Section 4
Permanent Erosion Prevention and Sediment Controls (PESCs)

Section 4 – Permanent Erosion Prevention and Sediment Control (PESC)

4.1 Introduction

This section presents the BMP fact sheets for Permanent Erosion Prevention and Sediment Control (PESC) management practices. Permanent BMPs are typically implemented most effectively when they are an integral part of the project design and should be selected during the early planning phase of a project. A multi-level strategy is required for BMP selection that incorporates source controls, a series of on-site treatment controls, and community-wide treatment controls. The BMP selection process was presented earlier in Section 1, Chapter 2.2.2.

BMPs for Permanent Stormwater Treatment Controls (PTPs) including Green Infrastructure Practices and 80% TSS Permanent Treatment Practices are covered in Section 5 of this manual.

4.2 Management Practice Fact Sheets

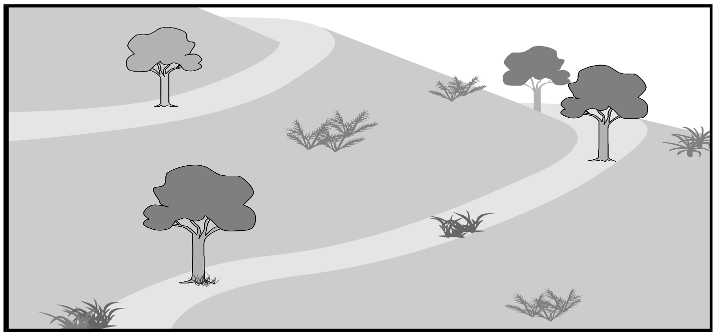
This section contains the following BMP fact sheets.

Permanent Erosion Prevention and Sediment Control Fact Sheets			
Fact Sheet ID	**Description**	**Fact Sheet ID**	**Description**
PESC - 01	Permanent Grass, Vines and Other Vegetation	**PESC - 05**	Gradient Terraces and Slope Roughening
PESC - 02	Geotextiles	**PESC - 06**	Flow Diversions, Drains and Swales
PESC - 03	Riparian Buffer Zones	**PESC - 07**	Outlet Protection
PESC - 04	Soil Bioengineering and Bank Stabilization	**PESC - 08**	Channel Linings

Each fact sheet has a quick reference guide indicating what pollutant constituents the BMP is targeting and implementation requirements. The BMPs presented in this section are intended to serve as permanent measures. Additional details are provided in sections covering Temporary Construction Site Runoff Management Practices (TCPs) for practices that are intended to function on a short-term basis (lasting only as long as construction activities) and Permanent Storm Water Treatment Controls (PTPs) for practices that are intended to function on a long-term basis.

Permanent Grass, Vines, and Other Vegetation

PESC – 01



Hamilton County
Water Quality Program

Description

Seeding of grasses and planting of trees, shrubs, vines and ground covers provide long-term stabilization of soil. The primary function of permanent seeding and planting is to: improve long-term aesthetics, reduce erosion by slowing runoff velocities, enhance infiltration and transpiration, trap sediment and other particulates, protect soil from raindrop impact, and provide habitat for wildlife. This management practice is likely to create a significant reduction in sediment as well as partial reductions in the impacts caused by nutrients and toxic materials.

Suitable Applications

- Appropriate for site stabilization both during construction and post-construction.
- Any graded/cleared areas where construction activities are completed.
- Open space cut and fill areas.
- Steep slopes not requiring more robust permanent stabilization techniques.
- Spoil or stock piles.
- Vegetated swales and ditches.
- Landscape corridors.
- Areas of stream banks with low velocities under most storm conditions.

Installation/ Application Criteria

These systems should be designed by a licensed professional civil engineer. Many of the measures presented in TDEC's E&SC Handbook under Stabilization Practices are applicable for establishing, stabilizing and maintaining permanent vegetation.

Application of appropriate vegetation must consider: the seedbed or plantbed, proper seasonal planting times, water requirements, fertilizer requirements and availability of the selected vegetation within the project's region.

Type of vegetation, site and seedbed preparation, planting time, fertilization and water requirements should be considered for each application.

- Seeding and planting should be applied as soon as final grading is done to all graded and cleared areas of the construction site where plant cover is ultimately desired. For example, vegetation may be established along landscaped corridors and buffer zones where they may act as filter strips.

- Vegetated swales, steep and/or rocky slopes and stream banks can also serve as appropriate areas for seeding and plantings.

- Permanent plantings during the construction stage of projects require careful coordination between the local agency inspectors, project managers, construction managers, and landscape contractor. Protocols for coordination and implementation procedures regarding site access, construction staging, and short- and long-term planting areas should be developed prior to the construction bid process. Where possible, these protocols should be established by and remain the responsibility of the site owner.

Grasses

Grasses, depending on the type, provide short-term soil stabilization during construction or can serve as long-term/ permanent soil stabilization for disturbed areas. In general, grasses provide low maintenance to areas that have been cleared, graded and mechanically stabilized. They are generally tolerant of short-term temperature extremes and waterlogged soil conditions. Appropriate soil conditions for unreinforced grasses: shallow soil base, good drainage, slope 2:1 (H:V) or flatter. Develop well and quickly from seeds. Mowing, irrigating, and fertilizing are vital for promoting vigorous grass growth.

Selection:
The selection of the grass type is determined by the climate, irrigation, mowing frequency, maintenance effort and soilbed conditions. Although grasses provide quick germination and rapid growth, they also have a shallow root system and are not as effective in stabilizing deep soils, where trees, shrubs and deep rooted ground covers may be more appropriate. Bluegrass is good on dry, sandy soils that have good drainage. Bermuda grass, on the other hand is well adapted to regions where soils are dry, coarse and heavier. Specific seed mix and/or varieties for each site should be provided by an approved/qualified plant materials specialist.

Planting:
The following steps should be followed to ensure established growth:

1. Select the proper grass for the site.
2. Prepare the seedbed; soil should be fertilized and contain good topsoil or soil at a 2:1 (H:V) or flatter slope, unless stabilized with permanent geotextiles, nets or mats.
3. Broadcast the seeding in the late fall or early spring.
4. Initial irrigation will be required often for most grasses, with follow-up irrigation and fertilization as needed. Light mulching may be required during drought years or to limit seed lost to wind and birds.

Trees and Shrubs

Soil conditions: select species appropriate for soil, drainage & acidity.
Other Factors: wind/exposure, temperature extremes, and irrigation needs.

Selection:
Trees and shrubs, when properly selected, are low maintenance plantings that stabilize adjacent soils, moderate the adjacent temperatures, filter air pollutants, and serve as a barrier to wind. Some desirable characteristics to consider in selecting trees and shrubs include: vigor, species, age, size and shape, and use as a wildlife food source and habitat.

The sites for new plantings should be evaluated. Consider the prior use of the land: adverse soil conditions such as poor drainage or acidity; exposure to wind; temperature extremes; location of utilities; paved areas, and security lighting and traffic problems.

Transplanting:
Time of Year – Late fall through winter (November to February) is the preferred time for transplanting.

Preparation – Proper digging of a tree/shrub includes the conservation of as much of the root system as possible. Soil adhering to the roots should be damp when the tree is dug, and kept moist until re-planting. The soil ball should be 12 inches in diameter for each inch of diameter of the trunk.

Site preparation – Refer to landscape plans and specifications for site and soil preparation, and for ability to coordinate construction strategy with permanent vegetation.

Supporting the trunk – Many newly planted trees/shrubs need artificial support to prevent excessive swaying.

Watering – Soil around the tree should be thoroughly watered after the tree is set in place. When the soil becomes dry, the tree should be watered deeply, but not often. Mulching around the base of the tree is helpful in preventing roots from drying out.

<u>Vines and Ground Covers</u>
Ground preparation: lime and fertilizer preparation.
Appropriate soil conditions: drainage, acidity, slopes.
Generally avoid invasive species (Kudzu, etc.).
Generally avoid species requiring frequent irrigation.

Selection:
Vines, ground covers, and low growing plants, that can quickly spread, come in many types, colors, and growth habits. Some are suitable only as part of a small maintained landscape area, while some can stabilize large areas with little maintenance. Flowers, which provide little long-term erosion control, may be planted to add color and varietal appearances.

Site Preparation:
Ground covers are plants that naturally grow very close together, causing severe competition for space, nutrients and water. Soil for ground covers should be well

prepared. The entire area should be spaded, disked, or rototilled to a depth of six to eight inches. Two to three inches of organic material, such as good topsoil or peat, should be spread over the entire area.

Planting:

The following steps will help ensure good plant growth.

1. Position the plantings to follow the contours of the land.
2. Dig the holes α larger than the plant root ball.
3. Know what depth to place the plants.
4. Use good topsoil or soil mixture with a lot of organic matter.
5. Fill hole α to ½ full, shake plants to settle soil among roots, then water.
6. Leave saucer-shaped depression around the plant to hold water.
7. Water thoroughly and regularly.
8. Space plants according to the type of plant and the extent of covering desired.

Materials:

There are many different species of vines and ground covers from which to choose, but care must be taken in their selection. It is essential to select planting materials suited to both the intended use and specific site characteristics. Additional information can be obtained from local nurserymen, landscape architects, and extension agents.

Maintenance

- Grass maintenance should be minimal to none. Irrigation and regular fertilizing may be required for some types of grasses. Mowing is only required in areas where aesthetics or fire hazards are a concern.
- Permanent vegetation may require supplemental irrigation where the natural rainfall is insufficient to establish and/or maintain the selected plant materials. Selecting native plants should be considered where supplemental irrigation is not available. However, even native plants benefit from supplemental irrigation during the establishment period.
- Young trees should receive an inch of water each week for the first two years after planting. The tree should be watered deeply, but not more often than once per week.
- Transplanted trees should be fertilized on an annual basis.
- Proper pruning, watering, and application of fertilizer are necessary to maintain healthy and vigorous shrubs. A heavy layer of mulch applied around the shrubs reduces weeds and retains moisture.
- Trim old growth as needed to improve the appearance of ground covers. Most covers need once-a-year trimming to promote growth.
- *See CP-16: Pesticides, Herbicides and Fertilizer Use.*

Limitations

If the site is susceptible to erosion, additional control measures may be necessary during the establishment of vegetation.

Caution should be exercised in introducing non-native vegetation because of impacts to native vegetation on adjacent lands. For example, species that may be planted at the construction site can quickly spread and compete with originally undisturbed vegetation.

- Permanent and temporary vegetation establishment may not be appropriate during dry periods without irrigation.
- Over-application of fertilizers, herbicides and pesticides may create stormwater

pollution.

- Construction activities are likely to injure or kill trees unless adequate protective measures are taken. Direct contact by equipment is the most obvious problem, but damage is also caused by root stress from filling, excavation, or compacting soil too close to trees.
- Temporary seeding can only be viable when adequate time is available for plants to grow and establish.
- Irrigation source and supply may be limiting or expensive.

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Geotextiles

PESC – 02

Hamilton County Water Quality Program

Description

Geotextiles are flexible, textile-like fabrics of controlled permeability used to provide filtration, separation, reinforcement, drainage functions and soil stability. Geotextiles prevent or reduce the discharge of sediment as a result of construction activity by stabilizing soil using a wide variety of geotextile materials and applications. Areas with current and potential erosion problems may also benefit from the installation of geotextiles. Geotextiles may also be used in conjunction with other construction methods or as part of a landscaped terrain to prevent potential erosion problems. This practice will create a significant reduction in sediment.

Suitable Applications

The following applications are suitable for geotextiles:

- Areas where disturbed soils must be stabilized on a construction project, for which erosion control matting, hydraulic mulch and other methods are not appropriate.
- Slopes steeper than 2.5:1 (H:V), or where the erosion hazard is high.
- Critical areas, such as streams, wetlands, or other highly valued resources needing protection.
- Channels intended to be vegetated or otherwise lined where the design flow exceeds the permissible velocity.

There are many types of geotextiles; selection of the appropriate type should be based on the desired need and site conditions. The following criteria should be considered in selecting a geotextile:

- Effectiveness (reducing erosion, slowing flow velocity, retaining soils)
- Engineering properties (strength, texture, weight, opening size)
- Acceptability (no environmental impacts, regulatory approval, aesthetics)
- Function (vegetation enhancement, safety, effect on wildlife)
- Maintenance (longevity, repair or replacement methods, inspection schedule)

Application Criteria

These systems should be designed by a licensed professional civil engineer.

Refer to TDEC's E&SC Handbook for discussion of material selection, site preparation, seeding, anchoring, installation on slopes, installation in channels, soil filling, and fiber roles.

Proper site preparation is essential to ensure complete contact of a geotextile with the subgrade. Grade and shape the installation area. Remove loose rocks, clods, vegetation or other obstructions.

Prepare subgrade by loosening at least 2 inches of topsoil. Incorporate topsoil amendments as necessary, such as compost, lime, and fertilizer, according to soil tests, vegetation plan, and manufacturer's recommendations.

Field joining may be accomplished by overlapping and then using stakes or staples in the overlapped portions or sewing for critical applications. The amount of overlap depends on the size and positioning of the stakes or staples.

Care should be taken to anchor edges (particularly on the up-slope side) and overlap joining sections to ensure adequate protection. Follow manufacturer's instructions.

Consult manufacturer's written guidelines for specific product installation procedures.

Geotextiles, which are to be placed permanently on long slopes or steep grades, must be selected and designed by a registered engineer with appropriate experience and knowledge. Slope stability and slope failure analyses may be necessary to ensure that a geotextile will not be a potential problem, particularly in areas that could endanger people or property. Placing geotextile under a layer of soil generally creates a potential slope failure plane, which could be mitigated by terraces or structural measures.

Install the geotextile in anchor trench at least 6 inches deep and 6 inches wide at the uphill location, or at the downstream location if in a channel. Backfill anchor trench and tamp earth firmly.

Unroll blanket down the slope or in the upstream direction of water flow. Lay blankets loosely and maintain direct contact with the subgrade soil. Do not stretch or twist geotextile fabric. Overlap edges of adjacent parallel rolls by at least 3 inches and then stake or staple within the overlap.

When blankets must be spliced, place blankets end over end (shingle style) with a minimum overlap of 6 inches. Install stakes or staples through overlapped area approximately 12 inches apart.

Stake or staple geotextiles as recommended by the manufacturer for the specific application. Stagger stakes or staples rather than installing in a straight line. Use biodegradable materials whenever possible. Place initial lift of material carefully onto geotextile; avoid damage from heavy equipment blades, buckets or tracks.

Maintenance

Installation of geotextiles shall be inspected after significant rainfalls to check for erosion and undermining. If washout or breakages occur, repair or replace geotextile immediately after repairing the damage to the slope or channel.

- Inspect fiber rolls whenever rain is forecast and perform required maintenance.

Inspect fiber rolls following rainfall events and at least daily during prolonged rainfall. Repair or replace fiber rolls that are torn or unraveling.

Limitations

Some slopes or channels may be difficult for heavy equipment to access, requiring substantial effort such as excavation and filling. Consider access needs early in the design phase and incorporate into design plans.

Geotextiles may not be suitable in areas where vegetation will be mowed regularly (since stakes and netting can catch in mowers and other equipment).

