3.0 Erosion Prevention and Sediment Control Plans

3.1 Purpose

EPSC measures are designed to reduce, capture, store, and treat sediment laden runoff from construction sites and are commonly categorized by their purpose. Some of the categories include erosion prevention, runoff velocity control, and sediment control, all of which will be discussed further in Chapter 4. EPSC measures are most effective when implemented from a set of design plans that include the placement, size, quantities, and detailed drawings for each of the proposed EPSC measures.

EPSC plans must be site-specific due to the unique combination of features present at each construction site. Site specific features may include confined or narrow areas, depth to ground water table, depth to bedrock, slopes, soil textures and classifications, proximity to receiving waters, etc. When creating EPSC plans, site specific knowledge is paramount in preventing sediment laden discharges from the construction site, a universally important process for protecting receiving waters.

3.1.1 System Approach Design

Due to the unique constraints of every construction site, typical EPSC measures may not be feasible to implement; therefore, multiple, less constrictive, measures can be paired in series to promote stormwater treatment. That is, a system of EPSC measures may be as effective or more effective in combatting the export of sediment than a single measure. Subsequently, designers and developers may consider implementing a system of less constricting measures to obtain the same expected result(s) as more intensive EPSC measures. This concept is known as treatment trains of EPSC measures. This systems approach can be used as treatment equivalency to replace a sediment basin or sediment trap. For example, on most construction sites, a sediment basin would likely remove the largest quantity (or mass) of sediment, but it may be infeasible to implement on some construction site due to some of the aforementioned site constrictions. Thus, designers can implement a treatment train of multiple, less extensive measures (e.g., rock check dams, silt fence, and sediment traps), to achieve the same treatment as a sediment basin. Designers and developers are referred to the chapter entitled “Equivalency and Treatment Trains” of this manual to better understand this process.

3.2 Erosion Prevention and Sediment Control Stages

EPSC measures must be implemented in a timing that parallels construction. For example, it would be illogical to implement pollution prevention measures when construction is near completion just as it would not be practical to implement erosion prevention measures (such as erosion control blankets) before soil is exposed during the initial phases of construction.

Therefore, EPSC measures are to be shown in three stages: initial, interim, and final to provide effective management of on-site sediment.

While there may be some disturbance around the limits of grading in order to create slopes, all EPSC measures are to be located inside the limits of disturbance. Offset the limits of disturbance from the proposed grading limits to ensure sufficient working room for construction of slopes and placement of EPSC measures.

For sites under five acres of disturbance a single plan sheet may adequately address all three EPSC stages. For example, a water line installation may have a single EPSC plan sheet that provides design information for the initial, interim, and final stages. If the entire alignment of the proposed pipeline does not fit on one sheet, then multiple sheets must be provided for the EPSC plans, but multiple sheets may not be needed for each stage. Multiple sheets would be required to show the EPSC plans for the entire project area not for each separate stage since all three stages of can be addressed on the sheet for that segment. In this example, the initial and interim stages may have the same proposed perimeter controls and may be indicated with a note: “Initial and Interim EPSC measures are the same. Replace and repair EPSC measures as needed.” An additional note to address the final stage could state “For final stage, grade back to preconstruction contours and stabilize with seed and mulch.” These notes would provide sufficient EPSC plan information on a single sheet for a defined area on the construction site of a water line installation.

3.2.1 Initial Stage

The initial EPSC stage shall establish perimeter controls to protect existing drainage features, outfalls, water resources, and off-site property. Initial stage EPSC measures must be in place prior to any earth-disturbing activities to prevent sediment from leaving the construction site. All measures must be inspected and maintained throughout the entire construction period.

3.2.2 Interim Stage

The interim EPSC stage shall display the proposed measures that are to be in place during grading operations. During this stage, drainage patterns and outfall locations can change with site grading, which may require different or additional measures in new locations. As more soil is exposed throughout construction, redundancy of measures can further decrease sediment loss. Ultimately, the objectives for this stage are to show additional measures used that continue to prevent sediment from migrating off site, despite earth disturbing activities altering site conditions.

3.2.3 Final Stage

Activities in the final stage include final grading, topsoil installation, and slope and ditch stabilization. Stabilization must occur within 14 days of temporarily or permanently ceased construction, or within seven days if slopes are greater than 35% (TDEC). Remove temporary EPSC measures from the plan sheets; only show the permanent measures.

3.3 Site Planning and Preparation

Site planning and preparation requires a site visit to assess pre-construction conditions. Notable features to assess include soil types and classifications, drainage patterns, existing vegetation, existing structures, existing pipe sizes, and topography. Planning documentation should indicate if soils are highly erodible or contaminated as well as the location of discharge points, steep slopes and slope lengths, and natural features requiring protection. Documenting these features is known as fingerprinting a site and the process is critical to ensure no damage to natural waterways or wetlands result from construction.

3.3.1 Outfalls

In the CGP, the term outfall and point source are synonymous and are defined as any discrete conveyance that discharges runoff as concentrated flow into waters of the state, offsite locations, or storm sewer systems (TDEC). All outfalls must be clearly marked on plan sheets, thereby also identifying inspection locations in which to gauge the effectiveness of EPSC measures. All outfalls have an associated drainage area. Drainage areas may include offsite drainage as well as a portion or all of the disturbed area. Per the CGP, offsite drainage must be included in outfall drainage areas since runoff following a flow path through the construction area can transport sediment and further erode soils from the disturbed area. Therefore, all runoff created within or routed through the limits of disturbance requires treatment. Planners must ensure selected EPSC measures have the capacity to retain, store, and treat the associated runoff from each drainage area before discharged via an outfall.

Outfalls can be challenging to identify. Outfalls are not exclusively defined as a point of hydrologic analysis, but also where construction site inspections must occur. Several complexities and common issues arise when identifying outfalls on a construction site:

- Identify where run-on enters the limits of disturbance as inflow, not an outfall. The inflow drainage area must be included in the total drainage area for the properly identified outfall, unless a structure is in place to divert the unpolluted water around the limits of disturbance;
- If a construction site is adjacent to a stream, do not identify outfalls within the stream but place them on the bank of the stream; and
- When disturbance is limited to a subsection of a property, identify the outfall where concentrated flow is discharged from the limits of disturbance, not the downstream

property line. The one exception to this is if the downstream property line and downstream subsection's limit of the disturbance overlap;

When outfalls are placed in a stream or outside of the disturbed area, the associated drainage area includes runoff from upstream tributaries and undisturbed sections of the property. By misidentifying the outfall, design of all EPSC measures would be required to include this additional runoff volume in their storage capacity. Outfalls are important to identify correctly, as they are the most downstream inspection point for each drainage area. This is where the inspector can gauge the effectiveness of all EPSC measures within each drainage area at preventing sediment loss.

3.3.2 Streambank Stabilization

Construction on and around streambanks results in removed and degraded vegetation, and soil disturbance, thereby impairing streambank stability. Soil particles are dislodged from the bare soil when heavy machinery and equipment disrupt the soil structure. Streambank destabilization and highly erosive flows during storms subject the stream to excessive sediment and habitat loss for the local ecosystem. Protecting and stabilizing streambanks from active construction is critical to preserve the land and ecosystem structure. Further, it is important to plan locations where heavy machinery can access or cross the stream if needed for construction purposes. When physical alterations to a stream or its banks are necessary, an Aquatic Resource Alter Permit (ARAP; Chapter 0400-40-04 Aquatic Resource Alteration) is required. Several EPSC measures are included in this handbook as guidance when working in or around streams.

The most common stabilization measure is riprap, which is large angular rock that resists erosion due to its size, weight, and interlocking nature when set in place. Classes of riprap, otherwise known as its gradation, are differentiated by the size of stone. In Tennessee, Class A-1, B, and C are the most commonly produced and have median stone dimensions (D_{50}) of nine, 15, and 20 inches, respectively. However, stone dimensions within each gradation can range from the upper size in the lower gradation to the lower sizer in the higher gradation. These ranges in size help fill void spaces between interlocking stones. Less common gradations may be considered for use when absolutely necessary and with proper approval from the design engineer. In addition to riprap gradation, riprap can also be classified by type: conventional, soil filled, and void-filled.

Conventional riprap is plain angular rock. Due to growing environmental concerns, minimize the use of conventional riprap where possible. The most ideal in locations for conventional riprap are where vegetation is not planned such as under bridges and pipe outfalls (MHFD 2024a; TDOT). Further, due to larger void spaces, conventional riprap requires placement of bedding material or geotextile fabrics between the stone and natural subgrade to prevent piping. Soil riprap is two-thirds part conventional riprap filled with one-third part native soil or topsoil, a combination which eliminates void spaces. Further, soil riprap can include an additional, uppermost layer of topsoil which provides a medium for vegetation. The combination of vegetation and riprap also eliminates the need for an underlying geotextile. Soil riprap may be ideal for bioengineered streambank protection, swales, and buried emergency spillways (MHFD, 2024a). Void-filled riprap is a mixture of conventional riprap, cobbles, gravels, sands, and soils which creates a densely, void-filled composition that keeps flowing water above the surface thereby preventing erosion. Void-filled mimics natural riffle-rock material and is most ideal where there is continuous streamflow (MHFD, 2024b).

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3.3.2.1 Bank Protection

Source: TDEC

Definition and Purpose

Bank protection is the stabilization of the side slopes of a waterbody. This can be vegetative, structural, or a combined method, such as bioengineered soil stabilization (See Section 3.3.2.2). Bank protection is necessary to repair and/or prevent erosion in areas where increased runoff rates and volumes are anticipated from development, construction, or stream alteration.

Appropriate Applications

Bank protection is appropriate where there is existing erosion or erosion is anticipated. This could be along straightened channels, in locations of (upstream) development, exposed streambanks, or where highly erosive flows have been observed.

Limitations and Maintenance

Few limitations exist for this practice as long as the protection is applied appropriately so as to withstand erosive forces and is firmly secured so the practice cannot become dislodged and migrate downstream. Otherwise, bank protection may require continual replacement or maintenance. Timing limitations exist for vegetative measures as they will not immediately stabilize the banks. Bank protection measures must not reduce the hydraulic capacity of the stream.

Installing bank protection in jurisdictional waters requires additional permits, such as an ARAP, and therefore, both the conditions of the CGP and ARAP must be followed. A Section 404 permit from USACE may also be required, and if the proposed bank protection is to be completed in a TVA reservoir, a TVA 26a permit may also be necessary. Consider the criteria and conditions of the necessary permits during the planning stages of the project and EPSC plans.

Planning and Design Considerations

Several options exist for bank protection, including grass, trees, conventional, soil, and void-filled riprap, concrete, fabric-formed revetments, grouted riprap, erosion control blankets, turf reinforced matting, coir matting, benching, geotextile containment, etc. Some of these bank protection measures can be used in conjunction with bioengineered soil techniques as presented in Section 3.3.2.2 (GSWCC, 2016). It is ideal to install bank protection when a stream diversion (Sections 3.3.2.3 and 3.3.2.4) is in place (i.e., dry conditions). This prevents the transport of disturbed sediment downstream. Consider the following site-specific conditions when selecting bank protection materials (ALSWCC, 2022):

- The overall condition of the stream within and adjacent to the reach is to be stabilized;
- Current and future watershed conditions;
- Velocity at full channel flow;
- Shear stress at full channel flow;
- Sediment load in the stream;
- Channel slope;
- Controls for bottom scour;
- Soil conditions;
- Present and anticipated channel roughness;
- Compatibility of selected protection with other improvements at the site;
- Changes in channel alignment; and
- Fish and wildlife habitats.

A well-conceived bank protection design consists of an interdisciplinary team, including (but not limited to) engineers, hydrologists, and wildlife biologists. Key considerations include stream geomorphology, stabilization of the channel bottom, and appropriate selection of bank protection measures based on velocity and shear stress. The channel bottom must be stabilized before installing bank protection to enhance long-term success. Grade control may be necessary to prevent stream downcutting (ALSWCC, 2022). Vegetated protection is typically preferred as it is inexpensive and resembles natural stream characteristics. However, vegetated banks do not provide immediate stabilization and do not provide as much stability under high flow conditions as other, typically structural materials (Tables 3.3.2.1-A and 3.3.2.1-B). Design velocities are to be determined by the designers under the appropriate design storm, which may be a local regulation. If no design storm is specified due to the project location and local government ordinances, utilizing the upstream channel capacity, estimated bankfull velocity, or the 2-year, 24-hour design storm are appropriate alternatives.

Table 3.3.2.1-A: Velocity thresholds for bank protection materials. Sources: FHWA and TDOT.

Material	Maximum Velocity (ft/s)
Bare Soil	-
Silt of fine sand	1.5
Sandy loam	1.75
Silt loam	2
Stiff clay	3.75
Ordinary firm loam	2.5
Fine gravel	2.5
Graded, loam to cobbles (noncolloidal)	3.7
Graded, silt to cobbles (colloidal)	4
Alluvial silts (noncolloidal)	2
Alluvial silts (colloidal)	3.7
Coarse gravel (noncolloidal)	4
Cobbles and shingles	5
Shales and hard pans	6
Sod	4
Lapped sod	5.5
Vegetation	Table 3.3.2.1-B
Conventional Riprap (Class A1, I)	5
Conventional Riprap (Class B, II)	10
Conventional Riprap (Class C, III)	12
Conventional Riprap (Class C, IV)	15
Conventional Riprap (Class D, V)	20

Table 3.3.2.1-B: Maximum velocity threshold for vegetated bank protection on slopes. Source: TDOT

Vegetation Type	Exit Channel Slope Range (%)	Maximum Velocity[a] (ft/s)
Bermudagrass	0 - 5	6
	5 - 10	5
	> 10	4
Kentucky Bluegrass, Buffalo Grass, Smooth Brome	0 - 5	5
	5 - 10	4
	> 10	3
Grass Mixture	0 - 5	4
	5 - 10	3
Lespedeza Sericea, Kudzu, Alfalfa, Crabgrass	0 - 5	2.5
Common Lespedeza, Sudangrass	0 - 5	2.5

[a]Based on erosive soils

Even if velocity permits a certain protective material, shear stress, the force per unit area exerted parallel to the streambank, must be checked to ensure compatibility. Streambanks are considered stable when the velocity criteria are met, and permissible shear stress (Table 3.3.2.1-C) is less than the tractive force (TDOT). Tractive forces are the hydrodynamic forces of flowing water in a channel. In a uniform flow, the tractive force is equal to the effective component of the gravitational force acting on the body of water, parallel to the bottom of the channel. Thus, the maximum shear stress for a straight channel occurs at the channel bottom and is less than or equal to the shear stress at maximum depth, which can be expressed as:

$$\tau_{max} = \gamma \times d \times S \qquad \text{(Eqn 12)}$$

where τ_{max} is the maximum shear stress in pounds per square foot, γ is the unit weight of water (62.4 pounds per cubic foot), d is the maximum depth of flow in feet, and S is the average bed slope or energy slope in feet per foot.

Concentrated flow traversing a bend imposes a higher shear stress on the inner bank within the curve and the outer bank downstream of the curve compared to a straightened reach. Maximum shear stresses in bends are a function of the ratio of the radius of curvature, R_C, to the channel bottom width, b. As this ratio decreases, the bend becomes sharper and shear stresses increase. Maximum shear stress in a bend can be calculated by the following equation:

$$\tau_{bend} = \tau_{max} \times K_b \qquad \text{(Eqn 13)}$$

where τ_{max} is calculated from Eqn 12 and K_b is a dimensionless factor accounting for the increased stress. This dimensionless factor is calculated by Eqn 14.

$$K_b = 2.36 \times e^{-0.082 \times R_C / b} \qquad \text{(Eqn 14)}$$

Table 3.3.2.1-C: Shear stress thresholds for bank protection materials. Sources: FHWA and TDOT.

Lining Category	Lining Type	Permissible Unit Shear Stress	
		(lb/ft^2)	(Pa)
Erosion Control Blanket[a]	Type 1	1.5	72
	Type 2	1.75	84
	Type 3	2	96
	Type 4	2.25	108
Turf Reinforced Mat[a]	Type 5 - unvegetated	3	144
	Type 5a	6	288
	Type 5b	8	384
	Class 5c	10	480
Grass	Class A	3.7	177
	Class B	2.1	101
	Class C	1	48
	Class D	0.6	29
	Class E	0.35	17
Conventional Riprap	Class A1, I	3	144
	Class B, II	4	192
	Class C, III	5	239
	Class C, IV	6	287
	Class D, V	7+	335
Bare Soil	Non-cohesive Cohesive	See Hydraulic Engineering Circular No. 15	

[a]General values based on vendor information, refer to Section 4.2.6.10 for detailed information.

When working around a water resource, such as a stream, consider the different zones within the riparian area and their susceptibility to erosion (NCDEQ, 2013). Typically, riparian areas consist of five zones, including toe zone, bank zone, overbank zone, transitional zone, and upland zone (Figure 3.3.2.1-A), though each zone may not be prevalent in streams impacted by development.

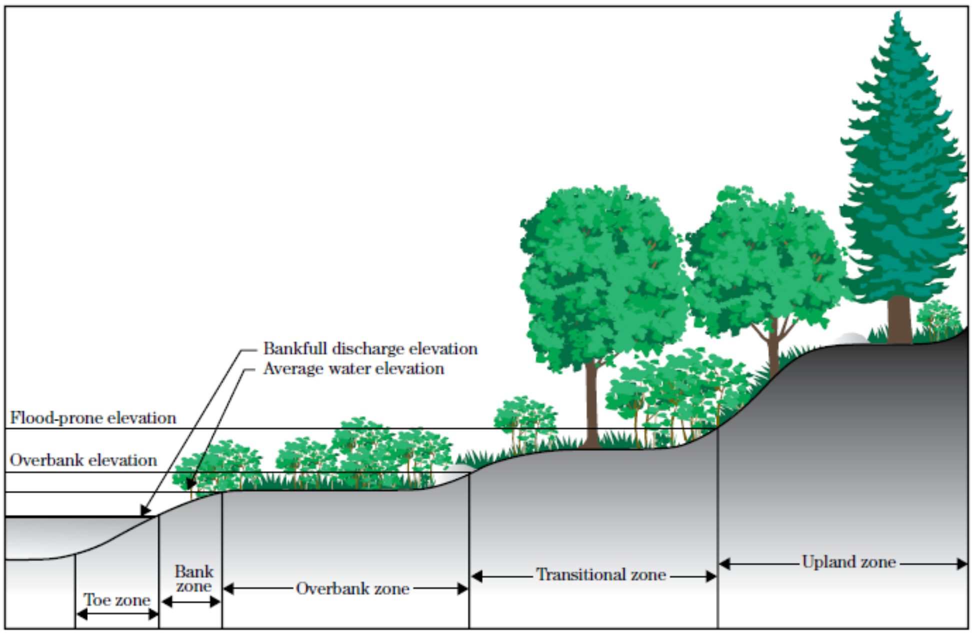

Figure 3.3.2.1-A: Riparian zones. Source: NRCS (2007).

The toe zone is located below baseflow water levels. This zone is perhaps the most critical to be stabilized, as it is continuously subjected to flow (NRCS, 2007). Because this zone is inundated (with the exception of drought periods), it is likely that no woody vegetation exists, nor would it be feasible to introduce woody vegetation as a protective measure. In the toe zone, nonliving protection (most commonly, structural) is most ideal.

The bank zone is the area situated between the typical water level and the bankfull discharge height. In this zone, the potential for erosion is high, but only during stormflow. Furthermore, this zone experiences wet and dry cycles, debris deposition, and in winter months, it can be subjected to freeze-thaw cycles. These exposures may exacerbate erosion potential. This zone is often covered by early-growing herbaceous and small woody plants with flexible stems. Such species may include willows, dogwoods, elderberries, and small shrubs (NRCS, 2007). Because this zone is subjected to erosive forces and there is a low potential of protection from natural vegetation, bank protection is likely necessary. Planting vegetation may provide adequate protection in small water bodies, especially if the upstream has little development. However, nonliving protection will likely be more effective.

The overbank zone is located above the bankfull discharge elevation, which floods approximately every two to five years. It is typically a flat area because it has been formed by sediment deposition when flooded. Vegetation found in this zone is generally flood tolerant, provides shade for the stream, and offers a riparian habitat for wildlife. Protection usually does not need to extend into this zone as long as existing vegetation is present and healthy (NRCS, 2007). However, support this zone with vegetative protection if needed. Typically, this zone is where the preservation of riparian buffer zones (Section 3.3.3.2) would begin.

The transitional zone and upland zone are seldomly subjected to erosion from the stream. The transitional zone may be flooded approximately every 50 years while the upland zone would be subjected to erosion from sheet flow and land disturbance (NRCS, 2007). Bank protection measures are not applicable in these zones.

