ATTACHMENT B

MIDPENINSULA REGIONAL OPEN SPACE DISTRICT

BEST MANAGEMENT PRACTICES AND STANDARD OPERATING PROCEDURES FOR ROUTINE MAINTENANCE ACTIVITIES IN WATER COURSES

MIDPENINSULA REGIONAL OPEN SPACE DISTRICT

MIDPENINSULA REGIONAL OPEN SPACE DISTRICT

BEST MANAGEMENT PRACTICES (BMPs) FOR
ROUTINE MAINTENANCE ACTIVITIES IN WATER COURSES

Sources

*	CA Salmonid Stream Habitat Restoration Manual, State of CA Resources Agency, Department of Fish and Game (2002)
+	Timothy C. Best, Certified Engineering Geologist (CEG), Engineering Geology and Hydrology, Santa Cruz, CA (2006)
^	Erosion Draw 5.0, Bio Draw 3.0, Environmentally-Sensitive Streambank Restoration (ESenSS), John McCullah, Salix Applied Earthcare, Redding, CA (2004)
○	Midpeninsula Regional Open Space District (2007)

Continued on next page

BEST MANAGEMENT PRACTICES (BMPs) FOR
ROUTINE MAINTENANCE ACTIVITIES IN WATER COURSES (Continued)

Page #	Source	BMP #	BMP Name	Detail
			Other BMPs	
19	^	**12**	Brushlayering with Geotextile Soil Wrap	☆
23	^	**13**	Brushlayering with Rock Toe Protection	☆
25	^	**14**	Brush Mattress (Brush Mat)	☆
30	^	**15**	Coir Roll with Brushlayering	☆
33	^	**16**	Energy Dissipator	☆
35	^	**17**	Erosion Control Blanket and Mat	☆
40	^	**18**	Grass-Lined Channel	☆
43	○	**19**	Herbicide Use	
44		**20**	Instream Diversion Techniques	
47	^	**21**	Instream Erosion and Sediment Control Isolation Techniques	☆
52	○	**22**	Large Woody Material/Debris Management and Removal	
54	^	**23**	Live Pole Drain	☆
57	^	**24**	Live Siltation	☆
59	^	**25**	Live Siltation (Modified)	☆
61	^	**26**	Live Staking	☆
64	^	**27**	Pole Planting	☆
66	^	**28**	Riprap	☆
69	^	**29**	Rootwad Revetment with Vegetated Riprap	☆
73	^	**30**	Silt Fence Installation	☆
77	^	**31**	Slope Drain	☆
78	^	**32**	Straw Rolls	☆
81	^	**33**	Structural Streambank Stabilization	☆
84	^	**34**	Temporary Diversion Dike	☆
86	^	**35**	Vegetated Mechanically Stabilized Earth	☆
89	^	**36**	Vegetated Riprap	☆
96	^	**37**	Wattle (Live Fascine)	☆

Characteristics of Storm-proofed Roads

Storm-proofed stream crossings

- All stream crossings have a drainage structure designed for the 100-year flow (with debris).
- Stream crossings have no diversion potential (functional critical dips are in place).
- Stream crossing inlets have low plug potential (trash barriers & graded drainage).
- Protect stream crossing outlets from erosion (extended, transported or dissipated).
- Culvert inlet, outlet and bottom are open and in sound condition.
- Undersized culverts in deep fills (greater than backhoe reach) have emergency overflow culvert.
- Bridges have stable, non-eroding abutments and do not significantly restrict 100-year flood flow.
- Fills are stable (unstable fills are removed or stabilized).
- Road surfaces and ditches are "disconnected" from streams and stream crossing culverts.
- Class I stream crossings meet DFG and NMFS fish passage criteria (Part IX).

Storm-proofed fills

- Unstable and potentially unstable road and landing fills are excavated or structurally stabilized.
- Excavated spoil is placed in locations where it will not enter a stream.
- Excavated spoil is placed where it will not cause a slope failure or landslide.

Road surface drainage

- Road surfaces and ditches are "disconnected" from streams and stream crossing culverts.
- Ditches are drained frequently by functional rolling dips or ditch relief culverts.
- Outflow from ditch relief culverts does not discharge to streams.
- Gullies (including those below ditch relief culverts) are dewatered to the extent possible.
- Ditches do not discharge (through culverts or rolling dips) onto active or potential landslides.
- Decommissioned roads have permanent drainage and do not rely on ditches
- Fine sediment contributions from roads, cutbanks and ditches are minimized by utilizing seasonal closures and installing a variety of surface drainage techniques including berm removal, road surface shaping (outsloping, insloping or crowning), rolling dips, ditch relief culverts, water bars and other measures to disperse road surface runoff and reduce or eliminate sediment delivery to the stream.

Figure X-9. Common characteristics of storm-proofed roads.

Road Upgrading Treatments

In general, road upgrading consists of stream crossing upgrades, excavation of selected unstable or potential unstable fillslopes, and dispersion of road runoff (Figure X-9).

Stream Crossing Upgrading

- Eliminate stream diversion potential by dipping the entire stream crossing fill or by installing a critical dip (Figure X-13). A critical dip is a rolling dip that is constructed on or close to the down-road hinge line of a stream crossing that displays a diversion potential.
- Upgrade stream crossings by installing culverts sized for the 100-year flood flow, including sufficient capacity for expected wood and sediment (Figure X-13 and Figure X-14). These requirements are determined by both field observation and calculations using a procedure such as the Rational Formula (PWA 1994). Where necessary, install inlet protection (trash barriers) to prevent culvert plugging on non-fish bearing streams.
- Replace large high-risk culverts with bridges. Consider replacing any culvert greater than 72 inches in diameter with a bridge, especially in Class 1 streams.
- Replace culverted fills with hardened fords or armored fills (Figure X-15 and Figure X-16) on non-fish bearing streams where regular winter inspections and culvert maintenance is not feasible, or on steep gradient stream crossings where the culvert plug potential will always be high.
- Install armored crossings (Figure X-15 and Figure X-16) in areas where debris torrents are common, can be expected or where small steep gradient streams cross the road. Armored fill crossings are for sites where it will be very difficult to prevent frequent culvert plugging due to high amounts of transported sediment and debris. The treatment requires excavating the fill in the stream crossing and leaving a very broad dip in the axis of the natural channel, with long and gently sloping ramps into and out of the stream crossing. This treatment may be most appropriate along roads built on a floodplain and terrace, or where roads cross steep gradient stream channels with relatively small depths of fill at the outboard edge of the road.

Excavation of Unstable Fillslope

Remove unstable sidecast and fill materials from steep slopes (Figure X-17), steep headwater swales, and along road approaches to deeply incised stream channels, where there is potential for sediment delivery.

Stream Crossing Culvert Installation for Non-fish Bearing Streams

- Align culverts with the natural stream channel orientation to ensure proper function, prevent bank erosion and minimize debris plugging problems.
- Place culverts at the base of the fill and at the grade of the original streambed or install a downspout past the base of the fill (Figure X-14).
- Culverts should be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
- Culvert beds should be composed of rock-free soil or gravel, evenly distributed under the length of the pipe.
- Compact the base and sidewall material before placing the pipe in its bed.
- To allow for sagging after burial, an upward camber should be between 1.5 to 3 inches per 10 feet culvert pipe length.
- Backfill material should be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around the pipe.
- Cover one end of the culvert pipe, then the other end. Once the ends are secure, cover the center.
- Tamp and compact backfill material throughout the entire process, using water as necessary for compaction.
- Backfill compacting will be done in 0.5 – 1.0 foot lifts until 1/3 of the diameter of the culvert has been covered (Figure X-14). A gas powered tamper or sheep's foot roller should be used for this work.
- Armor inlets and outlets with rock, or mulch and seed with grass as needed (not all stream crossings need to be armored).
- Install a trash rack (only on non-fish bearing streams) upstream from the culvert inlet where there is a high hazard of floating debris plugging the culvert.
- Push layers of fill over the crossing to achieve the final design road grade, at a minimum of one-third to one-half the culvert diameter.

Trash Racks

All trash racks require on-going maintenance. Two efficient trash rack designs include:

- On streams with culverts 48 inches diameter or greater, build a grate or sieve across the entire channel to collect the large material that would otherwise plug the culvert inlet. Locate the trash rack anywhere from five to 25 feet upstream from the culvert inlet.
- On streams with culverts under 48 inches diameter, set a single post vertically in the steam bed, centered directly upstream from the culvert inlet, and located one culvert diameter distance upstream from the inlet. Size the post and set the post deep into the streambed to withstand the size of woody debris transported by the stream during extreme runoff events.

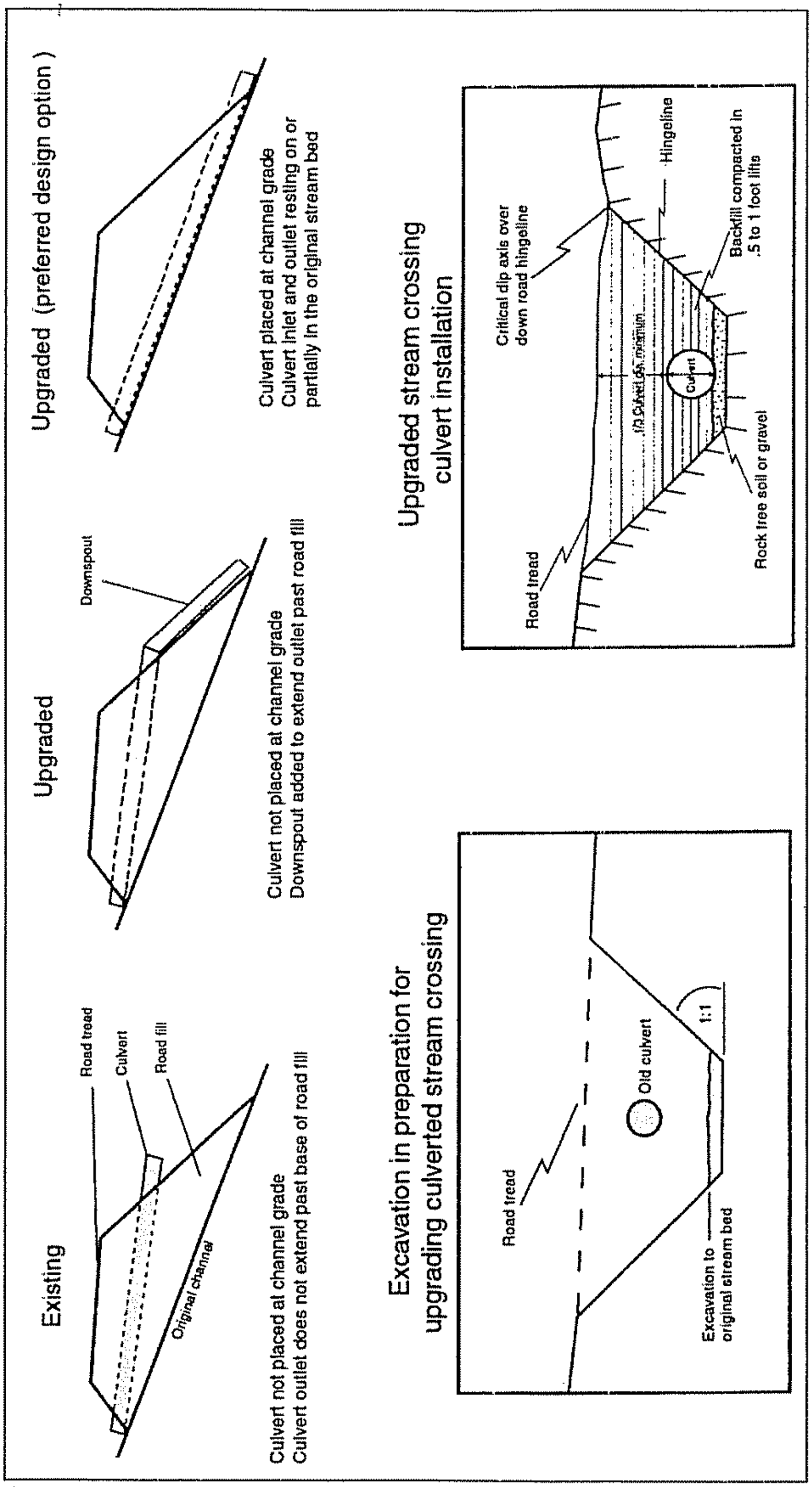
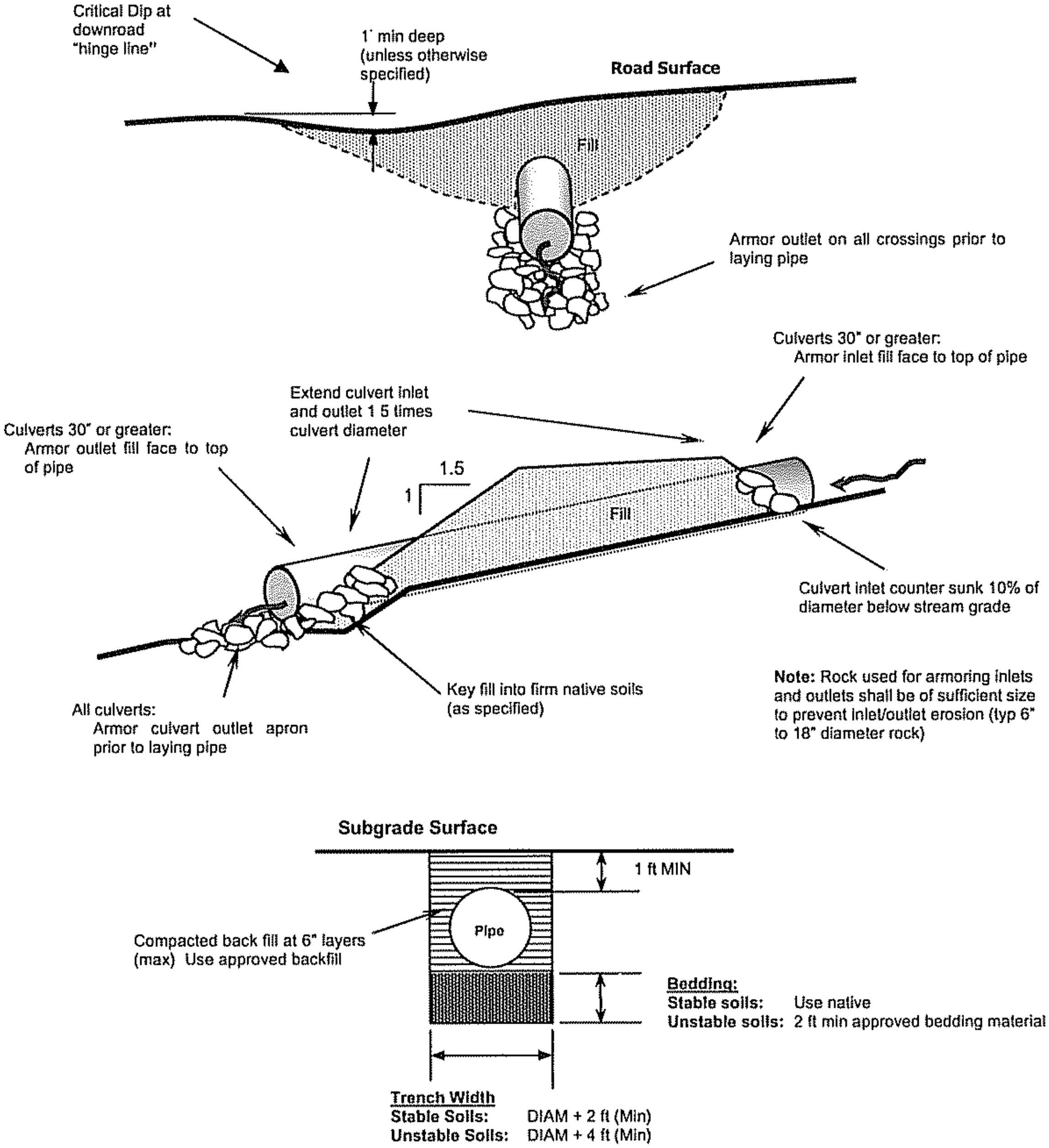


Figure X-14. Typical culvert installation on non fish-bearing streams.



Notes:

- The culvert bed shall be clean and free of large woody debris and large rocks
- Unsuitable foundation material (highly plastic material – "blue goo") shall be excavated below the invert elevation of the culvert to an approximate depth of 2 feet and a width of at least the culvert diameter plus 4 feet.
- Unsuitable material shall be replaced with selected granular foundation material and compacted to obtain a uniform foundation.
- Select mineral soil shall be used for culvert backfill. The back fill shall be free of lumps, chunks, highly plastic material, and organic materiel
- No rocks greater than 3" in any dimension placed closer than 1 foot to the culvert.
- Back fill shall be compacted to a degree greater than the surrounding soils Soil moisture shall be adequate to achieve suitable compaction

TIMOTHY C. BEST, CEG ENGINEERING GEOLOGY AND HYDROLOGY 1002 Columbia Street, Santa Cruz, CA 95060 (831) 425-5832 (831) 425 5830 fax	**PERMANENT WATERCOURSE CROSSING STANDARD PLAN**	**Standard Detail R1** Date: September 27, 2006

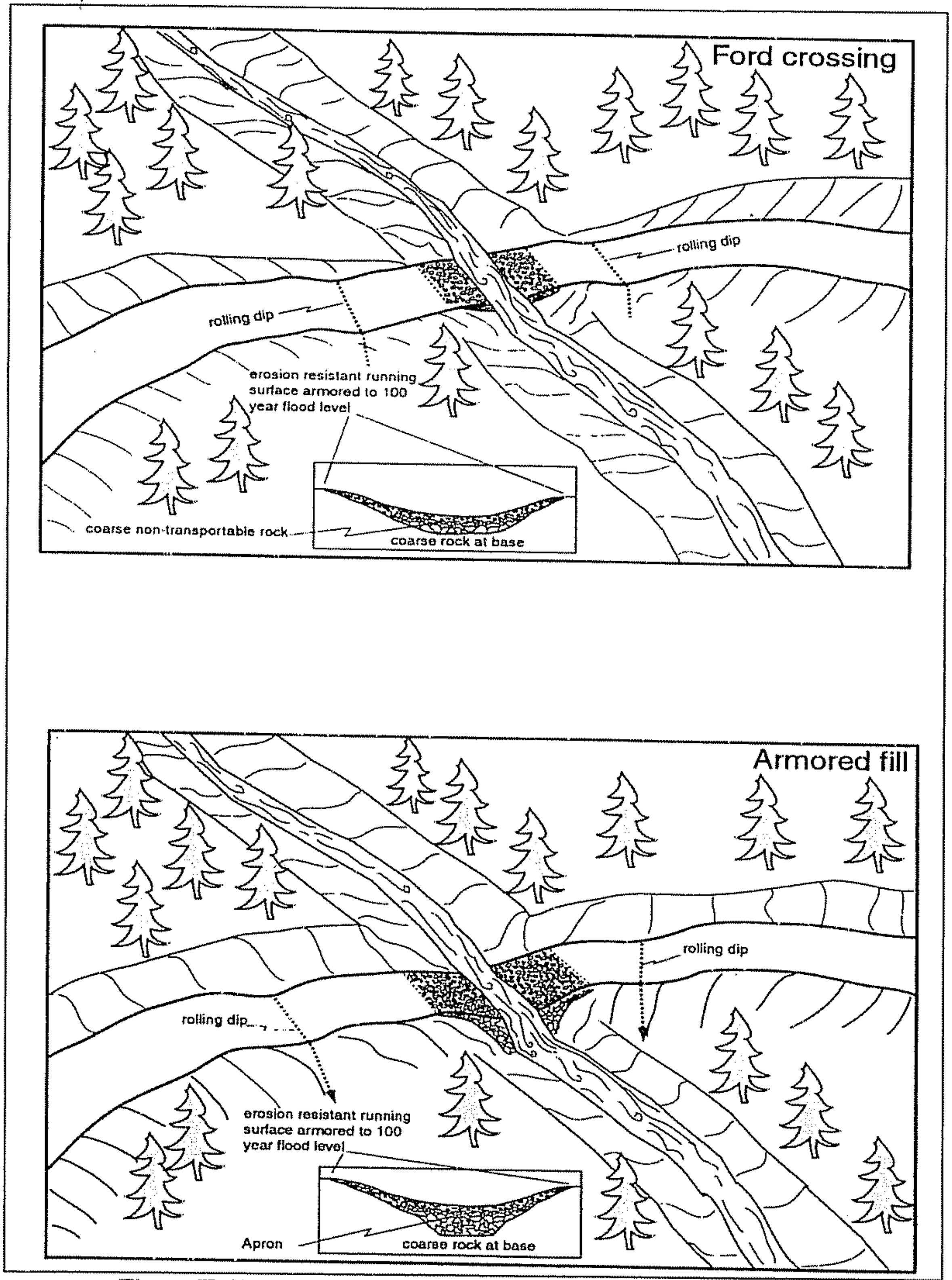
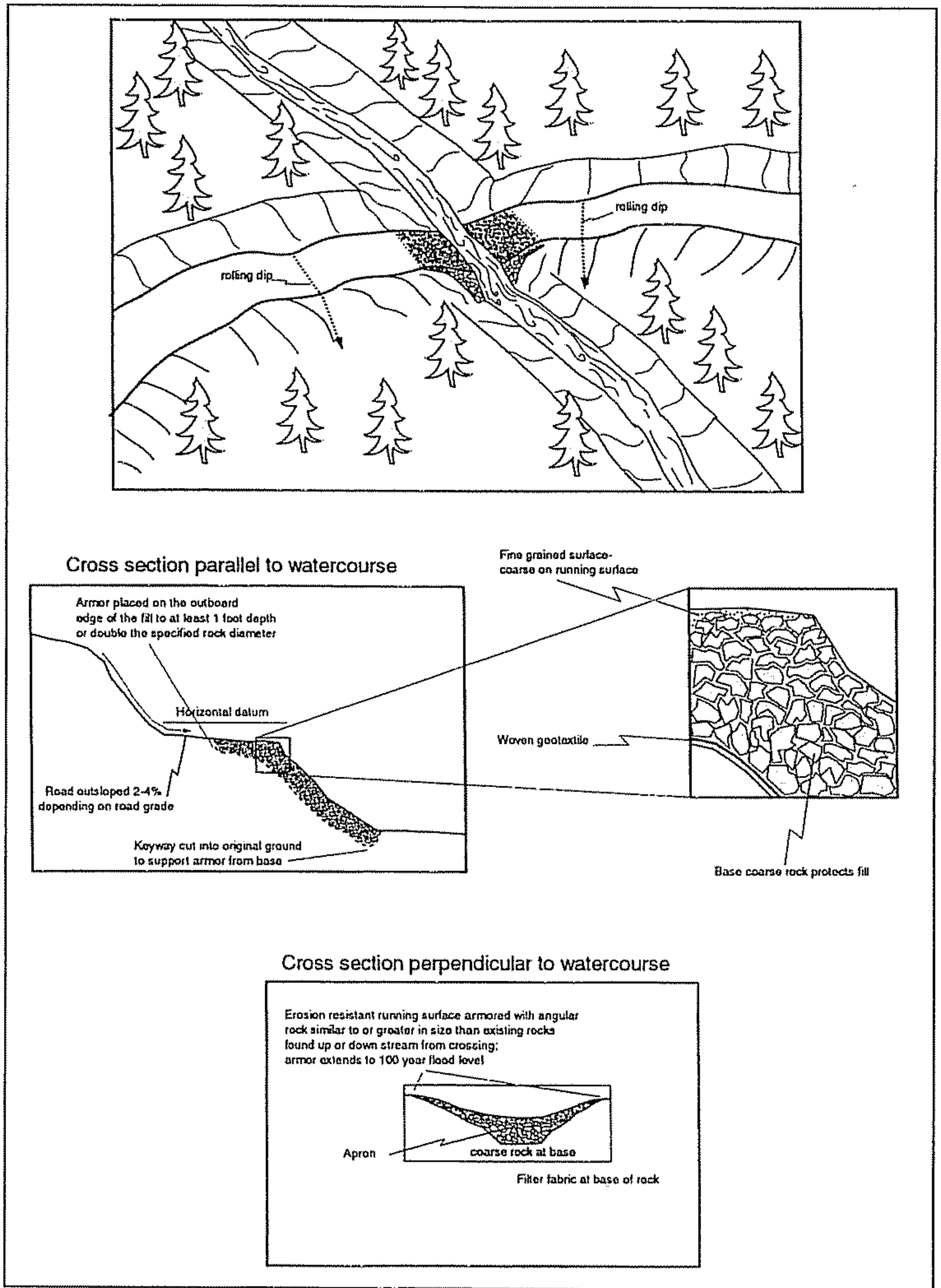


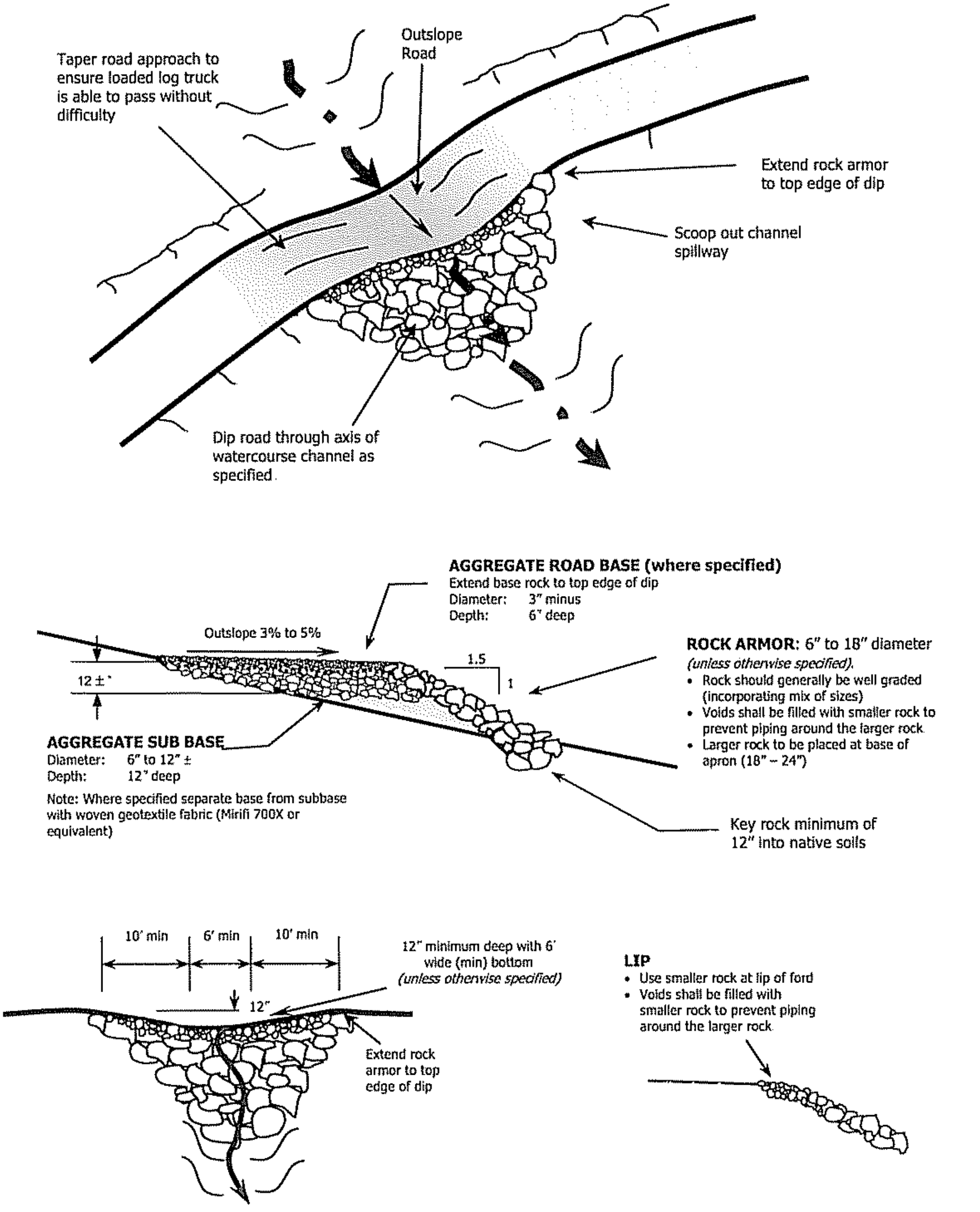
Figure X-15. Typical ford and armored fill stream crossings.



Note: Where geotextile fabric may interfere with passage of amphibians in any Class 2 or 3 crossing, bury geotextile fabric with at least 6 inches of rock. Do not use geotextile fabric in fish-bearing streams.

Figure X-16. Installation and specification of typical armored fill crossing.

ROCK FORD



NOTE
- Details are typical and intended for use as a guideline. Adjustments to the actual design may need to occur in field during time of construction due to local site conditions.
- Refer to site details for specific design criteria where applicable.

TIMOTHY C. BEST, CEG ENGINEERING GEOLOGY AND HYDROLOGY 1002 Columbia Street, Santa Cruz, CA 95060 (831) 425-5832 (831) 425 5830 fax	**ROCK FORD** **STANDARD PLANS**	**Standard Detail R4** Date: September 27, 2006

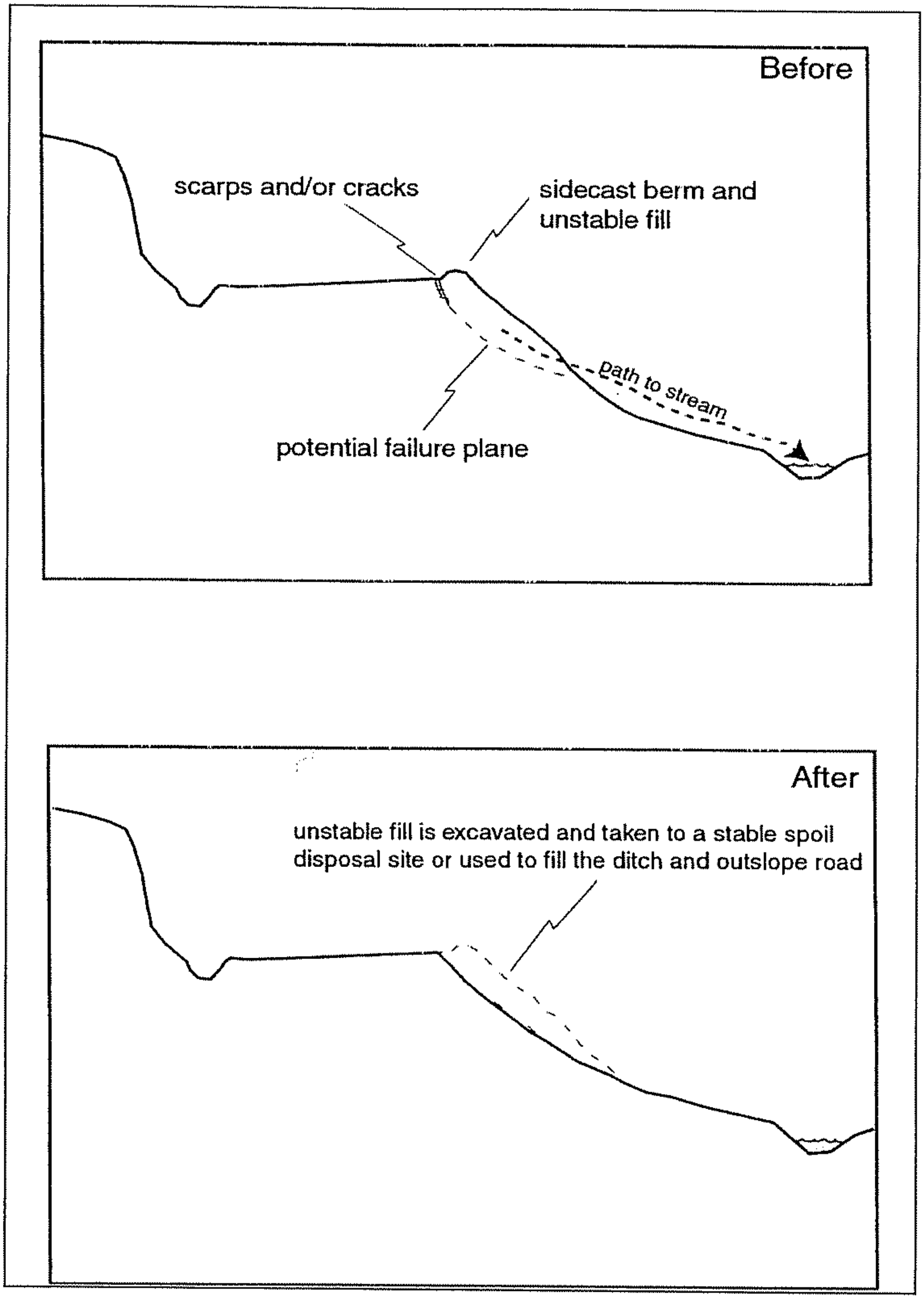


Figure X-17. Removal of unstable sidecast materials.

Outsloping pitch for roads up to 12% grade		
Road Grade	Outslope Pitch forUnsurfaced roads	Outslope Pitch for Surfaced Roads
4% or less	3/8" per foot	½" per foot
5%	½" per foot	5/8" per foot
6%	5/8" per foot	¾" per foot
7%	¾" per foot	7/8" per foot
12% or more	1" per foot	1-1/4" per foot

Table X-6. Outsloping pitch for roads up to 12% grade.

