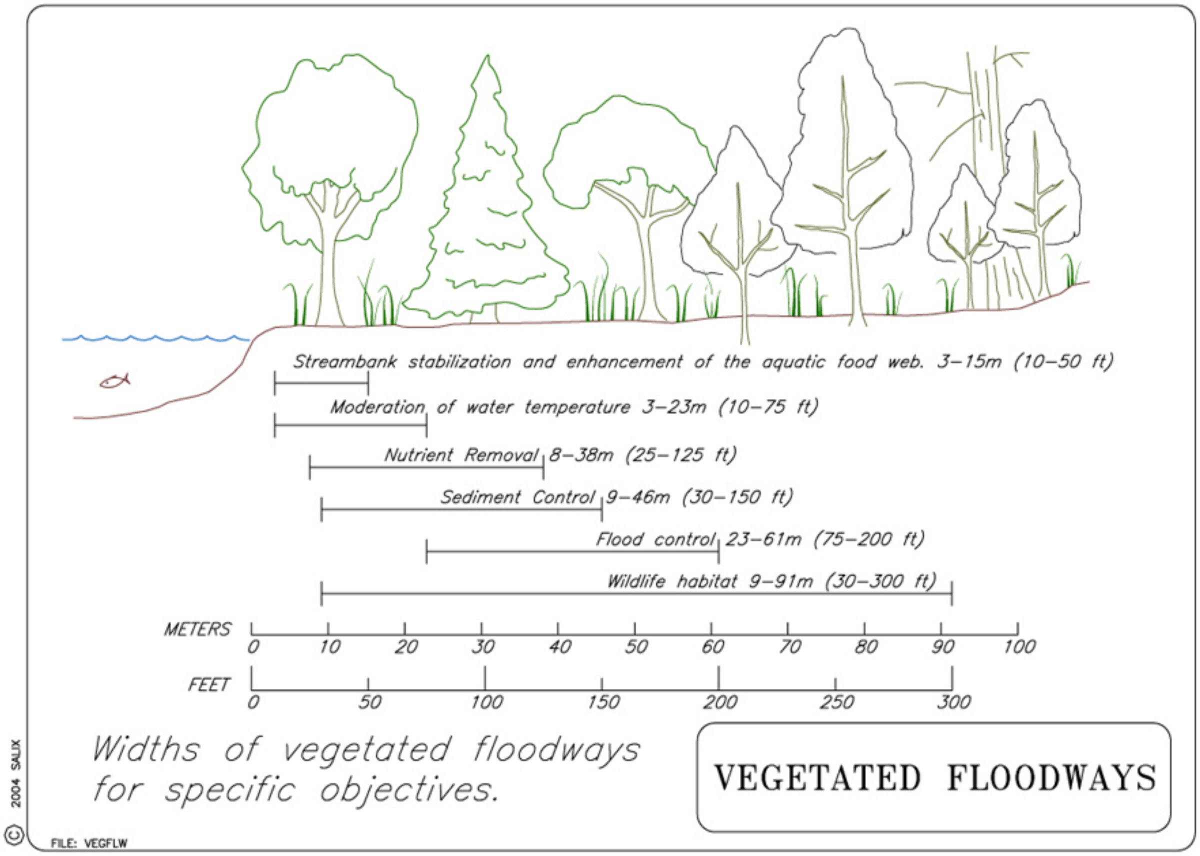
TYPICAL VANE WITH J–HOOK

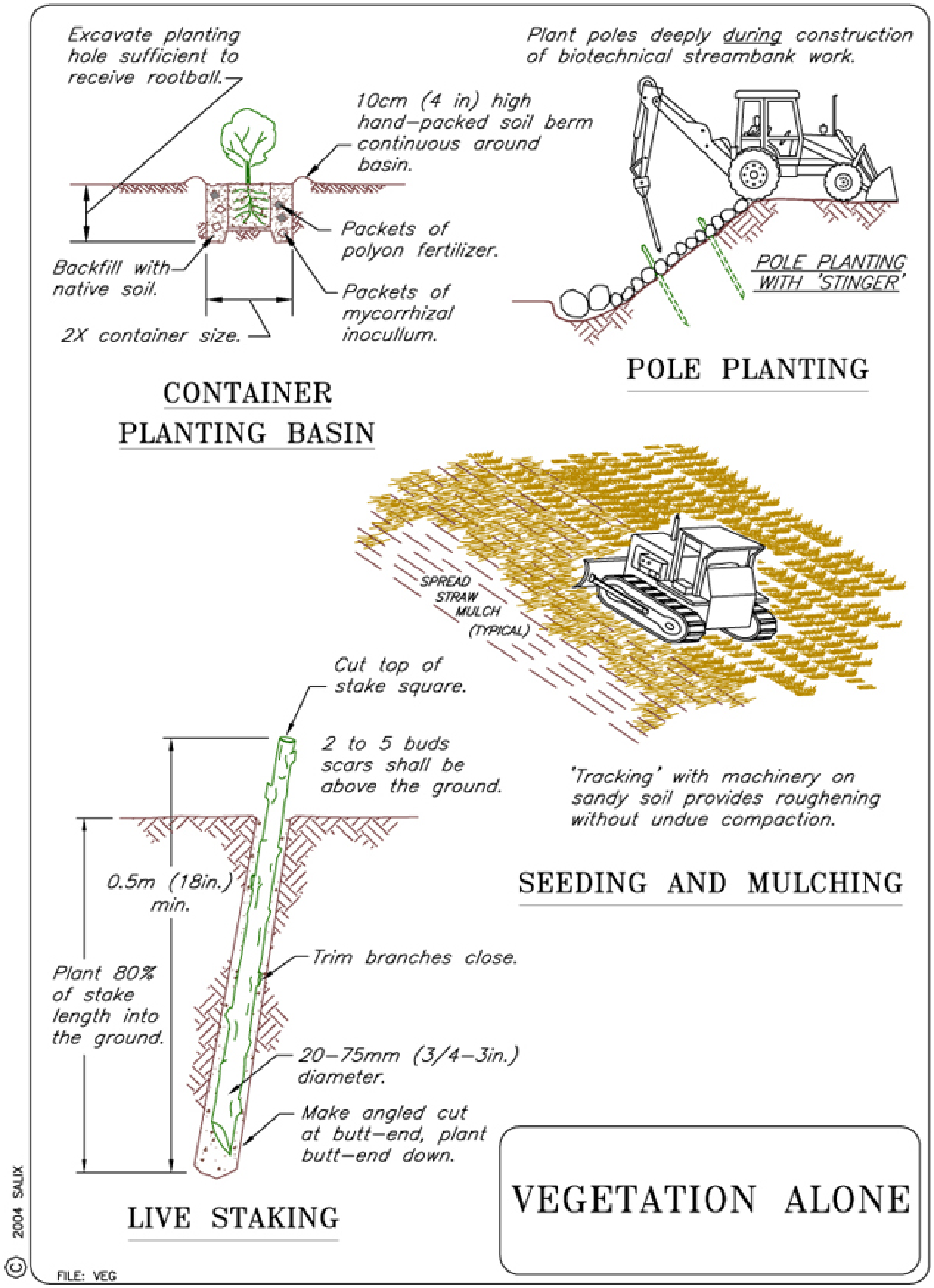

ORIGINAL SLOPE
TEMPORARY EXCAVATION LINE
BACKFILL
AHW
0.6–1m (2–3 ft.) KEY TRENCH
6"
INSTALL 4 STIFFENERS PER EXPOSED FACE, AND 2 PER BACK FACE
9 GA STIFFENER HOOKED AT THE INTERSECTION OF TWO WIRES
CRIMP HOOK CLOSED
VEGETATED GABION BASKETS
© 2004 SALIX
FILE: VGGAB


GABION LID
1. Assemble and place gabion basket with lid open.
2. Fill bottom 1/3 of basket with rock and install stiffener or corner tie at 1/3 height.
3. Fill front half of gabion with rock and insert willow poles.
4. Fill remainder of basket with stones, installing stiffeners or corner ties at 2/3 height.
5. Close lid and lace shut. Backfill behind gabion and compact. Place brushlayers on top of gabion.
6. Begin next rank of gabions.
VEGETATED GABION BASKETS INSTALLATION STEP-BY-STEP
© 2004 SALIX
FILE: VEGBIN


STEP 1.
Top of Bank
AHW
River Bottom
STEP 2.
Construct during periods of low water or isolate work area.
Top of Bank
Excavate Bank
70°
River Bottom
STEP 3.
Wrap soil with fabric.
Gravel/Soil
Fabric Wrap
STEP 4.
Crisscross layers of dormant cuttings and/or transplants.
Deposit layer of top soil over cuttings.
10"–20"
Anchor Fabric
STEP 5.
Wrap second layer of soil/gravel with fabric.
Gravel/Soil
Fabric Wrap
STEP 6.
Repeat steps 3, 4, 5 until desired height of bank is reached.
Revegetate with native plants.
70°
Secure toe of slope and provide habitat for fish.
VEGETATED MECHANICALLY STABILIZED EARTH
STEP BY STEP
© 2004 SALIX
FILE: VMSE


DHW
ORIGINAL BANK