When the velocity and shear stress align with vegetative design, incorporating diverse plant species is ideal. Consider natives first. However, there are difficulties when it comes to establishing natives, such as acquiring 70% vegetative cover and time to germination. Native vegetation can be supplemented with nurse crops in order to provide erosion control while the natives germinate and grow. See Section 4.2.6.11 Vegetation and Landscaping: Permanent for further details on native establishment. If native plants are not feasible, then consider non-invasive species for stabilization. Where high velocities, channel bends, steep slopes, or highly erodible soils exist, structural protection will be more desirable than vegetation. Common structural bank protection materials include conventional riprap, gabions, fabric-formed revetments, and reinforced concrete walls.

Conventional riprap is one of the most commonly used materials for bank protection, providing stability and erosion resistance in high-flow environments. To ensure its effectiveness, size riprap to withstand the expected flow conditions. The first step in this process is to determine the design velocity and maximum shear stress, based on either bankfull flow or a more conservative design storm. Machined riprap is categorized into different classes based on median stone size (D_{50}). Class A-1 has a D_{50} of nine inches and is placed at a minimum depth of 18 inches. Class A-2, though similar in material, is hand-placed at a depth of 12 inches and is generally not recommended due to its reduced stability. Class B and C


Source: NCDEQ (2013)

riprap have a D_{50} of 15 and 20 inches, respectively. For slopes steeper than 3H:1V, refer to Chapter 4 of the FHWA publication HEC-15 to ensure stability. Permissible velocities for riprap classes are presented in Table 3.3.2.1-A. However, using shear stress calculations provides a more accurate assessment of stability, and these thresholds must also be checked (Table 3.3.2.1-C). Additional considerations to prevent failure include ensuring that bank slopes do not exceed a maximum of 2H:1V, incorporating geotextile filter fabric between the soil and conventional riprap to prevent piping, and extending the riprap toe at least one foot below the streambed. Ideally and when possible, extend riprap up to the 2-year water surface elevation or bankfull flow unless a combination of vegetative measures is determined to provide sufficient protection. Where possible, consider the use of soil riprap or void-filled riprap in place of conventional riprap as a bioengineered soil technique (Section 3.3.2.2).

Gabions are stone-filled wire baskets that are semi-flexible and permeable. Because of their flexibility, gabion structures remain structurally sound and function during earth movement. Void spaces in gabions absorb energy from flowing water, thereby reducing velocity. Because this material is permeable, place a geotextile fabric between the gabions and soil subgrade to prevent any piping. Stone size is less critical for gabions on steep slopes (as opposed to riprap alone) because the wire mesh allows the material to act as a single unit. However, the stability and allowable shear stress of wire-enclosed riprap depends on the integrity of the wire mesh. In channels with high sediment yields, the wire mesh may be abraded and could potentially fail. In such conditions, the use of these structures are not advised. Check manufacturer specifications for permissible shear stresses of wire.


Source: NCDEQ (2013)

Fabric-formed revetments are manufactured, large, quilted envelopes that are pumped with fine-aggregate grout onsite. These systems are inexpensive and take only a few minutes to set in place. Essentially, they are cast-in-place rigid linings that are durable, flexible, and semi-permeable. Due to their flexibility, fabric-formed revetments are ideal with stream banks having irregular surfaces. Furthermore, the permeability of geotextile fabrics allows water filtration, which can be beneficial to the local ecosystem. There are various options for revetments on the market. Be sure to check manufacturer specifications to ensure the proper selection for each site and permissible shear stresses. Additionally, follow all manufacturer specifications during installation.

Reinforced concrete retaining walls are not ideal for bank protection but may be necessary to replace cut or fill slopes in confined areas, in areas with poor soils, or where a wall is necessary to achieve stable slopes. Designing retaining walls is a complicated process and site site-specific; thus, an engineered design is required. Many factors need to be considered, such as allowable stresses and forces outside and within the wall, allowable height, wall thickness, foundation design, footers, bearing values of soils, a factor of safety, etc. The foundation must include a method of draining excess water from behind the wall. Begin and end all structural protection methods along stable reaches of the stream.

The velocity and shear stress discharging from the protected to a natural stream reach must be considered, particularly if the reach was straightened. Ensure protected banks do not increase the velocity of water such that downstream erosion occurs. If the velocity or shear stress is too high, consider designing a transition in the bank protection to slow the erosive forces, thereby protecting the downstream channel bed and banks.

Example Application

Always ensure that the maximum velocity and shear stress are less than the permissible velocities and shear stresses of bank protection. Maximum velocities and shear stresses in streams are to be calculated by design engineers registered in Tennessee.

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3.3.2.2 Bioengineered Soil Bank Stabilization

Source: TNWRRC

Definition and Purpose

Soil bioengineering is defined as the use of living and nonliving plant materials in combination with natural and synthetic support materials for slope stabilization, erosion reduction, and vegetative establishment. These techniques incorporate natural and readily available plant materials such as root wads, coconut fiber rolls, and rock or log vanes to direct stream flow away from eroding banks and stabilizing the bank.

Appropriate Applications

Bioengineered soil bank stabilization is appropriate anywhere repair or protection from erosive forces on the banks is needed. This could be along straightened channels, in urbanized watersheds, exposed streambanks, or where highly erosive flows have been observed or are anticipated. Native vegetation is the preferred method of bank stabilization. However, when vegetation cannot provide adequate stabilization, bioengineered methods are favored.

Limitations and Maintenance

Bioengineered soil stabilization measures must be affixed in place so they cannot become dislodged migrate downstream. Continual repair or maintenance may be incurred if the stabilization practice is under-designed and cannot withstand the shear forces in which it is subjected. This can be costly and more impactful than initially designing a more stable option. Any implemented practice must not reduce the hydraulic capacity of the stream.

Installing bioengineered soil bank protection in jurisdictional waters requires additional permits, such as an ARAP, and therefore, both the conditions of the CGP and ARAP must be followed. A Section 404 permit from USACE may also be required. If the proposed bioengineered soil bank protection is to be completed in a TVA reservoir, a TVA 26a permit may also be necessary. Consider the criteria and conditions of the necessary permits during the planning stages of the project and EPSC plans.

Planning and Design Considerations

When selecting the best-suited bioengineered technique, it is important to have a clear understanding of the ecological systems in adjacent areas. Plant selection and the techniques used will play an initial role in site stabilization and, ultimately, serve as the foundation for the ecological restoration of the site. Long-term establishment and health of herbaceous, woody vegetation is critically important to the physical and biological functions of streams. See Section 3.3.2.1 Bank Protection for the different planting zones within the riparian buffer zone.

Bioengineered soil bank stabilization is especially useful as a transition between conventional, inert bank stabilization and natural downstream banks. Abrupt transitions from projects, such as conventional riprap, to natural channel linings are often prone to scour. Established bioengineered soil treatments can act to protect and reinforce the transition and reduce the possibility of washouts and flanking (NRCS, 2007). Combinations of vegetative and structural protection can often be used in place of most structural measures. As with structural measures, start and end all combined methods along stable reaches of the stream.

Cellular confinement matrices are commercially available products comprised of heavy-duty polyethylene and formed into a honeycomb-shaped matrix. The product is flexible to conform to irregular surfaces and the honeycombs can be filled with soil, sand, gravel, or cement. When soil is filled into the honeycombs, it is usually ideal to plant vegetation in addition. Install all cellular confinement systems according to manufacturer specifications.

Source: Yee (2012)

Live cribwalls are a bioengineered technique that consists of a hollow, box-like interlocking arrangement of untreated logs or timber. They are appropriate to use at the base of a slope where a low wall may be required to stabilize the toe and reduce steepness. They are also appropriate where space is limited, and a vertical structure is required. The live walls are natural material, thereby promoting environmental sustainability and allowing for the growth of plants within their structure, which can help with long-term bank stability. Cut live branches one-half to two inches in diameter. Construct the crib from logs or timbers from four to six inches in diameter or width. Branch lengths will vary depending on crib size. Starting at the lowest point of the slope, excavate loose material two to three feet 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. Place the first course of logs or timbers at the front and back of the excavated foundation, approximately four to five feet apart and parallel to the slope contour (Figure 3.3.2.2-A). Place the next set of logs or timbers orthogonal to the slope on top of the previously set timbers. Place each set of timbers in the same manner and affix to the preceding set. Place live branch cuttings on the top of each cribwall structure with growing tips oriented outward. Backfill the cribwall, compact the soil for good root-to-soil contact, and apply seed and mulch.

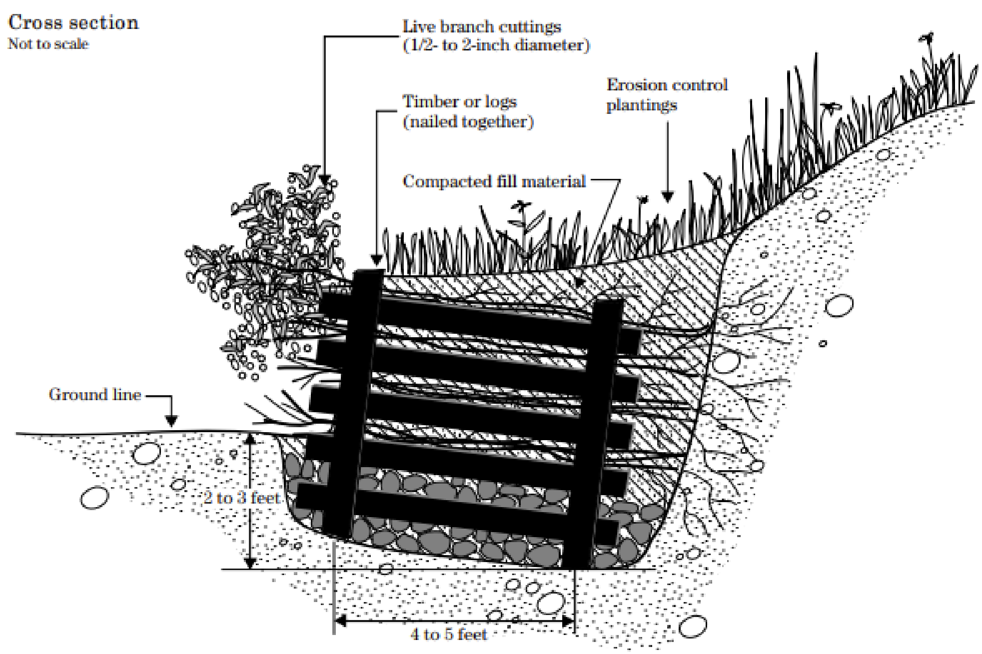

Figure 3.3.2.2-A: Live cribwall details. Source: NRCS (1996, 2021).

The Tennessee Cedar Revetment (TCR) is a bioengineered soil bank technique that combines small, locally harvested eastern red cedar trees with 700-gram coir matting to form a flexible, interlocking structure that traps sediment and protects eroding banks. Constructed with cedar branches as the internal framework and encased in coir matting, each TCR unit is typically 10 feet long and 14 to 22 inches in diameter, forming a sturdy, yet flexible structure that conforms to the streambank. This method is most suitable for small to medium-sized streams with active erosion but where heavy equipment access is limited or undesirable, especially in forested areas where preserving vegetation is a priority. Installation begins downstream, using duckbill anchors and aircraft cables to tightly secure each revetment into the bank, layering them in overlapping sequences to prevent water from getting behind the structure. Revetments may be stacked in multiple rows depending on bank height and are often paired with rock toes or vanes for added protection. Once in place, the coir matting filters suspended sediment while the cedar adds structure, creating a new, reinforced bank that supports natural revegetation. TCRs offer a cost-effective, minimally invasive, and volunteer-friendly alternative to conventional erosion control, with a proven track record of durability and ecological compatibility in Tennessee streams (Gregg & McFadden).


Source: Gregg & McFadden

Soil riprap is a bioengineered soil technique that mixes conventional riprap with natural soil or topsoil. The ideal mixture is two-thirds part conventional riprap and one-third part soil, which fills the voids between the angular stone. Mix the materials to a uniform consistency with a front end loader or excavator. Prior to installation, ensure that subgrade is excavated to the proper depth to account for the soil riprap upon placement and subsequent compaction. Because the soil fills the void spaces, erosion due to piping is not a concern and therefore an underlying geotextile or bedding material is not necessary, as with conventional riprap. As the soil riprap is installed, ensure it is compacted such that the angular stone forms interlocking compartments to hold the soil in place. Additionally, ensure there are no excessively large pockets of soil which may indicate weak spots. Once installed, all void spaced should be


Source: MHFD (2024a)

adequately filled and compacted by visual inspection. For some projects, an additional layer of topsoil may be added to the top of the soil riprap profile to provide a more suitable growing medium. This practice is particularly useful where aesthetics are important as vegetation will effectively hide the riprap (MHFD, 2024a). Ensure the soil and conventional riprap are stored separately onsite as pre-mixed compositions that are not compacted may allow the soils to migrate downward resulting in a nonuniform matrix.

Void-filled riprap is a soil bioengineered technique that consists of a composition of conventional riprap, cobbles, gravels, sands, and onsite (or natural) soils. The materials in void-filled riprap will form a dense, interlocking composition that more naturally mimic natural stream flow compared to soil riprap or conventional riprap. Thus, this practice is ideal where continual and/or larger flows are anticipated. Using a front end loader or excavator, mix an initial test batch of all void-filled riprap materials until a uniform consistency is achieved. Make note of the ratio of materials used such that the test batch can either be recreated or amended. Amending material proportions should be done during this initial test batch such that the finalized ratios most accurately resembles natural riffle material. Prepare the subgrade and place the void-filled riprap in the same manner as soil riprap. Ensure that the mixing and placement of the void-filled riprap results in some of the larger riprap flush and visible on the surface with other materials organized to minimize the voids. Before compacting, inspect the void fillings. It may be necessary to add bedding or cobbles to the surface and "wash it in" with a high pressure hose to fill any voids. After which, compacting can occur. These techniques ensure stability such that the void fillings are locked in place and cannot be eroded away or migrate downwards (MHFD, 2024b). Lastly, ensure void filling materials are stored separately onsite similar to soil riprap.


Source: MHFD (2024b)

Vegetated gabions are a bioengineered soil technique that combines layers of live branches and gabions (Section 3.3.2.1). This practice is appropriate at the base of a slope where a low wall is required to stabilize the toe of the slope and reduce its steepness. It is not designed to resist large lateral earth stresses. Ideal use is where space is limited and a more vertical structure is required. Keep the overall height, including the footing, less than five feet. Cut live


Source: TDOT

branches one-half to one inch in diameter and long enough to reach beyond the rock basket structure into the backfill. Starting at the lowest point of the slope, excavate loose material two to three feet below the ground elevation until a stable foundation is reached (Figure 3.3.2.2-B). Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability and ensure rooting. Place the wire baskets in the bottom of the excavation and fill with stone. Backfill between and behind the wire baskets. Place live branch cuttings on the wire baskets orthogonal to the slope, with the growing tips oriented away from the slope and extending slightly beyond the gabions. Root ends must extend beyond the wire baskets into the fill material. Place soil over the cuttings and compact it. Repeat the construction sequence until the structure reaches the required height.

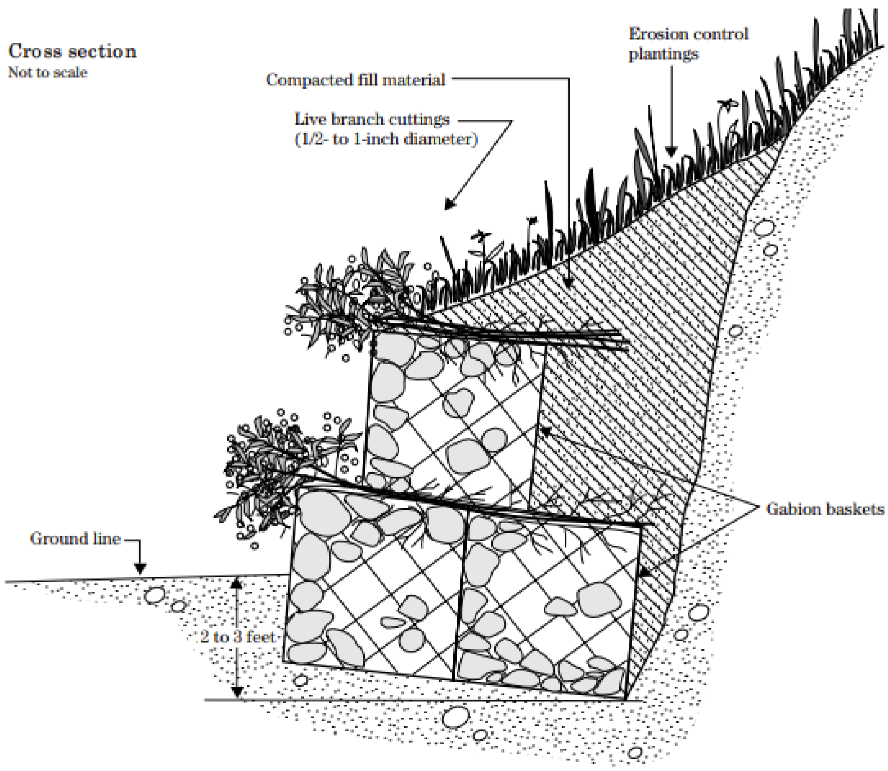

Figure 3.3.2.2-B: Vegetated gabion details. Source: NRCS (1996).

Joint plantings, sometimes referred to as vegetated riprap, are a bioengineered soil technique that involves tamping live cuttings into soil between the joints or open spaces in conventional riprap that is already set in place. Joint planting is ideal where riprap is required. This technique aids in soil moisture removal, preventing soil from washing out below the riprap, and in slope stability. Cut live branches one-half to one and one-half inches in diameter and long enough to extend into the soil below the riprap. Remove side branches from cuttings while leaving the bark intact. Tamp live branch cuttings into riprap void spaces during or after construction. Ensure the root ends extend into the soil beyond the riprap (Figure 3.3.2.2-C). Mechanical probes may be needed to create pilot holes for the live cuttings. Place cuttings orthogonal to the slope with growing tips protruding from the finished face of the riprap.

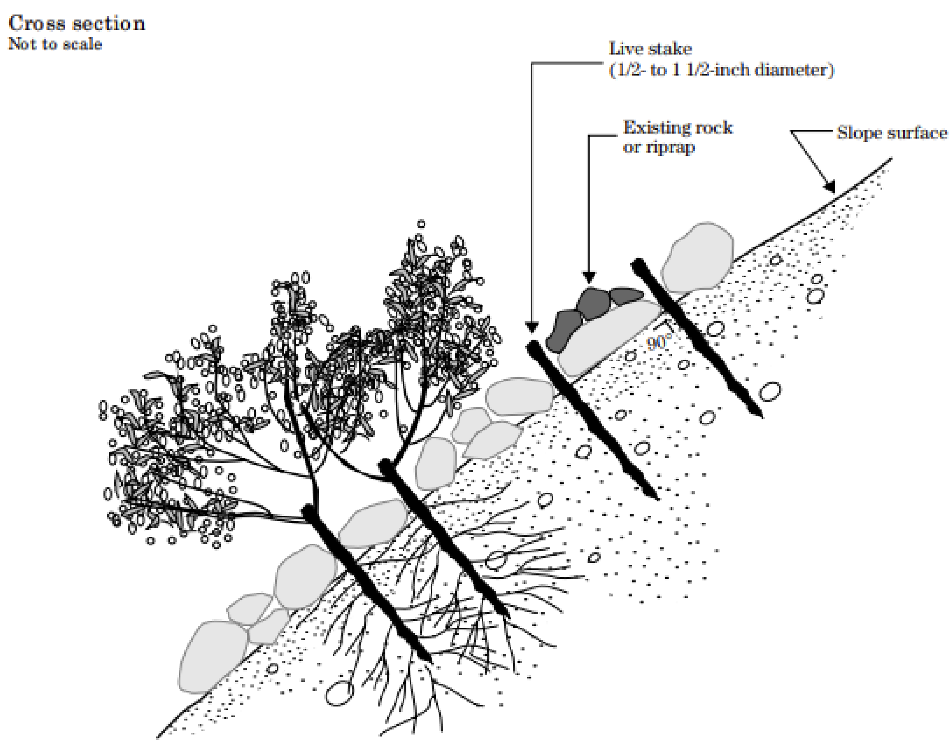

Figure 3.3.2.2-C: Joint planting details. Source: NRCS (1996).