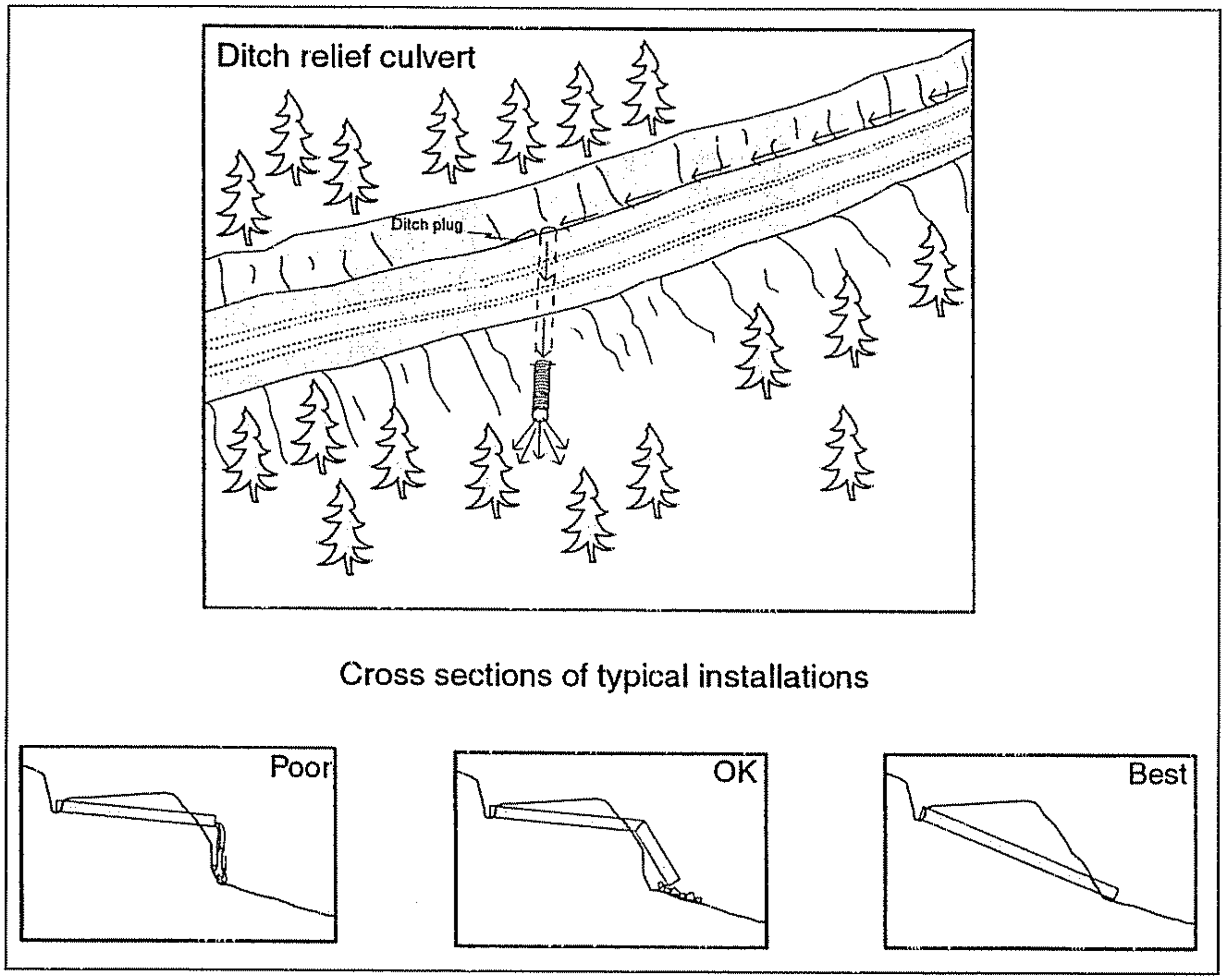
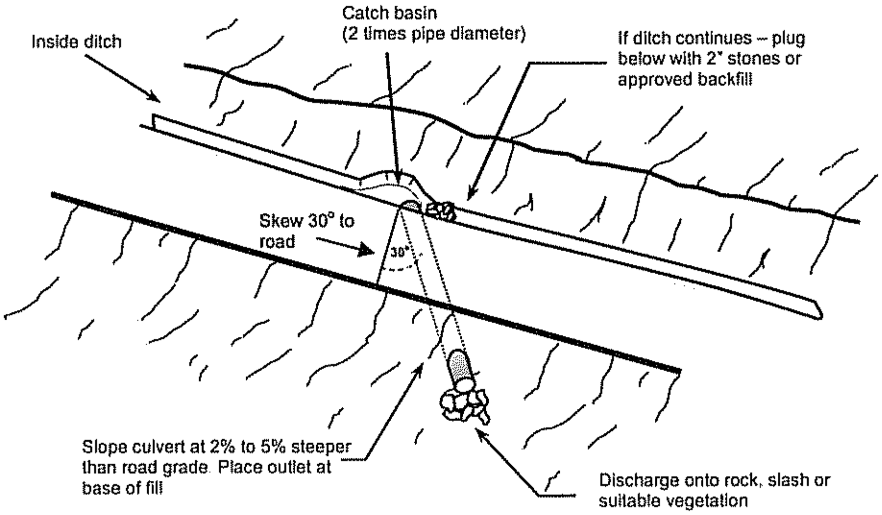
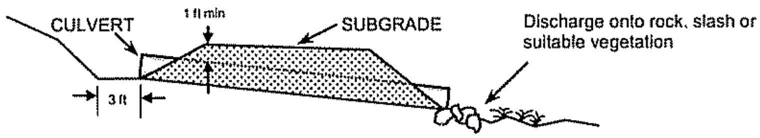


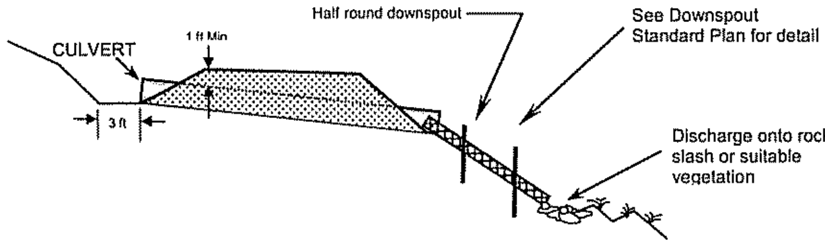
Figure X-19. Typical ditch relief culvert installation.



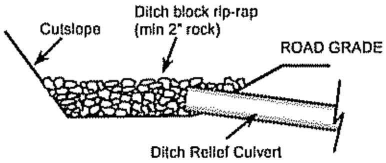
TYPE "A" DITCH RELIEF CULVERT
(no downspout)



TYPE "B" DITCH RELIEF CULVERT
(with round or half round downspout)



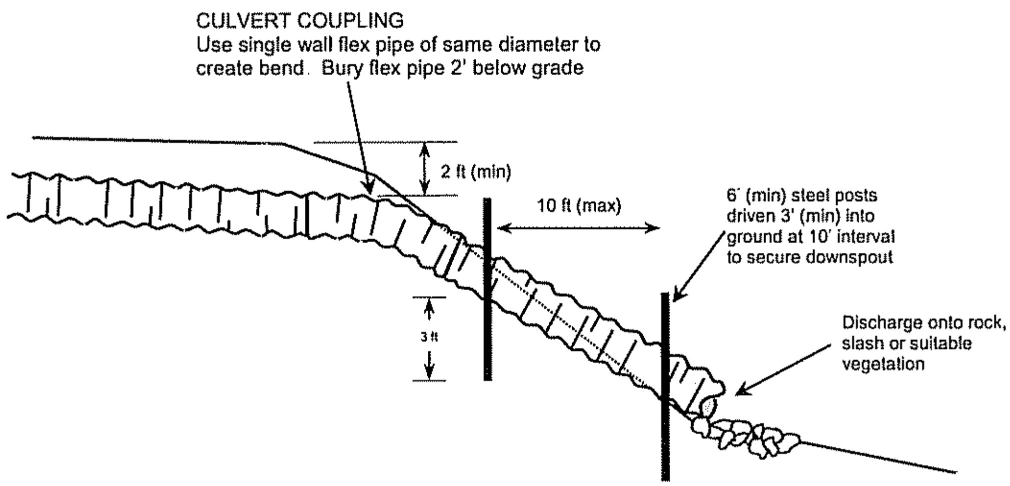
TYPICAL DITCH BLOCK SECTION



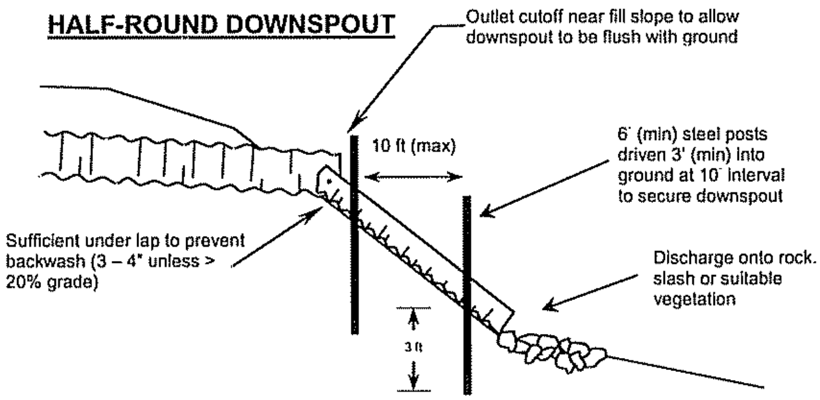
NOTES
Backfill should be compacted alongside and over top of the culvert.
Culverts should extend a minimum of 1' beyond base of road fill, or flume used to carry flow beyond fill.
Rock, slash or suitable vegetation should be used at discharge point.

TIMOTHY C. BEST, CEG ENGINEERING GEOLOGY AND HYDROLOGY 1002 Columbia Street, Santa Cruz, CA 95060 (831) 425-5832 (831) 425 5830 fax	**DITCH RELIEF CULVERT STANDARD PLAN**	**Standard Detail R2** Date: September 27, 2006

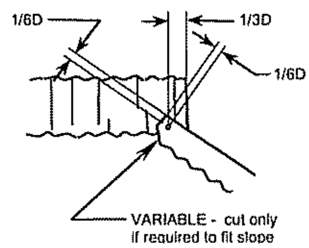
FULL-ROUND DOWNSPOUT



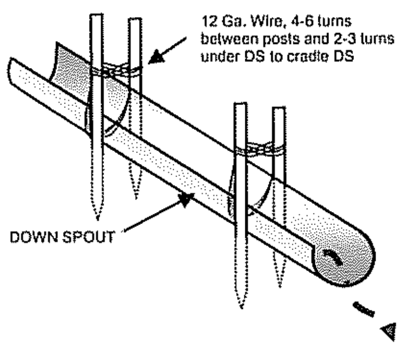
HALF-ROUND DOWNSPOUT



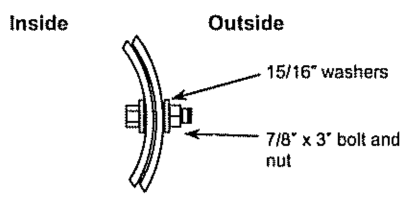
HALF ROUND CONNECTION



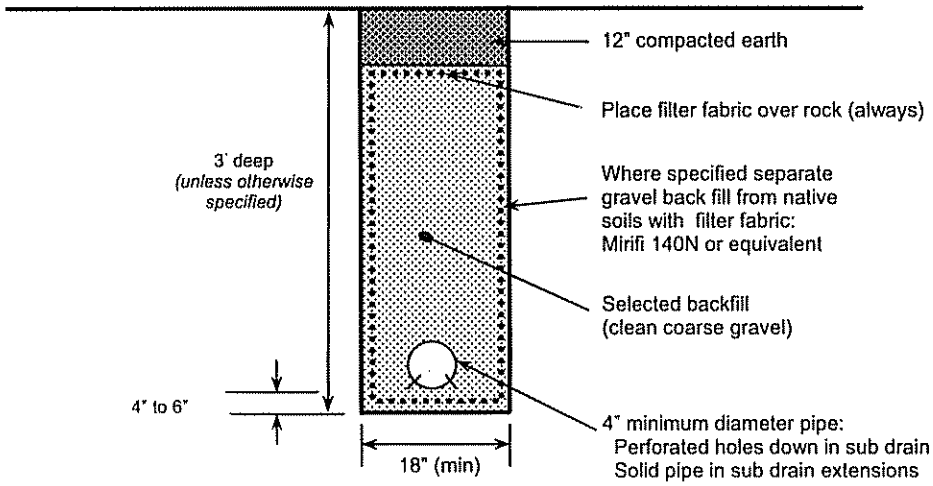
DOWNSPOUT STAKE WIRING DETAIL



BOLT DETAIL



TIMOTHY C. BEST, CEG ENGINEERING GEOLOGY AND HYDROLOGY 1002 Columbia Street, Santa Cruz, CA 95060 (831) 425-5832 (831) 425 5830 fax.	**DOWNSPOUT STANDARD PLAN**	**Standard Detail R3** Date: September 27, 2006



NOTES

1. Excavate 18" wide trench as specified. Trench should have positive gradient to discharge point.
2. Where specified, line trench with approved filter fabric (Mirifi 140N or equivalent).
3. Place perforated pipe 4" to 6" from bottom of trench. Soild pipe should extend from trench to discharge point.
4. Back fill trench with clean coarse gravel to within 12" of grade.
5. Place fabric over top of gravel back fill.
6. Cap with 12" of compacted earth.
7. Discharge in a reasonable and controlled manner.

TIMOTHY C. BEST, CEG ENGINEERING GEOLOGY AND HYDROLOGY 1002 Columbia Street, Santa Cruz, CA 95060 (831) 425-5832 (831) 425 5830 fax.	**PERFORATED SUBDRAIN STANDARD PLAN**	**Standard Detail R10** Date: September 27. 2006

Dispersion of Road Runoff

Disperse and disconnect road surface runoff from streams. Road cutbanks and road ditches are known to deliver substantial volumes of fine sediment to streams in some watersheds (e.g., Reid 1981; Reid and Dunne 1984) and they have been found to significantly affect watershed hydrology (Wemple 1994). Relatively simple treatments can be performed to upgrade road drainage systems to significantly reduce or largely eliminate this source of fine sediment delivery to streams. Sediment may be minimized by utilizing seasonal closures or traffic restrictions, and dispersing road runoff. Choose from a variety or combination of surface drainage techniques including berm removal, water bars (Figure X-10), road surface shaping (outsloping, insloping or crowning (Figure X-18 and Table X-6), ditch relief culverts (Figure X-19), rolling dips (Figure X-20), and other measures that effectively disperse road surface runoff and reduce or eliminate sediment delivery to the stream. To be effective, they must effectively disperse most road runoff and ditch flow before it reaches the stream. It is critical that all road surface drainage techniques effectively drain the road surface and be drivable for the expected traffic.

Road Upgrading Installation Instructions

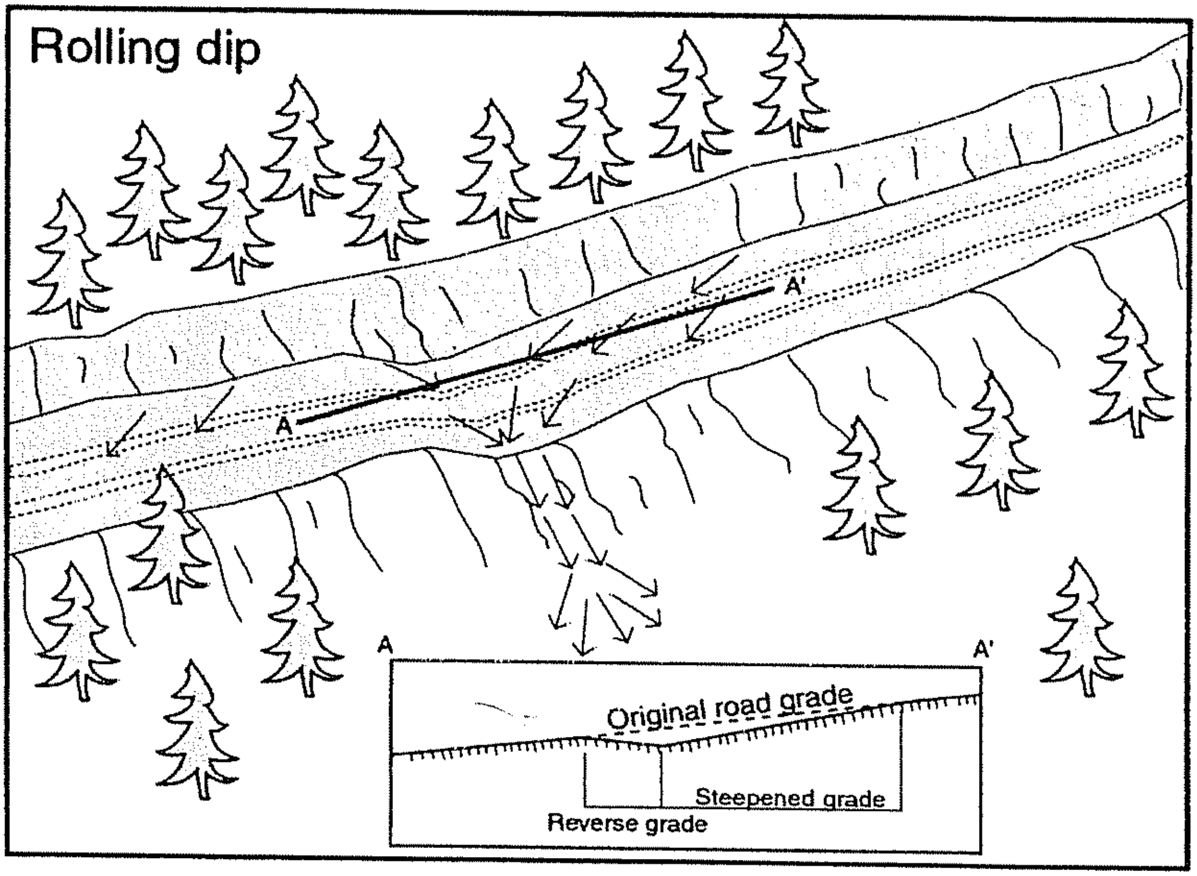
The following summarizes standard road upgrading techniques. For more detail, see *Handbook for Forest and Ranch Roads* (PWA 1994) or the corresponding video *Forest and Ranch Roads* (PWA 2003).

Rolling Dip Installation

- Install rolling dips in the roadbed as needed to drain the road surface. Rolling dips can be sloped either into the ditch or to the outside of the road edge as required to properly drain the road and disperse surface runoff.
- If the rolling dip is designed to divert both road surface and ditch runoff, block the down-road ditch with compacted fill.
- Rolling dips are usually built directly across the road alignment with a cross grade at least one percent greater than the grade of the road (so that it will drain).
- Excavate the rolling dip with a medium size bulldozer (D-7 size) with rippers or with a grader.
- Begin excavation of the dip approximately 50 to 100 feet up-road from the proposed axis of the dip (Figure X-18). Progressively excavate material from the roadbed, with the grade becoming steeper, until reaching the axis (Figure X-20).
- Determine the depth of the dip, by the grade of the road (Figure X-18). In all cases, rolling dip dimensions must be consistent with the type of vehicles that will be using the road (Figure X-20).
- On the down-road side of the rolling dip axis, install a grade change to prevent runoff from continuing down the road. Carry the rise in grade for about 15 to 25 feet, or more, and then fall back to the original slope (Figure X-20). The axis of the dip must be a broad "u" shape to facilitate good driveability.
- In all cases, the rolling dip must be driveable and not significantly inhibit traffic and road use. It must also effectively drain the road surface.

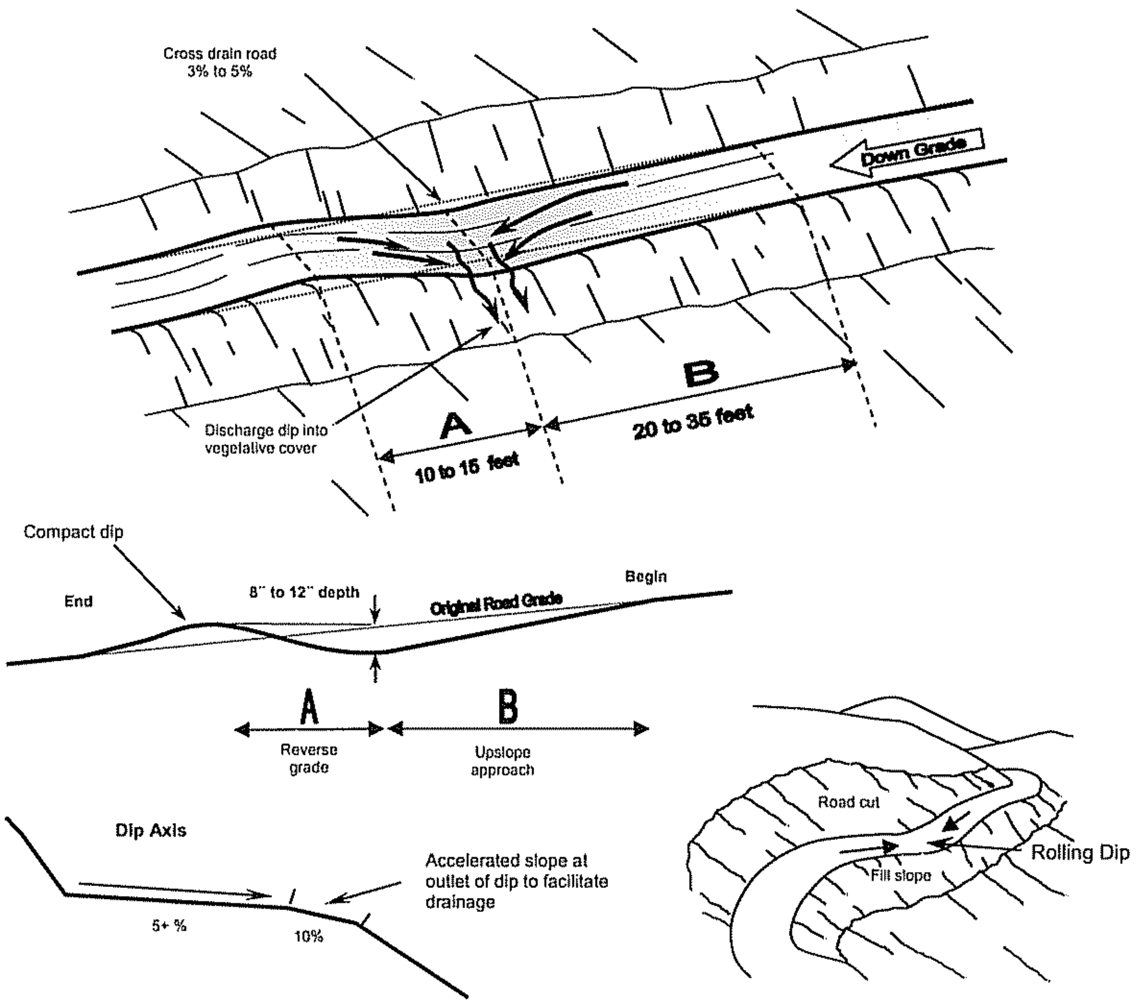
Table of Rolling Dip Dimensions				
Road grade %	**Upslope approach (distance from up-road start of rolling dip to trough) (ft)**	**Reverse grade (distance from trough to crest)**	**Depth below average road grade at discharge end of trough (ft)**	**Depth below average road grade at upslope end of trough (ft)**
<6	55	15-20	0.9	0.3
8	65	15-20	1.0	0.2
10	75	15-20	1.1	.01
12	85	20-25	1.2	.01
>12	100	20-25	1.3	.01

Table X-7. Table of rolling dip dimensions.



Note: Rolling dips must drain the road surface and be driveable for the expected traffic.

Figure X-20. Specifications and use of rolling dips to reduce ditch erosion and surface runoff.



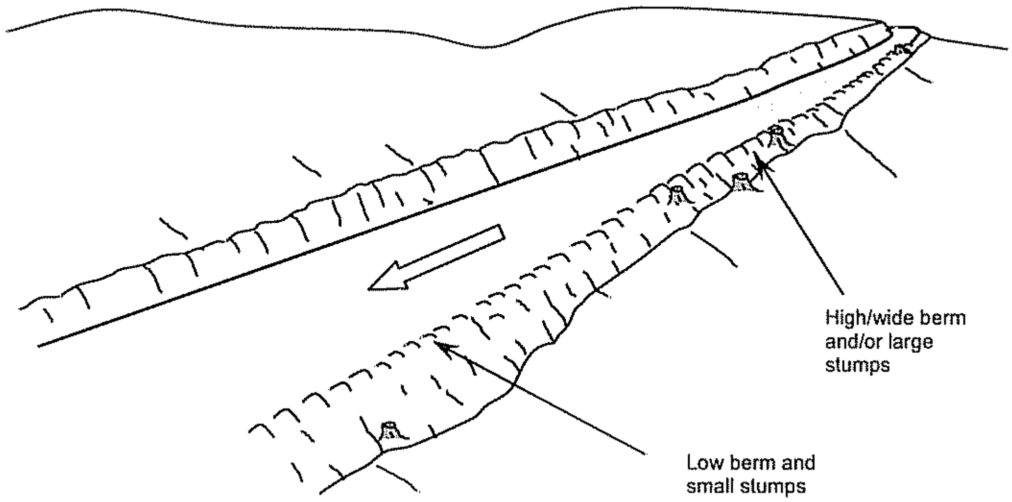
NOTES:

- A rolling dip is a broad long permanent dip constructed into native soils It is intended to drain the road while not significantly impeding traffic
- The cross drain road (outslope) at 3% to 5% road grade (maximum 15%)
- Dip outlets should be located to drain into areas with adequate sediment filter quality and non-erodible material such as rock, slash, brush, etc Where specified, the bottom of the outfall of the dip will be surface rocked
- Where natural slopes exceed 50%, fill shall not be pushed over the dip outlet A backhoe or excavator may be required to pull back fill at outlet of existing dips

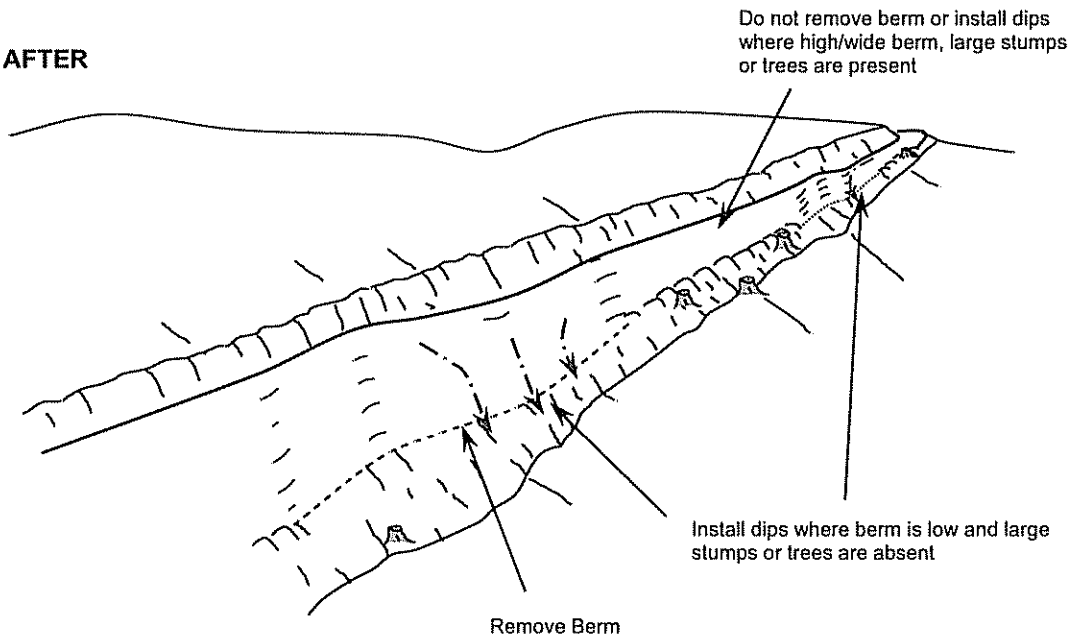
TIMOTHY C. BEST, CEG ENGINEERING GEOLOGY AND HYDROLOGY 1002 Columbia Street, Santa Cruz, CA 95060 (831) 425-5832 (831) 425 5830 fax.	**ROLLING DIP APPLICATION ON EXISTING ROADS**	**Standard Detail R5** Date: September 27, 2006

ROLLING DIP APPLICATION ON EXISTING ROADS

BEFORE



AFTER



NOTE: See Rolling Dip Standard Plan for design specifications

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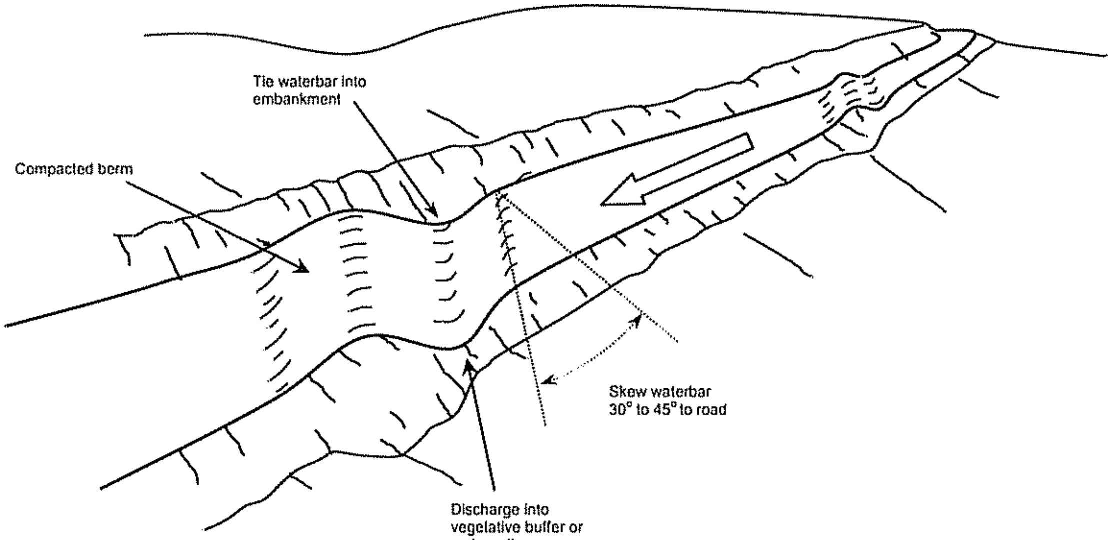
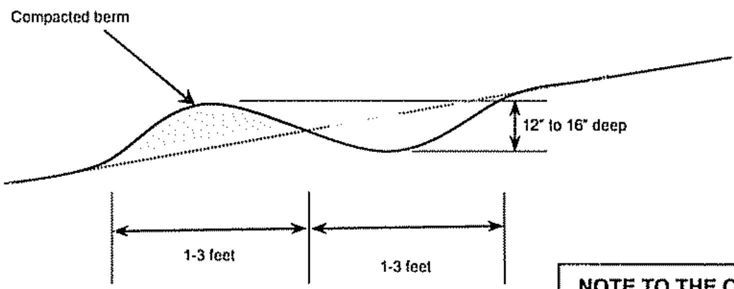
ROLLING DIP APPLICATION ON EXISTING ROADS

Standard Detail R6

Date: September 27. 2006





NOTE TO THE OPERATOR
The typical and associated guidelines are intended to: (1) provide for waterbar construction and (2) provide consistent implementation. Effective drainage facilities on native surface roads minimize erosion. maintain the integrity of the road prism and reduces future road maintenance issues It is understood that site-specific conditions may require deviation(s) from the typical approach. Primary considerations should be given to waterbar outlet location.

NOTES

1 Identify waterbar locations that take advantage of natural drainage features and minimize the amount of disturbance required for waterbar construction
2. All waterbars shall begin at the intersection of the roadbed surface and the cut slope and run the entire width of the road surface prism
3 Waterbar length shall not exceed 1 5 times the width of the road surface.
4. Acceptable waterbars shall be skewed 30 to 45 degrees
5 All waterbars shall have free flowing outlets with minimum 2% grade in the bottom of the channel that discharge onto vegetative surfaces or less erodible material where possible.
6 Native materials used to construct downslope berm shall be compacted with equipment to minimize wear resulting from trespass and/or administrative use.
7 Waterbar depth measured from the bottom of the waterbar channel to the top of the compacted berm must be between 12" and 16" high.
8 Compacted waterbars must be passable in a 4WD vehicle unless otherwise specified in the contract.

TIMOTHY C. BEST, CEG ENGINEERING GEOLOGY AND HYDROLOGY 1002 Columbia Street, Santa Cruz, CA 95060 (831) 425-5832 (831) 425 5830 fax.	**WATERBAR STANDARD PLAN**	**Standard Detail R7** Date: September 27. 2006

Brushlayering with Soil Wrap

This technique consists of live cut branches (brushlayers) interspersed between layers of soil wrapped in natural or synthetic geotextile materials. The brush is placed in a crisscross or overlapping pattern so that the tips of the branches protrude just beyond the face of the fill, where they act as horizontal drains and improve slope stability by redirecting the flow direction. Natural geofabrics, such as coir netting, are typically wrapped around the soil layer to provide additional soil surface protection and reinforcement.

Conditions Where Practice Applies

Brushlayering with geotextile soil wraps can be used to stabilize very steep slopes. They provide an alternative to vertical retaining structures for grade separation purposes and in situations that require avoiding right-of-way encroachment at the base or top of slopes. Geotextile soil wraps can also be used to protect slopes that are subject to periodic scour or tractive stresses, such as drainage channels or upper portions of streambanks.

Materials

Long branches of trees and brush which are capable of vegetative propagation, usually willows. The length of the branches will vary with the type of application (embankment or buttress fill) and desired depth of reinforcement; ideally they should be long enough to reach the back of a buttress fill. The inert construction material consists of natural geofabrics such as coir netting, or synthetic, polymeric geogrids. Natural geofabrics or geogrids are then wrapped around the soil layers to protect the slope face and provide a stable planting surface.

Implementation

Begin at the base of the slope and proceed upward. See typical drawing below for the step by step procedures of brushlayering with soil wrap. The vegetated soil wrap structure should be supported on a rock toe or base and be battered or inclined at an angle of at least 10 to 20 degrees to minimize lateral earth forces. A trench should be excavated to a competent horizon as well as below the likely depth of scour.

The fabric is installed by placing it on top of the soil so that at least 0.5 m (3 feet) can be anchored by wooden stakes to the soil-gravel layer. Allow 2 m (6 feet) of fabric to extend beyond the brushlayer so that it will lap over and cover the soil-gravel mix , then stake into place. Crisscross layers of dormant cuttings and/or transplants on top of the soil wrap, placing the cut ends into the slope with the tips extending beyond the edge of the bench (no more than ¼ of the total branch length). Care should be taken to place the branches at random with regard to size and age and species composition. Deposit a layer of topsoil over the cuttings and tamp into place.

Brushlayering with Soil Wrap (continued)

Repeat the branch, topsoil, and wrapped soil-gravel mix layering sequence until the desired bank height is achieved. Fill slopes can be created at the same time a brushlayer is installed. On a cut slope and existing streambanks, each layer is excavated at the time the brush layer is installed.

BRUSHLAYERING

Construction Specifications:

- Cuttings shall be harvested and planted when the willows, or other chosen species, are dormant. This period is generally from late fall to early spring.

- Choose plant materials that are adapted to the site conditions from species that root easily.

- Branch cuttings shall be 4-8 feet (1.2-2.5 m) long, 3/4-2 inches (20-50 mm) in diameter.

- Pre-soak cuttings for a minimum of 24 hours before installing.

- The surface of the bench shall be sloped so the outside edge is higher that the inside so the butt ends angle down slightly into the slope.

- Place branch cuttings, 3-8 inches (76-203 mm) thick, in a crisscross or over lapping configuration. The growing tips shall protrude 6-12 inches (152-305 mm) from the slope face with the butt end dipping into the slope.

- Immediately cover brushlayer with 6 inches (152 mm) of fill soil and compact according to construction specifications. Water the soil cover immediately to wet the cuttings and achieve adequate compaction.

