Best Management Practices for Construction in Karst Regions of Arkansas

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The majority of Best Management Practices (BMPs) are designed to remove larger sediment and cannot eliminate turbidity in stormwater runoff. The only methods that successfully eliminate fine silt and clay particles are filtering practices such as rain gardens and tall vegetation buffers. Therefore, it is key to prevent erosion by minimizing disturbance, sequencing construction and immediate revegetation of disturbed areas. Outlined below are basic guidelines for many of the most common and effective BMPs. *BMP schematics are courtesy of the Stormwater Compliance Group of Northwest Arkansas.*

Chapter 1: Preventative BMPs

BMP 1: Qualified Site Official (QSO)

Designate at least one qualified person as the responsible representative in charge of erosion control and water quality protection. The QSO is responsible for directing installation, inspection, maintenance, modification, and removal of BMPs. The QSO is also responsible for ensuring compliance with all local, state, and federal erosion and sediment control and water quality requirements.

BMP 2: Minimize Disturbance/Preserve Existing Vegetation and Wetlands

Purpose

Runoff with fine silt and clay sediment will pass through most BMPs untreated. Therefore, limiting site disturbance to the maximum extent practical is the single most effective method for reducing erosion. It is also the most cost effective method. For runoff that contains fine silt and clay particles, the dispersed flow of water through tall vegetation is an effective method of treatment.

Specifications

- Have at least one individual in charge of minimizing unnecessary disturbance.
- Mark clearing limits and keep all equipment and construction debris within those areas. Steel construction fencing is the most effective method of protecting sensitive areas and buffers. Alternatively, wire-backed silt fence on steel posts is marginally effective. Flagging alone is typically not effective.

BMP 3: Material Storage

Purpose

Prevent, reduce, or eliminate the discharge of pollutants from material storage to the storm water system or watercourses by storing hazardous materials on site only when necessary and when necessary only in a covered secondary containment structure.

Suitable Uses

These procedures are suitable for use at all construction sites with storage of any material, but in particular for the following:

- Petroleum products such as fuel, oil and grease
- Fertilizers, pesticides and herbicides
- Detergents
- Asphalt and concrete compounds
- Hazardous chemicals such as acids, lime, adhesives, paints, solvents and curing compounds
- Any other material that may be detrimental if released to the environment

Specifications

Follow these steps to minimize risk:

- Hazardous material storage on-site should be minimized and at least 300 feet (') from streams and karst features.
- Store hazardous materials in secondary containment structures, such as earthen dikes, horse troughs, or appropriate box trailers.
- Store liquids, petroleum products, and substances listed in 40 CFR Parts 4-53 110, 117, or 302 in approved containers and drums and do not overfill.
- Secondary containment facilities should be impervious to the materials stored therein for a contact time of 72 hours.
- Maintain secondary containment facilities free of accumulated rainwater and spills. In the event of spills or leaks, collect and place spills and accumulated rainwater into drums. Handle these liquids as hazardous waste unless testing determines them to be non-hazardous.

Maintenance Standards

Check secondary containment areas weekly; before and after each storm event; and after every delivery for spills and/or leaks.

BMP 4: Gross Solids and Solid Waste

Purpose

Provide appropriate containers to accept solid and liquid items of trash, packing materials, construction debris, sweepings, spill clean-ups, etc.

Specifications

Provide separate containers if hazardous materials are expected on-site. Hazardous material containers left on-site should be locked at all times. Recyclables can also be collected separately from regular "trash" and potentially hazardous materials.

Locate all containers where runoff will not enter the container.

Locate all containers away from karst features, streams, wetlands, etc.

BMP 5: Concrete Waste Management

Purpose

Concrete work can generate process water and slurry that contain fine particles and high pH, both of which can violate water quality standards in the receiving water. Treating process water, slurry and equipment appropriately reduces the likelihood of water contamination.

Specifications

Wash concrete truck chutes, pumps, and internals into formed areas awaiting installation of concrete or asphalt.

- Return unused concrete remaining in the truck and pump to the originating batch plant for recycling.
- Wash hand tools including, but not limited to, screeds, shovels, rakes, floats, and trowels into washouts or areas awaiting installation of concrete.
- Wash equipment that cannot be easily moved, such as concrete pavers, in areas that do not directly drain to karst features, ditches, streams, wetlands, etc.
- Contain water and leftover product in a lined container.
- Allow the contained water to evaporate and dispose of the solids properly (It is necessary to cover evaporation tanks during rain events).

Maintenance Standards

All containers shall be checked for holes daily during concrete pours and repaired the same day. Lined containers are more susceptible to puncturing; especially if cleaned out using anything larger than a shovel.

BMP 6: Washouts

Purpose

Washouts provide an area for cleaning equipment and tools while containing hazardous waste that may otherwise pollute waterways and groundwater.

Specifications

- Each site should provide a method for the disposal of washouts from paint brushes and sprayers, petroleum products, etc.
- Containers should be lined with at least a 10 mm thick liner or have secondary containment.
- Keep containers under a cover or have sufficient secondary containment capacity for a 10-year, 24-hour storm event.

Maintenance Standards

Containers should be checked regularly for leaks.
Empty containers regularly throughout the life of the project.
At the end of a project, washouts should:

- Have solids removed and properly disposed of.
- If liquids remain, properly dispose of them with other sanitary waste; per manufacturer's specifications; or as hazardous waste, if no other suitable option is available.

Locate all containers and other devices so that overflow out of the container will not fall into or interact with water that will enter a karst feature, ditch, stream, creek, or other temporary or permanent waterbody.

BMP 7: Sequencing Schedule

Purpose

The removal of surface ground cover leaves a site vulnerable to accelerated erosion. Construction procedures that limit land clearing; provide timely installation of erosion and sedimentation controls; and restore protective cover significantly reduce the erosion potential of a site. It is also one of the most cost-effective methods of controlling erosion for construction companies.

Description

The construction sequence schedule is an orderly listing of all major land disturbing activities together with the necessary erosion and sedimentation control measures planned for the project.

Design Considerations

- Schedule projects to disturb only small portions of the site at any one time.
- Complete grading as soon as possible. Immediately stabilize the disturbed portion before grading the next portion.
- Practice staged seeding in order to revegetate cut and fill slopes as the work progresses.

If extended wet periods delay the project schedule, revise schedules to ensure everyone involved is current on which processes should be underway and which areas require protection, treatment, and/or stabilization.

Chapter 2: Access and Source Control BMPs

BMP 8: Construction Road and Parking Area Stabilization

Purpose

Stabilizing entrances, roads, other on-site vehicle routes, and parking areas immediately after grading will reduce the amount of erosion caused by construction traffic.

Suitable Uses

- All roads or parking areas for construction traffic.

Design and Installation Specifications

- On areas that will receive asphalt as part of the project, install the first lift as soon as possible.
- Temporary road gradients should be graded to drain and should not exceed 15%. Provide drainage ditches on each side of the roadway in the case of a crowned section, or on one side in the case of a super-elevated section. Direct drainage ditches to a treatment BMP (BMPs 29-32).
- In some cases, the road can be graded to direct sheet flow runoff into a heavily vegetated area with a well-developed topsoil. Landscaped areas are not adequate. If the area has a vegetated strip that meets the criteria outlined in BMP 19 Vegetated Strip, then it is generally preferable to use the vegetation to treat runoff, rather than to build a sediment pond or other treatment BMP. The strip shall **not** include wetlands. If runoff is allowed to sheet flow through adjacent vegetated areas, it is vital to design the roadways and parking areas to avoid concentrated runoff.
- Protect storm drain inlets to prevent sediment-laden water entering the storm drain system (see BMP 25).

Maintenance Standards

- Inspect stabilized areas regularly, especially after storm events.
- Add crushed rock, gravel base, hog fuel, etc. as required to maintain a stable driving surface and to stabilize any areas that have eroded.
- Following construction, restore these areas to pre-construction condition or better to prevent future erosion.
- Remove any non-biodegradable mats or pads upon completion.

BMP 9: Temporary and Permanent Seeding

Purpose

Seeding helps reduce erosion by stabilizing exposed soils. A well-established vegetative cover is one of the most effective methods of reducing erosion.

Suitable Uses

- Seed throughout the project on disturbed areas that have reached final grade or that will not be worked for two months or more.

Design and Installation Specifications

- At final site stabilization, prepare all disturbed areas not otherwise vegetated or stabilized and seed as necessary to obtain dense vegetation.
- Prior to seeding, roughen graded areas that are not already rough, have greater than 3:1 slope, 20’ of length or 5’ of vertical change. This can be accomplished in a variety of ways, including "track walking," or driving a crawler tractor up and down the slope, leaving a pattern of cleat imprints parallel to slope contours (see BMP 14).
- Hydro-seeding, mulching, blankets, or netting may be required to properly establish vegetation, but chemical fertilizers, chicken litter, etc. should not be applied in karst regions.

- Whenever practical, the subgrade should be initially ripped and then rototilled to improve permeability, germination and growth.
- Organic matter is the most appropriate form of "fertilizer" because it provides nutrients (including nitrogen, phosphorus, and potassium) in the least water-soluble form. A natural system typically releases 2-10% of its nutrients annually.
- Cottonseed meal and seaweed extracts can take the place of chemical fertilizers, but should be used sparingly because they, similar to chemical fertilizers, can degrade water quality.
- Hydro-seed applications shall include a minimum of 1,500 pounds per acre of mulch with 3% tackifier. Mulch may be made up of 100% cottonseed meal; fibers made of wood, recycled cellulose, hemp, other plant-fibers; compost; or blends of these. Tackifier shall be plant-based (such as guar or alpha plantago). Any mulch or tackifier product used shall be installed per manufacturer's instructions. Seed is added at time of application.
- Mulch can be applied on top of the seed or simultaneously by hydro-seeding and may need to be "crimped" in to prevent erosion by wind.

Maintenance Standards
- Reseed any areas that fail to establish over 80% cover density (100% cover for areas that receive sheet or concentrated flows). If reseeding is ineffective, use an alternate method (such as sodding, mulching, netting, or blankets).
- After adequate cover is achieved, any areas that experience erosion shall be reseeded and protected by mulch. If the erosion problem is drainage-related, fix the problem, reseed the eroded area and protect the area with mulch.

BMP 10: Mulching

Purpose

The purpose of mulching soils is to provide immediate temporary protection from erosion. Mulch also enhances plant establishment by conserving moisture; holding fertilizer, seed, and topsoil in place; and moderating soil temperatures. There is an enormous variety of mulches available. Only the most common types are discussed in this section.

Suitable Uses

Use mulch:
- On disturbed areas that require cover measures;
- As a cover for seed during the wet season and during the hot summer months.

Design and Installation Specifications

Use only plant-based tackifiers.
For mulch materials, application rates, and specifications, see the Table 1.

Maintenance Standards
- The thickness of the cover must be maintained.
- Re-mulch and/or protect any eroded areas with a net or blanket. If the erosion problem is drainage-related, fix the problem and re-mulch.

Table 1. Mulching Standards

Material	Quality Standards	Application Rate	Remarks
Hydro-Mulch	Use only plant-based tackifier	About 50 to 60 lbs/1,000 ft^2 **OR** 3,000 to 4,000lbs/ac	Apply with appropriate equipment. If used with seed and plant-based tackifer, the application rate can be reduced, but by no more than 50%. Fibers should be kept to less than ¾ in to prevent clogging of machinery.
Compost And Composted Mulch	No visible water or dust during handling. Purchase from supplier with Solid Waste Permit or exempt from solid waste regulations	2 inches (") thick min. uses about 100 tons per acre **OR** 800 lbs per square yard	Excellent for protecting final grades until landscaping because it can be directly seeded or tilled into soil as an amendment. Composted mulch has a coarser size gradation than compost. More stable and practical to use in wet areas and during rainy weather conditions. More effective control can be obtained by increasing thickness to 3".
Chipped Site Vegetation	Average size shall be several inches long. Gradation from fines to 6" in length for texture, variation, and interlocking properties.	2" thick min.	Cost effective way to dispose of debris from clearing and grubbing. Eliminates the problems associated with burning. Generally it should not be used on slopes because tends to be transported by runoff. **Not** recommended within 200' of surface waters or in floodplains. If seeding shortly after mulch, the decomposition may tie up nutrients important to grass establishment.
Wood-based mulch	No visible water or dust during handling. Purchase from supplier with Solid Waste Permit or exempt from solid waste regulations.	2" thick min. uses about 100 tons per acre **OR** 800 lbs per square yard	Often called "hog fuel." Used as a material for stabilized construction exits and as a mulch. Its use as mulch ultimately improves the organic matter in the soil. Pay special attention to source and composition of wood-based mulches. Its preparation typically does not provide any weed seed control, so evidence of residual vegetation in its composition or known inclusion of weed plants or seeds should be monitored and prevented (or minimized).
Straw	Air-dried: free from undesirable seed and course material	2" to 3" thick uses one bale per 200 ft^2 **OR** 2 to 3 tons per acre	Straw often introduces and/or encourages the propagation of weed species and it has no long-term benefits. Use only if mulches with long-term benefits are unavailable locally. It should also not be used within the ordinary high-water elevation of surface waters (due to flotation). Otherwise, it is a cost-effective protection when applied with adequate thickness. Hand-application requires greater thickness than if blown. When used with seed, reduce thickness of straw by 50%. In windy areas, it must be held in place by crimping, using a tackifier, or covering with netting. Blown straw always has to be held in place with a tackifier or wind will blow it away.

