THE UNIVERSITY OF TENNESSEE KNOXVILLE

FACILITIES SERVICES

Best Management Practice Manual

A Stormwater Planning and Design Manual for Stormwater Management Practices

NPDES Phase II Municipal Separate Storm Sewer System (MS4) Permit No. TNS076121

June 2017

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Introduction

This Best Management Practice (BMP) manual is comprised of standards to be followed in order to reduce runoff, prevent pollution, and effectively minimize impacts to Stormwater at the University of Tennessee Knoxville Campus. The University operates as a Municipal Separate Storm Sewer System (MS4), where our primary goal is to improve the quality of surface waters by reducing the amount of pollutants that have the potential to impact our local Stormwater runoff. The various BMP's in this manual are categorized by their specific but equally important mitigation goals, such as the prevention of erosion, control of sediment, and pollution prevention of receiving rivers and streams.

Section 1:
Site Preparation

Site Preparation Practice 1.1: Identifying Sensitive Areas

Orange safety fencing was used as a visual marker to keep construction activity out of a stream buffer.

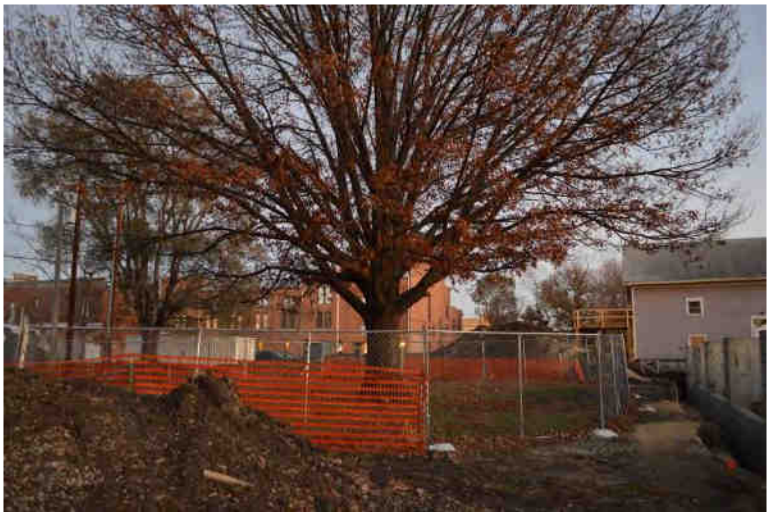
Purpose and Application: Identifying sensitive areas on a development site in preparation for construction has many benefits, including lowering the cost of the development. Protecting these areas is much more cost effective than replacing or repairing them after they have been impacted by construction.

Description: Before construction begins on the project, locate and visually mark sensitive areas such as streams, Aquatic Resources Alteration Permit boundaries, buffers, wetlands, sinkholes, caves, critical habitat, and historic areas. Markers can include brightly colored flagging or barrier fencing but should be different from other construction marking and flagging. Areas that pose certain dangers to the public should also be marked such as sediment ponds.

Limitations: some specific requirements for tree protection may be more stringent than orange construction fencing such as requiring chain link fence.

Maintenance: Whatever method is chosen to identify sensitive or critical areas must be maintained to ensure the measures remain in good condition and visible. This is especially important when there are multiple subcontractors on a project which may be otherwise unaware of the sensitive or critical areas.

Site Preparation Practice 1.2: Tree Preservation



The contractor installed chain-link fence paired with high visibility fencing around the drip line of the trees prior to construction to protect the root zone.

Purpose and Application: Preserving and protecting trees can often result in a more stable and aesthetically pleasing site. Trees stabilize the soil and help prevent erosion, decrease storm water runoff, moderate temperature, provide buffers and screens, filter pollutants from the air, supply oxygen, provide habitat for wildlife, and increase property values.

Description: Some desirable characteristics to consider in selecting trees to be protected include: tree vigor, tree species, tree age, tree size and shape, tree location, and use as a wildlife food source. Trees on stream banks may be required to be protected if they are located in a regulated stream buffer area.

Construction activities are likely to injure or kill trees unless adequate protective measures are taken around trees near the construction activity. Direct contact by equipment is the most obvious problem, but damage is also caused by root zone stress from filling, excavating, or over compacting the areas around the tree. It is therefore critical that trees to be saved should be clearly marked so that no construction activity will take place within the Critical Root Zone (CRZ). The CRZ varies by species and the environmental conditions. Two common methods to establish the CRZ include using the trees dripline as a guide or by using the trunk diameter to estimate the CRZ.

Using the dripline:

The dripline of a tree is generally defined as the soil area below ground and the space above ground defined by the tree's greatest extent of the outer tree branches.

Using the trunk diameter:
The International Society of Arboriculture (ISA) defines the CRZ as an area equal to 1 foot radius from the base of the tree's trunk for each 1 inch of the trees diameter at 4.5 feet above grade.

Note that it is recommended that both methods be evaluated and the largest CRZ should be chosen.

Activities that should be avoided within the established and protected CRZ include:

- Stockpiling demolition debris.
- Stockpiling soil and/or mulch.
- Storage of construction materials.
- Parking of vehicles or equipment.
- Wash-out operations
- Wound or break the tree trunks or branches through contact with vehicles and heavy equipment.

Guidelines:

Trees must be protected by one of the following fencing methods:

- Chain link or other metal wire (9 gauge minimum) supported by metal or wooden post.
- Wooden posts with wooden cross supports; posts must be 4x4 or greater with 2x4 or greater cross supports.
- High visibility fencing may be used in addition to the above fencing methods but not as an alternative.

Limitations: Isolating the areas around trees may severely limit the available land at a construction site and may require special planning by the contractor to access some parts of the project site.

Maintenance: Tree preservation methods must be maintained to ensure the measures remain in good repair and visible. This is especially important when there are multiple subcontractors on a project which may be otherwise unaware of the sensitive or critical areas.

Pictured: Wooden fence with wooden cross supports around the drip line of the tree.

Pictured: Metal panels supported by metal fence posts around the drip line of the tree.

Pictured: Chain-link fence supported by wooden posts around the drip line of the tree.

Site Preparation Practice 1.3: Topsoiling

The contractor applied topsoil over the cut slope before applying seed and mulch or sod.

Purpose and Application: Topsoil provides the substrate zone for root development and biological activities for plants, and should be stockpiled and spread wherever and whenever (i.e. in a timely manner) practical for establishing permanent vegetation.

Description: Topsoiling is a common practice where ornamental plants or turf will be grown. It may also be required to establish vegetation on shallow soils, soils located above a steam line, soils containing potentially toxic materials, very stony areas, and soils of critically low pH.
Advantages of topsoil include higher organic matter, more friable consistency, and greater available water-holding capacity and nutrient content. In addition, infiltration can be enhanced by re-spreading topsoil in areas that have been disturbed by construction activity.

Limitations: Do *not* place topsoil on slopes steeper than 2:1 without additional engineered slope stabilization practices to avoid slippage.

Maintenance: Establishment of vegetation as soon as possible after spreading topsoil is essential for preventing erosion of the topsoil.

Ideal Soil Quality: The following ideal characteristics of topsoil to be used when topsoiling are: Soluble Salts <2 dS/m; pH 5.5-7.5; Sand % <70; Silt % <70; Clay % <30; Texture Class L-SiL; Organic Matter % ≥2.0; % Coarse fragments ≤2; Sodium Adsorption Ratio <3. A topsoil that does not meet these qualities is not optimal to be used.

Site Preparation Practice 1.4: Surface Roughening and Tracking

This slope has been tracked, seed applied and then mulched or sodded. Tracking helps control erosion by slowing runoff, hold seed in place, and aids uniform vegetation establishment.

Purpose and Application: Roughening a sloping bare soil surface with horizontal depressions helps control erosion by aiding the establishment of vegetative cover with seed, reducing runoff velocity, and increasing infiltration. The depressions also trap sediment on the face of the slope.

Description: Tracking is typically performed with a bulldozer, working up and down a slope. Tracking should always leave horizontal tracks, as opposed to vertical tracks. Equipment such as bulldozers, tracked excavators, or tractors with disks may also be used. The final face of slopes should not be bladed or scraped to give a smooth hard finish.

Limitations: Consider tracking on all slopes. The amount of tracking required depends on the steepness of the slope and the type of soil. Stable rocky faces of a slope may not require tracking or stabilization, while erodible slopes steeper than 3:1 require special surface roughening. This measure needs to be used in conjunction with other practices such as temporary seeding and mulch to prevent erosion and sedimentation.

Maintenance: Seed and mulch or sod should be applied as soon as practicable on a tracked slope.

Site Preparation Practice 1.5: Soil Enhancement

Development practices often lead to compacted soils, drought sensitive lawns, and high storm runoff contributing to downstream flooding.

Purpose and Application: Soil enhancement refers to techniques employed at a construction project that can enhance infiltration and establishment of a permanent groundcover. Any portion of a construction site that has been graded can benefit from soil enhancement techniques.

Description: Soil enhancement includes the addition of materials to promote vegetative establishment and infiltration. Urban areas are plagued with drainage problems caused, in part, by poor soil management practices at new development sites. Removing the existing vegetation and disturbing and compacting soils is inherent to construction. When disturbance is unavoidable, several techniques can be employed at a site to reverse at least a portion of the damage caused to the soil structure and to increase infiltration. Those techniques include preserving and redistributing topsoil over disturbed areas, adding media to prevent over compaction, deeply tilling disturbed soils to break any crusted or hard panned soils, adding organic matter such as compost to the top 6 inches of soil, reintroducing soil biota, adjusting soil fertility to support vegetation, and planting deep rooted vegetation.

Limitations: These techniques must be used in conjunction with other techniques, such as rolled erosion control products, seed and mulch, to establish a permanent vegetative cover.

Maintenance: Continue to maintain sediment controls down gradient from areas where soil enhancement techniques are being employed. Repair erosion rills early to avoid reapplication or reworking areas where soil enhancement has been applied.

Site Preparation Practice 1.6: Construction Phasing/Sequencing

Description: Effective construction site management to minimize erosion and sediment transport includes attention to construction phasing, scheduling, and sequencing of land disturbing activities. On most construction projects, erosion and sediment controls will need to be adjusted as the project progresses and should be documented in the Erosion and Sediment Control Plan.

Construction phasing refers to disturbing only part of a site at a time to limit the potential for erosion from dormant parts of a site. Grading activities and construction are completed and soils are effectively stabilized on one part of a site before grading and construction begins on another portion of the site. Construction sequencing or scheduling refers to a specified work schedule that coordinates the timing of land disturbing activities and the installation of erosion and sediment control practices.

Purpose and Application: All construction projects can benefit from upfront planning to phase and sequence construction activities to minimize the extent and duration of disturbance. Larger projects and linear construction projects may benefit most from construction sequencing or phasing, but even small projects can benefit from construction sequencing that minimizes the duration of disturbance.

Typically, erosion and sediment controls needed at a site will change as a site progresses through the major phases of construction. Erosion and sediment control practices corresponding to each phase of construction must be documented in the Erosion and Sediment Control Plan.

Design Criteria: BMPs appropriate to the major phases of development should be identified on construction drawings. In some cases, it will be necessary to provide several drawings showing construction-phase BMPs placed according to stages of development (e.g., clearing and grading, utility installation, active construction, final stabilization).

Typical construction phasing BMPs include:

- Limit the amount of disturbed area at any given time on a site to the extent practical. For example, a 100-acre subdivision might be constructed in five phases of 20 acres each.
- If there is carryover of stockpiled material from one phase to the next, position carryover material in a location easily accessible for the pending phase that will not require disturbance of stabilized areas to access the stockpile. Particularly with regard to efforts to balance cut and fill at a site, careful planning for location of stockpiles is important.

Typical construction sequencing BMPs include:

- Sequence construction activities to minimize duration of soil disturbance and exposure. For example, when multiple utilities will occupy the same trench, schedule installation so that the trench does not have to be closed and opened multiple times.
- Schedule site stabilization activities (e.g., landscaping, seeding and mulching, installation of erosion control blankets) as soon as feasible following grading.
- Install initial erosion and sediment control practices before construction begins. Promptly install additional BMPs for inlet protection, stabilization, etc., as construction activities are completed.

Table CP-1 provides typical sequencing of construction activities and associated BMPs.

Maintenance: When the construction schedule is altered, erosion and sediment control measures in the Erosion and Sediment Control Plan and construction drawings should be appropriately adjusted to reflect actual "on the ground" conditions at the construction site. Be aware that changes in construction schedules can have significant implications for site stabilization, particularly with regard to establishment of vegetative cover.

Project Phase	BMP's
Pre-disturbance, Site Access	• Install sediment controls downgradient of access point (on paved streets this may consist of inlet protection). • Establish vehicle tracking control at entrances to paved streets. Fence as needed. • Use construction fencing to define the boundaries of the project and limit access to areas of the site that are not to be disturbed. **Note: it may be necessary to protect inlets in the general vicinity of the site, even if not downgradient, if there is a possibility that sediment tracked from the site could contribute to the inlets.**
Site Clearing and Grubbing	• Install perimeter controls as needed on downgradient perimeter of site (silt fence, wattles, etc). • Limit disturbance to those areas planned for disturbance and protect undisturbed areas within the site (construction fence, flagging, etc). • Preserve vegetative buffer at site perimeter. • Create stabilized staging area. • Locate portable toilets on flat surfaces away from drainage paths. Stake in areas susceptible to high winds. • Construct concrete washout area and provide signage. • Establish waste disposal areas. • Install sediment basins. • Create dirt perimeter berms and/or brush barriers during grubbing and clearing. • Separate and stockpile topsoil, leave roughened and/or cover. • Protect stockpiles with perimeter control BMPs. Stockpiles should be located away from drainage paths and should be accessed from the upgradient side so that perimeter controls can remain in place on the downgradient side. Use erosion control blankets, temporary seeding, and/or mulch for stockpiles that will be inactive for an extended period.

	• Leave disturbed area of site in a roughened condition to limit erosion. Consider temporary revegetation for areas of the site that have been disturbed but that will be inactive for an extended period. • Water to minimize dust but not to the point that watering creates runoff.
Utility and Infrastructure Installation	• Close trench as soon as possible (generally at the end of the day). • Use rough-cut street control or apply road base for streets that will not be promptly paved. • Provide inlet protection as streets are paved and inlets are constructed. • Protect and repair BMPs, as necessary. • Perform street sweeping as needed.
Building Construction	• Implement materials management and good housekeeping practices for home building activities. • Use perimeter controls for temporary stockpiles from foundation excavations. • For lots adjacent to streets, lot-line perimeter controls may be necessary at the back of curb.
Final Grading	• Remove excess or waste materials. • Remove stored materials.
Final Stabilization	• Seed and mulch/tackify. • Seed and install blankets on steep slopes. • Remove all temporary BMPs when site has reached final stabilization

Section 2: Pollution Prevention

Pollution Prevention Practice 2.1
Trash and Debris Management

Construction material waste and trash should be isolated and managed in designated areas to prevent offsite damage and pollution.

Purpose and Application: Construction inherently produces waste materials, including building waste debris, employee-generated trash, and waste concrete and asphalt. These materials can mix with Stormwater and discharge off the construction site.

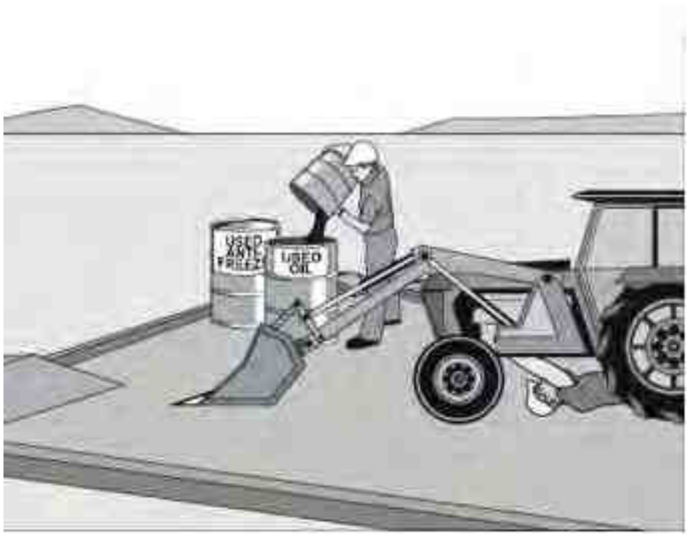
Description: Designated waste management areas should be identified throughout the construction project, separating trash from reusable or recyclable materials. Materials prone to leaching should be stored in covered dumpsters. All materials should be stored in a manner to prevent wind from blowing the material off site.

UT Requirements: For construction sites disturbing greater than or equal to 1 acre, the Construction General Permit states that the SWPPP shall include a description of controls used to reduce pollutants from materials stored on site, including storage practices to minimize exposure of the materials to storm water, and spill prevention and response. For smaller construction projects an Erosion and Sediment Control Plan should be implemented.

Limitations: Locate trash and debris stockpile areas away from streams, storm drains, sinkholes and other sensitive features.

Maintenance: Ensure that any debris containment measures are in good working condition. Pick up and dispose of trash located throughout the project. Employees and contractors should be educated about the proper disposal of all waste.

Pollution Prevention Practice 2.2: Vehicle Maintenance and Fueling



When fuel or lubricants are stored on a construction project, measures must be taken to prevent spills from causing Stormwater pollution.

Purpose and Application: Materials used to maintain and service vehicles onsite can mix with Stormwater and discharge pollutants off the construction project site and into waters of the state. When solvents, fuels and other chemicals are stored on a project, precautions must be taken to prevent pollutant discharge. This practice will create a significant reduction in VOCs, heavy metals, toxic materials, and oil and grease.

Description: Equipment on construction sites may need maintenance during the life of the project. It is preferable for equipment to be serviced and maintained off the construction project in a location that has a treatment system in place to prevent pollutant discharges such as oil or vehicle spills. However, offsite maintenance may not be an option. Maintenance activities on construction equipment or vehicles on the construction project require specific attention to potential sources of pollution, such as fuel and lubricant drums. These materials must be handled and disposed of in a manner that prevents the material from mixing with Stormwater and discharging into the storm drain system or waters of the state.
Use controls such as drip pans and containment barriers when maintenance activities occur on a project to prevent Stormwater contamination. If maintenance activities require fuel and lubricant storage vessels to be stored on the project, secondary containment or weatherproof covers must be provided to prevent spills. And area should be designated for vehicle maintenance and fueling and keep spill containment and cleanup materials at this location.

Maintenance: Watch for signs that construction equipment needs maintenance, such as soil staining from oils and lubricants, and have equipment repaired to prevent discharges.

Suitable Applications:

- Temporary fueling facilities at construction sites, such as fuel trucks and diesel tanks.
- Permanent fueling facilities, such motor pool.

Approach: Spills from fueling vehicles and equipment, or from the transfer of fuels to a storage tank can be a significant source of pollution. Fuels carry contaminants of particular concern to humans and wildlife, such as heavy metals, toxic materials, VOC's and oil and grease; these contaminants are not easily removed by most Stormwater treatment measures. In addition, many people do not realize that storm drains, curb inlets, grate inlets, and drainage culverts discharge directly into natural streams, rivers and lakes.
Consequently, pollution control at the source is particularly important. Adequate control can be achieved with careful design of the initial installation, retrofitting of existing installations, and proper spill control and cleanup procedures described below.

General Guidelines:

- Maintain fueling equipment in good condition. Comply with all federal and state requirements regarding the installation of aboveground and underground storage tanks, including requirements for secondary containment.
- The Spill Prevention Control and Countermeasure (SPCC) Plan, which is required by law for permanent fueling facilities such as motor pool, is an effective program to reduce the number of accidental spills and releases. Keep the SPCC Plan up-to-date by regular inventory of fuel tanks, cleanup equipment and cleanup supplies.
- Train employees in proper fueling and cleanup procedures, including periodic review of the SPCC Plan and locations of absorbent spill materials. Use absorbent materials.

Pollution Prevention Practice 2.3: Concrete Washout Area

Concrete washout areas should be provided on each construction site where concrete work occurs.