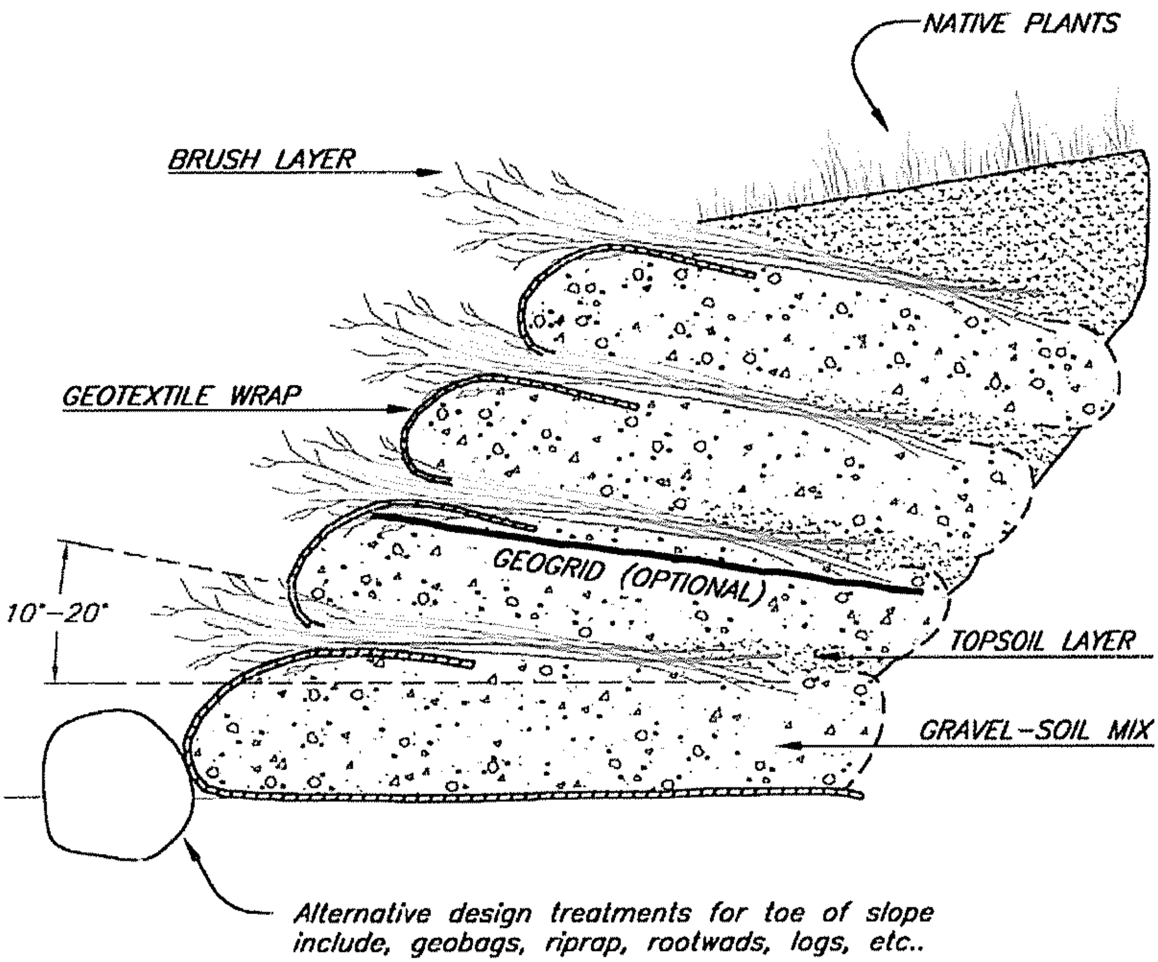
- Earth moving equipment shall not travel directly over the cuttings. Six inches (152 mm) of soil must be maintained between the brushlayer and equipment at all times.

- Fill and compact the soil placed above the brushlayer in successive lifts, maximum 6-8 inches (152-203 mm) deep.

- Install the next brushlayer 3-8 feet (1-2.5 m) above the previous row.

- Seed and mulch slope. Shallow slopes, generally 3:1 or flatter may be seeded and mulched by hand. Steeper slopes should have seed applied hydraulically and the mulch shall be anchored with tackifier or other approved methods.

Inspection and Maintenance: Regular inspection and maintenance of bioengineering installations should be conducted, particularly during the first year. Prompt correction of any failures is essential to prevent major problems from developing.



NOTES:
1. Brush layers, geofabrics and geogrids are tensile inclusions, which modify shear stress.
2. Additionally, once established the root systems bind the entire system together as a coherent mass.
3. Live brush layers act as horizontal drains and improve slope stability by redirecting the flow direction.
4. Cut branches 3' to 12' long from appropriate salix, cornus or populus species.
5. Branches up to 12' long can be used on fillslope installations. Branches for cutslope installation can be 2' to 10' long depending on the bench excavation.
6. Natural geofabrics (coir netting) or geogrids can be wrapped around soil layers to provide additional soil reinforcement.

BRUSHLAYERING WITH GEOTEXTILE SOIL WRAP

FILE: SOILWRAP

Brushlayering with Rock Toe Protection

Brushlayers with rock toe are rows of live woody cuttings that are layered, alternating with successive lifts of soil fill, to construct a reinforced slope or embankment above a rock toe that armors the bank until the vegetation becomes established.

Conditions Where Practice Applies

Streambanks with low velocities, and slopes up to 2:1 that are susceptible to shallow mass movement. Sea or lake shores with light to moderate wave energy.

Materials

Live willow branches (or cuttings of other adventitiously-rooting species) at least 6 ft long, with a minimum diameter of ¾ in. Rock sized appropriately to resist velocities at design discharge.

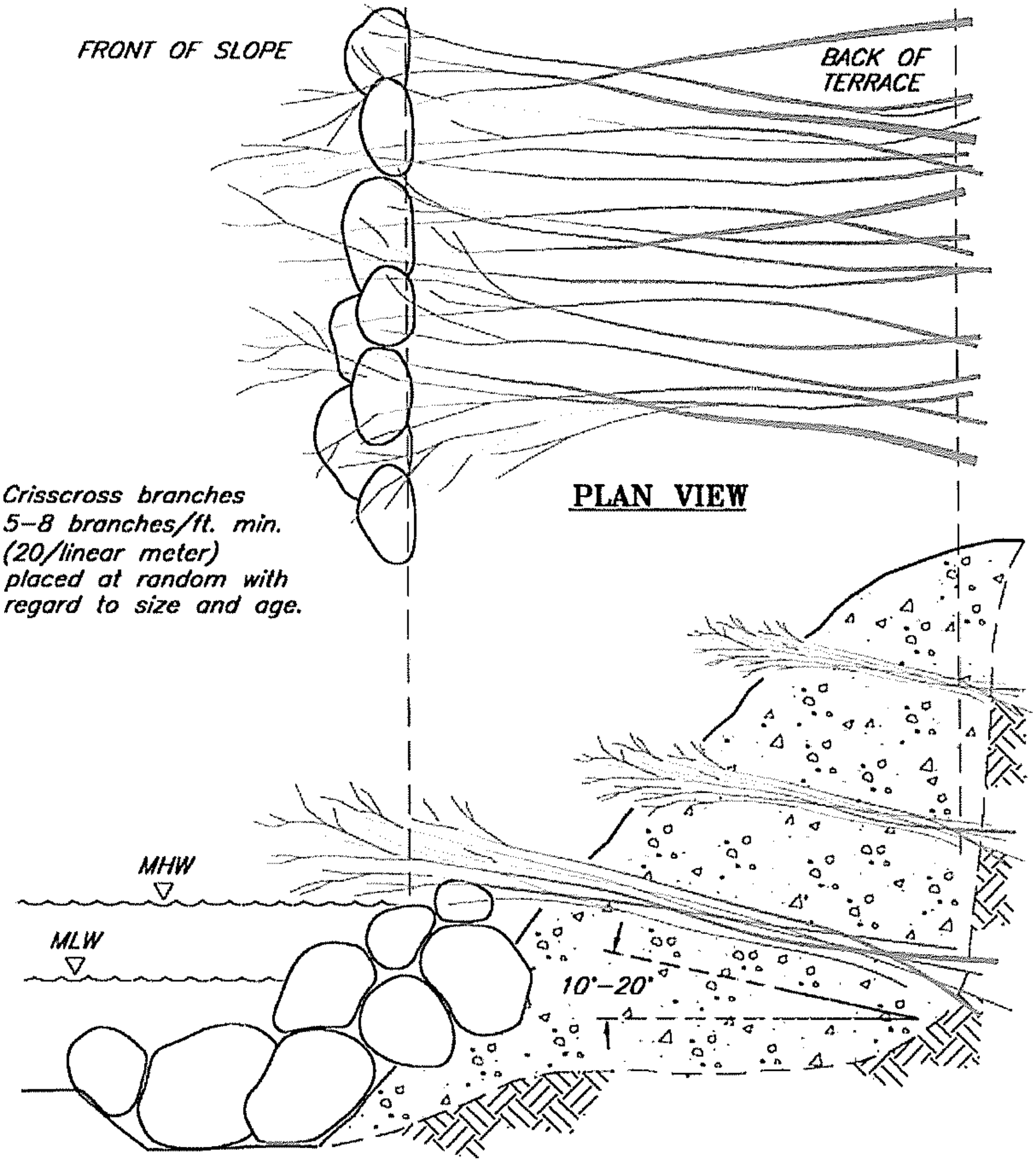
Advantages

Brushlayering involves relatively simple construction. Among the ground stabilizing techniques, the brushlayer has an immediate impact, its protective and stabilizing effect extending into lower soil horizons. At extreme sites where erosion, deposition, and rockfall are particular hazards, brush layers and the pioneer vegetation that develops with them gradually eliminate these problems. Fast establishment of a stable soil-root complex is possible. Relatively short and spreading branches of the scrub willows growing in mountainous regions can be used. Simultaneous brushlayering construction during fill operations is possible. It is one of the best techniques for revegetating and stabilizing streambanks and slopes. Living and non-living brush layers along streambanks also provide valuable fish habitat.

Brushlayers also provide a flexible strengthening system to fills. A bank can sag or distort without pulling apart the brushlayers. The brushlayers will “stretch” because they are laid in to the slope on a diagonal, and are also self-repairing to the extent that they regrow roots in the case of a shear failure. Brushlayers act as horizontal drains and favorably modify the soil water flow regime.

Implementation

Place rock as designed. The rock should extend up the bank to the expected mean high water. Construct by excavating or filling a terrace above the rock protection. The terrace must slope back into the slope 10-20 degrees minimum. Place branches at least 6 ft long on the terrace. Branches shall crisscross at random with regard to size and age. Place 5-8 branches per linear foot (20/linear m), and 8-18" should protrude beyond the face of the slope. Cover and compact (add water if necessary) the brush layer with 6-18" of soil and construct another terrace and brushlayer. Proceed up the bank as desired.



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 8–18in. (0.20–0.50 meters) beyond the face of the slope.

BRUSHLAYERING WITH ROCK TOE PROTECTION

FILE: BRLAY-RT

Brush Mattress (Brush Mat)

A brush mattress or brush mat is a revegetation technique that provides a protective covering to a slope or streambank as soon as it is installed. A brush mattress is typically constructed using live willow branches or other species that root easily from cuttings, but can also be constructed with any brushy, woody branches in order to provide immediate and effective slope protection.

Conditions Where Practice Applies

Brush mattresses are ideal for eroding streambanks or slopes where immediate protection is needed. Streambanks which are in jeopardy of being scoured due to high erosive forces can be rapidly stabilized by installation of a brush mattress along the eroding reach. Because of the dense layer of brush, the brush mattress can deflect water from the bank and protect it from scouring, while also providing habitat directly along the waters' edge. Brush mattresses also work well for shoreline protection. The density of the mat will break the impact of waves and instantly provide a thick protective layer of brush along the shoreline. If the desire is to stabilize and revegetate an eroding streambank or shoreline and discourage foot trails along sensitive areas, brush mats work well as impenetrable barriers, giving time for vegetation to become established. On slopes, brush mattressing provides rapid protection against surficial erosion. Brush mats are often combined with other soil stabilization techniques such as vegetated riprap, wattles, live Fascines, root wads, live siltation, or coir logs, which may be needed to secure the toe of the slope. The brush mattress technique is usually most effective on slopes no steeper than 2H:1V.

Advantages

Brush mattresses quickly stabilize a slope or streambank by providing a dense network of branches which prevent surficial erosion, while also collecting soil and native seeds. The overlapping branches provide an ideal environment for native seeds to germinate and establish. As the live branches root and grow, the soil is reinforced with an underground matrix of spreading roots. If used on streambanks, a brush mat will trap sediments during high water, and eventually the plant growth on the stabilized streambank will provide aquatic habitat. Brush mattresses work well for stabilizing reconstructed stream channels, as they provide immediate cover for fish and instant bank protection, even before they become established and grow.

Of all the streambank biotechnical practices, brush mattresses can withstand the highest velocities. Studies conducted by Christoph Gerstgraser, Universitat fur Bodenkultur, Vienna, Austria, demonstrated that brush mattresses stabilized the bank in a test flume against velocities exceeding 7 m/s (20 f/s), while other techniques, even rock riprap, failed.

Brush Mattress (Brush Mat) (continued)

Disadvantages

Large numbers of cuttings are required, probably more than any other biotechnical method, and the availability of plant material should be carefully evaluated before including this technique in a revegetation design. Brush mat installation is a labor-intensive construction method. As with most biotechnical projects, if using live cuttings, brush mattresses must be installed during the dormancy period of species used. In areas which receive little rainfall, brush mattresses installed on dry slopes may not survive long, as this technique does not entrench the branches deeply into the soil.

Implementation

- Prepare the slope or streambank by clearing away large debris, and the slope should be graded so that branches will lay flat on the bank. Do not disturb the slope or bank any more than necessary. Excavate a horizontal trench, 8 to 12 inches deep, at the toe of the streambank or at the base of applicable area on the slope. The basal ends of the branches should extend into moist soil.

- Lay the cuttings flat against the graded slope, slightly crisscrossed, with the basal ends placed as deeply into the trench as possible. Continue to lay the cuttings along the face of the bank or slope until about 80% groundcover is achieved (about 6-12 inches thick). If the length of the slope or bank is longer than the cuttings, stagger and overlap the cuttings so the entire area has adequate coverage. Rooted plants can be planted within the brush mattress, but these should be planted before the branches are laid, as it is too difficult to plant through the mattress afterward.

- Pound in a grid of 24 to 36 inch long stakes into the mattress at 3 to 4 foot centers. Do not pound the stakes completely in, as this will be done after tying. Use longer stakes in less cohesive (sandy) soil. Secure the brush mattress by using cord, rope, or 10-12 gauge galvanized wire tied in a diamond pattern between each row of stakes. (Tie the cord or wire to the stakes in such a manner that if it breaks, the integrity of the remaining cord or wire is still maintained). Notching or drilling stakes may make securing cord or wire to stakes easier, but is not necessary.

- After networking the mattress with cord or wire, drive the stakes in further to compress the mattress tightly against the slope. If constructing a brush mattress on a streambank, be careful not to leave loose overhanging branches which may catch on material floating down the stream channel. The mattress may be ripped from the streambank if this occurs.

Brush Mattress (Brush Mat) (continued)

- Secure the toe of the mattress using the technique best suitable for the site conditions. To secure the toe of the mattress using a willow wattle, first construct a wattle the length of the area to be treated (see wattle technique). Make sure the wattle is tied together tightly. Place the wattle in the trench over the cut ends of the brush mattress. Secure the wattle with 18 to 48 inch long wedge-shaped wooden stakes every 3-4 feet. In some cases, such as small streams or gentle slopes, simply placing large locally collected rocks around and on top of the basal ends of the cuttings is enough to secure the toe of the mattress. Other techniques which may be used include vegetated riprap, wattles, live fascines, rootwad revetments, live siltation, or coir logs.

- Backfill around and in between the branches of the mattress by using material excavated from the trench, working the soil in well. Buckets of water will help to wash the soil down into the stems. It is most important for the thicker, basal ends of the mattress to get good soil cover for rooting, but generally cover at least 1/4 of the depth of the mattress with soil. If installed along a stream, make sure the upstream end of the mattress and wattle is keyed into the streambank to prevent high flows from scouring behind the mattress. It is also a good idea to protect this area with some revetment, large rocks, or tree trunks. If possible, tie the mattress to existing vegetation or roots on the bank for extra security.

Maintenance

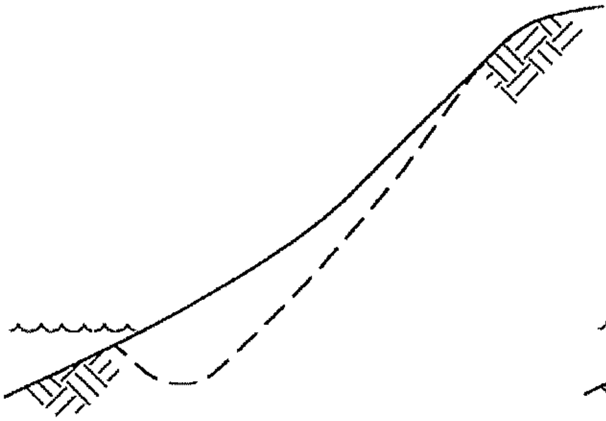
It is important to monitor the brush mattress after it has been installed. Periodic monitoring of the project will provide valuable insight into the stabilization process and may offer important information for future biotechnical projects. If the willow does not grow, the mattress will still provide stability, especially if it is backfilled and seeded with native grasses, sedges, or rushes.

Periodic maintenance includes making sure the stakes and cord/wire are still securing the mattress to the streambank. The upstream end should be carefully checked to make sure flows are not getting behind the mattress. To ensure the highest success for the treated area, determine the land management practices that created the eroded streambanks and modify those practices as necessary (From Bentrup and Hoag, 1998).

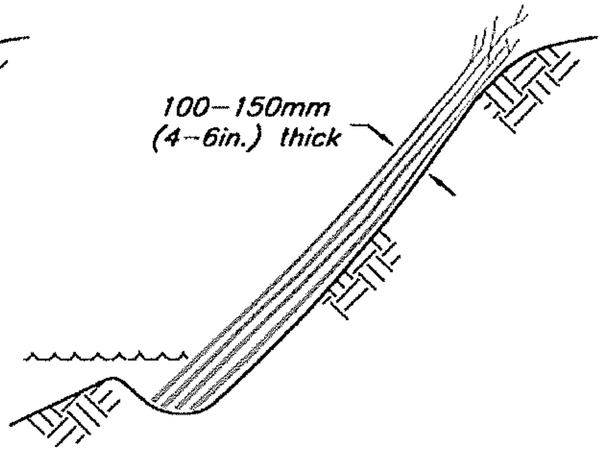
If the area is grazed, restrict livestock from treated area to allow the eroded section of the streambank to heal. Exclosure fences are the most efficient means to accomplish this goal. Managers should resist the temptation to put the exclosure fences at the high water line. The exclosure area should include enough of the riparian zone to allow the stream to shift naturally over time.

If the area is farmed, a riparian buffer strip should be established and maintained. A buffer strip on both sides of the stream should be set aside to allow for natural riparian vegetation and stream function. A wider buffer strip is strongly encouraged and will yield greater benefits.

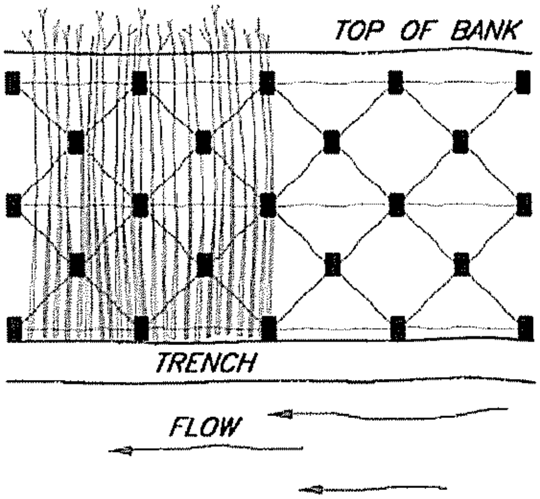
Finally, a stream is an interconnected system. Land use practices both upstream and downstream will affect the success of your bioengineering work.



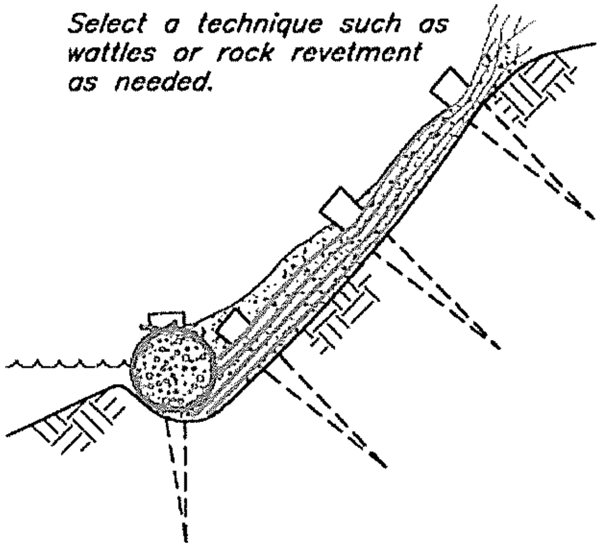
Step 1: Excavate trench and grade bank.



Step 2: Place willow branches making sure that the butt ends reach the bottom.



Step 3: Place stake (notched) on 1.0m (3ft.) centers and secure the mattress with twine, rope or wire.



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

FILE: BRSHMATT

Coir Rolls with Brushlayering

Coir logs (also called coir rolls or fiberschines) are long cylindrical tubes that are composed of interwoven coconut fibers which are bound together with durable coir netting. Coir rolls are particularly applicable for wetland, streambank, and shoreline projects. Coir rolls are most commonly available in 12 inch diameters and 20 foot lengths. These rolls can be linked together to form longer tubes, and are often used in combination with other biotechnical techniques, such as brushlayering or live siltation. Coir logs encourage siltation and wetland/floodplain creation.

Conditions Where Practice Applies

The tough, long-lasting coconut fibers make coir rolls appropriate for wetland, streambank, and shoreline applications. Coir rolls work well when immediate erosion control is needed. Brushlayers work well with coir roll applications, adding further stabilization with a live root system, while also providing excellent habitat features. The coir roll provides a base for the brushlayer cuttings to be laid upon at an appropriate angle which benefits the growth of cuttings. The cuttings provide further protection from breaking waves and high flows.

Materials

Coir rolls of the appropriate size and length, live cuttings for brushlayering, and strong rope and wooden stakes are necessary. Also needed is machinery and/or tools for leveling and compacting soil. If using a soil wrap, material (blanket or mats) appropriate to the application conditions is needed. If planning to plant coir rolls with container plants, suitable plant material such as wetland grasses are needed.

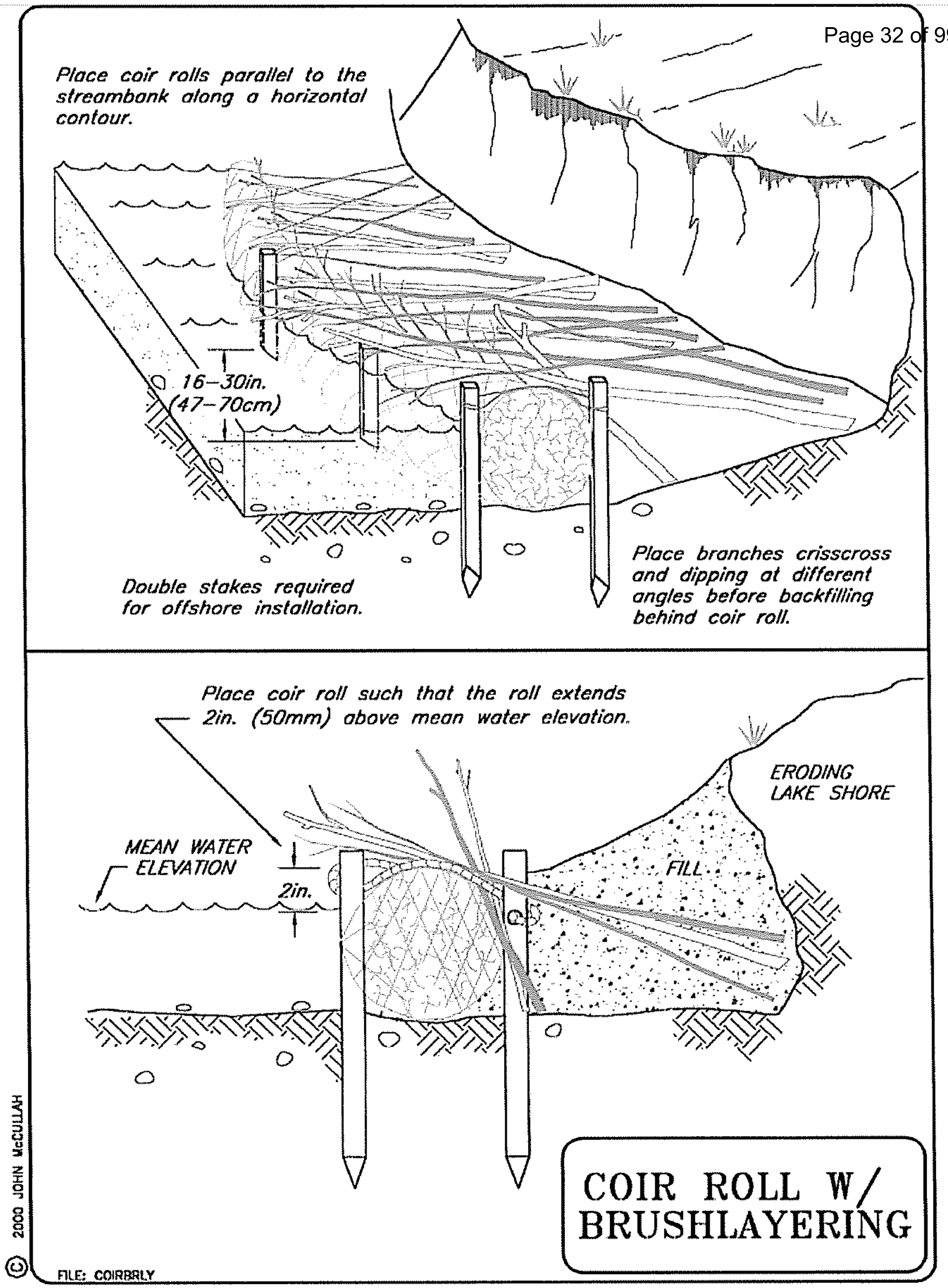
Advantages

Provides a "soft" engineering method for shoreline and streambank stabilization as opposed to "hard" engineering such as gabions and riprap alone. This makes coir rolls with brushlayering more appropriate for recreational use areas where swimmers could be injured by wire or rocks, or critical fisheries where habitat-friendly streambank stabilization is needed. The coir roll/brushlayering combination provides immediate shoreline and streambank protection, with additional benefits of riparian enhancement when the cuttings become established.

Implementation

Clear debris away and level area of application. Install coir rolls as specified (see fiberschines/coir rolls for implementation information). Prepare soil bed behind installed coir rolls for laying brushlayer cuttings. Determine soil level by laying a straight cutting on the coir roll with approximately 20% of the cutting sticking out past the roll, and with the basal ends dipping down into the soil. It is important that the bud ends of the live cuttings angle up to some degree from the basal ends. Lay cuttings in this fashion, slightly crisscrossed for additional strength. (See Brushlayering).

Next, backfill over cuttings with soil, covering the lower 80% of the branches. At this time, soil can be leveled and prepared for a soil wrap for additional height and soil stability. If simply covering the cuttings with soil, compact slightly and grade slope to appropriate angle. Use water to wash soil in between branch layers. Mulch and seed exposed areas with native species.

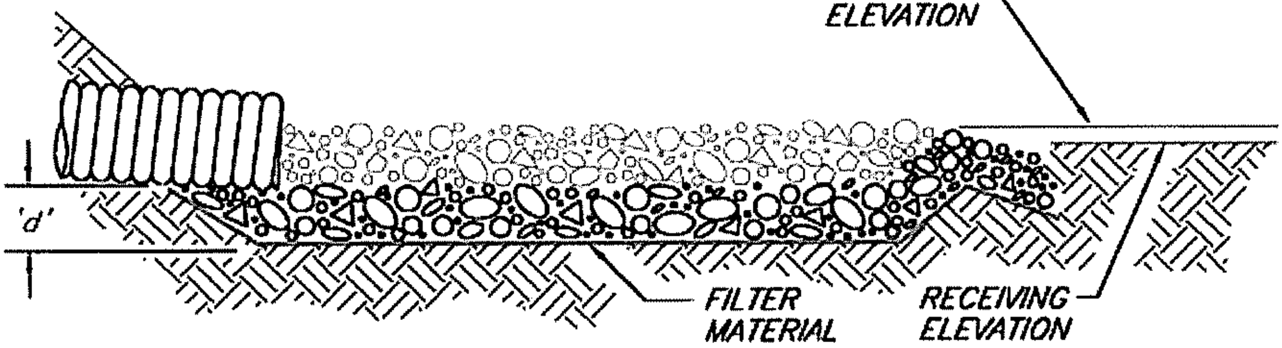

Place coir rolls parallel to the streambank along a horizontal contour.
16–30in. (47–70cm)
Double stakes required for offshore installation.
Place branches crisscross and dipping at different angles before backfilling behind coir roll.
Place coir roll such that the roll extends 2in. (50mm) above mean water elevation.
MEAN WATER ELEVATION
2in.
ERODING LAKE SHORE
FILL
COIR ROLL W/ BRUSHLAYERING
© 2000 JOHN McCULLAH
FILE: COIRBRLY

ENERGY DISSIPATOR

Construction Specifications:

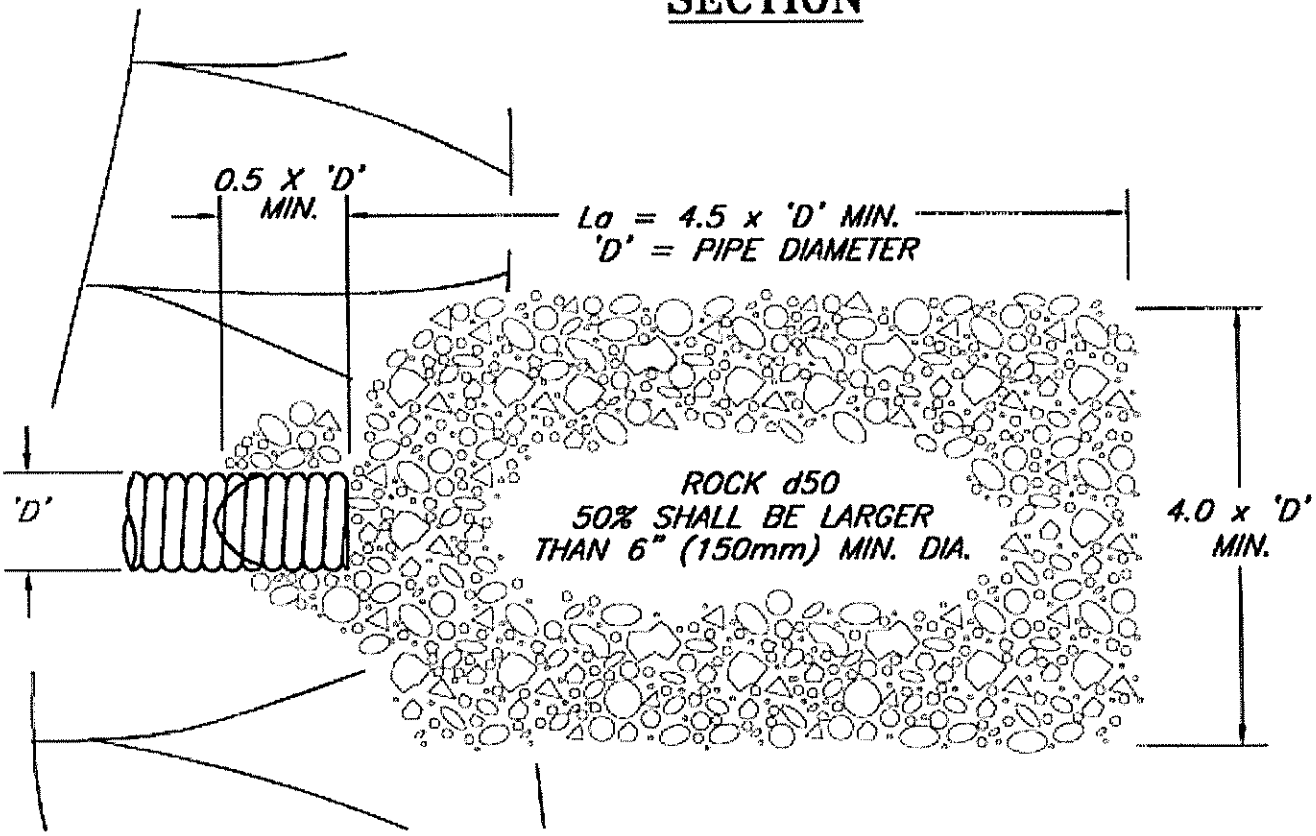
- Ensure that the subgrade for the filter and riprap follows the required lines and grades shown in the plan. Compact any fill required in the subgrade to the density of the surrounding undisturbed material. Low areas in the subgrade on undisturbed soil may also be filled by increasing the riprap thickness.
- The riprap and gravel filter must conform to the specified grading limits shown on the plans.
- Filter cloth, when used, must meet design requirements and be properly protected from punching or tearing during installation. Repair any damaged fabric by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap a minimum of 1 foot (0.3 m). If the damage is extensive, replace the entire filter cloth.
- Riprap may be placed by equipment, but take care to avoid damaging the filter.
- The minimum thickness of the riprap should be 1.5 times the maximum stone diameter.
- Riprap may be field stone or rough quarry stone. It should be hard, angular, highly weather-resistant and well graded.
- Construct the apron on zero grade with no overfall at the end. Make the top of the riprap at the downstream end level with the receiving area or slightly below it.
- Ensure that the apron is properly aligned with the receiving stream and preferably straight throughout its length. If a curve is needed to fit site conditions, place it in the upper section of the apron.
- Immediately after construction, stabilize all disturbed areas with vegetation.

Inspection and Maintenance: Inspect riprap outlet structures after heavy rains to see if any erosion around or below the riprap has taken place or if stones have been dislodged. Immediately make all needed repairs to prevent further damage.



THICKNESS ('d') = 1.5 x MAX. ROCK DIAMETER – 6" (150mm) MIN.

SECTION



PLAN

NOTES:

1. 'La' = LENGTH OF APRON. DISTANCE 'La' SHALL BE OF SUFFICIENT LENGTH TO DISSIPATE ENERGY.
2. APRON SHALL BE SET AT A ZERO GRADE AND ALIGNED STRAIGHT.
3. FILTER MATERIAL SHALL BE FILTER FABRIC OR 6" (150mm) THICK MINIMUM GRADED GRAVEL LAYER.

ENERGY DISSIPATOR

EROSION CONTROL BLANKETS AND MATS

Construction Specifications:

Site Preparation:

- Proper site preparation is essential to ensure complete contact of the protection matting with the soil.
- Grade and shape area of installation.
- Remove all rocks, clods, vegetative or other obstructions so that the installed blankets, or mats will have direct contact with the soil.
- Prepare seedbed by loosening 2-3 inches (50.8-76.2 mm) of topsoil above final grade.
- Incorporate amendments, such as lime and fertilizer, into soil according to soil test and the seeding plan.

Seeding:

- Seed area <u>before</u> blanket installation for erosion control and re-vegetation. Seeding <u>after</u> mat installation is often specified for turf reinforcement application. When seeding prior to blanket installation, all check slots and other areas disturbed during installation must be reseeded.
- Where soil filling is specified, seed the matting and the entire disturbed area after installation and prior to filling the mat with soil.

Anchoring: U-shaped wire staples, metal geotextile stake pins, or triangular wooden stakes can be used to anchor mats to the ground surface. Wire staples should be a minimum of 11 gauge. Metal stake pins should be 3/16 inch (4.8 mm) diameter steel with a 1 1/2 inch (38.1 mm) steel washer at the head of the pin. Wire staples and metal stakes should be driven flush to the soil surface. All anchors should be 6-8 inches (0.2-0.5 m) long and have sufficient ground penetration to resist pullout. Longer anchors may be required for loose soils.

Installation on Slopes:

- Begin at the top of the slope and anchor its blanket in a 6 inch (0.2 m) deep x 6 inch (0.2 m) wide trench. Backfill trench and tamp earth firmly.
- Unroll blanket downslope in the direction of the water flow.
- The edges of adjacent parallel rolls must be overlapped 2-3 inches (51-76 mm) and be stapled every 3 feet (0.9 m).
- When blankets must be spliced, place blankets end over end (shingle style) with 6 inch (0.2 m) overlap. Staple through overlapped area, approximately 12 inches (0.3 m) apart.
- Lay blankets loosely and maintain direct contact with the soil - do not stretch.
- Blankets shall be stapled sufficiently to anchor blanket and maintain contact with the soil. Staples shall be placed down the center and staggered with the staples placed along the edges. Steep slopes, 1:1 to 2:1, require 2 staples per square yard. Moderate slopes, 2:1 to 3:1, require 1-2 staples per square yard (1 staple 3' o.c.). Gentle slopes require 1 staple per square yard.

Installation in channels:

- Dig initial anchor trench 12 inches (0.3 m) deep and 6 inches (0.2 m) wide across the channel at the lower end of the project area.