NOTE: Thicknesses may be increased for disturbed areas in or near sensitive areas or other areas highly susceptible to erosion. Mulch used within the ordinary high-water mark of surface waters should be selected to minimize potential flotation of organic matter. Composted organic materials have higher densities than straw, wood, plant fibers, or other chipped material.

BMP 11: Nets, Mats and Blankets

Purpose

Erosion control nets, mats and blankets prevent erosion and hold seed and mulch in place on steep slopes and in channels so that vegetation can become well established. In addition, biodegradable nets and blankets can be used to permanently reinforce turf and to protect drainage ways during high flows.

Suitable Uses

Erosion control nets, mats and blankets should be used:

- To aid permanent vegetated stabilization of slopes 2:1 or greater and with more than 10' of vertical relief, and/or
- For drainage ditches and swales (highly recommended).

Design and Installation Specifications

Use biodegradable nets, mats and blankets.

In general, most nets require mulch in order to prevent erosion.

Figure 1 provides an example of installation of nets, mats, and blankets on a slope.

Installation is critical to the effectiveness of these products. If good ground contact is not achieved, runoff can concentrate under the product, resulting in significant erosion.

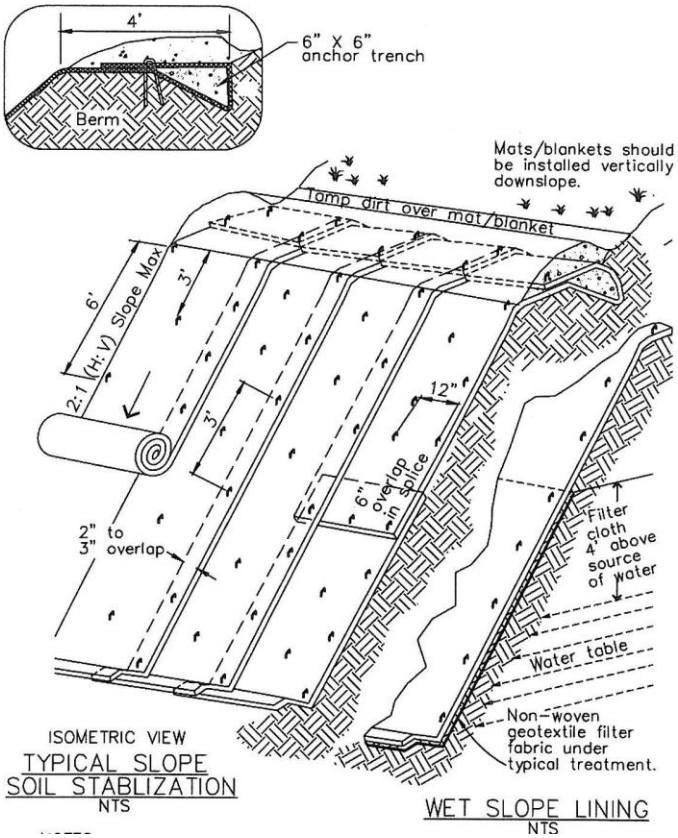

Figure 1. Specifications of net, mat and blanket installation practices.

Installation of blankets on slopes:

1. Complete final grade and track walk up and down the slope.
2. Install hydro-mulch with seed.
3. Dig a small trench, approximately 12" wide by 6" deep along the top of the slope.

4. Install the leading edge of the blanket into the small trench and stake or staple approximately every 18". **NOTE:** Staples are a minimum of 6" long. Use longer staples in sandy soils.
5. Roll the blanket slowly down the slope as installer walks backwards. **NOTE:** The blanket rests against the installer's legs. Install staples as the blanket is unrolled. It is critical that the proper staple pattern is used for the blanket being installed. Prevent the blanket from rolling down the slope on its own as this stretches the blanket and makes it impossible to maintain soil contact. In addition, do not allow anyone to walk on the blanket after it is in place.
6. If the blanket is not long enough to cover the entire slope length, the trailing edge of the upper blanket should overlap the leading edge of the lower blanket like a shingle and the two layers stapled together. On steeper slopes, install this overlap in a small trench, stapled, and covered with soil. Continue overlap process from the upstream to downstream reaches. Follow all manufacturer's installation specifications and requirements.

See Figure 2 for details of channel installations of nets, mats, and blankets.

Jute matting must be used in conjunction with mulch. Woven blankets, excelsior, and coir (coconut fiber) blankets may be installed without mulch. There are many other types of erosion control nets and blankets on the market that may be appropriate in certain circumstances.

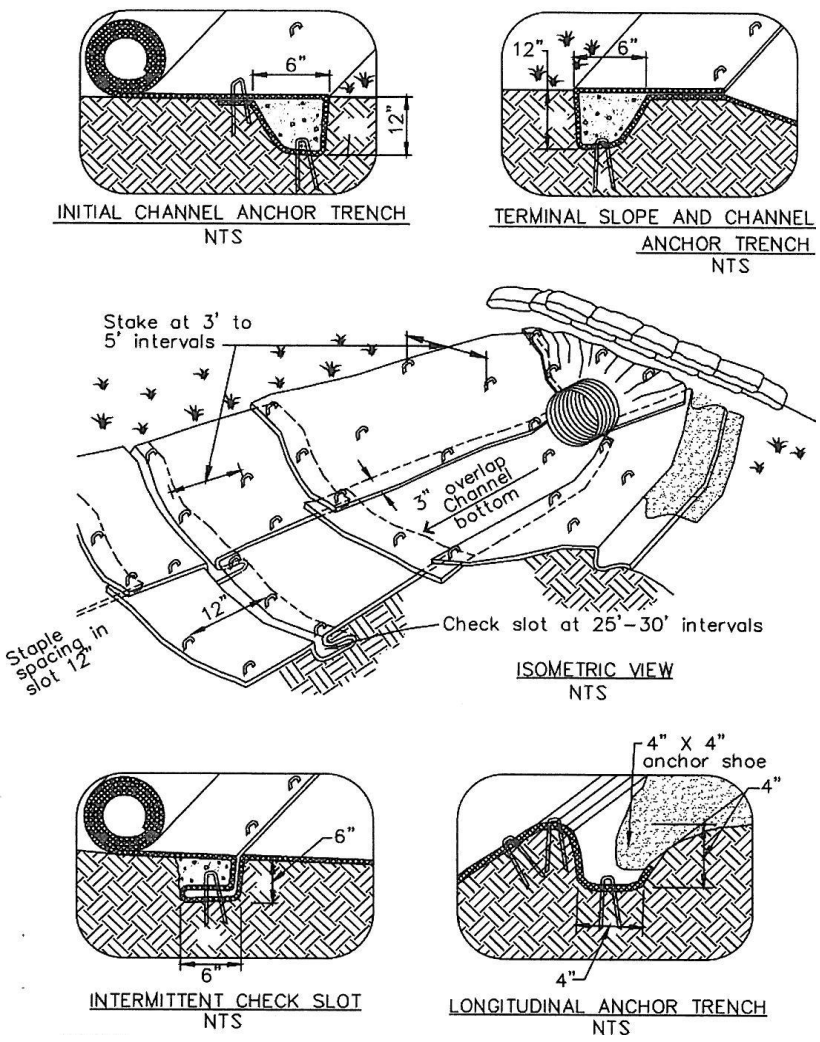

Figure 2. Example of channel installation of nets, mats and blankets.

BMP 12: Sodding

Purpose

The purpose of sodding is to establish permanent turf for immediate erosion protection and to stabilize drainage ways where concentrated overland flow will occur.

Conditions of Use

Sodding may be used in the following areas:

- Disturbed areas that require short-term or long-term cover.
- Disturbed areas that require immediate vegetative cover.
- All waterways that require vegetative lining.

Design and Installation Specifications

Use sod with a dense root mat for mechanical strength.

The following steps are recommended for sod installation:

1. Remove all rocks over 4" in diameter.
2. Shape and smooth the surface to final grade in accordance with the approved grading plan. The swale needs to be over excavated 4" to 6" below design elevation to allow room for placing soil amendment and sod.
3. Amend 4" (min.) of compost into the top 8" of the soil if the organic content of the soil is less than 10% or the permeability is slower than 0.6" per hour.
4. Work lime 1" to 2" into the soil, and smooth the surface.
5. Lay strips of sod beginning at the lowest area and perpendicular to the direction of water flow. Wedge strips securely into place. Square the ends of each strip to provide for a close, tight fit. Stagger joints at least 12". Staple on slopes steeper than 3:1. Staple the upstream edge of each sod strip.
6. Roll the sodded area and irrigate. Irrigation may be required daily until stabilization occurs.
7. When sodding is carried out in alternating strips or other patterns, seed the areas between the sod pieces immediately after finishing with the sod.

Maintenance Standards

If it is impossible to establish a healthy groundcover due to frequent saturation, instability, or some other cause, remove the sod. Then seed area with an appropriate mix and protect with a net, blanket, or other approved stabilization method.

BMP 13: Topsoiling

Purpose

To provide a suitable growth medium for revegetation of the site. Native soils and disturbed soils that have been organically amended not only retain much more stormwater, but they also serve as effective bio-filters for urban pollutants and, by supporting more vigorous plant growth, reduce the water, fertilizer and pesticides needed to support installed landscapes.

Suitable Uses

- Where native soils are disturbed during clearing and grading, restore soils to the maximum extent practicable. Leave native soils undisturbed to the maximum extent practicable.
- Stripping of existing, properly functioning soil system and vegetation for the purpose of topsoiling during construction is not acceptable. If an existing soil system is functioning properly preserve it in its undisturbed and uncompacted condition.

Design and Installation Specifications

Consider the following items when topsoiling:

- Maximize the depth of the topsoil wherever possible to provide the maximum possible infiltration capacity and beneficial growth medium.

- The final composition and construction of the soil system will favor certain plant species over time. For example, recent practices show that topsoil may favor grasses, while layering with mildly acidic, high-carbon amendments may favor more woody vegetation.
- Sandy topsoil over a clay subsoil is a particularly poor combination, as water creeps along the junction between the soil layers and causes the topsoil to slough.
- Ripping or re-structuring the subgrade may provide additional benefits regarding the overall infiltration and interflow dynamics of the soil system.
- Avoid areas of natural ground water recharge.

Confine stripping to the immediate construction area. A 4" to 6" stripping depth is common, but depth may vary depending on the particular soil. Surface runoff control structures shall be in place prior to stripping.

BMP 14: Surface Roughening

Purpose

Surface roughening aids in the establishment of vegetative cover, reduces runoff velocity, increases infiltration, and provides for sediment trapping through the provision of a rough soil surface.

Suitable Uses

- Roughen all slopes with greater than 25% slope, 20' of length or 5' of vertical change.
- Slopes with a stable rock face do not require roughening.
- Slopes where mowing is planned should not be excessively roughened.

Design and Installation Specifications

- There are different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends upon the type of slope. Roughening methods include gradient terracing (BMP 15), grooving, contour furrows, and tracking. Appropriate methods for mowed areas include disking, harrowing, raking, or seed-planting machinery operated on the contour. All depressions should be created perpendicular to the slope.
- **Tracking** is done by operating equipment up and down the slope to leave horizontal depressions in the soil (Figure 3).
- **Contour Furrows** are created by terracing a slope at grade (Figure 3).
- **Grooving** can be accomplished using a plow with furrows at least 3" deep and less than 15" apart.
- Contours furrows must be on contour or gullies will form on the slope.
- All disturbed areas on slopes should be immediately seeded, sodded or mulched once all work has been completed.