References

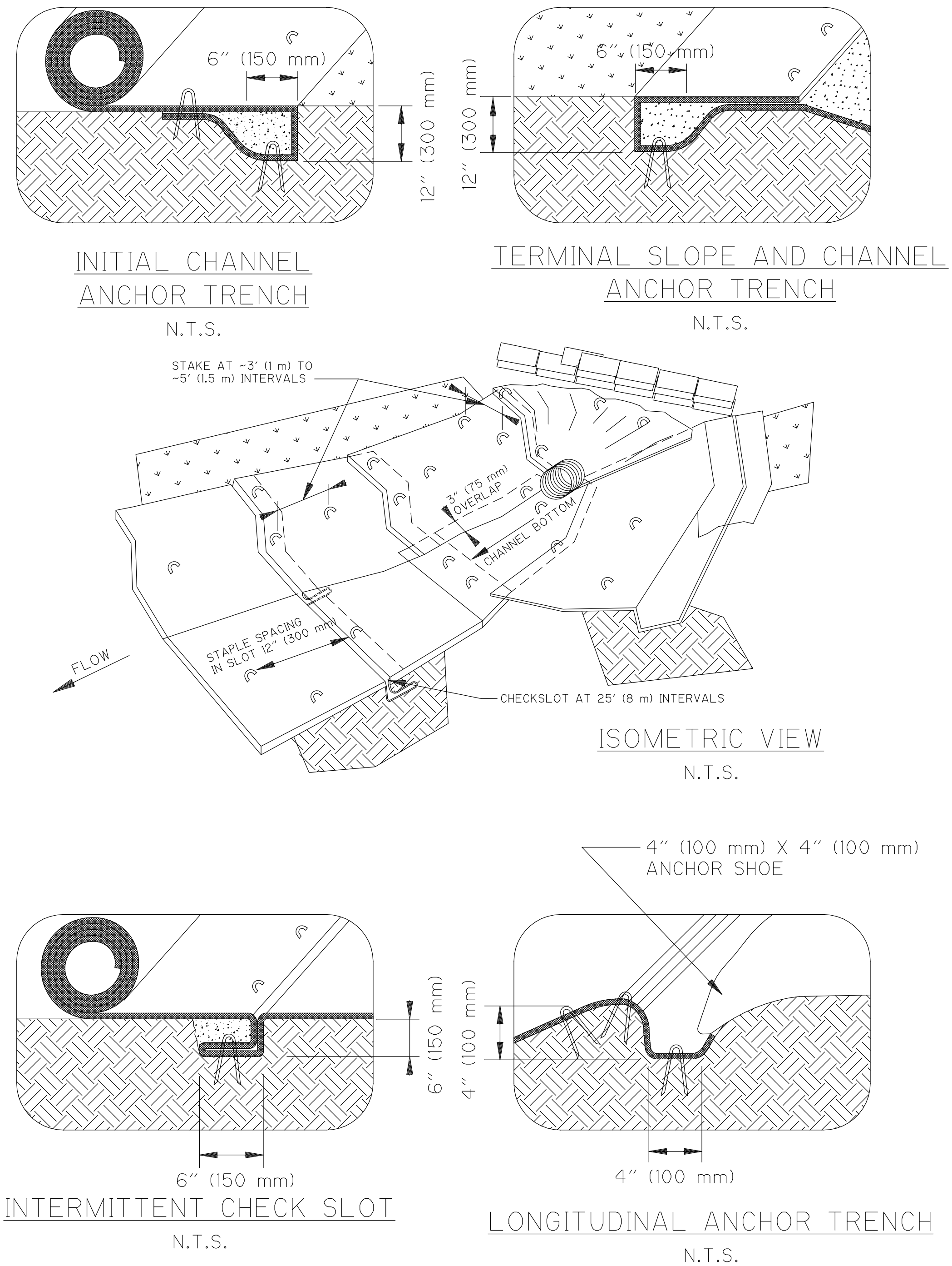
City of Franklin, Stormwater Management Program, January 2014. *City of Franklin Stormwater Best Management Practices Manual.*

Knoxville Stormwater Engineering Division, October 2007. *City of Knoxville BMP Manual,* http://www.ci.knoxville.tn.us/engineering/bmp manual/.

http://www.swicofil.com/

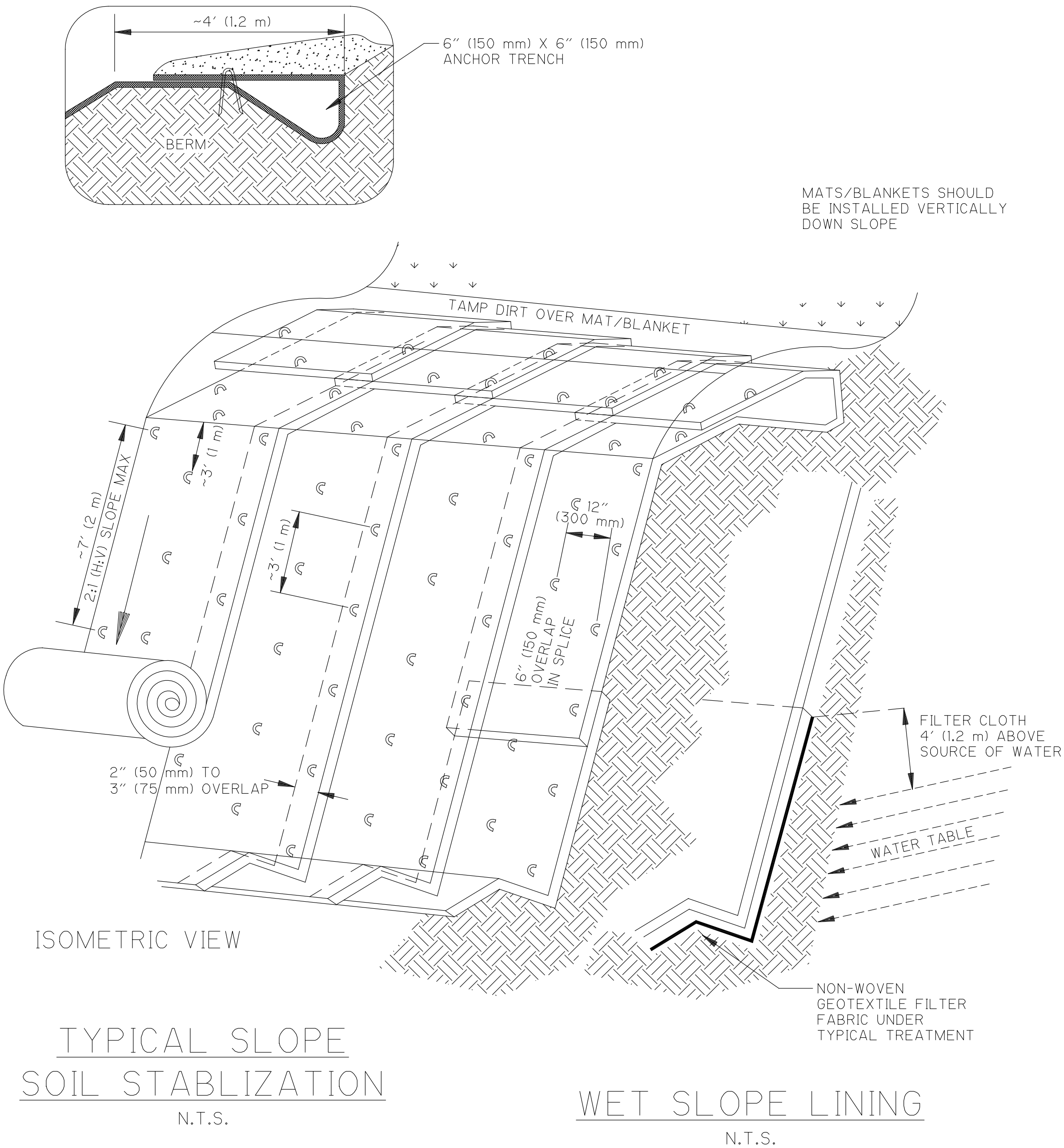
PESC – 02: PHOTOS 1 - 4
GEOTEXTILES IN VARIOUS APPLICATIONS

Geotextile mats not only protect ground surfaces from wind and stormwater erosion but also allow vegetative growth (Source: Rolanka International, 2000)



NOTES:
1. CHECK SLOTS TO BE CONSTRUCTED PER MANUFACTURER'S SPECIFICATIONS.
2. STAKING OR STAPLING LAYOUT PER MANUFACTURER'S SPECIFICATIONS.

Figure PESC-02-1
Typical Geotextiles in Channels

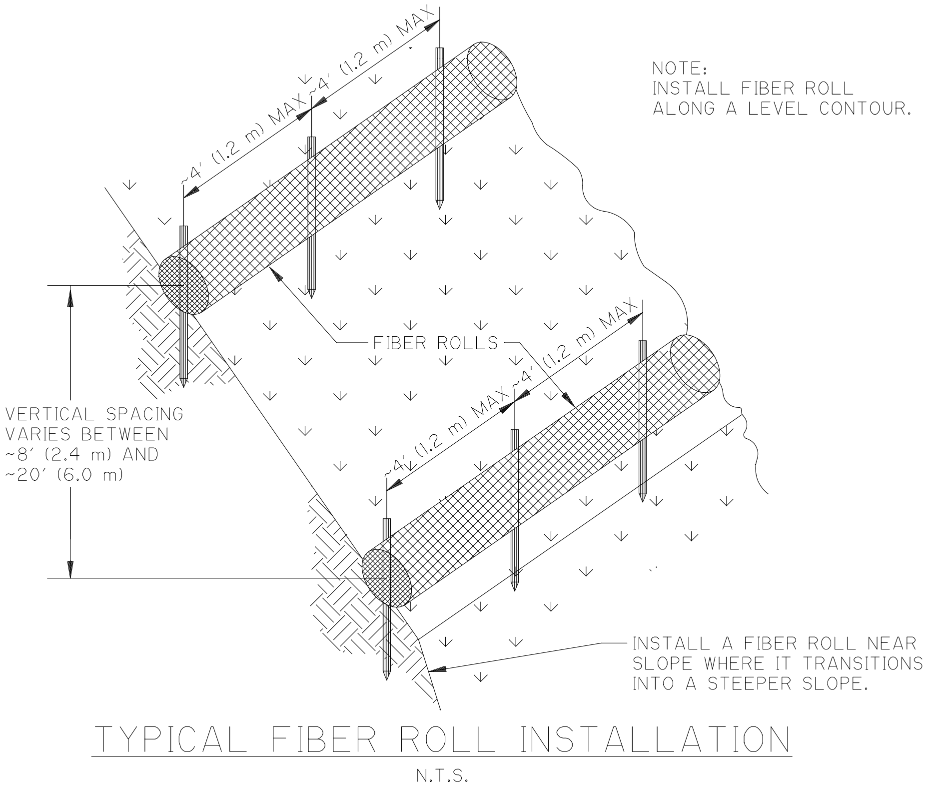


NOTES:

1. SLOPE SURFACE SHALL BE FREE OF ROCKS, SOIL CLODS, STICKS AND GRASS. MATS/BLANKETS SHALL HAVE GOOD SOIL CONTACT.

2. LAY BLANKETS LOOSELY AND STAKE OR STAPLE TO MAINTAIN DIRECT CONTACT WITH THE SOIL. DO NOT STRETCH.

Figure PESC-02-2
Typical Geotextiles on Embankments



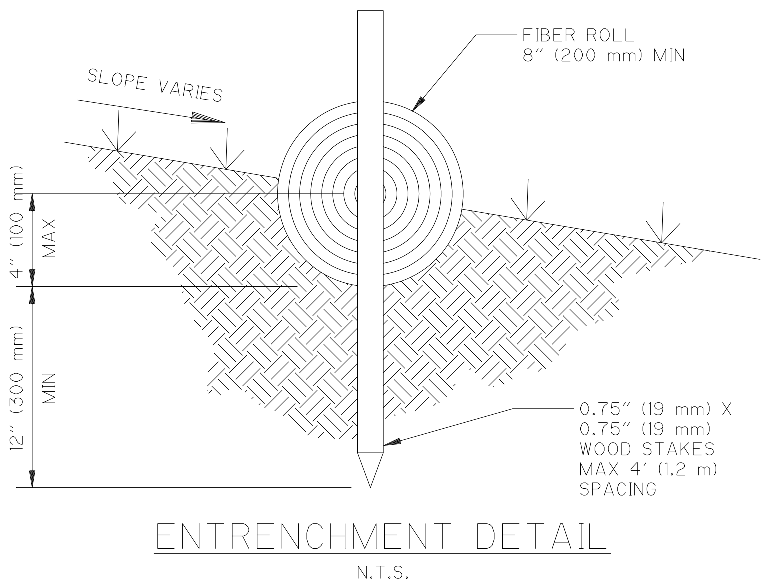


Figure PESC-02-3
Typical Fiber Rolls

Riparian Buffer Zones

PESC – 03

Hamilton County
Water Quality Program

Description

Prevent or reduce the discharge of pollutants to the storm drain system or to watercourses by utilizing vegetation to protect soils from erosion and to slow the velocity of runoff to allow the removal of sediment and other pollutants through filtering and settling. This management practice is likely to create a significant reduction in sediment as well as partial reductions in the impacts due to nutrients, heavy metals, toxic materials, floatable materials, oxygen demanding substances, and oil and grease. This fact sheet is to be used as a general guide.

Suitable Applications

Buffer zones are effective along stream banks, grassed dikes, swales, slopes, outlets, level spreaders, and filter strips. Buffer strips are particularly effective on flood plains, adjacent to wetlands or other sensitive water bodies, and on steep, unstable slopes.

Where a project is located adjacent to designated high-water quality or sediment impaired waters, a buffer zone consisting of undisturbed existing natural vegetation should be left between the limits of construction and the edge of water. It should be noted that these waters could include streams, lakes, or wetlands. Note that buffer zones are also desirable for waters, which are not designated as high-quality or sediment-impaired.

The benefits of buffers can be amplified if they are managed in a forested condition. In some settings, buffers can remove pollutants in stormwater or groundwater. Shoreline and stream buffers situated in flat soils effectively remove sediment, nutrients and bacteria from stormwater runoff and septic system effluent. This was found in a variety of rural and agricultural settings along the East Coast and to a lesser extent in urban settings. Buffers can provide wildlife habitat and recreation (EPA website)). They can also be re-established in urban areas as part of an urban forest.

Buffers can be applied to new development though the establishment of specific preservation areas and by sustaining management through easements or community associations. For existing developed areas, an easement may be needed from adjoining landowners. Local governments may set specific criteria for buffers to achieve stormwater management goals.

Installation/ Application Criteria

These systems should be designed by a licensed professional civil engineer.

In general, a minimum width of at least 60 feet is recommended to provide adequate stream protection. The three-zone buffer system, consisting of Filter Strips, Managed Forest, and Unmanaged Natural Area is an effective technique for establishing a buffer. The zones are distinguished by function, width, vegetative target, and allowable uses. Note that buffer averaging may allow developers to narrow the buffer width at some points if the average width of the buffer and the overall buffer area meet the minimum criteria.

Filter Strips

The filter strip zone is the first to encounter runoff. It functions to prevent encroachment while slowing and filtering sheet flow. The filter strip's width is at least 20 feet, and while forest is encouraged turf-grass can be a vegetative target. The filter strip's uses are unrestricted. They can include lawn, garden, compost, yard wastes, and most stormwater BMPs.

Managed Forest

The managed forest zone provides distance between upland development and the filter strip zone. It is typically 30 to 60 feet (minimum of 30 feet) depending on tributary area, slope, and 100-year floodplain. The vegetative target is managed forest. Usage is restricted to some recreational activities, some stormwater BMPs, and bike paths.

Unmanaged Natural Area

The unmanaged natural area zone protects physical and ecological integrity. It typically consists of a minimum of 30-feet plus wetland and critical habitats, depending on contributing drainage area. The vegetative target consists of mature forest. Its allowable uses are very restricted (flood controls, utility right-of-ways, footpaths, etc.).

Maintenance

Inspect buffer zones monthly for the first year after construction and annually thereafter.

Maintenance shall consist of mowing, weeding, and ensuring that the irrigation system is operating properly and as designed to sustain growth.

Inspect buffer strips after significant storm events (10-year storm event or larger). Repair eroded or damaged areas as needed to maintain original purpose and effectiveness of the buffer strip.

An effective buffer management plan should include establishment, management, and distinctions of allowable and prohibited uses in the buffer zones. Buffer boundaries should be well defined and visible before, during, and after construction. Without clear signs or markers defining the buffer, boundaries become invisible to local governments, contractors, and residents. Buffers designed to capture urban stormwater runoff will require more maintenance if the first zone is designated as a bioretention or other engineered depression area.

Additional Information

Sodding and plugging is the placement of permanent grass cover that has been grown elsewhere and brought to the site. Sodding stabilizes an area by immediately covering the soil surface with grass, thereby protecting the soil from erosion, enhancing infiltration, filtering sediment and other pollutants, and slowing runoff velocities.

Plugging stabilizes an area by planting clumps of grass material, which then grow and spread to provide complete covers. Plugging is generally used for hybrid grasses that cannot be established from seed.