Purpose and Application: Concrete washout areas are locations on a construction site designated for concrete trucks and other equipment to clean liquid or slurry concrete off the equipment without causing Stormwater pollution. When washout areas are used, the slurry is given time to harden and then can be removed without discharging pollutants from the project.

Description: Concrete is a very common building material which is used in road and street construction, drainage structures, retaining walls, footings and foundations, building construction and many other applications. Concrete slurry has the potential to contaminate Stormwater runoff, especially when washout occurs next to natural drainage channels or storm drain inlets. Concrete is most harmful to streams in the slurry form, though once hardened, it can cause blockage of storm drain systems and severely reduce the capacity of the storm drain system or waters of the state. Designated locations for concrete washout should be provided with clearly visible signage on each construction site. Concrete washout areas can be constructed above ground or below ground. They include a storage area lined with a geotextile fabric to allow infiltration of water while preventing the discharge of solids. Some liners are impermeable and rely on evaporation and concrete hardening to remove the liquid. Once the concrete has hardened, it can be removed from the project.

UT Requirements: Measures must be contained in the SWPPP and reflected in the field to control concrete slurry and related construction waste, and prevent the discharge of pollutants from the site.

Limitations: Do not locate concrete washout areas close to streams, sinkholes, storm drains, wetlands or other sensitive features.

Maintenance: Remove concrete once hardened to ensure there is storage for additional concrete washout material. Inspect the liner for rips and replace when necessary.

Pollution Prevention Practice 2.4: Chemical Storage

Discharging chemicals into storm drains causes stormwater pollution that ultimately reaches waters of the state.

Purpose and Application: Proper storage and disposal of chemicals on a construction site prevents or reduces the discharge of pollutants to Stormwater from leaks and spills by reducing the chance for spills, stopping the source of spills, containing and cleaning up spills, and properly disposing of spill materials.

Description: Accidental releases of materials from aboveground liquid storage tanks, drums, dumpsters, or other containers have the potential for contaminating Stormwater with many different pollutants. Materials spilled, leaked, or lost from storage containers and dumpsters may accumulate in soils or on the surfaces and be carried away by Stormwater runoff into waters of the state. Chemicals stored on a construction site should be stored in a weatherproof building or container. Other options include storing chemicals within a containment system. Chemicals should be stored in a centralized location. Keep spill containment and cleanup materials at the chemical storage area. Do not washout or pour leftover chemicals into the storm drain system.

Prevent or reduce the discharge of pollutants to Stormwater from outdoor container storage areas by installing safeguards against accidental releases, installing secondary containment, conducting regular inspections, and training employees on standard operating procedures and spill cleanup techniques. This management practice is likely to create a significant reduction in heavy metals, toxic materials, oil and grease, and oxygen demanding substances being discharged from the site.

Approach: Storage of liquid containers should preferably occur within a manufactured building so that any leaks or spills can be completely contained. In addition, a manufactured building will provide a degree of protection against natural disasters, vandalism, and other damage. It should be noted that the storage of reactive, ignitable, or flammable liquids must comply with all safety regulations and fire codes.

The most important factors in preventing pollution from contaminating Stormwater runoff are:

- Maintain organized and safe working conditions.
- Train all employees in proper methods and procedures.
- Limit exposure of material to rainfall and Stormwater runoff.
- Contain leaks and spills during transfer operations.
- Check and maintain equipment regularly for proper operation.

The most common causes of unintentional releases are:

- External corrosion and structural failure of containment vessels
- Installation issues
- Spills and overfills due to operator error
- Failure of piping systems (pipes, pumps, flanges, couplings, hoses and valves)

Training:

1. Well-trained employees can reduce human errors that lead to accidental releases or spills. Operator errors can be prevented by using engineering safeguards and thus reducing accidental releases of pollutant.
2. Employees should be familiar with the Spill Prevention Control and Countermeasure (SPCC) Plan. The employee should have the tools and knowledge to immediately begin cleaning up a spill if one should occur.
3. Employees should periodically review material safety data sheets (MSDS). They should be aware of material content, potential hazards, and safety procedures required in the event of a spill or leak.
4. Hold regular meetings to discuss and reinforce appropriate disposal procedures (incorporate into regular safety meetings). Designate a foreman or supervisor to oversee and enforce proper spill prevention and control.

Liquid Container Management:

To limit the possibility of Stormwater pollution, containers used to store dangerous waste or other liquids should be kept inside a manufactured building. However, this may be impractical due to site constraints. Small inexpensive storage buildings can often be used when a permanent building is not feasible. Service bays, shacks, or sheds are also alternatives to be considered, provided that safety and fire codes are not violated.

Protect outdoor liquid containers rainfall and Stormwater runoff with the following measures:

- Cover storage area with a roof
- Minimize Stormwater runoff by enclosing area with a berm or ditch
- Use covered dumpsters to store liquid containers

Storage of any threshold quantity of oil or hazardous materials must meet specific federal and state standards that include, as a minimum:

- SPCC Plan
- Secondary containment
- Leak-detection monitoring and inspections

Safeguard against accidental releases by using the following equipment:

- Overflow protection devices to warn operator
- Automatic shutdown transfer pumps
- Bollards around tanks and piping to prevent vehicle or forklift damage
- Clearly labeled tags and other identifiers, including color coding
- Restricting access to valves

Large storage tanks, piping systems, and other types of storage systems must be inspected regularly by specially-trained professionals. These trained professionals can identify and correct potential problems such as loose fittings, poor welding, and improper gaskets. Tank foundations, connections, and coatings should also be inspected. Document all inspections, including photographs when appropriate.

Regular inspection for corrosion, leaks, cracks, or other physical damage may require that the tank or piping system be emptied. Closely observe structural reactions during filling and emptying of tanks and piping systems in order to verify integrity; this is usually the time of greatest stress for a system.

Secondary Containment:

- Some common measures that are used for secondary containment include berms, dikes, vaults, double-walled tanks, and dumpsters. Some secondary containment structures need to be designed by a professional engineer with experience and training. The hydrostatic pressure of a few feet of water or other liquids can be very heavy.
- Secondary containment structures must be made of materials that will not react or degrade with the liquids in storage. Strong acids or bases may react with metal containers, concrete, and some plastics. Some organic chemicals may need certain special liners for dikes. Earthen dikes are strongly discouraged but may

be okay for some applications. A wide variety of coatings are available for tanks or dikes.

- Secondary containment measures will generally require a positive means of control, such as a clearly labeled valve or plug, to prevent the release of Stormwater contaminated by spills or leaks.
- Secondary containment structures should provide at least 10 percent of the volume of all of the containers or 110 percent of the volume of the largest container, whichever is greater. Secondary containment structures, which allow access for a truck or trailer, may need to consider the truck or trailer to be the largest container.
- Secondary containment structures open to the weather must provide an additional allowance for rainfall. Typically a volume that corresponds to a 10-year, 24-hour storm (4.8 inches of rainfall) is used, unless federal, state, or local regulations require storage for a larger rainfall event.
- Containment dikes may consist of berms, curbs, retaining walls, or manufactured walls that are designed to hold spills. Dikes are an effective pollution prevention measure for aboveground storage tanks, provided that an effective plan for managing Stormwater is in place. Dikes must be inspected and there must be clearly designated responsibilities for releasing Stormwater. Sampling of Stormwater may be required prior to releasing from a diked area.
- For small volumes of storage, the least expensive form of dikes is probably curbing. Curbing is commonly used beneath piping systems that contain small diameter pipes. Curbing can redirect contaminated Stormwater away from the storage area. Common curbing materials are asphalt, concrete, synthetic materials, metal, or other impenetrable materials. Inspection and maintenance should be conducted frequently on curbing, as vehicles and equipment can easily damage curbing so as to reduce the impounded storage volume.
- Dumpsters may be used as secondary containment, provided that they are properly labeled and are in good condition, without corrosion or leaky seams. All drain valves should be closed. Do not allow garbage to be placed into secondary containment dumpsters.

Spill Cleanup:

- The University of Tennessee Stormwater Department Environmental Health and Safety Department and the Tennessee Department of Environment and Conservation (TDEC) all require immediate notification of all spills or leaks to the water or soil.
- Place a stockpile of spill cleanup materials where it will be readily accessible. Train employees in spill prevention and cleanup procedures for the site. Educate

employees and subcontractors on potential dangers to humans and the environment from spills and leaks.

- Clean up leaks and spills immediately using dry methods when possible. Use a rag for small spills, a damp mop for general cleanup, and absorbent material for larger spills. If the spilled material is hazardous, then used cleanup materials are also hazardous and must be disposed of as hazardous waste.
- Many businesses, commercial facilities and industries are required to have a SPCC Plan. The SPCC Plan must have procedures for specific chemicals that are frequently used.

Maintenance:

1. Inspect storage areas at least weekly and during rainfall events to be sure that Stormwater pollution is not being generated. Verify that designated storage areas are kept clean and well organized. Verify that dikes and curbing maintain the ability to retain Stormwater.
2. Repair and replace perimeter controls, containment structures, and enclosures as needed to keep them properly functioning. The frequency of repairs may depend on the age of the facility.
3. Conduct routine weekly inspections that includes the following items:

    - External corrosion and structural failure
    - Evidence of spills and overfills due to operator error
    - Piping system (pipes, pumps, flanges, coupling, hoses, and valves)
    - Loose fittings and improper or poorly fitted gaskets
    - Tank foundations, connections, and coatings

Ensure all employees and subcontractors on the construction project have been trained on the proper use, storage and disposal of the chemicals.

Limitations: Specific spill containment and clean up procedures should be developed for each site, based upon the materials being stored. Use MSDS sheets provided with the chemicals for guidance on storage, cleanup and disposal. Space limitations or site constraints may preclude indoor storage. Storage sheds must meet building and fire code requirements.

Pollution Prevention Practice 2.5: Contaminated Soil Management

Description: Prevent or reduce the discharge of pollutants to Stormwater from contaminated soil and highly acidic or alkaline soils by conducting pre-construction surveys, inspecting excavations regularly, and remediating contaminated soil promptly. This management practice is likely to create a significant reduction in toxic materials and heavy metals as well as a partial reduction in sediment.

Suitable Applications:

1. Construction projects, especially those in highly urbanized or industrial areas, where soil contamination may have occurred due to spills, illicit discharges, and underground storage tanks.
2. Projects near roadways in older areas where median and shoulder soils may have been contaminated by aerially-deposited lead from vehicle emissions.

Approach: Contaminated soils are often identified in the project material report with known locations identified in the plans and specifications. The contractor shall review applicable reports and investigate appropriate callouts in the plans and specifications. Contaminated soils may occur on a site for several reasons including:

- Past site uses and activities
- Known spills and leaks
- Undetected spills and leaks
- Acid or alkaline solutions from exposed soil or rock formations
- Contaminated groundwater or leachwater from nearby properties

Most developers conduct pre-construction environmental assessments as a matter of routine. Recent court rulings have held contractors liable for cleanup costs when they unknowingly move contaminated soil. Therefore, it is necessary for contractors to confirm that a site assessment is completed before earth moving begins. Prevention of leaks and spills is very inexpensive when compared to the cost of treatment and disposal of contaminated soil. Leaks and spills reduce property values and may severely limit future land uses. To ensure prevention of pollutants conduct thorough site planning to include pre-construction site assessments. Include information from geologic surveys to determine extent of acidic or alkaline rock.

Pollution Prevention Practice 2.6: Pesticide, Herbicide and Fertilizer Use

Description: Promote efficient and safe housekeeping practices (storage, use, and cleanup) when handling potentially harmful materials such as fertilizers, herbicides, and pesticides. This management practice will create a significant reduction in nutrients, toxic materials, and oxygen demanding substances.

Approach: Fertilizer management involves controlling the rate, timing, and method of application to minimize the chance of polluting surface water or groundwater. Pesticide and herbicide management involves eliminating excessive pesticide use, employment of proper application procedures, and the use of alternatives to chemical control to reduce the pesticide and herbicide load in Stormwater runoff.

The use of fertilizers, herbicides, and pesticides have the potential to contribute to pollution of Stormwater runoff. All types of properties contribute to the problem: residential, commercial, industrial, institutional. Major users of these products, such as lawn care contractors or construction firms, should develop controls on the application of fertilizers, herbicides, and pesticides. Controls may include:

- Product and application information
- Equipment use and maintenance procedures
- Record keeping
- Public notice procedures

Carefully consider whether these products are essential. Selection of low-maintenance vegetation may reduce the need for fertilizers, pesticides, and herbicides. University of

Tennessee Agricultural Extension Service has many brochures and pamphlets concerning fertilizers and pesticides, including various alternatives.

Fertilizer Application:

- Avoid broadcast applications of fertilizers when immediate rainfall is expected. Apply fertilizer when there is already adequate soil moisture and little likelihood of immediate heavy rainfall, followed by sprinkling the lawn or garden.
- A soil test is recommended to assure the use of optimum lime and fertilizer application rates.
- Whenever fertilizer is used to establish vegetation on bare soil areas, erosion control is of primary importance in preventing fertilizer from leaving the site.
- Excessive application and misuse of pesticides and herbicides results in heavily polluted Stormwater runoff.

Pesticide and Herbicide Application:

- Apply pesticides and herbicides in a narrow rather than wide band; do not broadcast them over the entire lawn area. Spot-spray infested areas rather than applying excess amounts of pesticides and herbicides. Never apply over impervious surfaces.
- Examine all alternatives to pesticides and herbicides that, in the long term, may be much less costly than the use of a particular chemical. Use the least toxic chemical pesticide and herbicide that will accomplish the purpose.
- Pesticides and herbicides that degrade rapidly are less likely to become Stormwater runoff pollutants. Use pesticides and herbicides with low water solubility. Granular formulations are generally preferable to liquids because application losses are lower.
- Pesticides and herbicides should be sprayed only when wind speeds are less than 7 mph. Spray in the early morning or at dusk when wind speeds are usually lowest. Air temperature should range between 40 degrees to 80 degrees Fahrenheit.

Pesticide and Herbicide Types:

Dusts: This type is highly susceptible to wind drift, not only when being applied but also after reaching target. The application should be performed during the early morning or late evening hours when there is little or no air movement. The distance between the application equipment and the target must also be considered.

Sprays: This type may be in the form of solutions, emulsions, or suspensions. Droplet size is an important factor in determining susceptibility to wind drift. Large droplets fall faster and are less likely to contaminate non-target areas. Sprays should be applied during periods of low air movement. Ground sprays followed by soil incorporation are not likely to be sources of water pollution unless excessive erosion occurs.

Granular formulations: This type is applied to either the ground surface or below the soil surface. Surface applications may or may not be followed by soil incorporation. Pollution of surface waters from granular formulations is unlikely unless heavy runoff or erosion occurs soon after treatment. However, groundwater pollution may result from excessive leaching due to rainfall after application, depending on the pesticide composition. Loss of granular formulations can be controlled for the most part with adequate soil conservation practices.

Fumigants: This type must be kept in place for specific lengths of time in order to be effective. Containment methods include soil compaction, water seal, and sealing of the area with a plastic cover. Most fumigants act rapidly and degrade quickly. Consequently, water pollution is usually not a problem.

Antimicrobial paints and other surface coatings: This type is designed to resist weathering and is therefore not a likely source of pollution. Empty containers should be disposed in accordance with rules for all pesticide containers. Use extreme care when sanding or scraping surfaces that have been previously treated with these substances. Treat sanded and scraped residue as hazardous waste.

Pre-plant treatments: Seed, roots, tubers, etc., are frequently treated with pesticides prior to planting. Treatment is usually by dust, slurry, or liquids. Little pollution hazard exists from this application. Care must be taken, however, in disposing of residual treatment materials and with unused plants.

Organic pesticides: A wide variety of organic pesticides, produced from plants, bacteria, and other naturally-occurring substances, are available in quantities for both commercial and residential use. These substances usually present much less risk for contamination of groundwater and surface water, and much fewer problems for disposal of leftover product or containers.

Beneficial insects: This management method involves the use of insects in bulk or in amounts suitable for residential use. It can be used alone or in combination with other pesticides to eliminate or minimize the use of toxic substances.

Good Housekeeping and Safety:

1. Always use caution when handling any pesticide, herbicide, or fertilizer product. Many products contain toxic chemicals that can cause severe injury or death.
2. Store pesticide or fertilizer products securely in containers protected from Stormwater and away from people, and sources of heat, sparks, and flames. Store products in their original containers and keep them well-labeled. Very importantly, do not store chemicals in food containers.

3. Read and follow use instructions provided on packaging and in material safety data sheets (MSDS). Periodically review MSDS information and discuss precautions with employees or personnel using or handling pesticides, herbicides, or fertilizers.
4. Work only in well-ventilated areas. Avoid contact with eyes and skin. Wear gloves and eye protection when using or handling hazardous substances. Do not wear contact lenses, which can absorb hazardous vapors.
5. Use the entire product before disposing the container. Do not dispose of pesticide or fertilizer wastes in any of the following methods:

    - Into trash or waste containers
    - Into storm drains or into creeks
    - Onto the ground
    - By burning

UT Requirements: Employees who handle potentially harmful materials should be trained in good housekeeping practices.

Pollution Prevention Practice 2.7: Response to Sanitary Sewer Overflows

Description: This BMP is intended to describe the general procedures and precautions necessary when responding to sanitary sewer overflow (SSO) incidents. The public should report SSOs directly to the wastewater system operator for immediate response. Wastewater system employees receive training and equipment necessary to handle SSO incidents using procedures that meet state and local guidelines.

Wastewater System Operator Telephone Number to Report SSOs:

Knoxville Utilities Board (KUB) 524-2911 (http://www.kub.org)

Wastewater system employees will respond to reported SSO incidents and follow company procedures that meet state and local guidelines. These guidelines are intended as the minimum standards for SSO response by various wastewater system operators.

Approach: The primary objective in SSO response shall be to protect human health, private and public property, and the environment. It is a known fact that sanitary sewage may contain viruses, bacteria and other pathogens that are harmful to human and animal life. All practical steps must be taken to prevent the general public from having direct contact with areas contaminated by raw untreated sewage. The wastewater system operator is responsible for posting signs and barricades as soon as possible to warn the general public about SSO occurrences. Restrict access to the contaminated areas. In addition, SSO responders should be aware of indirect exposures (through pets, birds, flies, mosquitoes, etc.) and take steps to prevent or reduce these exposures. An SSO discharge is a direct violation of the NPDES industrial permit issued to each of the wastewater system operators.

SSO Response Guidelines:

- Wastewater system employees who respond to an SSO incident should wear appropriate personal protective equipment (PPE) to prevent any contact with raw sewage. PPE may include: rubber gloves, rubber boots, impermeable coveralls (tyvek), and protective headwear with a splash shield.
- Leather gloves and leather boots are not adequate PPE for wastewater system employees. Leather is easily contaminated and cannot be cleaned; discard leather gloves and boots if they have been exposed to raw sewage.
- Maintain adequate PPE supplies for each responding crew. Replace PPE as necessary during cleanup operations to ensure employee protection. Place used PPE into sealed bags for decontamination or disposal at a later time.
- In addition to adequate PPE supplies, each responding crew should be equipped with tools (shovels, rakes, pumps, hoses), damming materials (plugs, blocks, plastic sheeting, straw bales, sandbags), testing equipment, and decontamination chemicals (typically lime).

Recommendations to Limit and Control Exposures:

- Plan response activities and operations to prevent or minimize Stormwater contact. Identify the sources of raw sewage and probable causes. Determine the best manner to contain and reduce the area of SSO contamination. Field crew supervisors are expected to use their best judgment in controlling SSO discharges.
- Immediately protect nearby drainage structures (ditches, channels, curbs, drop inlets, culverts, natural streams and ponds, detention basins, etc.) from receiving raw sewage to the greatest extent possible. Available materials to contain SSOs include: pipe plugs, plastic or wood blocks, sandbags, straw bales, plastic sheeting, or dirt berms.
- In instances with large flows, the responding crew may immediately choose to create dirt berms to control the SSO discharge. Or it can even be beneficial to use an existing Stormwater detention basin to contain SSO discharges by plugging the detention outlet structure. The goals are to: 1) reduce exposure to humans, 2) protect property and the environment, and 3) reduce the extent of contaminated areas which need to be cleaned.
- Eliminate the SSO if possible by:
    - Directly removing blockages from the sanitary sewer line or manhole (if a blockage is clearly indicated).