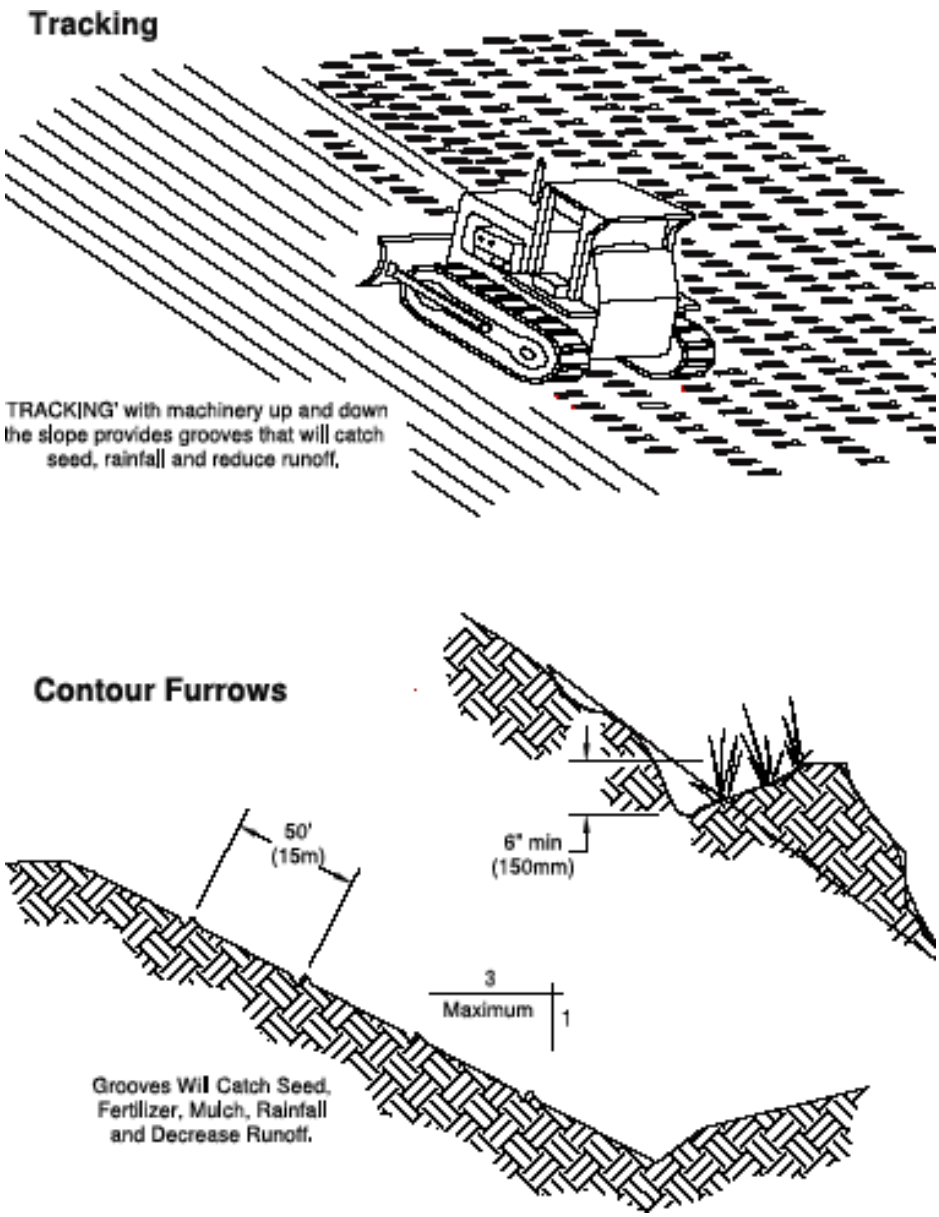

Figure 3. Examples of tracking and contour furrows.

Maintenance Standards

- Graded areas should be seeded as quickly as possible.
- Inspect area after each rain event until the site is 95% vegetated. If rills appear, they should be re-constructed, re-graded and re-seeded immediately.

BMP 15: Gradient Terraces

Purpose

Gradient terraces reduce erosion damage by intercepting surface runoff and conducting it to a stable outlet at a non-erosive velocity.

Suitable Uses

Gradient terraces should only be installed on slopes less than 50% and must be installed with outlets suitable to prevent erosion. Very sandy or rocky soils are inappropriate for terraces. See Figure 4 for an example of gradient terraces.

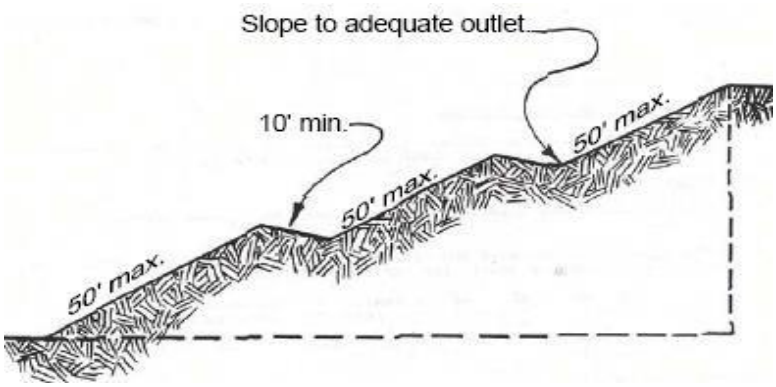

Figure 4. Example of gradient terraces.

Design and Installation Specifications

- The maximum spacing of gradient terraces should be determined by the following method where:

VI = 0.8s

VI = vertical interval in feet
s = land rise per 100', expressed in feet

- Channel grades may be either uniform or variable with a maximum grade of 7.5" per 100' length. For short distances, increase terrace grades as necessary to improve alignment. The channel velocity should not exceed that which is non-erosive for the soil type with the planned treatment.
- In all cases, the outlet must convey runoff from the terrace or terrace system to a point where the outflow will not cause damage. Use vegetative cover in the outlet channel.
- Vertical spacing determined by the above methods may be increased as much as 6" or 10%, whichever is greater, to provide better alignment or location, to avoid obstacles, to adjust for equipment size, or to reach a satisfactory outlet.
- The drainage area above the top should not exceed the area drained by a terrace with normal spacing.
- The terrace should have enough capacity to handle the peak runoff expected from a 2-year, 24-hour design storm without overtopping.

Chapter 3: Conveyance BMPs

BMP 16: Interceptor Dike and Swale

Purpose

Intercepts runoff and directs it to a stabilized outlet, sediment basin, etc. In doing so, it reduces the volume and velocity of runoff flowing down the slope.

Suitable Uses

- Use upslope of a construction site to prevent runoff from entering disturbed area, storage area, etc.
- Use downslope to collect runoff from a disturbed area and direct it to a sediment basin.
- Use at top of new fill before vegetation is established.
- Use as a permanent diversion channel to carry runoff.
- Release sediment-laden runoff through a sediment trapping facility.

Design and Installation Specifications

- See Table 2 and 3 for interceptor dike and swale specifications, respectively.
- Place horizontally across slope to reduce volume and velocity of runoff flowing downslope.
- Stabilize dike, swale and channel with temporary or permanent vegetation or other channel protection during construction.
- The maximum velocity should not exceed 5 fps.
- Provide energy dissipation measures at outlet to prevent erosion.

Table 2. Specifications for interceptor dikes.

Top Width	2’ minimum
Height	18” minimum. Measured from upslope toe and at a compaction of 90% ASTM D698 standard proctor
Side Slope	3:1 or flatter
Channel Grade	Minimum is 0.5% and maximum is 1%. Steeper channel grades require channel protection and check dams
Horizontal Spacing of Interceptor Dikes	Slopes <5% = 300’
	Slopes 5–10% = 200’
	Slopes 10–25% = 100’
	Slopes 25–50% = 50’
Stabilization	Slopes = <5%. Seed and mulch applied within 5 days of dike construction.
	Slopes = 5–40%. Dependent on runoff velocities and dike materials. Stabilization, using either sod or riprap, should be done immediately to avoid erosion
Outlet	The upslope side of the dike must provide positive drainage to the dike outlet.

Table 3: Specifications for interceptor swales.

Bottom Width	2’ minimum; the bottom is level
Depth	1’ minimum
Side Slope	3:1 or flatter
Channel Grade	Maximum 5%, with positive drainage to a suitable outlet (such as a sediment pond)
Horizontal Spacing of Interceptor Dikes	Slopes <5% = 300’
	Slopes 5–10% = 200’
	Slopes 10–25% = 100’
	Slopes 25–50% = 50’
Stabilization	Seed as per BMP 9 (Temporary and Permanent Seeding) or BMPs 17 and 18 (Channel Lining); 12” thick stone pressed into the bank and extending at least 8” vertical from the bottom
Outlet	Riprap to stabilized outlet/sedimentation pond

Maintenance Standards

- Routinely inspect diversion dikes and interceptor swales and immediately remove any sediment from the flow area.
- Check outlets and make timely repairs as needed to avoid rill and/or gully formation.
- When the area below the temporary diversion dike is permanently stabilized, remove the dike and fill and stabilize the channel to blend with the natural surface.

BMP 17: Grass-Lined Channels

Purpose

Provide a channel with a vegetative lining for conveyance of runoff. See Figure 5 for typical grass-lined channel cross-sections.

Suitable Uses

- Should only be used where vegetative lining can provide sufficient stability for the channel cross section. This means that the channel slopes are generally flatter than 5% and space is available for a relatively large cross section.

Design and Installation Specifications

- Grass channels, at a minimum, should carry peak runoff for temporary construction from the 10-year, 24-hour storm without eroding. Where flood hazard exists, increase the capacity according to the potential damage.
- Design channel to not be overtopped by peak runoff from a 10-year, 24-hour storm.
- Grassed channel side slopes generally are constructed 3:1 or flatter to aid in the establishment of vegetation and for maintenance.
- Locate channels to use natural drainage systems to the greatest extent possible.
- Vegetation should be well established (i.e., over 75% cover) before water is allowed to flow in the ditch. This means that channels will often need to be installed and seeded prior to major earth work. In channels that will have high flows, install erosion control blankets over the seed. If vegetation cannot be established from seed before water is allowed in the ditch, install sod in the bottom of the ditch in lieu of mulch and blankets.
- If design velocity of a channel to be vegetated by seeding is higher than 2 fps, install a channel liner. Geo-textile, special mulch protection, blankets or netting provides stability until the vegetation is fully established. See Figure 6.

- If velocity will exceed 5 fps additional permanent reinforcing of the channel bottom is necessary.
- Subsurface drainage or stone channel bottoms may be necessary on sites that are subject to prolonged wet conditions due to long duration flows or a high water table.
- Provide outlet protection at culvert ends and at channel intersections.
- Oversize channels a minimum of 2" to allow for soil bulking during seedbed preparations or sodding.

V-shaped grass channels generally apply where the quantity of water is small, such as in short reaches along roadsides. The V-shaped cross section is least desirable because it is difficult to stabilize the bottom where velocities may be high.

Trapezoidal grass channels apply where runoff volumes are large and slope is low so that velocities are non-erosive to vegetated linings. (Note: It is difficult to construct small parabolic shaped channels.)

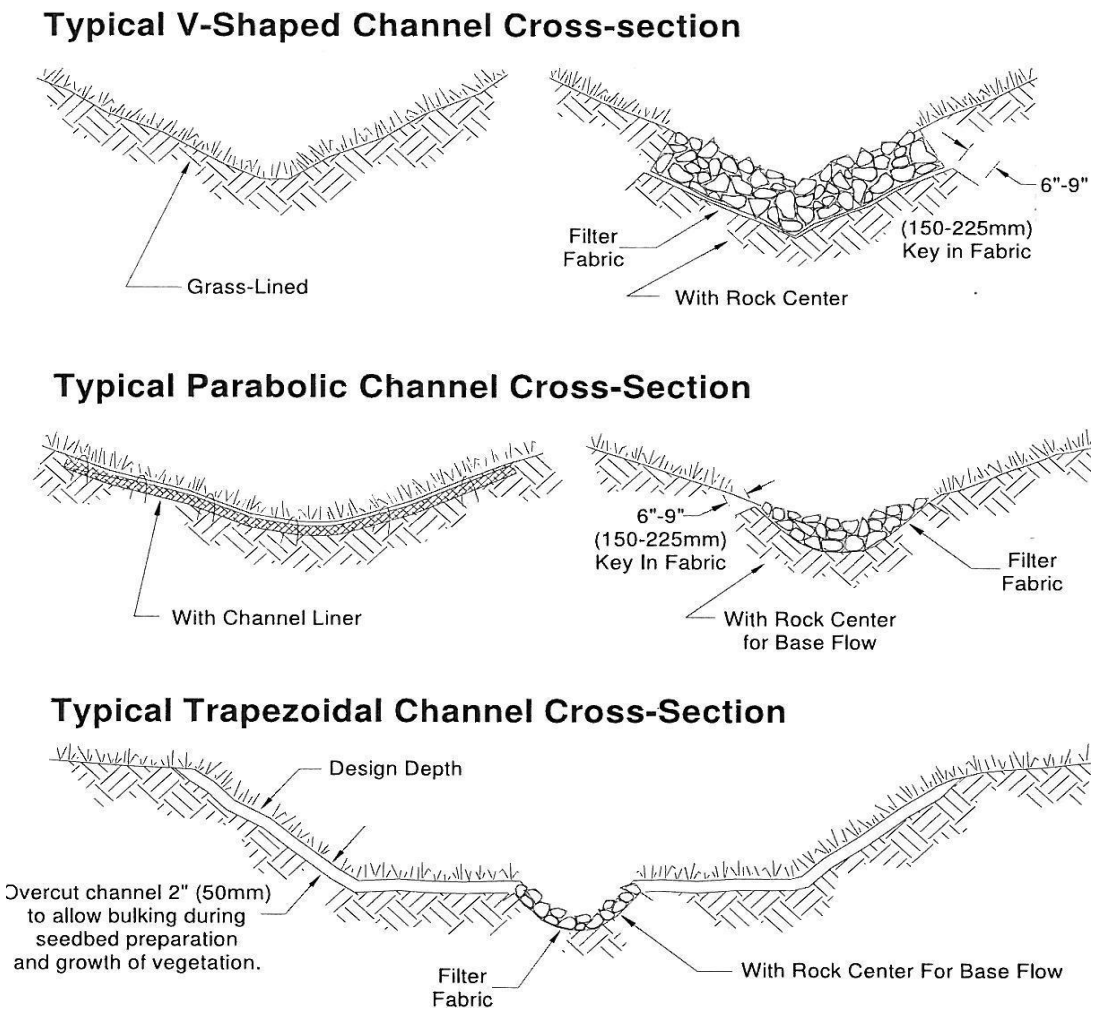

Figure 5. Cross sections of typical grass-lined channels.