References

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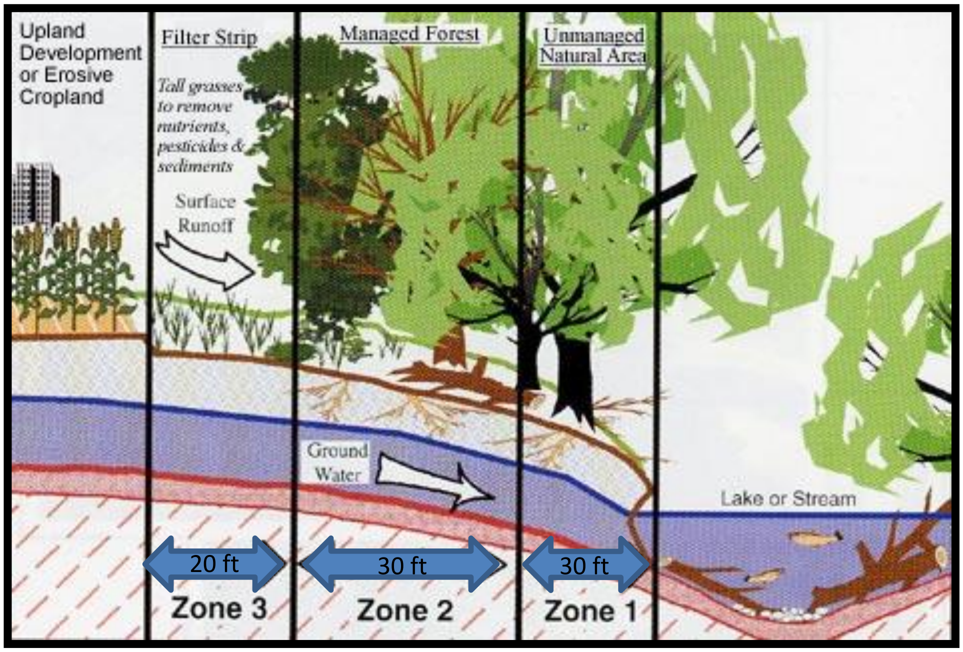


Figure PESC-03-1
Typical Three Zone Stream Buffer System

Soil Bioengineering and Bank Stabilization

PESC – 04

Hamilton County
Water Quality Program

Description

Prevent or reduce the discharge of sediment to the storm drain system or to watercourses by providing slope stabilization, protection and erosion reduction through the use of woody vegetative structures alone or in combination with simple retaining structures. This management practice is likely to create a significant reduction in sediment as well as a partial reduction in nutrients and floatable materials. Many of the measures presented in TDEC's E&SC Handbook for bioengineered stream bank stabilization are applicable to this BMP fact sheet.

Suitable Applications

For protection of slopes against surface erosion, shallow mass wasting, cut and fill slope stabilization, earth embankment protection, and small gully repair treatment.

Installation/ Application Criteria

These systems should be designed by a licensed professional civil engineer.

<u>Site Considerations</u>

- Observe surrounding slopes for vegetation density and overall plant health. Also observe the directions they are facing (some plantings generally do better in eastern exposure and do not survive in southern exposure). Plant health is a good indicator of soil moisture and/or soil conditions. These will help indicate the success of your specific bioengineering project.
- Make geologic observations of the project site noting soil types and their proneness to slide or fail.
- Retain existing vegetation whenever possible.
- Limit removal of vegetation by keeping the cleared area to the smallest practical size, limiting duration of the surface disturbance, and retaining existing woody vegetation for future planting.
- Stockpile and protect topsoil removed during clearing.
- Protect areas exposed during construction with temporary erosion and sediment control practices (TCP).

<u>Construction Techniques and Materials</u>

- Grade or terrace to flatten or make a steep undercut or slumping bank less severe.

- Make sure the vegetation chosen does not grow in such a way as to damage simple retaining structures in combination bioengineering systems.
- Retention backfill is to have sufficient fines and drainage so as to support chosen vegetation.
- Bioengineering systems' installation is best accomplished in the late fall at the onset of plant dormancy. Plants that are not dormant are less likely to survive.
- Live stake – the insertion of live, root vegetative cuttings into the ground.
    - Appropriate technique for repair of small earth slips and slumps that are frequently wet.
    - Live stakes shall be ½" to 1 ½" (1.3 to 3.8 cm) in diameter, 2 to 3' (0.63 to 0.94 m) long, with the basal end cut to an angled point for easy insertion. The top should be cut square.
    - Tamp the live stake into the ground at right angles to the slope. The installation may be started at any point on the slope face.
    - The live stakes should be installed 2 to 3 feet (0.63 to 0.94 m) apart using triangular spacing. The density of the installation will range from 2 to 4 stakes per square yard (0.8 m^2).
    - The buds should be oriented up.
    - Four-fifths of the length of the live stake should be installed into the ground and soil firmly packed around it after installation.
    - Do not split the stakes during installation. Stakes that split should be removed and replaced.
    - An iron bar can be used to make a pilot hole in firm soil. Drive the stake into the ground with a dead blow hammer (hammer head filled with shot or sand).
    - See Figures PESC-04-1 and 6.

- Live fascine-long bundles of branch cuttings bound together into sausage-like structures.
    - An effective stabilization technique for slopes.
    - Live materials should be from species that easily root and have long, straight branches.
    - Cuttings tied together to form live fascine bundles vary in length from 5 to 30 feet (1.6 to 9.4 m) or longer, depending on site conditions and limitations in handling.
    - The completed bundles should be 6 to 8 inches (15.2 to 20.3 cm) in diameter, with all of the growing tips oriented in the same direction. Stagger the cuttings in the bundles so that tops are evenly distributed throughout the length of the uniformly sized live fascine.
    - Live stakes should be 2 ½ feet (0.8 m) long in cut slopes and 3 feet (0.94 m) long in fill slopes.
    - Dead stout stakes used to secure the live fascines should be 2 ½-foot (0.8 m) long, untreated, 2 by 4 (5.1 by 10.2 cm) lumber. Each length should be cut diagonally across the 4-inch (10.2-cm) face to make two stakes from each length.
    - Prepare the live fascine bundles and live stakes immediately before

installation.

- Beginning at the base of the slope, dig a trench on the contour just large enough to contain the live fascine. The trench will vary in width from 12 to 18 inches (30.5 to 45.7 cm), depending on the angle of the slope to be treated. The depth will be 6 to 8 inches (15.2 to 20.3 cm), depending on the individual bundle's final size.
- Place the live fascine into the trench.
- Drive the dead stout stakes directly through the live fascine every 2 to 3 feet (0.63 to 0.94 m) to along its length. Extra stakes should be used at connections or bundle overlaps. Leave the top of the stakes flush with the installed bundle.
- Live stakes are generally installed on the downslope side of the bundle. Drive the live stakes below and against the bundle between the previously installed dead stout stakes. The live stakes should protrude 2 to 3 inches (5.1 to 7.6 cm) above the top of the live fascine. Place moist soil along the sides of the live fascine. The top of the fascine should be slightly visible when the installation is completed (Figure PESC-04-1).
- Next, at intervals on contour or at an angle up the face of the bank, repeat the preceding steps to the top of the slope (Table PESC-04-1).
- Long straw or similar mulching material should be placed between rows on 2.5:1 (H:V) or flatter slopes, while slopes steeper than 3:1 (H:V) should have jute mesh or similar material placed in addition to the mulch.

Table PESC-04-1
Live Fascine Installation Guidelines

Slope (H:V)	Slope distance Between trenches (ft)	Maximum slope length (ft)
1:1 to 1.5:1	3 - 4 (0.94 – 1.26 m)	15 (4.7 m)
1.5:1 to 2:1	4 - 5 (1.26 – 1.57 m)	20 (6.3 m)
2:1 to 2.5:1	5 - 6 (1.57 – 1.89 m)	30 (9.4 m)
2.5:1 to 3:1	6 - 8 (1.89 – 2.51 m)	40 (12.6 m)
3.5:1 to 4:1	8 - 9 (2.51 – 2.83 m)	50 (15.7 m)
4.5:1 to 5:1	9 - 10 (2.83 – 3.14 m)	60 (18.9 m)

- ❖ Brush layering – similar to live fascine systems, however, in brush layering the cuttings are oriented more or less perpendicular to the slope contour.
  - Branch cuttings should be ½ to 2 inches (1.3 to 5.1 cm) in diameter and long enough to reach the back of the bench. Side branches should remain intact for installation.
  - Starting at the toe of the slope, benches should be excavated horizontally, on the contour, or angled slightly down the slope, if needed to aid drainage. The bench should be constructed 2 to 3 feet (0.63 to 0.94 m) wide.

- The surface of the bench should be sloped so that the outside edge is higher than the inside.
- Live branch cuttings should be placed on the bench in a crisscross or overlapping configuration.
- Branch growing tips should be aligned toward the outside of the bench.
- Backfill is placed on top of the branches and compacted to eliminate air spaces. The brush tips should extend slightly beyond the fill to filter sediment.
- Each lower bench is backfilled with the soil obtained from excavating the bench above.
- Long straw or similar mulching material with seeding should be placed between rows on 3:1 (H:V) or flatter slopes, while slopes steeper than 3:1 (H:V) should have jute mesh or similar material placed in addition to the mulch.
- The brush layer rows should vary from 3 to 5 feet (0.94 to 1.57 m) apart, depending upon the slope angle and stability (Table PESC-04-2).

Table PESC-04-2
Brush Layer Installation Guidelines

Slope (H:V)	Slope distance between benches Wet slopes (ft)	Dry slopes (ft)	Maximum slope length (ft)
2:1 to 2.5:1	3 (0.94 m)	3 (0.94 m)	15 (4.7 m)
2.5:1 to 3:1	3 (0.94 m)	4 (1.26 m)	15 (4.7 m)
3.5:1 to 4:1	4 (1.26 m)	5 (1.57 m)	20 (6.3 m)

- Branchpacking – consists of alternating layers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes.
  - Live branch cuttings may range from ½ inch to 2 inches (1.3 to 5.1 cm) in diameter. They should be long enough to touch the undisturbed soil at the back of the trench and extend slightly from the rebuilt slope face.
  - Wooden stakes should be 5 to 8 feet (1.57 to 2.51 m) long and made from 3- to 4-inch (7.6 to 10.2 cm) diameter poles or 2 by 4 (5.1 by 10.2 cm) lumber, depending upon the depth of the particular slump or hole.
  - Starting at the lowest point, drive the wooden stakes vertically 3 to 4 feet (0.94 to 1.26 m) into the ground. Set them 1 to 1 ½ feet (0.31 to 0.47 m) apart.
  - A layer of living branches 4 to 6 inches (10.2 to 15.2 cm) thick is placed in the bottom of the hole, between the vertical stakes, and perpendicular to the slope face (Figure PESC-04-2). They should be placed in a crisscross configuration with the growing tips generally oriented toward the slope face. Some of the basal ends of the branches should touch the back of the hole or slope.
  - Subsequent layers of branches are installed with the basal ends lower

than the growing tips of the branches.
- Each layer of branches must be followed by a layer of compacted soil to ensure soil contact with the branch cuttings.
- The final installation should match the existing slope. Branches should protrude only slightly from the filled face.
- The soil should be moist or moistened to insure that live branches do not dry out.
- Branchpacking is not effective in slump areas greater than 4 or 5 feet (1.26 to 1.57 m) wide.

❖ Live gully repair – utilizes alternating layers of live branch cuttings and compacted soil to repair small rills and gullies.
- Limited to rills or gullies which are a maximum of 2 feet (0.63 m) wide, 1 foot deep (0.31 m), and 15 feet (4.71 m) long.
- Live branch cuttings may range from ½ inch to 2 inches (1.3 to 5.1 cm) in diameter. They should be long enough to touch the undisturbed soil at the back of the rill or gully and extend slightly from the rebuilt slope face.
- Starting at the lowest point of the slope, place a 3- to 4-inch (7.6- to 10.2-cm) layer of branches at lowest end of the rill or gully and perpendicular to the slope (Figure PESC-04-3).
- Cover with a 6- to 8- inch (15.2 to 20.3 cm) layer of fill soil.
- Install the live branches in a crisscross fashion. Orient the growing tips toward the slope face with basal ends lower than the growing tips.
- Follow each layer of branches with a layer of compacted soil to ensure soil contact with the live branch cuttings.

❖ Live cribwall – a hollow, box-like interlocking arrangement of untreated log or timber members. The structure is filled with suitable backfill material and layers of live branch cuttings which root inside the crib structure and extend into the slope.
- This technique is appropriate at the base of a slope where a low wall may be required to stabilize the toe.
- Live branch cuttings should be ½ to 2 inches (1.3 to 5.1 cm) in diameter and long enough to reach the back of the wooden crib structure.
- Logs, timbers or reinforced concrete beams should range from 4 to 6 inches (10.2 to 15.2 cm) in diameter or dimension. The lengths will vary with the size of the crib structure.
- Large nails or rebar are required to secure the logs or timbers together.
- Starting at the lowest point of the slope, excavate loose material 2 to 3 feet (0.63 to 0.94 m) below the ground elevation until a stable foundation is reached.
- Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure.
- Place the first course of logs, timbers or reinforced concrete beams at

the front and back of the excavated foundation, approximately 4 to 5 feet (1.26 to 1.57 m) apart and parallel to the slope contour.

- Place the next course of logs or timbers at right angles (perpendicular to the slope) on top of the previous course to overhang the front and back of the previous course by 3 to 6 inches (7.6 to 15.2 cm).
- Each course of the live cribwalls is placed in the same manner and nailed to the preceding course with nails or reinforcement bars.
- When the cribwall structure reaches the existing ground elevation, place live branch cuttings on the backfill perpendicular to the slope; then cover the cuttings with backfill and compact.
- Live branch cuttings should be placed at each course to the top of the cribwall structure with growing tips oriented toward the slope face. Follow each layer of branches with a layer of compacted soil to ensure soil contact with the live branch cuttings. Some of the basal ends of the live branch cuttings should reach to undisturbed soil at the back of the cribwall with growing tips protruding slightly beyond the front of the cribwall (Figure PESC-04-4).

❖ Vegetated gabions – Vegetated gabions begin as rectangular containers fabricated from a triple twisted, hexagonal mesh of heavily galvanized steel wire. Empty gabions are placed in position, wired to adjoining gabions, filled with stones and then folded shut and wired at the ends and sides. Live branches are placed on each consecutive layer between the rock-filled baskets. These will take root inside the gabion baskets and in the soil behind the structures. In time the roots consolidate the structure and bind it to the slope.

❖ Vegetated rock wall – a combination of rock and live branch cuttings used to stabilize and protect the toe of steep slopes.

- Live cuttings should have a diameter of ½ to 1 inch (1.3 to 2.5 cm) and be long enough to reach beyond the rock structure into the fill or undisturbed soil behind.
- Inert materials consist of rocks and fill material for the wall construction. Rock used should normally range from 8 to 24 inches (20.3 to 61 cm) in diameter. Larger boulders should be used for the base.
- Starting at the lowest point of the slope, remove loose soil until a stable base is reached. This usually occurs 2 to 3 feet (0.63 to 0.94 m) below ground elevation. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure.
- Excavate the minimum amount from the existing slope to provide a suitable recess for the wall.
- Provide a well-drained base in locations subject to deep frost penetration.
- Place rocks with at least a three-point bearing on the foundation material or underlying rock course. They should also be placed so that their center of gravity is as low as possible, with their long axis slanting

inward toward the slope if possible.
  - When a rock wall is constructed adjacent to an impervious surface, place a drainage system at the back of the foundation and outside toe of the wall to provide an appropriate drainage outlet.
  - Overall height of the rock wall, including the footing, should not exceed 5 feet (1.57 m).
  - A wall can be constructed with a sloping bench behind it to provide a base on which live branch cuttings can be placed during construction. Live branch cuttings should also be tamped or placed into the openings of the rock wall during or after construction. The butt ends of the branches should extend into the backfill or undisturbed soil behind the wall.
  - The live branch cuttings should be oriented perpendicular to the slope contour with growing tips protruding slightly from the finished rock wall face (Figure PESC-04-5).

- Joint planting – involves tamping live cuttings of root plant material into soil between the joints or open spaces in rocks that have previously been placed on a slope.
  - Roots improve drainage by removing soil drainage.
  - Effective with existing rip-rap structures.
  - The cuttings must have side branches removed and bark intact. They should range in diameter from ½ to 1 ½ inches (1.3 to 3.8 cm) and be sufficiently long to extend into soil below the rock surface.
  - Tamp live branch cuttings into the openings of the rock during or after construction. The butt ends of the branches should extend into the backfill or undisturbed soil behind the rip-rap.
  - Orient the live branch cuttings perpendicular to the slope with growing tips protruding slightly from the finished face of the rock (Figure PESC-04-6).