- Pumping sewage into a sewage tank trunk until the overflow stops, for later disposal at another sanitary sewer manhole or at wastewater treatment plant.
- Pumping sewage downstream into the nearest downstream manhole at a location where the sanitary sewer line is properly functioning.

Cleanup and Decontamination:

- After the SSO has been eliminated, then reclaim raw sewage from contaminated areas such as ground depressions, ditches, curb inlets, culverts, etc. Portable pumps and hoses can be used to collect raw sewage into sewage trucks. Do not wash SSO discharges into the storm drainage system while cleaning SSO residues; this is a violation of the University Stormwater Policies and will be subject to penalties and other legal action.
- Remove all solid materials and residues that were discharged during an SSO. Solid materials include, but are not limited to: feces, toilet paper, personal hygiene products, napkins, food products, congealed grease or fat, soap residue, etc. Unfortunately, almost any type of material conceivable can be placed into the sanitary sewer system by the general public (limited only by size).
- Decontaminate areas with lime or other disinfectant as needed. Apply the correct amount of disinfectant. Do not allow disinfectant to enter ditches, storm drains, or natural streams. Do not discharge lime into any flowing channels.
- Important -- Lime and other disinfectants are generally fatal to aquatic organisms, birds, pets and other animals. Only use as much lime as needed. Prevent lime from entering ditches, storm drains or flowing water. Field crews shall use their best judgment on the use and quantity of lime. Protection of human health is the highest priority.
- Contaminated areas with prolonged exposure to SSOs may need to be excavated, regarded, or replanted to fully repair SSO damage. Return site conditions so that human and animal contact with contaminated soils will not pose a health problem.
- Remove signs and barricades only after the contaminated areas are safe again for human contact.

Maintenance:

- Wastewater system operators are required to maintain and repair sanitary sewer lines in a timely manner. SSO discharges are not allowable under NPDES permits, and must be prevented to the maximum extent possible.
- If the cause of an SSO discharge has compromised the ability of the sanitary sewer system to function, then the system should be repaired immediately to prevent a reoccurrence of the SSO.

Pollution Prevention Practice 2.8: Air Conditioners and Refrigeration Maintenance

Description: The purpose of this BMP is to reduce pollution impacts from cleaning and maintenance of air conditioning and refrigeration units. It is allowable to discharge condensate water, which is essentially pure water from the atmosphere. It is illegal to discharge any water that contains chemicals, detergents, algae-killing agents and other manmade substances onto the ground or onto any surface which drains to the University Stormwater drainage system, ditches, swales, curbs, natural creeks and streams or wetlands. Even if the contaminated water does not directly reach the storm drainage system, the chemicals will wash into the Stormwater runoff during the next rainfall.

Approach: It is illegal to discharge any substance (liquid or solid) to the environment in any manner that could allow the substance to wash into the municipal Stormwater drainage system, ditches, swales, natural streams, wetlands or sinkholes. This prohibition is mandated by federal and state regulations. The University of Tennessee Knoxville is required to prohibit non-Stormwater discharge as part of the National Pollutant Discharge Elimination System (NPDES) permit issued to the University by the state of Tennessee.

UT Requirements: Both air conditioning condensate and refrigeration condensate are on the list of allowable discharges, provided that such water is distilled pure water taken from the atmosphere. However, any cleaning water or washwater cannot be discharged to the ground, but must be captured for disposal in the sanitary sewer system. When cleaning air conditioner coils capture the washwater and dispose properly. Minimize the use of chemicals and cleaning agents by scrubbing to remove dirt and deposits. If power or pressure washing, then contain all generated washwater for recycling and proper disposal.

Pollution Prevention Practice 2.9: Power or Pressure Washing

Description: The purpose of this BMP is to reduce pollution impacts from power washing, pressure washing, and cleaning of buildings, roofs, fences, floors, driveways, parking lots, etc. These practices dislodge pollutants such as grease, oil, paint chips, sediments, and food particles through the use of high-pressure water sprays, water containing a cleaning solution, or by heated water. Prevent or reduce the discharge of pollutants to Stormwater from power washing activities by:

- Employee training and education,
- Identifying alternatives, and
- Controlling wash water
- Using "Green" cleaning solutions

Pollution from these types of washing activities comes from two sources:

- Cleaning solutions
- Pollutants and dislodged materials

Cleaning solutions generally contain chemicals that are able to dissolve and dislodge grease and oils. These cleaning solutions are very dangerous to aquatic life and are likely to cause fish kills. It should be noted that all soaps, even biodegradable soaps, are harmful to fish and other aquatic organisms. Pollutants and dislodged materials will also pollute the aquatic environment and harm fish. Materials such as paint chips or automotive fluid leaks are toxic to all creatures.

Approach: The primary approach for most applications is to avoid the need for power washing, pressure washing or steam cleaning by using other methods such as:

1. Dry methods for cleanup of liquid wastes and dry materials
2. Dry Ice Blasting
3. Scrapers for removing mud, dirt, or old paint
4. Non-pressurized water in small amounts and prevent discharge from entering storm drains

Dry methods for cleanup of liquid wastes include the use absorbents and dry rags to contain the liquid. Then the area can be cleaned with a small amount of water using a mop or a scrub brush. Small amounts of wash water can generally be discharged to the sanitary sewer system if it does not contain hazardous chemicals or toxic materials. Scrapers should be used for removing old paint from buildings or moss from rooftops. If the old paint contains lead or tributyl tin, then it is considered a hazardous waste and must be disposed at a facility licensed to handle hazardous waste. Use tarps and groundcloths to collect paint chips, and then carefully verify that there are no paint chips on the ground or other surfaces prior to washing. Squeegees may be appropriate for cleaning mud or dirt from some surfaces. Scrubbing with sponges or rags will ensure that the surface is cleaned with the correct amount of pressure.

When it is deemed that pressure washing is necessary, it is important to manage washwater appropriately. Use sandbags, portable berms or other means to direct the washwater so it flows to one of the following:

- A grassy or vegetated area (if there are no oil or hazardous materials)
- A sump or an enclosed area where washwater will be trapped and then pumped for transport to an appropriate disposal location
- A Sanitary Sewer Drain

The storm drain system can also be protected using water-filled berms or water-filled storm drain covers. These types of barriers are reusable and generally conform to the ground or pavement surface, creating a tight seal. Do not dump mop water or carpet cleaning water outdoors. It can be poured into the sanitary sewer using an indoor drain, as long as it is not contaminated with hazardous materials. Mop water or carpet-cleaning water may need to be filtered if it contains large particles or sludge.

Pollution Prevention Practice 2.10: Facilities Maintenance

Parking Area Maintenance:

- Stormwater runoff from parking lots and roads may contain undesirable concentrations of oil, grease, suspended particulates, and metals such as copper, lead, cadmium, and zinc, as well as the petroleum byproducts of engine combustion. Deposition of air particulates, generated by the facility or by adjacent industries, may contribute significant amounts of pollutants.
- An appropriate method for removing pollutants from parking areas is to conduct periodic sweeping. A vacuum sweeper is a better method of sweeping rather than mechanical brush sweeping. The mechanical brush sweeper is not as effective at removing the fine particulates.
- Some form of Stormwater treatment may be necessary to reduce pollutants from sizable parking lots. An oil/water separator is highly recommended for most parking lots. Filter strips and swales will reduce the amount of pollutants by using vegetation and permeable soils. If some employees have cars that are leaking visible amounts of engine fluids, encourage them to have the problem corrected.

Building Maintenance:

- Collect and properly dispose of roofing debris prior to rainfall and upon completion of work to prevent entry of debris and materials into gutter downspouts.

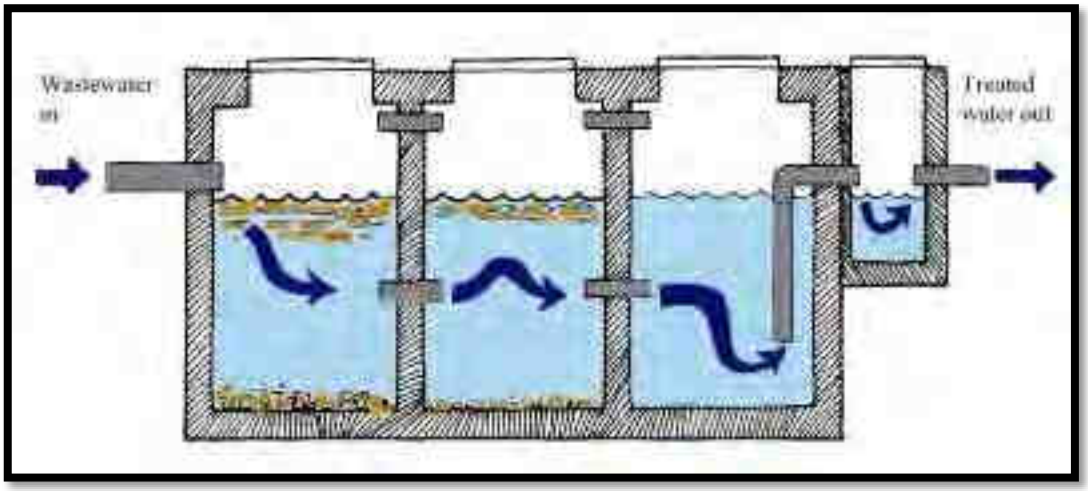
- When small particles have accumulated in the roof gutter, either sweep out the gutter or wash the gutter and trap the particles at the outlet of the downspout. A sock or geofabric, which can be securely fastened over the outlet may effectively trap the materials.

Larger buildings may have the downspouts connected directly to an underground header or a storm drain. In this case, place a temporary plug at the first convenient point in the storm drain. Wash the gutters and downspouts, then pump out the washwater with a vacuum truck. Clean the catch basin sump where the plug had been placed.

Painting: Painting operations should be properly enclosed or covered to avoid drift, typically by handing dropcloths or sheets from temporary scaffolding. Use paint application equipment that minimizes overspray. If painting requires scraping or sand blasting of the existing surface, use a groundcloth to collect the chips. If the paint chips contain lead or tributyl tin, it is considered a hazardous waste.

- Mix paint indoors before using so that any spill will not be exposed to rain. Do so even during dry weather because cleanup of a spill will never be 100% effective. Dried paint will erode from a surface and be washed away.
- If using a small amount of water-based paints, clean the application equipment in a sink that is connected to the sanitary sewer. Properly store leftover paints if they are to be kept for the next job or properly dispose of the leftover paints. For oil-based paints, paint out brushes to the extent practical, and then filter and reuse thinners. Oil-based paints must not be disposed into the sanitary sewer. Never clean paintbrushes or rinse paint containers into a street, gutter, storm drain, or watercourse.
- When using sealants on wood, pavement, roofs, etc. quickly clean up spills. Remove excess liquid with absorbent material or rags.

Pollution Prevention Practice 2.11: Oil/Water Separator



Description: Oil/water separators are designed to specifically remove floating oil, gasoline, light petroleum compounds, and grease. However, most separators will generally remove floatable debris and coarse sediment in order to reduce maintenance and cleaning requirements. There are two main methods of intercepting oil: a conventional gravity separator and a coalescing plate interceptor (CPI). This practice will significantly reduce coarse sediment, floatable materials, oil and grease, and heavy metals that are typically associated with vehicle operations and automotive exhausts.

Purpose and Application: Oil/water separators (also called oil/grit separators because most designs generally remove coarse sediment) are intended to remove floating gasoline, oil, grease, light petroleum products and other floating liquids from Stormwater runoff. Oil/water separators are commonly used for industrial applications and parking facilities, which have a constant flow of known quantity. Separators are very efficient in these types of applications. However, it is much more difficult to remove smaller concentrations (such as 10 ppm) from Stormwater runoff which has a much broader range of flows. The suitable applications for oil/water separators include:

- Parking lots, streets, driveways, truck loading areas
- Gasoline stations, refueling areas
- Automotive repair facilities, oil-change facilities, fleet maintenance yards
- Recycling or waste collection areas
- Commercial vehicle washing facilities

Construction Specifications: The oil/water separator system should only be constructed if:

1. there is a maintenance plan to regularly inspect and maintain the oil/water separator on a long-term basis, and
2. there is an agreement that the required maintenance resources will be available for the life of the system.

Without regular inspection and maintenance, an oil/water separator will fail and generally create a worse pollution problem. Another very important decision is whether to bypass large storm events around the oil/water separator without damaging the system, exceeding design flow capacity, or re-suspending collected pollutants. For larger storm events, Stormwater runoff will become turbulent and remix the oil droplets. Large flows can also scour sediments that have been deposited on the bottom of an oil/water separator over the course of several months. Essentially, pollutant removal is only ensured when the oil/water separator is cleaned out regularly, and the sediments are properly analyzed and disposed. Stormwater runoff is only detained briefly within oil/water separators because of size constraints for an engineered structure. Therefore, it is important that all factors leading up to the separator and also downstream from the separator are favorable for its effective operation.

An oil/water separator is frequently used as the upstream measure in a series of Stormwater treatment BMPs, ahead of a detention basin or constructed wetland. Advantages of an oil/water separator may include:

- Efficient use of valuable space (since it is usually located underground)
- Does not require as much vertical drop as some other types of BMPs
- Easily accessible and easy to clean with proper equipment
- Reliable if carefully designed (including upstream and downstream reaches)

Maintenance:

- Oil/water separators should be inspected on a regular basis (such as every six months) to ensure that accumulated oil, grease, sediment, trash and floating debris do not disturb the proper functioning of the system. Record observations in an inspection log and take pictures as necessary to document conditions. Make immediate repairs as needed, and make arrangements for cleanout if needed. Consider using a licensed commercial subcontractor, who may have special equipment and abilities to perform periodic cleanout on oil/water separators.
- Perform cleanout on regular basis using confined-space procedures and equipment as required by OSHA regulations, such as non-sparking electrical equipment, oxygen meter, flammable gas meter, etc. Remove trash and debris and dispose properly. Remove floating oil, grease and petroleum substances

using special vacuum hoses; treat as hazardous waste. Sediments may also contain heavy metals or other toxic substances and should be handled as hazardous waste. Removal of sediment depends on accumulation rate, available storage, watershed size, nearby construction, industrial or commercial activities upstream, etc. The sediment composition should be identified by testing prior to disposal.

Limitations: The design loading rate for oil/water separators is low; therefore, they can only be cost-effectively sized to detain and treat low storm flows and first flush volumes. It is usually not economical or feasible to size an oil/water separator to treat a design storm with a return period longer than 1 year. Oil/water separators require frequent periodic maintenance for the life of the structure. Maintenance can be minimized (and performance can be increased) by careful planning and design, particularly upstream and downstream from separator. There is usually uncertainty about what types of oil or petroleum products may be encountered. Significant percentages of petroleum products are attached to fine suspended solids and therefore are not easily removed by settling.

Section 3: Erosion Prevention

Erosion Prevention Practice 3.1: Rolled Erosion Control Products

Turf reinforcement mats are appropriate for steep slopes (greater or equal to 2:1) or where concentrated flows exceed channel design sheer stress.

Purpose and Application: Rolled erosion control products (RECPs) hold seed in good contact with the soil to promote seed germination and soil stabilization.

Description: These products are temporary degradable or long-term non-degradable material manufactured or fabricated into rolls designed to reduce soil erosion and assist in the growth, establishment and protection of vegetation. Use RECP's to help permanent vegetative stabilization of slopes 2:1 or greater and with more than 10 feet of vertical relief, as well as channels where sheer stress in the channel exceeds the allowable sheer stress for the 2 year storm event.

Limitations: Installation is critical to the effectiveness of these products. When close ground contact is not properly achieved, runoff can concentrate under the product causing significant erosion.

Maintenance: Monitor the products on a regular basis to avoid significant problems caused by rainfall and high flows.

Erosion Prevention Practice 3.2: Permanent Vegetation

Permanent vegetation is the most effective erosion prevention practice.

Purpose and Application: Permanent vegetation controls erosion by physically protecting a bare soil surface from raindrop impact, flowing water, and wind. Vegetation binds soil particles together with a dense root system and reduces the velocity and volume of overland flow. It is the preferred method of surface stabilization wherever site conditions permit.

Description: Seeding with permanent grasses and legumes is the most common and economical means of establishing a protective cover. The advantages of seeding over other means of establishing plants include the relatively small initial cost, wide variety of grasses and legumes available, lower labor input, and ease of application. Problems to consider are potential for erosion during the establishment period, the need to reseed areas, seasonal limitations on seeding dates, weed competition, and the need for water during germination and early growth. Give special attention to selecting the most suitable plant material for the site and intended purpose. Good seedbed preparation such as topsoiling, adequate liming and fertilization, and timely planting and maintenance are also important for good germination and establishment of a permanent groundcover.

UT Requirements: Application of temporary or permanent stabilization must be initiated within 14 days to disturbed areas of a site where construction activities have temporarily or permanently ceased.

Limitations: Establishing permanent vegetation within concentrated flow paths such as swales and ditches will likely require special considerations such as rolled erosion control to protect the seed and seedbed during (and possibly after) germination.

Maintenance: Generally, the more effort put into proper seedbed preparation, applying appropriate and adequate seed and mulch, and initial watering during germination, the less maintenance needs such as overseeding, reapplying mulch, and extended watering will be required.

Erosion Prevention Practice 3.3: Temporary Vegetation

A temporary ground cover was applied to this area because final grading was not to occur until spring.

Purpose and Application: Protective cover must be established on all disturbed areas within 14 days after a phase of grading is completed. Temporary seeding and mulching are the most common methods used to meet this requirement. Temporary vegetation is used to protect earthen sediment control practices and to stabilize denuded areas that will not be brought to final grade for several weeks or months. Temporary vegetation can also provide a nurse crop for permanent vegetation, provide residue for soil protection and seedbed preparation, and help prevent dust during construction.

Description: Annual plants that are adapted to site conditions and that sprout and grow rapidly should be used for temporary plantings. Proper seedbed preparation and the use of quality seed are also important.

UT Requirements: Application of temporary or permanent stabilization must be initiated within 14 days to disturbed areas of a site where construction activities have temporarily or permanently ceased.

Limitations: Because temporary seeding provides protective cover for less than one year, areas must be reseeded annually or planted with perennial vegetation.

Maintenance: Generally, the more effort put into proper seedbed preparation, applying appropriate and adequate seed and mulch, and initial watering during germination, the less maintenance needs such as overseeding, reapplying mulch, and extended watering will be required.

Erosion Prevention Practice 3.4: Sod

Sod is a fast and effective method of stabilizing bare soils.

Purpose and Application: Sodding provides an immediate and effective groundcover. It allows the use of vegetation to protect channels, spillways, and drop inlets where design flow velocities may reach the maximum allowable for the type of vegetation to be used. Sod is preferable to seed in waterways and swales because of the immediate protection of the channel after application. The installation of sod should also be considered in locations where a specific plant material cannot be established by seed or when immediate use is desired for aesthetics such as landscaping. Some additional advantages of sod are nearly year-round establishment capability, less chance of failure, freedom from weeds, and immediate protection of steep slopes.

Description: Sod consists of grass or other vegetation-covered surface soil held together by matted roots.

Limitations: Disadvantages include high installation costs, especially on large areas, and the necessity for irrigation in the early weeks. Sod also requires careful handling and is sensitive to transport and storage conditions.

Maintenance: Soil preparation, installation, and proper maintenance are as important with sod as with seed. Choosing the appropriate type of sod for site conditions and intended use is of utmost importance. Sod may need to be pinned in place on steep slopes and in channel applications.

Erosion Prevention Practice 3.5: Stabilization with Straw Mulch

When disturbed areas have been rough graded but not final graded. Straw mulch provides a temporary groundcover that reduces erosion until the final grading can occur.

Purpose and Application: Surface mulch is the most effective, practical means of controlling erosion on disturbed areas before establishing vegetation. Mulch protects the soil surface, reduces runoff velocity, increases infiltration, slows soil moisture loss, helps prevent soil crusting and sealing, moderates soil temperatures, and improves the microclimate for seed germination.