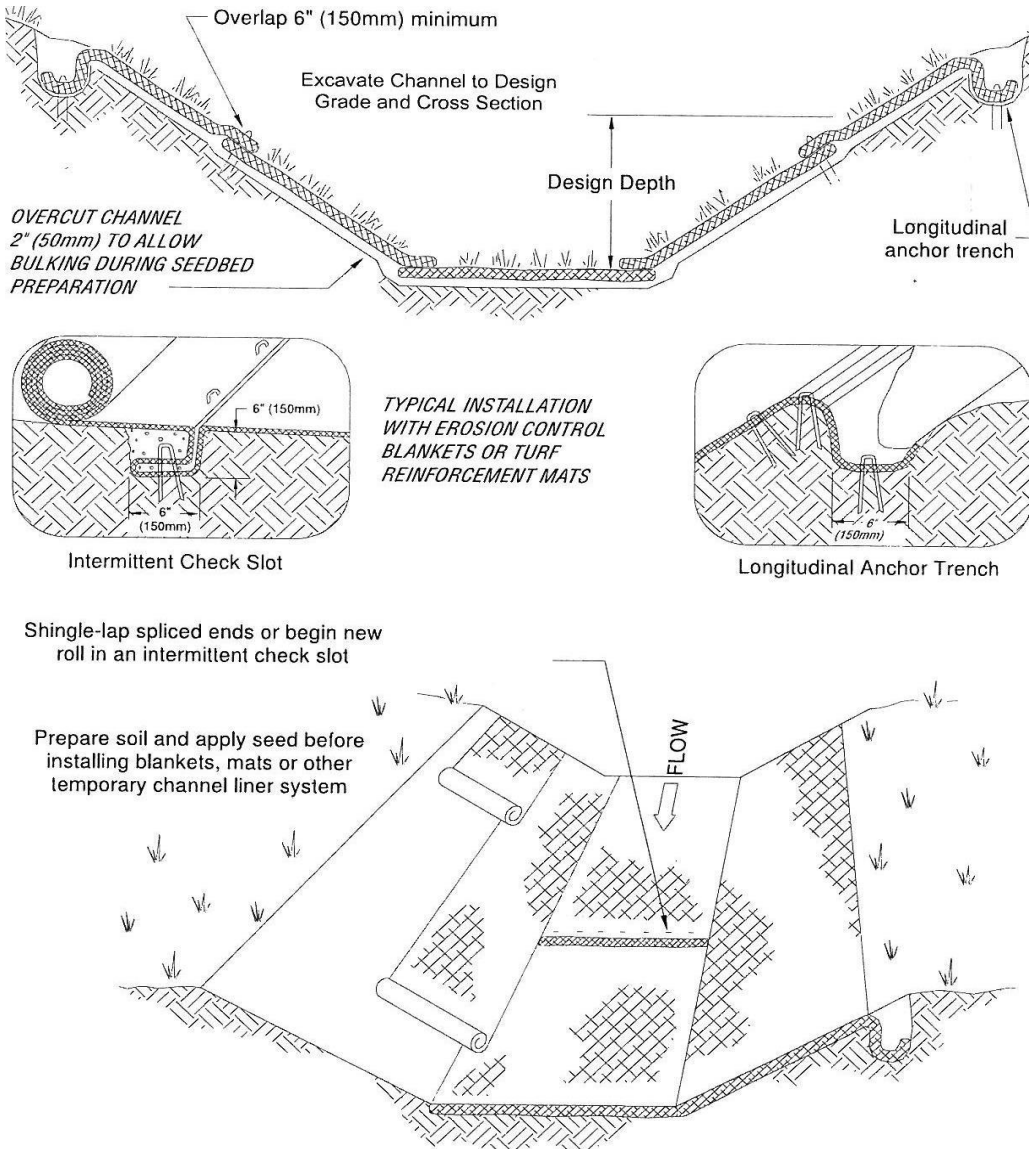

Figure 6. Installation of channel liners for temporary stabilization of a typical grass lined channel.

Maintenance Standards

Routinely monitor channels for over-topping or erosion and immediately make repairs.

Remove all significant sediment accumulations to maintain the designed carrying capacity. Keep the grass in a healthy, vigorous condition at all times, since it is the primary erosion protection for the channel.

BMP 18: Reinforced Channel Lining

Purpose

To protect erodible channels by providing a channel liner using blankets, articulated mats, stone or rubble.

Suitable Uses

- When natural soils or vegetated stabilized soils in a channel are not adequate to prevent channel erosion.
- As a temporary measure when installing a permanent ditch or pipe system.
- The Federal Highway Administration (FHA) recommends not using flexible liners whenever the slope is above 10%, or the shear stress is greater than 8 psf.

Design and Installation Specifications

See BMP 11 for information on rolled materials like mats, nets, and blankets. Sequence construction to minimize stone placement delays.

- Do not disturb areas until final preparation and placement of stone can follow immediately behind the initial disturbance. Where stone is used for outlet protection, it should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.
- Only use stones large enough to be stable under maximum flow conditions.
- An alternative is to use rubble concrete if it meets the requirement of the project designer's standards and specifications.
- Place a lining of engineering filter fabric (geo-textile) between the stone and underlying soil surface or if the stone is 12" or larger it can be used in conjunction with a layer of coarse aggregate. Key in the geo-textile at the top of the bank.
- All Mats, blankets, and nets require staples or other anchoring systems.

Maintenance Standards

Routinely monitor movement of stone and other materials and repair as necessary.
Do not use weed killers in or near ditches, channels or waterways.

BMP 19: Vegetated Strip

Purpose

Vegetated strips reduce the transport of coarse and fine sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

Suitable Uses

- Vegetated strips may be used downslope of all disturbed areas.
- Do not use vegetated strips to treat concentrated flows or substantial amounts of overland flow. Any concentrated flows must be conveyed to a sediment pond or similar treatment BMP. However, the use of vegetated strips in combination with other treatment BMPs can be very effective.

Design and Installation Specifications

- The slope within the vegetated strip should on average be less than 4:1.
- Landscaped areas are generally not adequate because the volume of sediment overwhelms the grass. Ideally, vegetated strips consist of undisturbed native growth (ungrazed fields, prairie, etc.) with a well-developed soil that allows for infiltration of runoff.
- The only circumstances in which overland flow can be treated solely by a vegetated strip, rather than by a sediment pond or similar treatment BMP, is when the flow is dispersed evenly across dense vegetation and the flow path across the vegetated strip exceeds the following: [(% Slope)(100)] X (Length of Flow) = Length of Vegetated Strip in feet. Meaning if the average slope was 25% and the length of flow was 10' the vegetated strip should be 250'.

Maintenance Standards

Seed and mulch areas damaged by erosion or construction activity immediately.
If more than 5' of the original vegetated strip has had vegetation removed or is being eroded install sod or alternative BMPs.
If concentrated flows are traveling across the buffer install surface water controls such as level spreaders, perimeter controls or a sediment pond.

BMP 20: Water Bars

Purpose

A small ditch or ridge of material constructed diagonally across a road or right-of-way to divert storm water runoff from the road surface.

Suitable Uses

Clearing right-of-way and construction of access roads for power lines, pipelines, and other similar installations often requires long narrow right-of-ways/roads over sloping terrain. To prevent the formation of rills and gullies, divert runoff across the width of the right-of-way/road to undisturbed areas using water bars (Figure 7).

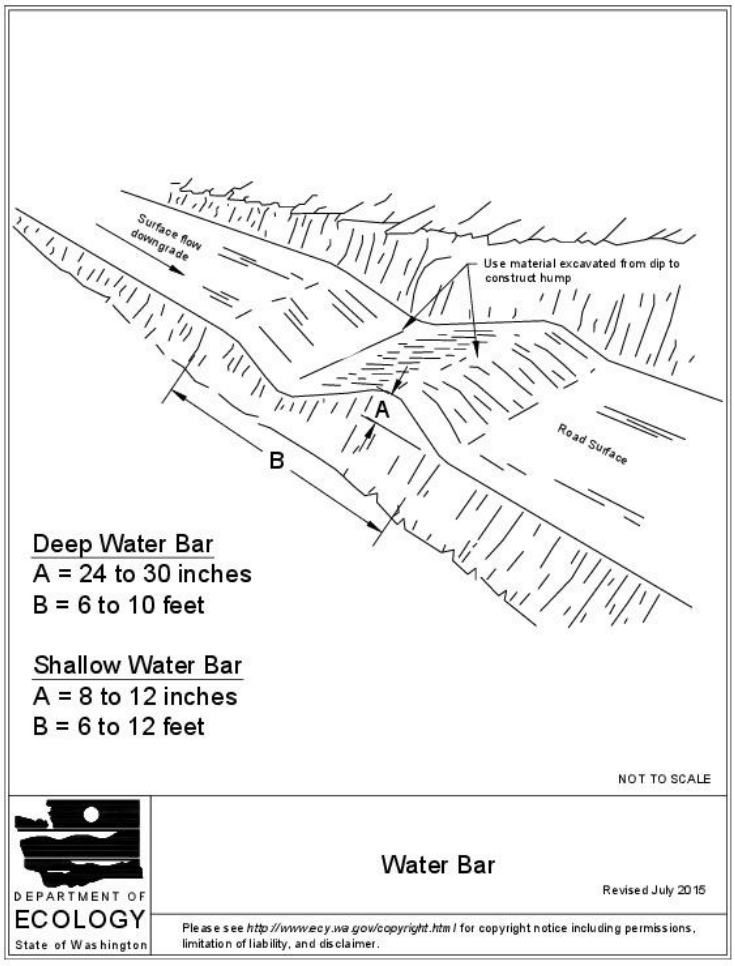

Figure 7. Schematic of typical water bar across a road.

Design and Installation Specifications

- Space water bars such that diverted water does not cause scouring (Table 4).
- Height: 8” minimum measured from the channel bottom to the ridge top.
- Side slope of channel: 2:1 maximum; 3:1 or flatter when vehicles will cross.
- Base width of ridge: 32” minimum.
- Grade and angle: Select angle that results in ditch slope less than 2%.
- Locate to discharge into stable, well-vegetated areas.
- Establish vegetation and riprap at outlet as necessary to prevent erosion/ditching.
- Establish holding ponds as necessary to prevent sediment transport into waterways and karst features.

- Compact the ridge when installed.
- Stabilize; seed; and mulch the portions that are not subject to traffic. Gravel the areas crossed by vehicles.

Table 4. Water bar spacing guidelines.

% Slope	Spacing
Less than 5%	125’
5-10%	100’
10-20%	75’
20-35%	50’
More than 35%	Use rock lined ditch

Maintenance Standards
- Routinely check for erosion and sedimentation, and make timely repairs as needed.

BMP 21: Waddles or Wattles

Purpose
Waddles or wattles are temporary erosion and sediment control barriers that reduce the velocity and can spread the flow of runoff while capturing and retaining sediment. Place wattles in shallow trenches and stake along the contour of disturbed or newly constructed slopes. See Figure 8 for typical construction details.

Suitable Uses
- Disturbed areas that require immediate erosion protection.
- Exposed soils during short construction delays, or over winter months.
- On slopes requiring temporary stabilization.
- For inlet protection and reclamation of specific pollutants such as heavy metals and phosphorous.

Design and Installation Specifications
- Install wattles parallel to theslope contour and avoid passing water underneath or over.
- Dig narrow trenches across the slope on contour to a depth of 2-3”.
- Install wattles from the base of the slope up, overlap the ends and backfill the upslope side.
- Install stakes at each end of the wattle, and every 4’ along entire length of wattle.
- If conditions are appropriate, biodegradable wattles can be staked to the ground using willow cuttings for added re-vegetation.
- All wattles should be biodegradable unless they are used for reclamation of specific pollutants and subsequently removed.

Maintenance Standards
Inspect the slope after each significant storm and repair any area where wattles are not tightly abutted together or where water has scoured beneath them.

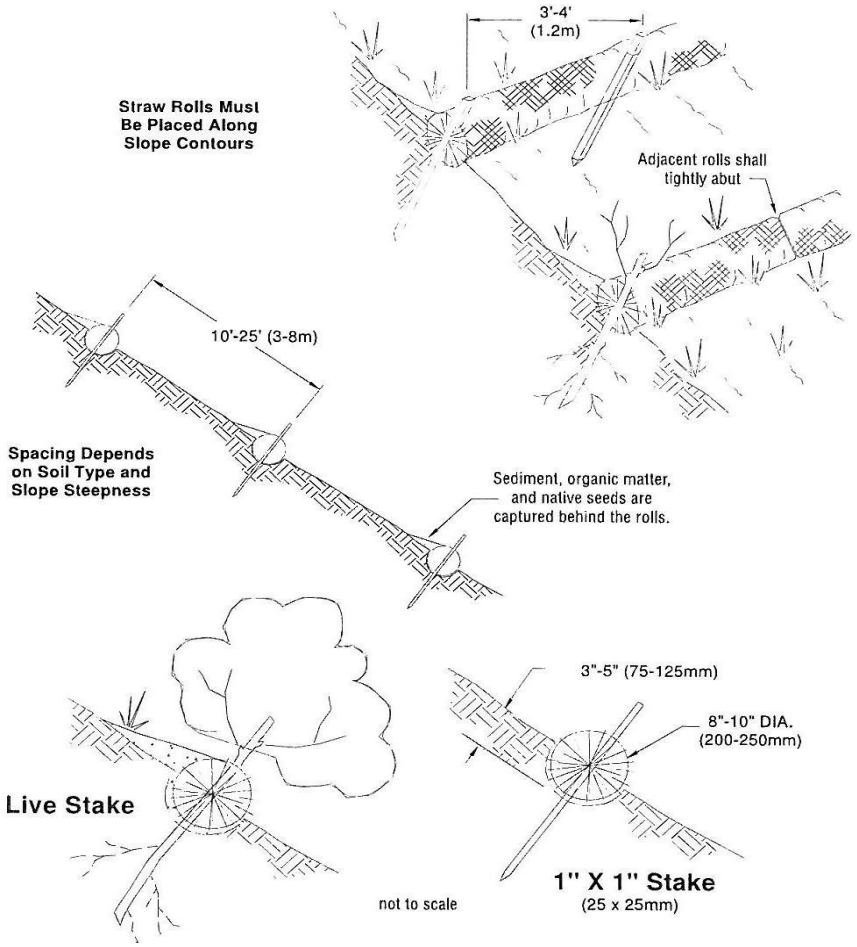

Figure 8. Schematic for installation of wattles/waddles.