Limitations

Where labor is either scarce or extremely expensive, the cost of soil bioengineering systems may be higher than traditional structural measures. However, it should be noted that soil-bioengineering techniques generally are less expensive. Constraints on planting times or the availability of the required quantities of suitable plant materials during allowable planting times may limit soil bioengineering methods. Rapid vegetative establishment may be difficult on extremely steep slopes. Rocky or gravelly slopes can lack sufficient fines or moisture for plant growth.

Maintenance

During the establishment period, inspect cuttings daily removing any dead stock and replacing it with fresh stock.

- Inspect biweekly for the first 2 months. Inspections should note insect infestations, soil moisture, and other conditions that could lead to poor survivability. Immediate action, such as the application of supplemental water, should be taken if conditions warrant.
- Inspect monthly for the next 6 months. Systems not in acceptable growing condition should be noted and, as soon as seasonal conditions permit, should

be removed from the site and replaced with materials of the same species and sizes as originally specified.

- ❖ Needed reestablishment work should be performed every 6 months during the initial 2-year establishment period. This will usually consist of replacing dead material.
- ❖ Extra inspections should always be made during periods of drought or heavy rains. Damaged sections should always be repaired immediately.

Final inspection – A final inspection should be held 2 years after installation is completed. Healthy growing conditions should exist.

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

Live stakes --------------------- 70%-100% growing
Live fascines ------------------- 20%-50% growing
Live cribwall ------------------- 30%-60% growing
Brushlayers --------------------- 40%-70% growing
Branchpacking ----------------- 40%-70% growing
Live gully repair --------------- 30%-50% growing
Vegetated rock wall ----------- 50%-80% growing
Vegetated gabion -------------- 40%-60% growing
Joint planting ------------------- 50%-70% growing

Growth should be continuous with no open spaces greater than 2 feet in linear systems. Spaces 2 feet (0.63 m) or less will fill in without hampering the integrity of the installed living system.

References

CDM et.al. for the California SWQTF, 1993. *California Storm Water Best Management Practice Handbooks, Construction Handbook*.

City of Franklin, Stormwater Management Program, January 2014. *City of Franklin Stormwater Best Management Practices Manual.*

Soil Conservation Service, October 1992. *Engineering Field Handbook, Chapter 18, Soil Bioengineering for Upland Slope Protection and Erosion Reduction*.

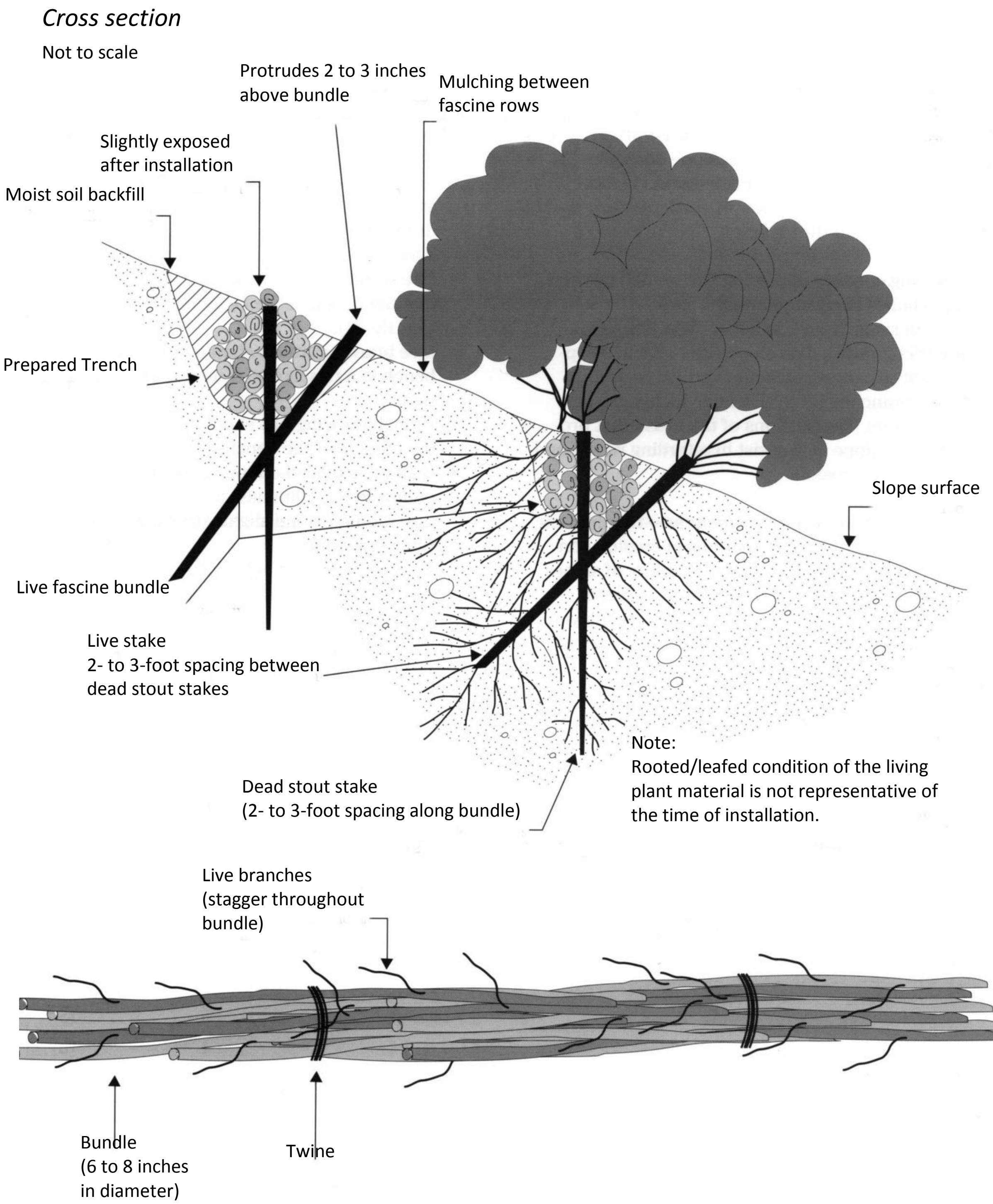


Figure PESC-04-1
Live Fascine Details

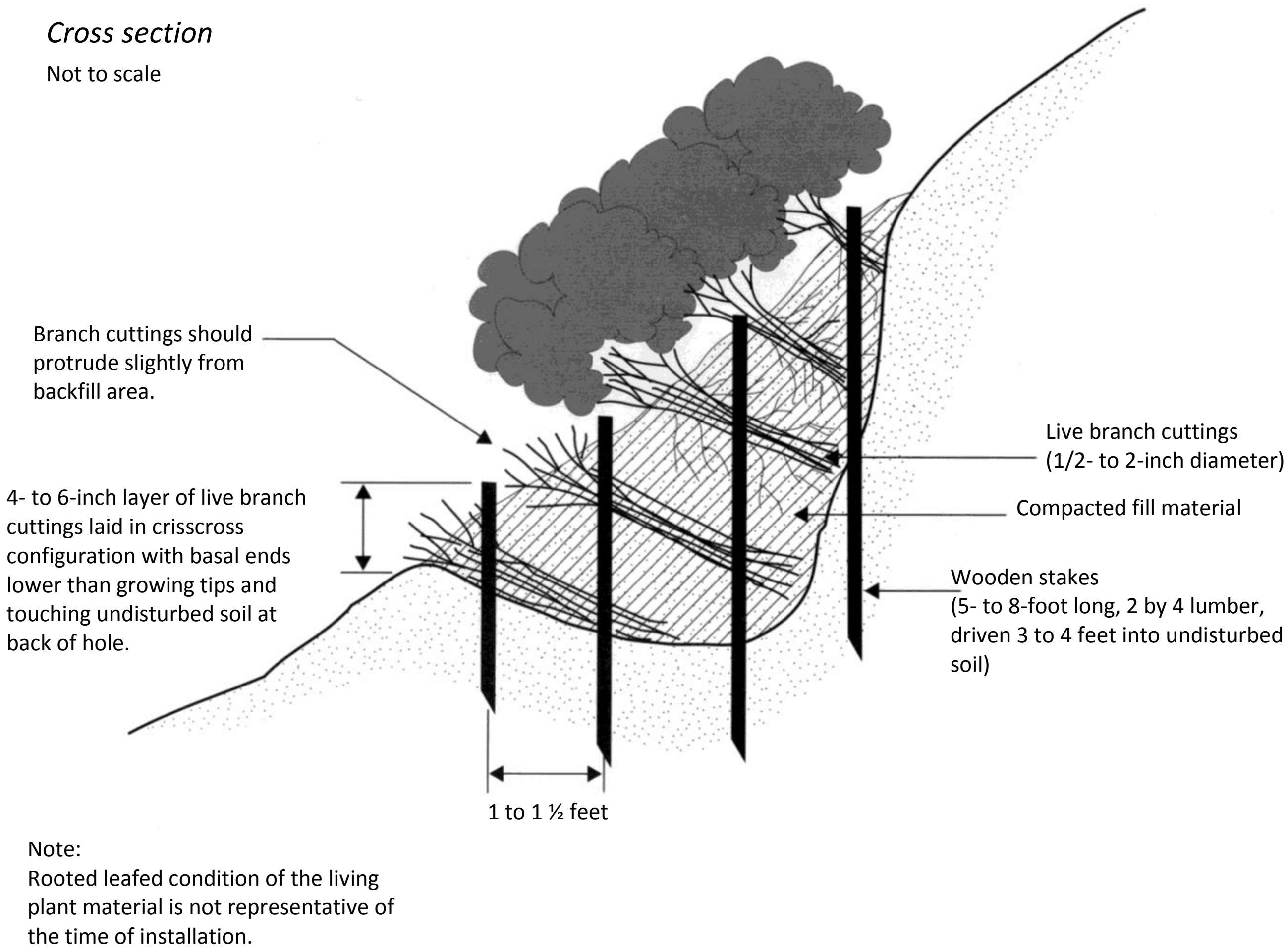


Figure PESC-04-2
Branchpacking Details

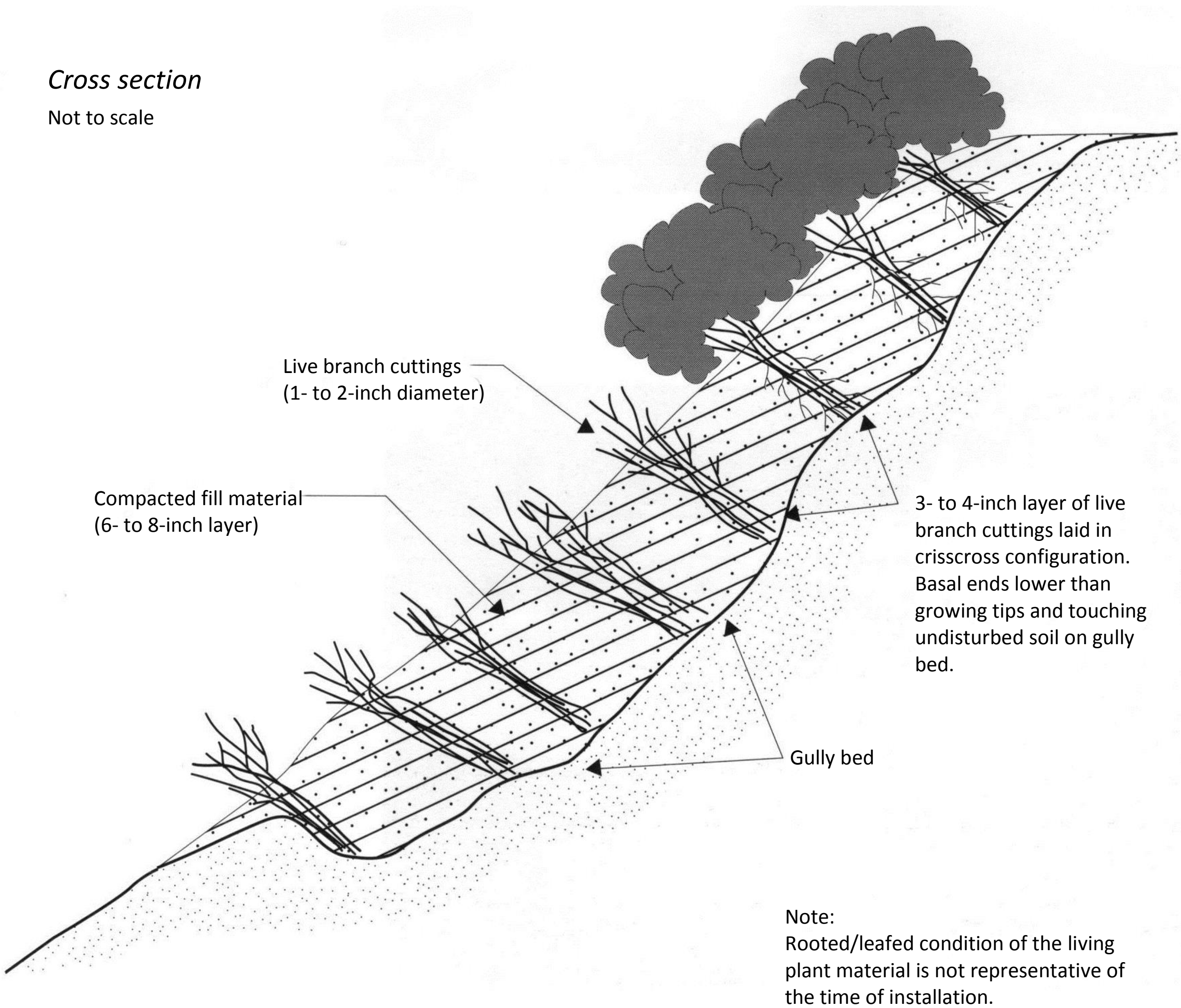
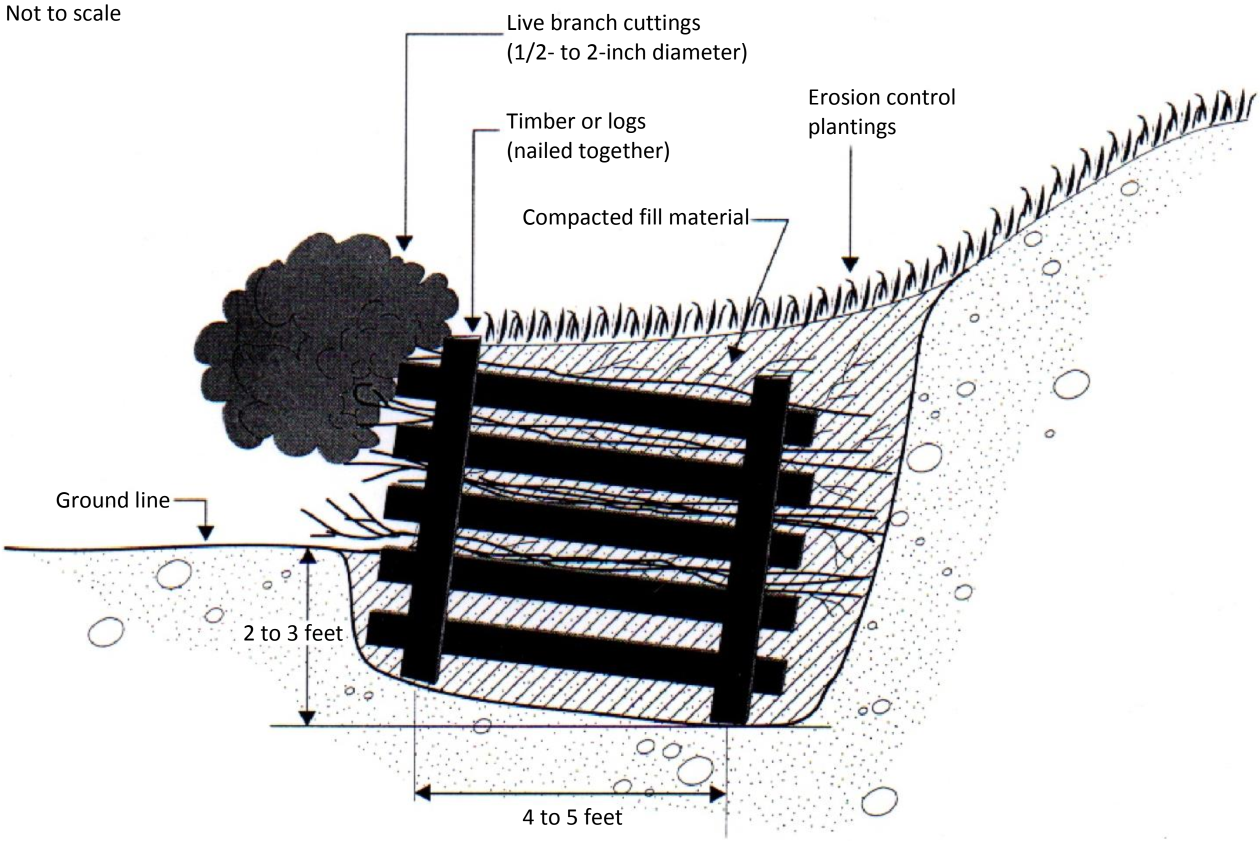


Figure PESC-04-3
Live Gully Repair Details

Cross section

Not to scale



Note:
Rooted/leafed condition of the living plant material is not representative of the time of installation.