Description: Organic mulch such as straw is effective for general use where vegetation is to be established. Straw mulch is most effective when it has been anchored with matting, crimping or a tackifier to prevent its movement. In recent years a variety of mats and fabrics have been developed that makes effective mulches for use in critical areas such as waterways and channels. Various types of tacking and netting materials are used to anchor organic mulches. Netting is generally not effective when used alone.

UT Requirements: Application of temporary or permanent stabilization must be initiated within 14 days to disturbed areas of a site where construction activities have temporarily or permanently ceased.

Limitations: Mulch is not intended to withstand the shear stress of concentrated flow; therefore, mulching a ditch must be accomplished in conjunction with other velocity reducing measures such as check dams or through the use of an engineered ditch lining material such as a turf reinforcement mat.

Maintenance: Maintenance of a good cover of mulch is one of the most effective erosion prevention measures because it helps prevent movement of the soil thereby reducing the need for sediment control measures. Maintenance of mulch can include but is not limited to applying more mulch where it has blown or washed away, securing the mulch through such actions as crimping or diverting run-on storm water from the mulched area to prevent future wash-outs.

Erosion Prevention Practice 3.6: Stabilization with other Mulch Materials

Shredded wood or pine straw mulch applied 2-3" thick can be used as stabilization.

Purpose and Application: Surface mulch is the most effective, practical means of controlling erosion on disturbed areas that will not have complete vegetation cover. Mulch protects the soil surface, reduces runoff velocity, increases infiltration, slows soil moisture loss, helps prevent soil crusting and sealing, moderates soil temperatures, and improves the microclimate for seed germination.

Description: There are many types of mulches. Selection of the appropriate type of mulch should be based on the type of application, site conditions, and compatibility with planned or future uses. Besides straw mulch (practice 3.5), other materials can be used as mulches, including wood chips, shredded bark and gravel. Use of onsite materials as mulch is strongly encouraged to reduce the environmental footprint of the site. For example, trees and other vegetation cleared from the site can be ground and used as mulch material for the site.

UT Requirements: Application of temporary or permanent stabilization must be initiated within 14 days to disturbed areas of a site where construction activities have temporarily or permanently ceased.

Limitations: Some mulch materials float when in contact with Stormwater runoff and should not be placed in areas receiving concentrated flow. In addition, offsite mulch materials should be certified as free from fire ants. Mulch is not intended to withstand the shear stress of concentrated flow; therefore, mulching a ditch must be accomplished in conjunction with other velocity reducing measures such as check dams or through the use of an engineered ditch lining material such as a turf reinforcement mat.

Maintenance: Maintenance of a good cover of mulch is one of the most effective erosion prevention measures because it helps prevent movement of the soil thereby reducing the need for sediment control measures. Maintenance of mulch can include but is not limited to applying additional mulch where it has blown or washed away, securing the mulch through such actions as packing, or diverting run-on storm water from the mulched area to prevent future wash-outs.

Erosion Prevention Practice 3.7: Emergency Stabilization with Plastic

Temporary covering was used to protect the topsoil stockpile from erosion.

Purpose and Application: Exposed slopes are common around box culvert construction, utility work and stockpile areas. Often, temporary seeding of these areas is not feasible due to the slope or activity on or around them. In situations where soils are exposed and in close proximity to receiving streams, plastic sheeting can provide a temporary ground cover that prevents erosion and off site sediment discharges.

Description: Plastic sheeting must be anchored or held in place to prevent the material from moving. Rocks or other weight can be placed on the sheeting or the sheeting can be trenched in at the top and toe of the slope.

Limitations: Plastic sheeting is a very short term practice for use on exposed slopes in close proximity to streams or wetlands.

Maintenance: Plastic sheeting should be replaced when torn, and care should be taken when overlapping sections of plastic by doing so in a shingle fashion to shed storm water.

Section 4: Runoff Mitigation and Management

Runoff Mitigation and Management Practice 4.1: Outlet Protection

Outlet protection is necessary at the pipe outfalls, ditches and other conveyances where sheer stress exceeds the allowable sheer stress for grass-lined channels.

Purpose and Application: Outlet protection provides permanent stabilization for the material at the outlet of the pipe, channel or other conveyance system. Outlet protection is also needed at outlets to temporary slope drains to prevent scour while the slope drain is in place.

Description: Outlet protection can be constructed of many different types of erosion-resistant materials but must be designed based upon the velocity and sheer stress at the outlet of the conveyance. Rip rap is a common outlet protection material. Outlet protection must be keyed into the existing ground and constructed as close to a zero grade as possible. For rip rap outlet protection, a geotextile underlayment or filter fabric is required to prevent piping.

Limitations: An often-overlooked consideration in outlet protection installation is the over excavation required to sufficiently key in the riprap. In addition, the size of riprap required to withstand the force of the water exiting the pipe may be prohibitive (i.e. too large) and other methods may need to be considered.

Maintenance: Monitoring for bypassing of the outlet protection and scour of the surrounding area is critical. This is a common problem when the outlet protection has either not been sufficiently keyed into the soil or the outlet protection is not covering a large enough area.

Runoff Mitigation and Management Practice 4.2: Channel Linings

Stabilized channels convey stormwater in a non-erosive manner, encouraging infiltration and filtering runoff.

Purpose and Application: Channels are permanent structures that convey concentrated runoff. Many methods of permanent stabilization are available, including vegetation, vegetation with a permanent liner, rip rap, and concrete.

Description: The preferred channel lining is vegetation. Grass lined channels provide benefits above simply conveying Stormwater runoff while maintaining a stable channel. The grass provides some filtering of Stormwater after the site has been stabilized. In addition, grass lined channels are typically on gentle slopes with low velocities and promote infiltration. As shear stresses and slopes increase, rolled erosion control products (RECPs) should be incorporated into the channel stabilization design, leaving rip rap and concrete lined channels as the last options for stabilization, only where site conditions will not allow stabilization with grass and a liner (temporary or permanent). Temporary linings should be designed based upon the 2 year storm, while permanent linings are designed based upon the 10 year storm.

Limitations: Channels are designed based upon the 2-year and 10-year storm events. Storms larger than the design storm can cause channel linings to fail.

Maintenance: Once established, grass lined channels are easier to maintain long term than rip rap and concrete lined channels. However, once the channels are temporarily or permanently stabilized, they should be protected from construction activity – particularly runoff with heavy sediment loads.

Runoff Mitigation and Management Practice 4.3: Channels (Stable Channel Design)

Definition: A runoff conveyance measure constructed to the design cross section and grade, and stabilized with erosion-resistant linings such as vegetation, riprap, paving, or other structural material. For the purposes of this section, channels do not include streams.

Purpose and Application: To convey and dispose of concentrated surface runoff without damage from erosion, deposition, or flooding. This practice applies to sites that contain concentrated runoff in a ditch or open channel. Typical locations of channels or ditches include roadside ditches, channels at property boundaries, channels created by diversion structures, or channels designed as part of a site's permanent storm water conveyance system.

Construction Specifications: Generally, channels should be located to conform with and use the natural drainage system. Channels may also be needed along development boundaries, roadways, and landscaped areas. Avoid channels crossing watershed boundaries or ridges. Plan the course of the channel to avoid sharp changes in direction or grade. Site development should conform to natural features of the land and use natural drainage ways rather than drastically reshape the land surface. Major reconfiguration of the drainage system often entails increased maintenance and risk of failure.

Design Criteria:

- Avoid supercritical flow or include a drop structure and hard armoring in the design. Where design indicates supercritical flow, consider changing the channel geometry.
- Design must consider the construction phase and permanent Stormwater management conveyance (after construction is complete) phase. Factors used in the design should reflect these conditions.
- On steep slopes, shorten the effective slope length by installing drop structures or "turn outs" that discharge runoff non-erosively over stable slopes.
- At a minimum, the freeboard should be sufficient to prevent waves or fluctuations in water surface from washing over the sides. In a permanent roadway channel, about 0.5 ft of freeboard should be adequate, and for transitional channels, zero freeboard may be acceptable. Steep gradient channels should have a freeboard height equal to the flow depth. This allows for large variations to occur in flow depth for steep channels caused by waves, splashing and surging. Lining materials should extend to the freeboard elevation.
- Check overall channel width for fitting within available alignment space, easement or right-of-way.

Stabilized channels must be isolated from sedimentation from disturbed areas:

- Stable grass-lined channels resemble natural drainage systems and, therefore, are usually preferred if design shear stress is below 2 lb/sqft and velocities below 5 ft/sec.
- Construct and stabilize channels early in the construction schedule before grading and paving increase the rate of runoff. Where grass-lined channels are designed, geotextile fabrics or straw and netting provide stability until the vegetation is fully established. These protective liners must be used whenever design velocities exceed 2 ft/sec for bare soil conditions. It may also be necessary to divert water from the channel until vegetation is established, or to line the channel with sod.
- Sediment traps may be needed at channel inlets and outlets.

V-shaped 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.

Parabolic channels are often used where larger flows are expected and space is available. The swale-like shape is pleasing and may best fit site conditions.

Trapezoidal channels are used where runoff volumes are large and slope is low. Subsurface drainage, or riprap channel bottoms, may be necessary on sites that are subject to prolonged wet conditions due to long duration flows or high water tables.

Construction drawings should include specifications to provide sufficient channel undercutting to allow for thickness of some linings such as rock to preserve the required flow depth.

Outlets: Channel outlets must be stable. Where channel improvement ends, the exit velocity for the design flow must be non-erosive for the existing receiving system conditions. Stability conditions beyond the property boundary should always be considered.

Where velocities exceed 2 ft/sec, more durable channel liners are required.

Liners for channels may be classified as either flexible or rigid. The primary difference between rigid and flexible channel linings from an erosion control standpoint is the lining's response to changing channel shape. Flexible linings are able to conform to changes in the channel shape while rigid linings will not. Flexible linings can accommodate some change in channel shape while maintaining their overall integrity. Rigid linings tend to fail if a portion of the lining is damaged by undermining or slumping. Thus, where flexible linings are capable of withstanding the design shear stress, they are preferred over rigid linings. Flexible linings usually will consist of sod or seeded grasses, erosion control blankets or turf reinforcement mats, machined rock (riprap), cobbles, or wire-enclosed rock (such as gabions or mattresses). Rigid linings may consist of either cast-in-place concrete, grouted riprap, or stone masonry. As a general rule, the use of rigid linings should be avoided unless they are intended to be permanent.

Runoff Mitigation and Management Practice 4.4: Slope Drain

The goal of a slope drain is to convey Stormwater down a slope to prevent erosion while the slope is being stabilized.

Purpose and Application: Slope drains are temporary measures that are used where sheet or concentrated storm water flow could cause erosion as it moves down the face of a slope to prevent erosion from sheet or concentrated flow on or below the slope. Special attention is needed at *entrance, tight joints, pipe anchors,* and *exit*. These structures are removed once the slope has been stabilized and the permanent storm water conveyance system has been installed.

Description: Temporary slope drains consist of flexible tubing or conduit extending from the top to the bottom of a cut or fill slope. Sediment controls are installed at the inlet and erosion controls at the outlet.
Prior to installing slopes drains, the slope being protected must be stabilized.

Limitations: The maximum drainage area to any one slope drain is 1 acre.

Maintenance: Stabilize the diversion berm at the top of the slope. Ensure that the slope drain is located in the low point above the slope. Remove sediment from the sediment control practice when 50% of the sediment storage volume has been filled. Ensure that the slope drain has been secured properly to the slope to prevent disconnection of pipe joints. Failure of the slope drains can occur when the anchor berm installed over the slope drain at the top of the slope hasn't been compacted or stabilized.

Runoff Mitigation and Management Practice 4.5: Diversion

Diversions convey Stormwater around or through a site. They can be temporary or permanent measures.

Purpose and Application: Diversions carry runoff around a construction area; to reduce slope length and minimize erosion; or to carry sediment laden runoff to a treatment practice. They can be designed as temporary or permanent measures and must be stabilized accordingly.

Description: Diversions can be created through excavation or by building a ridge. This practice applies to construction areas where runoff can be diverted and disposed of properly to control erosion, sedimentation, or flood damage. Specific locations and conditions include above disturbed existing slopes, and above cut or fill slopes to prevent runoff over the slope; across unprotected slopes, as slope breaks, to reduce slope length; below slopes to divert excess runoff to stabilized outlets; where needed to divert sediment-laden water to sediment traps; at or near the perimeter of the construction area to keep sediment from leaving the site; and above disturbed areas before stabilization to prevent erosion, and maintain acceptable working conditions. Temporary diversions may also serve as sediment traps when the site has been over excavated on a flat grade. They may also be used in conjunction with silt fence.

Limitations: Unless stabilized, diversions can exacerbate erosion prevention and sediment control on a project.

Maintenance: After diversions have been constructed, stabilize them against erosion. Sediment deposits should be removed to prevent overtopping of the diversion. Additional erosion controls, such as check dams, may be necessary to reduce erosion.

Runoff Mitigation and Management Practice 4.6: Level Spreader

Purpose and Application: The most prevalent application of level spreaders is converting concentrated flow into sheet flow before discharging into stream buffers.

Description: Level spreaders can be constructed out of many different materials. They consist of a conveyance (a channel or diversion), energy dissipation, a ponding area, and a level lip. Stormwater should flow as sheet flow across the level lip. Construct level spreaders in undisturbed soil. The lip must be level to ensure uniform spreading of storm runoff, and the outlet slope uniform to prevent the flow from concentrating. Water containing high sediment loads should enter a sediment trap before release in a level spreader.

Limitations: The drainage area limitation is 5 acres and the spreader must be sized based on design runoff. If the lip of the level spreader is not level, Stormwater will re-concentrate and cause erosion.

Maintenance: All areas draining to the level spreader must be stabilized. Sediment and other debris must be removed from the ponding area to prevent bypassing. Repair eroded areas.

Runoff Mitigation and Management Practice 4.7: Check Dam

Purpose and Application: Check dams are structures installed in channels to reduce velocities and erosion in channels to aid in permanent stabilization. Check dams also provide some sediment control benefit. Check dams may be installed to reduce velocity in small temporary channels that are degrading, but where permanent stabilization is impractical due to their short period of usefulness; or to reduce velocity in small eroding channels where construction delays or weather conditions prevent timely installation of non-erosive liners.

Description: A check dam is a small, temporary structure constructed across a drainage way (not a stream). Most check dams are constructed of rip rap. However, other manufactured check dam devices are available. Check dams must contain a center spillway section that is lower than the check dam sides. When rip rap is used, geotextile or filter fabric must be installed at the soil-rock interface. Place washed stone on the face of the rip rap check dam.

Limitations: The drainage area is limited to 5 acres maximum. Problems with check dams typically occur at the abutments when the sides are lower than the middle spillway, causing erosion around the abutments. Erosion can also occur at the downstream toe of the check dam. These measures must be monitored and sediment cleaned out from behind the structures to prevent overtopping and failure. In addition, ponding behind the structures must not cause a traffic hazard.

Maintenance: Sediment should be cleaned out from behind check dams when 50% of the storage capacity has been filled with sediment. Particular attention must be given to check dam abutments and the downstream toe, as these areas are susceptible to erosion.

Runoff Mitigation and Management Practice 4.8: Dewatering Treatment

Dewatering structures are often needed when working in a stream on the construction of box culverts or deep footings.

Purpose and Application: Dewatering treatment practices treat water that is pumped from excavations into the treatment areas. Treatment can include filtering, chemical flocculation, or settling of sediments prior to discharging Stormwater. Dewatering treatment practices are typically necessary in conjunction with utility work and in-stream construction activities such as box culvert, pipe or bridge construction.

Description: Dewatering treatment practices are temporary practices that include manufactured and non-manufactured products. Where fine clay soils are present in Stormwater runoff, chemical treatment with flocculants may be necessary. These practices must be identified and sited during SWPPP preparation to ensure that there is room for the practice and that the practice can be maintained while in use.

Limitations: Problems with dewatering structures typically occur when the pump discharges a higher volume of water than the outlet structure can handle or when the structure is not maintained. Removal and disposal of geotextile bags can also cause problems if overfilled or located too close to a stream.

Maintenance: Ensure that the treatment practice is either cleaned out or removed once the storage is full. Visually verify that discharges from the treatment practices are not turbid. Filter bag removal method must be considered before relying on a filter bag for dewatering treatment.

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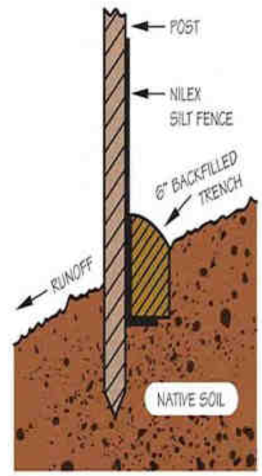
Section 5: Sediment Control

Sediment Control Practice 5.1:

Silt Fence



Definition: A temporary sediment control measure, composed of woven geotextile fabric supported by steel or wood posts, used to intercept sediment transported from areas where runoff occurs as sheet flow.

Purpose: To prevent sediment carried by sheet flow from leaving the site and entering natural drainage ways or storm drainage systems by slowing storm water runoff, causing ponding and the deposition of sediment at the structure.

Conditions Where Practice Applies: Silt fence may be used in a variety of locations including:

- at the toe of, or on, an exposed slope
- around the perimeter of an exposed construction site
- along the banks of ditches or swales
- around the perimeter of a soil stockpile
- around buffer areas

Silt fence shall not be installed across streams, ditches, waterways, or other concentrated flow areas.

Planning Considerations: Silt fence is a system to retain sediment on the construction site. The fence retains sediment primarily by retarding flow and promoting deposition. In operation, the geotextile silt fence material ponds runoff behind it, as the flow rate through the geotextile is often much lower than the flow rate of the runoff coming to the silt fence. Ponding behind the silt fence is necessary to encourage sediment settling. The designer should anticipate ponding and provide sufficient storage areas and overflow outlets to prevent flows from overtopping the fence. Since silt fence is not designed to withstand high water levels, locate them so that only shallow pools can form. Tie the ends of silt fence into higher ground to prevent flow around the end of the fence before the pool reaches design level. Silt fence should be curled uphill on each end of the fence in a "J" pattern to prevent end flow and scour. Provide stabilized outlets to protect the fence system and release storm flows that exceed the design storm. Deposition occurs as the storage pool forms behind the fence. The designer can direct flows to specified deposition areas through appropriate positioning of the fence or by providing an excavated area behind the fence. Plan deposition areas at accessible points to promote routine cleanout and maintenance. Silt fence serves no function along ridges or near drainage divides where there is little movement of water. Confining or diverting runoff unnecessarily with a sediment fence may create erosion and sedimentation problems that would not otherwise occur. Anchoring of silt fence is critical. The toe of the fabric must be anchored in a trench backfilled with compacted earth. Mechanical compaction must be provided in order for the fence to effectively pond runoff.

Design Criteria: Silt fence should be installed along the contour, never up or down a slope. This is essential to ensure that the fence will not accidentally concentrate Stormwater flows, thus creating worse erosion problems.
Silt fence can be installed without backing or with wire backing.