- Excavate intermittent check slots, 6 inches (0.2 m) deep and 6 inches (0.2 m) wide across the channel at 25-30 foot (7.6-9.1 m) intervals along the channel.

- Cut longitudinal channel anchor slots 4 inches (101 mm) deep and 4 inches (101 mm) wide along each side of the installation to bury edges of matting. Whenever possible extend matting 2-3 inches (51-76 mm) above the crest of channel side slopes.

- Beginning at the downstream end and in the center of the channel, place the initial end of the first roll in the anchor trench and secure with fastening devices at 1 foot (.3 m) intervals. **Note:** matting will initially be upside down in anchor trench.

- In the same manner, position adjacent rolls in anchor trench, overlapping the preceding roll a minimum of 3 inches (7.6 cm).

- Secure these initial ends of mats with anchors at 1 foot (0.3 m) intervals, backfill and compact soil.

- Unroll center strip of matting upstream. Stop at next check slot or terminal anchor trench.

- Unroll adjacent mats upstream in similar fashion, maintaining a 3 inch (76 mm) overlap.

- Fold and secure all rolls of matting snugly into all transverse check slots. Lay mat in the bottom of the slot then fold back against itself. Anchor through both layers of mat at 1 inch (25.4 mm) intervals, then backfill and compact soil. Continue rolling all mat widths upstream to the next check slot or terminal anchor trench.

- <u>Alternate method for noncritical installations</u>: place two rows of anchors on 6 inch (0.2 m) centers at 25-30 feet (7.6-9.1 m) intervals in lieu of excavated check slots.

- Shingle-lap spliced ends by a minimum of 1 foot (0.3 m) with upstream mat on top to prevent uplifting by water or begin new rolls in a check slot. Anchor overlapped area by placing two rows of anchors, 1 foot (0.3 m) apart on 1 foot (0.3 m) intervals.

- Place edges of outside mats in previously excavated longitudinal slots, anchor using prescribed staple pattern, backfill and compact soil.

- Anchor, fill and compact upstream end of mat in a 12 inch (0.3 m) x 6 inch (0.2 m) terminal trench.

- Secure mat to ground surface using U-shaped wire staples geotextile pins or wooden stakes.
- Seed and fill turf reinforcement matting with soil, if specified.

<u>Soil filling</u> if specified for turf reinforcement:

- After seeding, spread and lightly rake 1/2-3/4 inches (12.7-19.1 mm) of fine topsoil into the mat apertures to completely fill mat thickness. Use backside of rake or other flat implement.

- Spread topsoil using lightweight loader, backhoe, or other power equipment. Avoid sharp turns with equipment.

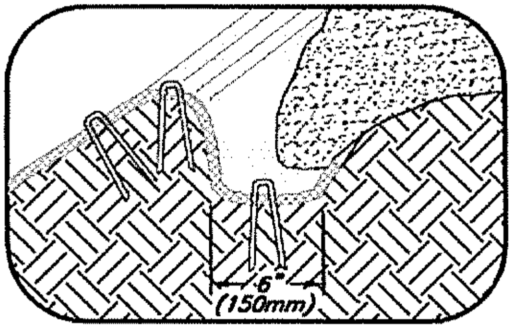
- Do not drive tracked or heavy equipment over mat.
- Avoid any traffic over matting if loose or wet soil conditions exist.
- Use shovels, rakes or brooms for fine grading and touch up.
- Smooth out soil filling, just exposing top netting of matrix.

Inspection and Maintenance:

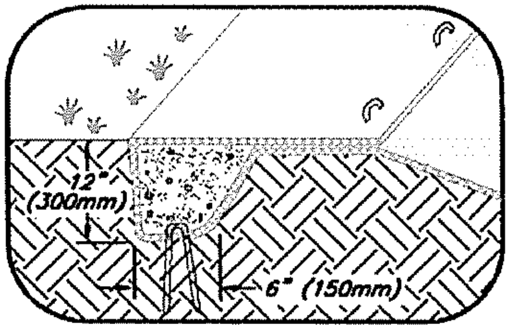
- All blanket and mats should be inspected periodically following installation.

- Inspect installation after significant rainstorms to check for erosion and undermining. Any failure should be repaired immediately.

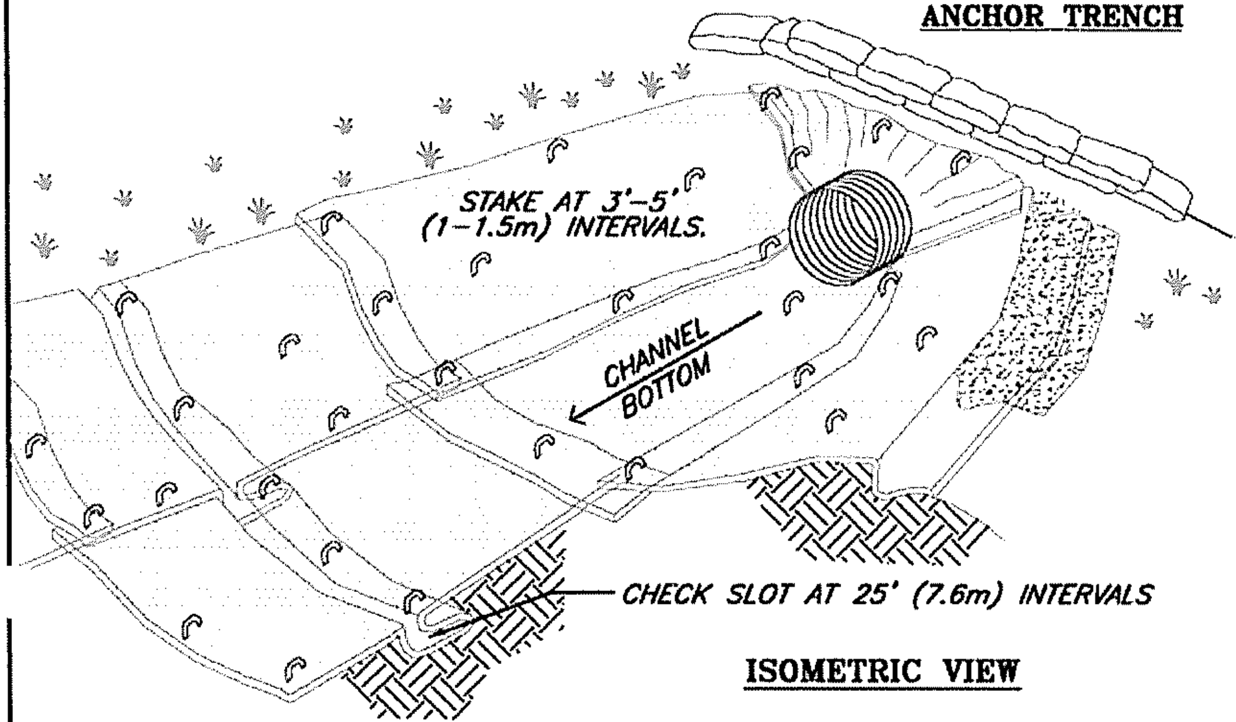
- If washout or breakage occurs, re-install the material after repairing the damage to the slope or drainageway.



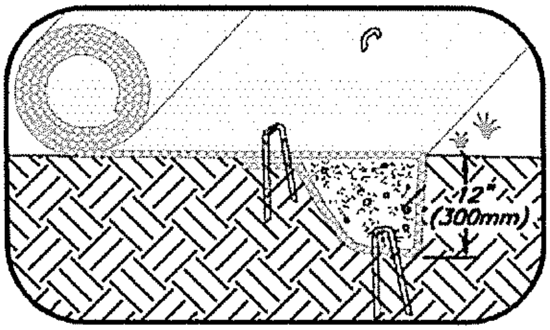
LONGITUDINAL ANCHOR TRENCH



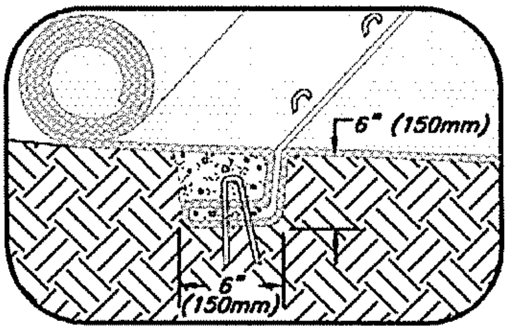
TERMINAL SLOPE AND CHANNEL ANCHOR TRENCH



ISOMETRIC VIEW



INITIAL CHANNEL ANCHOR TRENCH



INTERMITTENT CHECK SLOT

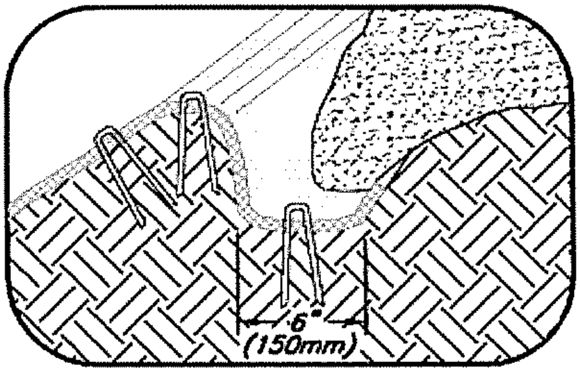
NOTES:

1. CHECK SLOTS TO BE CONSTRUCTED PER MANUFACTURERS SPECIFICATIONS.

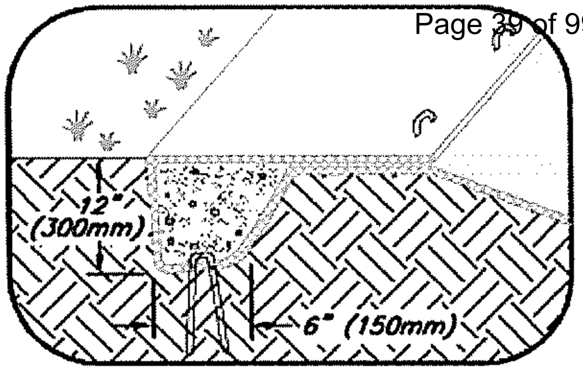
2. STAKING OR STAPLING LAYOUT PER MANUFACTURERS SPECIFICATIONS.

FILE: BLNKTCHA

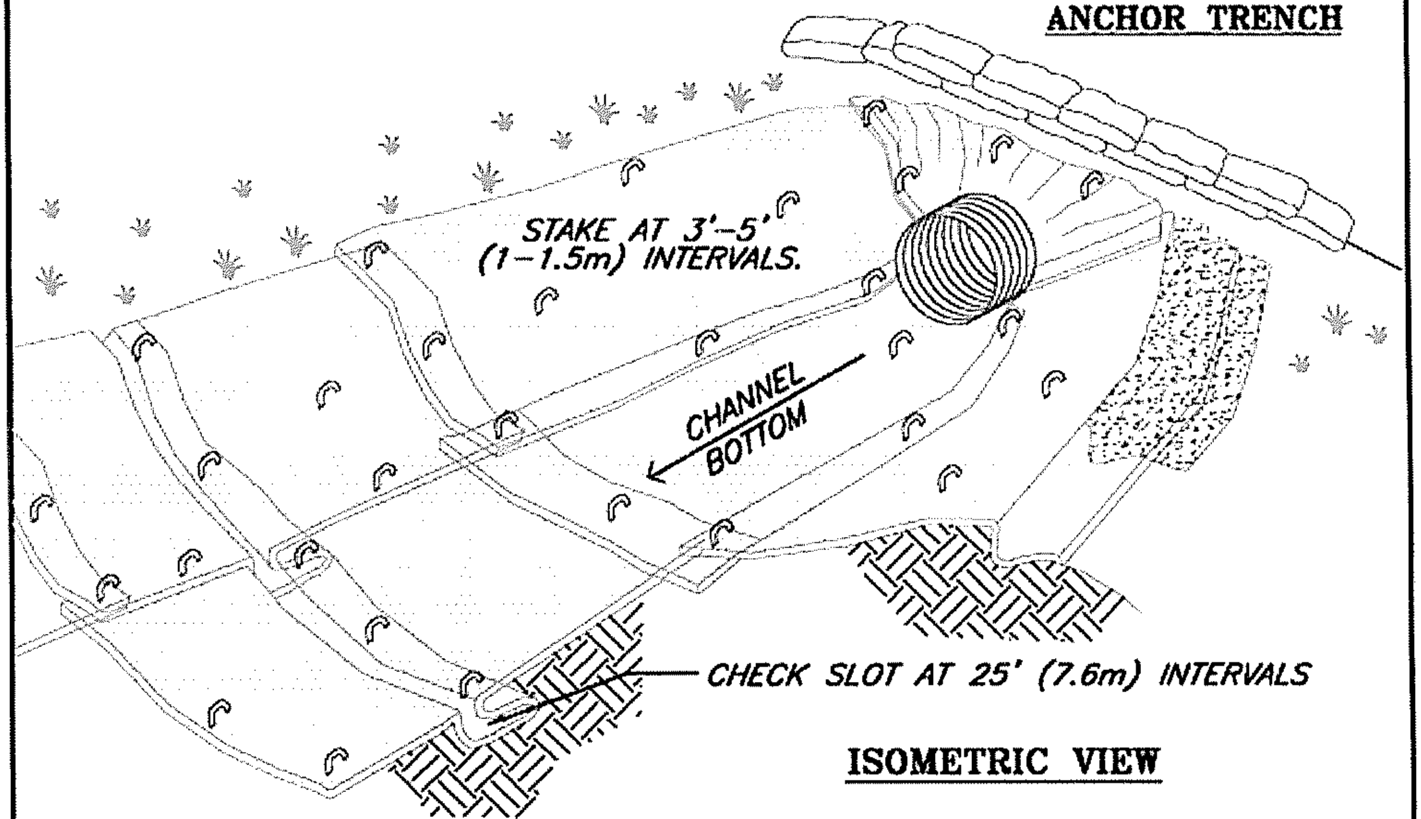
EROSION BLANKETS & TURF REINFORCEMENT MATS CHANNEL INSTALLATION



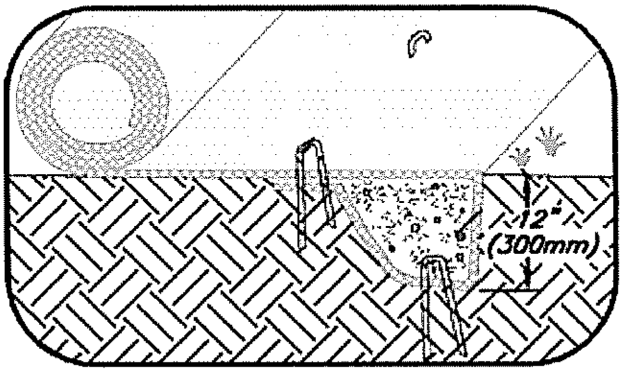
LONGITUDINAL ANCHOR TRENCH



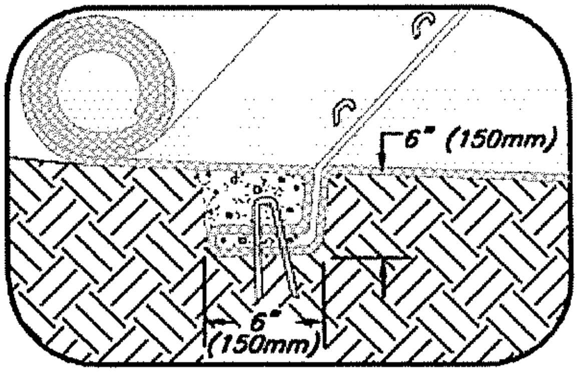
TERMINAL SLOPE AND CHANNEL ANCHOR TRENCH



ISOMETRIC VIEW



INITIAL CHANNEL ANCHOR TRENCH



INTERMITTENT CHECK SLOT

NOTES:

1. CHECK SLOTS TO BE CONSTRUCTED PER MANUFACTURERS SPECIFICATIONS.

2. STAKING OR STAPLING LAYOUT PER MANUFACTURERS SPECIFICATIONS.

EROSION BLANKETS & TURF REINFORCEMENT MATS CHANNEL INSTALLATION

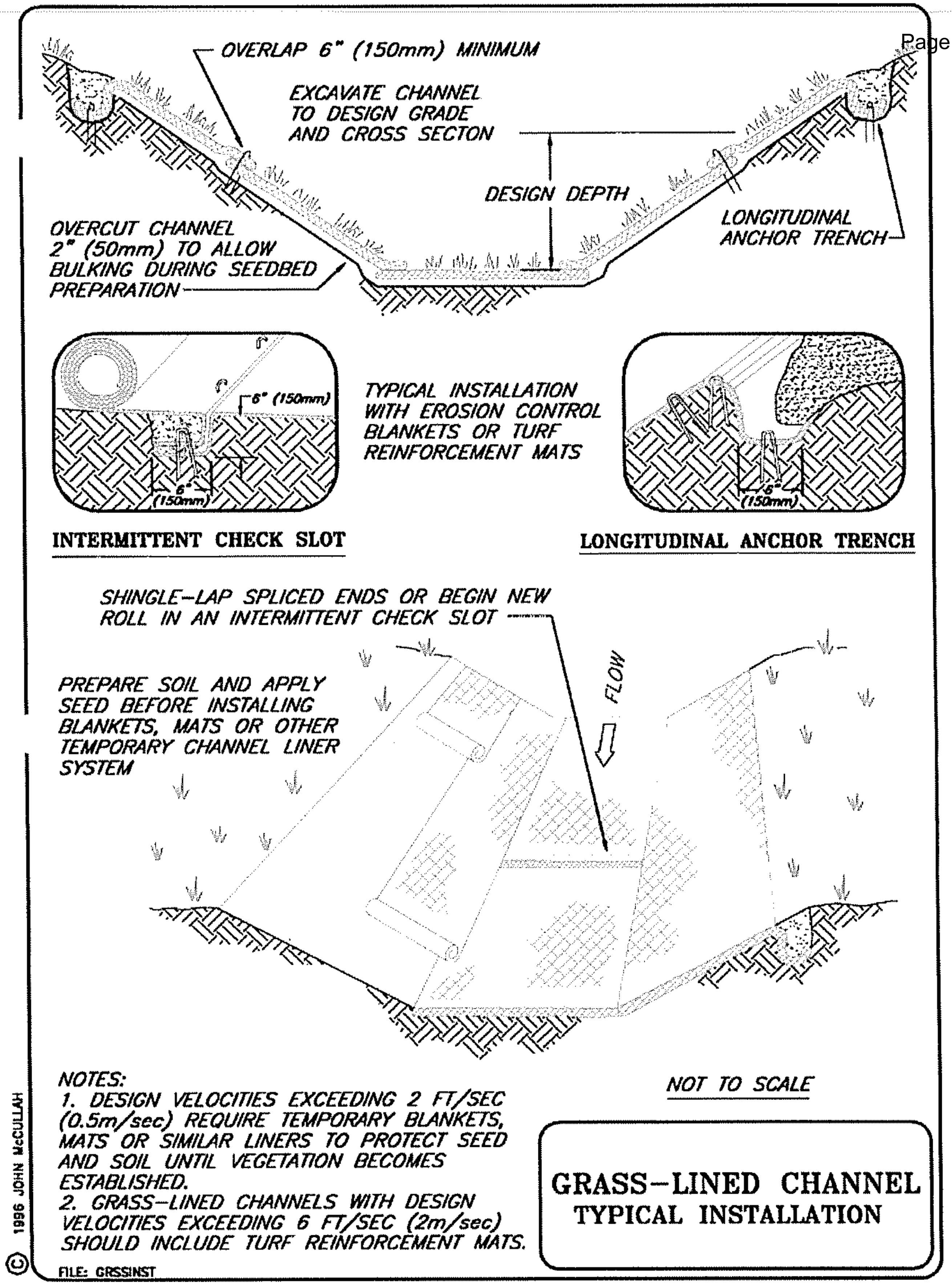
FILE: BLNKTCHA

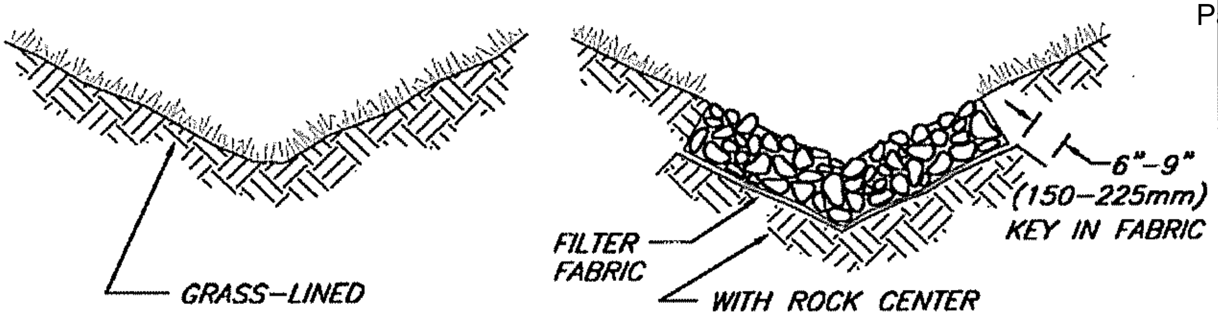
GRASSED-LINED CHANNELS

Construction Specifications: See Permanent Seeding and Erosion Control Blankets and Mats BMPs.

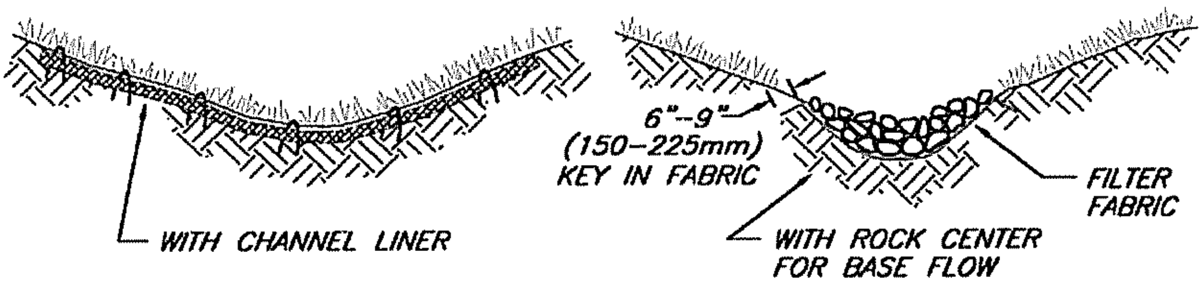
Inspection and Maintenance:

- During the initial establishment, grass-lined channels should be repaired and grass re-established if necessary.
- After grass has become established, the channel should be checked periodically to determine if the channel is withstanding flow velocities without damage.
- Check the channel for debris, scour, or erosion and immediately make repairs. It is particularly important to check the channel outlet and all road crossings for bank stability and evidence of piping or scour holes and make repairs immediately.
- Remove all significant sediment accumulations to maintain the designed carrying capacity.
- Keep the grass in a healthy, vigorous condition at all times, since it is the primary erosion protection for the channel.
- Permanent grassed waterways should be seasonally maintained by mowing or irrigating, depending on the type of vegetation selected.

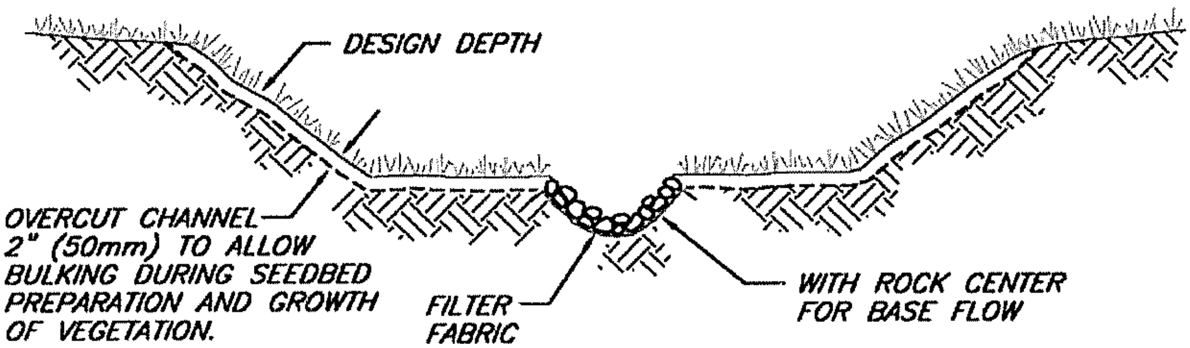

OVERLAP 6" (150mm) MINIMUM
EXCAVATE CHANNEL TO DESIGN GRADE AND CROSS SECTON
DESIGN DEPTH
OVERCUT CHANNEL 2" (50mm) TO ALLOW BULKING DURING SEEDBED PREPARATION
LONGITUDINAL ANCHOR TRENCH
6" (150mm)
6" (150mm)
TYPICAL INSTALLATION WITH EROSION CONTROL BLANKETS OR TURF REINFORCEMENT MATS
6" (150mm)
INTERMITTENT CHECK SLOT
LONGITUDINAL ANCHOR TRENCH
SHINGLE-LAP SPLICED ENDS OR BEGIN NEW ROLL IN AN INTERMITTENT CHECK SLOT
PREPARE SOIL AND APPLY SEED BEFORE INSTALLING BLANKETS, MATS OR OTHER TEMPORARY CHANNEL LINER SYSTEM
FLOW
NOTES:
1. DESIGN VELOCITIES EXCEEDING 2 FT/SEC (0.5m/sec) REQUIRE TEMPORARY BLANKETS, MATS OR SIMILAR LINERS TO PROTECT SEED AND SOIL UNTIL VEGETATION BECOMES ESTABLISHED.
2. GRASS-LINED CHANNELS WITH DESIGN VELOCITIES EXCEEDING 6 FT/SEC (2m/sec) SHOULD INCLUDE TURF REINFORCEMENT MATS.
NOT TO SCALE
GRASS-LINED CHANNEL
TYPICAL INSTALLATION
© 1996 JOHN McCULLAH
FILE: GRSSINST



TYPICAL V-SHAPED CHANNEL CROSS-SECTION



TYPICAL PARABOLIC CHANNEL CROSS-SECTION



TYPICAL TRAPEZOIDAL CHANNEL CROSS-SECTION

GRASS-LINED CHANNEL TYPICAL CROSS SECTIONS

FILE: GRASS-XS

HERBICIDE USE

The use of herbicides for routine maintenance within aquatic or riparian areas will be restricted to the following activities and best management practices described in the Agreement. Best management practices implemented for such herbicide use are:

- Utilize an Integrated Pest Management approach that considers the full range of pest control alternatives. Choose site-specific strategies and times of treatment that provide the best combination of protecting preserve resources, human health, and non-target organisms and that are efficient and cost-effective in controlling the target invasive species. Direct the control method narrowly at the target organism to avoid broad impacts on the ecosystem. Modify control methods over time as site conditions and treatment techniques change. Use pesticides only where alternative methods are known to be ineffective. Apply pesticides in an environmentally safe manner. Take all reasonable precautions to protect the environment, the health and safety of employees, adjacent lands and preserve visitors.

- Only herbicides and surfactants registered for aquatic use will be applied to aquatic areas or within the banks of channels. All conditions of the herbicide label will be followed.

- Drift will be avoided by not applying herbicides under windy conditions, and by using ground-based applicators, low tank pressures and spray nozzles adjusted for larger droplet sizes.

- Herbicides will not be applied during or within 24 hours prior to rain.

- None of the following activities will be undertaken in aquatic or riparian areas: mixing, loading and storage of pesticides; rinsing of equipment and pesticide containers;

- District staff will undergo annual pesticide safety training.

Instream Diversion Techniques

Definition: A stream diversion is a temporary bypass through a pipe, flume, or excavated channel that carries water flow around work areas. Stream diversion is commonly used during culvert installation or replacement. Where possible, a stream diversion should be the first choice to control erosion and sediment during the construction of culverts or other instream structures.

Purpose: During construction in a watercourse, particularly culvert installation and repair, these temporary water bypass structures are an effective sediment and erosion control technique.

Design Considerations: The selection of which stream diversion technique to use will depend upon the type of work involved, physical characteristics of the site, and the volume of water flowing through the project.

Advantages of a pumped diversion include:

- Downstream sediment transport can almost be eliminated
- De-watering of the work area is possible
- Pipes can be moved about to allow construction operations
- The dams can serve as temporary access.
- Increased flows can be managed by adding more pumping capacity.

Some disadvantages of a pumped diversion are:

- Flow volume is limited by pump capacity
- Requires 24-hour monitoring of pumps
- Sudden rain could overtop dams
- Minor in-stream disturbance to install and remove dams

Advantages of excavated channels and flumes are:

- Isolates work from water flow and allows dewatering
- Can handle larger flows than pumps

Disadvantages of excavated channels and flumes are:

- Bypass channel or flume must be sized to handle flows, including possible floods
- Channels must be protected from erosion
- Flow diversion and then re-direction with small dams causes in-stream disturbance and sediment

Stream diversions should not be used:

- Without identifying potential impacts to the stream channel
- In or adjacent to water bodies until all necessary permits have been obtained

Instream Diversion Techniques (continued)

Construction Specifications:

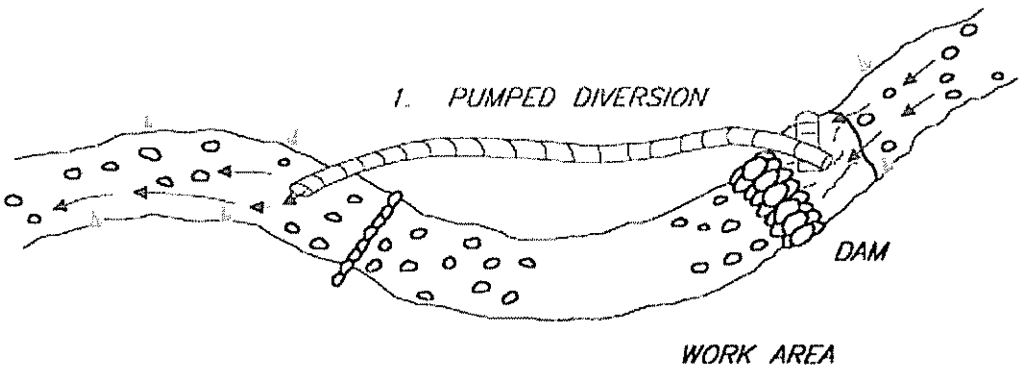
Guidelines will vary based on existing site conditions.

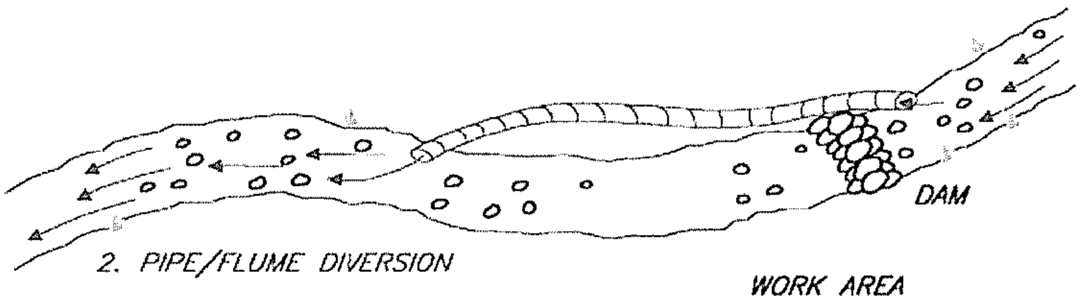
The pumped diversion is suitable for intermittent and low flow streams that can be pumped. Pump capacity must be sufficient for design flow. The upper limit is about $10ft^3$/sec, the capacity of two 8 inch pumps. A temporary dam is constructed upstream and downstream of the work area and water is pumped through the construction project in pipes. Dam materials should be selected to be erosion resistant, such as steel plate, sheetpile, sandbags, continuous berms, inflatable water bladders, etc.

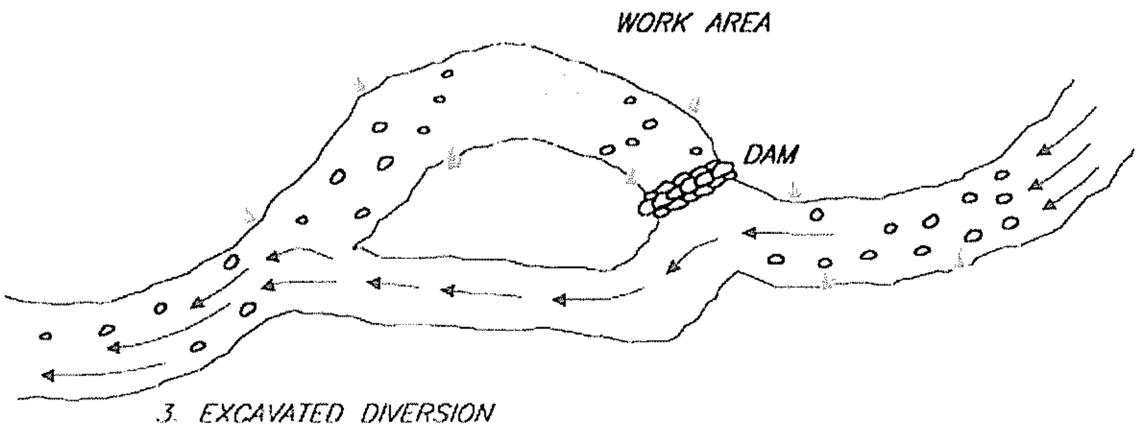
A temporary bypass channel can also be constructed by excavating a temporary channel or passing the flow through a heavy pipe (called a “flume), and excavating a trench under it. Typical stream sizes are less than 20 ft wide and less than 100 ft^3/sec.

Inspection and Maintenance:

- All stream diversions must be closely maintained and monitored
- Pumped diversions require 24-hour monitoring of pumps
- Upon completion of the work performed, the stream diversion should be removed and flow should be re-directed through the new culvert or back into the original stream channel.







TYPICAL STREAM DIVERSION TECHNIQUES

FILE: STREAM DIVERSION

Instream Isolation Techniques

Definition: An instream isolation technique is a temporary structure built into a waterway to enclose a construction area and reduce sediment pollution from construction work in or adjacent to water. The structures may be made of rock, sand bags, wood or water-filled geotextiles (aqua barriers).

Purpose: During construction in a watercourse, these structures are designed to reduce turbidity and sediment discharge, allowing contractors to follow clean water regulations.

Design Considerations: Isolation structures may be used in construction activities such as streambank stabilization, culvert installation, bridges, piers or abutments. It may be used in combination with other methods such as clean water bypasses and/or pumps.

This technique should not be used:

- If there is insufficient streamflow to support aquatic species
- In deep water unless designed or reviewed by an engineer
- To completely dam streamflows

Construction Specifications: When used in watercourses or streams, cofferdams must be used in accordance with permit requirements. Materials for cofferdams should be selected based on ease of maintenance and complete removal following construction activities.