Vegetated mechanically stabilized earth (MSE) walls are soil retaining bioengineered structures designed to stabilize steep slopes while incorporating vegetation to improve environmental benefits. These walls use a porous fascia, and tensile inclusions (reinforcements) integrated into the soil to distribute loads and resist lateral forces. Two common types are geocell systems and wrapped soil systems, each utilizing different materials for the fascia and reinforcements. Geocells contain soil and vegetation, with perforated cells allowing for root growth, while wrapped soil systems use geosynthetic fabric to hold compacted soil layers and support vegetation. The design of vegetated MSE walls requires careful consideration of factors such as slope, wall height, material selection, and geotechnical analysis. These walls can be constructed with various slopes, typically ranging from nearly vertical to 1H:1V, and may incorporate vegetation through seeding or live cuttings, depending on the project needs. A key concern is ensuring the stability of the structure, particularly with respect to shear stresses and erosion protection. Walls are often reinforced with a stone toe to prevent undermining from scour. The structure must be engineered to handle external forces such as overturning, sliding, and soil pressure while ensuring proper drainage and vegetation growth. Design details are presented in Figure 3.3.2.2-D. Consult geotechnical experts when necessary, as factors such as shear stresses, erosion protection, and reinforcement placement are crucial for stability.


Source: TDOT

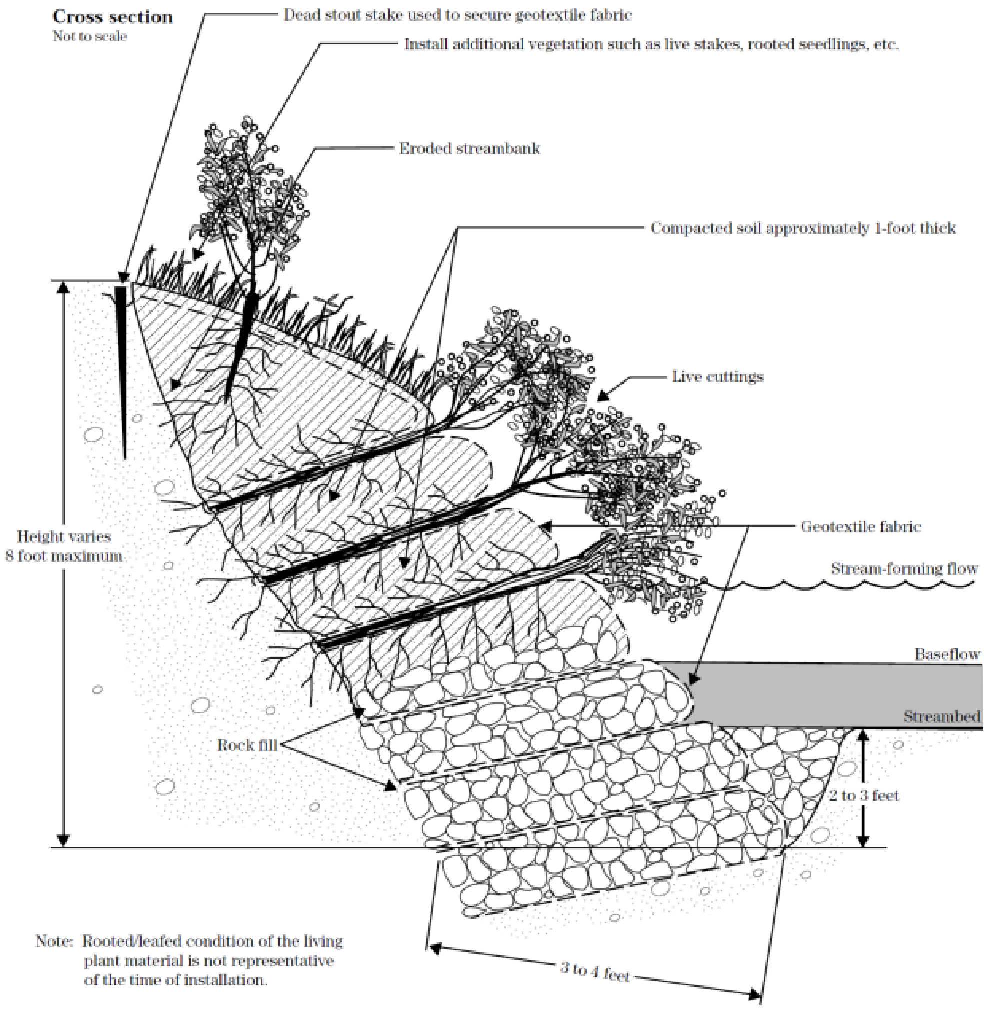

Figure 3.3.2.2-D: Design details of mechanically stabilized earth walls. Source: NRCS (1996).

Geotextile containments are bioengineered soil techniques that are relatively novel and commercially available products. The containment systems vary broadly in design within manufacturers and from manufacturer to manufacturer because of their broad applicability on bank slopes, lake perimeters, coastlines, dunes, etc. Typically, geotextile containments are to be staked below the finished grade at both the top and bottom of the bank. Containments can be filled with eroded sediment, soil fill, etc., and planted to ensure long-term stability. Refer to manufacturer specifications on stake material, stake spacing, alternative tie-down methods, tensile strengths, etc. All geotextile containments must in installed according to such specifications.

Soil bioengineering techniques use live, woody vegetative cuttings to increase slope stability. It can either be a woody vegetation system alone or woody vegetation combined with simple inert structures. Beyond structural benefits, these systems enhance riparian habitats, improve water quality, and offer aesthetic and ecological advantages (ALSWCC, 2022). Native plant species that root easily, such as willow, are ideal for soil bioengineering projects. Use plants that are well-suited to the conditions of each site and sourced locally, either from natural stands or reputable nurseries. However, careful consideration must be given to local wildlife interactions, as some species may pose challenges. For example, in west Tennessee, beavers are particularly drawn to willows, often undermining their effectiveness in stabilizing streambanks by causing additional erosion. When harvesting plant materials, cuttings can range from one-half to two inches in diameter and two to six feet in length, depending on project needs. To ensure regrowth, cut plants at a blunt angle, leaving an eight- to ten-inch trunk above the ground. Once harvested, cuttings are to be bundled, stripped of side branches, and kept moist to preserve viability. Careful handling during transport is essential to prevent damage and drying. It is ideal for cuttings to be delivered to the construction site within eight hours of harvest and installed immediately, particularly in temperatures above 50°F. If short-term storage is necessary, submerge cuttings in water or place them in moist, shaded soil to maintain their integrity for up to two days. For successful establishment, install cuttings during the dormant season, typically from late September to March. Soil conditions must support healthy plant growth, with compacted backfill ensuring proper contact between cuttings and the soil to eliminate air pockets. Thoughtful planning and careful handling of plant materials are essential for a resilient, long-lasting bioengineered streambank. Common slope stability techniques include live staking, live fascines, brushlayering, branchpacking, and brushmattresses.

Live staking is a slope stability technique that involves inserting and tamping live, rootable vegetative cuttings directly into the ground. As these stakes establish, they develop a dense root mat that binds soil particles, reinforces streambanks, and extracts excess moisture, making them particularly effective for stabilizing wet areas and repairing small earth slips. This method is cost-effective, quick to install, and can be used to secure surface erosion control materials or enhance vegetation colonization. Proper preparation includes removing side branches while keeping the bark intact, cutting the bottom end at an angle for easier insertion, and ensuring that the buds face upward. Stakes, typically one-half to one and one-half inches in diameter and two to three feet long, are spaced two to three feet apart in a triangular pattern, with four-fifths of each stake embedded in the soil (Figure 3.3.2.2-E). In firm ground, a pilot hole can be made with an iron bar, and stakes can be driven in using a dead blow hammer. To ensure effectiveness, compact the soil tightly around each stake, and replace any split or damaged stakes.

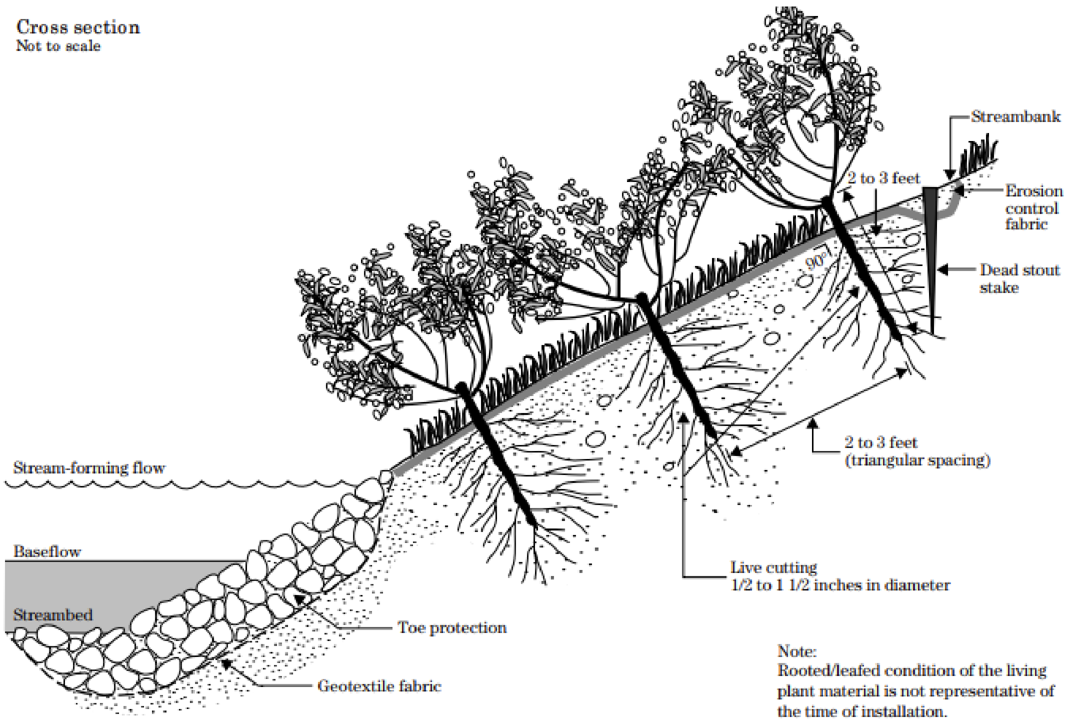

Figure 3.3.2.2-E: Live staking details. Source: NRCS (1996).

Live fascines are a slope stability technique involving cylindrical bundles of branch cuttings strategically placed in shallow trenches that can be ideal for steep or rocky slopes. These structures create a series of shorter slopes that minimize surface runoff and prevent shallow sliding. Typically composed of easily rootable species like young willows or shrub dogwoods, fascines also enhance drainage and encourage the natural colonization of vegetation. When properly installed, they provide immediate surface protection while gradually integrating into the landscape, reinforcing soil stability, and fostering plant growth. Construction involves tying cuttings into bundles, usually six to eight inches in diameter and five to 30 feet long, ensuring that growing tips align in one direction. The bundles are placed in trenches dug along the contour of the slope, secured with untreated twine and dead stout stakes driven at regular intervals. Live stakes are positioned downslope to promote additional root development (Figure 3.3.2.2-F). Proper soil contact is essential, with moist soil packed around the bundles, leaving them slightly exposed to facilitate rooting. Erosion control materials such as jute mesh or coconut netting may be added between rows for extra reinforcement. Over time, the fascines trap sediment, stabilize the soil, and create a microclimate conducive to long-term vegetation establishment.

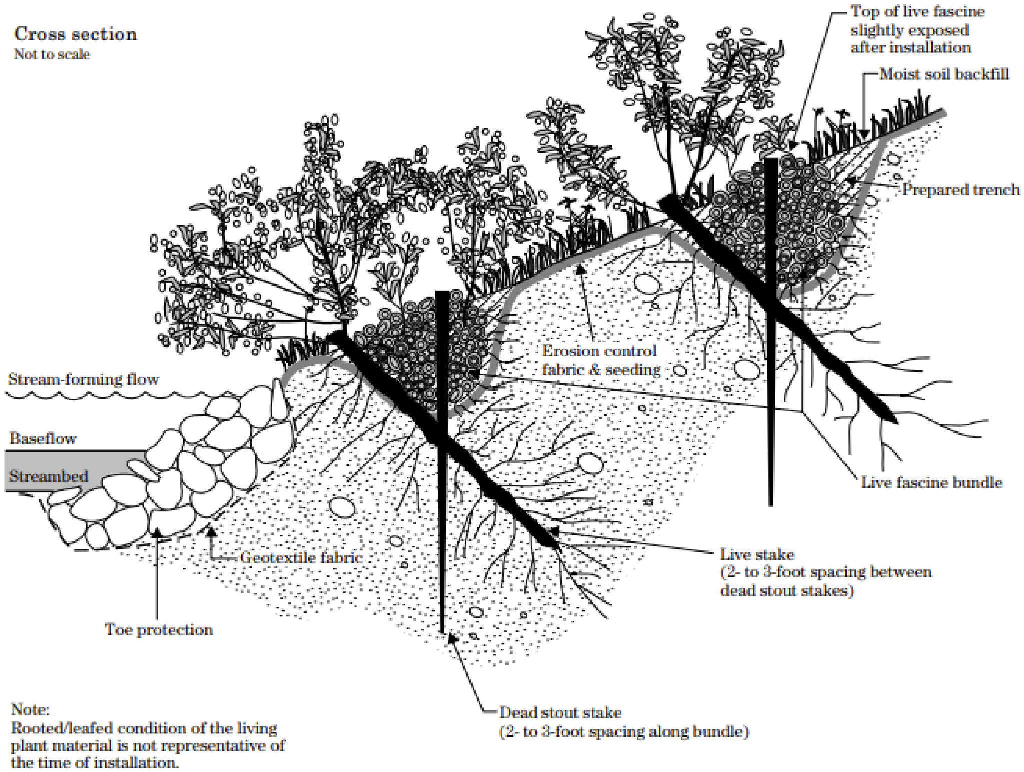

Figure 3.3.2.2-F: Live fascine details. Source: NRCS (1996, 2021).

Brushlayering is a slope stabilization technique that involves embedding live branch cuttings into excavated benches on a slope to provide stability and erosion control. Unlike live fascine systems, brush layering positions the cuttings perpendicular to the slope contour, allowing the protruding branch ends to disrupt surface runoff and reduce erosion. This method is particularly effective on slopes up to 2H:1V in steepness but no more than 15 feet in vertical height. The process begins at the toe of the slope, where horizontal benches, typically two to five feet wide, are excavated on contour or slightly angled downward to facilitate drainage. The benches are sloped inward to direct water away from the slope face. Branch cuttings, ideally from species that root easily, such as willows or shrub dogwoods, are arranged in overlapping or crisscrossed patterns with their basal ends embedded in the back of the bench. A layer of soil, sourced from the next upslope bench, is placed over the root ends, compacted to remove air pockets, and built up in six to eight-inch lifts until the desired thickness is achieved. Ensure the growing tips of the cuttings extend beyond the slope face

to help trap sediment and aid vegetation establishment. This technique provides immediate soil reinforcement through the unrooted stems while offering long-term stabilization as the cuttings take root and develop into mature vegetation. The live stems act similarly to geotextiles, increasing frictional resistance and preventing shallow slides. Brushlayering also serves multiple ecological functions, including breaking up long slopes into smaller segments to slow surface runoff, trapping debris, adjusting microclimates for seed germination, and redirecting slope seepage. On slopes with a gradient of 3H:1V, long straw or similar mulch can be applied between brush layers, while steeper slopes require additional reinforcement with jute mesh or other erosion control materials. Over time, the rooted branches integrate into the slope, enhancing stability, improving infiltration, and fostering the natural regeneration of vegetation.

Branchpacking is a slope stability technique that involves layering live branches with compacted soil to repair small slumps or holes in slopes. This method is particularly effective for reinforcing earth in small fill sites where erosion control and mass stability are needed. Typically used on areas no deeper than four feet and no wider than five feet, branchpacking relies on the mechanical reinforcement provided by both the branches and wooden stakes. The process begins by driving wooden stakes, ranging from five to eight feet in length, vertically into the ground at one to one and a half foot intervals. The lowest point of the slump is treated first. A layer of live branches, about three to six inches thick, is placed between the stakes, with their growing tips extending slightly beyond the face of the slope, while the root ends touch the undisturbed soil at the back of the hole. Each layer of branches is followed by a layer of compacted soil to ensure close contact between the cuttings and the backfill. This alternating process continues until the hole is completely filled, and the final installation blends seamlessly with the natural slope (Figure 3.3.2.2-G). Branchpacking provides immediate reinforcement to the soil while promoting long-term stability as the live cuttings take root and establish vegetation. The protruding branches serve to slow surface runoff, trap debris, and reduce the risk of shallow slides by increasing friction within the slope. Over time, as the branches develop into rooted plants, they enhance the slope’s resistance to shear displacement and further strengthen the embankment. This technique is not suitable for repairing larger slumps but is highly effective for stabilizing minor earth movements and maintaining slope integrity. To maximize effectiveness, keep the soil moist throughout the installation to prevent drying of the live cuttings and properly trim the terminal buds to encourage lateral sprouting.

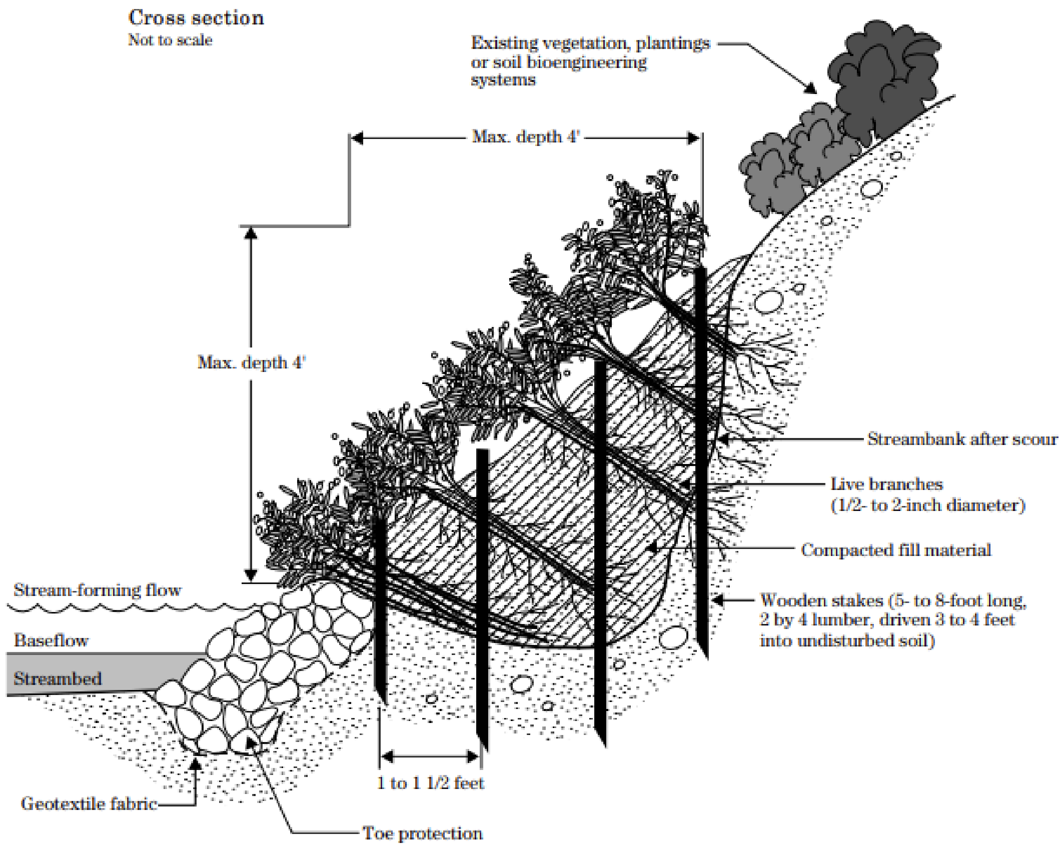

Figure 3.3.2.2-G: Branchpacking details. Source: NRCS (1996, 2021).

A brushmattress is a slope stability technique that integrates live stakes, live fascines, and branch cuttings to stabilize streambanks. Installed from the base of the slope upward, it provides immediate erosion control, making it particularly useful for steep, fast-flowing streams. Beyond structural reinforcement, it captures sediment during floods, rapidly restores riparian vegetation, and fosters conditions for native plant colonization, enhancing streamside habitat. The construction of a brushmattress requires flexible branches, typically six to nine feet long and about one inch in diameter, secured with untreated twine and wire. Installation begins by grading the unstable bank to a gradual slope, followed by excavating a trench at the base to anchor the vegetation. Live and dead stout stakes are driven into the slope in a uniform grid to secure the brush layer, with live fascines placed over the basal ends of the branches (Figure 3.3.2.2-H). Thin layers of soil are added between the branches to encourage rooting while leaving the surface slightly exposed. This method not only reinforces the streambank but also accelerates ecological recovery, blending natural function with long-term stability.