Figure PESC-04-4
Live Cribwall

Cross section

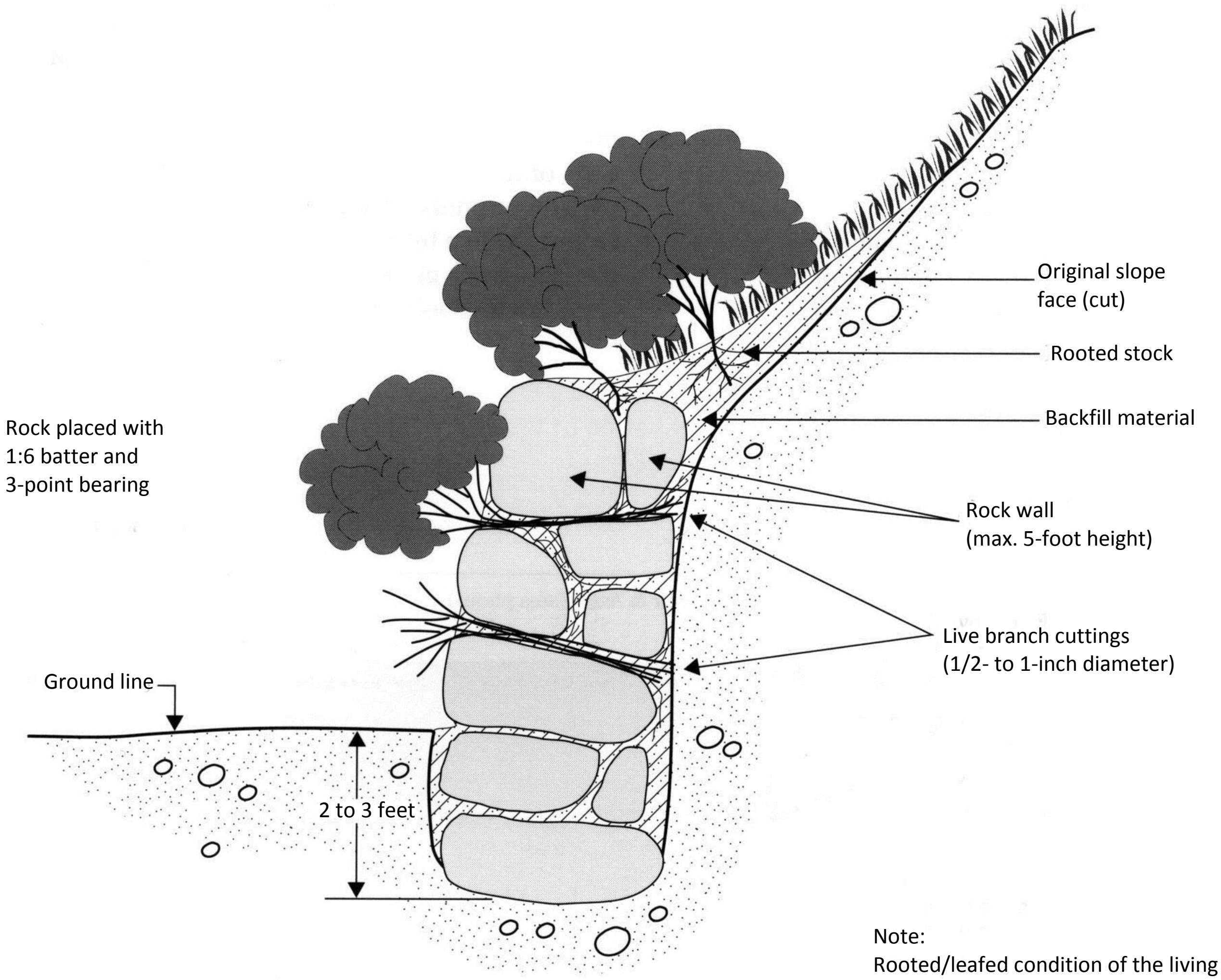
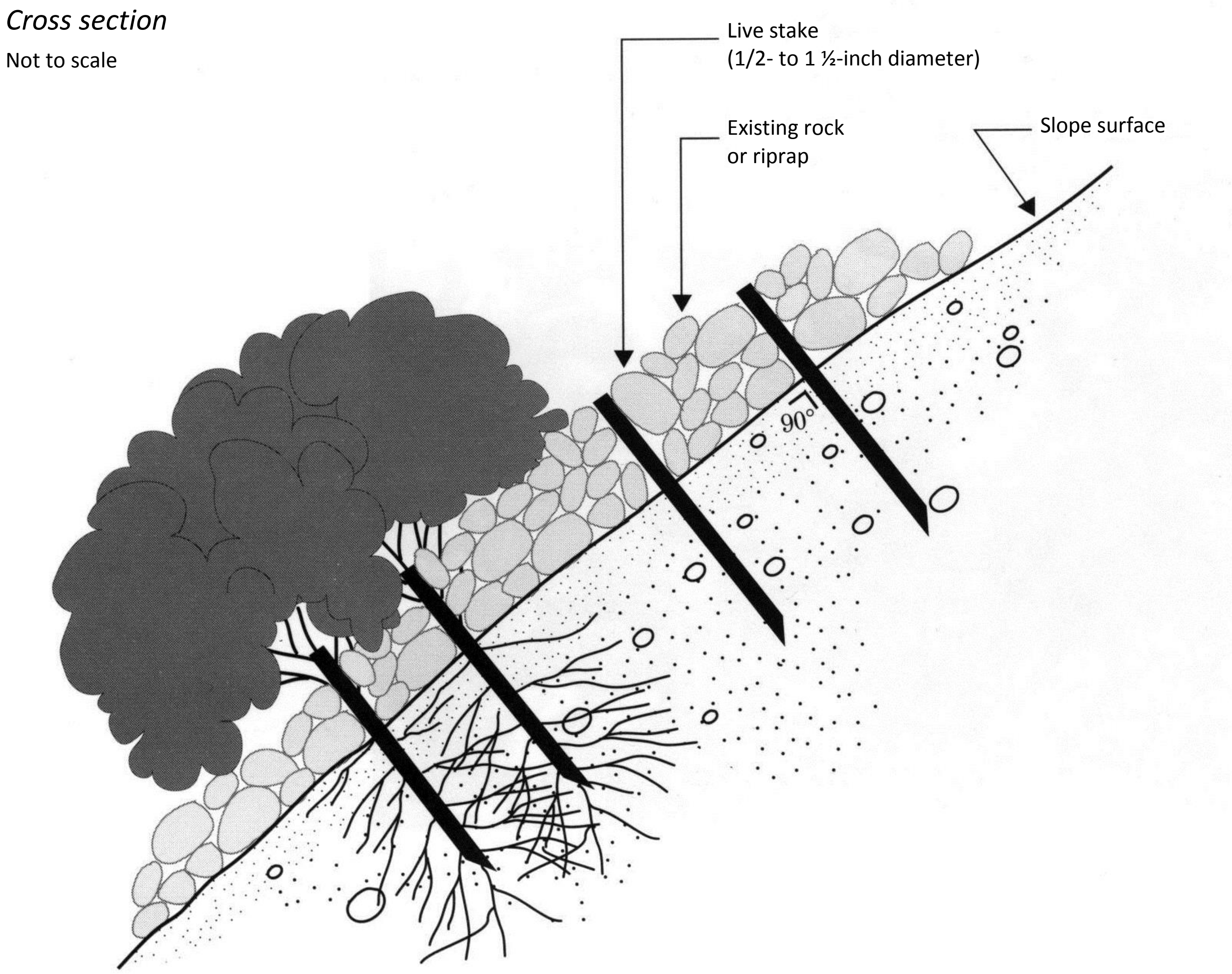


Figure PESC-04-5
Vegetated Rock Wall Details



Note:
Rooted/leafed condition of the living plant material is not representative of the time of installation.

Figure PESC-04-6
Joint Planting Details

Gradient Terraces and Slope Roughening

PESC – 05

Hamilton County
Water Quality Program

Description

Prevent or reduce the discharge of pollutants to the storm drain system or to watercourses as a result of construction activity by terracing slopes to reduce erosion by decreasing runoff velocities, trapping sediment, increasing infiltration, and aiding in supporting vegetative cover. This management practice is likely to create a significant reduction in sediment.

Suitable Applications

Slopes steeper than 3:1 (H:V) and greater than 5 feet in height, which are not part of a trench or excavation. Terraces and benches are commonly used in trenches or excavations as a means of providing slope stability. It is extremely important that trenches and excavations meet all of the Occupational Safety and Health Administration (OSHA) regulations in 29 CFR 1926, Subpart P – Excavations, latest edition. The gradient terraces in this section are intended for slopes and hillsides, not for use in trenches and other excavations.

Graded areas with smooth, hard surfaces or any cleared area prior to permanent seeding and planting.

Where length of slopes needs to be shortened by terracing. Note: terracing is usually permanent, and should be designed under the direction of and approved by a licensed professional civil engineer based on site conditions. Terraces must be designed with adequate drainage and stabilized outlets.

Installation/ Application Criteria

These systems should be designed by a licensed professional civil engineer.

In the event that terraced slopes become unstable or flow is diverted to them to an extent that the practice becomes ineffective in limiting erosion or stabilizing vegetation, then alternative measures should be considered. Alternative measures can include flow diversion, drains, swales, level spreaders, geotextiles and bank stabilization practices as described in TDEC's E&SC Handbook. These measures should be designed to consider the permanent structure/slope and other site conditions.

There are several ways to create a gradient terrace that will meet slope stability requirements. Factors to be considered are the steepness of slope, mowing requirements, and whether the slope is formed by fill or by excavation. Generally, a slope cannot be mowed if it is steeper than 3:1 (H:V).

The following methods are shown in the attached figures:

Figure 1	Contour Furrow
Figure 2	Serrated Slope
Figure 3	Stepped Slope
Figure 4	Terraced Slope

There are also different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends upon the type of slope. Roughening methods include grooving and tracking. The use of different equipment in various areas may be used to accomplish different levels of compaction or roughening.

<u>Contour Furrows</u>

Contour furrows may be used for slopes which are 3:1 (H:V) or flatter. Diversion berms or channels may be necessary at the top of slope and along the edges of the slope in order to prevent concentrated stormwater runoff from eroding the slope. The maximum distance between furrows shall be 40 feet, and the maximum slope length shall be 200 feet.

<u>Stepped Slopes</u>

Graded areas steeper than 3:1 (H:V), which will not be mowed, should preferably have a stepped slope as in Figure 2. The stair-stepping effect will help vegetation become attached and also trap soil eroded from the slopes above. Stepped slopes are particularly appropriate in soils containing rock. Each step catches rocky material, which sloughs from above, and provides a level site where vegetation can become established.

Steps should be wide enough to work with standard earth moving equipment. Preferably, the horizontal distance should be at least 1.5 times the vertical cut distance. Slightly grade the horizontal bench inwards (e.g. back towards the top of slope). Do not make individual vertical cuts more than 24 inches high in soft materials or more than 3 feet high in rocky materials. Groove the slope using machinery to create a series of ridges and depressions that run across the slope and on the contour.

<u>Terraced Slopes</u>

Terraced slopes are preferable for longer slopes that will be regularly mowed. A designed drainage channel is located within the terraces at regularly spaced intervals. The designed drainage channel shall have a regular cross section that includes slope and depth requirements. Locate intersecting channels in a manner that will safely convey stormwater to the bottom of the slope. Consider using downdrains, riprap, energy dissipaters, stilling basins, concrete aprons and other measures at channel intersections to safely control velocities and erosive forces.

<u>Serrated Slopes</u>

A serrated slope may be used for slopes which are 2:1 (H:V) or flatter. This type of gradient terrace is labor-intensive in that bladed equipment will be needed to make numerous passes along a slope, beginning at the top and working downward. The maximum slope length shall be 100 feet.

Fill Slope Roughening

Place fill slopes with a gradient steeper than 3:1 (H:V) in lifts not to exceed 8 inches and make sure each lift is properly compacted. Fill slopes are not as stable as cut slopes, no matter how much compaction is applied.

Ensure that the face of the slope consists of loose, uncompacted fill 4 inches to 6 inches in depth. This is not to be confused with proper compaction necessary for slope stabilization. Use grooving or tracking to roughen the face of the slopes, if necessary. Apply fertilizer, mulch, or other soil amendments as necessary and as specified. Do not over fertilize. Then track or crimp. Do not blade or scrape the final slope face.

Cut Slope Roughening

Create shallow grooves by normal tilling, disking, harrowing, or use a mechanical seeder. Make the final pass of any such tillage along the contour.

Make grooves formed by such implements close together, less than 10 inches apart, and not less than 1 inch deep. Excessive roughness is undesirable where mowing is planned.

Maintenance

Periodically check the seeded or planted slopes for rills and washes, particularly after significant storm events greater than 0.5 in. (12 mm). Fill these areas slightly above the original grade, then reseed and mulch as soon as possible.

Inspect monthly for the first year after construction. The slope should be inspected in early fall thereafter.

Limitations

A stepped slope (or stair-step grading) is not practical for sandy soils or other soils with low cohesiveness.

Terraced slopes and stepped slopes, as well as any slopes which are steeper than 3:1, should be designed by a licensed professional civil engineer based upon actual site conditions. Adequate drainage channels and diversions must be provided.

References

Caltrans, April 1997.*Caltrans Storm Water Quality Handbooks, Construction Contractor's Guide and Specifications*.