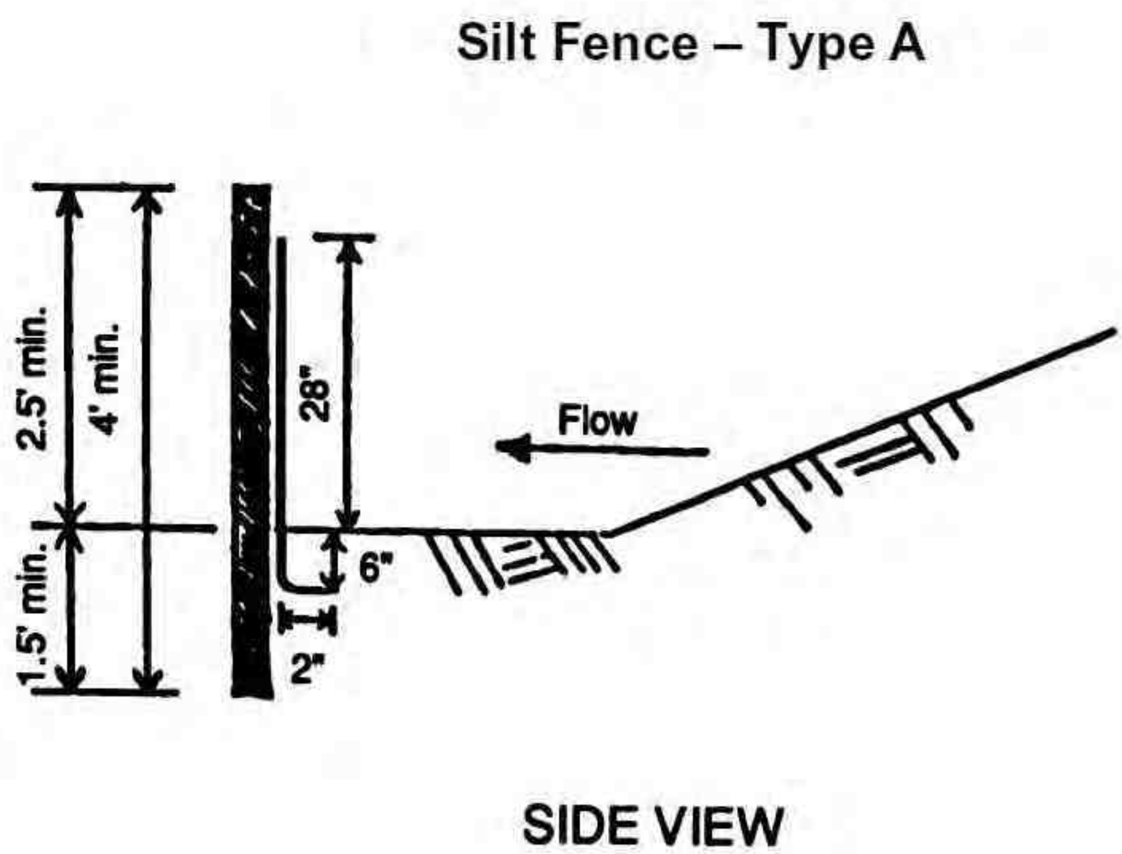
- The maximum drainage area for a continuous fence without backing shall be 1/4 acre per 100 linear feet of fence length, up to a maximum area of 2 acres. The maximum slope length behind the fence on the upslope side should be 110 feet (as measured along the ground surface).
- The maximum drainage area for a continuous silt fence with backing shall be 1 acre per 150 linear feet of fence length. The slope length above the silt fence with backing should be no more than 300 feet.

Silt fence should be installed so as to be as close as possible to the ground contour.
The bottom of the fence at the ground line should be on a 0% grade, plus or minus 0.5%.
When used at the bottom of a slope, silt fence should be installed 5 feet to 7 feet away from the toe to allow extra space for the ponding of water and collection of sediments.
The expected life span of the silt fence is 6 to 12 months. Therefore, projects of long duration may require a complete replacement of the silt fence. The quantity for silt fence to be in place for a long period of time should be based on the assumption that the material will be replaced every 9 months, on the average.

Type A Silt Fence: This fencing is 36-in wide filter fabric and is used on sites with a project life six months or greater and is designed to handle a flow rate of 25 Gal/Min/Sq. Ft.

Type B Silt Fence: This fencing is only 22-in wide but allows for the same flow rate as Type A silt fence. Type B silt fence should be limited to use on minor projects where permanent stabilization will be achieved in six months or less.

Type C Silt Fence: This type of fence is 36-in wide with wire reinforcement allowing it to handle almost three times the flow rate as Type A silt fence (70 Gal/Min/Sq. Ft.) This fence should be used for areas with particularly high runoff flows or velocities and where slopes exceed a vertical height of 10 feet. Type C silt fence requires steel posts with a minimum 4' length and a size of 1.3lb./ft. Type C Silt Fence should be used along stream buffers and other particularly sensitive areas



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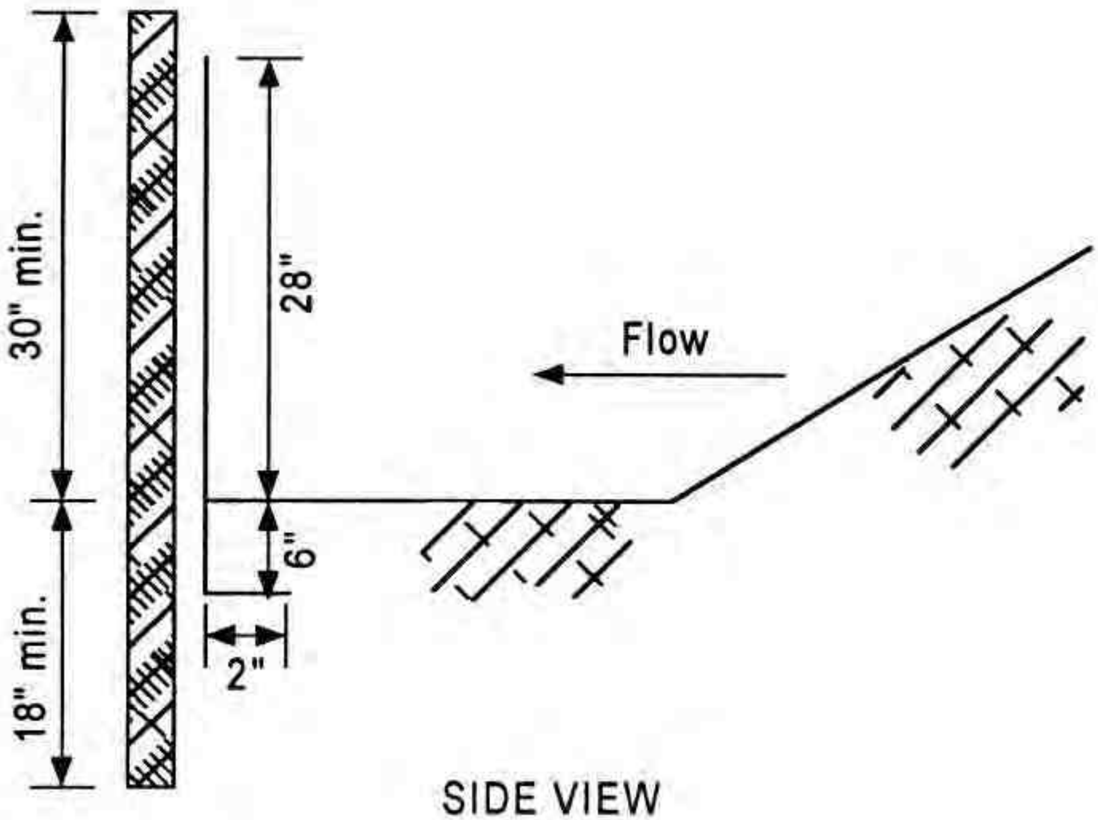
Silt Fence – Type C



Source: GA SWCC

Construction Specifications:

- Ensure that the height of the sediment fence does not exceed 24 inches above the ground surface. Ponding water depth should not exceed 1.5 feet. (Higher fences may impound volumes of water sufficient to cause failure of the structure.)
- Construct the filter fabric from a continuous roll cut to the length of the barrier to avoid joints. When joints are necessary, securely fasten the filter cloth only at a support post with 4 feet minimum overlap to the next post or roll the fabric together and fasten to one post to create a stronger joint.
- Where joints are necessary, plan the roll layout so as not to have joints at low points.
- Do not attach filter fabric to trees.

- When silt fence is installed adjacent to streams, wetlands and other natural resources, silt fence with backing should be used.
- Install posts no more than 6 feet apart.
- Install posts 2 feet deep on the downstream side of the silt fence, and as close as possible to the fabric, enabling posts to support the fabric from upstream water pressure.
- Securely attach the silt fence fabric to the posts on the upstream side of the posts. For steel posts, attach fabric to the posts using wire or plastic zip ties with a minimum 50 pound tensile strength, at least 5 to a post. Three ties should be installed in the upper 8 inches for top strength. Ties should be installed on the diagonal, as opposed to on the horizontal, to grab more strands. For hardwood posts, attach fabric with 17 gauge wire staples (3/4" wide x 1/2" long), at least 5 to a post. 3 staples should be installed in the upper 8 inches for top strength.
- Install J-hooks for confining the water behind the fence and maximizing the trapping efficiency.

Traditional silt fence trenching method for installation:

- Excavate a trench approximately 4 inches wide and 6 inches deep along the proposed line of posts and upslope from the barrier
- Place 10 inches of the fabric along the bottom and side of the trench. Backfill the trench with soil placed over the filter fabric and compact. Thorough compaction of the backfill is critical to silt fence performance. Poor compaction can cause failure of the silt fence along the toe.
- The base of both end posts should be at least one foot higher than the middle of the fence. Check with a level as necessary.

Slicing method for installation:

- A slicing machine can be used to install silt fence. This method of installation provides excellent compaction and joint integrity along the toe.
- Posts should be set a maximum of 6 feet apart.
- The geotextile fabric should be inserted in a slit in the soil 8-12 inches deep. The slit should be created such that a horizontal chisel point, at the base of a soil-slicing blade, slightly disrupts the soil upward as the blade slices through the soil. This upward disruption minimizes horizontal compaction and creates an optimal soil condition for mechanical compaction against the geotextile. The geotextile should be mechanically inserted directly behind the soil-slicing blade in a simultaneous operation, achieving consistent placement and depth. Turning over (plowing) of soil is not allowed for the slicing method.

Maintenance and Inspection Points:

1. Remove sediment once it has accumulated to ½ the original height of the barrier.
2. Replace filter fabric whenever it is worn or has deteriorated to such an extent so that the effectiveness of the fabric is reduced.
3. All sediment accumulated at the fence should be removed and properly disposed of before the fence is removed.
4. Repair sagging silt fence to prevent failure or overtopping.
5. Monitor the toe for evidence of piping or erosion along the toe. Install J-hooks wherever runoff flows along the toe of the fencing to prevent undermining.

Silt fence should remain in place until disturbed areas have been permanently stabilized.

Sediment Control Practice 5.2: Inlet Protection


Definition: A temporary protective device formed around a storm drain drop inlet to trap sediment.

Purpose: To prevent sediment from entering the storm drainage system, prior to temporary or permanent stabilization of the disturbed area.

Conditions Where Practice Applies: Many different types of inlet protection devices are available. The types highlighted in this section are non-manufactured. Manufactured inlet protection devices are allowable alternatives, provided the following:

- At least 3600 ft3/acre of drainage is available to store sediment.
- No more than 1 acre of drainage to each measure - 0.5 acre drainage area per each measure is preferable.
- An overflow is provided to safely pass storm events larger than the 5-yr storm.

Non-manufactured inlet protection devices:

- Excavated Drop Inlet Protection is applicable where relatively heavy flows are expected and overflow capability is needed.
- Hardware Cloth and Gravel Inlet Protection is applicable where the flow is light to moderate. This method is effective where the inlet is expected to drain shallow

sheet flow. The immediate land area around the inlet should be relatively flat (less than 1 percent) and located so that accumulated sediment can be easily removed.

- Block and Gravel Inlet Protection is applicable to both drop inlets and curb inlets where heavy flows are expected, and an overflow capacity is necessary to prevent excessive ponding around the structure. Shallow temporary flooding after rainfall however, should be expected.
- Sod Drop Inlet Protection is applicable where the drainage area of the drop inlet has been permanently seeded and mulched, and the immediate surrounding area is to remain in dense vegetation. This practice is well suited for lawns adjacent to large buildings.
- Rock Ring Inlet Protection is applicable at drop inlets with large drainage areas or at drop inlets that receive high velocity water flows, possibly from many directions.
- Rock Pipe Inlet Protection is applicable at pipes with a maximum diameter of 36 inches. This inlet protection may be used to supplement additional sediment traps or basins at the pipe outlet, or used in combination with an excavated sediment storage area to serve as a temporary sediment trap.

Planning Considerations: Inlet protection should be installed at or around all storm drain drop inlets that receive runoff from disturbed areas. Inlet protection should not be used in streams or other natural water resources. It should also not be placed in ditches, swales or other depressions with a depth greater than 1 foot. Due to the high maintenance requirements, inlet protection should be considered *secondary* sediment controls and not primary sediment controls. These measures should be used in conjunction with other erosion prevention and sediment control measures to be effective.

Exercise installation caution so that Stormwater runoff cannot back up out adjacent traffic lanes.

Design Criteria:

<u>Excavated Drop Inlet Protection</u>:

- Limit the drainage area to 1 acre. Keep the minimum depth at 1 foot and the maximum depth of 2 feet as measured from the crest of the inlet structure.
- Maintain side slopes around the excavation no steeper than 2:1
- Keep the minimum volume of excavated area around the drop inlet at approximately 3600 ft3/acre of drainage.
- Shape the sediment storage area to fit site conditions, with the longest dimension oriented toward the longest inflow area to provide maximum trap efficiency.
- Install provisions for draining the temporary pool to improve trapping efficiency for small storms and to avoid problems from standing water after heavy rains.
- Ensure that drainage area does not exceed 1 acre per inlet.

- Secure the wire mesh hardware cloth barriers using steel T posts. The posts need to be 1.25 lb/linear ft steel with a minimum length of 5 feet. Make sure the posts have projections to facilitate fastening the hardware cloth. Securely drive each stake into the ground to a minimum depth of 2 feet. The maximum spacing for the posts is 4 feet.
- The wire mesh should be at least a 19-gauge hardware cloth with a ¼ inch mesh opening. The total height should be a minimum of 2 feet. Providing a flap of hardware cloth on the ground projecting away from the inlet can aid in removal of the stone at the project's completion. Place #57 washed stone to a height of 16 inches on the upstream face of the cloth with an outside slope of 2:1.
- The top elevation of the structure must be at least 12 inches lower than the ground elevation downslope from the inlet. It is important that all storm flows pass over the structure into the storm drain and not bypass the structure.
- Temporary dikes below the structure may be necessary to prevent bypass flow.

Block and Gravel Inlet Protection:

- Keep the drainage area no greater than 1 acre unless site conditions allow for frequent removal and adequate disposal of accumulated sediment.
- Keep the height of the barrier at least 12 inches and no greater than 24 inches. Do not use mortar. Limit the height to prevent excess ponding and bypass flow.
- Recess the first course of blocks at least 2 inches below the crest opening of the storm drain for lateral support. Support subsequent courses laterally if needed by placing a 2 x 4-inch wood stud through the block openings that are perpendicular to the block course needing support. Lay some blocks on their side in the bottom row for dewatering the pool.
- Place gravel just below the top of the blocks on slopes of 2:1 or flatter. Place hardware cloth or comparable wire mesh with 1/2-inch openings over all block openings to hold gravel in place.

Sod Drop Inlet Protection:

- Keep velocity of design flow over the sod area at all points less than 5 ft/sec.
- Place sod to form a turf mat completely covering the soil surface for a minimum distance of 4 feet from each side of the drop inlet where runoff will enter.
- Maintain the slope of the sodded area no greater than 4:1.
- Keep the drainage area no greater than 1 acre; maintain this area undisturbed or stabilize it.

Rock Ring Inlet Protection:

- Place measure at least 30 feet away from vehicular traffic. This inlet protection can be modified to protect one side of the inlet if only one side receives flow.
- Stone – A minimum 1-foot wide level area set 4 inches below the drop inlet crest will add protection against the entrance of material. Structural stone should be Class A-1 riprap with 2:1 side slope, and a minimum crest width of 18 inches. The height of the stone should be from 2 to 3.5 feet. The outside face of the riprap

should be covered in a 12-inch thick layer of #5 or #57 washed stone. Wire mesh with 2-inch openings may be placed over the drain grating but must be inspected frequently to avoid blockage by trash.
- The top elevation of the stone structure must be at least 12 inches lower than the ground elevation downslope from the inlet. It is important that all Stormwater flow over the structure into the storm drain, and not past the structure. Temporary diking below the structure may be necessary to prevent bypass flow. Material may be excavated from inside the sediment pool for this purpose.

Rock Pipe Inlet Protection:
- When used in combination with an excavated sediment storage area to serve as a temporary sediment trap, the design criteria for temporary sediment traps must be satisfied. The maximum drainage area should be 5 acres, and
- 3600 cubic feet of sediment storage per acre of drainage area should be provided.
- The minimum stone height should be 2 feet, with side slopes no steeper than 2:1. The stone "horseshoe" around the pipe inlet should be constructed of Class A-1 or Class B riprap, with a minimum crest width of 3 feet. The outside face of the riprap should be coved with a 12-inch thick layer of #57 washed stone.
- In preparing plans for rock pipe inlet protection, it is important to protect the embankment over the pipe from overtopping. The top of the stone should be a minimum of 1 foot below the top of the fill over the pipe. The stone should tie into the fill on both sides of the pipe. The inside toe of the stone should be no closer than 2 feet from the culvert opening to allow passage of high flows.
- The sediment storage area should be excavated upstream of the rock pipe inlet protection, with a minimum depth of 18 inches below grade.

Construction Specifications:

Excavated Drop Inlet Protection:
- Clear the area of all debris that might hinder excavation and disposal of spoil.
- Grade the approach to the inlet uniformly.
- Protect weep holes by gravel.
- When the contributing drainage area has been permanently stabilized, seal weep holes, fill the basin with stable soil to final grading elevations, compact it properly, and stabilize.

Hardware Cloth and Gravel Inlet Protection:
- Uniformly grade a shallow depression approaching the inlet.
- Drive 5-foot steel posts 2 feet into the ground surrounding the inlet. Space posts evenly around the perimeter of the inlet, a maximum of 4 feet apart.

- Surround the posts with wire mesh hardware cloth. Secure the wire mesh to the steel posts at the top, middle, and bottom. Placing a 2-foot flap of the wire mesh under the gravel for anchoring is recommended.
- Place clean gravel (#57 stone) on a 2:1 slope with a height of 16 inches around the wire, and smooth to an even grade.
- Once the contributing drainage area has been stabilized, remove accumulated sediment, and establish final grading elevations.
- Compact the area properly and stabilize it with groundcover.

Block and Gravel Drop Inlet Protection:

- Lay one block on each side of the structure on its side in the bottom row to allow pool drainage. The foundation should be excavated at least 2 inches below the crest of the storm drain. Place the bottom row of blocks against the edge of the storm drain for lateral support and to avoid washouts when overflow occurs. If needed, give lateral support to subsequent rows by placing 2 x 4 wood studs through block openings.
- Carefully fit hardware cloth or comparable wire mesh with ½-inch openings over all block openings to hold gravel in place.
- Use clean gravel, ½- to ¾-inch in diameter, placed 2 inches below the top of the block on a 2:1 slope or flatter and smooth it to an even grade. #57 washed stone is recommended.
- If only stone and gravel are used, keep the slope toward the inlet no steeper than 3:1. Leave a minimum 1-foot wide level stone area between the structure and around the inlet to prevent gravel from entering inlet. On the slope toward the inlet, use stone 3 inches in diameter or larger. On the slope away from the inlet use ½ to ¾-inch gravel (#57 washed stone) at a minimum thickness of 1 foot.

Sod Drop Inlet Protection:

- Bring the area to be sodded to final grade elevation with top soil. Add fertilizer and lime, if necessary.
- Lay all sod strips perpendicular to the direction of flows.
- Keep the width of the sod at least 4 feet in the direction of flows.
- Stagger sod strips so that adjacent strip ends are not aligned.

Rock Doughnut Inlet Protection:

- Clear the area of all debris that might hinder excavation and disposal of spoil.
- Grade shallow depression uniformly towards the inlet with side slopes no greater than 2:1. Grade a 1 foot wide level area set 4 inches below the area adjacent to the inlet.
- Install the Class A-1 or Class B riprap in a circle around the inlet. The minimum crest width of the riprap should be 18 inches, with a minimum bottom width of 7.5 feet. The minimum height of the stone is 2 feet.
- The outside face of the riprap is then lined with 12 inches of #57 washed stone.

Rock Pipe Inlet Protection:

- Clear the area of all debris that might hinder excavation and disposal of spoil.
- Install the Class A-1 or Class B riprap in a semi-circle around the pipe inlet. The stone should be built up higher on each end where it ties into the embankment. The minimum crest width of the riprap should be 3 feet, with a minimum bottom width of 11 feet. The minimum height should be 2 feet, but also 1 foot lower than the shoulder of the embankment or diversions.
- A 1 foot thick layer of #5 or #57 stone should be placed on the outside slope of the riprap.
- The sediment storage area should be excavated around the outside of the stone horseshoe 18 inches below natural grade.
- When the contributing drainage area has been stabilized, fill depression and establish final grading elevations, compact area properly, and stabilize with ground cover.