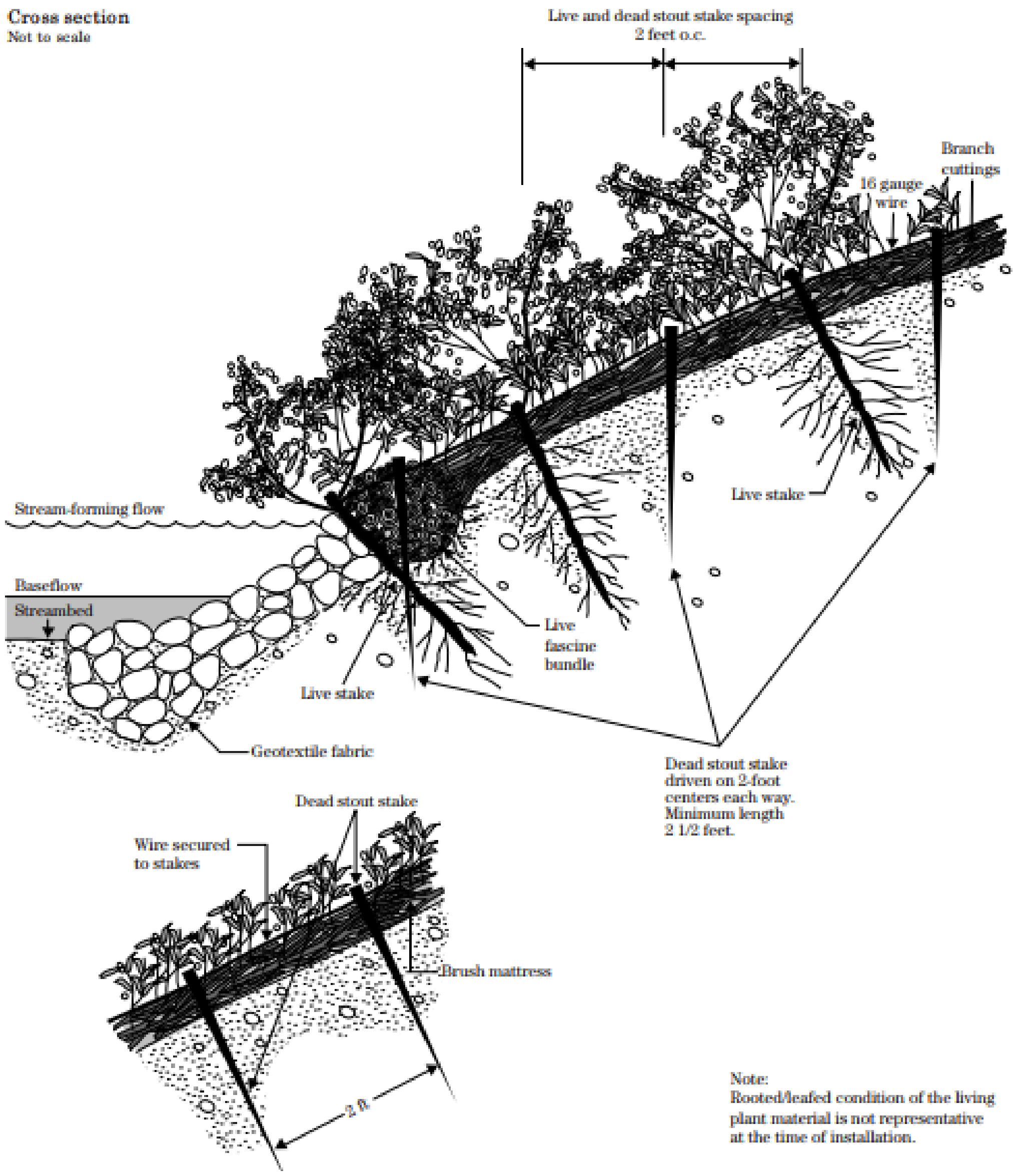

Figure 3.3.2.2-H: Brushmattress details. Source: NRCS (1996).

Designers are referred to NRCS (1996, 2021) for additional bioengineered soil bank stability and slope stability techniques if none of the presented material herein are suitable or desirable for specific project constraints. Though less commonly implemented, other techniques presented in the referenced material are allowable for use in construction sites with coverage under the Tennessee CGP.

Example Application

-Example courtesy of TDOT-

Given:

A channel bank approximately 6 feet high and 50 feet long is experiencing bank stability problems. The stream has a bedrock channel bed and hydraulic analysis indicated that the channel velocity in the 50-year flood event is 7.23 ft/s.

Determine:

The quantity of vegetated gabions for this project.

Solution:

Utilizing the Geotechnical Engineering Section in TDOT, it has been determined that sufficient structural integrity can be achieved by stacking two rows of gabions to form a near vertical wall. To meet the 6 foot height of the channel bank, it is determined that the wall should be constructed to 3 × 3 × 6 ft gabion baskets. Further, lateral stability will be ensured by cutting a shallow groove into the exposed basket to serve as a foundation for the gabion wall.

Based on the hydraulic analysis for the 50-year event, it is determined that machined riprap Class B would be required (Tables 3.3.2.1-A and 3.32.1-C). Although the velocity appears somewhat high for the structure of gabions, it is anticipated that the presence of vegetation along the structure will reduce flow velocities and thus prevent abrasions on the wire coatings.

Each layer of the wall will be constructed by placing 3 x 3 x 6-foot gabions end to end. Thus, 9 gabions will provide a length of 54 ft, and an additional gabion will be placed to provide a sufficient length of erosion protection past the end of the curved section of the channel alignment (60ft). Thus, the wall will contain 20 gabions, each with a volume of 54 ft^3 for a total volume of 1080 ft^3 or 40 cubic yards. The geotextile will be placed across the top and down the inside face of the wall. In order to provide additional protection against the piping of fill through the wall, an additional length of 3 ft will be placed on the bedrock at the toe of the wall to form an apron. Thus, the total surface area of the geotextile may be computed as:

$$A = W \times L = (3 + 6 + 3) \times 60 = 720 \text{ ft}^2 = 80.0 \text{ square yards.}$$

-Example courtesy of TDOT-

Given:

Vegetated riprap is proposed on a 200-foot reach of a small stream. The stream has a bottom width of 5 feet and 1.5H:1V side slopes. Hydraulic analysis of the stream for the channel forming discharge yields a flow depth of 2.5 feet and a velocity of 3.7 ft/s. The hydraulic analysis for the 50-year event yields a flow velocity of 5.66 ft/s.

Determine:

The quantity of vegetated riprap for this project.

Solution:

Based on the hydraulic analysis for the 50-year event, it is determined that machined riprap Class B would be required (Tables 3.3.2.1-A and 3.3.2.1-C). Based on TDOT standard specifications, the minimum depth of the riprap layer should be 2.5 feet.

The height along the slope over which riprap is to be installed will be equal to 1.5 times 2.5 feet, which is 3.75 feet. The quantity of vegetated riprap for each side of the channel can be determined by computing the required volume of riprap as follows:

$$V = H \times D \times L = 3.75 \times 2.5 \times 200 = 1875 \text{ ft}^3$$

Thus, the total volume for both sides of the channel will be 3750 ft^3 which can be divided by 27 to determine the final quantity of 139 cubic yards.

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3.3.2.3 Temporary Instream Diversion

Source: TDOT

Definition and Purpose
Instream diversions use temporary dikes to redirect stream baseflow, allowing for construction activities such as multi-barrel box culverts, bridges, bank stabilization, structural repairs, and intake or outfall installations. This method typically channels water into an existing or newly built barrel, keeping other construction areas dry. By isolating the work zone from the active flow of water, instream diversions help minimize sediment transport and protect water quality.

Appropriate Applications
Instream diversions are practical solutions for projects requiring instream work, particularly when constructing multiple barrel structures. When properly phased, they can also accommodate projects where roadway traffic must be maintained during construction (TDOT). Where applicable, an instream diversion may be more cost-effective than a temporary diversion channel or a temporary diversion culvert.

Limitations and Maintenance
Instream diversions are designed to convey low flow conditions as opposed to a design event like temporary channels or culverts. As a result, they are more susceptible to overtopping during rainfall. When selecting a diversion method, evaluate both the duration of construction and the potential impacts of flooding within the work area. Dewatering

practices used for the diversion will need to be maintained to function as intended (Section 4.4.12.2).

Installing instream diversions in jurisdictional waters requires additional permits, such as an ARAP, and therefore, both the conditions of the CGP and ARAP must be followed. A Section 404 permit from USACE may also be required, and if the proposed instream diversion is to be completed in a TVA reservoir, a TVA 26a permit may also be necessary. Consider the criteria and conditions of the necessary permits during the planning stages of the project and EPSC plans.

Planning and Design Considerations
Effective instream diversions require careful sequencing to ensure both regulatory compliance and functional efficiency. The symbol and detail can be shown in the plan set with generalized sequencing notes. These notes not only assist TDEC reviewers in verifying compliance with the CGP but also establish a foundation for more detailed sequencing notes once a contractor is selected. After a contractor is hired, refine and update these notes, as necessary, on the plan sheets to reflect the specific construction approach. Ultimately, the permittee bears responsibility for ensuring that all permit conditions are met before approving the work.

To ensure effective flow management, set the diversion elevation at least one foot above the baseflow elevation within the reduced channel width of the stream (TDOT). Though not required in the state of Tennessee, some states implement side slope limitations of the diversion to 2H:1V (ALSWCC, 2022; GSWCC, 2016). For projects requiring uninterrupted roadway access during construction, the engineer may need to extend the overall length of the box structure to accommodate traffic considerations.

To assess whether the instream diversion can adequately accommodate baseflow under various channel configurations, the following methodology is recommended (TDOT):

1. *Estimate flow characteristics*: Determine the typical width and depth of flow within a representative section of the stream under normal conditions. This can be achieved using field measurements, aerial imagery, or site topographical data.
2. *Calculate cross-sectional flow area*: If the channel is rectangular, multiply the estimated flow depth by the stream width to compute the total cross-sectional flow area. For other channel configurations, refer to Table 2-A.
3. *Determine diverted flow depth*: Identify the width of flow through the diversion channel and divide the original cross-sectional area by this new width to estimate the depth of flow in the diverted section, if rectangular. For other geometries, refer to Table 2-A.

4. *Verify wetted perimeter*: Compute and compare the wetted perimeter of both the natural stream cross-section and the diverted section (Table 2-A). If the diverted section exhibits a greater wetted perimeter, it indicates excessive channel narrowing. In such cases, adjust the design to provide a wider flow width to prevent excessive flow constriction.
5. *Establish final diversion height*: Set the final elevation of the diversion at least one foot above the newly determined diverted flow depth to ensure adequate containment.

Hydraulic computations for each channel shape are governed by channel geometries (Table 2-A), the Continuity Equation (Eqn 7), and Manning's Equation (Eqns 6 and 8). However, tools can be used to reduce computation time, ensure accurate computations, and/or for less typical cross sectional shapes (Fang, 2007; Mejia & Ponce; Perez et al. 2015) as specified in Section 2.1.2.

Where possible, design the sinuosity of the diverted section to mimic the natural flow path of the stream to minimize hydrologic disruption, such that the diversion length is greater than or equal to the length of the diverted stream portion (ALSWCC, 2022). If excavation is required to achieve the necessary flow dimensions, consider alternative diversion methods rather than expanding the existing stream channel, as widening may introduce unnecessary environmental impacts.

A variety of materials can be employed in constructing instream diversions, with polyethylene sheeting (minimum six mil thickness) commonly incorporated to enhance effectiveness. For instance, integrating polyethylene sheeting within a sandbag berm or draping it over jersey barriers can help maintain flow separation and prevent seepage into the work area.

Conduct dewatering using a pump system once the instream diversion is in place and has successfully isolated the work area from the active flow. Effluent from this operation must be properly managed by directing it through a sediment filter bag (refer to Section 4.4.12.6) or a designated dewatering structure (refer to Section 4.4.12.2) to prevent sediment discharge and maintain water quality standards.

Example Application

-Example courtesy of TDOT-

Given:

An existing slab bridge on vertical abutments with a span of 20 feet is to be replaced by a box bridge with three 12-foot spans. A temporary run around will be used to maintain traffic so that the structure can be replaced without traffic. The designer has determined that an instream diversion may be used at this site.

Determine:

The height for the instream diversion.

Solution:

Step 1- Assume a phasing plan: Although it is the responsibility of the contractor to devise a phasing plan, the designer will need to make an educated guess of the plan in order to estimate lengths for each section of the instream diversions.

Based on the bridge layout plan, it appears that the channel will be shifted somewhat to the west in order to accommodate the increased width of the proposed structure. Thus, it is assumed that the phase 1 instream diversion will extend from the west bank of the channel to the west side of the existing structure. This will maintain flows through the existing structure while allowing the western most barrel of the proposed structure to be built. In phase 2, flows would be diverted into the new barrel of the proposed structure by extending instream diversions from the east bank of the channel to the east side of the new barrel. This will allow the demolition of the existing structure and the construction of the two remaining barrels.

Step 2- Determine heights of the instream diversions: Aerial photography of the site is examined in order to estimate the average water surface width of the stream in the project area. This is found to be 25 feet. In this same area, the project survey data indicated that the flow line of the stream is about 1.2 feet below the elevation at the edge of the water. Thus, the cross-sectional flow area (A) and wetted perimeter (P) of the normal flow are computed following Table 2-A:

$$A = 25 \times 1.2 = 30 \text{ ft}^2$$

$$P = 25 + 2 \times 1.2 = 27.4 \text{ ft}$$

In phase 1, the width of flow in the diverted section will be 20 feet. Since the cross-sectional area of the flow in the diverted section is assumed to be equal to the natural cross-sectional flow area, the depth in the diverted section (d_d) is estimated as:

$$d_d = 30 / 20 = 1.5 \text{ ft}$$

Based on this depth, the wetted perimeter of the flow in the diverted section is computed following Table 2-A:

$$P = 20 + 2 \times 1.5 = 23 \text{ ft}$$

Since the wetted perimeter in the diverted section is less than in the natural section, the flow width will be adequate. Thus, the required minimum height of the instream diversion will be 2.5 feet.

In phase 2, the width of the diverted section will be reduced to 12 feet. Using the same process as described above, the depth in the diverted section is found to be 2.5 feet, and the wetted perimeter is found to be 17 feet. Again, the wetter perimeter in the diverted section is found to be less than that in the natural section, and the height of the instream diversion will be 3.5 feet.

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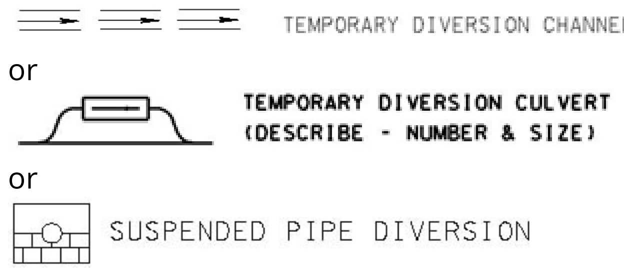
3.3.2.4 Temporary Stream Diversion



Source: TDEC

Definition and Purpose

Temporary stream diversions are implemented to redirect baseflow from active construction areas, such as bridges and culverts, allowing work to proceed in dry conditions. By isolating construction from the active flow of water, these diversions effectively minimize sedimentation and protect water quality, reducing potential environmental impacts associated with in-stream disturbances.

Appropriate Applications

Stream diversions are used where work in the stream is unavoidable and where the diversion will not cross an existing roadway where traffic is maintained (TDOT). This measure is best suited in low flow conditions. Often, a temporary stream diversion is used for smaller channels where baseflow can be entirely contained in a manmade channel, pipe or conveyed through a pipe temporarily.

Limitations and Maintenance

ALSWCC (2022) and TDOT suggest temporary diversions be constructed in drainage basins smaller than one and two square miles, respectively. Instream diversions may be better suited for larger streams where conveying baseflow is more challenging.

Installing instream diversions in jurisdictional waters requires additional permits, such as an ARAP, and therefore, both the conditions of the CGP and ARAP must be followed. A Section 404 permit from USACE may also be required. If the proposed diversion is to be completed in a TVA reservoir, a TVA 26a permit may also be necessary. Consider the criteria and conditions of the necessary permits during the planning stages of the project and EPSC plans.

Inspect stream diversion channels at the end of each day to ensure flow control measures and construction material are positioned and adequately secured, thereby eliminating material waste downstream. All repairs should be made immediately. Dewatering practices used for the diversion will need to be maintained in order to function as intended (Section 4.4.12.2).

The maintenance for the different temporary stream diversions is type-specific:

Bypass pumps require routine maintenance to remain effective as a stream diversion. Conduct daily inspections to ensure proper pump operation, check temporary piping for leaks, and repair any damage to the impervious dike. The discharge point must be monitored for potential erosion, and flow should be confirmed as adequately diverted through the pipe. Bypass pumping may not be suitable when discharge locations cannot be stabilized, ponding to submerge the suction line is impractical, or the pump cannot handle normal flow within the stream.


Source: NCDOT (2003)

Suspended pipe diversions require regular inspections of the inlet and impervious dike to confirm no damage or leakage and to confirm proper flow diversion. Regularly clear sediment and debris from behind the dike and inlet to prevent blockages. The outlet must also be checked for potential erosion and to ensure the system is functioning effectively. Additionally, the inlet should be securely anchored and sealed to maintain stability.

Piped diversions require frequent inspections for any signs of damage or malfunction. Accumulated sediment and debris must be removed from the berm and inlet to maintain unobstructed flow. Monitor the outlet for erosion potential, and any diverted flow bypassing the temporary pipe must be addressed as soon as possible to prevent surface erosion.


Source: TDOT

Fabric-lined diversion channels require regular inspection for stability under normal flow conditions and following all rainfall events. Signs of displacement or failure must be addressed promptly. It is essential to ensure that earthen material does not come into direct contact with the water body to prevent contamination and maintain water quality.

Planning and Design Considerations

Disturbance within the confines of stream banks is required to be conducted during dry weather or separate from flowing water. Operation of excavation equipment is not to take place in flowing waters. Minimize the duration of the instream work as well as clearance of the stream- bed and banks.

Common temporary stream diversions include bypass pumping, suspended pipe diversions, piped diversions, and fabric-lined diversion channels. Diversions that use impervious dikes or berms require methods for potential stormwater entering the construction area, such as pumping stormwater from the work area to a sediment filter bag (Section 4.4.12.6) that is placed downstream near the top of the bank. Consider placing the EPSC measure outside of the designated buffer zone or at least the minimum buffer distance required in the CGP. Regardless of the type of stream diversion chosen, ensure the dimensions of the diversion can adequately convey the bankfull capacity of the stream (ALSWCC, 2022) or the required design flow, which is specified by either the CGP or local standards.

Use bypass pumping during low flow conditions to minimize land disturbance. This method involves using a bypass pump along with an impervious dike or berm to redirect water from an upstream section to a downstream section through controlled pumping. Since this process transfers water directly from one point to another, it is crucial to discharge at a low flow rate to prevent erosion at the outlet. Bypass pumping is most effective for short-duration construction activities that do not require prolonged water diversion. Construction specifications include:

- Set up bypass pump and hose. Place the hose outlet in such a way to minimize erosion at the discharge site or provide temporary energy dissipation measures. Consider anchoring the pump and hose;
- Construct outlet protection if needed for the diverted water so as not to create erosion;
- Construct an impervious dike or berm upstream of the work area to impound water for the bypass pump intake. Consider using a floating intake for pumps;
- Construct an impervious dike or berm downstream to isolate the work area;
- Check the operation of the pump system. Have an operation plan in place for when the pump will be run and who will manage it if it is not automatic; and

- Upon completion of construction, stabilize the work area in the stream and then remove the impervious dikes or berms, bypass the pumping system.

Use the suspended bypass pipe where an existing pipe or culvert is extended and is large enough to accommodate the bypass pipe. This bypass pipe is constructed inside the existing pipe or culvert to divert the watercourse through the construction area, thereby keeping the work area dry. Construction specifications include:

- Install a temporary pipe through the existing pipe or culvert to be extended. Place outlet of temporary pipe to minimize erosion at discharge site or provide temporary energy dissipation measures;
- Construct an impervious dike or berm upstream of the work area to divert flow through the temporary pipe. Anchor and seal the temporary pipe securely at the inlet;
- Construct an impervious dike or berm at the downstream side of the bypass pipe to isolate the work area; and
- Upon completion of the culvert or pipe extension and once the work area is stabilized, remove the impervious dikes or berms and the temporary pipe.