BMP 22: Check Dams

Purpose

Construction of small rock dams across a swale or ditch reduces the velocity of concentrated flow and dissipates energy while providing a location for sediment and other items to settle out of the water.

Suitable Uses

In ditches or swales to reduce water velocity.

Do not place check dams in seasonal or permanent streams or wetlands without approval from all permitting agencies.

Design and Installation Specifications

- The dam should form a triangle when viewed from the side (Figure 9). This prevents undercutting as water flows over the dam.
- Check dams with sumps work more effectively at slowing flow and retaining sediment than a check dam alone.
- The maximum spacing between the dams shall be such that the toe (bottom) of the upstream dam is at the same elevation as the top of the downstream dam (Figure 9).
- The center of the dam should be at least 12” below both ends of the dam.
- The dam should be a minimum of 24” deep at center.
- Keep the side slopes of the check dam at 2:1 or flatter. Key the stone into the ditch banks and extend it beyond the abutments a minimum of 18” to avoid washouts from overflow around the dam.
- The rock used must be large enough to stay in place given the expected design flow through the channel as

well as over the dam face.

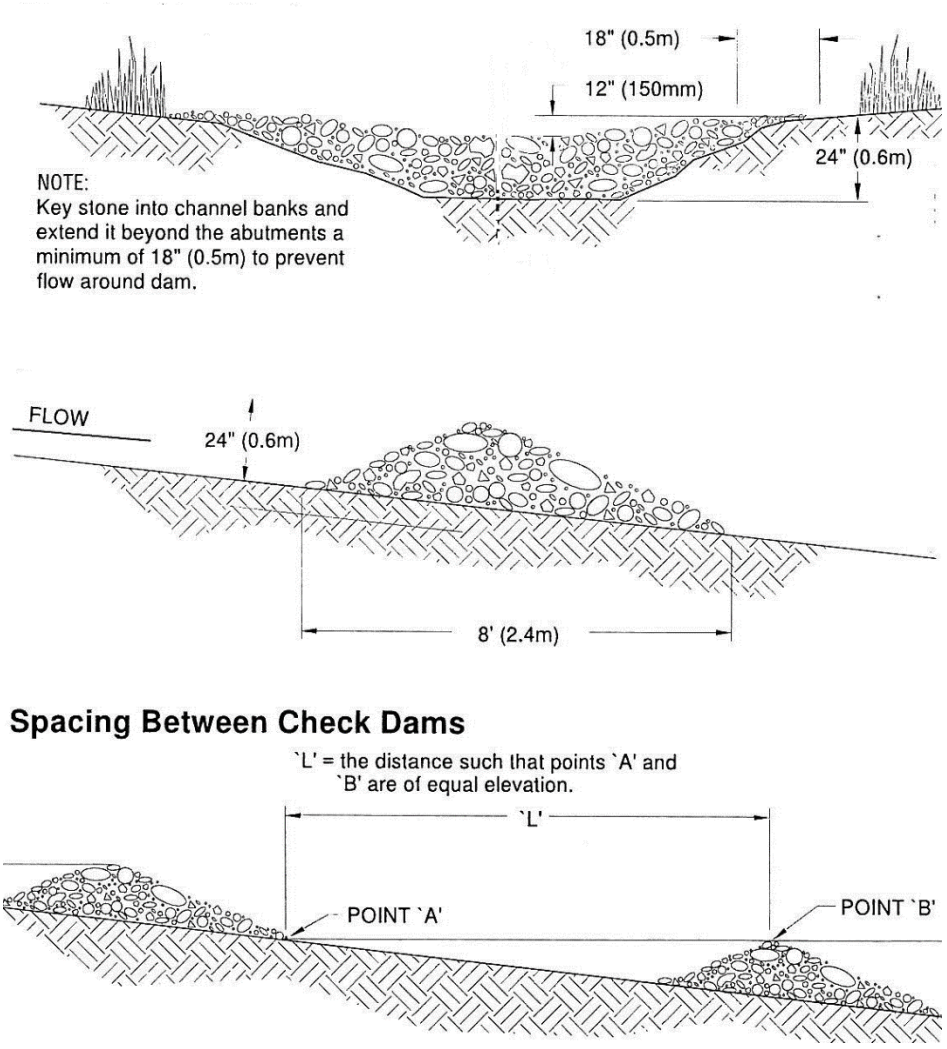

Figure 9. Schematic of check dam specifications.

Maintenance Standards

- Routinely inspect check dams and remove sediment when it reaches half the dam height.
- Replace missing or dislodged materials to maintain the dam's shape and function.
- If significant erosion occurs between dams, install a protective stone liner in that portion of the channel.

BMP 23: Brush Barrier

Purpose

The purpose of brush barriers is to reduce the transport of coarse sediment from a construction site by providing a physical barrier to sediment and reducing the runoff velocities of overland flow.

Suitable Uses

- Brush barriers may be used downslope of all disturbed areas of less than 10,000 square feet (sf).
- Brush barriers are not intended to treat concentrated flows, nor are they intended to treat substantial amounts of overland flow. Convey concentrated flows through the drainage system to a sediment pond, constructed wetland or similar treatment BMP.
- Brush barriers should only be installed on contours

Design and Installation Specifications

- Height: 24” minimum
- Width at base: 5’ minimum
- Filter fabric may be anchored over the brush berm to enhance the filtration ability of the barrier. 10-oz burlap is an adequate alternative for fabric.
- Chipped site vegetation, composted mulch, or wood-based mulch can be used to construct brush barriers.
- There should be no metal, plastic, trash, or other contaminants in the barrier.
- A 100% biodegradable installation can be constructed using 10-ounce burlap held in place by wooden stakes for barriers that will be left in place. Figure 10 below depicts a typical brush barrier.

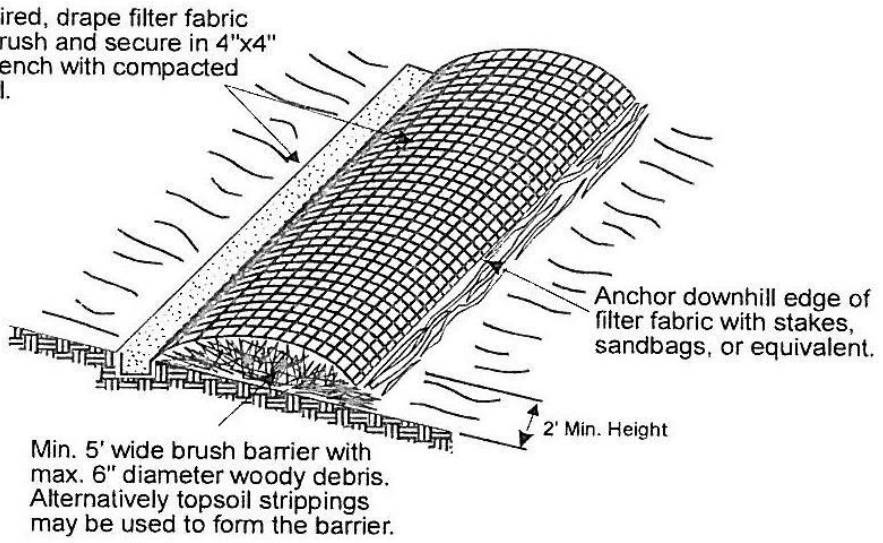

Figure 10. Schematic of brush barrier and specifications.

Maintenance Standards
- Routinely inspect barriers and address concentrated runoff under or around the barrier.

BMP 24: Gravel Filter Berm

Purpose
A gravel filter berm is used to retain sediment.

Suitable Uses
Around parking lots, roads, or areas of ground disturbance.

Design and Installation Specifications
- Use ¾” to 3” size; washed; well-grade gravel or crushed rock with fewer than 5% fines for berm material.
- Make the berm as level as possible to avoid erosive concentrated flows.
- Spacing of berms:
  - Every 300’on slopes flatter than 5%
  - Every 200’ on slopes between 5% and 10%
  - Every 100’ on slopes steeper than 10%

Berm Dimension:
  - At least 12” high with 3:1 side slopes
  - 8’ of channel length per 1.0 cfs runoff, based on the 10-year, 24-hour design storm

Maintenance Standards
- Regularly inspect the filter berm. Remove sediment and replace filter material as necessary.

- Check for concentrated flow conditions behind and around the berm.

BMP 25: Storm Drain Inlet Protection

Purpose

To prevent sediment and other attached pollutants (i.e. oil, grease, trash, debris, herbicides, and pesticides) from entering drainage systems.

Suitable Uses

Protecting all storm drain inlets downslope of ground disturbance, even if the runoff is conveyed to a sediment pond or trap.

Protection should also be provided below staging, storage, and parking areas.

See Table 5 for inlet protection options. All methods for storm drain inlet protection are prone to plugging and require a high frequency of maintenance. Emergency overflows may be required where stormwater ponding would cause a hazard. If an emergency overflow is provided, additional beyond-the-end-of-pipe treatment is necessary.

Table 5. Storm drain inlet protection options.

Drop Inlet Protection			
Type of Protection	**Emergency Overflow**	**Paved or Earthen Surfaces**	**Suitable Uses**
Excavated	Temporary flooding will occur	Earthen	Applicable for heavy flows; easy to maintain; larger drainage area; requires 30’ by 30’ per drained acre
Block and gravel	Yes	Paved or Earthen	Applicable for heavy flows; will not pond
Gravel and wire	No	----	Applicable for heavy concentrated flows; will pond; can withstand traffic
Basin filters	Yes	Paved or earthen	Frequent maintenance required
Curb Inlet Protection			
Wooden weir	Small capacity overflow	Paved	Used for sturdy, more compact installations
Sediment trap	----	Paved or earthen	18 months expected life
J-Hook	Small capacity overflow	Paved	----

Design and Installation Specifications

No protection should create ponding or flooding on adjoining travel way surfaces, such as streets, driveways, and sidewalks. Where existing curb, gutters, driveways, streets, etc. neighbor an inlet protection device, the device should be no taller than the existing curb height to prevent creating a driving hazard.

Excavated Drop Inlet Protection is for an excavated impoundment around a storm drain allowing sediment to settle out of the stormwater before it enters a storm drain (Figure 11).

- Depth 12”-24” as measured from the crest of the inlet structure
- Side slopes no steeper than 2:1
- Minimum volume of excavation: 35 cubic yards
- Shape basin to fit site with longest dimension oriented across the longest inflow area
- Install provisions for draining to prevent standing water problems
- Clear the area of all debris
- Grade the approach to the inlet uniformly
- Drill weep holes into the side of the inlet
- Protect weep holes with screen wire and washed aggregate

- Seal weep holes when removing structure and stabilizing area
- It may be necessary to build a temporary dike to the downslope side of the structure to prevent bypass flow

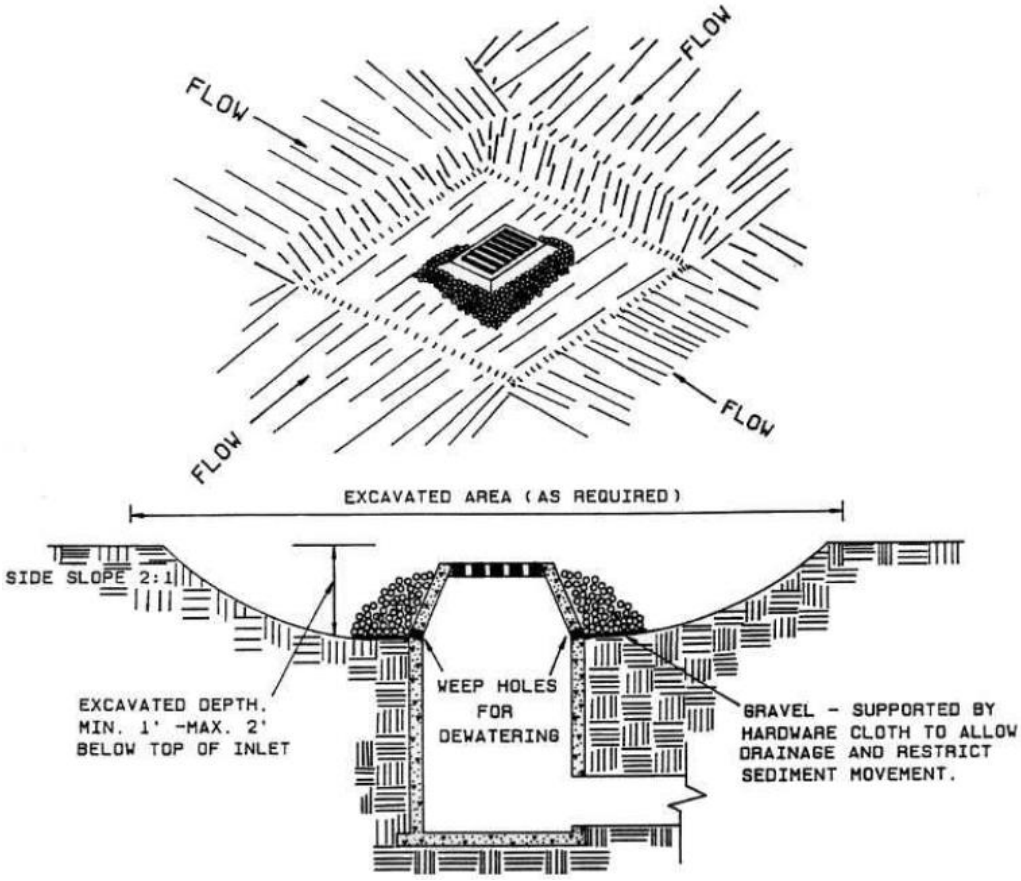

Figure 11. Excavated drop inlet schematic (Empire State Chapter Soil and Water Conservation Society, 1997).