Maintenance and Inspection Points: Sediment should not be allowed to wash into the inlet. It should be removed from the inlet protection and disposed of and stabilized so that it will not enter the inlet again. Remove sediment from the deposition areas when half the height of the storage area has been filled.
Check measure for damage or evidence of erosion and bypassing around the inlet protection. If inlets are in series, runoff that bypasses an upgradient inlet can overwhelm a downgradient inlet protection device. Sand bags, erosion eels, diversions, or other methods should be used to direct runoff into storm drain inlets. When the contributing drainage area has been permanently stabilized, all materials and any sediment should be removed, and either salvaged or disposed of properly. The disturbed area should be brought to proper grade, then smoothed and compacted. Appropriately stabilize all disturbed areas around the inlet.

Sediment Control Practice 5.3: Sediment Basin

A slotted drain pipe has been installed to dewater this basin. Note that discharge doesn't occur from this basin until the water level in the storage area reaches the bottom of the slotted drain pipe.

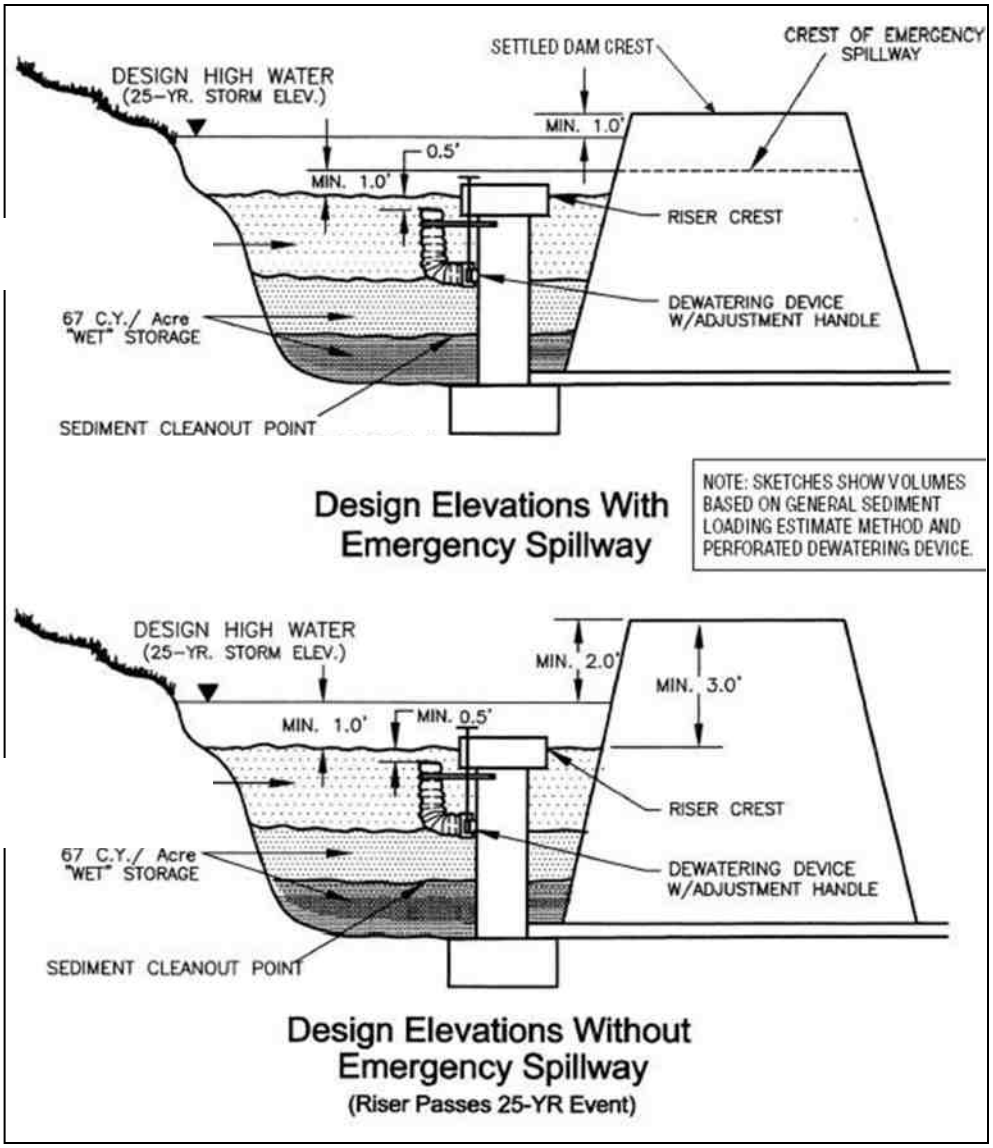
Purpose and Application: Sediment basins are temporary engineered structures designed to capture sediment from construction site Stormwater runoff prior to being discharged.

Description: Sediment basins contain the following components: an embankment, a sediment storage area, a permanent pool, a sediment forebay, a principal and emergency spillway system, outlet protection at the outlet of the spillway barrel, and a dewatering mechanism. Sediment basins are constructed by building a low earthen dam across a drainageway, by excavating a storage area, or by a combination of both to form the sediment storage pool. A properly designed spillway outlet system with adequate freeboard is essential. The embankment should be well compacted and vegetated. A permanent pool of water is required to provide better settling efficiency, and dewatering from the top of the basin pool is required to also aid in settling efficiency.

UT Requirements: For an outfall in a drainage area of a total of 5 or more acres, a temporary sediment basin (or equivalent controls) is required that provides storage and a spillway system for controlling runoff from a 5 year, 24 hour storm for each acre drained. A permanent pool must be designed into the sediment storage zone. In addition, a sediment forebay is required to aid in maintenance. Discharges from sediment basins cannot cause an objectionable color contrast with the receiving stream.

Limitations: Sediment basins must be designed by an engineer or landscape architect. Basins typically require large areas for adequate settling, as the crucial design component for basins is available sediment storage zone surface area. A 4:1 length to width ratio is required.

Maintenance: Ease of basin cleanout and spoil disposal must be considered in site selection. The forebay decreases the frequency of dredging or cleaning out the sediment storage area in the basin.



Schematic drawing of a typical sediment basin.

Sediment Control Practice 5.4: Sediment Trap

Definition: A sediment trap is a temporary sediment storage area with a permanent pool, formed by an embankment or excavation, or combination. Sediment traps will contain a spillway, and often also have porous baffles. Sediment traps should be constructed as a first step in any land disturbing activity, often in conjunction with diversions and other temporary measures. Geotextile fabric is installed at the interface of the rock spillway and soil.

Purpose: To detain sediment-laden runoff from small, disturbed areas, allowing larger sediment particles to settle out of runoff. Sediment traps are temporary ponding areas formed by excavating a sediment storage area and constructing an earthen embankment with a simple rip rap spillway. They serve small drainage areas.

Conditions Where Practice Applies: The sediment trap may be constructed either independently or in conjunction with a diversion. Sediment should be periodically removed from the trap to maintain the required volume. The SWPPP should detail how excavated sediment is to be disposed of, such as by use in fill areas on site or removal to an approved off-site location.

This practice is applicable for use in applications such as:

- At the outlets of diversions, channels, slope drains, or other runoff conveyances that discharge sediment-laden runoff.
- Below areas that are draining < 5 acres.
- Where access can be maintained for sediment removal and proper disposal.

- In the approach to a Stormwater inlet location below a disturbed area as part of an inlet protection system.

Sediment traps are not to be located in a stream.

Construction Specifications: Traps should be installed in the first stages of project development before any land disturbance activity upslope takes place.
Select locations for sediment traps during site evaluation. Note natural drainage divides and select trap sites so that runoff from potential sediment producing areas can easily be diverted into traps. Diversion berms and ditches should be installed to direct runoff into traps as needed. Ensure the drainage areas for each trap does not exceed 5 acres.

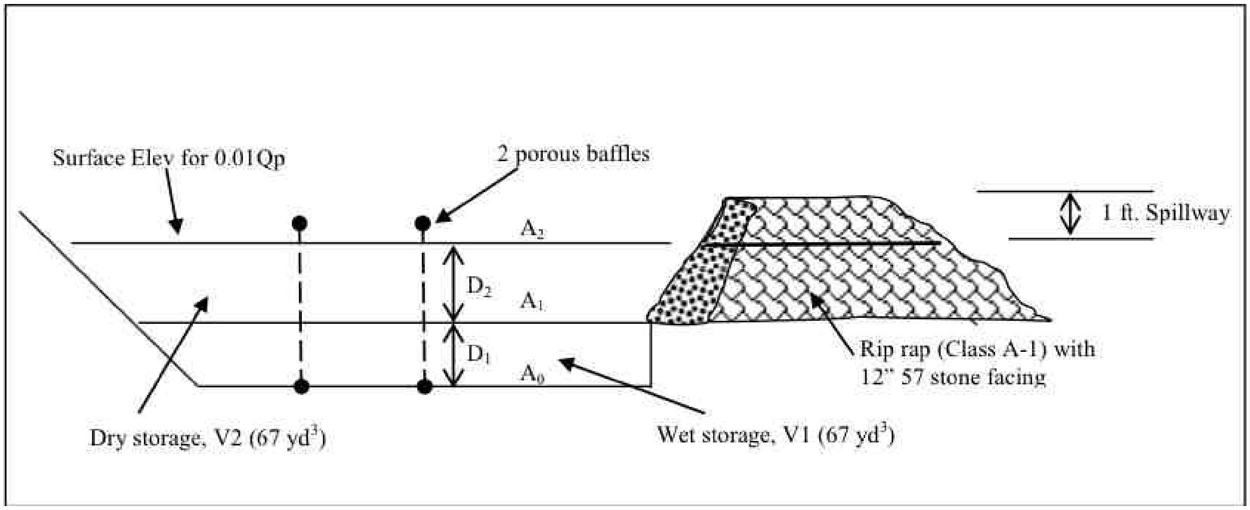
Storage Capacity: The trap shall have an initial storage volume of 3618 cubic feet (134 cubic yards) per acre of drainage area. The required storage volume may also be determined by modeling soil loss using RUSLE or other approved methods. Half of the storage volume must be in the form of a permanent pool or wet storage to provide better settling efficiency. To provide the wet storage area, the sediment storage zone will have to be over excavated below the surrounding ground elevation. The other half of the sediment storage is in the form of a draw down or dry storage that provides extended settling time during storm events. The volume of the wet storage area is measured from the low point of the excavated area to the base of the outlet structure. The volume for dry storage is measured from the base of the outlet to the crest of the outlet overflow.

Trap efficiency: The following design elements must be provided for adequate trapping efficiency:

- Provide a surface area of 0.01 acres (435 square feet) per cfs based on the 2-year or 5-year storm
- Convey runoff into the trap through stable diversions or temporary slope drains
- Locate sediment inflow to the trap away from the outlet to prevent short circuiting from the inlet to the outlet
- Provide at least 2 porous baffles
- The sediment storage area should have a length to width ratio of 3:1, measured from the point of maximum runoff introduction to outlet. Settling efficiency is improved with longer flow paths and residence time in the sediment storage zone

Spillway: The spillway is constructed of rip rap and smaller graded; clean stone such as #57 stone. Geotextile fabric must be placed between the rip rap and soil to prevent piping and erosion of the spillway. A four (4) foot minimum weir width must be provided. The weir section of the spillway must be designed to pass the 2-year or the 5-year storm event, based upon the total drainage area.

Sediment Trap Embankment:



The embankment should be no taller than five (5) feet. Side slopes must be 2:1 or flatter and stabilized as soon as construction on the trap has been completed. Keep the crest of the spillway outlet 1.5 feet below the settled top of the embankment. Embankments must have a minimum top width of 5 feet.

Maintenance and Inspection Points:

- Sediment traps must be maintained and function as designed until all areas draining to the trap have been stabilized.
- The structure should be checked regularly to ensure that it is structurally sound and has not been damaged by erosion or construction equipment. The height of the stone outlet should be checked to ensure that its center is at least 1 foot below the top of the embankment.
- Any rip rap displaced from the spillway must be replaced immediately.
- Filter stone should be checked to ensure that filtration performance is maintained.
- Replace stone caked with sediment.
- Sediment shall be removed when it has accumulated to one half the design volume of the wet storage. Sediment removed from the trap should be deposited in an area up gradient from the sediment trap and other measures and stabilized or removed from the site. Do not place removed sediment below sediment controls.
- Once the areas draining to the sediment trap have been stabilized, remove the stone and rip rap spillway and backfill the sediment storage area. Stabilize the area.

Sediment Control Practice 5.5: Tire Washing Facility

Where tire washing facilities are installed, particular attention should be given to runoff management to prevent sediment from being discharged from the site.

Purpose and Application: Tire washing facilities should be used where rock construction exits do not provide adequate protection from tracking sediment and mud off the construction sites. Sites with high clay content soils may benefit from tire washing facilities. Long term construction projects may also benefit from tire washing facilities.

Description: Several different types of tire washing facilities can be constructed based upon the project longevity and the desire for an active or passive washing facility. Washing facilities can simply be a cattle guard design coupled with a water source and hose with sprayer or more robust such as a pre-fabricated tire washing facility. The washing facility must have provisions for intercepting and treating the sediment laden wash water and directing it into a deposition area.

Limitations: If using this practice, an adequate source of water must be provided. In addition, the dirty water generated by the washing activity must be directed to a sediment basin or trap to be treated before being discharged. Stormwater runoff and process water handling around the tire washing facility must be adequately addressed in the SWPPP and throughout the life of construction to avoid traffic hazards and the discharge of untreated process water.

Maintenance: When visual inspections note sediment deposition in the wash water treatment practices, sediment must be removed and properly disposed. Sediment tracked off the construction project must be cleaned up before the next rain event or by the close of regular business hours, whichever is shorter.

Sediment Control Practice 5.6: Construction Exit

Rock construction exits should be installed at each location that construction traffic leaves the construction project.

Purpose and Application: Construction exits are temporary sediment control devices installed where ever construction traffic leaves an active construction site. Most often, construction exits are constructed of clean stone. However, several manufactured construction exits are available that do not include stone.

Description: Construction exits reduce or eliminate the transport of sediment from the construction site onto a public right of way. Rock construction exits should be constructed with 2"-3" sized clean stone, installed at least 6" deep. The rock exit should be constructed to be a minimum of 50' in length. A geotextile underliner must be installed under the rock to prevent sediment from piping up through the rock from the underlying soil surface. In addition, the geotextile fabric underliner makes maintenance of construction exists easier. The rock construction entrance should extend the full width of the entrance area. Avoid entrances on steep grades or at curves in public roads. Stormwater must be properly managed around the construction exit to prevent washing sediment off the construction exit. In situations where a properly installed and maintained construction exit does not adequately clean tires before leaving the construction site, especially in cases where a 50' exit length is not practical, efforts must be made to remove sediment on tires before the equipment leaves the site.

Limitations: Soils that contain a high percentage of clay may require a more robust tire washing facility.

Maintenance: When visual inspections note an excessive buildup of sediment on the construction exit, the sediment and rock should be removed and replaced with clean stone. Sediment tracked off the construction project must be cleaned up before the next rain event or by the close of regular business hours, whichever is shorter.

Sediment Control Practice 5.7: Construction Road Stabilization

Definition: The stabilization of temporary construction access routes, on-site vehicle transportation routes, and construction parking areas.

Purpose: To provide a stabilized surface for construction traffic, and to reduce erosion and subsequent re-grading of permanent roadbeds between the time of initial grading and final stabilization.

Conditions Where Practice Applies: This practice is applicable where travel ways are needed in a planned land use area or wherever stone-base roads or parking areas are constructed, whether permanent or temporary, for use by construction traffic.

Planning Considerations: Improperly planned and maintained construction roads can become a continual erosion problem. Excess runoff from roads causes erosion in adjacent areas and an un-stabilized road may become a dust problem. Construction vehicle routes are especially susceptible to erosion because they become compacted, and collect and convey runoff water along their surfaces. Rills, gullies, and troublesome muddy areas form unless the road is stabilized. During wet weather un-stabilized dirt roads may become so muddy they are virtually unusable, generating sediment and causing work interruption. Proper grading and stabilization of construction routes often saves money for the contractor by improving the overall efficiency of the construction operation while reducing the erosion problem. Situate construction roads to reduce erosion potential, following the natural contour of slopes, wet or rocky areas, and highly erosive soils.

Controlling surface runoff from the road surface and adjoining areas is a key erosion control consideration. Generally locate construction roads in areas where seasonally high water tables are deeper than 18 inches. Otherwise, subsurface drainage may be necessary.

When practical, install permanent paved roads and parking areas and use them for construction traffic early during the construction operation to minimize site disruption.

Design Criteria Location: Temporary roads should be located to serve the purpose intended; facilitate the control and disposal of water; control or reduce erosion; and make the best use of topographic features. Temporary parking areas should be located on naturally flat areas to minimize grading.

Temporary roads should follow the contour of the natural terrain to minimize disturbance of drainage patterns. If a temporary road must cross a stream, the crossing must be designed, installed, and maintained according to specification.

Grade and Alignment: The gradient and vertical and horizontal alignment should be adapted to the intensity of use, mode of travel, and level of development. Grades for temporary roads should not exceed ten percent except for very short lengths (200 feet or less), but maximum grades of 20 percent or more may be used if necessary for special uses. Frequent grade changes generally cause fewer erosion problems than long continuous gradients. Grades for temporary parking areas should be sufficient to provide drainage but should not exceed four percent. Curves and switchbacks must be of sufficient radius for trucks and other large vehicles to negotiate easily. On temporary roads, the radius should be no less than 35 feet for standard vehicles and 50 feet for tractor trailers.

Width: Temporary roadbeds should be at least 14 feet wide for one-way traffic and 20 feet wide for two-way traffic. The width for two-way traffic should be increased approximately four feet for trailer traffic. A minimum shoulder width should be two feet on each side. Where turnouts are used, road width should be increased to a minimum of 20 feet for a distance of 30 feet.

Side Slopes: All cuts and/or fills should have side slopes designed to be stable for the particular site conditions and soil materials involved. All cuts and/or fills should be 2:1 or less, to the extent possible. When maintenance by machine mowing is planned, side slopes should be no steeper than 3:1.

Drainage: The type of drainage structure used will depend on the type of activity and runoff conditions. The capacity and design should be consistent with sound engineering principles and should be adequate for the class of vehicle, type of road, development, or use. Structures should be designed to withstand flows from a 25- year, 24-hour frequency storm. Ditches should be designed to be on stable grades and/or protected with structures or linings for stability.

Stabilization: A 6-inch layer of coarse aggregate, such as TDOT #57, should be applied immediately after grading or the completion of utility installation within the right-of-way. In areas experiencing heavy traffic, stone should be placed at an 8 to 10 inch depth to avoid excessive dissipation or maintenance needs.

Geotextile: Geotextile should be applied beneath the stone for additional stability. All roadside ditches, cuts, fills, and disturbed areas adjacent to parking areas and roads should be stabilized with appropriate temporary or permanent seeding or with rock armoring.

Permanent Roads and Parking Areas: Permanent roads and parking areas should be designed and constructed according to criteria established by the University. Permanent roads and parking areas should be stabilized in accordance with this specification, applying an initial base course of gravel immediately following grading.