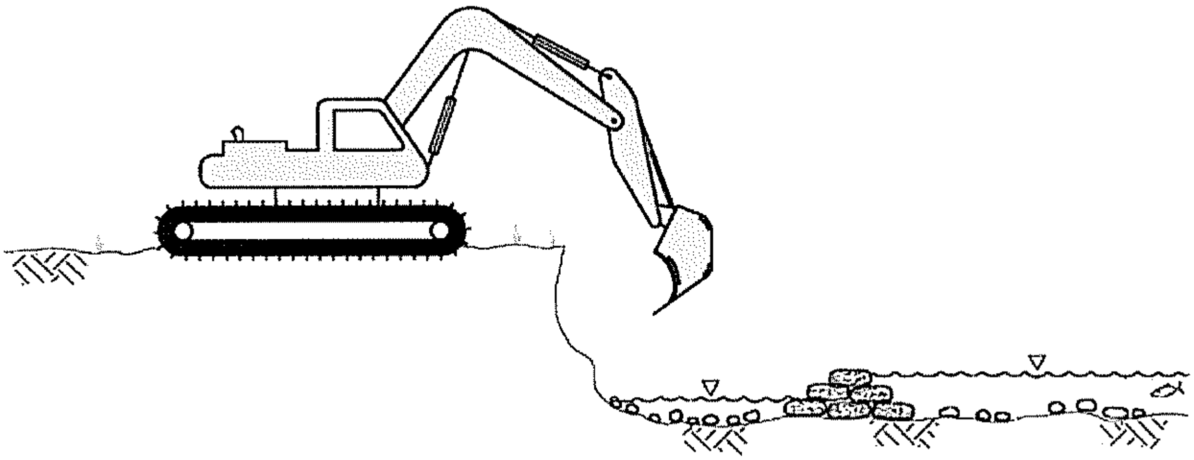
Inspection and Maintenance:

- During construction, inspect daily during the work week.
- Schedule additional inspections during storm events.
- Immediately repair any gaps, holes or scour.

Upon construction completion, the structure is removed.

- Remove sediment buildup.
- Remove structure. Recycle or re-use if applicable.
- Revegetate areas disturbed by cofferdam removal if applicable.

BENEFITS/LIMITATIONS
- *Difficult to dewater*
- *Inexpensive*
- *Labor intensive to install and remove*
- *Sand may be deposited in stream if bags break, better to use clean gravel*

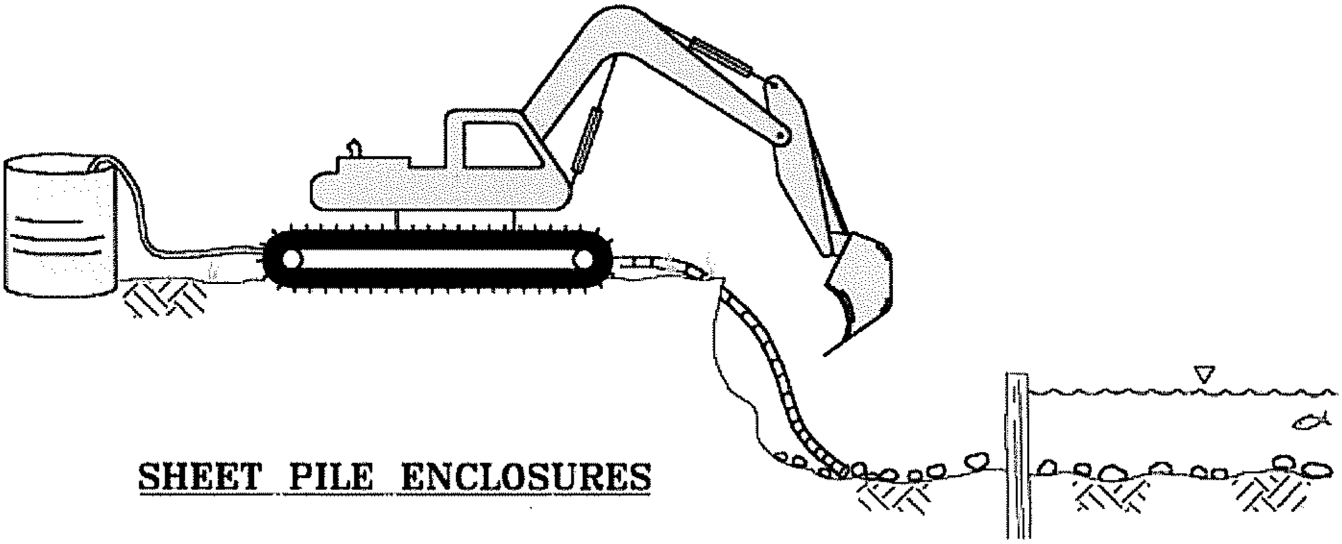


SAND BAG/GRAVEL BAG TECHNIQUE

FILE: INSTREAM TECHNIQUES3

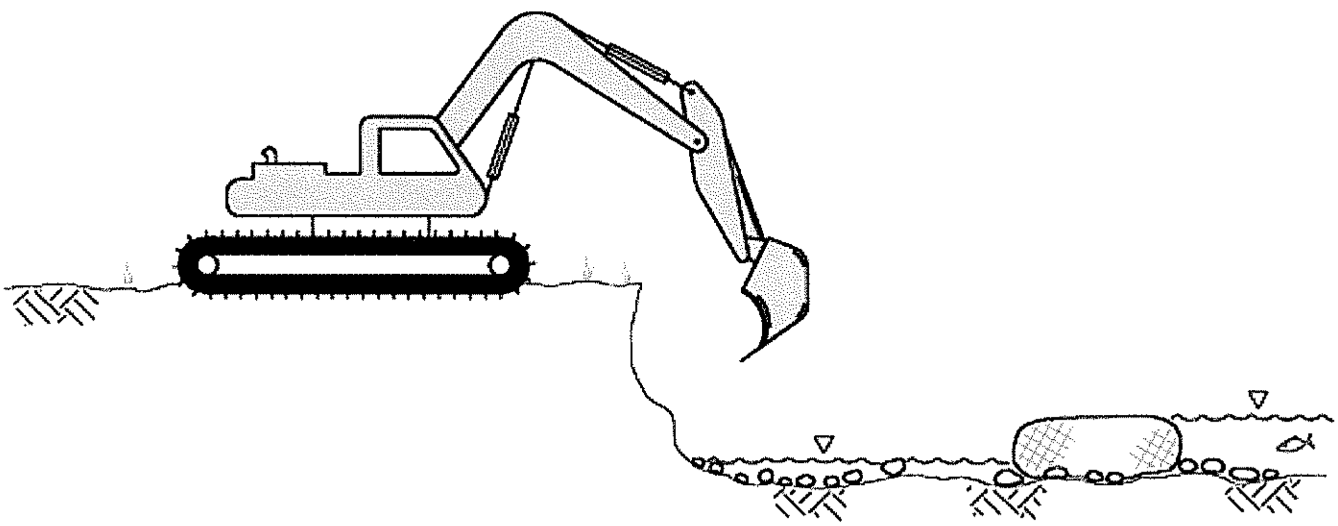
INSTREAM EROSION AND SEDIMENT CONTROL ISOLATION TECHNIQUES

BENEFITS/LIMITATIONS
- *Allows full dewatering*
- *Relatively expensive*
- *Useful in large rivers, lakes, high velocity*
- *Not really appropriate for small streams*
- *Requires staging and heavy equipment access areas*



SHEET PILE ENCLOSURES

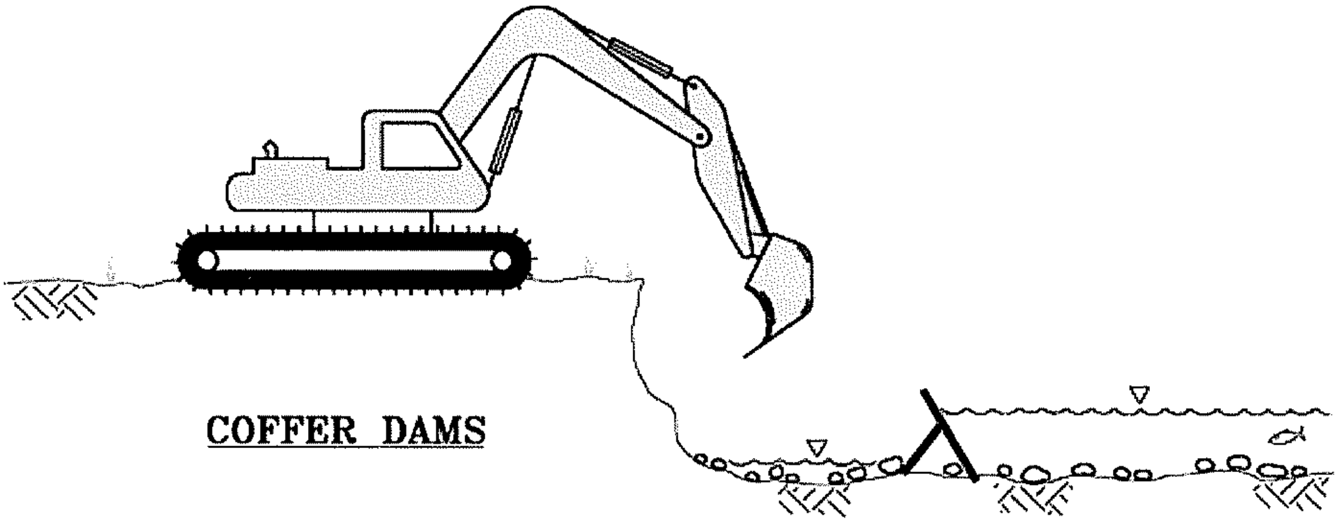
BENEFITS/LIMITATIONS
- *Allows partial dewatering*
- *Moderately expensive*
- *Ease of installation and removal unknown*
- *Can be designed for small streams to large rivers*



WATER–FILLED GEOTEXTILE (AQUA DAM)

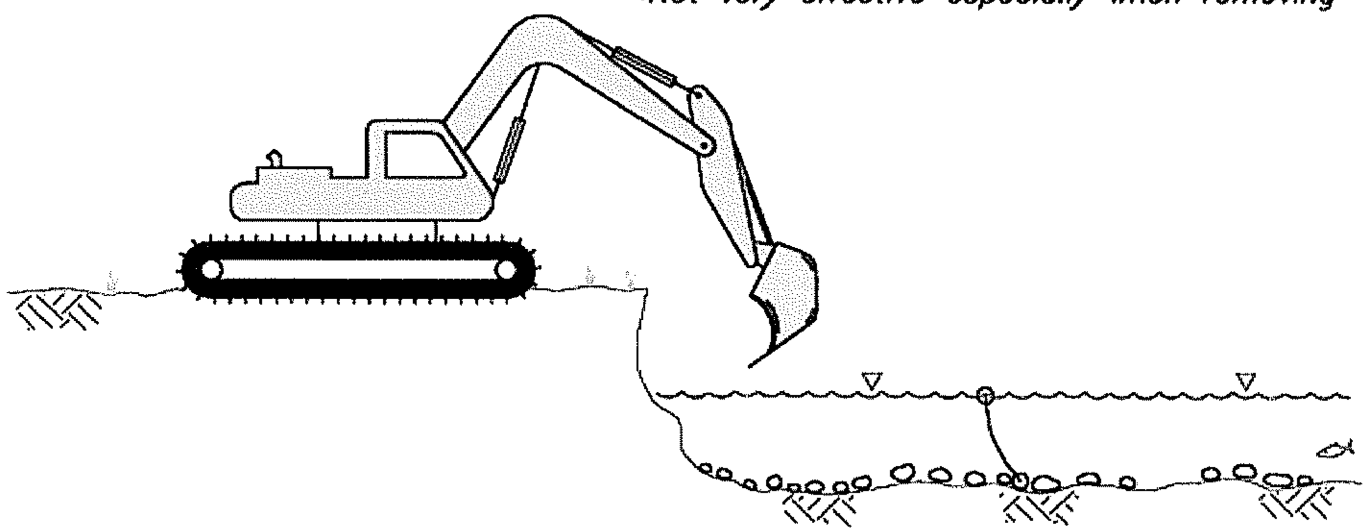
INSTREAM EROSION AND SEDIMENT CONTROL ISOLATION TECHNIQUES

BENEFITS/LIMITATIONS
- *Allows partial dewatering*
- *Many different types available*
- *Relatively expensive*
- *Can be designed for large and small streams*
- *Ease of installation and removal unknown*



COFFER DAMS

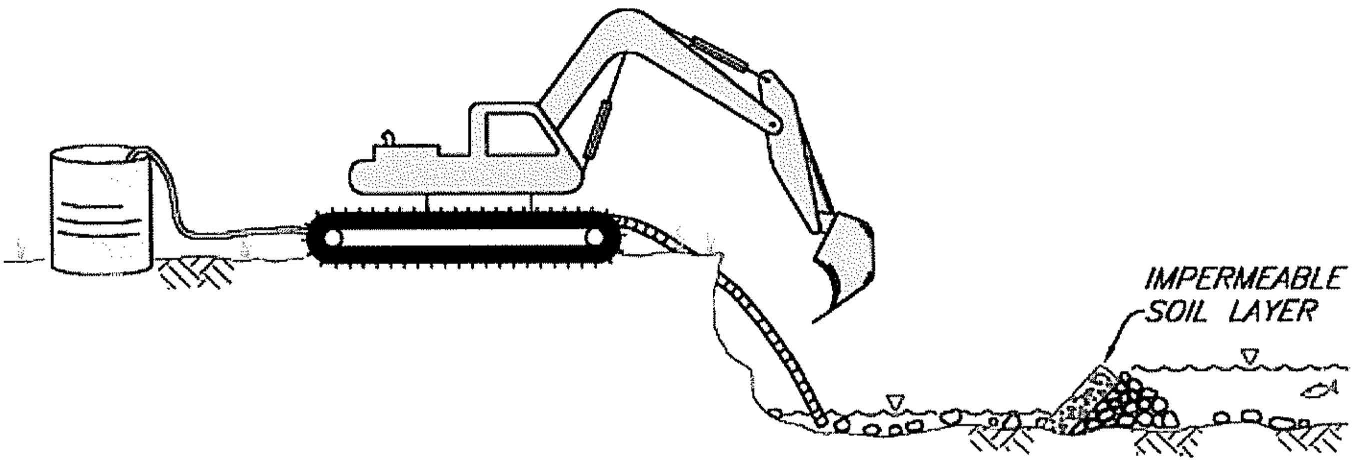
BENEFITS/LIMITATIONS
- *Does not allow dewatering*
- *Inexpensive*
- *Used in slow water or lakes only*
- *Not very effective especially when removing*



GEOTEXTILES, SILT BARRIERS, CURTAINS

INSTREAM EROSION AND SEDIMENT CONTROL ISOLATION TECHNIQUES

BENEFITS/LIMITATIONS
- Allows partial dewatering
- Relatively inexpensive
- Useful for small streams
- Minimal TSS when removed



NOTES:

Step 1. Install clean gravel

Step 2. Place impermeable soil

Step 3. Do work

Step 4. Decommission berm by removing soil layer first

Step 5. Pump work area. Head differential will cause turbid water to flow into work area through gravel

Step 6. Remove or spread gravel

GRAVEL/SOIL BERM INSTREAM ISOLATION TECHNIQUE

FILE: BERM INSTREAM TECHNIQUES

Large Woody Debris Management and Removal

Large woody debris (LWD) in streams has many positive benefits to the aquatic environment, including increased habitat complexity for resident trout, amphibians, and birds, as well as a host of plants and fungus. Large wood also performs geomorphic functions within stream channels such as grade control, bank stabilization, and stream bedload (cobbles and gravel) scour and sorting. The goal of large wood management is to retain as much wood as possible. Large wood is defined as logs with a diameter of 6" or greater and a length of 10' or longer, rootwads and stumps.

There are, however, situations where large wood maintenance can be in conflict with the maintenance of District infrastructure such as roads, bridges, and culverts. These conflicts arise when LWD accumulates around bridge footings, culvert inlets and outlets, and adjacent to roads or structures. Redirection of flow, and streambed elevation changes associated with the LWD accumulation, towards District facilities, can lead to the catastrophic failure of these facilities. In these limited circumstances, LWD will need to be managed or removed. Planning and Operations staff will confer regarding the specific course of action.

Management and removal will be undertaken only as a last resort to mitigate ongoing or imminent damage. Locations will be assessed for sensitive species prior to beginning any work at the site. LWD shall be managed to maintain as much LWD in the stream channel as possible. Often, smaller branches and logs accumulate on a few large key log pieces, and it is possible to pick through the smaller material maintaining the large key pieces for habitat and geomorphic function. LWD can also be rearranged or relocated within the stream channel, to decrease hazard to District infrastructure, and maintain LWD within the channel. These become sites that will need periodic maintenance and is the preferred method of LWD management on District Preserves.

There are also isolated circumstances where LWD has to be removed from the channel where the potential for catastrophic failure of District infrastructure is so great that no other alternative exists to protect the infrastructure. This option will only be employed where an evaluation has been made by Planning and Operations staff, which concludes that LWD management as described in the paragraph above is not sufficient to address the heightened level of concern. Again, the volume of LWD removed will be minimized to maintain as much LWD in channel as possible. LWD removed from the channel that cannot be immediately incorporated within the stream at a nearby location, shall be stockpiled for future use. LWD removed shall be left as large as possible for incorporation into future projects, particularly large logs and rootwads with attached bole. Smaller pieces of LWD shall be removed to above the high water mark of the channel, and can be stacked or spread for terrestrial habitat.

All work involving in-channel LWD will be completed by hand crews. No heavy equipment will be operated within the stream channel, or live flowing water. Hand crews may be aided by heavy equipment if it can be operated from an existing access road adjacent to the project site. No fueling of chain saws will occur within the stream channel, and will be done at a location where fuel can not enter the watercourse.

LWD project sites will be surveyed by a qualified biologist prior to beginning any work to determine if any sensitive species are present. Appropriate agency consultations will be conducted if listed species are identified during pre-construction surveys or encountered during construction.

Live Pole Drains

A live pole drain is a biotechnical and reclamation technique which is intended to drain excess moisture away from an unstable site. The plants used to construct the bundles (willow) will sprout and grow, with the moisture continuing to drain from the lower end. The bundles of cuttings are usually placed in shallow trenches in a manner that they intersect and collect excessive slope moisture. That excess water is then allowed to drain onto a stabilized area.

Conditions Where Practice Applies

Unstable slopes, landslides, and small slumping gullies can often be successfully treated with live pole drains. This is a good technique to initiate the process of natural healing.

Materials

Use fascine or wattle techniques to construct the bundles. Keep some of the twigs and branches on the cuttings, as this will add bulk and aid drainage. Live pole drain bundles can be constructed using branches which are longer than those typically used for wattles or fascines. Live pole drains require construction stakes and/or live stakes in order to secure them firmly to the slope. Sometimes large rocks may also be used to hold the drains down.

Advantages

If constructed from willow species, live pole drains will provide cover for the site and initial stabilization while allowing other species to invade. The pole drains will continue to grow for an extended period, while allowing drainage to occur.

David Polster, M.Sc., R.P. Bio. Plant Ecologist, British Columbia, has been extremely successful using live pole drains for landslides and gullies. He has completed projects where the pole drains have provided initial stability and then drained water for years after establishment.

Disadvantages

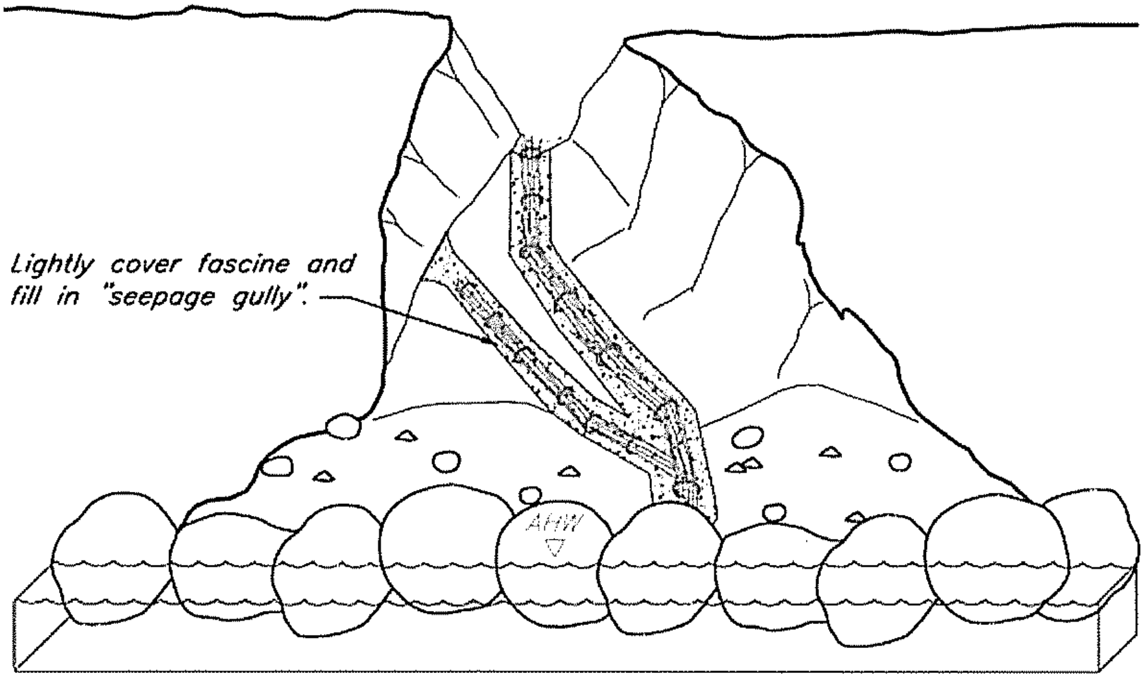
Live pole drains are not effective in larger, well defined channels with concentrated flows, as the pole drains will simply plug the channel and cause more erosion as the channel adjusts to maintain capacity. Biotechnical projects are typically conducted at times of the year when weather conditions are cool and moist and the plant material is dormant. Timing constraints can sometimes be ameliorated by irrigation, storage of plant materials, or a combination of the above. However, some reduction of plant establishment and vigor should be anticipated.

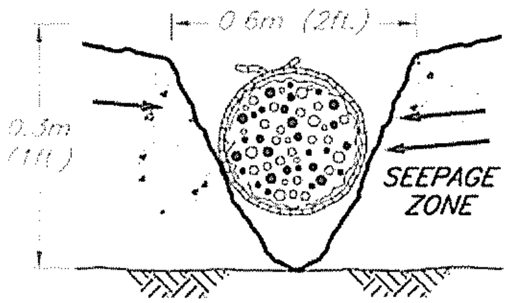
Live Pole Drains (continued)

Implementation

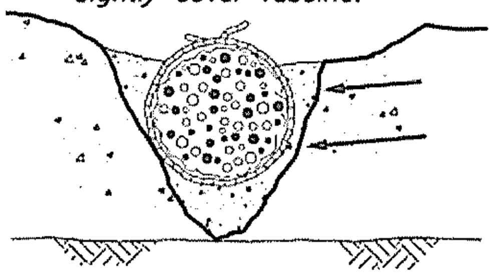
The key to successful pole drain construction is to install the drains in the areas of seepage, either by excavating a shallow trench or utilizing an existing drainage gully, so the drains intercept and control the excess moisture. Use fascine or wattle techniques to construct the bundles. The bundles should be tied tightly with twine or rope. Place the bundle of cuttings in the trench. Construct side drains as needed. It is important to key the bundles into each other by jamming the ends firmly together.

Use construction stakes and/or live stakes to hold the fascines in place. Insert the stakes adjacent to the rope ties for additional support. Stake the pole drains at 1-2 m intervals. Lightly backfill the bundles with native soil. Some twigs and branches should be left above the ground as the willow material requires some sunlight exposure to grow.





Excavate a shallow trench or utilize existing "seepage gully" (small<2ft.^{2}).



Place bundle of cuttings (fascine) in the trench and lightly backfill with native material.

NOTES:
1. Live pole drain is a biotechnical technique which drains excess moisture from the bank and provides an initial cover of woody vegetation.
2. The cuttings used to form the fascines are intended to sprout and grow while the excess moisture continues to drain from the lower end.

LIVE POLE DRAIN

FILE: LPD

Live Siltation

Live siltation is a revegetation technique used to secure the toe of a streambank, trap sediments, and create fish rearing habitat. The system can be constructed as a living or a non-living brushy system at the water's edge.

Conditions Where Practice Applies

Live siltation is a biotechnical technique for the edges of rivers and streams. This technique is useful along stream reaches where it is desired to encourage deposition and siltation, such as floodplains and along inner banks. It would not be an appropriate practice along an outer bend without sufficient scour or toe protection.

Materials

Natural stone, willow wattles, logs or root wad revetments are needed for toe and scour protection. The live siltation will require live branches of shrub willows of 1-1.5 m length. The branches should be dormant, and need to have the side branches still attached. Any woody plant material, such as alder, can be installed for a non-living system.

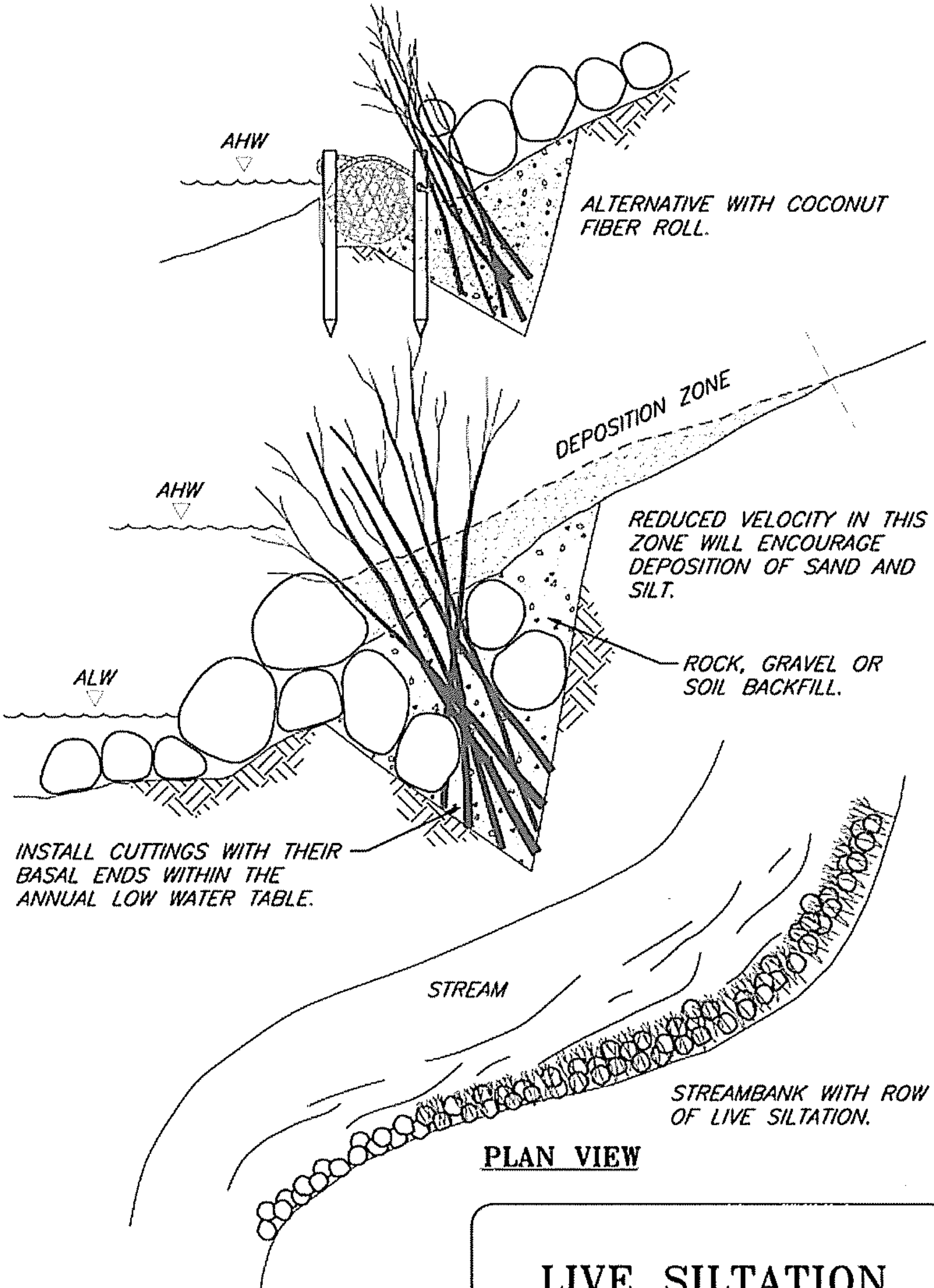
Advantages

This is a very effective and simple conservation method using local plant materials. This technique is particularly valuable for providing immediate cover and fish habitat while other revegetation plantings become established. The protruding branches provide roughness, slow velocities, and encourage deposition of sediment. The depositional areas are then available for natural recruitment of native riparian vegetation.

Implementation

Construct a V-shaped trench at the mean high water (MHW) level, with hand tools or a backhoe. Excavate a trench so that it parallels the toe of the streambank and is approximately 2 feet deep. Lay a thick layer of willow branches in the trench so that 1/3 of the length of the branches is above the trench and the branches angle out toward the stream. Place a minimum of 40 willow branches per meter in the trench.

Backfill over the branches with a gravel/soil mix and secure the top surface with large washed gravel, bundles/coir logs, or carefully placed rocks. Both the upstream and downstream ends of the live siltation construction need to transition smoothly into a stable streambank to reduce the potential for the system to wash out. More that one row of live siltation can be installed. A living and growing siltation system typically is installed at MHW. A non-living system can be constructed below MHW during low water levels. If it is impossible to dig a trench, the branches can be secured in place with logs, armor rock, bundles made from wattles, or coir logs.



LIVE SILTATION

FILE: LVSILT

Modified Live Siltation

Conditions Where Practice Applies

Use modified live siltation for the inner bends of streams or areas periodically flooded.

Modified live siltation can be placed in a manner which can direct high flows toward the center of the stream, while providing hydraulic roughness which will encourage deposition and siltation.

Materials

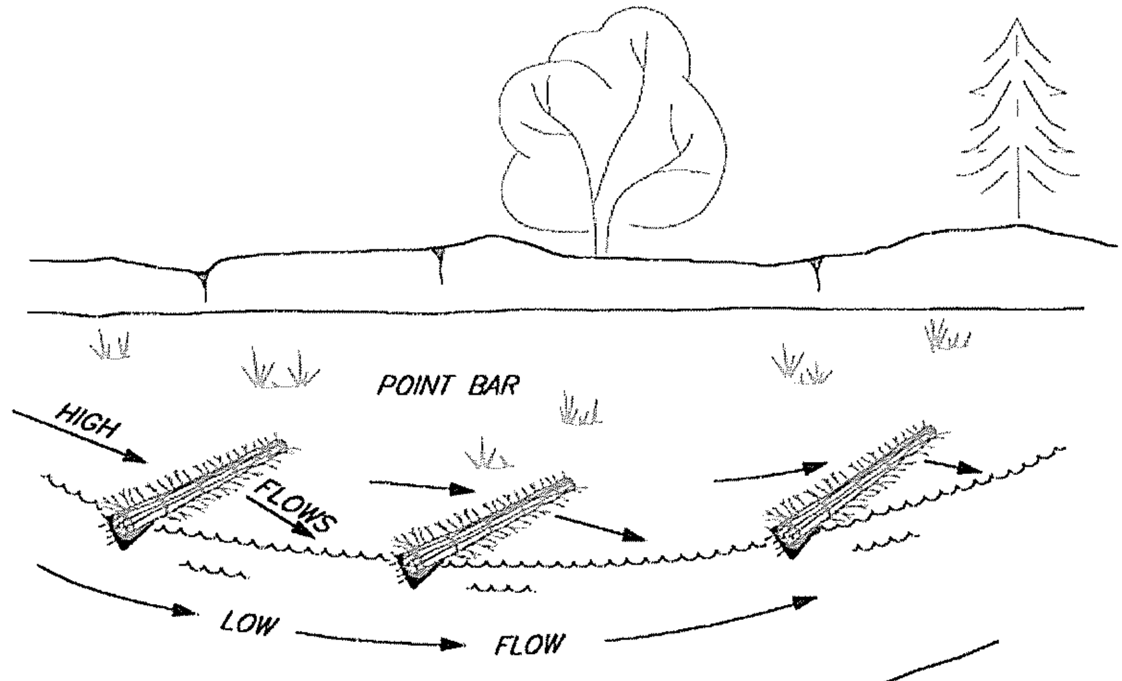
Primarily willow species are used for live siltation, however, even dead branches and non-living bundles can provide the desired hydraulic roughness. The willow species will generally thrive in depositional areas. Use willow wattles and live staking or poles. Rope will be needed for bundles, and wooden stakes will be needed to secure wattles.

Advantages

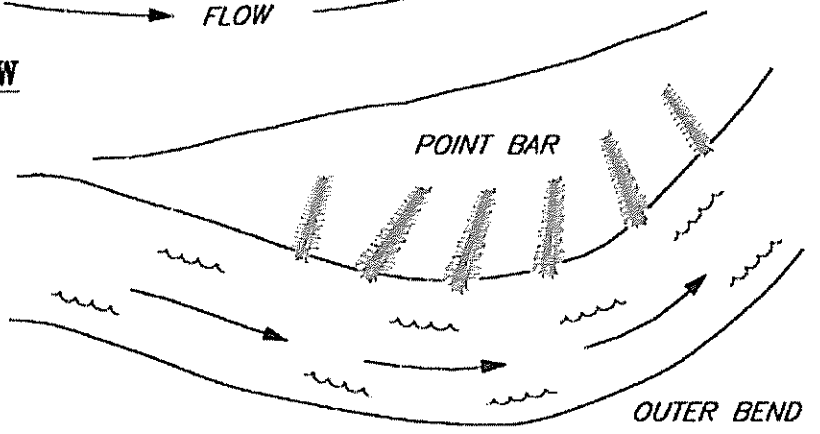
This is an inexpensive revegetation and stream stabilization technique which provides habitat enhancements and encourages deposition.

Implementation

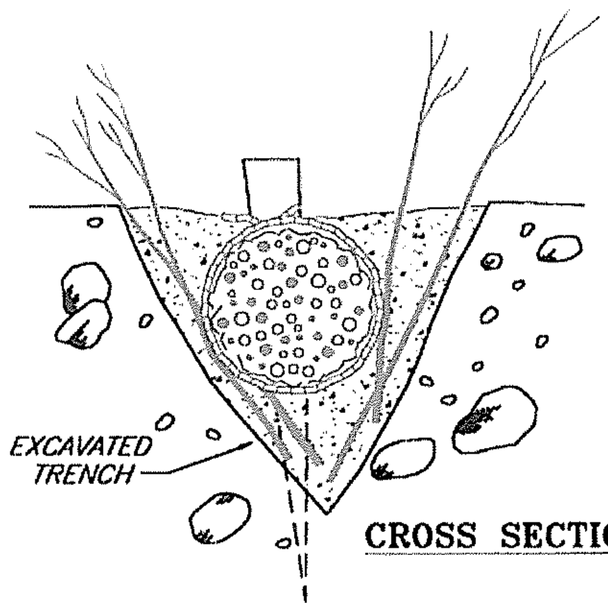
Prepare trenches. Trenches for modified live siltation should point in a slight upstream direction, no more than 20 degrees. Lay live willow bundle or dead branch bundle into trench. Secure the bundle firmly using wooden stakes. Lay in branches for live siltation. Backfill trench with soil and rock.



FRONT VIEW



PLAN VIEW



CROSS SECTION

NOTES:

1. Modified live siltation is a revegetation technique intended to encourage deposition (reduce erosion and scour) of the inner bend (point bar formation).

2. The vegetated spurs or live veins are angled slightly into the flow such that high flows will be redirected toward the center of the stream.

MODIFIED LIVE SILTATION

FILE: MDLVSILT

LIVE STAKING

Construction Specifications:

Harvesting:

- Stakes shall 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.

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

- Use live wood at least 1 year old or older. Avoid suckers of current years growth as they lack sufficient stored energy reserves to sprout consistently. The best wood is 2-5 years old with smooth bark that is not deeply furrowed.

- Make clean cuts with unsplit ends. Trim branches from cutting as close as possible. The butt end of the cutting shall be pointed or angled and the top end shall be cut square.

- Identification of the top and bottom of cutting as accomplished by angle cutting the butt end. The top, square cut, can be painted and sealed by dipping the top 1-2 inches (25-51 mm) into a 50-50 mix of light colored latex paint and water. Sealing the top of stake will reduce the possibility of desiccation and disease caused mortality, assure the stakes are planted with the top up, and makes the stakes more visible for subsequent planting evaluations.