City of Franklin, Stormwater Management Program, January 2014. *City of Franklin Stormwater Best Management Practices Manual.*

Knoxville Stormwater Engineering Division, October 2007. *City of Knoxville BMP Manual.* http://www.ci.knoxville.tn.us/engineering/bmp manual/

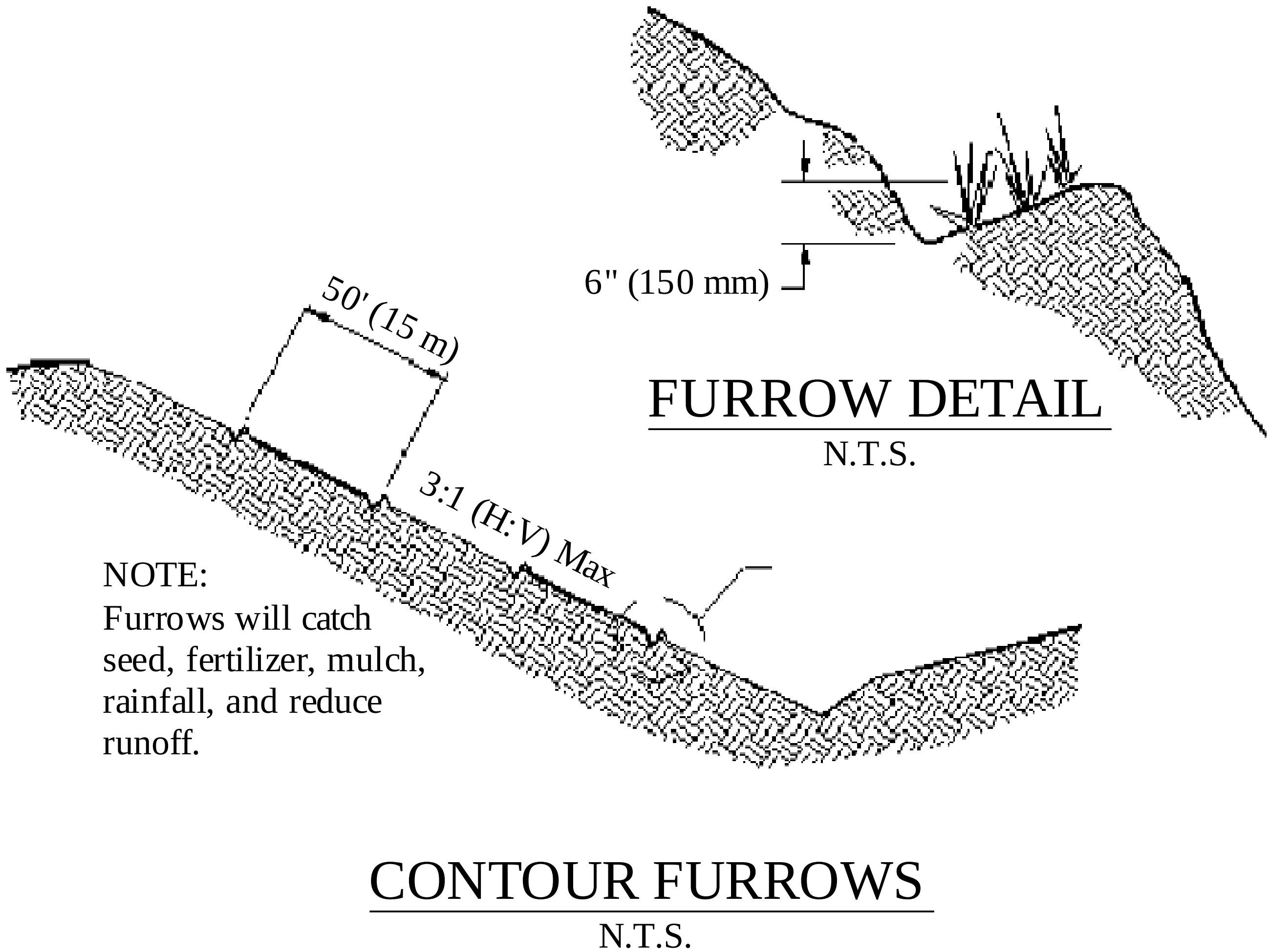
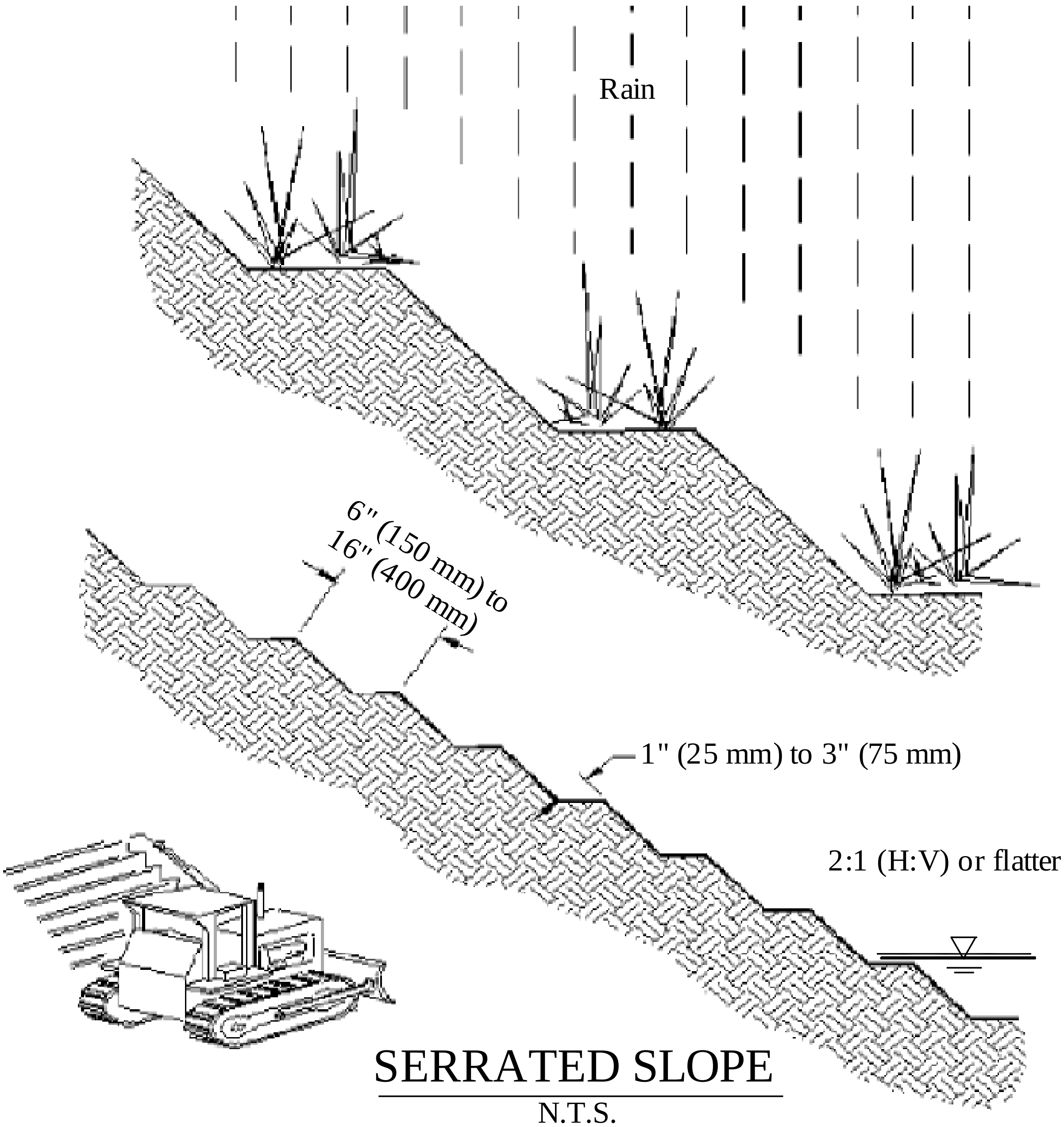
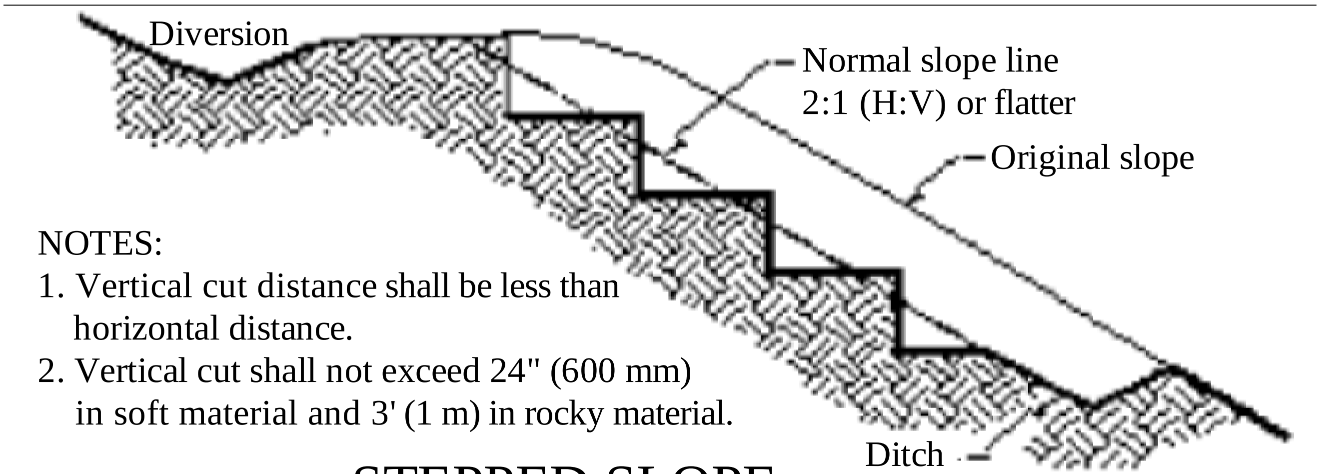


Figure PESC-05-1
Furrow Layout



NOTE:
Groove by cutting serrations along the contour. Irregularities in the soil surface catch rainwater, seed, mulch and fertilizer.

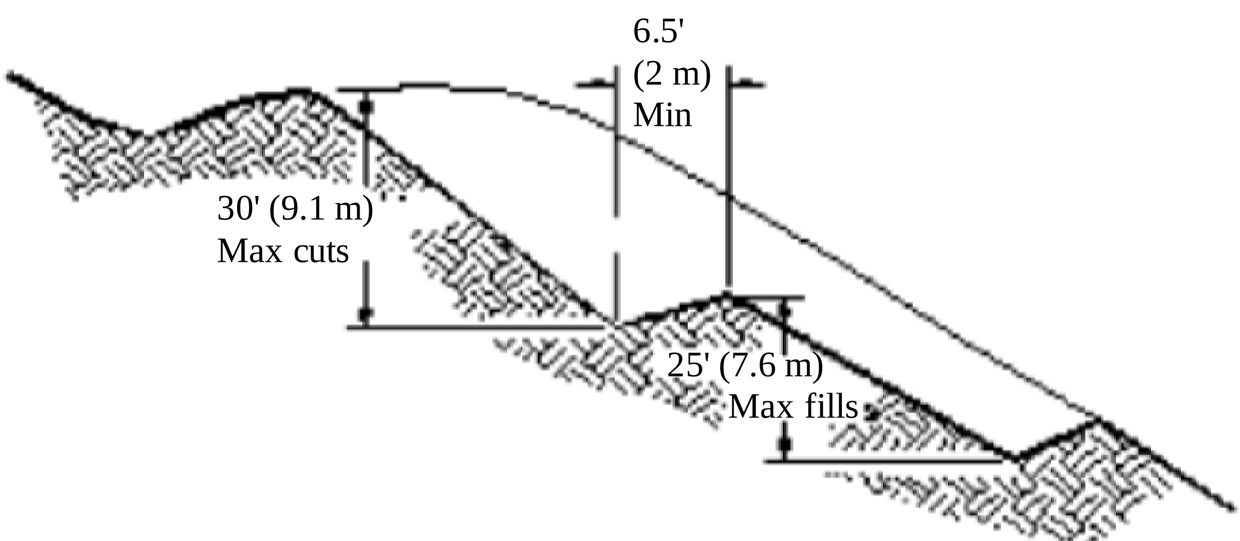
Figure PESC-05-2
Serrated Slope Layout



STEPPED SLOPE

N.T.S.

Figure PESC-05-3
Stepped Slope Layout



TERRACED SLOPE

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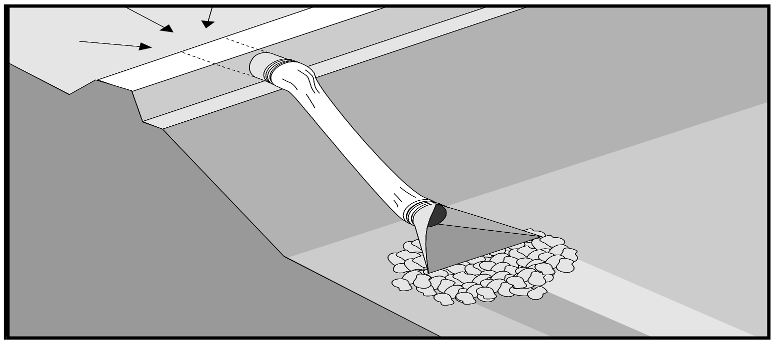
Figure PESC-05-4
Terraced Slope Layout

Flow Diversions, Drains and Swales

PESC – 06



Hamilton County Water Quality Program

Description and Suitable Applications

Permanent drains and swales are used to divert runoff from stabilized areas around disturbed areas, and direct runoff into sediment basins or detention ponds. The primary function of a slope drain is to convey runoff down cut or fill slopes, while the primary function of a subsurface drain is to drain excessive soil saturation in sloping areas. The primary function of top and toe of slope diversion swales, ditches, and berms is to minimize sheet flow over slope surfaces and reduce sedimentation by conveying collected runoff to a protected drainage system. This management practice is likely to create a significant reduction in sediment.

Installation/ Application Criteria

These systems should be designed by a licensed professional civil engineer.

Installation/Application criteria for permanent flow diversions and drains can be found in TDEC's E&SC Handbook. The principal difference between temporary and permanent measures of this type is factor of safety over sizing to account for large storm events and less frequent inspections.

Maintenance

Drains should be inspected monthly the first year after construction and annually thereafter.

Diversions should be inspected every other month the first year after construction and annually thereafter.

The diversions and drains should be inspected immediately after any storm event equal to or larger than the 10-year storm event.

Inspect outlet for erosion and downstream scour. If eroded, repair damage and install additional energy dissipation measures. If downstream scour is occurring, it may be necessary to reduce flows being discharged into the channel unless other preventative measures are implemented.

Inspect slope drainage for accumulations of debris and sediment.

Remove built-up sediment from entrances and outlets as required. Flush drains if

necessary; capture and settle out sediment from discharge.
Inspect ditches/berms for washouts. Replace lost riprap, damaged linings or soil stabilizers as needed.

To avoid creating indentions that could reconcentrate flows, avoid operation of vehicles and heavy equipment in the level spreader. When indentions are formed, grade, fill, and revegetate as needed.

Inspect for debris and sediment accumulation in spreader channel. Remove accumulated debris and sediment as needed. Sediment should be removed from the level spreader if it has reached ½ of sediment storage capacity.

Inspect level spreaders prior to the rainy season and after significant rainfall events.

Inspect level spreader lip to verify a zero percent slope.

Inspect for evidence of erosion below spreader. This could indicate lip is no longer level.

Inspect for evidence of flow reconcentration of spreader discharge.

Limitations

Subsurface drains may remove fine soils which can result in collapse of the slope. Filter cloth should be used in this case.

Severe erosion may result if slope drains fail by over topping, soil piping, or pipe separation.

Maximum flow into the spreader should not exceed 30 cfs (0.85 m^3/s).

Lip of level spreader must have a zero slope for proper operation.

A level spreader is not a sediment trapping or filtering device, but may accumulate sediment that must be removed.