Construction Specifications:

- Trees, stumps, brush, roots, weeds, and other objectionable material should be removed from the work area.
- Unsuitable material should be removed from the roadbed and parking areas.
- Ensure that road construction follows the natural contours of the terrain if possible.
- Locate parking areas on naturally flat areas, if they are available. Keep grades sufficient for drainage, but generally not more than 2 to 3 percent.
- Grading, subgrade preparation, and compaction should be done as needed. Fill material should be deposited in layers not to exceed 9 inches and compacted with the controlled movement of compacting and earth moving equipment.
- Provide surface drainage, and divert excess runoff to stable areas by using water bars or turnouts.
- Keep cuts and fills at 2:1 or flatter for safety and stability and to facilitate the establishment of vegetation and maintenance.
- Spread, at minimum, a 6 inch course of TDOT #57 stone evenly over the full width of the road and smooth to avoid depressions.
- Where seepage areas or seasonally wet areas must be crossed, install subsurface drains or geotextiles fabric cloth before placing the crushed stone.
- Vegetate all roadside ditches, cuts, and fills, and other disturbed areas or otherwise appropriate stabilization as soon as grading in complete.
- Structures such as culverts, pipe drops, or bridges should be installed to the lines and grades shown on the plans or as staked in the field. Culverts should be placed on a firm foundation. Selected backfill material should be placed around the

culvert in layers not to exceed 6 inches. Each layer should be properly compacted.

Maintenance and Inspection Points:

- Add top dressing of stone to roads and parking areas to maintain a gravel depth of 6 inches.
- Remove any silt or other debris causing clogging of roadside ditches or other drainage structures.
- Treat sediment-producing areas immediately.

Sediment Control Practice 5.8: Filter Berm

Definition: Filter berms are a linear sediment trapping measure composed either of wood chips (mulch) or a 50/50 combination of wood chips and compost material.

Purpose: To reduce runoff flow velocities so that eroded sediments can be settled upstream of the filter, and to act as a filter as runoff passes through the materials in the berm.

Conditions Where Practice Applies: Filter berms may be applied on any slope along the contour where runoff can be expected to be in the form of sheet flow. Usually, this will be on slopes less than 300 feet in length or at the toe of a given slope. Filter berms may also be used where silt fence would not be feasible due to exposed rock or other conditions which would prevent the fence from being trenched in. However, care should be taken in locating filter berms, as mulch material is easily floated away in runoff. Mulch berms are most appropriate treating very small drainage areas.

Planning Considerations:

- This measure consists of un-compacted buoyant materials and tends to be moved by concentrated flows. Thus, filter berms should be used only where sheet flow conditions are expected. They cannot treat flows in gullies, ditches, or channels. Mulch berms may require the addition of structural components, such as silt fence or wattles, to prevent movement of mulch.
- Design Criteria: Detailed design of this measure is not required; however, when filter berms are specified, the following standards should be used.
- Wood chips can be produced on-site as a byproduct of site clearing activities. The choice of measure (mulch berm, compost berm, etc.) to be applied at a given site should be based on the availability and relative costs of the required materials.

- The filter berm shall be at least 1.5' in height and 3' wide at the base.
- The drainage area upstream of a filter berm should be less than ¼ acre per 100 linear feet of berm. On long slopes where this limit would be exceeded, structural components, such as silt fence and wattles, should be installed on the upgradient side of the filter berm. The fence or wattle will prevent excessive hydraulic forces from displacing the material in the berm, while the filter berm provides increased filtration of runoff passing through the fence.
- Both ends of a run of filter berm should be turned up-slope to a point where the base of the berm at the terminus points will be higher than the top of the berm anywhere along the contour.
- The material used to construct a filter berm should be well-graded. Usually, the particles in a berm will range in size from ¼ inch to 6 inches in length. The smaller particles serve to increase the effectiveness of the measure as a filter while the larger particles help to increase its stability under the pressure exerted by the runoff.

Construction Specifications:

- Filter berms should be trapezoidal in shape and installed along the contour by means of pneumatic blowers or by other suitable equipment. It is important that a berm be placed along the ground contour as they will be sensitive to failure due to concentration of flows. Runoff must be intercepted on the contour to insure that sheet flow is not converted into concentrated flow. When placed at the base of a slope, the berm should be located at least 10 feet away from the toe in order to provide an area for the storage of sediments. As a general rule, steeper slopes would require a larger berm size. In addition, the bottom width of a berm should be about twice its height.
- The material in a mulch filter berm usually will not support vegetation; therefore, these berms should not be seeded with either temporary or permanent seed. A compost filter berm will support vegetation if the material is properly graded and the portion of compost is 65% or less. Compost materials with greater percentages of organic matter usually contain more nutrients than required by the seeded grasses.
- A compost filter berm which has been seeded can be left in place as a permanent feature as long as the structure is stable against erosion and movement from water.

Maintenance and Inspection Points: Routinely inspect filter berms and maintain to a functional condition throughout construction. Install additional filter material if necessary. Upon project completion, disperse or remove the berm.
Remove sediment from behind the filter berm when it has accumulated to ½ the original height of the structure.

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Sediment Control Practice 5.9: Filter Ring

Filter rings should be part of an overall system of BMPs. The filter ring pictured is providing sediment control while the mulch is providing erosion control.

Purpose and Application: Filter rings are temporary sediment control structures constructed of rip rap and installed at the entrance to storm drains and culverts. To enhance filtering, washed 57 stone is placed on the upstream face of the filter ring.

Description: Filter rings include a rock berm and sediment storage area. These should be installed at the entrances to storm drains to prevent sediment from entering, accumulating in and being transferred through the culvert or storm drain system. Filter rings are installed with a sediment storage area on the upstream side of the filter ring to aid in sediment deposition. Geotextile fabric is installed at the interface between the rock and soil to prevent piping under the structure.

Limitations: These practices are used at storm drain inlets with large drainage areas or at drop inlets that receive high velocity water flows, possibly from multiple directions. Sediment is captured in an excavated depression surrounding the inlet. When drainage area exceeds 1 acre, additional measures are necessary. This practice must not divert water away from the storm drain.

Maintenance: Sediment deposits must be cleaned out when half the storage capacity of the sediment deposition area has been filled. **It is important that all Stormwater flows through the structure into the storm drain, and not past the structure.** Temporary diking below the structure may be necessary to prevent bypass flow.

Sediment Control Practice 5.10: Turbidity Curtain

Definition: An in-stream sediment control measure designed to trap or filter sediment without impeding the movement of the water itself. This device consists of a filter fabric curtain suspended from floats and held vertically in the water by means of a bottom ballast chain.

Purpose: To provide an isolated work zone where sediments generated by the project can settle. By allowing additional settling time, it prevents the migration of these sediments into the larger remaining water body.

Conditions Where Practice Applies: Floating turbidity curtains may be applied adjacent to the shoreline of a river or lake to contain sediments which may be carried into the water by construction site runoff. They should be considered only where adequate or conventional on-shore sediment control measures are not feasible or possible. They may also be used to surround a work site within the channel of a river (i.e. bridge pier construction, dredging or filling) or within a larger water body in order to prevent worksite sediments from being dispersed.

Planning Considerations: Any work in a stream, river or lake requires permitted approval by TDEC and the Army Corps of Engineers. To minimize the impact to the resource, the in-stream construction period should be minimized and should be conducted during periods of low flow.

- Turbidity curtains should not be applied where the anticipated flow velocities will exceed 5 ft/sec. In addition, turbidity curtains are not designed as prefabricated dams; and therefore, should not be used across high velocity streams.
- In ponds and lakes, large changes in stage can cause the curtain to become submerged or to be damaged. This measure is best applied in situations or during periods of time when anticipated changes in the water surface elevation will be minimal. Also, wave action from boats or wind can significantly reduce the effectiveness of a floating turbidity curtain.

Design Criteria: A floating turbidity curtain consists of a geotextile filter cloth with sufficient permeability to allow flow to pass through while retaining sediments. The cloth is suspended from floats which are anchored into place to maintain the shape and location of the barrier. A ballast chain is included in a pocket at the bottom of the curtain to help hold the cloth in a vertical position and to provide tensile strength when the material is stressed.

The curtain is formed by joining segments of geotextile fabric which are 50 to 100 feet long, and an anchor (consisting of two weights, cables and floats) should be placed at each joint in the fabric. Additional anchors may be utilized, depending upon the anticipated flow velocities or wave action, based on manufacturer recommendations. At a minimum, each end of the curtain should be provided with an on-shore anchor and two anchors would be required in the water.

The designer should consider the morphology of the river in evaluating the anticipated flow velocities at a proposed turbidity curtain site. Where a river runs a straight course, flow velocities adjacent to shore are usually much lower than the velocities in the center of the channel. On the other hand, flow velocities can be very high on the outside of a bend in the river. The measure should not be applied where the anticipated flow velocities will exceed 5 ft/sec.

Proper consideration should be given to safety measures at locations where boat traffic may be present. Usually, this is addressed by providing floats with a bright yellow or orange color and by providing lighted marker buoys for night time use.

The Army Corps of Engineers, TVA, or other regulating agency may require the use of lighted buoys on navigable waterways.

Construction Specifications:

- The floating turbidity curtain **must not** be installed perpendicular across the main flow of a significant body of moving water.
- When applied in a river, a floating turbidity curtain should be installed parallel to the shore such that it would not intercept the main force of the current.

- The turbidity curtain must be anchored to prevent drift shoreward or downstream.
- Anchorage should be installed on both shore and stream side. The curtain should be located as close as possible to the project, while allowing sufficient room for any equipment which must work in or near the water.
- The bottom of the curtain should be approximately 12 inches above the bottom of the lake or river to prevent the bottom of the curtain from being buried by retained sediments, and in turn, reduce the quantity of sediment released into the water when the curtain is removed.
- In situations where significant wave action is anticipated, either as the result of wind or boat traffic, the depth of the curtain should be no greater than 12 feet. This will prevent stresses in the fabric from becoming excessive as it billows with the force of the waves.
- In shallow water (2 feet in depth of less) a turbidity curtain may be installed on stakes driven into the bed of the water body.
- When installed in a navigable waterway, buoys should be lit according to regulatory agency standards.

Maintenance and Inspection Points: Maintain a 12 inch minimum gap between the skirt bottom and channel bottom to prevent accumulated sediment from pulling the top of the curtain below the water surface.

The turbidity curtain and adjacent work areas should not be disturbed 12 hours prior to removal of the curtain from the water body. Maintenance should be performed as needed. The curtain should be removed upon completion of the work in a manner that will prevent siltation of the waterway. During removal extreme care should be taken to not disturb any sediment deposits.

Sediment Control Practice 5.11: Tubes and Wattles

Definition: A small temporary sediment barrier constructed to intercept sheet flow. In this application, wattles and tubes are primarily sediment control measures.

Purpose: To interrupt flow, decrease velocities, pond water and allow runoff-produced sediment to settle out behind barrier.

Conditions Where Practice Applies: This practice is applicable along or on the ground contour or at the toe of slopes and aids in sediment retention. While they are generally used at regular intervals on a slope, they may also be placed at the top or toe of the slope, or at breaks in grade.
In addition, they may be placed on or around the perimeter of soil stockpiles, around catch basin inlets or the perimeter of small disturbed areas.

Planning Considerations: The stability of tubes, wattles, and socks are very dependent upon proper staking.
Thus, they may not be utilized on pavement, rocky soil or at any location where the stakes cannot be driven to the required depth.

Design Criteria: When applied on slopes, temporary sediment tubes should be placed along the contour, and the ends of the tubes should be turned upslope in order to prevent erosion which could occur as flow bypasses around the ends of the row. This will force the discharge to overtop the row away from the end points.

The size of a sediment tube for a slope application should be selected based on the gradient and length of the slope. In general, larger tube diameters should be selected for steeper or longer slopes. Where long rows are required on a slope, the ends of the individual tube segments should be overlapped as shown on the standard drawing. This will ensure that gaps will not occur between individual tube segments, allowing sediment-laden water to escape the measure. Tube/wattle netting should be a knitted material with 1/8 to 3/8 inch openings and made of photodegradable (polypropylene, HDPE) or biodegradable (cotton, jute, coir) material.

Construction Specifications: Proper site preparation is essential to ensure sediment wattles and tubes are in complete contact with the underlying soil or underlying surface. Remove all rocks, clods, vegetation or other obstructions so installed sediment tubes have direct contact with the underlying soil or surface. Install tubes by laying them flat on the ground. Excavate a small trench 2-3 inches in depth on the contour and perpendicular to water flow. Soil from the excavation should be stored close by for use after the wattle has been installed. Install tubes so no gaps exist between the soil and the bottom of the sediment tube. Lap the ends of adjacent sediment tubes a minimum of 6-inches to prevent flow and sediment from passing through the field joint. Wooden stakes should be used to fasten the wattles to the soil. When conditions warrant, a straight metal bar can be used to drive a "pilot hole" through the wattle and into the soil. Drive wooden stakes through the wattle and angled slightly against the direction of flow. Install wooden stakes at 4 feet intervals, unless the wattle manufacturer specifies otherwise, leaving less than 1-2 inches of stake exposed above the wattle. Alternately, stakes may be placed on each side of the wattle tying across with a natural fiber twine or staking in a crossing manner ensuring direct soil contact at all times.
Terminal ends of wattles may be dog legged up slope to ensure containment and prevent channeling of sedimentation.
Care shall be taken during installation so as to avoid damage occurring to the wattle as a result of the installation process. Should the wattle be damaged during installation, a wooden stake shall be placed either side of the damaged area terminating the log segment.

Maintenance and Inspection Points:

- Inspect wattles and tubes after installation for gaps under and between the joints of adjacent ends of wattles and tubes.
- Repair all rills, gullies, and undercutting near wattles and tubes.
- Remove all sediment deposits that impair the filtration capability of the tubes when the sediment reaches 1/3 the height of the exposed tube.
- Remove and/or replace installed sediment tubes as required to adapt to changing construction site conditions.
- Prior to final stabilization, backfill all trenches, depressions and other ground disturbances caused by the removal of the devices.

Sediment Control Practice 5.12: Stormdrain Flushing

Description: A storm drain is flushed with water to suspend and remove deposited materials. Flushing is particularly beneficial for storm drain pipes with grades too flat to be self-cleansing. Flushing helps ensure that pipes convey design flow and also removes pollutants from the storm drain system. This management practice is likely to create a significant reduction in sediment if flushed effluent is properly collected or treated.

Purpose and Application: Storm drain flushing usually takes place along segments of pipe with grades that are too flat to maintain adequate velocity to keep particles in suspension. An upstream manhole is selected to place an inflatable device that temporarily plugs the pipe. Further upstream, water is pumped into the line to create a flushing wave. When the upstream reach of pipe is sufficiently full to cause a flushing wave, the inflated device is rapidly deflated with the assistance of a vacuum pump. The backed-up water is quickly released, resulting in the cleaning of the storm drain segment.

- Locate reaches of storm drain with deposition problems and develop a flushing schedule to clear storm drain of excessive deposits.
- Flushed effluent should be collected and pumped to a holding tank, sediment trap, sediment basin, or a detention basin.
- If the flushed water does not drain to a Stormwater treatment device (e.g., detention basin or swale), then a second inflatable device, placed well downstream, may be used to collect the flushed water after the force of the flushing wave has dissipated. A pump may then be used to transfer the water and accumulated material to a Stormwater treatment practice. In some cases, an interceptor structure may be more practical to collect the flushed waters.

Requirements: Prevent discharge of soil, debris, refuse, hazardous waste, and other pollutants that may hinder the designed conveyance capacity or impact Stormwater quality in the storm drain system. This includes flushing any system connected to "Waters of the State" (any blue-line stream on the USGS quadrangle, sinkhole, or other waterway so determined by TDEC or University personnel in the field).

Equipment Needed:

- Water source (water tank truck or fire hydrant)
- Sediment collector (eductor/vacuum truck or dredge)
- Inflatable devices to block flow
- Containment/treatment equipment for sediment and turbidity if flushing to an open channel

Limitations:

- Most effective in smaller pipes (36-inch diameter pipe or less), depending on water supply and sediment collection capacity.
- May have difficulty finding downstream area to collect sediments. Requires liquid and sediment collection and disposal.

Planning Considerations: It has been found that cleansing efficiency of periodic flush waves is dependent upon flush volume, flush discharge rate, drainage slope, pipe length, flow rate, pipe diameter, and population density. As a rule of thumb, the length of line to be flushed should not exceed 700 feet. At this maximum recommended length, the percent removal efficiency from the pipe at the time of flushing ranges between 65-75 percent for organics and 55-65 percent for dry weather grit/inorganic material. The percent removal efficiency drops rapidly beyond that. Water is commonly supplied by a water truck, but fire hydrants can also supply water. To make the best use of water, it is recommended that reclaimed water be used or that fire hydrant line flushing coincide with storm drainage system flushing.

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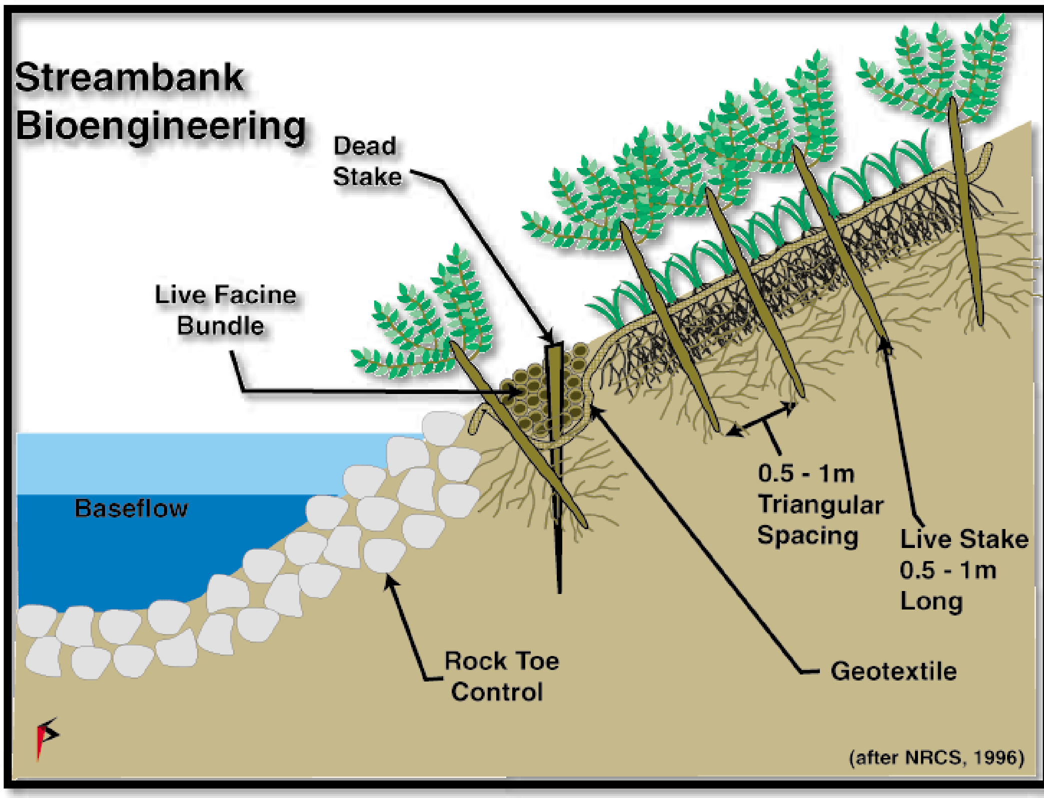
Section 6: Stream Protection Practices

Stream Protection Practice 6.1: Bioengineered Streambank Stabilization



Definition: Bioengineered streambank stabilization is the use of readily available native plant materials to maintain and enhance stream banks; or to prevent, or repair and restore small stream bank erosion problems.

Purpose:

- Form a root mat to stabilize and reinforce the soil on the stream bank
- Provide wildlife habitat
- Enhance the appearance of the stream
- Develop the natural stream corridor
- Lower summertime water temperatures providing a healthy aquatic environment

Conditions Where Practice Applies: Stream bank stabilization techniques may be required if steep slopes and/or hydrologic patterns deem it necessary.

Planning Considerations: Stream bank stabilization without an NRCS approved plan requires authorization from the Tennessee Division of Water Pollution Control and may require authorization from the United States Army Corps of Engineers. For more information, see: http://www.state.tn.us/environment/permits/arap.shtml.

Design Criteria: Bioengineering is a streambank stabilization technique that uses natural materials such as grasses, shrubs, trees, roots and logs to manage stream flow and stabilize the banks. Bioengineering is the preferred method of streambank stabilization and is permitted without notification where no work is done in stream with mechanized equipment; and where the work is done in accordance with an approved bioengineering plan from the United States Department of Agriculture, Natural Resource Conservation Service (NRCS).