Block and Gravel Filter is a barrier formed around the storm drain inlet with standard concrete blocks and gravel. See Figure 12 for an example applicable to surface inlets. See Figure 13 for an example in the curb line.

- Maximum Height 12" above top of curb.
- Recess the first row 2" into the ground for stability.
- Support subsequent courses by placing a 2"x4" through the block opening.
- Do NOT use mortar. Lay some blocks in the bottom row on their side on either side of the inlet to form a dewatering pool. Place hardware cloth or comparable wire mesh with ½" openings over all block openings.
- Place gravel on the cloth or mesh to an elevation just below the top of blocks and on slopes of 2:1 or flatter. An alternative design is a gravel donut.
- Barrier should allow water to pond - separating sediment from runoff before entering the inlet - but allow all waters to overflow from severe storm events.
- Inspect barriers and remove sediment after each storm event. Remove sediment and gravel from travel ways immediately.

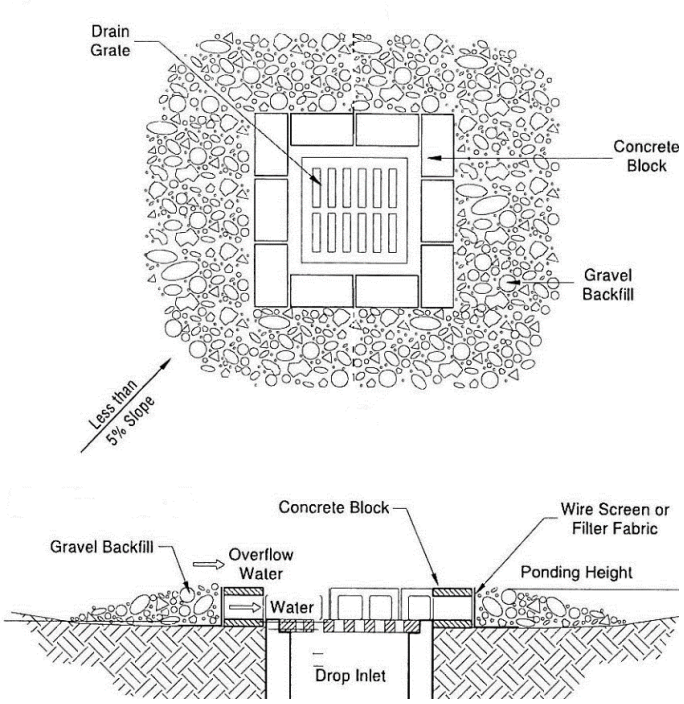

Figure 12. Block and gravel storm drain filter schematic suitable for surface inlets.

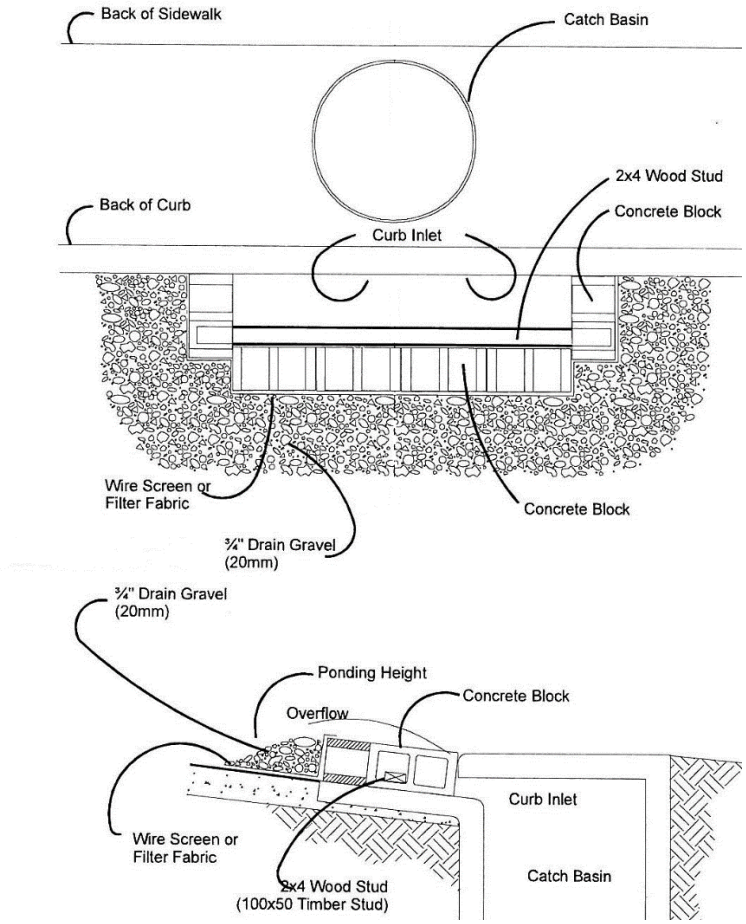

Figure 13. Block and gravel storm drain filter schematic suitable for curb inlets.

Catch-basin Filters are inserts designed by manufacturers for limited sediment storage capacity. They require increased inspection and maintenance, possibly daily. The maintenance requirements can be reduced by combining a catch-basin filter with another type of inlet protection. This type of inlet protection provides flow bypass without overflow and therefore may be a better method for inlets located along active rights-of-way.

- 5 cubic feet of storage
- De-watering provisions
- High-flow bypass that will not clog under normal use at a construction site
- The catch-basin filter is inserted in the catch-basin just below the grating

Curb Inlet Protection with Wooden Weir is a barrier formed around a curb inlet with a wooden frame and gravel.

- Wire mesh with ½" openings
- Extra strength filter cloth
- Construct a frame
- Attach the wire and filter fabric to the frame
- Pile coarse washed aggregate against wire/fabric
- Place weight on frame anchors

Curb and Gutter Sediment Trap is usually a sandbag or rock berm filled with pea gravel or other aggregates) 12" high by 3'-0" wide in a horseshoe shape (Figure 14).

- Construct the shaped berm and face with coarse aggregate 3' high by 3' wide, at least 24" from the inlet.
- Barrier can be constructed of burlap or woven geo-textile fabric bags filled with gravel. Layer bags and pack tightly to form the barrier with a 1-bag-gap in the top row to create an overflow spillway.
- Trap should allow water to pond - separating sediment from runoff before overflowing the barrier and entering the inlet - but should allow all runoff from severe storm events to reach the inlet.

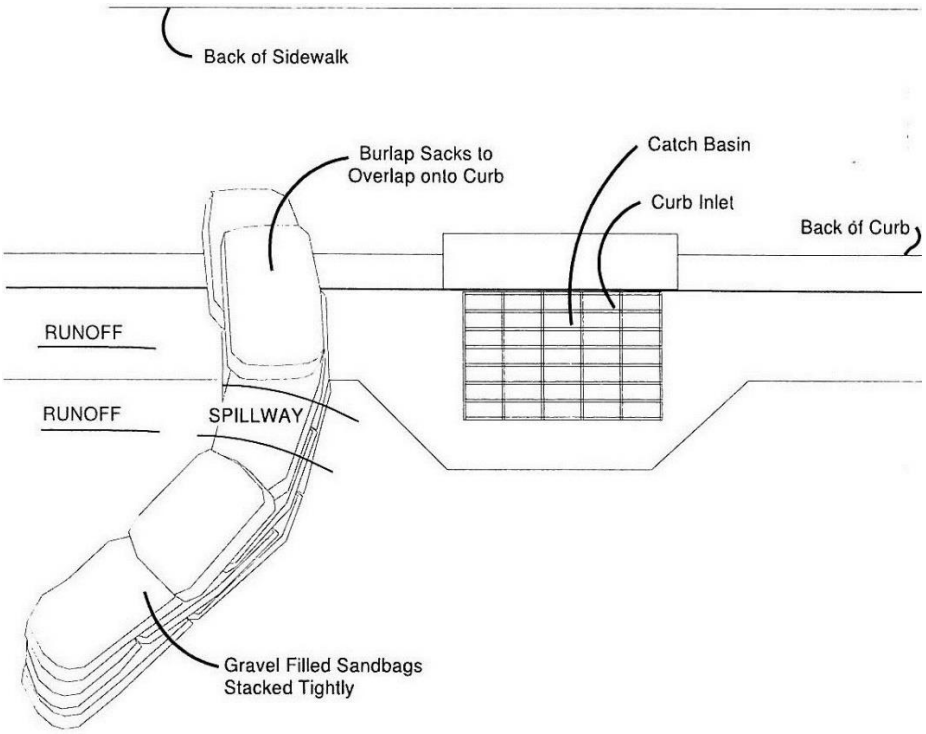

Figure 14. Schematic of curb and gutter sediment trap.

Maintenance Standards

Regular maintenance is required to prevent ponding or sediment on paved, open-to-the-public, surfaces as well as flooding of adjoining and other nearby facilities and properties.
Inspect catch basin filters frequently, especially after storm events. If the insert clogs, clean or replace the filter immediately.
For systems using stone filters: If the stone filter clogs with sediment, pull the stones away from inlet and clean or replace the stones. Since cleaning of gravel at a construction site may be difficult, an alternative approach would be to use the clogged stone as fill and put fresh stone around the inlet.
Do not wash sediment into storm drains while cleaning. Spread all excavated material evenly over the surrounding land area or stockpile and stabilize as appropriate.
Materials removed from behind inlet protection devices generally are the most erosive and lightweight soil particles. If replaced on the construction site, place them as far as possible from erodible areas to prevent re-erosion.

BMP 26: Outlet Protection

Purpose

Outlet protection prevents scour at conveyance outlets; reduces the velocity of concentrated flows; and reduces the energy of concentrated flows - all of which minimize potential erosion downstream from outlets.

Suitable Uses

Install protection at outlets of ponds, pipes, ditches, or other conveyances and when conveying runoff to a natural or manmade drainage feature such as a stream, wetland, lake, or ditch.

Design and Installation Specifications

- Protect the receiving channel at the outlet of a culvert from erosion for a minimum of 6' downstream and extending up the channel sides a minimum of 12" above the maximum tail-water elevation. For pipes larger than 18" in diameter, lengthen the outlet lining of the channel to four times the diameter of the culvert.
- Standard wing-walls, tapered outlets and paved channels should also be considered for permanent culvert outlet protection.
- With low flows, vegetation (including sod) can be effective.
- Use the following guidelines for stone outlet protection:
    - If the discharge velocity at the outlet is less than 5 fps and pipe slope is less than 1%, use 2-8" stone. Minimum thickness is 12".
    - For 5 to 10 fps discharge velocity at the outlet and pipe slope less than 3%, use 24" to 4' stone. Minimum thickness is 24".
    - For outlets at the base of steep slopes (or pipe slopes steeper than 10%), us an energy dissipater (BMP 27).
- Use filter fabric or erosion control blankets under the stone to prevent scour and channel erosion.

Maintenance Standards

- Routinely inspect and replace missing rock.
- Routinely inspect and clean energy dissipaters if sediment reduces their effectiveness.

BMP 27: Energy Dissipaters

Purpose

Energy dissipaters slow the movement of water and prevent erosion in high-energy environments such as outlets, steep open channels and storm drains.

Suitable Uses

Place energy dissipaters in areas of high water velocity/energy to prevent erosion. They may also be appropriate in areas where it is desirable to slow the movement of water into other areas

Design and Installation Specifications

Energy can be dissipated by disrupting the path of flow or dispersing flow over a broader area.
Concrete baffled outlets, riprap and chute blocks are appropriate methods of disrupting the path of flow, but many others methods may suffice depending on the situation.
Broad flat bottomed ditches, level spreaders or outlets can be used to disperse a flow over a broader area and can often be combined with baffled outlets, riprap chute blocks or vegetation to be more effective.
The effectiveness of riprap is generally limited to 19 fps.
Baffled Outlets can be used with velocities up to 50 fps.
Vegetation should only be used in areas where flow is minimal enough that scouring will not occur.

Maintenance Standards

Depending on what the device is made of and how much energy it is subjected to, it may need routine maintenance or replacement. Routine review of its stability, connectivity, and location within the channel should occur.

BMP 28: Reinforced Silt Fence

Purpose

Use of a reinforced silt fence reduces the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow. The reinforcement is placed behind the filter fabric and supports it as sediment is captured during a storm event.