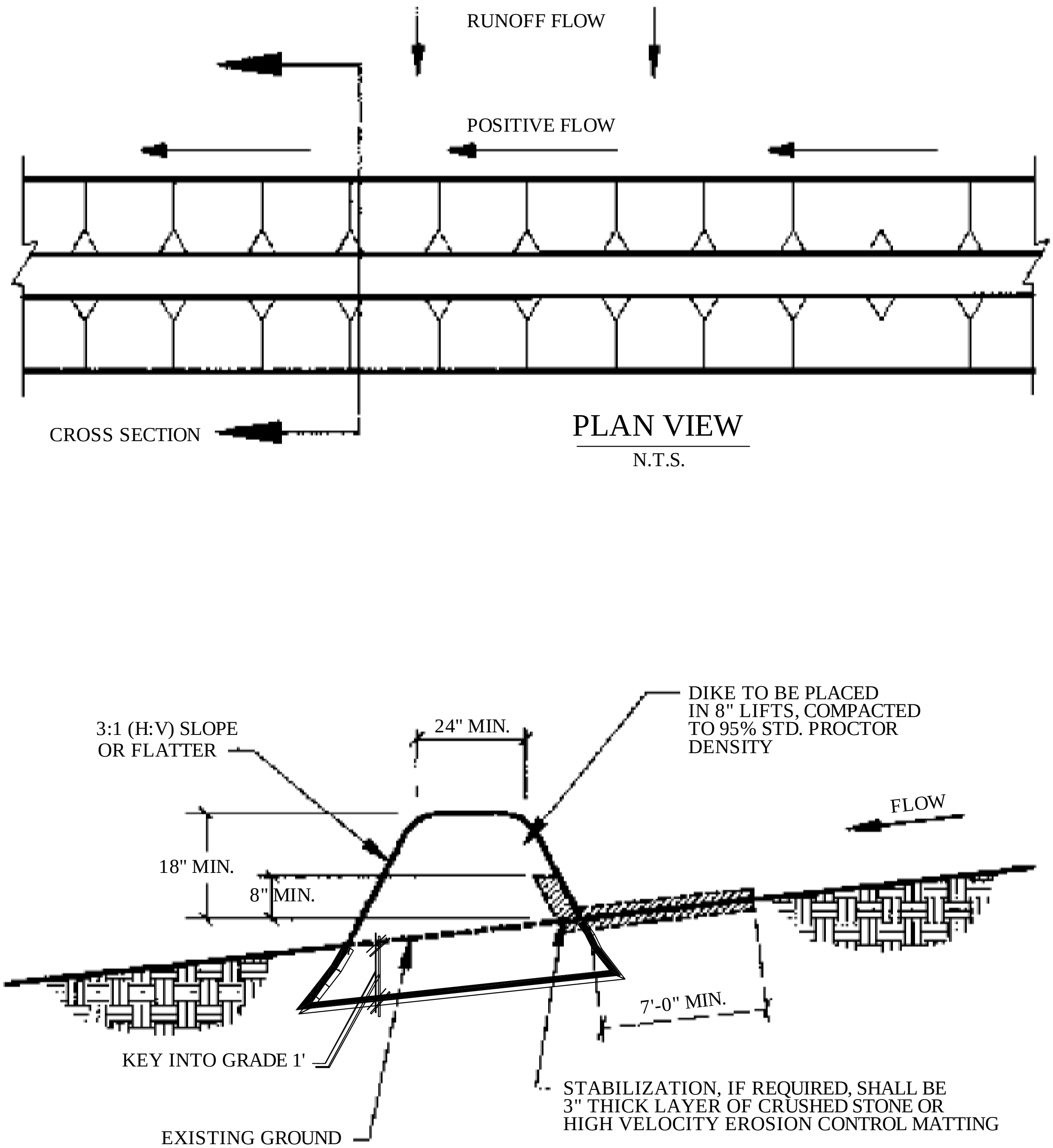
Ditches/berms are not sediment trapping devices, but may accumulate sediment that must be removed.

References

CDM et.al. for the California SWQTF, 1993.*California Storm Water Best Management Practice Handbooks, Construction and Industrial Handbooks.*

CDM et.al. for the California Department of Transportation, 1997.*Caltrans Storm Water Quality Handbooks*.

City of Franklin, Stormwater Management Program, January 2014. *City of Franklin Stormwater Best Management Practices Manual.*

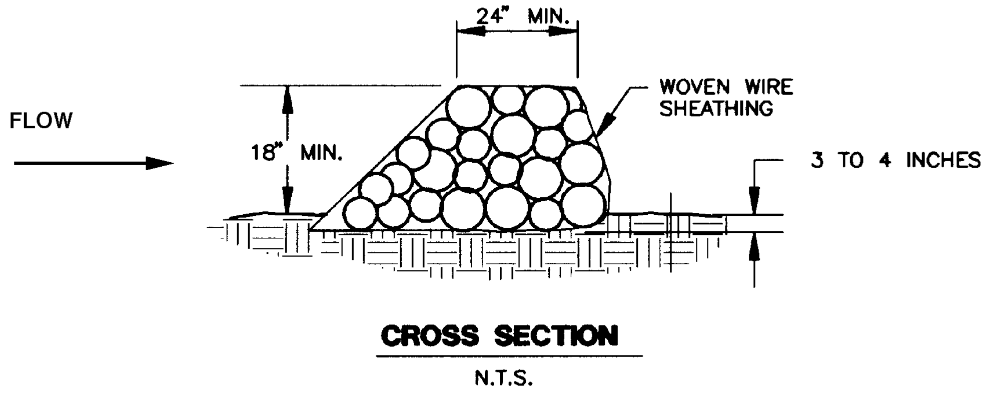


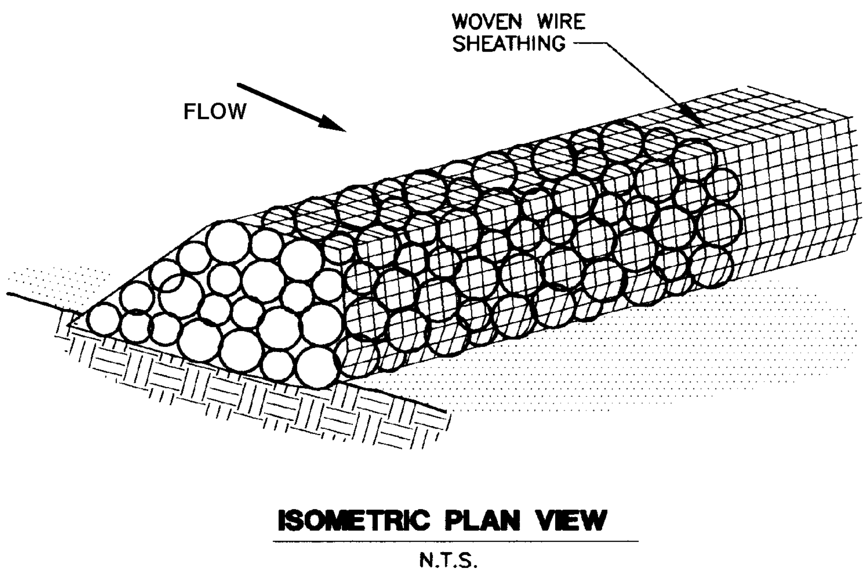
Note: This technique is similar to methods presented in TCP-15: Sand Bag Barrier and TCP-16: Brush or Rock Filters and Continuous Berms.

CROSS SECTION

N.T.S.

Figure PESC-06-1
Diversion Dike w/o Excavation

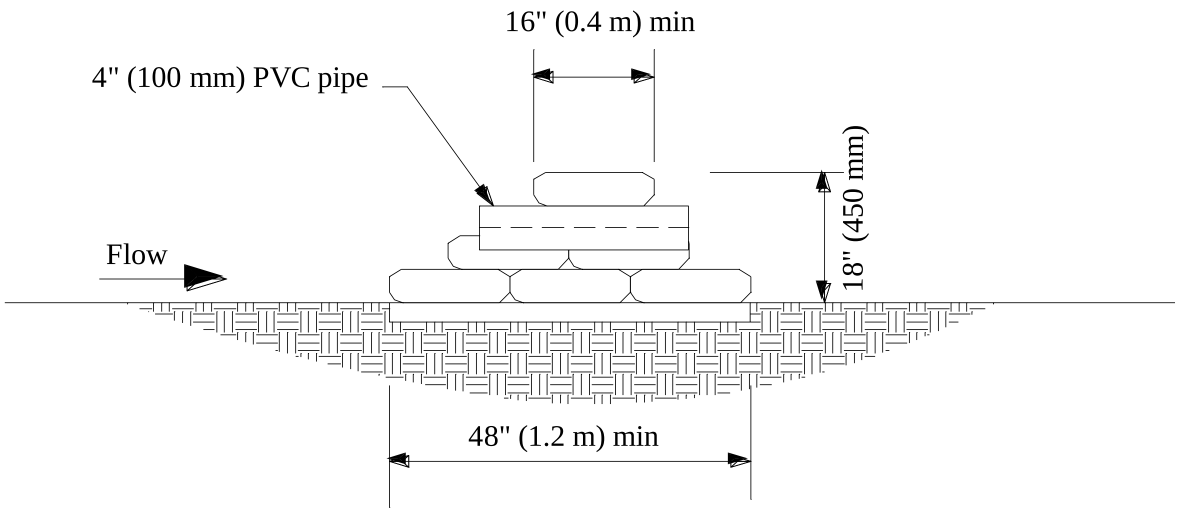




Note: This technique is similar to methods presented in TCP-15: Sand Bag Barrier and TCP-16: Brush or Rock Filters and Continuous Berms.

Figure PESC-06-2

Rock Berm



CROSS SECTION
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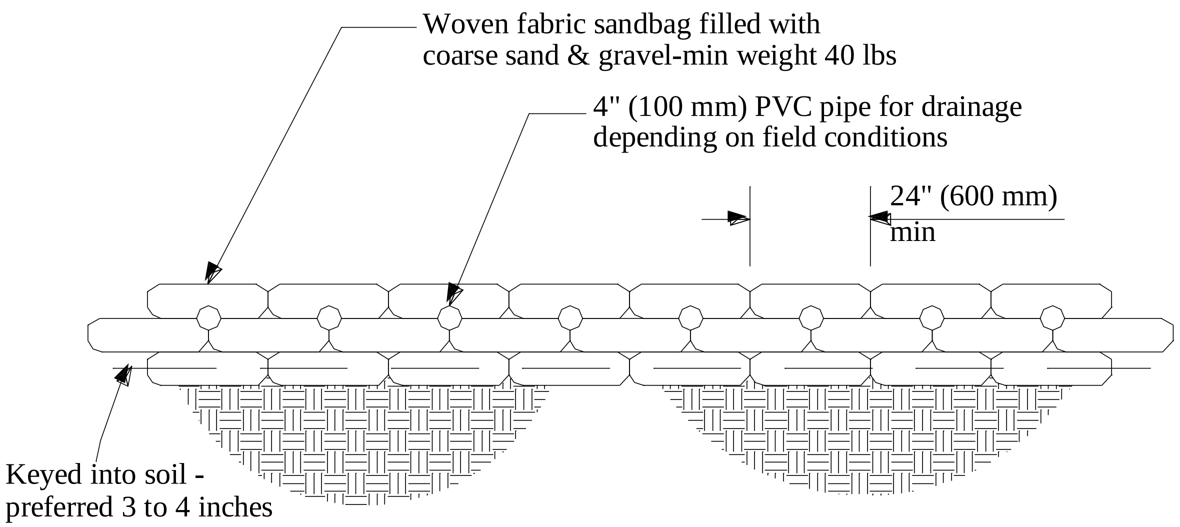
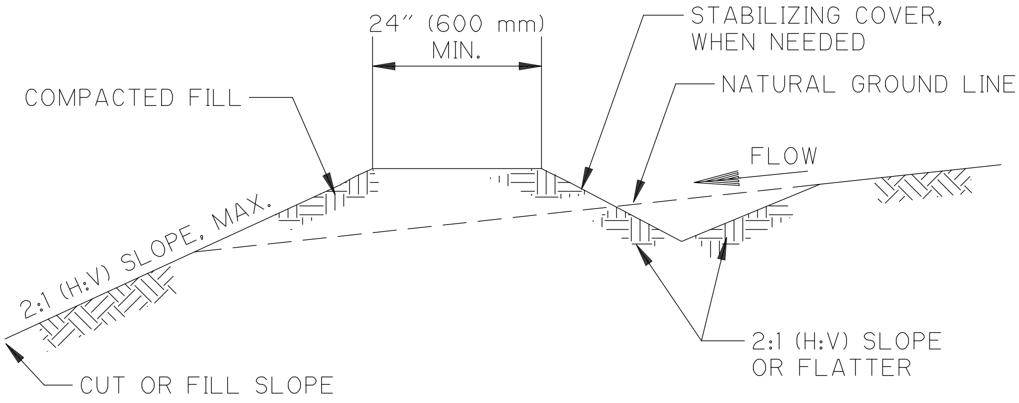


PROFILE VIEW
N.T.S.

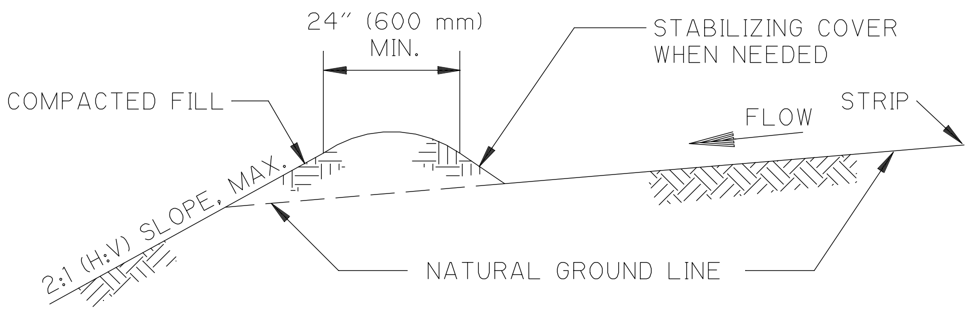
Figure PESC-06-3
Sand Bag Berm



DIVERSION BERM/SWALE

N.T.S.

NOTES:
1. STABILIZE INLET, OUTLETS AND SLOPES.
2. PROPERLY COMPACT THE SUBGRADE.

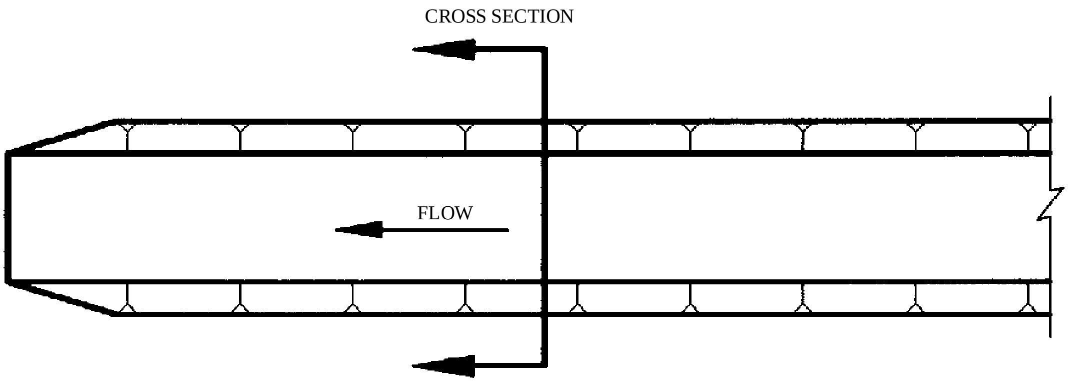


DIVERSION BERM

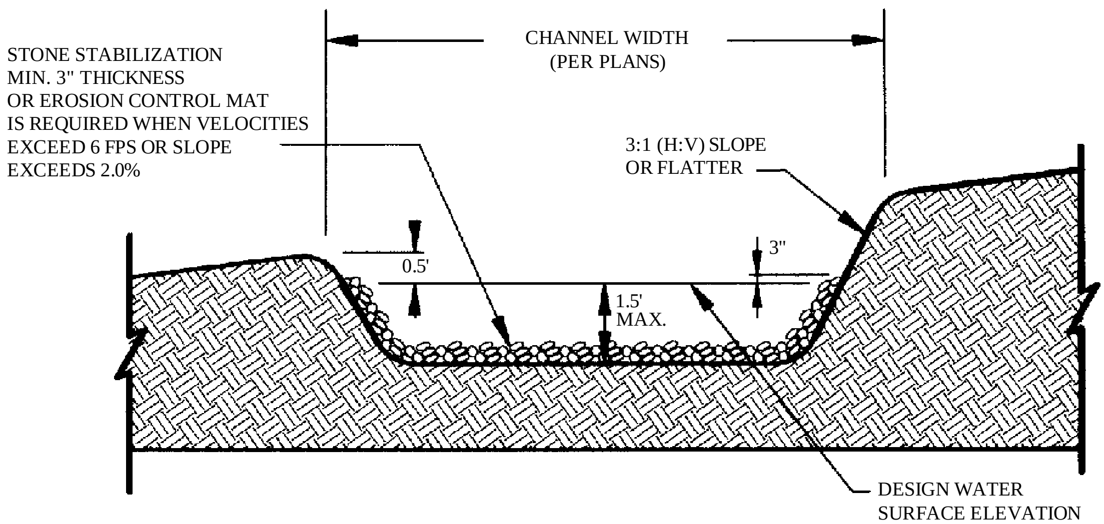
N.T.S.

Figure PESC-06-4

Diversion Berm and Berm/Swale



PLAN VIEW
N.T.S.



CROSS SECTION
N.T.S.