<u>Diameter</u>:

- Cuttings should generally be 3/4 inch (19 mm) or larger depending on the species. Highest survival rates are obtained from using cuttings 2-3 inches (51-76 mm) in diameter. Larger diameter cuttings are needed for planting into rock riprap.

<u>Length</u>:

- Cuttings of small diameter (up to 1 1/2 inches (38 mm)) shall be 18 inches (0.5 m) long minimum. Thicker cuttings should be longer.

- Cuttings should be long enough to reach into the mid-summer water table, if possible.

- No less than 1/2 total length must be into the ground.

- Stakes should be cut so that a terminal bud scar is within 1-4 inches (25-101 mm) of the top. At least 2 buds and/or bud scars shall be above the ground after planting.

Installation:

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

- Stakes must not be allowed to dry out. All cuttings should be soaked in water for a minimum of 24 hours. Soaking significantly increases the survival rate of the cuttings, however they may be planted the same day they are harvested.

- Plant stakes 1-3 feet (0.3-1 m) apart.

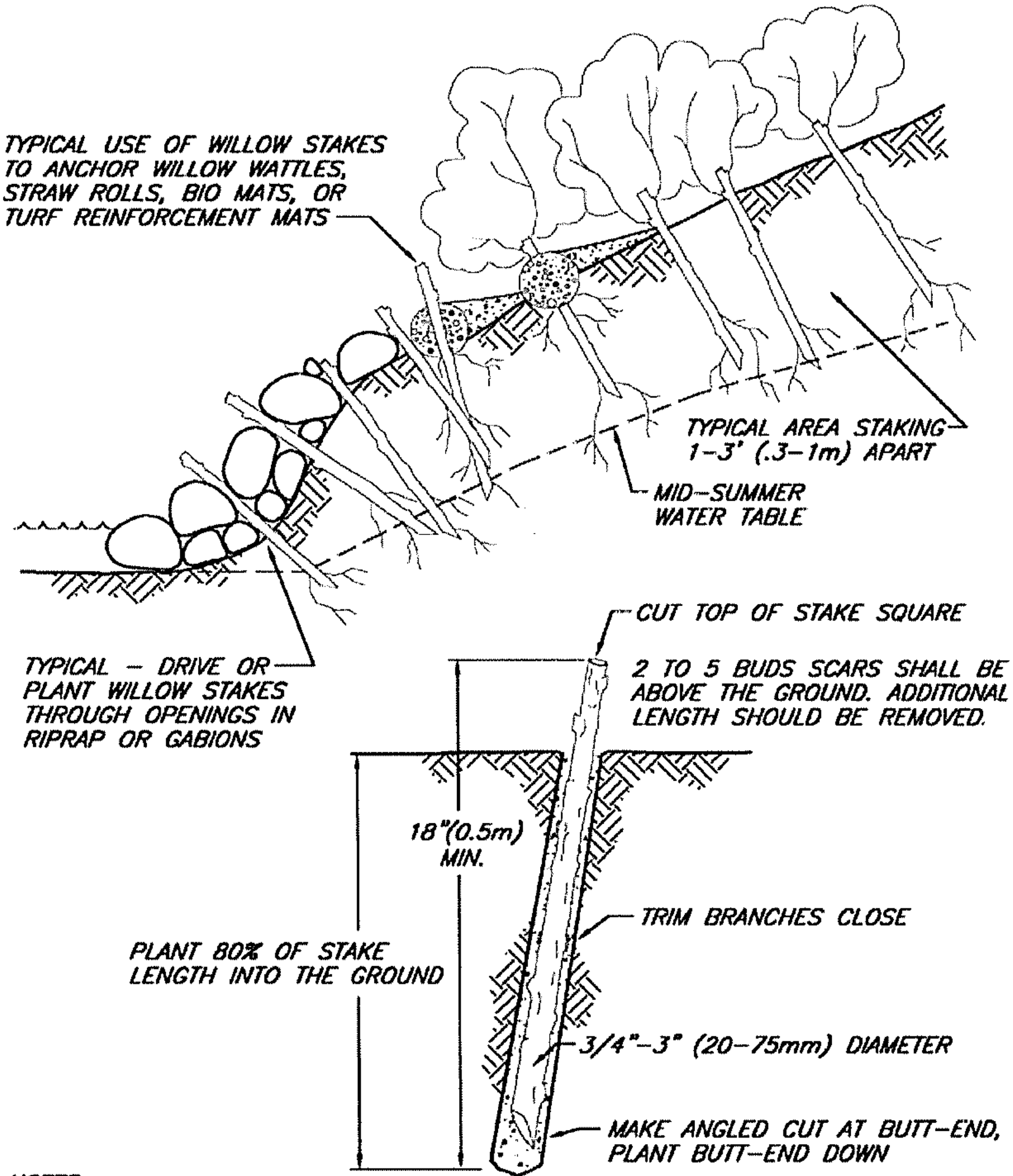
- Set the stake as deep as possible into the soil, preferably with 80 percent of its length into the soil and in contact with mid-summer water table.

- It is essential to have good contact between the stake and soil for roots to sprout. Tamp the soil around the cutting.

- Use a iron stake or bar to make a pilot hole in firm soil.
- Do not damage the buds, strip the bark or split the stake during installation.
- Split or damaged stakes shall be removed and replaced.

Inspection and Maintenance:

- All temporary and permanet erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function.
- Streambanks and steep slopes are highly susceptible to erosion and damage from significant storm events. Willow stakes alone provide very little initial site protection during the establishment period.
- Periodic inspection repair and maintenance will be required during the first two years or until the vegetation is established.
- All temporary or permanent erosion control practices shall be maintained and repaired as needed to assure continued performance of their intended function.



NOTES:
1. HARVEST AND PLANT STAKES DURING THE DORMANT SEASON.
2. USE HEALTHY, STRAIGHT AND LIVE WOOD AT LEAST 1 YEAR OLD.
3. MAKE CLEAN CUTS AND DO NOT DAMAGE STAKES OR SPLIT ENDS DURING INSTALLATION, USE A PILOT BAR IN FIRM SOILS.
4. SOAK CUTTINGS FOR 24 HOURS (MIN.) PRIOR TO INSTALLATION.
5. TAMP THE SOIL AROUND THE STAKE.

NOT TO SCALE

LIVE STAKING

FILE: LIVESTK

POLE PLANTING

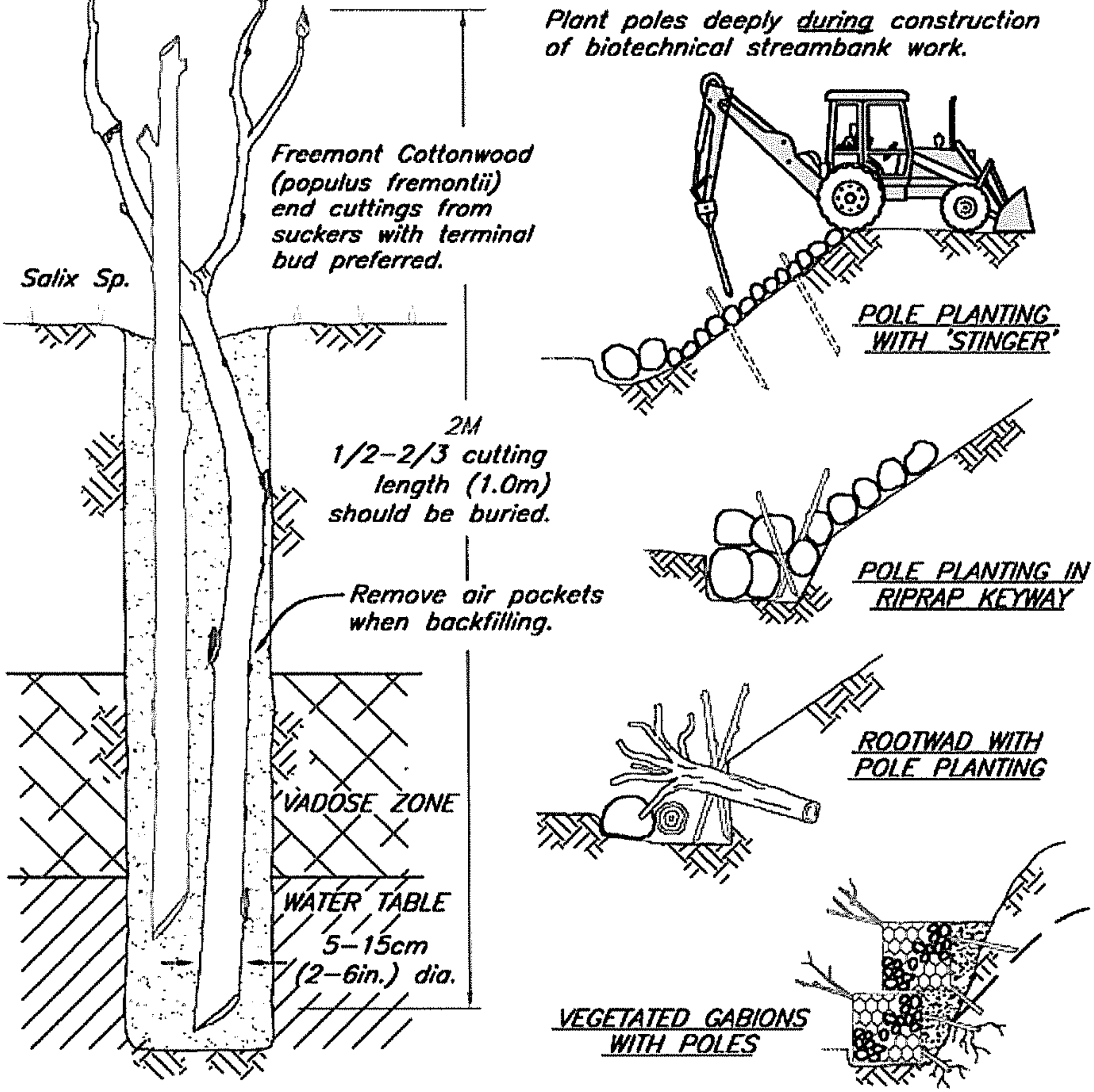
Construction Specifications:

Collect and harvest cuttings (ideally during the dormant season) and then soak the poles for 5 to 7 days. Plant poles into an augered, "punched", or excavated hole. The holes should extend to approximately 1 foot above the water table and through the vadose zone. This depth can be difficult to determine in areas with reservoirs and streams with widely fluctuating seasonal water levels. In this case, ensure that the ends of the poles reach the low waterline at the time of planting if possible.

Pole plantings should ideally be installed during the construction of any structural appurtenances. For instance, plant the poles with the placement of riprap, especially into any trenches excavated for keyways or scour trenches. Another example is to plant the poles during riprap placement such that the poles extend through the riprap and backfill and into contact with the "native" bank. The backfill can be placed over and around the poles rather than having to "punch" holes through the riprap. Another method is to plant the poles during gabion construction.

The pole plantings, especially the basal ends, must have good contact with the soil. "Mudding" (filling the hole with water and then adding soil to make a mud slurry) can remove air pockets.

CONSTRUCTION TECHNIQUES



NOTES:

1. Pole cuttings of willow or cottonwood are longer and have a larger diameter than branch cuttings or live stakes.
2. Larger diameter cuttings have a greater supply of stored energy (stored photosynthesis) than smaller diameter cuttings.
3. Pole cuttings are better suited for highly erodible areas and sites with fluctuating water levels.
4. The pole cuttings should extend through the vadose zone and into the permanent water table. At least 1/2 to 2/3 of the pole should be below the ground, at least 1.0m (3 ft.), and long enough to emerge above adjacent vegetation.
5. "Muddying" – filling the hole with water and then soil to make a mud slurry can remove air pockets.

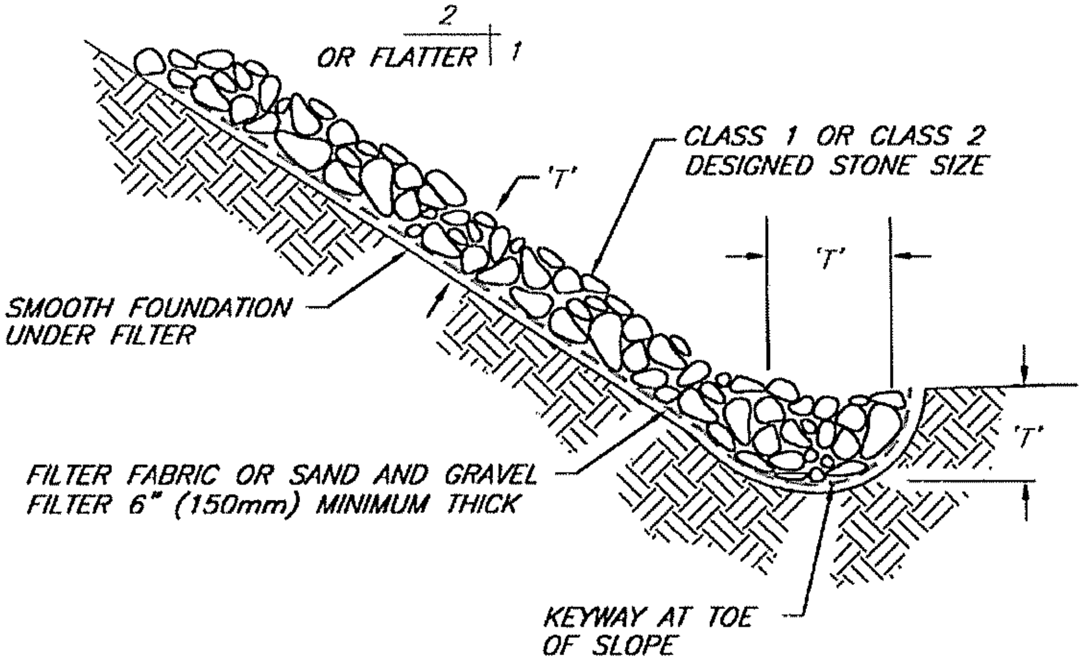
POLE PLANTING

RIPRAP

Construction Specifications:

- Before laying riprap and filler, prepare the subgrade to the required lines and grades shown on the plans. Compact any fill required in the subgrade to a density approximating that of the surrounding undisturbed material.
- Overfill depressions with riprap.
- Remove brush, trees, stumps, and other objectionable material.
- Cut the subgrade sufficiently deep so that the finished grade of the riprap will be at the elevation of the surrounding area. Channels should be excavated sufficiently to allow placement of the riprap in a manner such that the finished inside dimensions and grade of the riprap meet design specifications.
- Place the sand and gravel filter blanket immediately after the ground foundation is prepared. For gravel, spread filter stone in a uniform layer to the specified depth. Where more than one layer of filter material is used, spread the layers with minimal mixing.
- Place the filter fabric directly on the prepared foundation. Overlap the edges by at least 12 inches (0.3 m), and space anchor pins every 3 feet (0.9 m) along the overlap. Bury the upper and lower ends of the cloth a minimum of 12 inches (0.3 m) below ground. Take care not to damage the cloth when placing riprap. If damage occurs remove the riprap and repair the sheet by adding another layer of filter material with a minimum overlap of 12 inches (0.3 m) around the damaged area. If extensive damage is suspected, remove and replace the entire sheet.
- Where large stones are used or machine placement is difficult, a 4 inch (101 mm) layer of fine gravel or sand may be needed to protect the filter fabric.
- Placement of riprap should follow immediately after placement of the filter. Place riprap so that it forms a dense, well-graded mass of stone with a minimum of voids. The desired distribution of stones throughout the mass may be obtained by selective loading at the quarry and controlled dumping during final placement.
- Place riprap to its full thickness in one operation.
- Do not place riprap by dumping through chutes or other methods that cause segregation of stone sizes.
- Take care not to dislodge the underlying base or filter when placing the stones.
- The toe of the riprap slope should be keyed to a stable foundation at its base.
- The toe should be excavated to the depth about 1.5 times the design thickness of the riprap and should extend horizontally from the slope.
- The finished slope should be free of pockets of small stone or clusters of large stones. Hand placing may be necessary to achieve the proper distribution of stone sizes to produce a relatively smooth, uniform surface. The finished grade of riprap should be apparent.

Inspection and Maintenance: Properly designed and installed riprap requires very little maintenance. Riprap should be inspected periodically for scour or dislodged stones. Control of weed and brush growth may be needed in some locations.



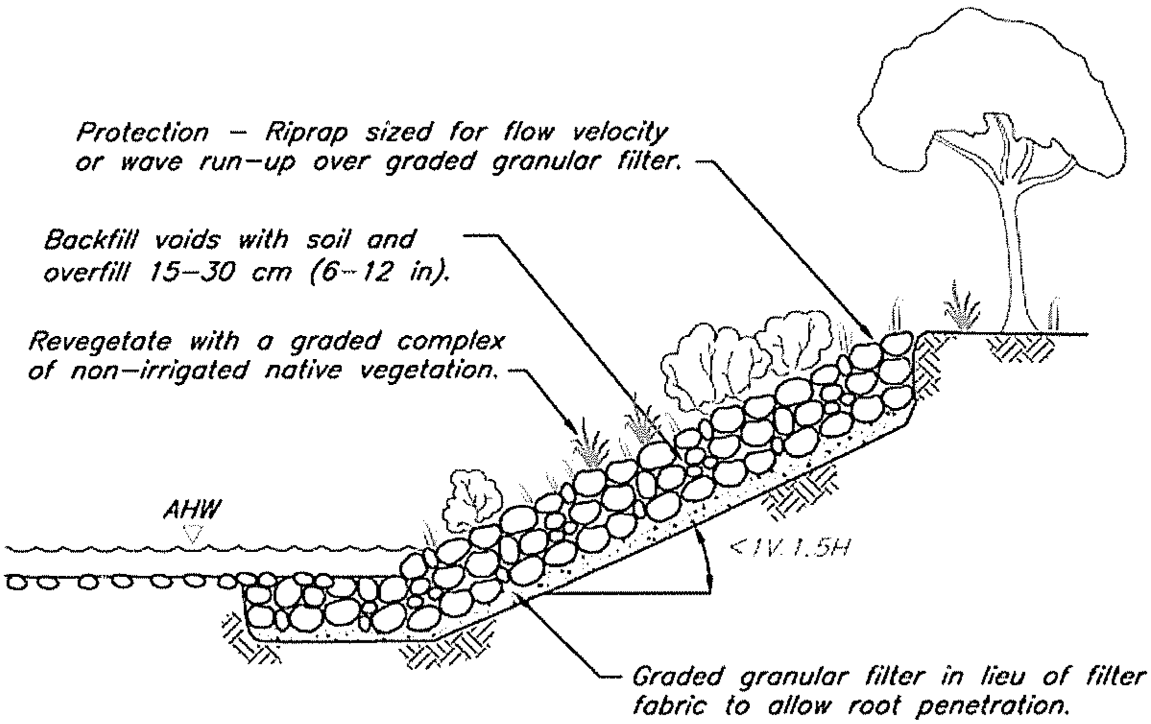
TYPICAL SECTION

NOTE:
'T' = THICKNESS: THICKNESS SHALL BE DETERMINED BY THE ENGINEER.

MINIMUM THICKNESS SHALL BE 1.5x THE MAXIMUM STONE DIAMETER, NEVER LESS THAN 6" (150mm).

RIPRAP PROTECTION

FILE: 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

Rootwad Revetment with Vegetated Riprap

Native material revetments are viable alternatives to riprap armoring and gabion type structures. Root wads and logs are constructed to protect the streambank from erosion, provide in-stream and overhead cover for fish. The practice discussed here combines root wads with a layer of stones and/or boulder armoring, generally referred to as riprap revetment. The root wads and riprap are placed along a streambank and will be vegetated with pole planting, brushlayering, and live staking (joint planting).

Conditions Where Practice Applies

The implementations of root wad revetments are beneficial if these type of structures are naturally-occurring in adjacent stream reaches or in similar stream types. Analysis of channel morphology and stream type should be performed to determine if natural material revetments will achieve the desired results.

Vegetated riprap techniques should be considered with project in streams with fishery resources. See Vegetated Riprap. The inclusion of root wads and other large woody debris will enhance the fishery habitat. The root wads are intended to produce scour pools while the overhanging wood and vegetation will provide cover and shade.

Materials

The root wad should have the bole (trunk) attached to allow anchoring into the bank. The length of the bole is dependent on site conditions, however, it should be a 2-m (6 foot) minimum.

For the riprap component, the size and weight is dependant on design velocity or slope stability analysis. A filter layer, either graded aggregate or filter fabric, placed under the riprap will prevent the washout (piping) of fines through the armor layer.

Willow material for brushlayers and pole planting will be required. The length of the cuttings will depend on the depth through the riprap and filter layer to the native soil. Live cuttings can be included and should consist of relatively straight willow branches, 25-40 mm (1-1.5 inches) diameter and long enough to reach beyond the riprap and filter layer and into native ground.

Advantages

By combining boulders, logs and live plant materials to armor a streambank fish habitat is enhanced, in addition to creating a natural looking stabilization structure. Root wad revetments can be used for a wide range of fishery enhancement structures for various stream types. Vegetated rootwads combined with vegetated riprap can protect the streambank, provide in-stream and overhead cover for fish, provide shade, provide detritus and terrestrial insect habitat, look natural, and provide habitat diversity.

Rootwad Revetment with Vegetated Riprap (continued)

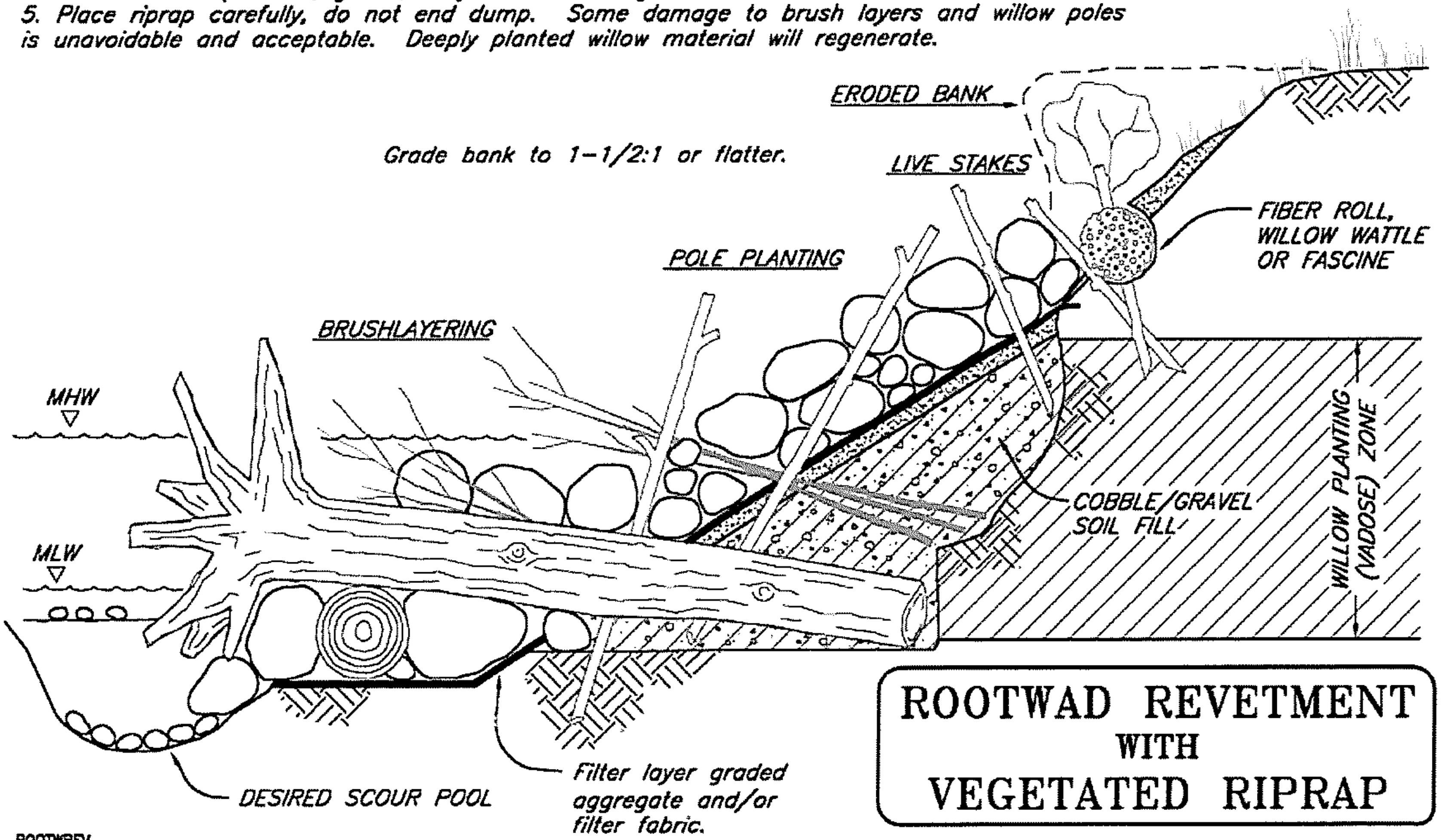
Disadvantages

The woody materials will probably not have the durability of other structural components. However, the inclusion of live woody vegetation, along with the accompanying root reinforcement, may make these structures stronger and more durable.

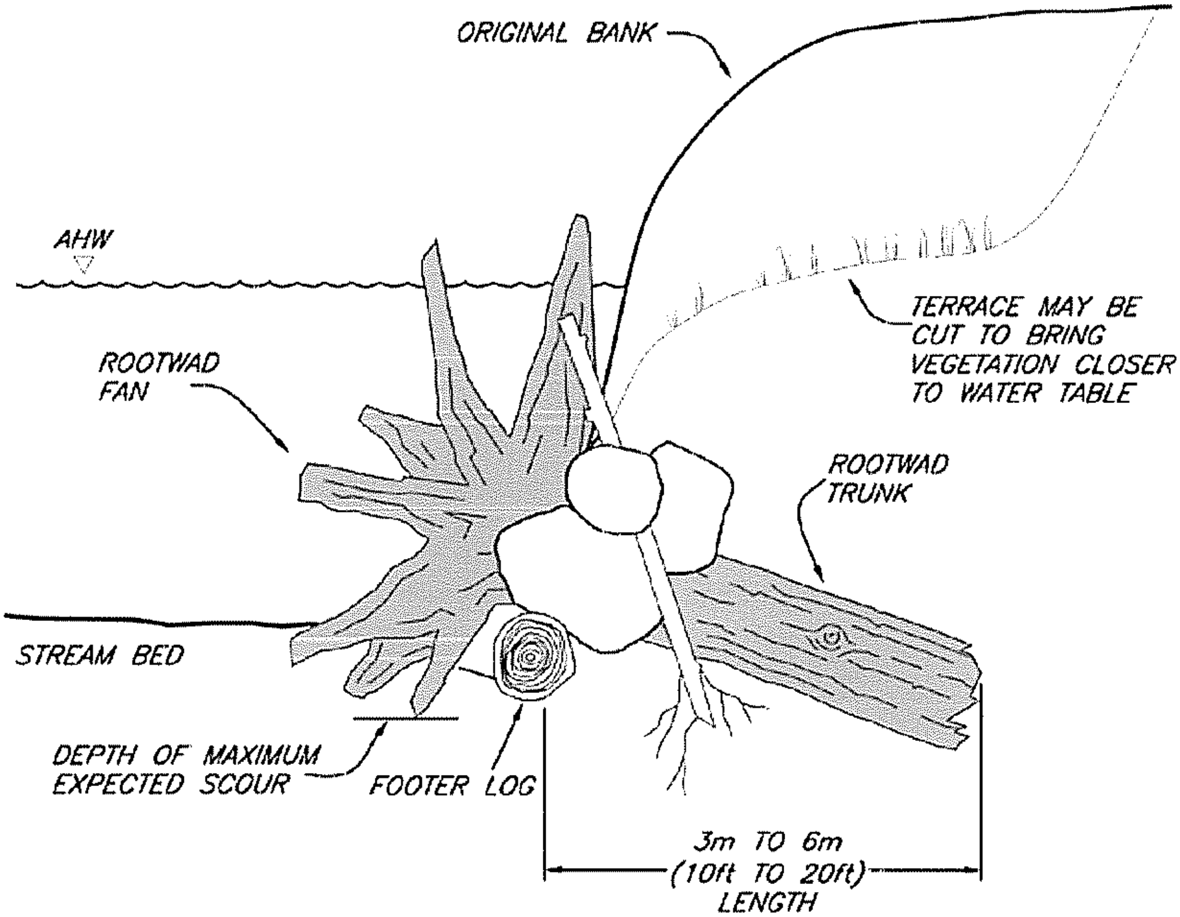
Implementation

Use a backhoe or excavator to set a "footer" log in a trench excavated below the thalweg (lowest point in the channel), running roughly parallel with the bank. A second log with the root wad attached is set on top of the footer log diagonally, forming an "X". The root wad end is set pointing upstream into the flow and the butt end lying downstream 45-60° degrees. The butt end of the root wad should be set in a trench excavated into the bank. Large boulders and willow poles should be used to secure the root wad, especially at the apex. Placement of the willow poles into the excavations will ensure they are deeply embedded and able to contact the water table. Further incorporation of live woody cuttings (brushlayering and pole planting) will enhance the structure.

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.



ROOTWREV



ROOTWAD REVETMENT CROSS-SECTION

FILE: RRC

Effective Silt Fence Installation

Definition

A silt fence is a temporary sediment barrier consisting of filter fabric entrenched into the soil and attached to supporting posts. Silt fence installed with a trencher or by slicing is the most effective installation method to ensure against common silt fence failures.

Purpose

Silt fence is a sediment control practice. Silt fence is intended to be installed where sediment-laden water can pond, thus allowing the sediment to fall out of suspension and separate from the runoff. It is not intended to be an erosion control practice.

Design Considerations

Typical silt fence specifications were written 25 years ago and have changed little since. Some states have recognized some of the inherent problems, such as inadequate trench depth, and implemented minor changes to improve efficacy. Time and experience has shown that the outdated construction specifications, combined with the improper application and incorrect installation of silt fences, has resulted in it being one of the most ineffective storm water pollution controls in use.

Do not install silt fences across streams, channels, or drainage ways. Silt fences cannot"filter" the volumes generated by channel flows. When installed across a concentrated flow path, undercutting or "end cutting" of the fence often occurs. Silt fences should not be designed to impound sediment or water more than 18 inches (0.5 m) high.

Construction Specifications

Silt fences have a useful life of one season. Their principal mode of action is to slow and pond the water and allow soil particles to settle. Silt fences are not designed to withstand high heads of water, and therefore should be located where only shallow pools can form. Their use is limited to situations in which sheet or overland flows are expected.

- Install silt fence material into a trench, 4” wide and at least 6” deep, with vertical sides. A preferred installation technique involves static slicing with an implement such as the "Tommy Silt Fence Machine" or equivalent. The soil should be sliced and the fabric mechanically installed into the soil.
- The trench must be backfilled and compacted.
- Install silt fences with 'smiles' or J-hooks to reduce the drainage area that any segment will impound

Effective Silt Fence Installation (continued)

- Silt fences placed at the toe of a slope shall be set at least 6 feet (1.8 m) from the toe in order to increase ponding volume.
- The soil should be sliced and the fabric mechanically installed into the soil.
- The height of a silt fence shall not exceed 36 inches (0.9 m). Storage height and ponding height shall never exceed 18 inches (0.5 m).
- The ends of the fence should be turned uphill.
- Steel support posts should be utilized, properly spaced and driven into compacted soil. Place the posts on the downstream side of the fabric/
- Post spacing shall not exceed 6 feet (1.8 m).
- The filter fabric is wire-tied directly to the posts with three diagonal ties. Filter fabric shall not be stapled to existing trees.

Inspection and Maintenance

- Inspect fence for proper installation and compaction by pulling up on the fence while kicking the toe of the fabric. If the fence comes out of the ground, do not "accept" the installation.
- If there are long, linear runs of silt fence without J-hooks or "smiles", do not "accept" the installation.
- Sediment shall be cleaned from behind the fence when it reaches 50% of the designed impoundment height (9 inch (0.2 m).

- Silt fences and filter barriers shall be inspected weekly after each significant storm (1 inch (25.4 mm) in 24 hour). Any required repairs shall be made immediately.
- Sediment should be removed when it reaches 1/3 height of the fence or 9 inches (0.3 m) maximum.
- The removed sediment shall conform with the existing grade and be vegetated or otherwise stabilized.
- Silt fences shall be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized and any sediment stored behind the silt fence has been removed.

EFFECTIVE SILT FENCE INSTALLATION WITH SMILES

Construction Specifications:

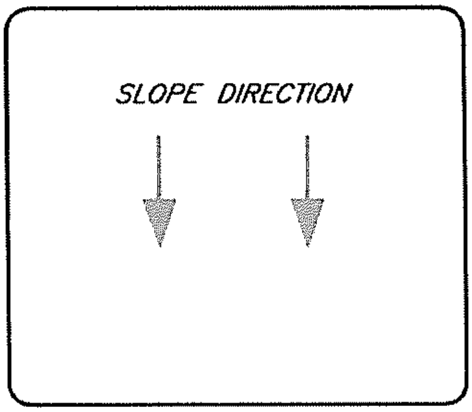
Typical silt fence specifications were written 25 years ago and have changed little since. Some states have recognized some of the inherent problems, such as inadequate trench depth, and implemented minor changes to improve efficacy. The 25 year-old specifications, referred to as the trenching method, have never been tested for efficacy and proven worthwhile. A trencher was simply the only piece of equipment available at the time capable of securing the fabric into the soil, regardless of efficacy.

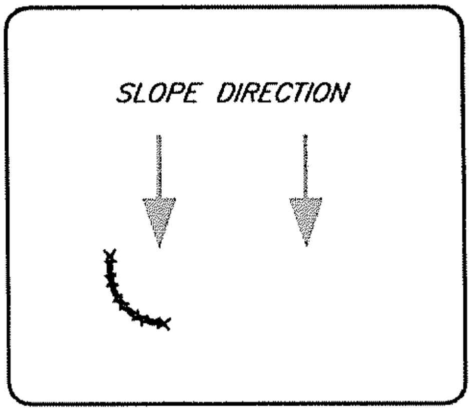
Today, many contractors just open a furrow with a blade and backfill onto the fabric with the crumbs. Loose soil, both from the trencher or the blade, absorbs water quickly and becomes saturated, easily washing out under the fabric.

- The soil should be sliced and the fabric mechanically installed into the soil
- The height of a silt fence shall not exceed 36 inches (0.9 m). Storage height and ponding height shall never exceed 18 inches (0.5 m).
- To minimize erosion, install silt fence at the head of a slope to slow velocity and to create a large storage area.
- The fence line shall follow the contour as closely as possible.
- The ends of the fence should be turned uphill.
- Steel support posts should be utilized, properly spaced and driven into compacted soil
- Post spacing shall not exceed 6 feet (1.8 m).
- The filter fabric is stapled or wired directly to the posts. Filter fabric shall not be stapled to existing trees.
- Fabric should be attached to the posts with three diagonal ties
- Silt fences placed at the toe of a slope shall be set at least 6 feet (1.8 m) from the toe in order to increase ponding volume.