Temporary pipes are used to divert the small flows around the work area without the use of pumping operations. While the cost is higher for this operation than an open plastic-lined channel, the probability of sediment loss is much lower than with an open diversion channel. Use this practice where adequate slope and space exist between the upstream and downstream ends of the diversion. Construction specifications include:

- Install a temporary pipe adjacent to the work area. Excavation may be required to provide a positive drainage slope from the upstream to the downstream side;
- Connect the downstream temporary pipe to the existing downstream channel. Place outlet of pipe to minimize erosion at the discharge site or provide temporary energy dissipation measures;
- Connect the upstream temporary pipe to the upstream existing channel;
- Construct an impervious dike or berm at the upstream side of the existing channel to divert the existing channel into the temporary pipe;
- Construct an impervious dike or berm at the downstream side of the bypass pipe to isolate the work area; and
- Upon completion of construction, stabilize the disturbed area, then remove the impervious dikes or berms and temporary pipe.

A fabric lined temporary diversion channel is used to divert normal stream flow and small storm events around the work area without the use of pumping operations. The temporary diversion channel is typically constructed adjacent to the work area and is stabilized by lining with a geotextile fabric (Type III) to minimize the potential for erosion within the temporary diversion channel (TDOT). Ensure the selected lining can withstand design velocities per Tables 3.3.2.1-A and 3.3.2.1-B, as well as per manufacturer specifications (ALSWCC, 2022). Geotextile linings alone may not be sufficient to prevent erosion. In cases where design velocities exceed two and a half feet per second, consider the use of conventional riprap or other structural linings in addition to geotextiles (TDOT). Use this practice where adequate space and slopes exist adjacent to the work area. Avoid creating steeper slopes than preexisting natural conditions. Consider alternative methods in summer months, as plastic linings can thermally enrich stream water. Though this is not a CGP requirement, many aquatic species in Tennessee are sensitive to thermal fluctuations. Construction specifications include:

- Excavate the diversion channel without disturbing the existing channel. Ensure the dimensions of the channel can convey the design flow. Refer to Section 3.3.2.3 to adequately size a channel;
- Place poly-fabric liner in the diversion channel with a minimum of 4 feet of material overlapping the channel banks. Secure the overlapped material using at least 1 foot of fill material. Ensure the liner and fill material can withstand the velocity of water during the design flow. Refer to Section 4.2.6.1 to adequately line a channel;
- Connect the downstream diversion channel into the downstream existing channel and secure the poly-fabric liner at the connection;
- Connect the upstream diversion channel into the upstream existing channel and secure the poly fabric liner at the connection;
- Construct an impervious dike or berm in the existing channel at the upstream side to divert the flow into the diversion channel;
- Construct an impervious dike or berm in the existing channel at the downstream side to isolate the work area and capture any construction stormwater;
- Dewater the work area of any construction stormwater through a sediment filter bag or similar, as needed;
- Upon completion of construction and stabilization of the work area, remove the impervious dikes or berms and divert the channel back into the newly constructed reach or culvert;
- Remove the poly-fabric liner and fill in the diversion channel to the previous grade unless new elevations are shown on the plans; and
- Establish vegetation on all disturbed areas.

Example Application

No formal design or quantities are required for most of the temporary stream diversions. For designing a fabric-lined diversion channel, refer to Section 3.3.2.3 for an example regarding the sizing of the channel and Section 4.2.6.1 for lining the channel.

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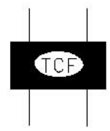
3.3.2.6 Temporary Construction Ford



TEMPORARY CONSTRUCTION FORD

Source: TNWRRC

Definition and Purpose

A temporary construction ford is a short-term erosion control measure designed to facilitate the movement of construction vehicles and equipment across ditches, swales, or shallow watercourses without causing damage to the channel or increasing sediment transport. Typically, it consists of a layer of stone placed over geotextile fabric to create a stable crossing while minimizing erosion and sediment disturbance. This method ensures that intermittent flows are not obstructed or contaminated while providing a durable access point for construction activities.

Appropriate Applications

Temporary construction fords are ideal for short-term crossings where wide, shallow depressions, side ditches, or intermittent swales must be traversed during construction. They are most applicable in areas where alternative access routes are impractical, construction activities are expected to last less than a year, crossings are relatively infrequent, and channel banks do not exceed five feet in height (TDOT). These fords provide a stable and efficient solution for moving light-duty construction vehicles across drainage features. Crossing with heavy-duty equipment may be appropriate, depending on the size of the stream.

Limitations and Maintenance

Temporary construction fords must be designed to allow unimpeded water flow, minimizing the risk of upstream ponding. It is best if the accumulation of water does not exceed 12 inches or half the height of existing banks, whichever is smaller (TDOT). Regular inspections, particularly after runoff producing events, are essential to identify and address blockages, erosion, riprap displacement, or other structural issues. Further, inspections after runoff producing events are critical to ensure that upgradient EPSC measures are effective in keeping sediment away from the ford. Prompt repairs are necessary to prevent further degradation and full effectiveness of the ford.

Because construction fords are not suitable for use in larger streams, wetlands, jurisdictional water bodies, or water bodies with ecological significance, it is unlikely an ARAP will be required. Additionally, other permits, such as a Section 404 permit from USACE or a TVA 26a permit, are likely not necessary. However, it is best practice to refer to the CGP to understand if the watercourse meets the criteria of a stream. Any additional permits and their conditions are to be considered during the planning stages of the EPSC plans.

Planning and Design Considerations

When planning and designing a temporary construction ford, it is best for the construction to take during periods of dry conditions to minimize disturbance. The ford is to be positioned perpendicular to the watercourse whenever possible, with any necessary skew limited to 15 degrees. The location chosen for crossing is to minimize disruption to the channel banks , bottom, and riparian area. To ensure stability and accessibility, the approach slopes are not to exceed 5H:1V, and any excavated materials are to be removed by pulling it back rather than pushing it into the watercourse. The crossing width ranges between 12 and 20 feet, with side slopes no steeper than 2H:1V (TDOT).

Erosion control measures are to be incorporated to prevent surface runoff from construction roads from entering the watercourse, such as low berms or diversions placed along the channel. The ford itself consists of a 12-inch layer of Class A-3 conventional riprap placed over Type III geotextile fabric to provide stability.

Once the ford is no longer needed, all materials will be removed, and the channel banks restored to their original dimensions. Exposed soil must be stabilized with appropriate erosion control methods, such as seeding with mulch or erosion control blankets. Properly designed and installed temporary fords allow for safe, short-term vehicle crossings while minimizing sedimentation and hydrologic impacts.

Example Application

-Example courtesy of TDOT-

Given:

A temporary construction ford is to be constructed across a roadway side ditch. The ditch has a bottom width of 4 feet, side slopes are 3.5 feet high at slopes of 3H:1V and is grass-lined.

Determine:

The required quantities and dimensions for the crossing include:

a.) Length of the excavation along the bank
b.) Volume of the excavation along the bank
c.) Volume to be excavated on the ditch bottom
d.) Total excavation volume
e.) Area and volume to be covered by riprap as well as the total amount of conventional riprap.

Solution:

a.) Since the ditch has a grassed lining, the bottom will be excavated to a depth of 12 inches in order to provide a firm base for the stone layer and to ensure that it will not cause an obstruction to flow. Thus, the total height from the bottom of the excavation to the point where the excavated slope meets the existing grade will be 4.5 feet. Since the approaches will be excavated to a 5H:1V slope, the length of the excavation on one side will be:

$$L = H \times Slope = 4.5 \times 5 = 22.5 \text{ ft; use } 23 \text{ ft}$$

b.) The volume within the excavated area on one bank will be equal to the length of the excavation times the average cross sectional area of the excavation. Since the proposed ford will have a width of 12 feet, and the side slopes of the excavation will be 2H:1V, the cross sectional area adjacent to the channel may be computed as a trapezoid:

$$Area_{channel} = b \times H + Slope \times H^2 = 12 \times 4.5 + 2 \times 4.5^2 = 94.5 \text{ ft}^2$$

Since the cross sectional area is zero where the excavated slope meets the existing grade, the average cross sectional area may be computed as half of the area adjacent to the channel, or 47.3 SF. Thus, the total volume of excavation for one side of the channel is:

$$V = L \times A_{avg} = 23 \times 47.3 = 1087.9 \text{ ft}^3$$

However, a large portion of this volume is "empty air" above the exiting ditch side slope. As stated above, the height of the channel is 3.5 feet. Thus, the length along the 3H:1V slope is:

$$L = H \times Slope = 3.5 \times 3 = 10.5 \text{ ft}$$

Using similar logic as was employed above, the volume of "empty air" above the channel side slope may be computed as:

$$Air_{empty} = ½ \times (12 \times 3.5 + 2 \times 3.5^2) \times 10.5 = 349.1\ ft^3$$

The net volume to be excavated on one side of the channel may then be computed as:

$$V_{side} = V – Air_{empty} = 1087.9 – 349.1 = 738.8\ ft^3$$

c.) The volume to be excavated on the ditch bottom may be computed as:

$$V_{bottom} = H \times b \times W = 1 \times 12 \times 4 = 48\ ft^3$$

d.) The total volume to be excavated is thus:

$$V_{total} = V_{side.1} + V_{side.2} + V_{bottom} = 738.8 + 738.8 + 48 = 1525.6\ ft^3 = 56.5\ yard^3$$

e.) The total length of the ford is 50 feet (23 feet on each side plus the 4 foot width of the ditch). Since the width of the ford will be 12 feet, the area covered by riprap will be:

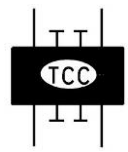
$$A_{riprap} = W \times L_{total} = 12 \times 50 = 600\ ft^2$$

Since the depth of the riprap will be 1 foot, the volume will be 600 ft^3, which is equal to 22.2 $yard^3$. If the weight of riprap is 1.75 tons per cubic yard, the final quantity of riprap is 38.9 tons.

References

TDOT. *Drainage Manual Ch10*. Retrieved from https://www.tn.gov/tdot/engineering-division/engineering-production-support/design-standards/drainage-manual.html

3.3.2.7 Temporary Culvert Crossing



TEMPORARY CULVERT CROSSING

Source: TDEC

Definition and Purpose

A temporary culvert crossing consists of pipes or culverts placed within a flowing stream or watercourse and covered with clean stone or riprap to provide site access for construction vehicles. As the most common type of stream crossing, culverts are cost-effective, readily available, and capable of supporting heavy equipment. They are an effective means to stream crossings without causing damage to the stream bed, channel, or banks during use; however, they may contribute to erosion during installation and removal.

Appropriate Applications

Temporary culvert crossings can be installed where construction traffic cannot be routed around a stream. Culvert crossings are an ideal measure for crossings with heavy machinery, where many crossings occur throughout the workday, and when the channel is too wide for normal bridge construction (VDEQ, 2024).

Limitations and Maintenance

Storms larger than the design event may yield significant damage to the crossing such as wash outs, blockages, overtopping, or loss of materials. Larger streams may not be suitable to have temporary culvert crossings, due to the amount of drainage area and flow that is draining to that point.

Inspect the crossing after every rainfall and at least twice a week during required inspections. Repair any damage to the crossing as soon as possible. Unstable stream banks require lining with conventional riprap or appropriate stabilization measures.

Installing temporary culvert crossings in jurisdictional waters requires additional permits, such as an ARAP, and therefore, both the conditions of the CGP permit and ARAP must be followed. A Section 404 permit from USACE may also be required. If the proposed crossing is to be completed in a TVA reservoir, a TVA 26a permit may also be necessary. Consider the criteria and conditions of the necessary permits during the planning stages of the project and EPSC plans. Temporary culvert(s) may not be permitted in streams with sensitive or endangered aquatic life. Culverts may create hydraulic jumps or fish barriers, thereby preventing passage (see example photograph) if they are not installed correctly. Temporary culverts should only be constructed when necessary as they create the greatest obstructions to flood flow and aquatic habitat (GSWCC, 2016).


Source: GSWCC (2016)

Planning and Design Considerations

The culverts used for the temporary culvert crossing can vary in shape, size, and material (GSWCC, 2016; VDEQ, 2024). The design of the temporary culvert crossing requires hydrologic and hydraulic analysis to ensure they can safely convey expected flow rates and velocities. This is necessary to compute the ideal number, diameter, and length of pipe. Include all design specifications in the EPSC plans.

There are various planning and design considerations to be aware of before constructing temporary culvert crossings. The crossings need to be protected from washout during periods of high flows. This can be achieved by diverting high flows around or over the structures. To limit disturbances and preserve the local ecosystem to the maximum extent possible, implement the following (TDOT):

- Limit the clearing or riparian vegetation as much as possible;
- During installation, divert the flowing water around the structure;
- Design the crossing perpendicular to the stream to impede flow as little as possible;
- Design the crossing to support the maximum anticipated loads such that maintenance burdens are not repeatedly observed;
- Place culverts on the streambed to minimize fish blockages and hydraulic jumps; and
- Extend the culverts at least one foot beyond the upstream and downstream toe of placed aggregate.

The culverts need to be sized to convey the peak flow from the designated design storm: either the 2-year, 24-hour, or 5-year, 24-hour, depending on the quality of the stream. Further, recurrence intervals may be different per local regulations. The minimum pipe size suggested is 18 inches (TDOT). The diameter of *circular pipes* can be computed following a reformulated version of Manning's Equation (Eqn 15):

$$D = 16 \times \left(\frac{q_p \times n}{\sqrt{S}}\right)^{3/8} \qquad \text{(Eqn 15)}$$

where D is the pipe diameter (inches), q_p is the peak flow rate (cubic feet per second), n is Manning's roughness coefficient (unitless), and S is the pipe slope (feet per foot). Round the computed pipe diameter up to the next common size. Rounding up the pipe diameter changes the peak flow capacity, hydraulic radius, wetted perimeter, etc., and therefore, also the peak velocity (V_P) in the pipe.

A single culvert may result in a pipe diameter too large for the channel dimensions. In such cases, Table 3.3.2.6-A provides the equivalency of pipe capacities. For example, a 36-inch pipe has the capacity of three 24-inch pipes. When multiple culverts are desired, they should be separated by one-half the diameter of the culvert or 12 inches, whichever distance is greater.

Table 3.3.2.6-A: Number of smaller diameter culverts (top row) required to achieve the same flow capacities as larger diameter culverts (first column). Source: Wisconsin Tubing.

Diameter (in)	18	24	30	36	42	48	54
18	1						
24	2	1					
30	3	2	1				
36	5	3	2	1			
42	7	4	3	2	1		
48	10	5	3	2	2	1	
54	13	7	4	3	2	2	1
60	16	8	5	4	3	2	2
66	20	10	6	4	3	2	2
72	25	12	8	5	4	3	2
84	35	18	11	7	5	4	3

Before placement of the pipe culvert(s) and aggregate, place a geotextile fabric on the stream- bed and banks to prevent subgrade sediment migration. Ensure the geotextile covers the streambed and extends a minimum of six inches and a maximum of one foot beyond the end of the culvert and bedding material. Cover the culvert(s) with clean small, riprap, such as Class A-1, such that the depth of conventional riprap above the top of the culvert is one-half the diameter of the culvert or 18 inches, whichever is greater. Use a geotextile fabric to separate the Class A-1 riprap from No. 57 stone, which is to be used as the top six inches of the crossing. For sites that are crossing an ETW or waters with unavailable parameters for siltation, use a nine inch layer of Class A-3 riprap instead of the six inches of 57 stone. Crown the top of the culvert crossing in the center of the crossing above the channel banks and grade down to each approach. Extend the conventional riprap past the top of bank of each approach to prevent potential erosion. Ensure the top width of the crossing does not exceed 20 feet.

Provision to prevent construction road runoff from entering the stream is necessary. The preferred method for accomplishing this is to provide low approaches which will form “sag” points on either side of the stream channel (TDOT). Direct runoff into these “sag” points into erosion-resistant areas adjacent to the access road. These low approaches will also facilitate the safe passage of flood flows greater than the design flow rate. If possible, construct the “sag” points such that they are no lower than the crown of the temporary culvert. Where “sag” points cannot be constructed, low berms, six inches high with 5H:1V side slopes may be placed on either side of the channel to divert flows.

The culverts, rock, and geotextile should be removed immediately after construction is finished, and the stream- bed and banks must be stabilized and restored to pre-construction conditions.

Example Application

-Example courtesy of TDOT-

Given:

A temporary culvert crossing is to be constructed across a stream in Wilson County, TN (Type II rainfall distribution) which has the following characteristics:

- Drainage Area = 120 acres (0.1875 square miles)
- Slope of stream at site = 2.0%
- Channel bottom width = 8 feet
- The channel side slopes are 3.5 feet high at a slope of 1.5H:1V
- Runoff Curve Number CN=75 Wilson County, TN
- Time of Concentration, T_c =1 hour
- Assume no pond and swamp areas, F_p =1.

Determine:

The temporary culvert crossing design for this site and compute the required quantities.

Solution:

Step 1- Determine the design flow rate: The design flow rate should be based on the 2-Year, 24-hour storm. The Rational method may be applicable to estimate the design flow rate based on professional judgement (Chapter 2); however, the NRCS method is more appropriate. For a 2-year, 24 hour storm the rainfall depth, P = 3.64 in. Compute the various variables required in Eqn 10 from Section 2.1.3.

a.) Runoff depth, Q_{CN}, Eqns 1-3 from Section 2.1.1:

$$S = 1000 / CN - 10 = 3.33$$

$$I_a = \lambda \times S;\ \text{assume } \lambda = 0.2$$

$$I_a = 0.2 \times 3.33 = 0.667 \text{ in}$$

$$Q_{CN} = \frac{(P - I_s)^2}{P - I_a + S} = \frac{(3.64 - 0.667)^2}{3.64 - 0.667 + 3.33} = 1.4 \text{ in.}$$

b.) Unit peak discharge, q_u:

$$I_a / P = 0.667 / 3.64 = 0.183$$

q_u = 340 csm/in (Exhibit 4-II or 5-II, NRCS, 1986)

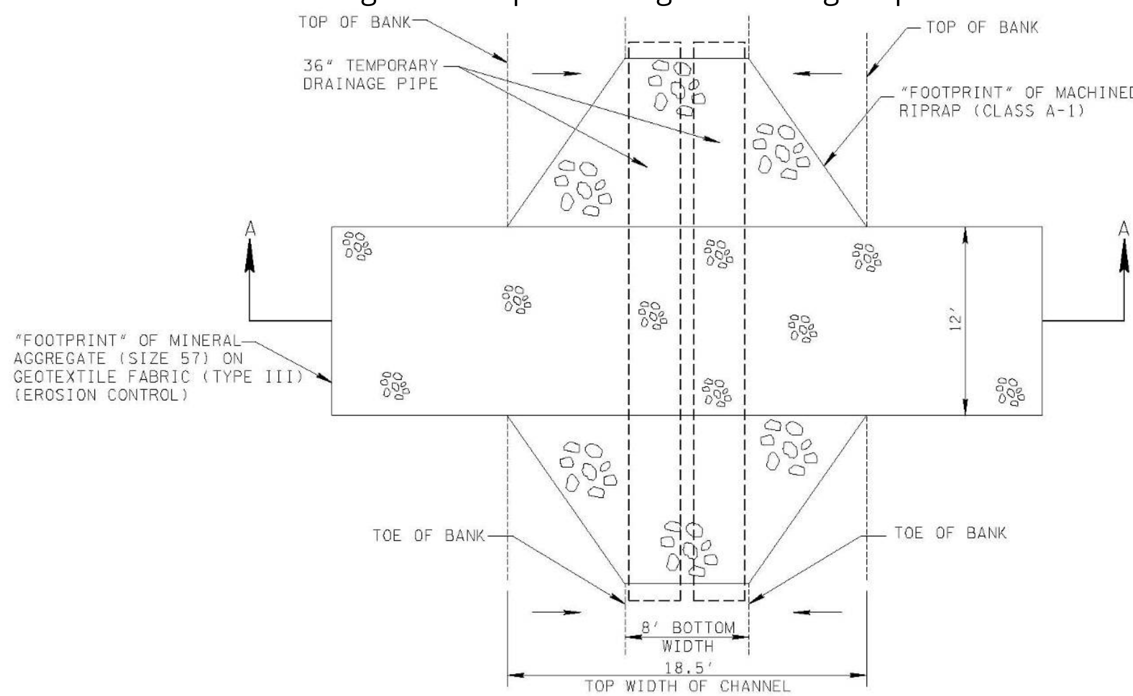
c.) Peak discharge, q_p:

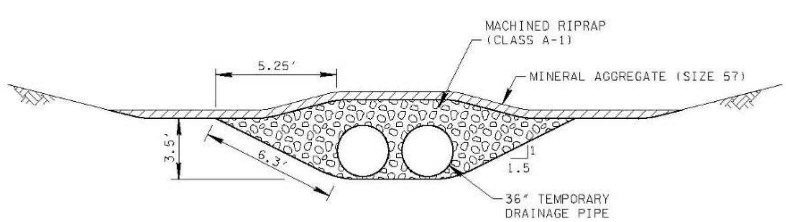
$$q_p = q_u \times A_m \times CN \times F_p = 340 \times 0.1875 \times 1.4 \times 1 = 89.3 \text{ ft}^3/\text{s}$$

Step 2- Select pipe size and number: Using Eqn 15 shown herein, the diameter pipe (assuming corrugated metal; n = 0.022) required to convey 89.3 cubic feet per second can be calculated:

$$D = 16 \times \left(\frac{q_p \times n}{\sqrt{S}}\right)^{3/8} = 16 \times \left(\frac{89.3 \times 0.022}{\sqrt{0.02}}\right)^{3/8} = 42.9 \text{ inches}$$

Thus, the smallest diameter pipe that can convey 89.3 cubic feet per second of water is 48 inches. However, as indicated on the standard drawing, this pipe would require two feet of cover in addition to six inches of mineral aggregate (size 57). Thus, the total height of this structure would be 6.5 feet, which is judged to be too large to fit into the channel height. As an alternative, twin 36-inch pipes are considered to handle the same flow rate (Table 3.3.2.6-A). The spacing between the pipes should be 1.5 feet for a total width of 7.5 feet, which can be accommodated in the channel bottom. Further, these pipes require 1.5 feet of cover, which combined with 6 inches of mineral aggregate (size 57), results in a total height of 5.0 feet. This height is judged to be a much better fit compared to the channel height, and twin 36-inch pipes are selected for the crossing. An example drawing of the design is presented.