Iron bar used to make pilot hole for Salix stake.
Anchor into top of bank.
ARTICULATED CONCRETE BLOCKS/MATS
AHW
SECTION A–A
WOVEN GEOTEXTILE
Key in mattress toe with at least two blocks below finished bank toe.
KEY IN 2 BLOCKS MIN.
A
A
KEY IN 2 BLOCKS MIN.
PLAN VIEW
ARTICULATED CONCRETE BLOCKS/MATS
© 2004 SALIX
FILE: ACB


Streambank stabilization and enhancement of the aquatic food web. 3–15m (10–50 ft)
Moderation of water temperature 3–23m (10–75 ft)
Nutrient Removal 8–38m (25–125 ft)
Sediment Control 9–46m (30–150 ft)
Flood control 23–61m (75–200 ft)
Wildlife habitat 9–91m (30–300 ft)
METERS
0 10 20 30 40 50 60 70 80 90 100
FEET
0 50 100 150 200 250 300
Widths of vegetated floodways for specific objectives.
VEGETATED FLOODWAYS
© 2004 SALIX
FILE: VEGFLW


Excavate planting hole sufficient to receive rootball.
10cm (4 in) high hand-packed soil berm continuous around basin.
Packets of polyon fertilizer.
Backfill with native soil.
Packets of mycorrhizal inocullum.
2X container size.
CONTAINER PLANTING BASIN
Plant poles deeply during construction of biotechnical streambank work.
POLE PLANTING WITH 'STINGER'
POLE PLANTING
SPREAD STRAW MULCH (TYPICAL)
'Tracking' with machinery on sandy soil provides roughening without undue compaction.
SEEDING AND MULCHING
Cut top of stake square.
2 to 5 buds scars shall be above the ground.
0.5m (18in.) min.
Plant 80% of stake length into the ground.
Trim branches close.
20–75mm (3/4–3in.) diameter.
Make angled cut at butt-end, plant butt-end down.
LIVE STAKING
VEGETATION ALONE
© 2004 SALIX
FILE: VEG