Suitable Uses

- Reinforced silt fence may be used downslope of all disturbed areas.
- Do not use reinforced silt fence to treat concentrated flow or substantial amounts of overland flow. Convey all concentrated flow through the drainage system to a sediment pond. They are not an adequate method of silt control for anything other than sheet or minor overland flow.

Design and Installation Specifications

- Drainage area should be less than 39,000 sf unless combined with sediment pond (BMP 31).
- Install reinforced silt fences with maximum flow paths of 100', maximum slopes of 1:1, and maximum water velocities of 0.5cfs.
- Replace silt fence after 6 months or when damaged.
- Bury the geo-textile at the bottom of the fence in a trench to a minimum depth of 4" below the ground surface on the upstream side of the fence posts. Backfill the trench and tamp the soil in place over the buried portion of the geo-textile, such that no flow can pass beneath the fence and scouring cannot occur. Extend the wire or mesh support into the trench a minimum of 4".
- The fence posts shall be driven a minimum of 12".
- Reinforced silt fences should be perpendicular to the slope, except at the ends of the fence, where the fence turns uphill such that the silt fence captures the runoff water and prevents water from flowing around the end of the fence.
- Support posts spacing should be a maximum of 6'.
- The geo-textile used should meet the standards in Table 6. All properties listed are minimum average roll values.
- Support standard strength fabrics with woven-wire mesh with maximum 4" by 4" openings, safety fence, or jute mesh to increase the strength of the fabric.
- 100% biodegradable silt fence is available that is strong and long lasting.

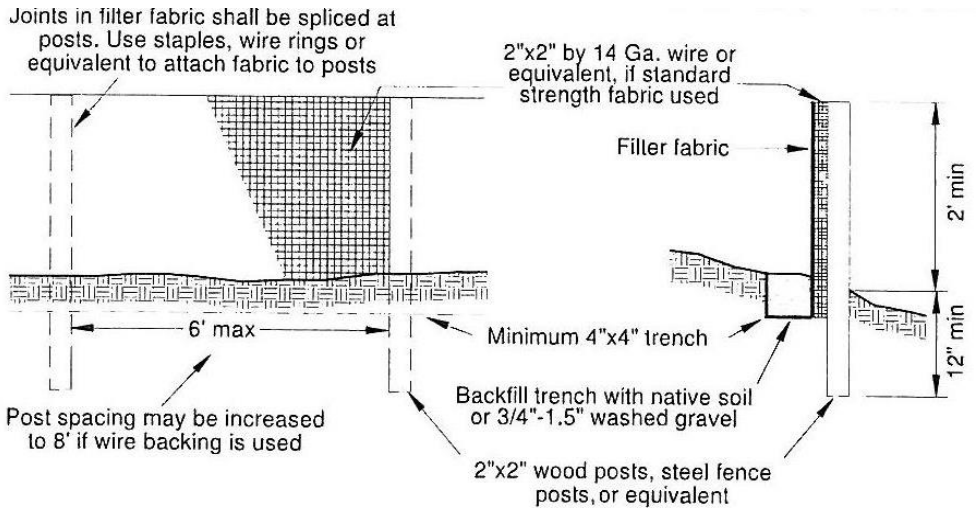

Figure 15. Specifications for reinforced silt fence.

Table 6. Geo-textile standards for reinforced silt fence barriers.

Polymeric Mesh AOS (ASTM D4751	0.15 mm min. for all types (#100 sieve
	0.60 mm max. for slit-film woven (#30 sieve)
	0.30 mm max. for all other types (#50 sieve)
Water Permittivity (ASTM D4491)	0.02 sec^{-1} minimum
Grab Tensile Strength (ASTM D4632)	100 lbs. min. for standard strength fabric
	180 lbs. min. for extra-strength fabric
Grab Tensile Strength (ASTM D4632)	30% maximum
Ultraviolet Resistance (ASTM D4355)	70% minimum

Maintenance Standards

- Conduct routine inspections, clean as needed and repair all damages immediately.
- If concentrated flows are evident uphill of the fence, intercept them and convey to a sediment pond.
- Replace all barriers at least every 6 months.
- Upon stabilization, remove the barrier.

Chapter 4: Treatment BMPs

Safety: Drowning is a leading cause of death for children ages 1-4. Safety should be considered during the construction of all treatment BMPs, fencing may be necessary.

BMP 29: Constructed Wetlands (CWs)

Purpose

Constructed Wetlands (CWs) are effective at removing many common stormwater pollutants including suspended solids, heavy metals, total phosphorus, total nitrogen, toxic organics, and petroleum products.

Suitable Uses

Prior to leaving a construction site all stormwater runoff should pass through CWs or other appropriate sediment removal best management practices.

CWs are suitable to treat all sizes of watersheds and are often considered the best treatment option. Treatment capability can be increased using a combination of multiple cascading wetlands. This is particularly applicable in areas with greater elevation change.

It is important that CWs receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability. Shallow marsh areas can become dry at the surface but not for greater than one month. Maintain a permanent water surface in the deeper areas of the CWs during all but the driest periods.

Do not modify naturally occurring vegetated wetlands for the purpose of CWs. Proper permitting is necessary for building in jurisdictional waters. Avoid building in perennial streams whenever possible.

Design and Installation Specifications

CWs should be greater than 5% of the drainage area. Greater area is necessary for developed areas or treatment of large nutrient loads. Length:width should be 3:1 or greater and whenever possible, slope in and immediately around CWs should be between 4:1 and 5:1.

The flow pathway through the CWs should be maximized as in Figure 16 and depth distributed according to Table 7. Alternating deep and shallow areas is important. Deep areas can prevent short-circuiting by encouraging mixing, enhancing aeration of water, preventing resuspension of sediment, minimizing thermal impacts, and limiting mosquito growth, while varied shallow depths enhance vegetation growth for improved filtering capability.

Table 7. Optimal depth distribution and vegetated condition of constructed wetlands (CWs).

Percent of Wetland	Water Depth	Condition
35%	0-8”	Vegetated
40%	8-16”	Vegetated
35%	18” to 6’	Open Water

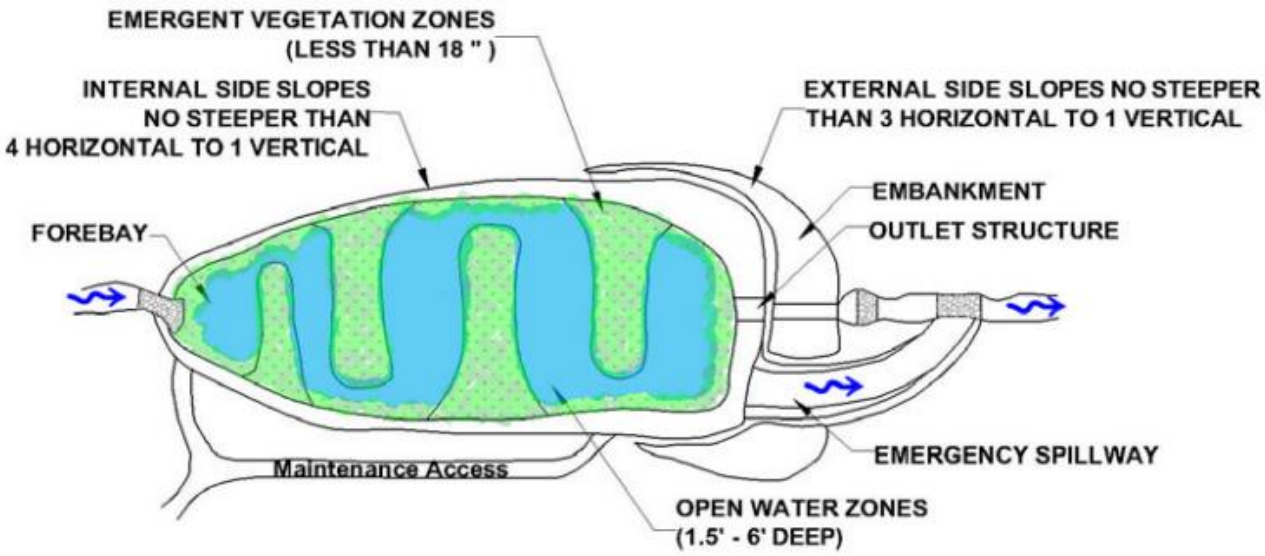

Figure 16. Constructed wetland designed to maximize flow pathway.

Vegetation: Vegetation is an integral part of a wetland system. A diverse array of robust, non-invasive, perennial plants that establish quickly are ideal for CWs. Suggested species are outlined in Table 8.

Table 8. Suggested plants for incorporation into constructed wetlands (CWs).

Recommended Species	Max. Water Depth	Notes
Peltandra virginica	12”	Full sun to partial shade. High wildlife value. Foliage and rootstocks are not eaten by geese or muskrats. Slow grower. pH: 5.0-6.5.
Sagittaria latifolia	12”	Aggressive colonizer. Mallards and muskrats can rapidly consume tubers. Loses much water through transpiration.
Scirpus pungens	6”	Fast colonizer. Can tolerate periods of dryness. High metal removal. High waterfowl and songbird value.
Scirpus validus	12”	Aggressive colonizer. Full sun. High pollutant removal. Provides food and cover for many species. of birds. pH: 6.5-8.5.
Iris versicolor	3”-6”	Attractive flowers. Can tolerate partial shade but requires full sun to flower. Prefers acidic soil. Tolerant of high nutrient levels.
Typha latifolia	12”-18”	Aggressive. Tubers eaten by muskrat and beaver. High pollutant treatment, pH: 3.0-8.5.
Typha angustifolia	12”	Aggressive. Tubers eaten by muskrat and beaver. Tolerates brackish water. pH : 3.7-8.5.
Phalaris arundinocea	6”	Grows on exposed areas and in shallow water. Good ground cover for berms
Saururus cernuus	6”	Rapid grower. Shade tolerant. Low wildlife value except for wood ducks
Pontedaria cordata	12”	Full sun to partial shade. Moderate wildlife value. Nectar for butterflies. pH: 6.0-8.0.

Recommended Species	Max. Water Depth	Notes
Juncus effuses	3”	Tolerates wet or dry conditions. Food for birds. Often grows in tussocks or hummocks.
Elocharis palustris	3”	Tolerates partial shade.
Carex spp.	3”	Many wetland and several upland species. High wildlife value for waterfowl and songbirds.
Nuphar luteum	5 ft, 2 ft minimum	Tolerant of fluctuating water levels. Moderate food value for wildlife, high cover value. Tolerates acidic water (to pH 5.0).
Acorus calamus	3”	Produces distinctive flowers. Not a rapid colonizer. Tolerates acidic conditions. Tolerant of dry periods and partial shade. Low wildlife value.
Zizania aquatic	12”	Requires full sun. High wildlife value (seeds, plant parts, and rootstocks are food for birds). Eaten by muskrats. Annual, nonpersistent. Does not reproduce vegetatively.

Forebay:

CWs should have a forebay or sediment pond at all major inflow points to capture coarse sediment, prevent excessive sedimentation in the remainder of the CW, and minimize erosion by inflow. The forebays should contain 10-15% of the total permanent pool volume and should be 4’-6’ deep. Separate them from the rest of the wetland by a berm, gabion wall, etc. Flows exiting the forebay should be non-erosive to the wetland. Install forebays with permanent vertical markers that indicate sediment depth. Inflow channels should be fully stabilized. Protect CWs from the erosive force of the inflow to prevent the resuspension of previously collected sediment during large flows.

Principal Spillway: The Principal spillway should be in open water areas 4’-6’ deep and allow the CW to be drained for maintenance. Outlet devices are generally multistage structures with orifices, or weirs for flow control. If using pipe, anti-seep collars must be installed every 10’-25’. If using pipe, the principal spillway shall have a trash rack installed (Figure 17). **The principal spillway should be fitted with a valve to drain the entire pond during cleaning operations (not depicted in drawings)**.

Auxiliary Spillways: Auxiliary spillways should safely pass the 100-year storm. Broad, flat spillways are desirable over narrow spillways.

Maintenance Access: Provide permanent vehicular access to the forebay, outlet, and embankment areas.

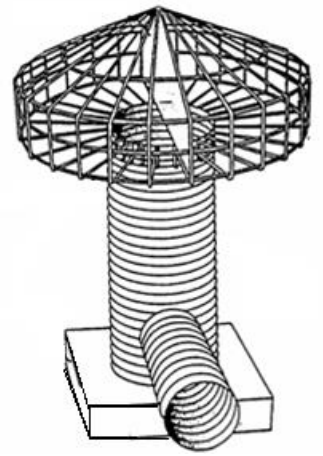

Figure 17. Trash rack and baffle.

BMP 30: Sediment Trap

Purpose

A sediment trap is a small temporary ponding area with a gravel outlet used to collect and store sediment in runoff from disturbed sites.

Suitable Uses

Prior to leaving a construction site, stormwater runoff must pass through a sediment pond or other appropriate sediment removal best management practice.

- Sediment traps are intended for use on sites where the tributary drainage area is smaller than 3 acres, with no unusual drainage features, and a projected build-out time of 6 months or less.

- Sediment traps and ponds are only effective in removing sediment down to about the medium silt size fraction. Runoff with sediment of finer grades (fine silt and clay) will pass through untreated - emphasizing the need to prevent erosion first and to control erosion overall before reaching the pond.

Do not use naturally occurring vegetated wetlands as sites to build sediment ponds, sediment traps, rain gardens or constructed wetlands. Proper permitting is necessary for building in streams.