Figure PESC-06-5
Interceptor Swale

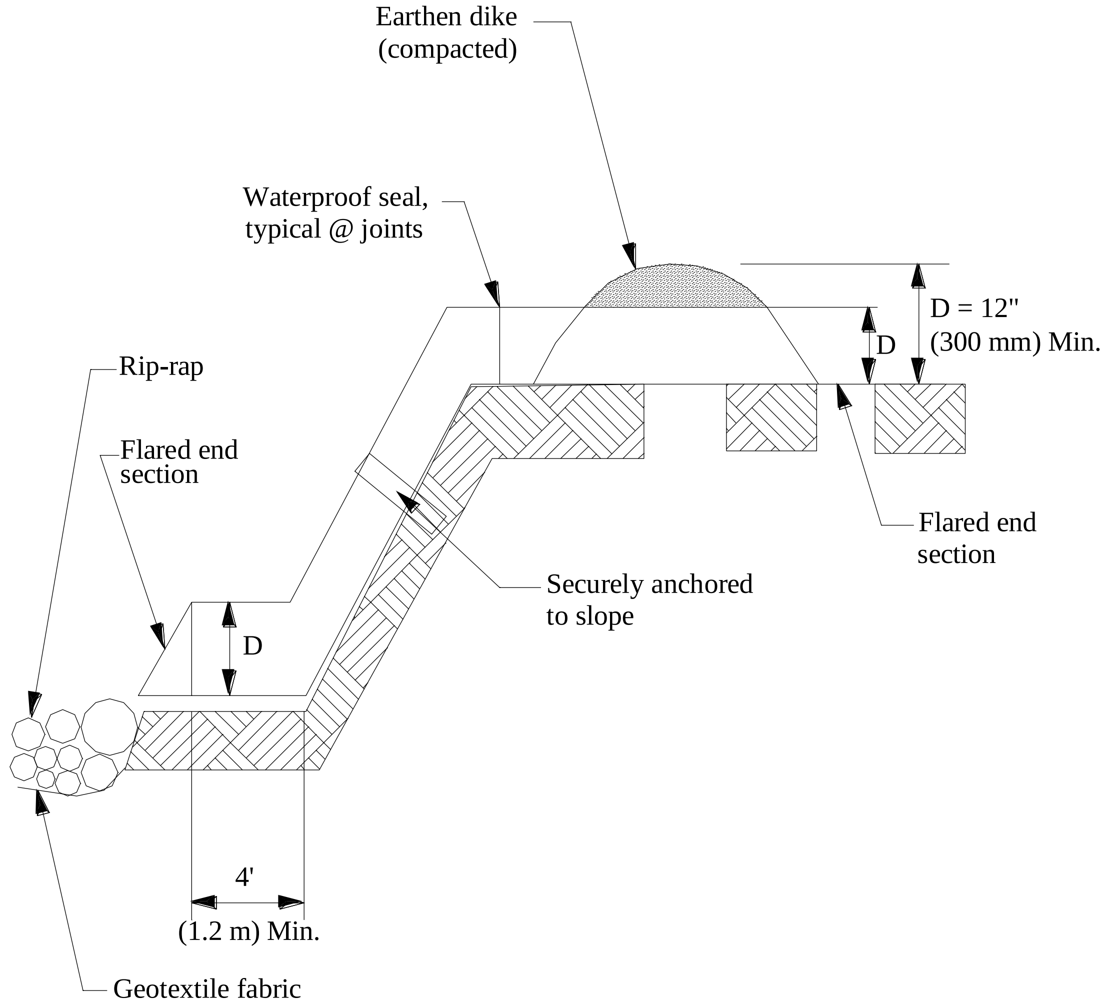
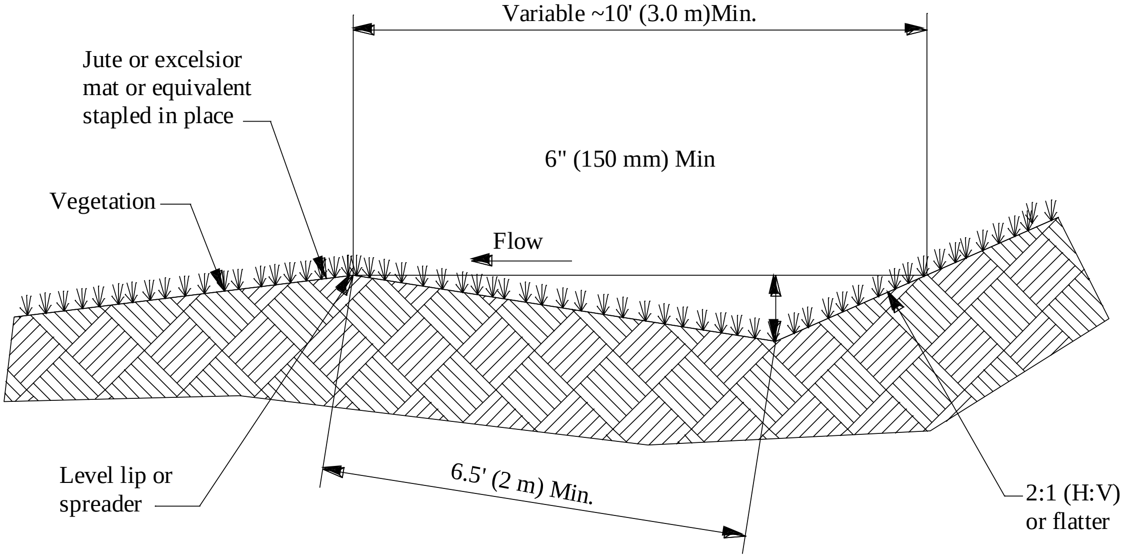
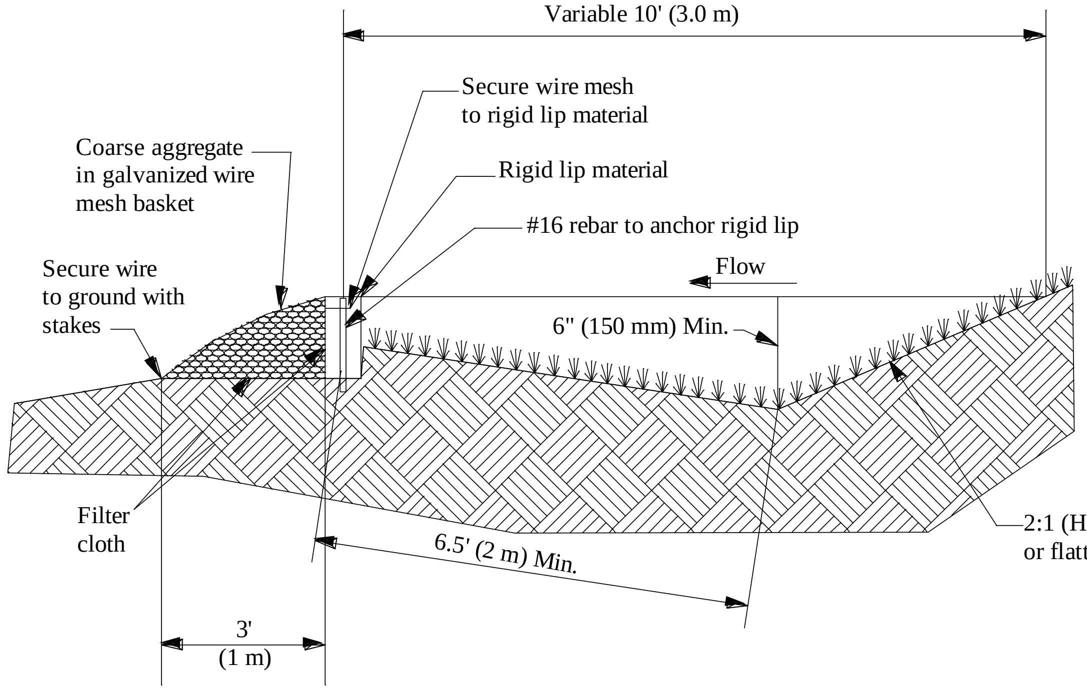


Figure PESC-06-6
Diverted Flow Slope Drain



VEGETATED LIP

N.T.S.



RIGID LIP

N.T.S.

Figure PESC-06-7

Level Spreaders

Outlet Protection

PESC – 07

Hamilton County Water Quality Program

Description

Outlet protection for culverts, storm drains, steep ditches, and flumes is essential to preventing major erosion from damaging downstream channels and drainage structures. Outlet protection can be a channel lining, structure, or flow barrier designed to lower excessive flow velocities from pipes and culverts, prevent scour, and dissipate energy. However, effective outlet protection must begin with efficient storm drainage system design that uses adequately sized pipes, culverts, ditches and channels placed at the most efficient slopes and grades. Good outlet protection will significantly reduce erosion and sediment by reducing flow velocities.

Suitable Applications

Outlet protection is needed wherever discharge velocities and energies at the outlets of culverts, pipes, conduits, channels, or ditches have potential to erode downstream reach.

Installation/ Application Criteria

These systems should be designed by a licensed professional civil engineer.

Carefully place rip-rap to avoid damaging the filter fabric.

For proper operation of apron:

- Construct apron at zero grade.
- Align apron with receiving stream and keep straight throughout its length. If a curve is needed to fit site conditions, place it in upper section of apron.
- If size of apron rip-rap is 12 in. (300 mm) or larger, protect underlying filter fabric with 4 in. (100 mm) minimum gravel blanket.

Outlets at top of cut slopes or on slopes steeper than 10 percent should have additional protection due to reconcentration and large velocity of flow leaving the structural apron.

Temporary devices should be completely removed as soon as the surrounding drainage area has been stabilized, or at the completion of construction. However, temporary devices can serve as permanent devices if properly sized and reinforced with a factor of safety to account for less frequent inspection and maintenance.

Maintenance

Permanent outlet protection should be inspected monthly through the first year after construction and annually thereafter.

Permanent outlet protection should be inspected after any storm events equal to or larger than a 10-year storm event.

Inspect apron for displacement of the rip-rap and/or damage to the underlying fabric. Repair fabric and replace rip-rap which has washed away.

Inspect for scour beneath the rip-rap and around the outlet. Repair damage to slopes or underlying filter fabric immediately.

Limitations

Large storms can wash away the rock outlet protection and leave the area susceptible to erosion.

Sediment captured by the rock outlet protection may be difficult to remove without removing the rock.

While reducing flow velocities, outlet protection may negatively impact the channel habit.

Grouted rip-rap may break up in areas of freeze and thaw, or from hydrostatic pressure without adequate drainage.

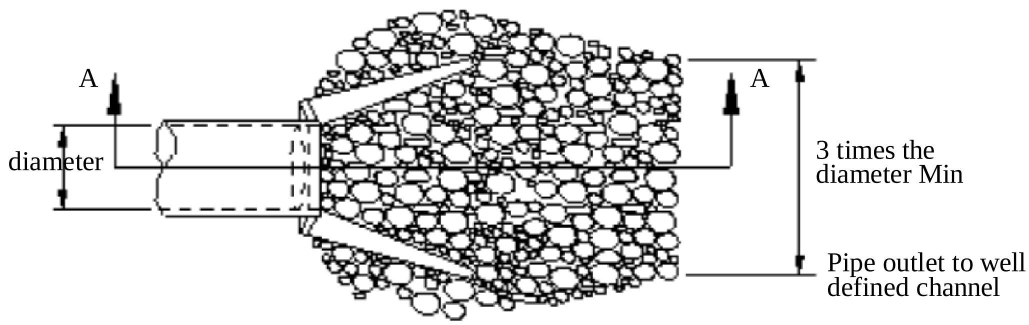
References

CDM et.al. for the California Department of Transportation, 1997.*Caltrans Storm Water Quality Handbooks*.

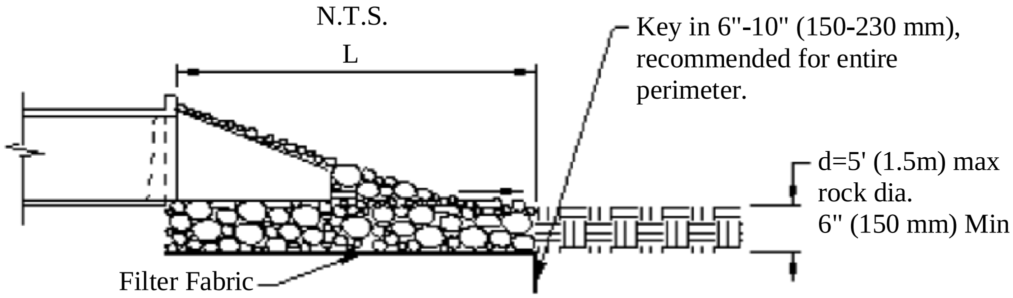
City of Franklin, Stormwater Management Program, January 2014. *City of Franklin Stormwater Best Management Practices Manual.*

Georgia State Soil and Water Conservation Commission (SSWCC), 1999. *Manual for Erosion and Sediment Control in Georgia*, Fifth Edition.

North Carolina Sediment Control Commission, September 1988. *Erosion and Sediment Control Planning and Design Manual*.



PLAN VIEW
N.T.S.



SECTION A-A
N.T.S.

Adapted from: Virginia Erosion & Sediment Control Handbook, 1992

Pipe Diameter in (mm)	Discharge ft ^{3}/s (m^3/s)	Apron Length, L ft (m)	Rip-Rap D_{50} Diameter Min in (mm)
12 (300)	4.9 (0.14) 9.89 (0.28)	10 (3) 13 (4)	4 (100) 6 (150)
18 (450)	9.89 (0.28) 20.13 (0.57) 30.01 (0.85) 39.90 (1.13)	10 (3) 16 (5) 23 (7) 26 (8)	6 (150) 8 (200) 12 (300) 16 (400)
24 (600)	30.01 (0.85) 39.90 (1.13) 50.14 (1.42) 60.03 (1.70)	16 (5) 26 (8) 26 (8) 30 (9)	8 (200) 8 (200) 12 (300) 16 (400)
For larger or higher flows, consult a registered civil engineer			

Source: Adapted from USDA-SCS

Figure PESC-07-1
Outlet Protection Sizing

Channel Linings

PESC – 08

Hamilton County Water Quality Program

Description

Channel lining is the artificial surfacing of bed, banks, shore or embankments to resist erosion or scour. This management practice is likely to create a significant reduction in sediment.

Suitable Applications

Soft (geotextiles) channel lining can be used to support permanent vegetative growth in a drainage way or as protection prior to placement of a permanent protective layer.

Permanent (hard or soft) channel lining can be used when an ordinary seeding and mulch application would not be expected to withstand the force of channel flow.

Permanent lining can only be applied in dry-weather channels (having flow most the year) with expressed permission from TDEC.

Approach

These systems should be designed by a licensed professional civil engineer.

The following materials are applicable for soft (or "green") channel linings. Generally, these types of practices are not applied in dry-weather streams (have water flowing most of the year). These practices are most often effective in wet-weather conveyances (only have flow when it rains).

- Excelsior
- Jute mats and cells
- Wood fiber mats and cells
- Geosynthetic mats or cells
- Brushlayering

The following "hard" materials are applicable for permanently lining channels.

- Pre-cast concrete block ("woven" or individually placed)
- Rip rap
- Cast-in-place concrete
- Gabions
- Sacked concrete
- Soil cement
- Air blown mortar

Rip rap, cast-in-place concrete, and pre-cast concrete blocks should only be utilized with expressed permission from the Engineering Department.

Application of channel linings can be found in TDEC's E&SC Handbook.

Maintenance

Soft (or "green") channel linings should be inspected monthly for the first year after construction, quarterly through the second year after construction and biannually (twice per year) thereafter.

Hard channel linings should be inspected monthly for the first year after construction and annually thereafter.

If net or matting materials are damaged, repair or replace immediately.

Any spaces left bare in riprap or brush layering applications due to erosion or scouring are to be repaired and replaced with their respective lining materials.

Limitations

Hard (concrete, rip rap, etc.) permanent channel linings often result in prevention of habitat establishment.

Inadequate coverage results in erosion, washout, and poor plant establishment.

If the channel grade and liner are not appropriate for the amount of runoff, channel bottom erosion may result.

If the channel slope is too steep or riprap is too small, displacement may occur.

Riprap may block channel resulting in erosion along the edge.

References

California Storm Water Best Management Practice Handbooks, CDM et.al. for the California SWQTF, 1993.

Caltrans Storm Water Quality Handbooks, Construction Contractor's Guide and Specifications, April 1997.

CDM et.al. for the California Department of Transportation, 1997.*Caltrans Storm Water Quality Handbooks*.

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University of Tennessee, Knoxville, Department of Civil and Environmental Engineering, August 1998. *Soil Erosion Prevention and Sediment Control Reducing Nonpoint Source Water Pollution on Construction Sites*.