SECTION A-A

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3.3.2.7 Utility Stream Crossing

Source: VDEQ (2024)

Definition and Purpose

The utility stream crossing measure is to help protect water bodies from disturbed sediment during the construction of a utility line. Crossings entail temporarily diverting the stream from its normal flow course or can employ trenchless technologies like horizontal directional drilling.

Appropriate Applications

This is applicable where utility lines are crossing a stream, wetland, or other jurisdictional feature. These can be fiber, electric, water, sewer, storm sewer, or other utility pipes or conduits that are to be buried and pass under a waterbody.

Limitations and Maintenance

Care must be taken to inspect any stream crossing area at the end of each day to confirm construction materials cannot be moved downstream. Proper maintenance and inspection for each type of flow diversion measure ensures that best practices are followed, and the working area remains dry.

Utility crossings in jurisdictional waters require additional permits, such as an ARAP, and therefore, both the conditions of the CGP and ARAP must be followed. A Section 404 permit from USACE may also be required. If the proposed crossing is to be completed in a TVA reservoir, a TVA 26a permit may also be necessary. Consider the criteria and conditions of the necessary permits during the planning stages of the project and EPSC plans.

Planning and Design Considerations

Utility construction frequently crosses and impacts streams. Thus, there is potential for excessive sediment loss by both the disturbance of the approach areas and by the work within the stream. To the greatest extent possible utility line crossings are to be perpendicular to the stream so that it overlaps the streambed the least amount possible (VDEQ, 2024).

In cases where instream work is unavoidable, it is necessary to provide adequate protection for sediment loss while minimizing the amount of encroachment and time spent working in the channel. If the stream bed is to be disturbed for the utility crossing and can be completed within a few days, coordinate construction during dry weather for ephemeral and intermittent streams. If that is not possible, other measures can be taken to minimize siltation in the stream (WVDEP, 2016).

Selecting the appropriate method for a utility stream crossing can be challenging as it requires balancing environmental impacts, feasibility, and regulatory compliance. Horizontal directional drilling and Jack and Bore drilling are preferred techniques because they minimize disturbance to the waterbody by avoiding direct excavation of the streambed. These trenchless methods are particularly advantageous in environmentally sensitive areas, as they reduce sedimentation, protect aquatic habitats, and maintain natural stream flow (VDEQ, 2024; WVDEP, 2016). Horizontal direction drilling is ideal for long-distance crossings and challenging terrain, providing a cost-effective solution with minimal surface disruption. Jack and Bore is well-suited for shorter, more controlled crossings, especially in areas with high groundwater or unstable soils. Given the complexity of selecting the right approach, designers and plan reviewers may consider conducting on-site evaluations to determine the most suitable method for each project. When neither option is feasible, open trench methods exist, which are more intrusive and likely time-consuming.

Horizontal directional drilling is a trenchless construction method used to install underground pipelines, conduits, and cables with minimal surface disruption. Position entry and exit points at least 50 feet from the top of the stream bank, allowing the drill to achieve sufficient depth beneath the streambed and minimizing the risk of disturbing the stream environment. The bore depth must be adequate to prevent the inadvertent release of drilling fluids, which could contaminate the watercourse. Additionally, develop a site-specific contingency and containment plan to address any unintended release of drilling fluids, ensuring that it is readily available on-site during construction for immediate response.

Furthermore, conducting thorough geotechnical investigations is crucial to understanding soil composition and subsurface conditions. This information aids in designing an appropriate bore path and selecting suitable drilling techniques, reducing the likelihood of complications during operations.

Jack and Bore drilling, also known as auger boring, is a trenchless construction method used to install underground pipes, casings, or conduits beneath the stream. A bore pit is excavated at the entry point, and a receiving pit is established at the exit point, both of which are to be located at least 20 feet from the top of the stream bank. In this method, a steel casing is placed at the entry pit, and a hydraulic jack pushes the casing forward while an auger drill inside the casing removes the soil. The auger rotates and removes soil from the front of the bore as the casing is jacked forward, gradually advancing through the earth. Once the casing reaches the receiving pit, the auger is removed, and the utility pipe is installed inside the casing. Jack and Bore drilling is not ideal in loose or wet soils or where open space is limited.

An open trench requires clearing, excavation, pipe installation, riprap backfill, and bank restoration. This results in removing trees, vegetation, and root systems that hold stream banks together and could potentially cause additional bank stabilization issues.

a. *Stream Diversion Channel*: Consider this method if construction will remain in the area of the stream for an extended period (longer than 72 hours) and if site conditions are agreeable. See Section 3.3.2.4 for guidance on stream diversion channels. See below for notes that apply specifically to utility crossings.
    - This method allows continuous base flow of the stream around the construction of the utility crossing. Construct the utility trench perpendicular to the stream bank and fully cross the stream bed and bank prior to removing the diversion channel; and
    - Once the trench and surrounding area have been backfilled and stabilized, the stream can be rediverted back to the original streambed alignment. Stabilize the disturbed stream- bed and banks and the approach areas immediately following the attainment of the final grade.
b. *Instream Diversion*: This can be used when the stream is wide enough (10 feet or wider). See Section 3.3.2.3 for guidance on stream diversion channels. See below for notes that apply specifically to utility crossings.

- Remove large rocks, woody vegetation, or other material from the streambed and banks that may get in the way of placing the riprap, sandbags, sheet metal, or wood planks used for diversion or installing the utility pipe or line;
- When the stream flow is successfully diverted, dewater the work area;
- Excavate the utility trench in the work area and install the utility line in half of the streambed;
- Stabilize the stream- bed and banks and the approach areas for the initial half of the installed utility line immediately following the attainment of the final grade; and
- Shift the flow from one side of the diversion to the other, such that the next half of the utility crossing can be constructed, and the water can be diverted to the newly stabilized portion of the stream.

c. *Bypass Pumping*: Bypass pumping is beneficial for work that is to be completed within a week and for smaller streams with low baseflow. This is due to a person having to run the pump and be present to manually turn it on and off. See Section 3.3.2.4 for details on bypass pumping. See below for notes that apply specifically to utility crossings.
   - This method allows for the use of a temporary pump to transfer water from upstream to downstream and for placing berms across the streambed to prevent flow from entering the work area; and
   - If stormwater does enter the work area, it will need to be dewatered. This allows for work to be done in the dry and as well as allowing the streambed to be stabilized before reintroducing the stream's flow back into the channel.

There are a plethora of good practices when installing utility crossings.

- As with all utility line crossings, approach areas may need to be controlled with perimeter measures such as silt fence;
- For a sewer line crossing a stream, consider providing non-erodible fill and cover, such as concrete or controlled low-strength materials (flowable fill), and trench plugs at each end of the crossing;
- Avoid placing manholes in wetlands and consider providing a minimum distance of 50 feet from the stream bank to the nearest edge of the manhole;
- It is important that the utility crossing prevent permanent impoundment or loss of normal or baseflow;
- Dewatering of the utility trench and construction area may be necessary during construction. A good practice to use in this case would be to pump to a sediment filter bag that is located downstream of the work area. See Section 4.4.12.5 for guidance on the use of Sediment Filter Bags;

- It is best not to blast for the excavation of trenches that are parallel or lie within 50 feet of a stream or wetland. This can impact the streambed and cause the loss of baseflow;
- It is best practice to have a minimum of one trench plug between manholes and one trench plug at each end of the stream crossing or wetland; and
- It is important to be aware of existing erosion occurring near the proposed utility crossing. If the headcut is happening at a downstream point and there is potential for the erosion to continue upstream where the utility crossing is proposed. This may encourage the designer to try to pick a more stable portion of the stream for crossing or provide additional bank stabilization so there is little risk of the utility line becoming exposed due to bank erosion.

Example Application
For sizing, refer to Section 3.3.2.3. No formal design or quantities are required for trenchless technologies.

References
VDEQ. (2024). *Virginia Stormwater Management Handbook.*
WVDEP. (2016). *Erosion and Sediment Control Best Management Practice Manual*.

3.3.3 Protected Areas

Prior to and during construction, it is crucial to have a visual delineation around natural areas and features such as streams, wetlands, ponds, cemeteries, historically significant sites, sinkholes, etc. Visual demarcation helps to prevent environmental or historical damage as well as to preserve ecosystems and areas of concern. Section 3.3.3 is specifically in reference to non-permitted impacts to waterbodies and other natural features. Often, these areas can play a vital role in filtering pollutants, reducing erosion, and maintaining water quality. By safeguarding them, construction activities can minimize such ecological degradation and maintain the integrity of the surrounding ecosystem, which is more cost effective than replacing or repairing the areas if destroyed or degraded.

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3.3.3.1 High-Visibility Fencing

Source: TNWRRC

Definition and Purpose
High-visibility fencing is temporary fencing that can be installed to safeguard protected areas. The fencing is intended to restrict clearing and prevent disturbances to sensitive areas and their buffers.

Appropriate Applications
High visibility fencing may be used to establish clearing limits, restrict construction traffic to designated entrances or roads, and protect areas where marking with survey tape or flagging may not provide adequate protection or visibility. Fencing may be used at the boundary of sensitive areas, their buffers, areas required to be left uncleared, and as necessary to control vehicle access to and on the site.

Limitations and Maintenance
Repair or replace the fencing if it has been damaged or if the visibility has been reduced.

Planning and Design Criteria
Ensure high-visibility plastic fencing is composed of a high-density polyethylene material, colored orange, four feet in height and has a tensile strength of 360 pounds per foot using the ASTM D4595 testing method. Posts for the fencing can be steel or wood and placed every 6 feet on center (maximum) or as needed to ensure rigidity. Fasten the fencing material to the post every six inches with a polyethylene tie. On long, continuous lengths of fencing,

a tension wire or rope may be used as a top stringer to prevent sagging between posts. Fencing should not be wired or stapled to trees.

If appropriate, fabric silt fence can be used in accordance with silt fencing requirements (refer to Section 4.4.10) to act as a high visibility fence. The silt fence is to be 3 feet high and highly visible to meet the requirement of high visibility fencing.

Metal fencing is also permitted and is to be installed according to manufacturer specifications. Metal fences should be at least 3 feet high and highly visible to meet the requirements of high visibility fencing.

Example Application

No formal design or quantities are required for this measure and therefore are not presented here.

References

None.

3.3.3.2 Riparian Buffer Zones

STREAM BUFFER
DO NOT DISTURB

Source: TDEC

Definition and Purpose

A riparian buffer zone is a protected area along an onsite water resource that can be temporary or permanent. Its primary function is to physically protect the water resource and act as a separator between the water body and disturbance. Though not a sediment control, riparian buffers provide water quality benefits through filtration by the vegetation. These zones also protect banks and promote bank stabilization by slowing construction site runoff with vegetative resistance (City of Albany, 2024; NCDEQ, 2013).

Appropriate Applications

All streams, wetlands, ponds and reservoirs are required to have riparian buffer zones between the top of the bank and soil disturbance during construction and in regulated municipal areas after construction. However, buffers can be beneficial in additional areas, such as ditches or wet weather conveyances.

Several municipalities and counties have more restrictive requirements for the width and/or maintenance of riparian buffer zones. While the CGP only has requirements for temporary construction buffers, MS4s may have permanent buffer requirements that must also be met. If there are differences between local and CGP buffer requirements, the more conservative of the two must be met.

Limitations and Maintenance

Source: TDEC

Inspections must focus on the stability of the riparian buffer zone, examining the zone for transported sediment and erosion and ensuring buffer boundaries are well defined and clearly marked in the field. If erosion or sediment deposition is found within the buffer zone, implement measures to minimize upgradient erosion and restore the buffer. Disturbances to riparian buffers are not permitted unless the designer justifies encroachment, which typically occurs on roadway or utility line projects. In the case where the temporary average buffer width requirement cannot be met, designers must implement other measures to obtain riparian buffer equivalency.

Maintenance of riparian buffer zones may extend into post-construction phases. This depends on the location of the project: if it is within the limits of a regulated municipality, permanent buffers may be required with a continuous maintenance agreement. Permanent buffer widths can vary between municipalities and CGP requirements. This information can be important in the construction planning process, and owners are encouraged to reach out to the local MS4 for pre- and post- construction requirements.

Planning and Design Considerations

Effective riparian buffer zones consist of an undisturbed tree line along the waterbody and upland vegetation. The CGP requires preserved buffers to have an average width of 30 feet between the waterbody and limits of disturbance, with a minimum of 15 feet at any given location. Waters with unavailable parameters for siltation and ETWs are required to have 60 feet of undisturbed vegetation on average, with a minimum width of 30 feet. Though there is no one ideal buffer zone width, the width is directly related to its effectiveness (ALSWCC, 2022). For optimal stormwater treatment, it is recommended to convert concentrated flow into sheet flow with a level spreader or similar prior to discharging into the riparian buffer zone to prevent erosion within the buffer zone. If a buffer is disturbed, promptly stabilize disturbed buffers with a dense cover of strong-rooted grasses, native plants, and native trees.

All construction-related materials and equipment must be stored outside the buffer area. EPSC measures such as high-visibility fencing (Section 3.3.3.1) are ideal to install along the edge of the riparian buffer zone, creating a visual and physical barrier which prevents inadvertent disturbance. Ensure that EPSC measures are installed upgradient from the buffer to protect it from sediment-laden runoff.

An example of a riparian buffer zone plan is as follows:

1. All areas of the riparian buffer zone undergoing restoration must be planted with non-invasive or native vegetation and nurse crops. Mixing cover crops with native seeds may be necessary, depending on the time of year;
2. Refer to Section 4.2.6.11 (Vegetation and Landscaping: Permanent) for guidance on soil bed preparation for native mixes;
3. EPSC measures must be installed to protect the water resource during restoration. These measures can include coir matting, erosion control blankets, wattles, etc., to stabilize the area short and long term. All measures used within the buffer should be made of natural materials that are biodegradable and can be left in place.
4. Plant species, density, placement, and diversity in the buffer restoration plan must be appropriate to ensure a healthy buffer zone. See Appendix D for example seed mixes, planting seasons, and application rates.
5. Native seedlings can take several years to fully establish and may require maintenance, such as the removal of invasive species. Vegetation mortality must be included in planting densities to ensure meeting the 70% density requirement per the CGP. This benchmark may be difficult to obtain by natives alone; therefore, supplementing with turf grasses and nursery crops may be necessary.

Example Application

No formal design or quantities are required for this measure and therefore are not presented here.

References

ALSWCC. (2022). *Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas*.

City of Albany. (2024). *Erosion Prevention and Sediment Control Manual*.

NCDEQ. (2013). *Erosion and Sediment Control Planning and Design Manual.*

3.3.3.3 Sensitive Areas

Source: TNWRRC

Definition and Purpose

Sensitive areas require protection from construction activities such as clearing, grading, mowing, staging activities, materials storage, and other related activities. Identify such areas with high visibility markings, flags, or fencing to make them known to all personnel.

Appropriate Applications

Features considered to be sensitive need to be identified. Sensitive areas can include tree preservation areas, streams, wetlands, endangered or protected species and/or habitats, water quality buffers, mitigation or stream relocation boundaries, sinkholes, stormwater treatment areas, caves, cemeteries, and historic preservation areas.

Limitations and Maintenance

Boundary markers or high visibility fencing must be maintained throughout construction. Markers that have been damaged, removed or degraded to the point that they are no longer visible require replacement. At the end of construction remove all markers unless a regulatory authority has required them to be left in place.

Planning and Design Criteria

Any sensitive area within the project boundaries are to be identified in the SWPPP and on the EPSC plans. It is the responsibility of the design professional to clearly label all areas on the plans and specify the type of marking materials to be used. Mark all sensitive features in the field accordingly. If these areas are disturbed, additional site design components may be needed to meet local or state requirements.

Sensitive areas that require markings and protection include:

- Streams and wetland buffers;
- Permitted Impact;
    - If the ARAP allows a specific area of stream or wetland encroachment, clearly marking these boundaries in the field aids in maintaining compliance with the ARAP conditions.
- Stream mitigation or relocation boundaries;
    - It is likely that a two-step field marking process is necessary for stream relocations and/or mitigation. The first boundary should identify the permitted impacts to the natural resource and should occur before work in the area. Once the relocation or mitigation has been installed and stabilized, these areas should be marked to show the outer limits and prevent disturbance or damage to vegetation.
- Sinkholes;
    - Sinkhole basins should be protected from sediment from construction sites by using appropriate erosion prevention and sediment controls upgradient from the basin. Leaving sinkhole basins undisturbed provides additional protection. It should be noted that discharges to sinkholes may require an underground injection control permit (Chapter 1.3.2).
- Areas to remain undisturbed;
    - Often, undisturbed open space requirements are established and enforced by the local jurisdiction. The amount of undisturbed open space per development is typically a percentage of the development. Disturbing these areas can lead to additional development restrictions or mitigation requirements. In addition, disturbed areas increase the required capacity of sediment control. Disturbing areas of land that were intended to be left undisturbed may result in overwhelming sediment controls and potential violations.
- Threatened and/or endangered species habitat; and
    - Critical habitat for threatened or endangered species should be protected from land disturbing activities. These areas should be clearly identified on the plans and in the field to prevent inadvertent disturbance or encroachment.
- Stormwater management areas.

- Land-disturbing activities destroy the infiltration capacity of soils by changing the soil structure, compacting the soils, and subjecting soil organic matter to a more rapid decay process. Many stormwater management practices, such as bioretention areas and water quality swales, rely on the soil infiltration capacity. When the infiltration capacity of the in-situ soils is substantially altered, the area may no longer be suitable for permanent stormwater management controls.

Many types of boundary markers are available. Flags, stakes, posts or fencing can be used as field boundary markers. Any marker must be highly visible and installed along the outer perimeter of the boundaries of the protected feature. Bright colors and highly distinguishable marking materials, such as orange fencing, neon or brightly colored flags, or highly visible signage, are the best for construction. Some markers will be temporary (such as ARAP permit boundaries) while others may be more permanent (such as permanent buffer zones). The decision about the type of marker to be used at the site may in part be dictated by the lifespan of the feature being marked.

Example Application
No formal design or quantities are required for this measure and therefore are not presented here.

References
None.

3.3.3.4 Tree Preservation

Source: TDEC

Definition and Purpose
Tree preservation includes practices to protect desirable trees from damage during construction activities. Trees can have present or future value, as healthy, mature trees enhance property values, improve aesthetics, promote soil stability, and filter air pollutants (NCDEQ, 2013; City of Albany, 2024).

Appropriate Applications
These practices can be applied on any construction site with existing trees.