Whenever possible, discharge sediment-laden water to on-site relatively level, vegetated areas (see BMP 19 – Vegetated Strip). This is the only passive way to effectively remove fine particles from runoff. Filtration using silt fence, sand filters, etc. can be used to actively remove the particles.

Design and Installation Specifications

- Install sediment traps, along with other perimeter controls, before any land disturbance takes place in the drainage area.
- Sediment Trap volume shall be 3600 cubic feet/acre of contributory drainage area and have a length:width of at least 2:1.
- To aid in determining sediment depth, all sediment traps shall have a staff gauge with a prominent mark 1' above the bottom of the trap.
- See Figure 18 below for the cross-section of a typical sediment trap and Figure 19 for outlet details.

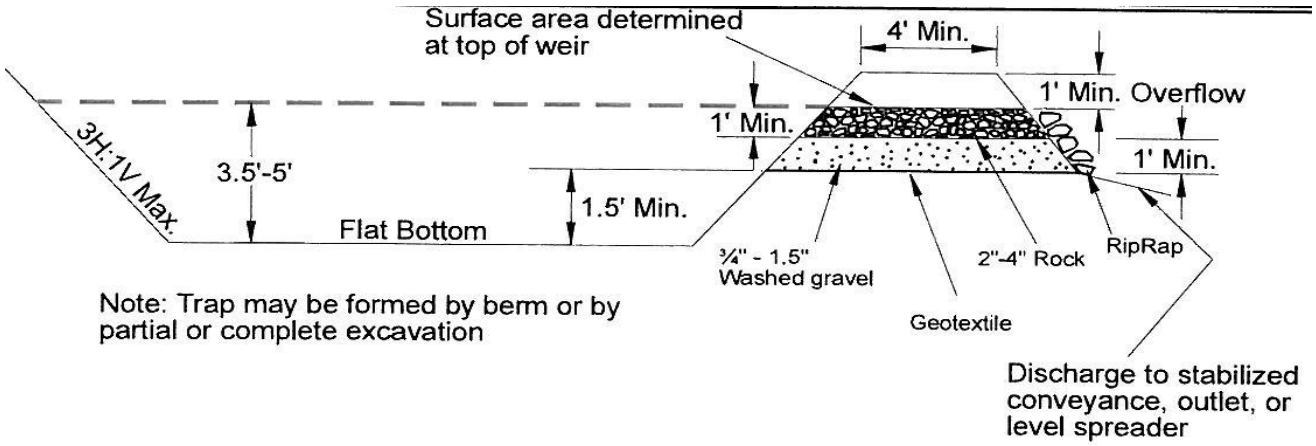

Figure 18. Cross-section of sediment trap.

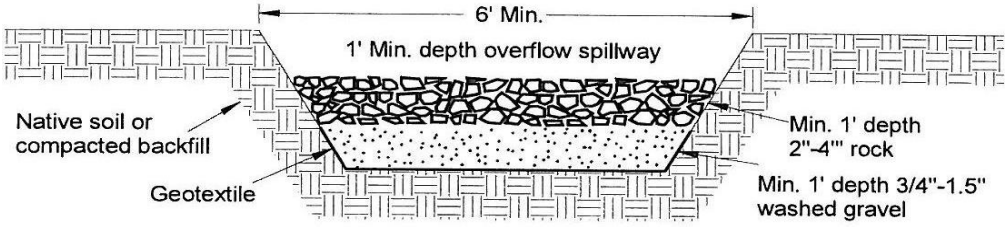

Figure 19. Sediment trap outlet.

Maintenance Standards

- Remove sediment from the trap when it reaches 12" in depth.
- Routinely inspect and repair any damage.

BMP 31: Sediment Pond

Purpose

A sediment pond captures and detains sediment-laden runoff for a sufficient length of time to allow sediment to settle out in the pond.

Suitable Uses

Prior to leaving a construction site all stormwater runoff should pass through a sediment pond or other appropriate sediment removal best management practice. Sediment ponds are suitable to treat all sizes of watersheds for medium size and larger silt. Runoff with sediment of finer grades (fine silt and clay) will pass through untreated - emphasizing the need to prevent erosion first and to control erosion overall before reaching the basin.

Do not use naturally occurring vegetated wetlands as sites to build sediment ponds, sediment traps, rain gardens or constructed wetlands. Proper permitting is necessary for building in streams.

Whenever possible, discharge sediment-laden water to on-site relatively level, vegetated areas (see BMP 19 – Vegetated Strip). This is the only passive way to effectively remove fine particles from runoff. Filtration using silt fence, sand filters, etc. can be used to actively remove the particles.

Design and Installation Specifications

Use Table 8 to calculate permanent pool size for your project based on land use.

Table 8. Permanent pool size for varying land uses.

Land Use	**Permanent Pool Size**
Construction	1.5% of drainage area
Undeveloped Areas	0.6% of drainage area
Paved Areas	3% of drainage area

- Permanent pool must be minimum of 3' deep and additional depth is necessary for all sediment storage (Figures 20 and 21). Design the sediment storage for a minimum of 900ft^3/acre of disturbed area.
- Pond length should be 3-5 times the width and the inlets and outlets should be widely spaced to avoid short circuiting.
- Pond side slopes should be minimal or fenced for safety reasons.
- In temporary sediment ponds a silt fence with wire backing can be installed across the pond to filter additional sediment. Use steel posts.

- Install energy dissipaters such as baffles or large stones that exceed normal maximum pool level on the upper end of the sediment pond to disrupt/slow water flow. Place them far enough from the inlet to prevent damage during high flow events.
- Permanent sediment ponds should be at least 3% of drainage area and have vegetation to further disrupt flow and filter contaminants. Species should be chosen that will not interfere with sediment removal.

Principal Spillway:

The Principal spillway pipe conduit shall be placed under or through the dam (Figure 20) and anti-seep collars must be installed every 10'-25'. The top of the principal spillway shall be 1' or more below the auxiliary spillway and a minimum of 1' above the permanent pool level (Figure 20). Perforate the length of pipe above permanent pool so that draw down to permanent pool is gradual, but leave the top open so that it can run at full capacity when the pipe is overtopped. The diameter of pipe must be 6" or greater. The principal spillway shall have a trash rack installed (Figure 17). **Fit the principal spillway with a valve to drain the entire pond during cleaning operations** (not depicted in drawing).

Auxiliary spillways. Auxiliary spillways should safely pass the 100-year storm. Broad, flat spillways are desirable over narrow spillways.

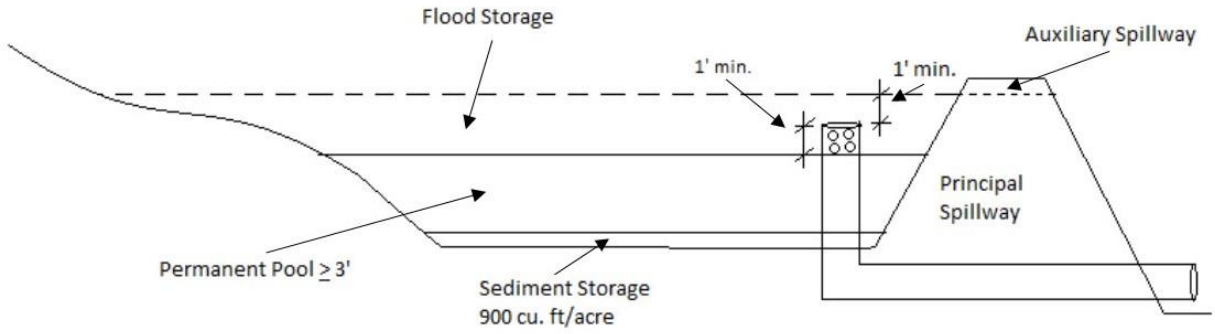

Figure 20. Cross section of a sediment pond (not drawn to scale).

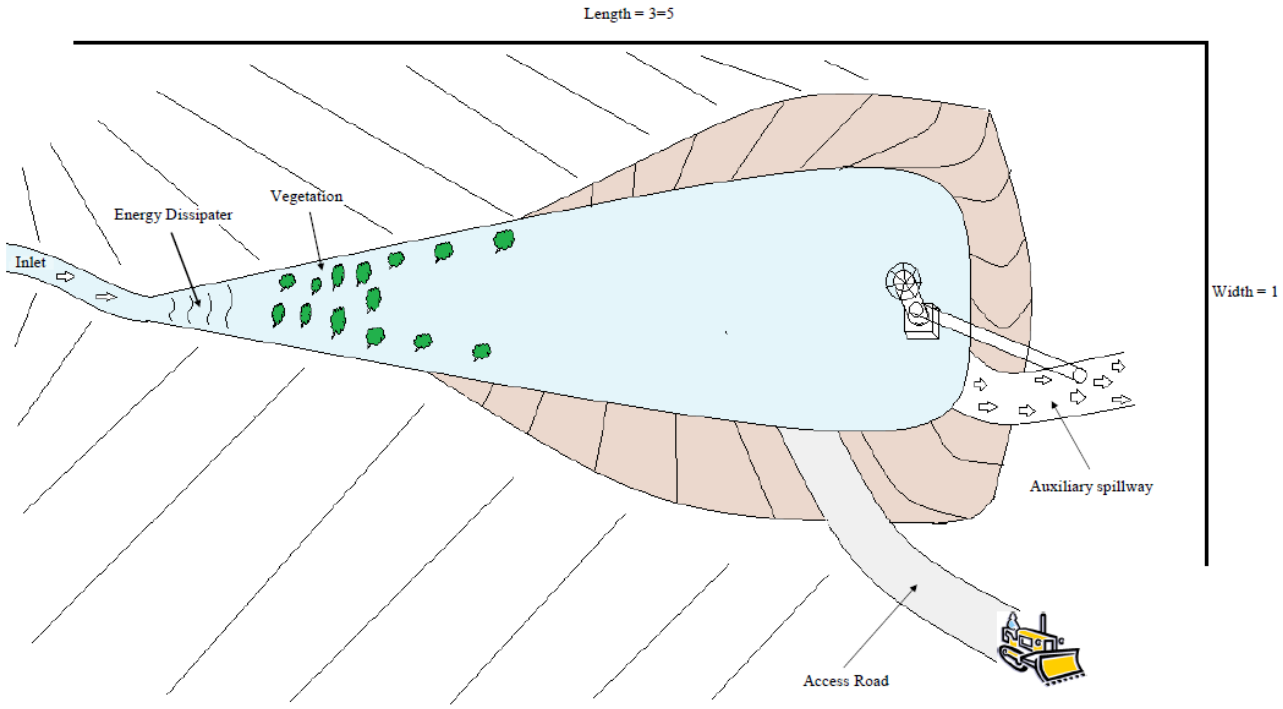

Figure 21. Aerial view of sediment pond with energy dissipater and vegetation (not drawn to scale).

Maintenance Standards

- Remove sediment from the trap as necessary.
- Routinely inspect and repair pond inlets, banks, spillways, energy dissipaters, etc. in a timely manner.

BMP 32: Rain Garden

Purpose

An excavated shallow surface depression planted with specifically selected native vegetation to capture and treat small amounts of stormwater.

Suitable Uses

- Treating stormwater runoff from developed areas such as roads, parking lots, rooftops, and yards.
- Can be incorporated into stormwater conveyance structures (ditches) to reduce runoff treated by sediment ponds and wetlands.

Design and Installation Specifications

- Size 5:1 (drainage area to infiltration area).
- Positive overflow can be through domed riser or weir structure.
- Ponding depth generally limited to 6” and should empty within 48 hours.
- Stormwater can enter via pipe, swale or sheet flow, but ensure entering velocities are non-erosive.
- Soil should have a infiltration rate >0.2 in/hr or have drains placed to assist water movement (Figure 22). Alternatively, replace native soil with planting mix to assist infiltration.
- The bottom of the excavated rain garden should be 2’ above the ground water table during all seasons.

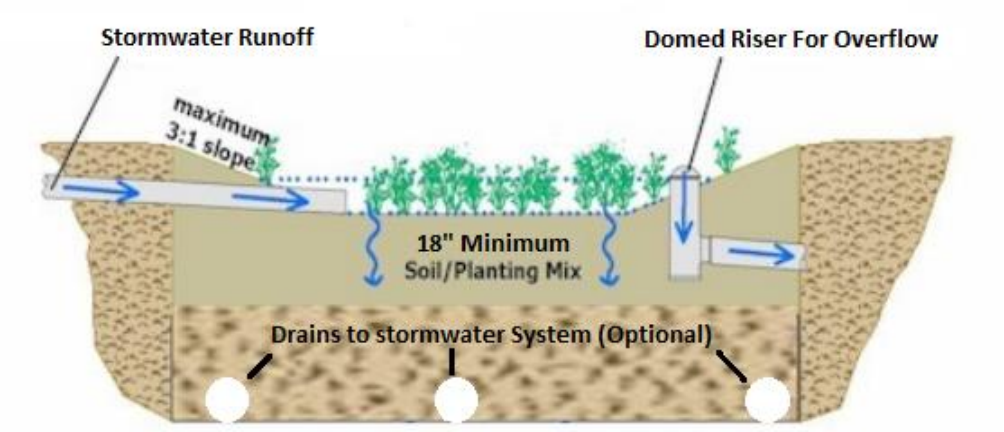

Figure 22. Rain garden schematic and specifications.

Maintenance Standards

Routinely monitor and remove detritus and sediment buildup.