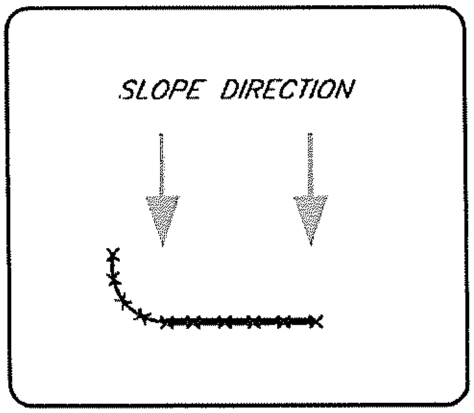
Inspection and Maintenance:

- Silt fences and filter barriers shall be inspected weekly after each significant storm (1 inch (25.4 mm) in 24 hours. Any required repairs shall be made immediately.
- Sediment should be removed when it reaches 1/3 height of the fence or 9 inches (0.3 m) maximum.
- The removed sediment shall conform to the existing grade and be vegetated or otherwise stabilized.
- Silt fences shall be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized and any sediment stored behind the silt fence has been removed.

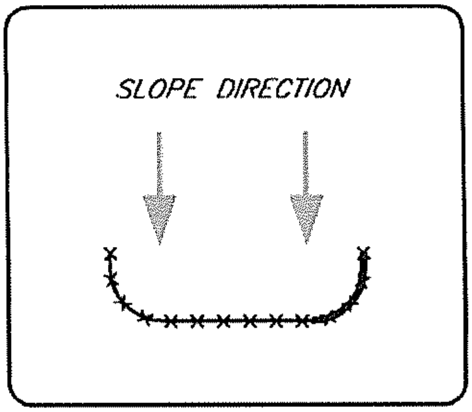




STEP 1 – CONSTRUCT LEG



STEP 2 – CONSTRUCT DAM



STEP 3 – CONSTRUCT LEG 2

INSTALLATION WITH J–HOOKS OR 'SMILES' INCREASE SILT FENCE EFFICIENCY.

SILT FENCE
TYPICAL PLACEMENT–ONE SLOPE

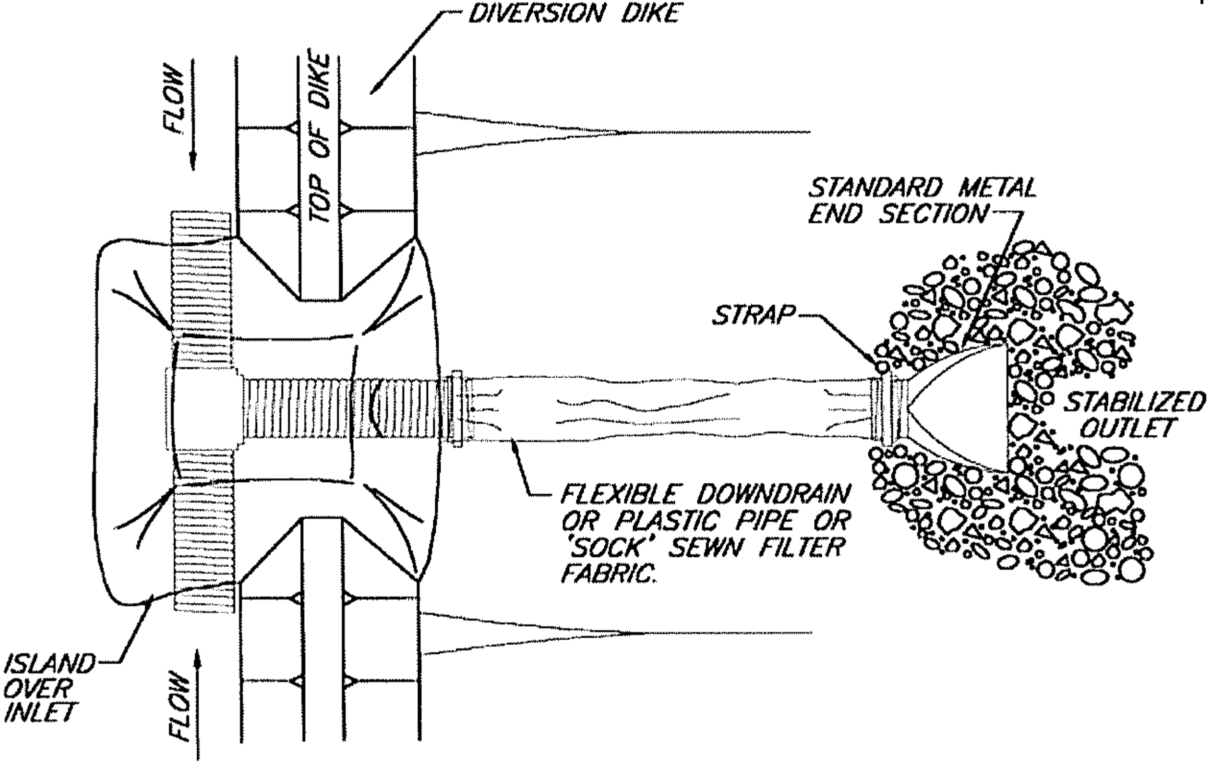
FILE: SF–ONE SLOPE

SLOPE DRAIN

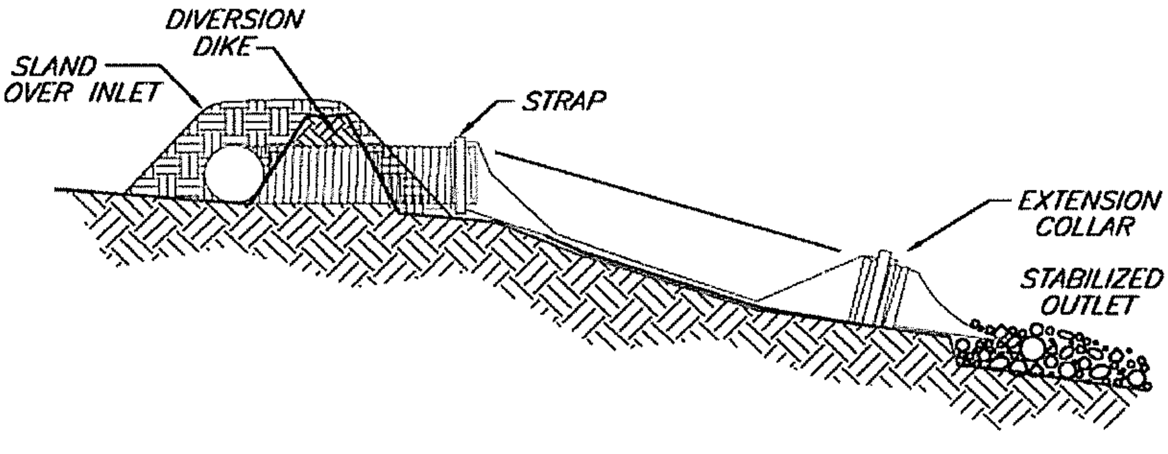
Construction Specifications: A common failure of slope drains is caused by water saturating the soil and seeping along the pipe. Proper backfilling around and under the pipe haunches with stable soil material and hand compacting in 6 inch (.2 m) lifts to achieve firm contact between the pipe and the soil at all points will reduce this type of failure.

- Place slope drains on undisturbed soil or well-compacted fill at locations and elevations shown on the plans.
- Slightly slope the section of pipe under the dike toward its outlet.
- Compact the soil under and around the entrance section in lifts not to exceed 6 inches.
- Ensure that fill over the drain at the top of the slope has a minimum depth of 1.5 feet (0.5 m) and a minimum top width of 4 feet (1.2 m). The sides should have a 3:1 slope.
- Ensure that all slope drain connections are watertight.
- Ensure that all fill material is well-compacted. Securely fasten the exposed section of the drain with grommets or stakes spaced no more than 10 feet (3.1 m) apart.
- Extend the drain beyond the toe of the slope and adequately protect the outlet from erosion.
- Make the settled, compacted dike ridge no less than 1 foot (0.3 m) higher than the top of the pipe inlet.
- Immediately stabilize all disturbed areas following construction.

Maintenance: Inspect the slope drain and supporting diversions after every significant rainfall and promptly make necessary repairs. When the protected area has been permanently stabilized, temporary measures may be removed, materials disposed of properly, and all disturbed areas stabilized appropriately.



PLAN VIEW



SECTION

SLOPE DRAIN

FILE: SLOPEDRN

Straw Rolls

Straw rolls are manufactured from straw that is wrapped in black plastic netting. They are approximately 200 mm (8 inches) in diameter by 8-9 m (25-30 feet) long. Rolls are placed and staked along the contour of newly constructed or disturbed slopes, in shallow trenches.

Conditions Where Practice Applies

Sites appropriate for straw rolls are slopes susceptible to sheet and rill erosion, slopes producing dry ravel, slopes susceptible to freeze/thaw activity, or slopes difficult to vegetate because of soil movement. Straw rolls are not intended for use in concentrated flow situations. Straw rolls will last an average of one to two years. This is an important factor when planning the optimum length of time the slope will need mechanical stabilization. Straw rolls can be staked with live stakes if site conditions warrant. The moisture retained by the straw roll will encourage cutting establishment.

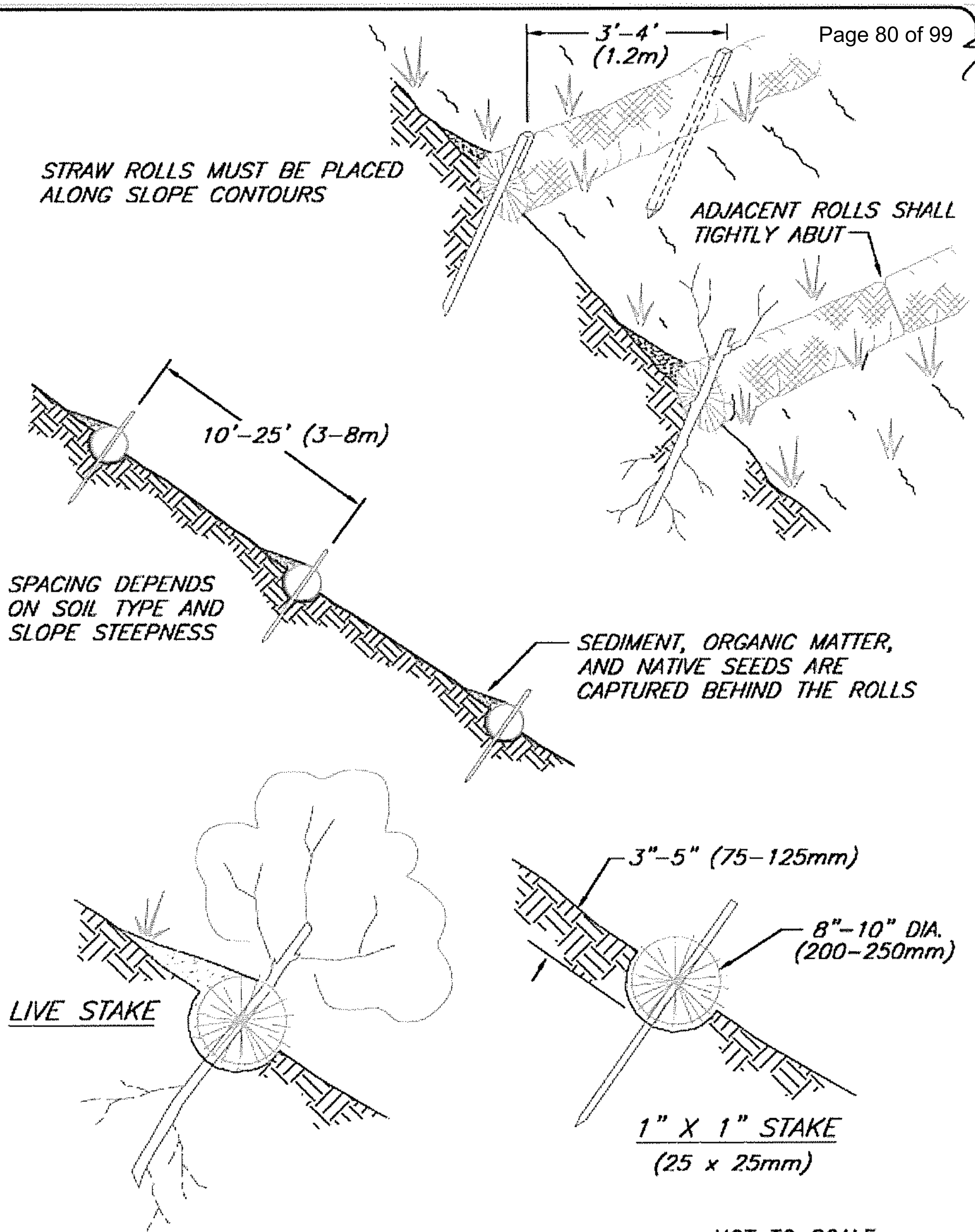
Advantages

Straw rolls are a relatively low-cost solution to sheet and rill erosion problems. They better suited than silt fences or straw bales for placement on steep slopes. Straw Rolls help establish native vegetation as rolls store moisture for vegetation planted immediately upslope. The moisture retention can help in the establishment of willows from live cuttings. The plastic netting will eventually photodegrade, eliminating the need for retrieval of materials after the straw has broken down. The straw will become incorporated into the soil with time, adding organic material to the soil and retaining moisture for vegetation.

Implementation

Prepare the slope before the installation procedure is started. Shallow gullies should be smoothed as work progresses. Dig small trenches across the slope on contour to place the rolls in. The trench should be deep enough to accommodate half the thickness of the roll. When the soil is loose and uncompacted, the trench should be deep enough to bury the roll 2/3 of its thickness because the ground will settle.

Start building trenches and install rolls from the bottom of the slope and work up. Construct trenches at contour intervals of 3-12 feet (1-4 m) apart depending on steepness of slope. The steeper the slope, the closer together the trenches. Make sure no gaps exist between the soil and the straw wattle. Use a straight bar to drive holes through the wattle and into the soil for the willow or wooden stakes. Drive the stake through prepared hole into the soil. Leave only 25-50 mm (1-2 inches) of stake exposed above roll. Install stakes at least every 1.2 m (4 feet) apart. Use straight willow stakes, 20-mm (3/4 inch) diameter in addition to wooden stakes.



NOTE:

1. STRAW ROLL INSTALLATION REQUIRES THE PLACEMENT AND SECURE STAKING OF THE ROLL IN A TRENCH, 3"–5" (75–125mm) DEEP, DUG ON CONTOUR. RUNOFF MUST NOT BE ALLOWED TO RUN UNDER OR AROUND ROLL.

STRAW ROLLS

FILE: STRWROLL

STRUCTURAL STREAMBANK STABILIZATION

Construction Specifications:

Riprap: Riprap is the most commonly used structural material for stabilizing streambanks. When possible, slope banks to 2:1 or flatter, and place a gravel filter or filter fabric on the smoothed slopes before installing riprap. Place the toe of the riprap at least 1 foot (0.3 m) below the stream channel bottom or below the anticipated depth of channel degradation. Where necessary, riprap the entire stream cross section. It is important to extend the upstream and downstream edges of riprap well into the bank and bottom. Extend riprap sections the entire length between well-stabilized points of the stream channel.

~~**Gabions**: These rectangular, rock-filled wire baskets are pervious, semi-flexible building blocks or mats which can be used to armor the bed and/or banks of channels or to divert flow away from eroding channel sections. Gabions should be designed and installed in accordance with manufacturer's standards and specifications.~~

Deflectors: Deflectors are structural barriers, in the form of groins or jetties which project into the stream to divert flow away from eroding streambank sections. Stone and rock deflectors, used as instream structures, may also be useful for environmental and habitat enhancement.

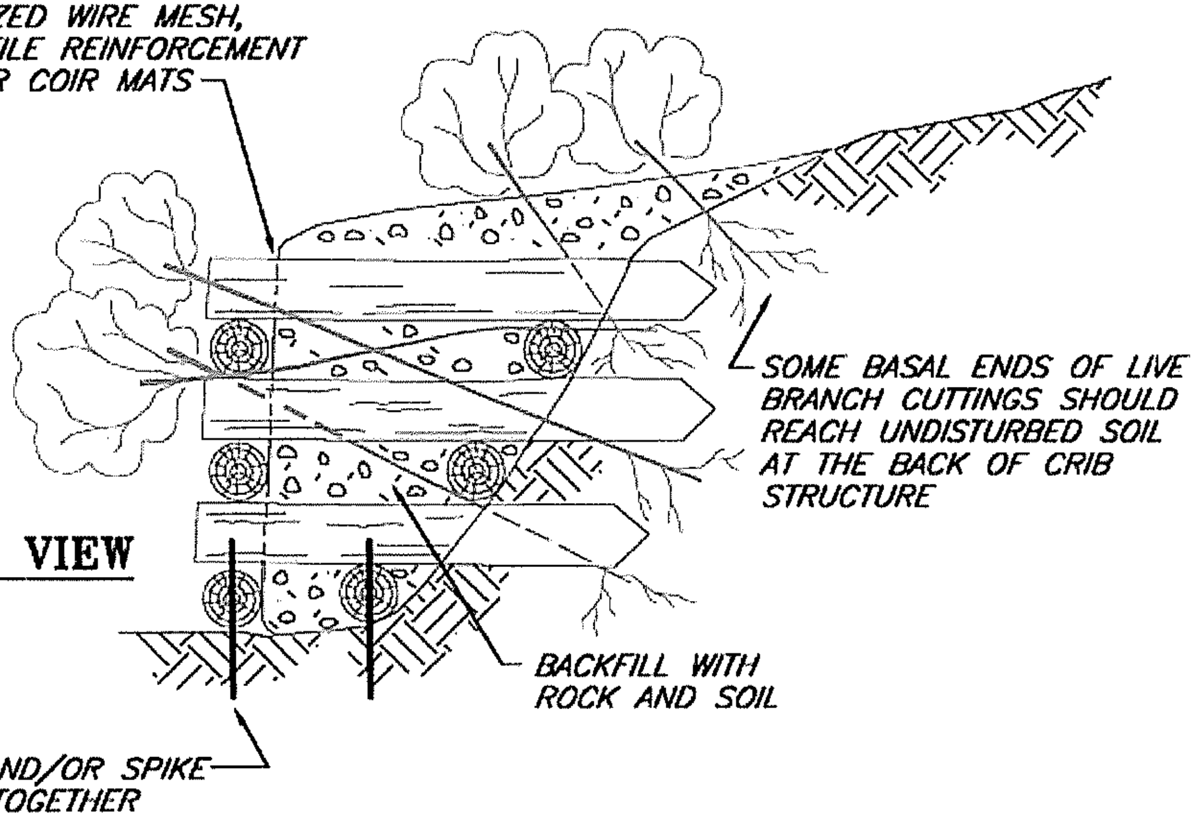
- Live willow (or other riparian species) staking may be incorporated into the construction of the rock deflectors.
- The deflectors should be shaped in a 30-60-90 degree triangle with the 30 degree angle upstream and against the bank.
- The deflectors are generally spaced 3-5 times the length of its groin.
- Single wing deflectors should extend 1/4 to 1/2 of the way across the stream.
- Double wing deflectors will extend no more than 1/4 of the way across the stream, opposite each other. The narrowest point between deflector will be 1/2 of the stream width.
- In general, the first and last deflectors should be double wing deflectors and the general deflector pattern will alternate between double wing and single wing, unless structures are intended to protect an outer bend. Then non-alternating, consecutive single wings may be required.
- The rock deflector should be constructed with a 1.5 foot (0.5 m) minimum diameter rock. Larger channels will require larger rock.
- Rock deflector should be keyed into the stream bottom a minimum of 1 foot (0.3 m).
- The top of the rock should extend 1 foot (0.3m) above normal stream flow (near bank) and slope down to a height of 0.5 feet (0.2 m) above stream flow at apex.
- The deflectors should be contiguous with riprap or other streambank protection measures.

~~**Reinforced Concrete** may be used to armor eroding sections of the streambank by constructing retaining walls or bulk heads. Positive drainage behind these structures must be provided. Reinforced concrete may also be used as a channel lining.~~

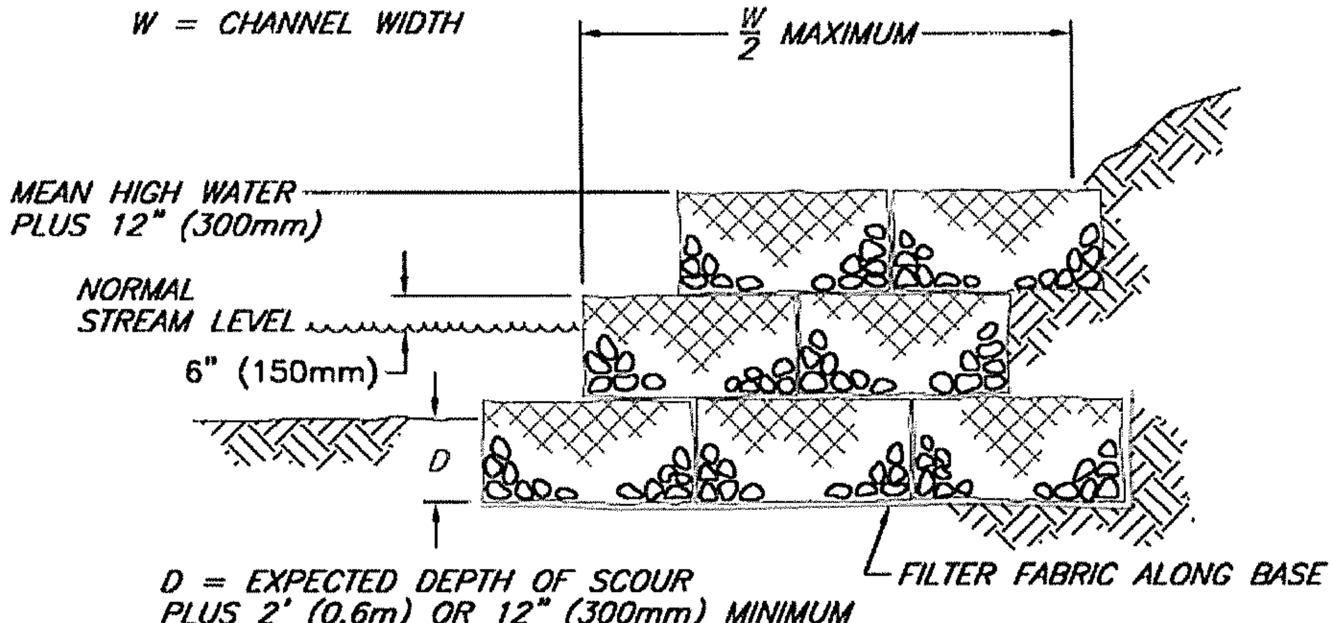
Log Cribbing is a retaining structure built of logs to protect streambanks from erosion. Log cribbing is normally built on the outside of stream bends to protect the streambank from the impinging flow of the stream. Log cribbing can have live willow (or other riparian species) stakes be planted between the logs, behind the structure and immediately adjacent to the cribbing.

~~**Grid Pavers** are modular concrete units with interspersed void areas which can be used to armor the streambank while maintaining porosity and allowing the establishment of vegetation. These structures may be obtained in pre-cast blocks or mats, or they may be formed and poured in place. Grid pavers are installed like riprap. The specific design and installation should follow manufacturers instructions.~~

Inspection and Maintenance: All structures should be maintained in an "as built" condition. Structural damage caused by storm events should be repaired as soon as possible to prevent further damage to the structure or erosion of the streambank.



TYPICAL LOG CRIBBING



TYPICAL GABION DEFLECTOR

STREAMBANK STABILIZATION

FILE: STREAMBK

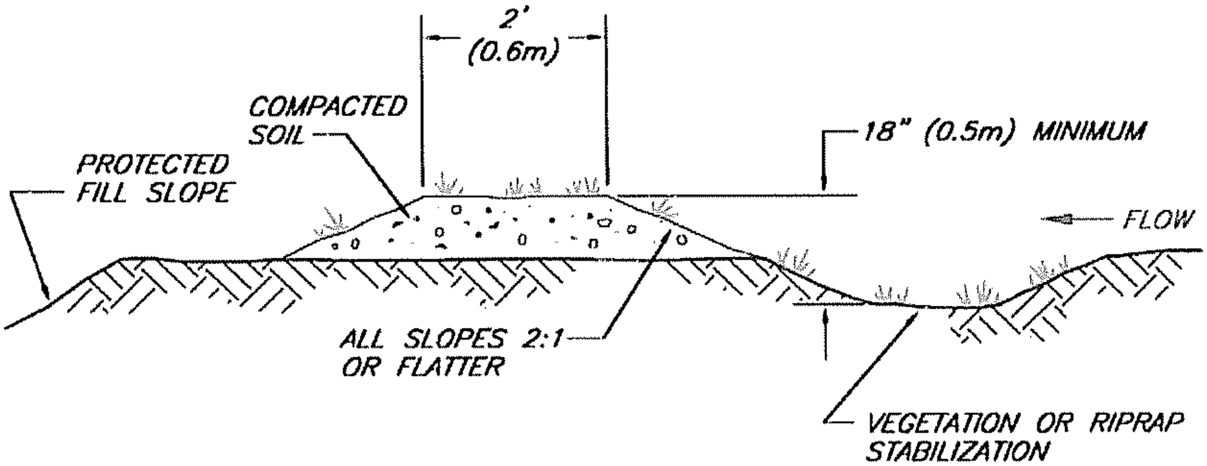
TEMPORARY DIVERSION DIKE

Construction Specifications:

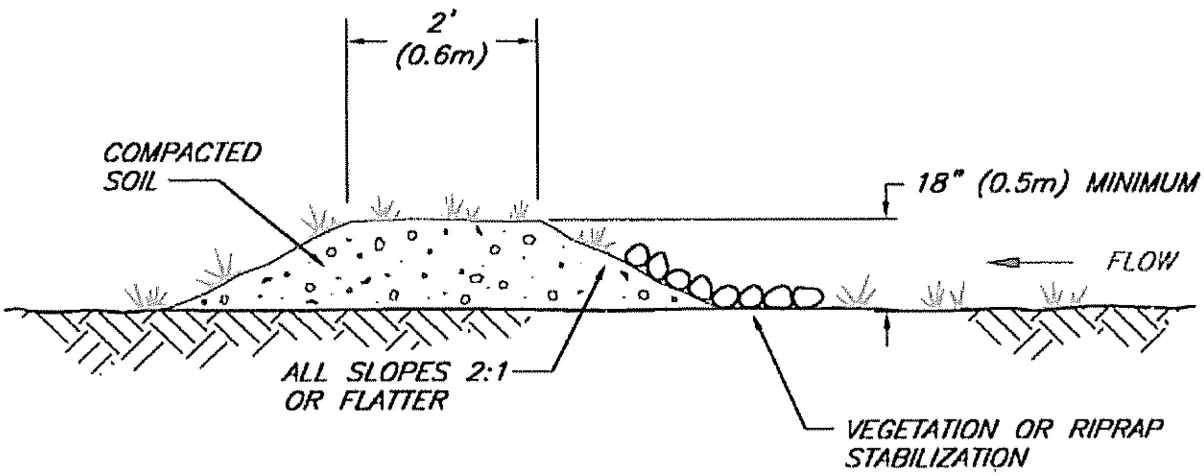
- Temporary diversion dikes must be installed as a first step in the land-disturbing activity and must be functional prior to upslope land disturbance.
- The dike should be adequately compacted to prevent failure.
- Temporary or permanent seeding and mulch shall be applied to the dike immediately following its construction.
- The dike should be located to minimize damages by construction operations and traffic.

Inspection and Maintenance:

- The measure shall be inspected after every storm and repairs made to the dike, flow channel, outlet or sediment trapping facility, as necessary.
- Once every two weeks, whether a storm event has occurred or not, the measure shall be inspected and repairs made if needed.
- Diversion Dikes used to trap sediment shall be inspected and cleaned out after every significant storm.
- Damages caused by construction traffic or other activity must be repaired before the end of each working day.
- If vegetation has not been established, reseed damaged and sparse areas immediately.



TYPICAL FILL DIVERSION



TYPICAL TEMPORARY DIVERSION DIKE

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

TEMPORARY DIVERSION DIKE

FILE: TEMPDIKE

Vegetated Mechanically Stabilized Earth

Description:

This technique consists of live cut branches (brushlayers) interspersed between lifts of soil wrapped in natural fabric, e.g., coir, or synthetic geotextiles or geogrids. The live brush is placed in a criss-cross or overlapping pattern atop each wrapped soil lift in a manner similar to conventional brushlayering. The fabric wrapping provides the primary reinforcement in a manner similar to that of conventional mechanically-stabilized earth (Koerner, 1998; Mitchell & Villet, 1987). The live, cut branches eventually root and leaf out, providing vegetative cover and secondary reinforcement as well. In some cases, the vegetative treatment may consist of using a coarse netting for the soil wraps and establishing an herbaceous or grass cover by simply hydroseeding through the openings in the fabric.

Purpose:

Vegetated Mechanically Stabilized Earth (VMSE) can be viewed as a union between conventional, mechanically stabilized earth methods that utilize inert, tensile inclusions, and brushlayering, a soil bioengineering technique that utilizes live, cut branches as the tensile soil inclusions. The treatments complement one another. Fabric wraps provide the primary reinforcement and mechanical stabilization, permitting much steeper slopes to be constructed than would be possible with live brushlayers alone. The vegetation shields the fabric against damaging UV radiation and provides visual and habitat benefits.

Conditions Where Practice Applies:

VMSE can be used to stabilize slopes as steep as 1V:0.5H. This technique provides an alternative to vertical retaining structures, e.g., timber pile walls, and to techniques that require slope flattening or bank lay back, which results in excessive right-of-way encroachment at the top of bank. The use of synthetic geotextiles or geogrids provides greater long-term durability and security. The fabric or geotextile wrap also provides additional protection to upper portions of streambanks that are subject to periodic scour or tractive stresses. If either steady, long term seepage or temporary bank return flows after flood events are a problem, the brushlayers act as a drainage layer or conduits that relieve internal pore water pressure, and favorably modify the groundwater flow regime within the slope to minimize slope stability problems.

Complexity:

High. VMSE is relatively complex, because it entails designing, melding together, and constructing two similar yet distinct methods, conventional MSE and live brushlayering. Both techniques are widely used and well understood, however; simultaneous use introduces complexity.

Vegetated Mechanically Stabilized Earth (continued)

Design Guidelines / Typical Drawings:

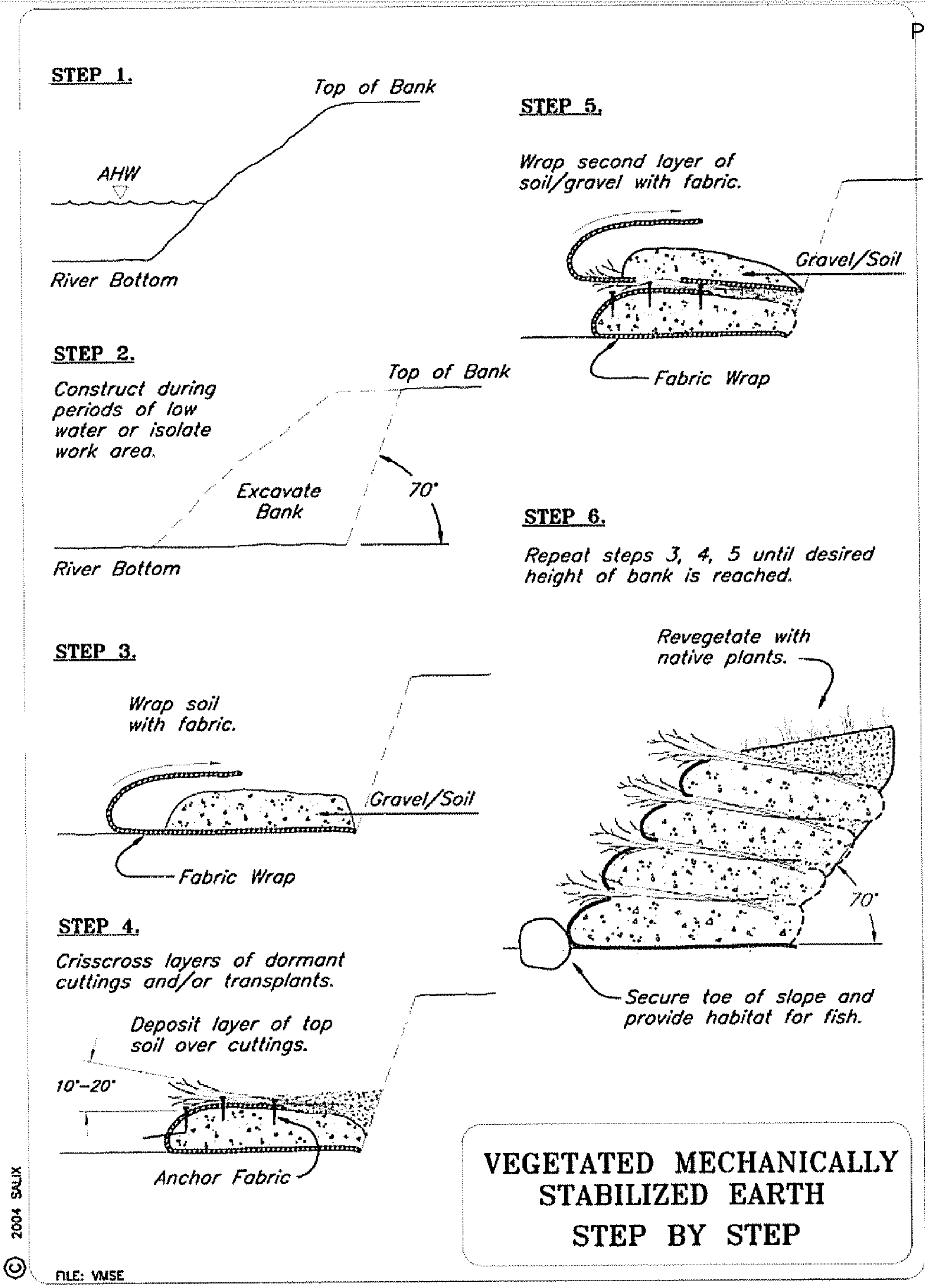
Many different types of inclusions with various shapes and properties can be used to reinforce and buttress earthen slopes. These inclusions range from imbedded metal strips, geogrids fabricated from polymeric nets, and natural or synthetic geotextiles or fabrics. Earthen slopes, embankments, or structural fills that are stabilized or reinforced with such tensile inclusions are referred to as "mechanically stabilized earth." Shear stresses that develop in the soil matrix are transferred into tensile resistance in the imbedded inclusions via friction along the soil-inclusion interface.

Mechanically stabilized earth retaining structures must satisfy external stability requirements, i.e., have adequate resistance to sliding, overturning, and bearing capacity failure. Internal stability requirements are also important in reinforced earth and mechanically stabilized earth structures. The tensile inclusions or reinforcements in these structures must have a sufficient unit tensile resistance and/or be placed in sufficient numbers to resist breaking in tension. The inclusions must also be sufficiently long and "frictional" enough to resist failure by pullout.

Synthetic geogrids fabricated from high-tensile strength polymeric materials are widely used in reinforced earth embankments and retaining walls. Geogrids tend to have superior pullout resistance compared to geotextile or fabric sheets because of passive resistance mobilized along the transverse elements in a mesh or geogrid. They can be used either in a wrap-around fashion to provide both backfill reinforcement and containment at the front face. This approach permits the insertion of live cuttings or branches between successive lifts of "wrapped soil" as shown schematically in Figure 1.

Live cuttings inserted in the above manner also act as tensile inclusions and help to stabilize a slope, embankment, or structural fill. Live brushlayers behave exactly in this fashion. Gray & Sotir (1992) discuss how brushlayers can be analyzed and their contribution to slope stability determined in a rational, quantitative manner. This contribution could be included as well when inert reinforcements are used in conjunction with live brushlayers such as in VMSE. In this combined approach, however, the contribution to mechanical reinforcement from the live cuttings is simply treated as a bonus, and the design analysis is focused on the fabric or geogrid reinforcements themselves.