Limitations and Maintenance
In spite of precautions, some damage to protected trees may occur. If damages to existing trees occurs, repair the damages by the following maintenance specifications (NCDEQ, 2013):

- Repair roots by cutting off the damaged areas and painting them with tree paint. Spread peat moss or moist topsoil over any exposed roots;
- Repair damage to bark by trimming around the damaged area, taper the cut to provide drainage, and paint with tree paint; and
- Cut off all damaged tree limbs above the tree collar at the trunk or main branch. Use three separate cuts to avoid peeling bark from healthy areas of the tree.

Planning and Design Criteria

During the site evaluation, note where valuable trees and other natural landscape features are to be preserved, then consider these trees and plants when determining the location of roads, buildings, or other structures. When marking trees to protect, be sure to install practices around the drip line of tree branches as opposed to solely around the trunk (Figure 3.3.3.4-A).

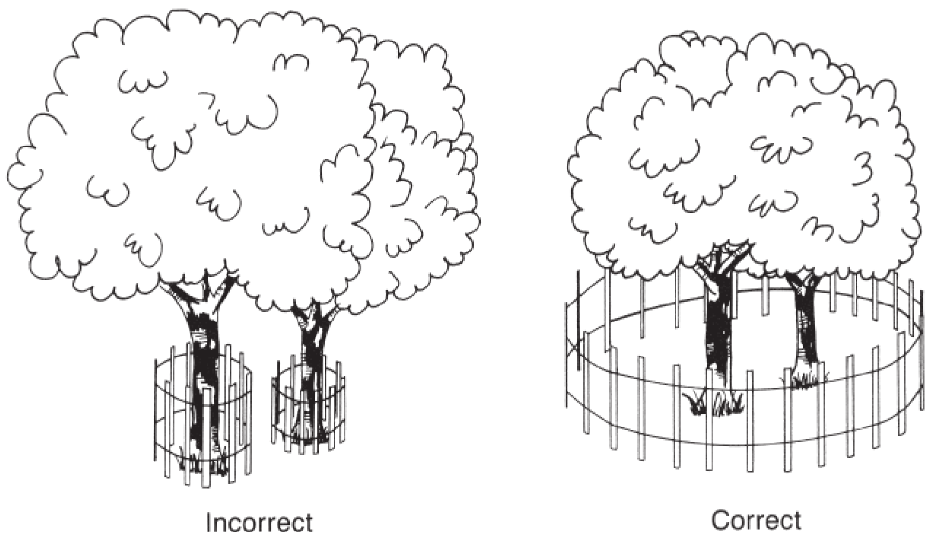

Figure 3.3.3.4-A: Construction barriers should be installed at the drip line of the tree branches. Source: NCDEQ (2013).

Construction activities can significantly injure or kill trees unless protective measures are taken. Trees are considered for preservation for the following benefits:

- They stabilize the soil and prevent erosion;
- They reduce stormwater runoff by intercepting rainfall, promoting infiltration, and lowering the water tables through transpiration;
- They moderate temperature changes, promote shade, and reduce the force of wind;
- They provide buffers and screens against noise and visual disturbances, providing a degree of privacy;
- They filter pollutants from the air and produce oxygen;
- They provide a habitat for animals and birds; and
- They increase property values and improve site aesthetics.

Consider the following characteristics when selecting trees to be preserved and protected (NCDEQ, 2013):

- Tree vigor – Preserve healthy trees. A tree of low vigor is susceptible to damage by environmental changes that occur during site development. Healthy trees are less susceptible to insects and disease. Indications of poor vigor include dead tips of branches, small annual twig growth, stunted leaf size, sparse foliage, and pale foliage. Hollow or rotten trees, cracked, split or leaning trees, or trees with broken tips have less chance for survival;
- Tree age – Old, picturesque trees may be more aesthetically valuable than smaller, younger trees, but they may require more extensive protection;
- Tree species – Preserve those species that are the most suitable for site conditions and landscape design. Trees that are short-lived, brittle, or are susceptible to attack by insects and disease may be poor choices for preservation;
- Tree aesthetics – Choose trees that are aesthetically pleasing, shapely, large, and colorful. Avoid trees that are leaner and in danger of falling. Occasionally, an odd-shaped tree or one of unusual form may add interest to the landscape if strategically located. However, be sure the tree is healthy; and
- Wildlife benefits – Choose trees that are preferred by wildlife for food, cover, or nesting. A mixture of evergreens and hardwoods may be beneficial. Evergreen trees are important cover during winter months, whereas hardwoods are more valuable for food.

Although direct contact by equipment is an obvious means of damaging trees, most serious damage is caused by root zone stress from compacting, filling, or excavating within close proximity to trees. Clearly mark boundaries to maintain sufficient undisturbed areas around the trees. The following general criteria should be considered when developing in a wooded area:

- Leave critical areas (such as floodplains, steep slopes, and wetlands) with desirable trees in their natural condition or only partially cleared;
- Locate roadways, storage areas, and parking pads away from valuable tree stands. Follow natural contours, where feasible, to minimize cutting and filling in the vicinity of trees;
- Select trees to be preserved before constructing roads, buildings and other structures;
- Minimize trenching in areas with trees. Place several utilities in the same trench;
- Designate groups of trees and individual trees to be saved on the EPSC plan sheets and in the SWPPP; and
- Do not excavate, traverse, or fill closer than the drip line, or perimeter of the canopy, of trees to be preserved.

Use the following guidelines at all times throughout the construction process:

- Do not nail boards to trees during building operations;
- Do not cut tree roots inside the drip line;
- Do not place equipment, construction materials, topsoil, or fill dirt within the limit of the drip line of trees to be preserved;
- If a tree marked for preservation is damaged, remove it and replace it with a tree of the same or similar species, two inch caliper or larger, and from a balled and burlap nursery stock when activity in the area is complete; and
- During final site cleanup, remove barriers from around trees.

Example Application

No formal design or quantities are required for this measure and therefore are not presented here.

References

City of Albany. (2024). *Erosion Prevention and Sediment Control Manual*.
NCDEQ. (2013). *Erosion and Sediment Control Planning and Design Manual*.

3.3.4 Construction Exit

A designated construction exit is necessary to minimize the movement of sediment offsite. This specific measure focuses on preventing the spread of sediment by ensuring vehicles leaving the site are not tracking excess mud, dirt, or sediment before entering public roadways. Unlike other EPSC measures that treat runoff, prevent pollution, or stabilize soil, construction exits are unique because they are a distinct component of overall site management and a public safety feature. Large clumps of sediment on the road and dried mud from equipment tires can dislodge at high speeds, impacting other motorists.

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3.3.4 Construction Exit

Source: TDEC

Definition and Purpose

Construction exits often consist of stone pads on a geotextile fabric that are located at any point where traffic will be moving from a construction site onto a public roadway or other paved area. Construction exists may also consist of rumble strips or HDPE material that can be used to reduce track out. The intentions of this measure are to reduce or eliminate the transport of sediment offsite.

Appropriate Applications

This practice is applicable where construction traffic leaves a construction site and enters a public right-of-way.

Reusable HDPE construction exits may be a more economic choice for areas of Tennessee where rock is harder to find and more expensive. Maintenance is required to clean off the construction exit. Manufacturer recommendations should be followed.

Limitations and Maintenance

The exit must be maintained in a condition that will prevent tracking or flow of material onto public rights-of-way or into storm drain systems. This may require periodic top dressing with fresh stone or full replacement of stone and underlying geotextiles as conditions show clogging. All materials spilled, dropped, washed, or tracked from vehicles or site onto roadways or into storm drains must be removed as soon as possible. Additionally, dislodged stones spilling into the adjacent roadway must be cleared as soon as possible.

Planning and Design Criteria

Construction exits are to be installed at any point where construction traffic exits the project. Avoid areas with hydric or saturated soils as well as steep gradients.

A layer of geotextile fabric is used to stabilize and support the aggregate. Extend the geotextile fabric the full length and width of the construction exit and ensure the fabric meets the requirements of the standard specifications for geotextiles, AASHTO designated M-288, erosion control. Construct the stone pad from clean, washed stone. The gradation, width of the stone pad, and length of the pad must be sized appropriately such that tracking onto public roadways is eliminated. There may be specific requirements from local or state requirements for larger projects (e.g., TDOT projects). While no specific dimensions, gradation, or depth of aggregate are required per the CGP, neighboring states recommend minimum lengths of 50 to 70 feet, minimum widths of 12 to 20 feet; minimum depths of six to eight inches, and one to two inch diameter aggregates (TDOT Class A-3 Machined Riprap) (ALSWCC, 2022; GSWCC, 2016; NCDEQ, 2013; VDEQ 2024). Install, at minimum, a turning radius of 20 feet on each side of the pad where it intersects with the public roadway (TDOT).

Stormwater management around the construction exit must also be considered, such that stormwater cannot flow across the stone pad and into the right-of-way. On sites where the grade toward the public roadway is greater than two percent, a waterbar diversion six to eight inches in depth with 3H:1V side slopes can be constructed at the upper end of the construction exit to prevent stormwater from washing sediment off the construction exit and into the public roadway or storm drain system (GSWCC, 2016).

Example Application

No formal design or quantities are required for this measure and therefore are not presented here.

References

ALSWCC. (2022). *Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas*.

GSWCC. (2016). *Manual for Erosion and Sediment Control in Georgia*.

NCDEQ. (2013). *Erosion and Sediment Control Planning and Design Manual.*

TDOT*. Drainage Manual Ch10.* Retrieved from https://www.tn.gov/tdot/engineering-division/engineering-production-support/design-standards/drainage-manual.html

VDEQ (2024). *Virginia Stormwater Management Handbook.*

3.4 Pollution Prevention

Pollution prevention practices are good housekeeping practices that reduce pollution potential. Practices in this category are essential to minimize the release of harmful substances such as trash, debris, construction waste, chemicals, sediments, etc. into the environment. By implementing these measures, construction sites can protect local ecosystems, safeguard water quality, and ensure compliance with environmental regulations.

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3.4.1 Chemical Storage

Source: CalTrans (2017)

Definition and Purpose

Chemical storage areas are equipped to eliminate the discharge of chemicals, fertilizers, and other non-sediment pollutants. This is achieved by minimizing the storage of all such materials onsite, storing onsite materials in a designated area, installing secondary containment, providing overhead or indoor coverage, and conducting regular inspections.

Appropriate Applications

This practice is applicable for storage of the following materials (CalTrans, 2017):

- Soil stabilizers and binders;
- Pesticides and herbicides;
- Fertilizers;
- Detergents;
- Plaster;
- Petroleum products such as fuel, oil, and grease;
- Asphalt and concrete components;
- Hazardous chemicals such as acids, lime, glues, adhesives, paints, solvents, and curing compounds;
- Concrete compounds; and
- Other materials that may be detrimental if released to the environment.

Limitations and Maintenance

Keep storage areas clean, well-organized, and equipped with ample cleanup supplies as appropriate for the materials being stored. Repair or replace perimeter controls, containment structures, covers, and liners as needed to maintain proper function.

Planning and Desing Criteria

Keep an up-to-date inventory of materials stored onsite. All chemicals must be stored in covered areas or in containment systems constructed in or around the storage areas. Further, keep chemicals in their original labeled containers. Reactive, ignitable, or flammable liquids must be stored in compliance with local fire codes. Locate storage areas as far away as possible from waterbodies, sensitive areas, and inlets.

Ideally, store materials that are likely to contribute to pollution indoors. Storage sheds must meet local building and fire code requirements. If indoor storage of materials is not possible, providing coverage is the next best option. Do not store chemicals, drums, or bagged materials directly on the ground. Place these items on a pallet, in secondary containment, and under cover when possible (TDOT, 2017). These methods shield construction materials from raindrop impact and keep them out of flow paths. When providing overhead coverage is not feasible, plastic dome toppers can be purchased and snapped to the top of drums, which prevent rainwater from ponding on the drums.

Ensure all sites have spill kits. If a spill occurs, avoid washing the materials away with water as the water may runoff and spread the contamination. Instead, use dry methods to safely transfer the spilled materials into the designated spill containers for proper handling and disposal. Include emergency contact information for spills, such as the local emergency management agency's contact information. TDEC’s local environmental field office should be contacted in the event that a chemical spill reaches a waterway. If residual materials remain after cleaning a spill or after construction completion, properly remove materials and any contaminated soil. If the area is to be paved, pave as soon as materials are removed to stabilize the soil and reduce the chance of spreading any contaminants.

Example Application

No formal design or quantities are required for this measure and therefore are not presented here.

References

CalTrans. (2017). *Construction Site Best Management Practices (BMP) Manual*.
TDOT. (2017). *EPSC Inspection Manual*.

3.4.2 Concrete Washout

Source: Hamilton Co. (2008)

Definition and Purpose

Concrete washouts are pits lined with plastic (or other watertight materials) or leak proof containments that can hold and store liquid or slurry concrete washed off heavy machinery and vehicles. The washoff is held in place until it is dried to a point at which it can be disposed of properly.

Appropriate Applications

Concrete washout areas are applicable when:

- Concrete trucks and other concrete-coated equipment are washed onsite;
- Slurries containing portland cement concrete or asphalt concrete are generated, such as from saw cutting, coring, grinding, grooving, and hydro-concrete demolition; and
- Washing of exposed aggregate concrete occur.

Limitations and Maintenance

Concrete washouts are temporary facilities that require emptying on a routine schedule such that a minimum freeboard of four inches is provided for above grade washout facilities and 12 inches for below grade washout facilities. Remove concrete once it has hardened to ensure sufficient storage for additional concrete washout. Alternatively, remove accumulated materials once 75% of the storage capacity is filled. Inspect plastic linings, geotextiles, and sidewalls of site-built washouts to ensure there are no tears or leaks. During cleaning processes, pump any excess wash water into a containment vessel that can be properly disposed. Plastic linings may need to be replaced after each cleaning of the washout facility (VDEQ, 2024). Inspect all surfaces of prefabricated washouts to ensure the container is not leaking.

Identify whether washout facilities are being used regularly. If the inspector finds that concrete trucks are being washed out in locations other than designated areas, the inspector must notify the site superintendent and/or operator immediately.

Avoid mixing excess concrete for a pour and also perform washout of concrete trucks offsite or in designated areas. Do not allow concrete trucks to wash into storm drains, open ditches, streets, or streams. Do not allow excess concrete to be dumped onsite, except in designated areas. Do not wash sweepings from exposed aggregate concrete into the street or storm drainage systems.

Planning and Design Criteria

Educate all construction site personnel on the use of the washout facilities (USEPA, 2012). There are two main types of concrete washouts: prefabricated washout containers and site-built washouts. Private companies often offer heavy-duty, prefabricated concrete washout containers that are delivered to the site. Some services provide only the containers while others also provide the maintenance and disposal of the materials. When selecting a company to handle concrete waste, ensure they properly dispose of all materials. If the project utilizes a concrete pump truck, the prefabricated container should have an adequate ramp to accommodate the concrete pump truck. When using prefabricated washout containers, ensure containers can withstand heavy impacts and are watertight.

Source: TDEC

Source: TDEC

Site-built washouts can be below-grade in order to prevent breaches. They are constructed by providing a temporary pit or bermed area large enough to handle solids, wash slurry, and rainfall to prevent overflow. They often are 10 ft by 10 ft and include a minimum of 12 inches of freeboard. Above-grade structures may be used if they are sized properly, leak proof, and maintained regularly to provide a minimum of four inches of freeboard. Site built concrete washouts may use a 10mil plastic lining or a nonwoven geotextile lining. When removing concrete and disposing of the hardened concrete be sure to dispose of the linings separately and not to bury them with the concrete. This is to reduce the amount of microplastics that will be found onsite.

Locate concrete washout areas as far as possible from streams, sinkholes, wetlands, or other sensitive features yet accessible for concrete trucks and waste removal (USEPA, 2012). It is a good practice to use signage to indicate where the location of the washout. Line vehicular pathways to and from the washout with appropriately sized gravel to prevent tracking offsite and erosion. Consider having multiple washouts on large sites.

Example Application
No formal design or quantities are required for this measure and therefore are not presented here.

References
Hamilton County. (2008). *Stormwater BMP Manual Best Management Practices*.
USEPA. (2012). *Stormwater Best Management Practice: Concrete Washout*.
VDEQ. (2024). *Virginia Stormwater Management Handbook.*

3.4.3 Tire Washing

Source: TNWRRC

Definition and Purpose

Tire washing refers to an established station for washing tires and undercarriages prior to construction traffic exiting the construction site. In addition to construction exits, tire washing helps reduce mud, dirt, and sediment tracking onto public roads.

Appropriate Applications

Tire washing facilities are used in combination with construction exits when gravel construction exits do not provide sufficient dirt, mud, and sediment removal from construction equipment. Tire washes are not necessary in all cases but may be ideal for sites located in sensitive areas or where additional sediment control measures are necessary.

Limitations and Maintenance

Remove accumulated sediment in the tire wash rack and surrounding sediment control measures as necessary to maintain system performance. Inspect routinely for damage and repair as needed. This application may require a turnaround or doublewide exit to prevent vehicles from driving through the wash area (CalTrans, 2017).

Using soaps or solvents for vehicle and equipment washing is not covered under the CGP and is prohibited from discharging.

Planning and Design Criteria

A reliable water supply is essential for most tire washing techniques, which can be provided through an overhead tank, pressurized tank, water pipeline, or other means. Wash water must be directed to a sediment-trapping device, such as a sediment basin or sediment trap, before being discharged off-site to prevent contamination. Runoff from the wash area may require conveyance to sediment controls or trapping devices via a drainage ditch of appropriate grade, width, and depth. If chlorinated water, such as tap water or hydrant water, is used, runoff should be detained at a minimum of 24 hours before discharge. Pool test kits can be used to test the chlorine content of the water.

There are various methods for tire washing such as flooded basin, countercurrent channel, low pressure inundation, and high-pressure cleaning, any of which may be implemented based on which will work best for site-specific or economic constraints.

Example Application

No formal design or quantities are required for this measure and therefore are not presented here.

References

CalTrans. (2017). *Construction Site Best Management Practices (BMP) Manual.*
City of Knoxville. (2003). *Best Management Practices Manual*.

3.4.4 Trash and Debris

Source: CalTrans (2017)

Definition and Purpose
The management of trash and debris refers to the proper containment and disposal of macro debris, also known as gross solids. It ensures good housekeeping by providing designated waste collection and scheduling regular disposal. Though not often thought of as a stormwater pollutant, gross solids can leach various chemicals and toxins, yield increased microplastics, and clog drainage infrastructure (Roesner and Kidner, 2007).

Appropriate Applications
Trash and debris management apply to construction sites where waste is generated. These include debris from land clearing, such as trees and shrubs, and rubble from demolished structures; packaging materials, such as wood, paper, and plastic, as well as scrap or surplus building materials like metals, rubber, plastic, glass; and masonry products. Additionally, construction waste such as brick, mortar, timber, steel, pipe cuttings, electrical scraps, Styrofoam, and other packaging materials require proper disposal. Lastly, proper disposal of domestic waste, including food containers, beverage cans, plastic wrappers, and cigarettes, and onsite sanitary waste facilities are critical components of this practice.

Limitations and Maintenance
Inspect the site for evidence of trash and construction debris being placed outside of the designated collection areas. Ensure construction waste is collected, removed, and disposed of only at authorized disposal areas. Remove and dispose of macro litter on a regular or as-needed basis and following the completion of construction activities to prevent container overflow. Spills and overtopping require immediate attention.

To prevent clogging of the storm drainage system, litter and debris removal from drainage grates, trash racks, and ditch lines should be a priority. Inspect trash and debris collection areas before and after wind and/or rain events to ensure that trash and debris are being adequately contained.

Planning and Design Criteria

Effective trash and debris management on construction sites is crucial for reducing environmental impact and maintaining regulatory compliance. Trash and Debris storage areas should be placed to minimize the exposure of building materials, building products, construction wastes, trash, landscape materials, fertilizers, pesticides, herbicides, detergents, sanitary waste and other materials present on the site to stormwater. Include a designated debris storage area in the SWPPP and on-site drawings when such materials are anticipated. These areas are not to be near sensitive site features like streams, wetlands, sinkholes, flood-prone areas, wet weather conveyances, and drainage infrastructure. It can be helpful to incorporate preventative measures such as berms, dikes, or other means around storage areas to reduce stormwater runoff from contacting waste (CalTrans, 2017). It is best to enclose, cover, or equip all containers with lids to minimize exposure to rain (KYTC, 2015). It is helpful when signage clearly designates waste disposal areas. Collect and place onsite waste in disposal areas before rain events, regardless of if it was sourced from construction activities/personnel or not.