The main considerations in the design of geogrid or geotextile reinforced earthen slopes and embankment fills is the required vertical spacing (d) and total length (L) of the reinforcing layers. The total length (L) is comprised of a length or distance required to reach the expected failure surface in the backfill and an additional length, the effective or imbedment length (L_E), extending beyond the failure surface required to prevent pullout. The reader should consult with a geotechnical engineer as necessary.


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
FILE: VMSE
© 2004 SALIX

Vegetated Riprap

A layer of stones and/or boulder armoring, generally referred to as riprap revetment, placed along a streambank and designed to be vegetated with pole planting, brushlayering, and live staking (joint planting).

Conditions Where Practice Applies

Rock riprap is the most common and effective form of streambank protection. Rock can settle and conform if some scour should occur. Conventional riprap placement, however, does not increase wildlife habitat nor is it aesthetically pleasing. It often takes many years for riprap to become vegetated if revegetation is not planned in advance and integrated with construction. The agencies whose task it is to ensure fish habitat recognize that the continued use of riprap, gabions, and other inert streambank structures have long-term negative impacts on aquatic habitats.

This practice applies whenever there is a desire to install riprap, which is more attractive and has the potential to enhance, not degrade, fish and wildlife habitat. Additionally, woody vegetation establishment will prevent soil loss (piping) from behind the structures and increase pull out resistance. Vegetated riprap techniques should be considered with projects in streams with fishery resources.

Materials

The main elements are quarry stone or other suitable rock, the size and weight dependant on design velocity or slope stability analysis. A filter layer, either graded aggregate or filter fabric, placed under the riprap will prevent the washout (piping) of fines through the armor layer.

Willow material for brushlayering and pole planting will be required. The length of the cuttings will depend on the depth through the riprap and filter layer to the native soil. Live cuttings can be included and should consist of relatively straight willow branches, 25-40 mm (1-1.5 inches) diameter and long enough to reach beyond the riprap and filter layer and into native ground.

Vegetated Riprap (continued)

Advantages

Studies have shown that the frequency of revetment failure was lower in vegetated revetments than unvegetated sections. The vegetation's roots, particularly the fibrous willow roots, prevent washout of fines and stabilizes the native soil. Vegetation helps to anchor the armor stone to the bank and increases their lift-off resistance. In addition, vegetated revetments provide riparian benefits and wildlife habitat. Vegetated riprap has a more natural appearance and is therefore more aesthetically pleasing. Along streambanks, the vegetation will slow water velocities and encourage deposition and sedimentation. Experience has shown that environmental clearances and permits are easier to obtain if the project has biotechnical, habitat enhancement, elements incorporated into the design.

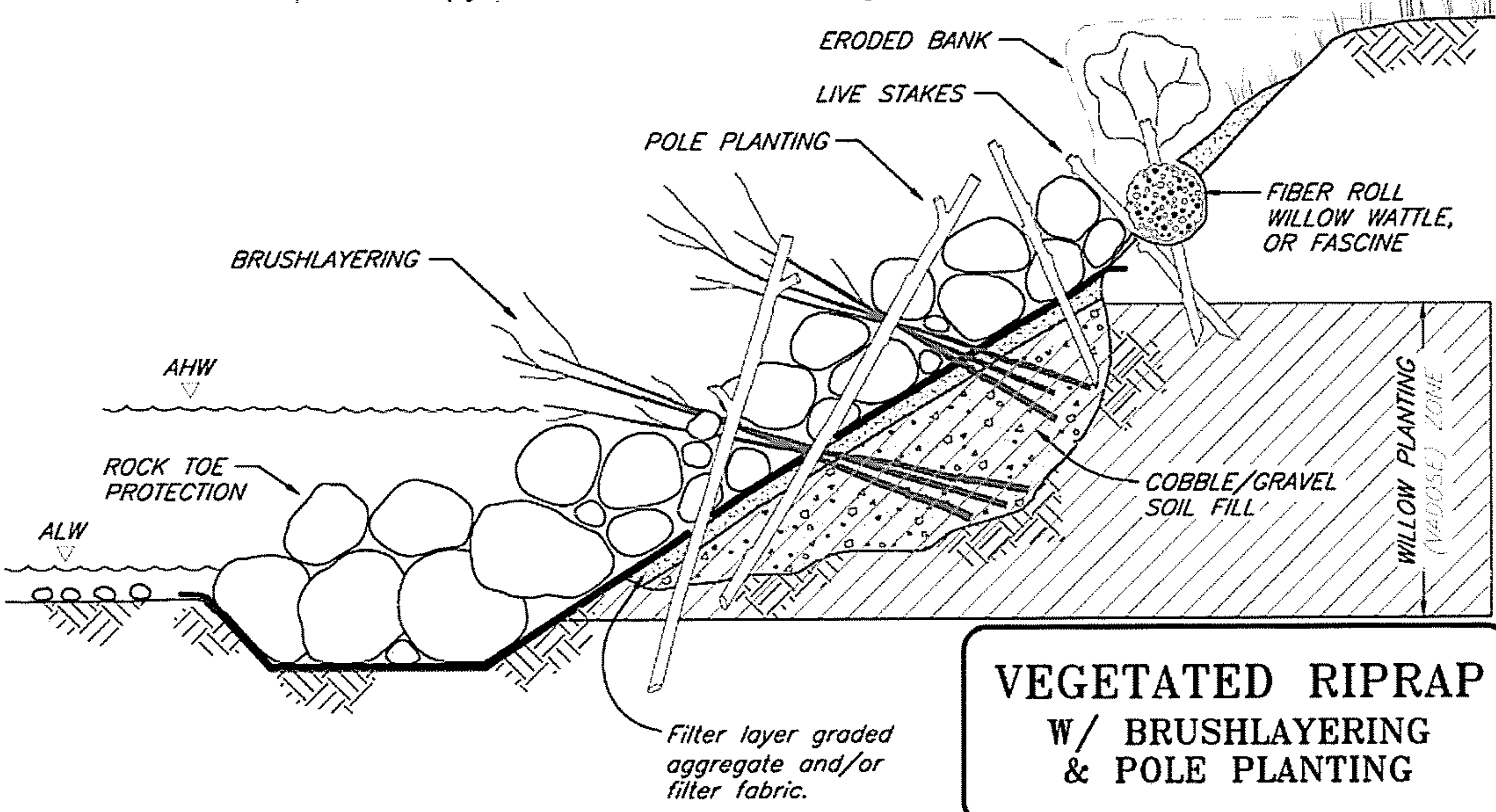
Disadvantages

It is sometimes difficult to drive the willow stakes between the rock joints, through filter fabric and into the native soil. The cuttings, brushlayering and pole planting, should be installed while the revetment is being constructed. Installation of the vegetative practices during construction will facilitate the planting but it will requires additional care when placing the rock (end dumping may damage to the cuttings).

Implementation

The branches are inserted during construction in crushed stone or riprap so that the butt ends are imbedded in the soil behind the cover to a depth of 0.3-0.5 m or into the seasonal water table or capillary fringe. The branch tips should protrude for approximately 0.5 m from the stone layer and face at an oblique angle downstream. The lowest branches are below the level of the mean summer flow and well wedged amongst the stone to prevent them from being washed out.

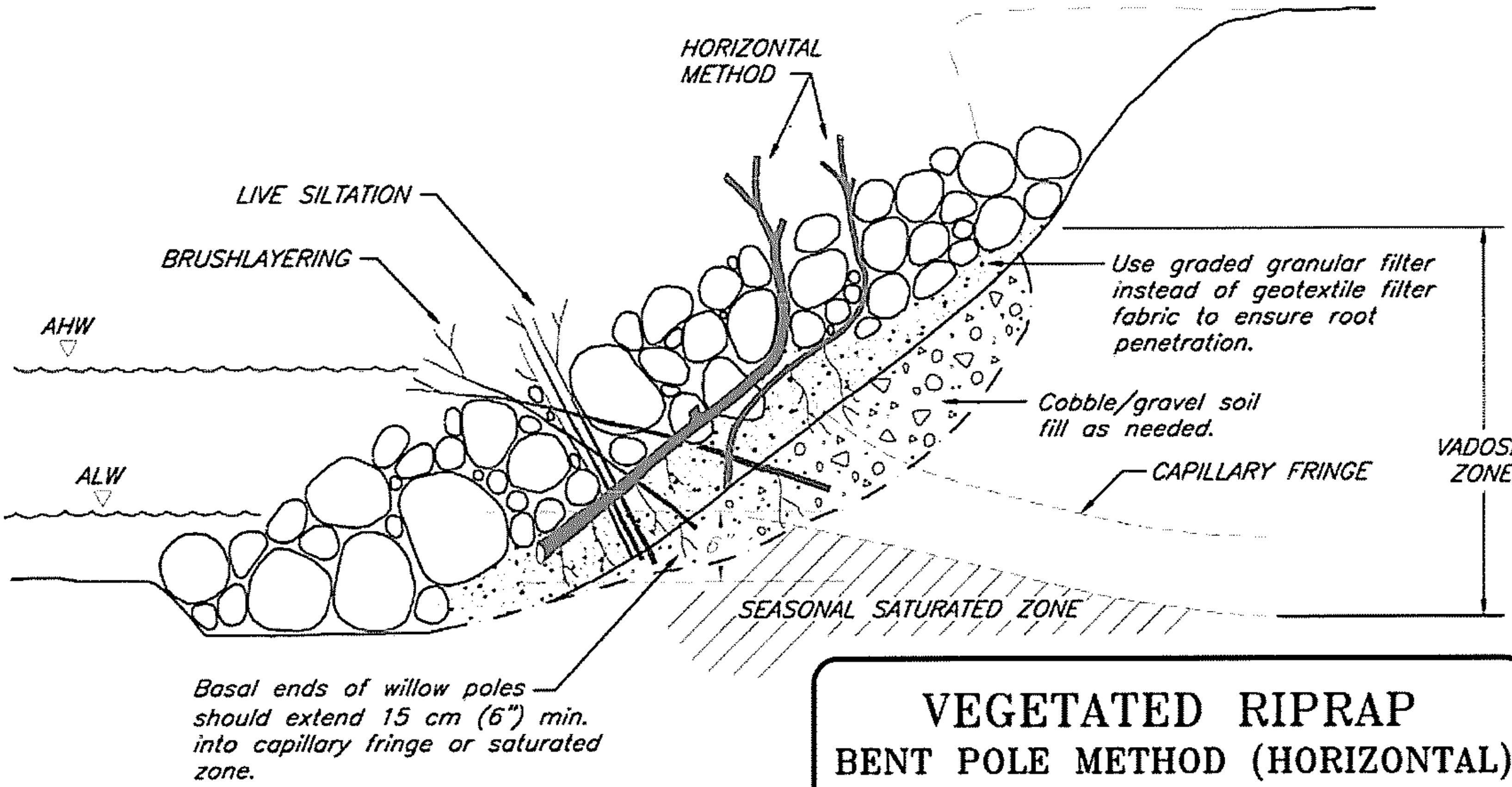
NOTES:
1. Install willow pole planting and brushlayering during bank grading and riprap placement to ensure good contact with 'native ground' and/or soil fill.
2. Willow poles and brush layers should extend down into expected soil moisture zones (vadose).
3. Cut small holes or slits in filter fabric 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.



VEGETATED RIPRAP
W/ BRUSHLAYERING & POLE PLANTING

FILE: VRBLPP

NOTES:
1. Integrate brushlayering, pole planting and live siltation techniques during rock placement to ensure contact with native ground. Laying poles 'horizontally" is an efficient and cost-effective way to maximize rooting.
2. As a general rule, place basal ends of the cuttings 15 cm (6") into the capillary fringe or seasonal saturated zone.
3. Graded, granular filter is preferable to filter fabric to improve root penetration or slip poles through slits cut into fabric.
4. Place soil fill (cobbles, gravel, soil) around cuttings and 'water in' if possible.

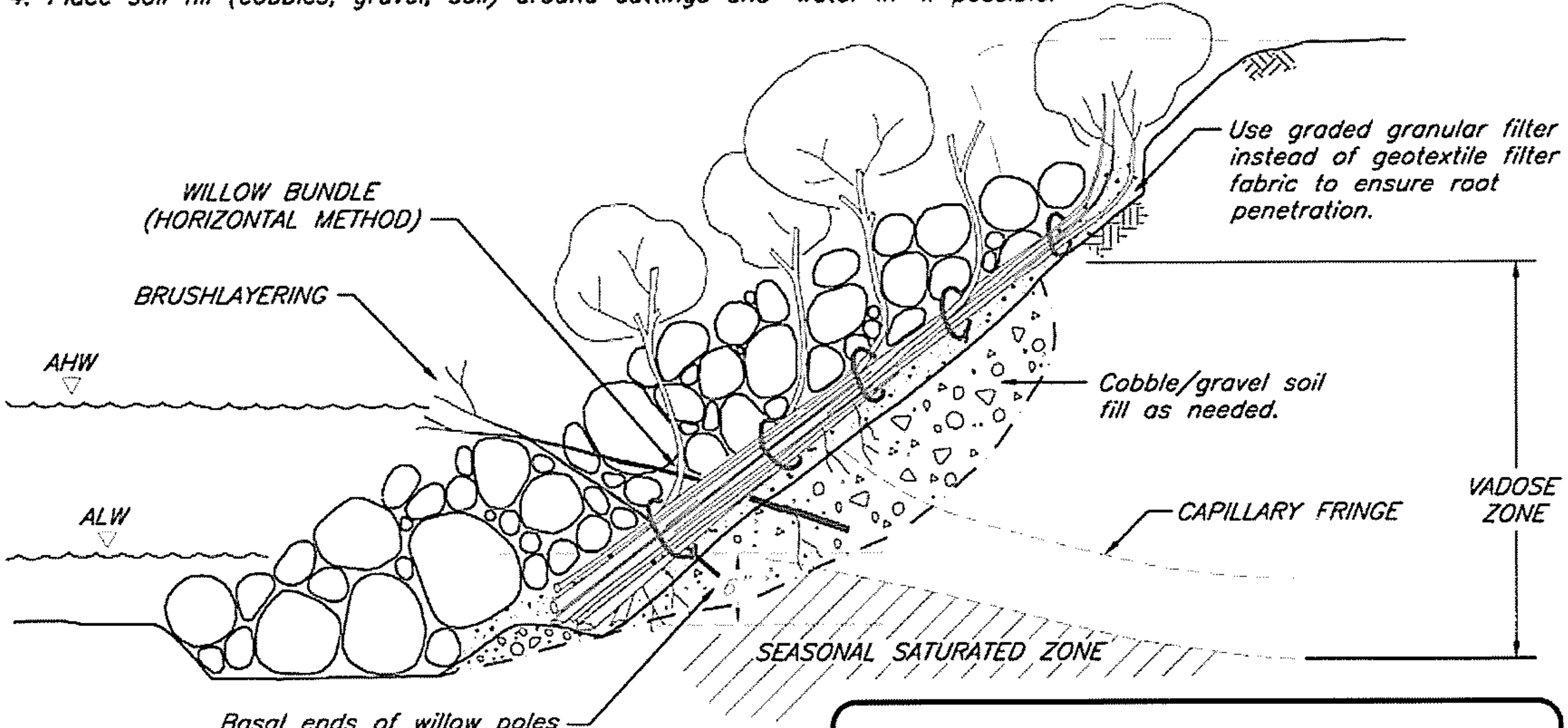


VEGETATED RIPRAP
BENT POLE METHOD (HORIZONTAL)

FILE: VRBP

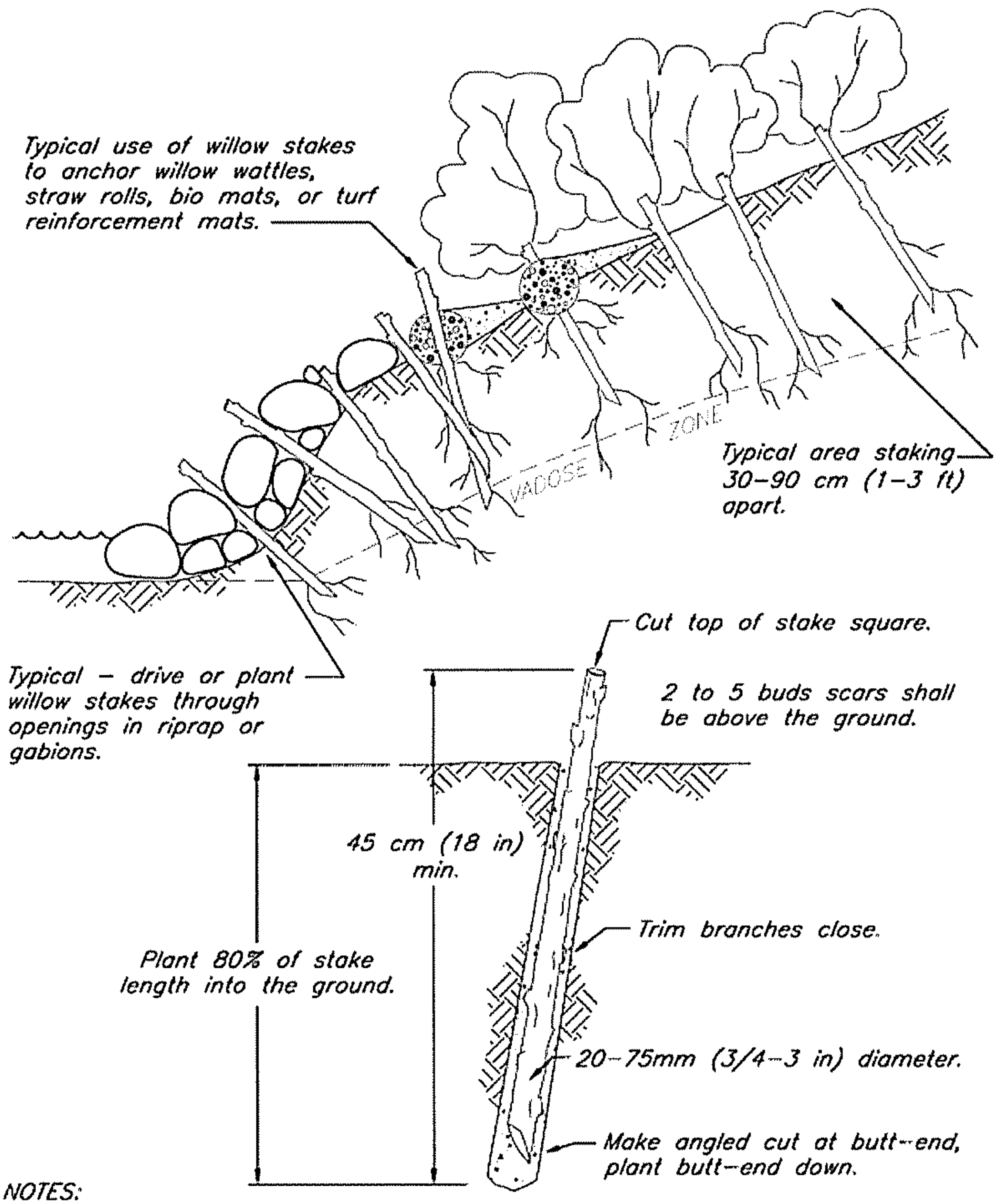
NOTES:

1. As a general rule, place basal ends of the cuttings 15 cm (6") into the capillary fringe or seasonal saturated zone.
2. Bend individual poles up through the riprap during placement while ensuring contact of the stem with native ground. Laying poles 'horizontally" is an efficient and cost-effective way to maximize rooting.
3. Graded, granular filter is preferable to filter fabric to improve root penetration or slip poles through slits cut into fabric.
4. Place soil fill (cobbles, gravel, soil) around cuttings and 'water in' if possible.



VEGETATED RIPRAP
WILLOW BUNDLE METHOD (HORIZONTAL)

FILE: VRBND

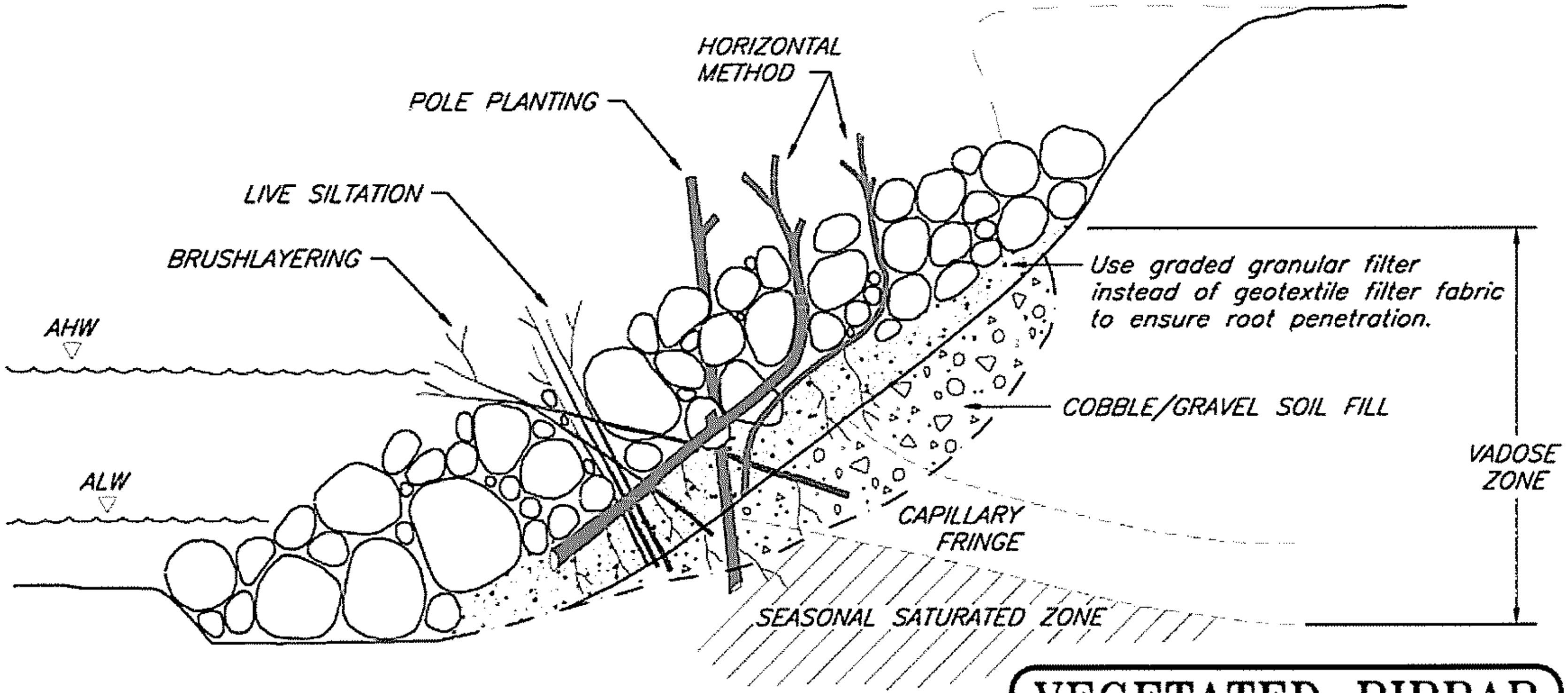


NOTES:
1. Harvest and plant stakes during the dormant season.
2. Use healthy, straight and live wood at least 1 year old.
3. Make clean cuts and do not damage stakes or split ends during installation, use a pilot bar in firm soils.
4. Soak cuttings for 24 hours (min.) prior to installation.
5. Tamp the soil around the stake.

VEGETATED RIPRAP
W/ JOINT PLANTING
(LIVE STAKING)

FILE: VRJP

NOTES:
1. Integrate brushlayering, pole planting and live siltation techniques during rock placement to ensure contact with native ground.
2. Plant deeply if possible. Place cuttings deeply into vadose zone, into the capillary fringe or 15 cm (6") into the seasonal saturated zone (water table).
3. Graded, granular filter is preferable to filter fabric to improve root penetration or slip poles through slits cut into fabric.
4. Place soil fill (cobbles, gravel, soil) around cuttings and 'water in' if possible.
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.



VEGETATED RIPRAP
DURING CONSTRUCTION
SUMMARY OF TECHNIQUES

FILE: VRDC

WATTLES (LIVE FASCINES)

Construction Specifications:

Wattle Preparation:

- Cuttings shall be harvested and planted when the willows, or other chosen species, are dormant. This period is generally from late fall to early spring.

- Choose plant materials that are adapted to the site conditions from species that root easily. A portion (up to 50%) of the bundle may be of material that does not root easily or dead material.

- The cuttings should be long (3 feet (1 m) minimum), straight branches up to 1 1/2 inches (4 cm) in diameter. Trimmings of young suckers and some leafy branches may be included in the bundles to aid filtration. The number of stems varies with the size and kind of plant material.

- Cuttings shall be tied together to form bundles, tapered at each end, 6-30 feet (2-10 m) in length, depending on site conditions or limitations in handling.

- The completed bundles should be 6-12 inches (152-305 mm) in diameter, with the growing tips and butt ends oriented in alternating directions.

- Stagger the cuttings in the bundles so that the tips are evenly distributed throughout the length of the wattle bundle.

- Wattle bundles shall be compressed and tightly tied with rope or twine of sufficient strength and durability. Polypropolyne 'tree rope' approximately a 3/16 inch (0.5 cm) diameter provides the necessary strength and durability.

- Wattle bundles shall be tied 12-15 inches (305-381 mm) apart.

- For optimum success wattles should be pre-soaked for 24 hours or installed on the same day they are harvested and prepared. The wattles should be installed within 2 days after harvest unless pre-soaked. Wattles must be stored in the shade and under cover or under water. They are live material and should be treated as such.

Installation:

- Work shall progress from the bottom to the top of the slope.

- Install wattles into trenches dug into the slope on contour

- Spacing of contour trenches (wattles) is determined by soil type, potential for erosion and slope steepness.

- Perform any slope repairs, such as gully repair, slope scaling, diversion dike, gabion, or toe wall construction, prior to wattle installation.

- Beginning at the base of the slope, dig a trench on contour. The trench shall be shallow, about 1/2 the diameter of the wattle. The trench width will vary from 12-18 inches (305-457 mm) depending on the slope angle.

- Place the wattles immediately after trenching to reduce desiccation of the soil.

- Wattles shall be staked firmly in place with one row of construction stakes on the downhill side of the wattling, not more than 3 feet (1m) apart. A second row of stakes shall be placed through the wattles, near the ties, at not more than 5 feet. (1.5 m) apart.

- Overlap the tapered ends of adjacent wattles so the overall wattle thickness of the wattle is uniform. Two stakes shall be used at each bundle overlap such that a stake may be driven between the last two ties of each wattle.

- Live stakes, if specified, are generally installed on the downslope side of the bundle. Drive the live stakes below and against the bundle between the previously installed construction stakes.

- Proper backfilling is essential to the successful rooting of the wattles. Backfill wattles with soil from the slope or trench above. The backfill shall be worked into the wattle interstices and compacted behind and below the bundle by walking on and working from its wattling terrace.

- Repeat the proceeding steps to the top of the slope.

- Place moist soil along the sides of the live bundle. The top of the bundle should be slightly visible when the installation is completed.

- Plant the slope as specified.

- Seed and mulch slope. Shallow slopes, generally 3:1 or flatter may be seeded and mulched by hand. Steeper slopes should have seed applied hydraulically and the mulch shall be anchored with tackifier or other approved methods.

Inspection and Maintenance:

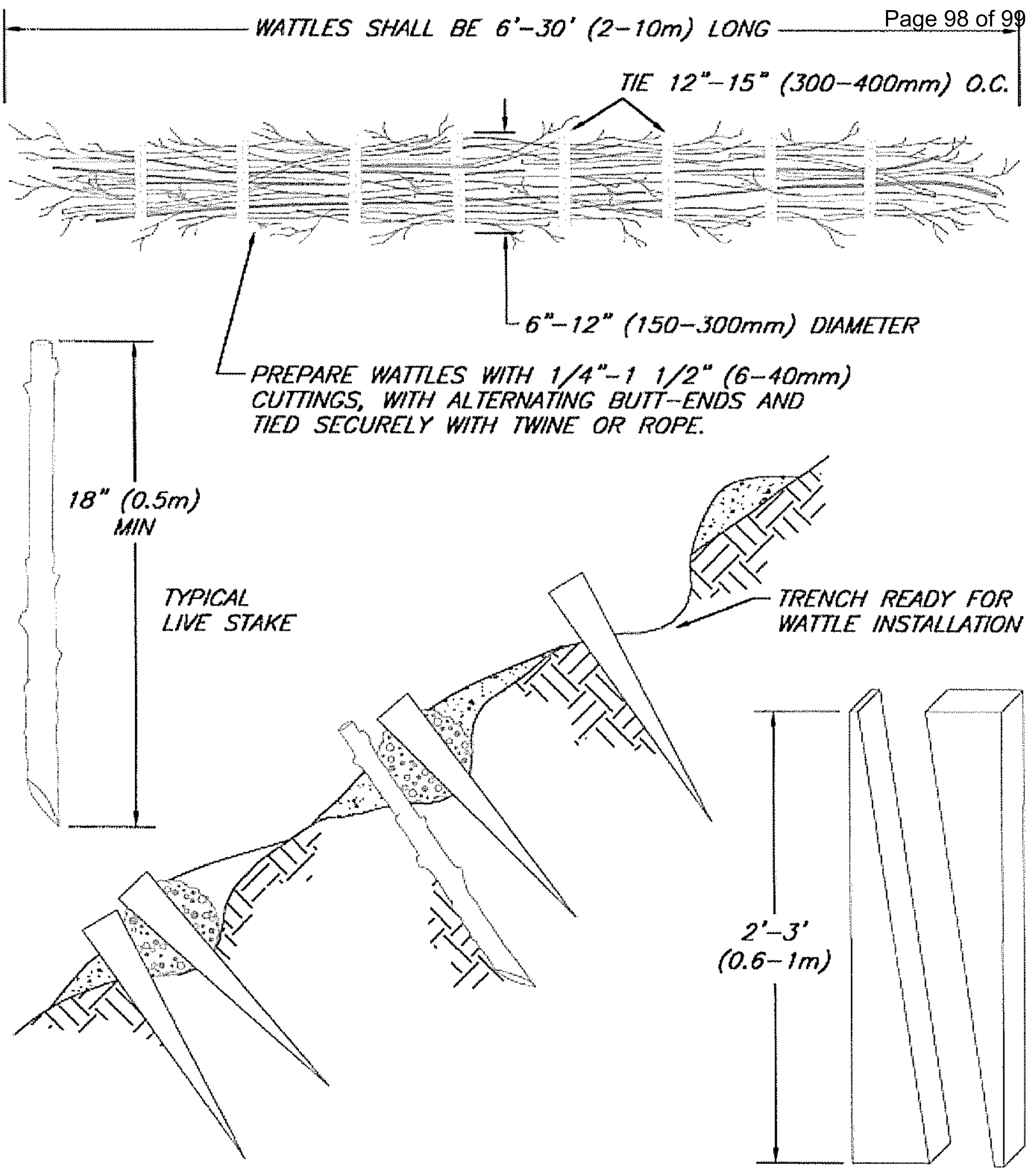
- Regular inspection and maintenance of wattle installations should be conducted, particularly during the first year.

- Repairs shall be made promptly. Stakes that loosen because of saturation of the slope or frost action shall be re-installed.

- Rills and gullies around or under wattles shall be repaired. Perform slope scaling and brushpacking as necessary.

- Repairs to vegetative practices shall be conducted promptly.

- All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function.



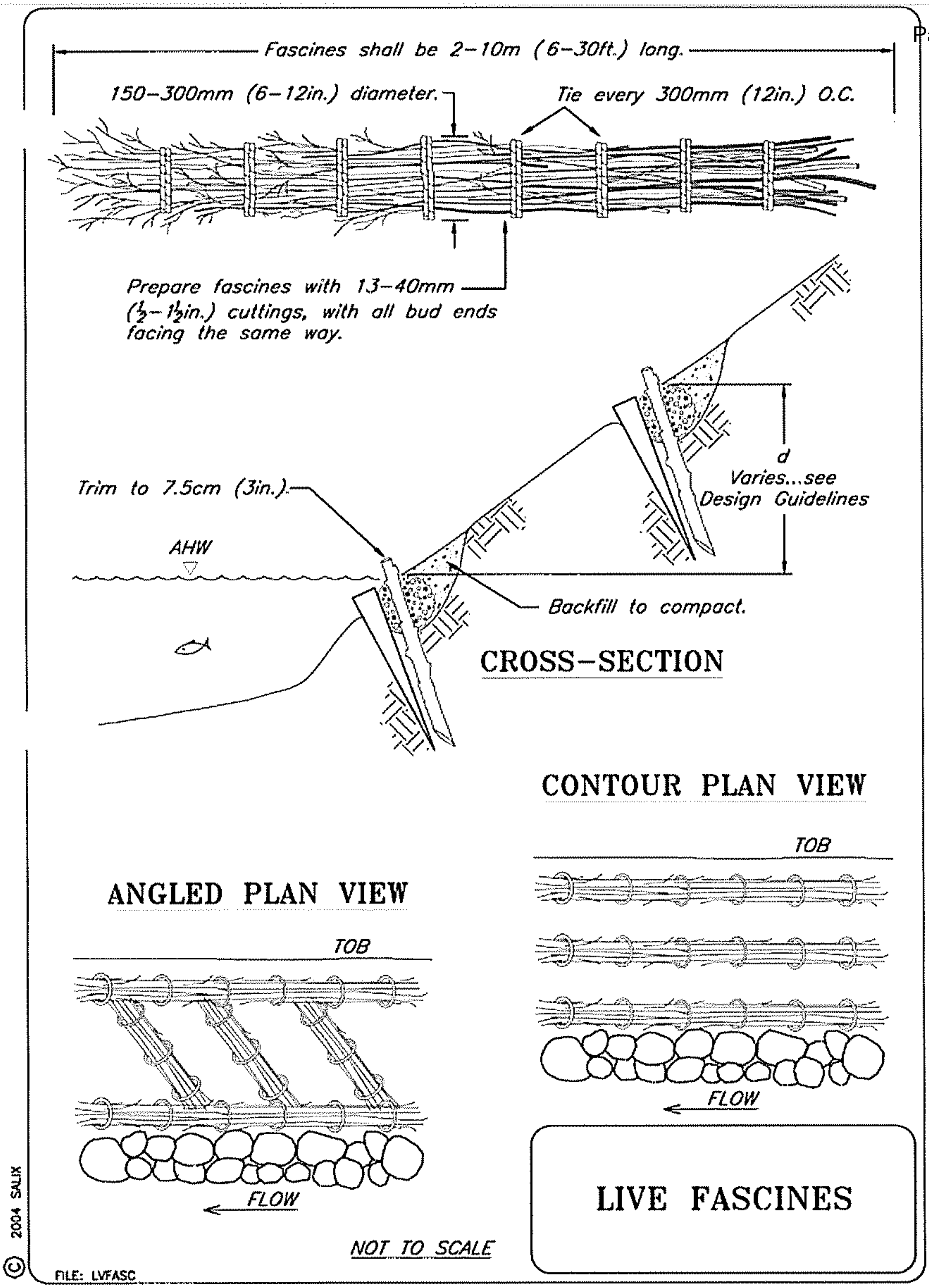
TYPICAL CONSTRUCTION STAKE
SAW 2X4 (100X50mm) LUMBER
ON DIAGONAL

NOTES:
1. HARVEST AND INSTALL WATTLES DURING DORMANT SEASON.
2. INSTALL WATTLES ON SLOPE CONTOURS.
3. ALL WORK PROCEEDS FROM THE BOTTOM OF THE SLOPE TO THE TOP.
4. FILL OR PARTIALLY COVER WATTLE WITH SOIL FROM SLOPE OR TRENCH ABOVE.
5. COMPACT AND WORK SOIL INTO COMPLETED WATTLES.

NOT TO SCALE

WATTLE (LIVE FASCINE)

FILE: WATTLE



LIVE FASCINES