Toxic liquid wastes and chemicals, including oils, solvents, paints, acids, pesticides, and curing compounds, must not be disposed of in construction debris containers and should follow guidance outlines in Section 3.4.1. Construction debris and trash can only be used as fill if explicitly approved by regulatory authorities. Proper planning, consistent maintenance, and adherence to these guidelines ensure effective trash and debris management while protecting water quality and surrounding ecosystems.

Example Application

No formal design or quantities are required for this measure and therefore are not presented here.

References

CalTrans. (2017). *Construction Site Best Management Practices (BMP) Manual.*

KTC. (2015). *Kentucky Erosion Prevention and Sediment Control Field Guide.*

Roesner, L. A., & Kidner, E. M. (2007). Improved protocol for classification and analysis of stormwater-borne solids. In *WEFTEC 2007* (pp. 5539-5566). Water Environment Federation.

3.4.5 Vehicle Maintenance

Source: TDEC

Definition and Purpose

Vehicle maintenance includes procedures and practices to reduce the discharge of pollutants to storm drain systems, or to watercourses as a result of vehicle wear and tear. Like other good housekeeping practices, this measure is intended to eliminate non-stormwater discharges and non-sediment pollutants.

Appropriate Applications

Procedures for vehicle maintenance are applicable on projects where heavy equipment and vehicles are maintained onsite.

Limitations and Maintenance

Vehicles and equipment require daily inspections. Leaks should be repaired immediately, and problematic vehicle(s) or equipment should be removed from the project site. Keep ample supplies of spill cleanup materials onsite.

Planning and Design Criteria

Vehicle and equipment maintenance on construction sites can be a significant source of stormwater pollution due to potential spills and leaks of engine fluids, lubricants, and other hazardous materials. While off-site maintenance is preferred (City of Albany, 2024), it is not always practical. When maintenance must occur on-site, proper planning and control measures are necessary to minimize environmental impacts. Confine maintenance activities to designated areas that are level, located at least 50 feet away from drainage facilities and watercourses, and protected from stormwater run-on and runoff. Additionally, provide cover to maintenance areas where feasible and equip maintenance areas with secondary containment to capture spills and leaks. Use drip pans or absorbent pads under vehicles and equipment during maintenance to catch fluids. For long-term projects, consider constructing permanent or portable covers over maintenance areas. Educate all personnel involved in vehicle and equipment maintenance on proper disposal procedures and spill cleanup protocols.

Develop a comprehensive spill prevention and response plan and provide it to all maintenance personnel. Absorbent spill cleanup materials and spill kits must be readily accessible at maintenance areas, fueling stations, and on fueling trucks. Clean small spills using absorbent materials (i.e., dry methods) instead of hosing down or burying spills. Promptly and properly dispose of all contaminated absorbent materials.

Recycle or properly dispose of all used vehicle fluids, including oil, antifreeze, hydraulic fluids, and cleaning solutions to prevent contamination of soil and water. Separate waste such as oil filters, batteries, and tires for proper disposal or recycling. Under no circumstances should used oil be placed in dumpsters, poured onto the ground, or into storm drains. Similarly, fuel and lubricant disposal must comply with environmental regulations to prevent contamination.

Signs of leaks, such as soil staining under parked equipment, should be investigated and remediated promptly. Inspect incoming vehicles and equipment, including delivery trucks and subcontractor vehicles, for leaks before being allowed on-site. Vehicles and equipment should be kept clean to prevent excessive buildup of oil and grease, reducing the risk of pollutant runoff.

Example Application
No formal design or quantities are required for this measure and therefore are not presented here.

References
CalTans. (2017). *Construction Site Best Management Practices (BMP) Manual*.
City of Albany. (2024). *Erosion Prevention and Sediment Control Manual.*

3.5 Construction Sequencing and Phasing

A description of all construction activities must be documented in the Stormwater Pollution Prevention Plan (SWPPP) and on the EPSC plans. Include in these documents, the sequence of all soil disturbing activities. Construction sequencing is a schedule specific to each project that coordinates the timing of land disturbing activities, installation of EPSC measures, stabilization measures, and permanent stormwater management controls. Though not required, phasing is recommended on all construction sites regardless of size as it can be an effective measure for minimizing disturbance, erosion potential, and sedimentation. Site developers are encouraged to limit the total disturbed area to less than 50 acres at a given time. After a portion of construction is complete and stabilization measures have been implemented, developers can begin construction activities in other onsite locations to maintain a disturbance of less than 50 acres.

While the initial, interim, and final stages of EPSC plans are a form of sequencing, notes detailing sequencing of activities are required. The sequencing notes on the EPSC plans provide more detail, order of construction processes and activities, demonstrate compliance with the CGP by detailing that perimeter controls such as silt fence and a construction exit (and/or other necessary EPSC measures) are in place before land disturbing activities occur. When changes in construction activities must occur, amend the sequence schedule in advance to maintain management control.

The following demonstrates an example of basic construction sequencing:

1. Install construction exits, delineate buffers zones, and designate laydown yards;
2. Install temporary EPSC perimeter measures, including sediment traps, sediment basins, silt fence, etc.;
3. Perform on-site clearing and grubbing;
4. Excavate and grade the site;
5. Throughout grading and as drainage patterns change, install appropriate EPSC measures such as, check dams, outlet protection, wattles, silt fence, etc. Continue to maintain existing measures;
6. Implement final stabilization of disturbed soil; and
7. Remove all temporary EPSC measures once permanent stabilization has been established.

If phasing is proposed to minimize disturbance or limit the amount of area disturbed at once, notes detailing the phasing are required. For example, when a stream runs through a construction site, construction phasing can be used to show how off-site water will remain unpolluted by implementing a diversion or bypass. In this case, specify that a diversion channel will be constructed and stabilized to divert water around the construction. The diversion reduces the drainage area of the outfall and in turn the volume of stormwater requiring treatment, as detailed in Section 3.3.1. Another example would be placing pipes such that stormwater passes through the construction site without exposure to disturbed soils. When planning to phase the project in order to disturb less than 50 acres at a given time, a construction sequence is required for each phase. While beneficial, sequencing alone does not demonstrate compliance with the CGP. To demonstrate compliance, construction details must be provided in the narrative, notes, and drawings of the EPSC plans and SWPPP. When water features are to be impacted within project limits, notes and sequencing can provide detail to the reviewer that the permitted conditions are acknowledged and met.

The following are generalized examples of sequencing notes for construction activities impacting waters of the state.

Stream Bank Construction Sequencing Example
Such as riprap placement, other revetment, placement or repair of structures, etc. (Figure 3-A)

1. Provide minimal clearing to stream for equipment access;
2. Place EPSC measures;
3. Place instream diversion. Instream diversions can be constructed of sandbags, jersey barrier, conventional riprap, sheet piling, or other materials (Figure 3-a);
4. Pump out water inside of diversion, continue to pump the water out as needed;
5. Repair bank or repair intake structure or bridge pier;
6. Remove instream diversion;
7. Apply permanent stabilization measures to disturbed areas; and
8. Remove EPSC measures once disturbed soils are stabilized.

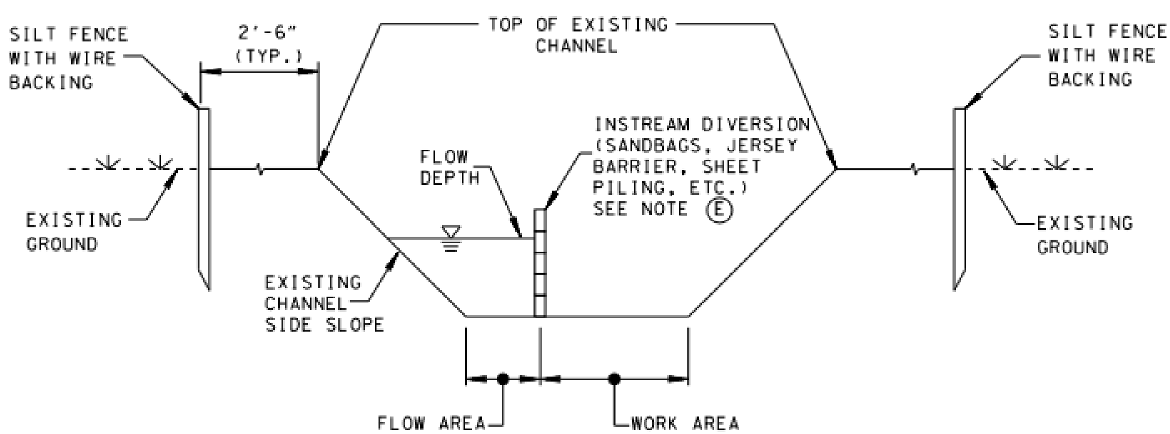

Figure 3-A: Instream diversion details. Source: TDOT - EC-STR-30.

Culvert Crossing Replacement Sequencing Example

Using a pump around diversion may have similar sequencing for a diversion channel or pipe (Figure 3-B)

1. Place EPSC measures adjacent to stream;
2. Place sandbag berm in stream channel before and after work area;
3. Install pump around diversion, pump and pipe from the upstream side to the downstream;
4. Remove any water from the construction area by pumping into a sediment filter bag located downgradient of the work area;
5. Excavate and remove existing culvert;
6. Replace culvert with a new pipe and backfill;
7. Stabilize the inlet and outlet of new crossing;
8. Remove the pump-around diversion and the sandbag berms;
9. Visually inspect the new culvert crossing to see if the pipe is functioning and that no erosion is occurring at the inlet or outlet;
10. Apply permanent stabilization measures to disturbed areas; and
11. Remove EPSC measures.

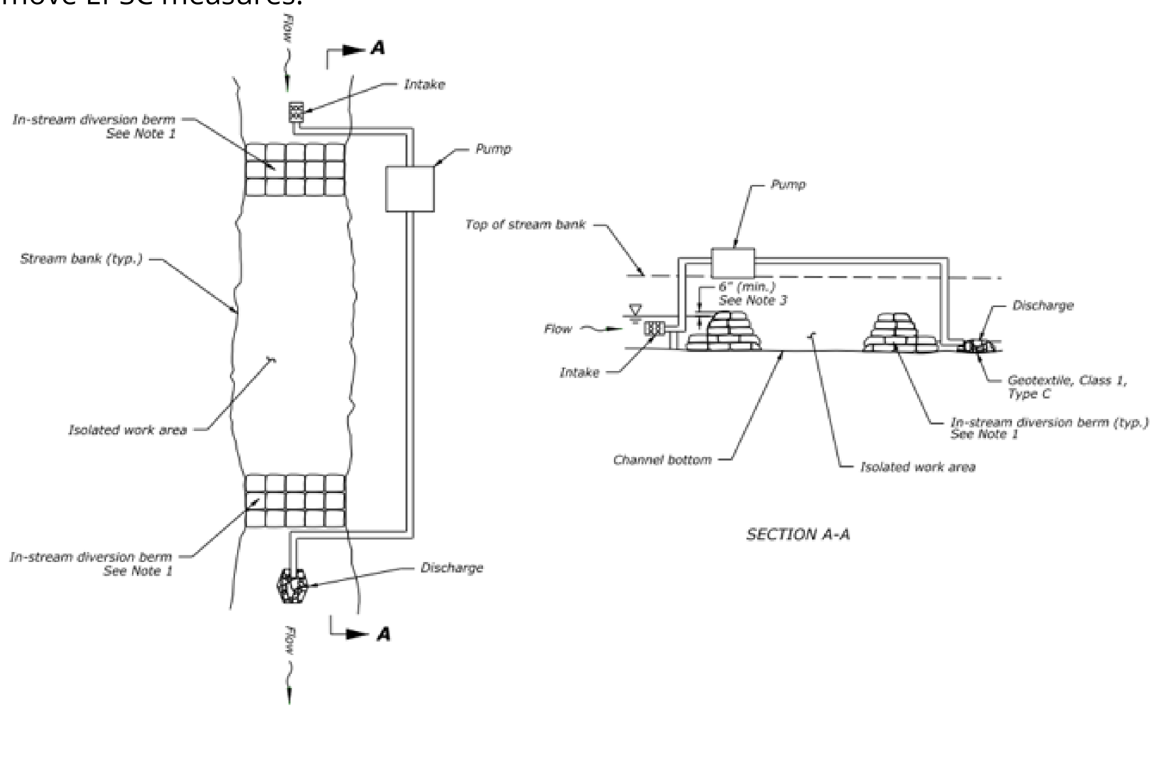

Figure 3-B: Culvert crossing details. Source: FHWA – E628-02 and E628-01for Diversion Berm.

Wetland Impact Sequencing Example

Such as access through a wetland, repair of existing utilities through a wetland, etc. (Figure 3-C).

1. Place timber mats for equipment access to wetland;
2. Place any temporary EPSC measures, if needed;
3. Remove and stockpile the first 12 inches of topsoil from the area to be impacted;
4. Excavate to replace utility line, use a trench box if needed;
5. Replace section of line and backfill;
6. Restore area to pre-construction grade with stockpiled topsoil;
7. Permanent vegetative stabilization using native species of all disturbed areas in or near the wetland must be initiated within 14 days of project completion, Non-native, non-invasive annuals may be used as cover crops until native species can be established;
8. Remove all temporary EPSC measures; and
9. Remove timber mats and vegetate any disturbed soil remaining from construction.

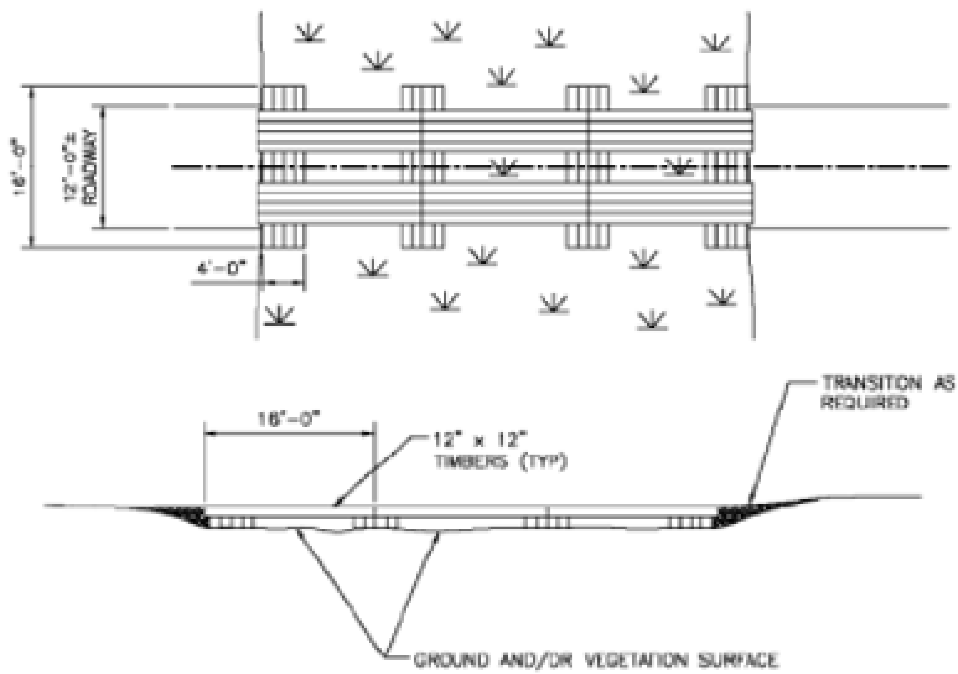

Figure 3-C: Stream crossing with mats details. Source: USACE (2016).

Lake Impact Sequencing Example

Such as revetment to a dam, building a bridge pier, work in a marina, etc. (Figure 3-D).

1. Install access road;
2. Place EPSC measures, such as floating turbidity curtains;
3. Place a cofferdam;
4. Pump out the water from behind the cofferdam so that it exposes the bottom of the lake. The water can be pumped to a sediment filter bag on land or behind a floating turbidity curtain to minimize sediment from migrating in the lake;
5. Pump as needed to keep area work area in cofferdam dry;
6. Construct the bridge pier;
7. Remove the cofferdam and access; and
8. Remove EPSC measures.

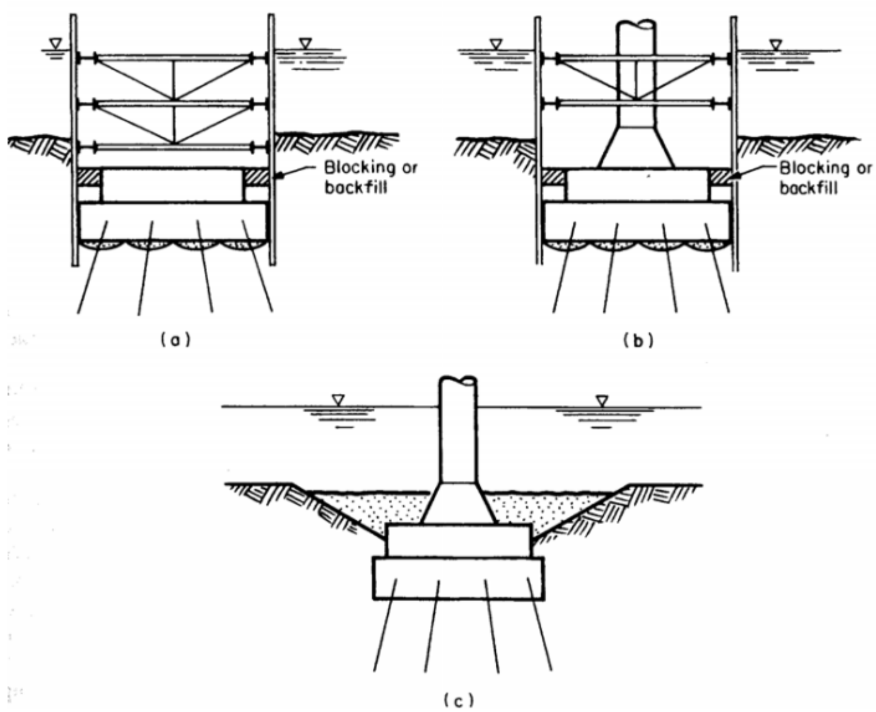

Figure 3-D: Cofferdam construction details. (a). Check blocking, dewater, construct footing block, block between footing and sheet piles. (b) Remove lower bracing, construct pier pedestal, construct pier shaft. (c) Flood cofferdam, pull sheets, remove bracing, backfill. Source: UW Department of Construction Management (2007).

Channel Restoration Sequence and Implementation Example

Conditions: Erosion and sediment controls will be placed onsite prior to any groundwork or soil destabilization and remain in place and maintained during land disturbing activities. The new stream channel shall be excavated and stabilized during low-flow conditions. Temporary flow diversion may be used if necessary. Mulch and seeding shall be installed immediately following channel completion in accordance with accepted plans. Trees shall be installed in the first planting season following channel excavation. Water shall be diverted into the new channel **ONLY** after it is completely stabilized, and **ONLY** during a low-water period.

Channel restoration example sequence:

1. Flag edge of the new channel top of bank prior to clearing. Do not clear large trees in position to shade the new channel. Leave as many native trees and shrubs as possible;
2. Excavate the new channel "in the dry" by leaving areas of undisturbed earth (diversion berms) in place at both ends;
3. Shape channel. Any water collected in the new stream channel during construction shall be filtered prior to discharge;
4. Place topsoil, erosion control blanket or turf reinforcement, seed, and sod as specified;
5. Remove diversion berms, beginning with the most downstream. Banks and bottom elevation of the old channel shall transition smoothly into the new channel. The elevations of the new channel at both ends of the relocation shall match the elevations of the old channel;
6. Provide a minimum of 72 hours from initial diversion of flow until alteration/filling of the original stream to allow emigration of semi-aquatic organisms; and
7. Install plantings along stream banks as specified in accepted plans.

References:

FHWA. FLH Standard Drawings for the FP-24. https://highways.dot.gov/federal-lands/std-drawings.

MHFD. (2024a). *Conventional and Soil Riprap Construction Guidance Checklist*. https://www.mhfd.org/resources.

MHFD. (2024b). *Void-Filled Riprap Construction Guidance Checklist.* https://www.mhfd.org/resources.

TDEC. *Tennessee Contstruction General Permit*. https://www.tn.gov/environment/permit-permits/water-permits1/npdes-permits1/npdes-stormwater-permitting-program/npdes-stormwater-construction-permit.html.

TDOT. *Standard Drawings: Erosion Prevention and Sediment Control*. https://www.tn.gov/tdot/engineering-division/engineering-production-support/standard-drawings-library/standard-roadway-drawings/erosion-prevention-and-sediment-control/

UM Department of Construction Management. (2007). *CM 420 Temporary Structures: Cofferdams*.

USACE. (2016). *Construction Mat Best Management Practices*.