Design of streambank stabilization must be performed by a professional experienced in stream design.

A low flow channel shall be provided to convey the smaller storms, and a floodplain shall be included to the extent feasible, given site constraints.

Construction Specifications: Re-vegetation includes seeding and sodding of grasses in combination with erosion control fabrics, and the planting of woody vegetation (shrubs and trees). Any blankets or matting used within the stream channel shall be jute or other fully biodegradable materials. Floodplain areas can be stabilized with erosion control blankets and/or turf reinforcement mat. Seed or sod used on the streambanks shall be long rooted, native grasses.

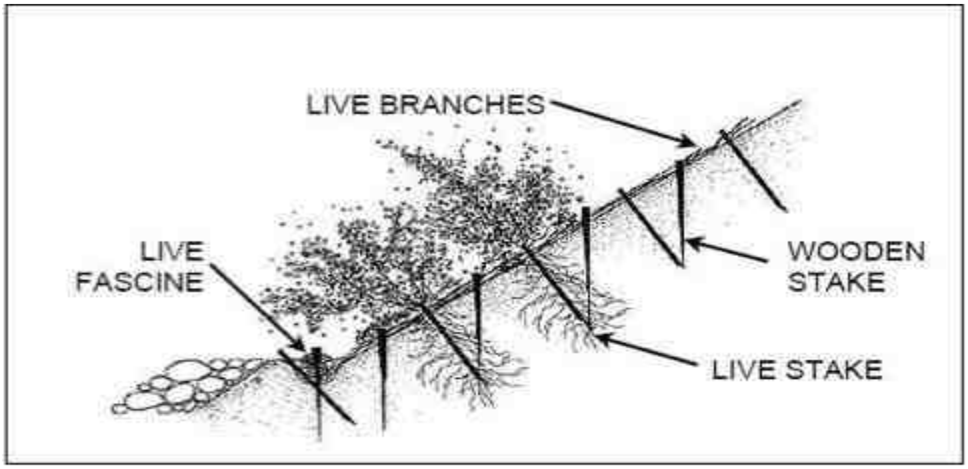
Live Stake: Fresh, live cut woody plant cuttings are driven into the ground as stakes, intended to root and grow into mature shrubs that will stabilize soils and restore the riparian zone habitat. Live stakes provide no immediate stream bank stabilization. Only certain species of woody plants will work well for this application. Willow species work best.

Live stakes may also be driven into riprap protected banks to help with permanent stabilization, and improve aesthetics.

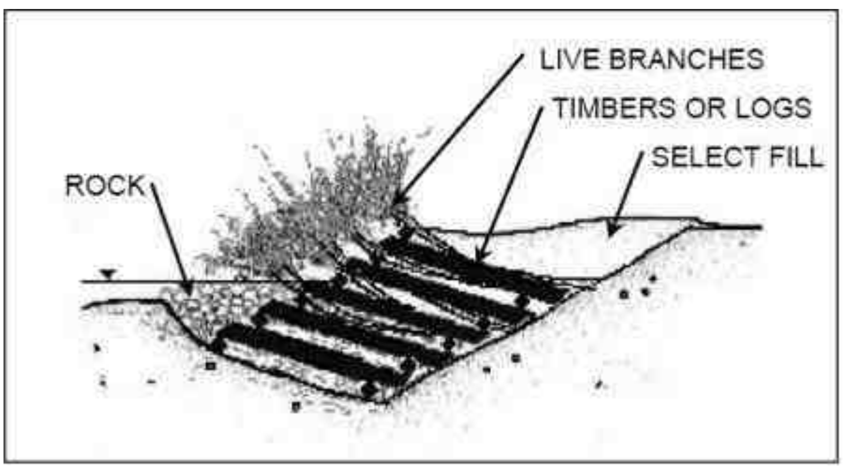
Live Fascine: Live fascines are sausage-like bundles of live cut branches placed into trenches along the stream bank. They provide immediate protection from erosion when properly used and installed. Willow species work best.

Live fascines create very little site disturbance as compared to other systems and works especially well when combined with surface covers such as jute mesh or coir fabrics.

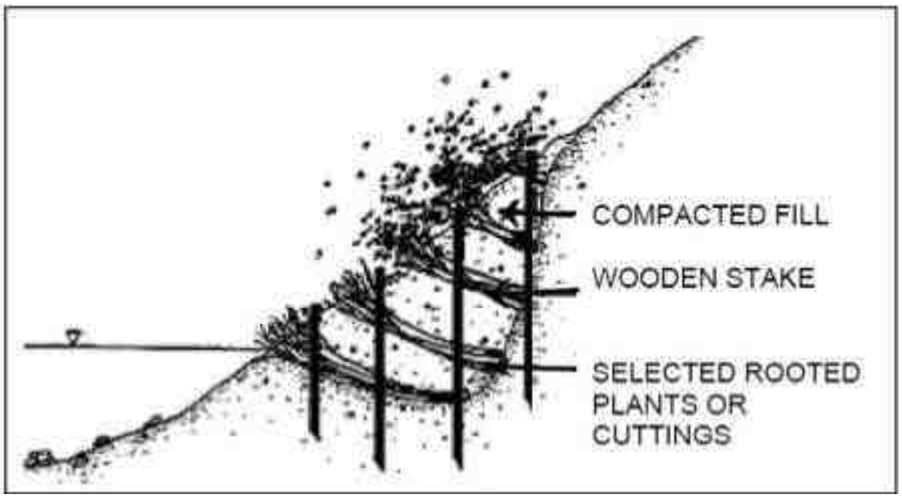
Brushmattress: A combination of living units that forms an immediate protective surface cover over the stream bank. Living units used include live stakes, live fascines and a mattress branch cover (long, flexible branches placed against the bank surface). Brushmattresses, which require a great deal of live material, are complicated as well as expensive to evaluate, design, and install.
Brushmattresses capture sediment during flood conditions, produce habitat rapidly and quickly develop a healthy riparian zone.



Live Cribwall: A rectangular framework of logs or timbers, rock and woody cuttings. This requires a great deal of assessment and understanding of stream behavior. Cribwalls can be complicated and expensive if a supply of wood is not available.
Benefits include developing a natural stream bank or upland slope appearance after is has begun to grow and provides excellent habitat for a variety of fish, birds, and animals. It is very useful where space is limited on small, narrow stream corridors.



Branchpacking: Process of alternating layers of live branches and soil, incorporated into a hole, gully, or slumped-out area in a slope or streambank. There is a moderate to complex level of difficulty for construction. Branchpacking produces an immediate filter barrier, reducing scouring conditions, repairing gully erosion and providing habitat cover and bank reinforcement. This is one of the most effective and inexpensive methods for repairing holes in earthen embankments along small stream sites.



Maintenance and Inspection Points:

- During restoration activities, inspect construction to ensure that sediment control and erosion controls are installed and functioning.
- Check for germination or seedling emergence.
- The banks should be inspected after every high-water event, fixing gaps in the vegetative cover at once with structural materials or new plants, and mulching if necessary. Fresh cuttings from other plants may be used for repairs.

Stream Protection Practice 6.2: Temporary Stream Crossing

Definition: A temporary stream crossing is a temporary structure installed across a flowing stream or watercourse for use by construction equipment.

Purpose: This standard provides a means for construction vehicles to cross streams or watercourses without moving sediment into the stream, damaging the streambed or channel, or causing flooding.

Conditions Where Practice Applies: Temporary stream crossings should be installed anywhere construction traffic cannot be routed around the stream but where the crossing will later be removed.

Planning Considerations: All work in a stream must have prior permitted approval from TDEC through the Aquatic Resource Alteration Permit (ARAP) process and all conditions of the ARAP must be followed. For more information, see:
http://www.state.tn.us/environment/permits/arap.shtml.
Structures may include bridges, pipes, or pipe arches. Temporary stream crossings should be in place for less than one year and should not be accessible to the public.

Design Criteria Professionals familiar with the hydraulic calculations necessary to accomplish the work should design stream crossing construction plans and drawings using sound engineering practices.

Size: The structure may be sized large enough to convey the bankfull flow of the stream, typically flows produced by a 2-year, 24-hour frequency storm, with normal high water protection since the flood plain will become effective at the bankfull elevation. However, if the crossing is designed as a low-water crossing, provision must be made for additional overflow protection of the structure, to prevent washout during high flow events.

Location: The temporary stream crossing should be perpendicular to the stream. Where approach conditions dictate, the crossing may vary up to 15° from the perpendicular.

Overflow Protection: Structures should be protected from washout during periods of peak discharges by diverting high flows around or over the structures. Methods to be considered for washout protection may include elevation of bridges above adjacent flood plain lands, crowning of fills over pipes or by the use of diversions, dikes or island type structures. Frequency and intended use, stream channel conditions, overflow areas, potential flood damage, and surface runoff control should be considered when selecting the type of temporary stream crossing to be used.

Temporary Bridge Crossing: A temporary access bridge causes the least erosion of the stream channel crossing when the bridge is installed and removed. It also provides the least obstruction to flow and fish migration. If the bridge is properly designed and appropriate materials are used, a temporary access bridge typically is long lasting and requires little maintenance. It may also be salvaged at project's end and used again in the future. However, a temporary bridge crossing is generally the most expensive crossing to design and construct. It also creates the greatest safety hazard if not adequately designed, installed and maintained.

Temporary Culvert Crossing: A temporary access culvert is the most common stream crossing. It can control erosion effectively, but can cause erosion when it is installed and removed. A temporary culvert can be easily constructed and enables heavy equipment loads to be used. However, culverts create the greatest obstruction to flood flows and are subject to blockage and washout.

The crossing may be designed based on the stream flows resulting from a 2-year 24-hour frequency storm, in which case, Class A or B riprap may be used for normal erosion protection of the aggregate fill, and the roadbed would be at the elevation of the top of the banks. For temporary crossings of streams with large watersheds, the crossing may also be designed based on the low-flow channel conditions as a low water crossing. The culvert size would be adequate to convey base flows, but high water events would overtop the structure and make the crossing temporarily unusable. Additional erosion protection of the fill would be necessary for this design, in the form of Class C or larger riprap to prevent the washout of the culverts.

Construction Specifications:

All Crossings:

- In-stream work should be performed in dry conditions. Utilize a stream diversion or cofferdams to provide dry conditions for conducting the work. Clearing of the streambed and banks should be kept to a minimum.
- All surface water from the construction site should be diverted onto undisturbed areas adjoining the stream. Unstable stream banks should be lined with riprap or otherwise be appropriately stabilized.
- The crossing alignment shall be at right angles to the stream. Where approach conditions dictate, the crossing may vary up to 15° from a line drawn perpendicular to the centerline of the stream at the intended crossing location.
- All fill materials associated with the roadway approach shall be limited to a maximum height of 2 feet above the existing flood plain elevation.
- A water diverting structure such as a waterbar diversion should be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet distance is measured from the top of the waterway bank. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.
- The crossing structure should be removed as soon as it is no longer necessary for access. During structure removal, utilize a stream diversion channel or cofferdams to provide dry conditions for conducting the work.
- Upon removal of the crossing structure, the stream shall immediately be restored to its original cross-section and properly stabilized.

Temporary Bridge Crossing: The temporary bridge should be constructed at or above bank elevation to prevent the entrapment of floating materials and debris.

- Abutments should be placed parallel to the stream and on stable banks.
- Bridges should be constructed to span the entire channel. If the channel width exceeds eight feet (as measured from the tops of the banks), a temporary footing, pier, or bridge support may be constructed within the waterway.
- Decking materials should be of sufficient strength to support the anticipated load. Decking materials must be butted tightly to prevent any soil material tracked onto the bridge from falling into the waterway below.
- Bridges should be securely anchored at only one end using steel cable or chain. This will prevent channel obstruction in the event that floodwaters float the bridge. Large trees, large boulders or driven steel anchors can serve as anchors.

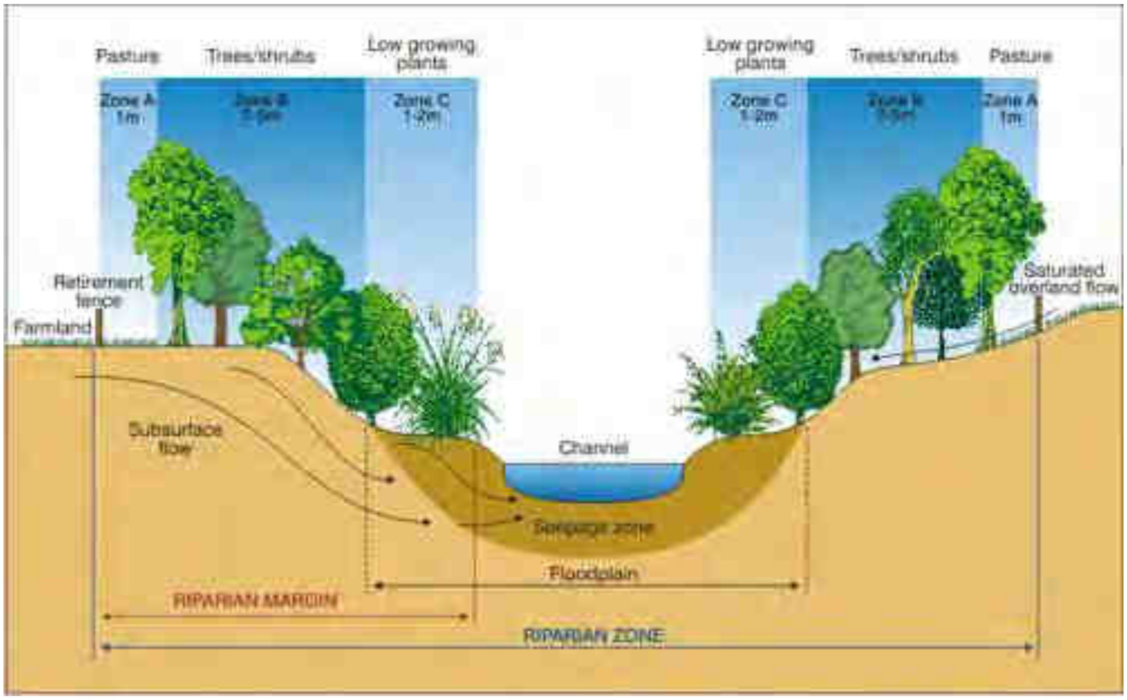
Temporary Culvert Crossing:

- All culverts must be strong enough to support their cross-sectioned area under maximum expected loads.

- The invert elevation of the culvert should be installed on the natural streambed grade at both ends.
- A geotextile should be placed on the streambed and stream banks prior to the placement of the pipe culvert(s) and aggregate. The geotextile will prevent the migration of soil particles from the subgrade into the graded stone. The geotextile should cover the streambed and extend a minimum of six inches and a maximum of one foot beyond the end of the culvert and bedding material.
- The culverts should extend a minimum of one foot beyond the upstream and downstream toe of the aggregate placed around the culvert.
- The culvert(s) should be covered with small riprap. The depth of riprap above the top of the culvert should be one-half the diameter of the culvert or 18", whichever is greater.
- Multiple culverts should be separated by one-half the diameter of the culvert or 12" whichever distance is greater. A final layer of coarse aggregate should be applied to minimum depth of 6 inches.

Maintenance and Inspection Points: The structure should be inspected after every rainfall and at least twice a week, and all damages repaired immediately. Any material lost to the stream shall be removed but only after discussion with TDEC and / or Army Corps of Engineer staff. The structure should be removed immediately after construction is finished, and the streambed and banks must be stabilized and restored to pre-construction conditions.

Stream Protection Practice 6.3: Stream Buffers



Definition: A stream buffer is a non-structural low impact development control in areas along a stream or wetland where disturbance is restricted or prohibited.

Purpose: A stream buffer's primary function is to physically protect and separate a stream or wetland from future disturbance or encroachment. It is **not** a sediment control.

Conditions Where Practice Applies: All construction sites containing and/or adjacent to receiving streams or waters are required to have stream buffers between the top of the stream bank and the disturbance.

Planning Considerations: Effective stream buffers consist of undisturbed natural vegetation, including maintaining the original tree line along the stream or channel banks. Promptly stabilize disturbed buffers with a dense cover of strong rooted grasses, native plants and native trees.

Construction related materials and equipment must be stored outside the buffer area.

Design Criteria:

STREAM BUFFER: DO NOT DISTURB A 60-foot natural riparian buffer zone adjacent to all streams at the construction site shall be preserved, to the maximum extent practicable, during construction activities at the site. The riparian buffer zone should be preserved between the top of stream bank and the disturbed construction area. The 60-feet criterion for the width of the buffer zone can be established on an average width basis at a project, as long as the minimum width of the buffer zone is more than 40 feet at any measured location.
For optimal Stormwater treatment, it is recommended that concentrated flow be converted into sheet flow through the use of a level spreader prior to discharging into the buffer. Concentrated flow can cause erosion in the buffer.

Construction Specifications: Install controls along the outer upstream edge of the stream buffer to prevent inadvertent disturbance to the buffer. Consider high visibility controls, such as fencing.
Where a stream crossing is necessary, comply with the conditions of the Aquatic Resource Alteration Permit for the amount of stream buffer that can be disturbed. Ensure that sediment controls are installed upgradient from the buffer to protect it from sediment-laden runoff.
Install level spreaders to convert concentrated flow into sheet flow prior to discharging across the buffer.

If a buffer is disturbed, the buffer should be restored as follows:

1. All areas of the buffer being restored must be planted with native or natural vegetation that is appropriate to achieve a stable stream protection corridor, including tree canopy.
2. All areas of the buffer being restored must be stabilized against erosion.
3. During restoration activities, erosion prevention and sediment control measures must be installed to protect the stream. These measures can include turf reinforcement mats, erosion control blankets, wattles, etc., to stabilize the area in the short- and long-term.
4. To increase the chances for the success and health of the buffer, the plant species, density, placement, and diversity in the buffer restoration plan must be appropriate for stream buffers. Proposed planting and long-term maintenance practices must also be appropriate and properly performed.
5. Vegetation mortality must be included in the planting densities in buffer restoration plans.

More detailed information on streambank and buffer restoration techniques, planting guidelines and native plant species can be found from the following sources:
- Tennessee Valley Authority's Riparian Restoration webpage, located at www.tva.com/river/landandshore/stabilization/index.htm
- Tennessee Valley Authority's Native Plant Finder webpage, located at

www.tva.com/river/landandshore/stabilization/plantsearch.htm;
- Banks and Buffers: A guide to selecting native plants for streambanks and shorelines. Contact information to obtain this publication is provided at www.tva.com/river/landandshore/stabilization/websites.htm;
- The Tennessee Native Plant Society at www.tnps.org
- The Tennessee Exotic Plant Pest Council website, located at www.tneppc.org; and
- The Natural Resource Conservation Service (NRCS).

Maintenance and Inspection Points: Inspections must focus on stability of the buffer. No disturbance of the buffer is allowed unless accounted for in the overall plan and a minimum average buffer width is provided, as noted above.
During inspections, ensure that buffer boundaries are well defined and clearly marked.
Where erosion in the buffer is identified, measures shall be taken to halt the erosion and repair the buffer.
Where the buffer is disturbed, a buffer restoration plan shall be developed and included in the SWPPP.

Stream Protection Practice 6.4: Stream Diversion

Definition: A stream diversion is a temporary diversion constructed to convey stream flow around in-stream construction.

Purpose: Stream diversion channels are required by Aquatic Resource Alteration Permits in order to perform in-stream work separate from flowing water.

Conditions Where Practice Applies: Construction often includes stream crossings thus creating a potential for excessive sediment loss into the stream, by both the disturbance and approach areas, and by work within the streambed and banks.
Stream diversions separate the flowing stream from the active construction area, reducing the potential for impacts from the instream construction activity.

Planning Considerations:

- Disturbance within the confines of stream banks are required to be conducted "in the dry" or separate from flowing water. No excavation equipment should ever be operated in flowing waters.
- In cases where in-stream work is unavoidable, a stream diversion should be considered to prevent excessive damage from sedimentation. To limit land-disturbance, overland pumping of the stream should be considered in low-flow conditions whenever possible.

- Temporary pipes can also convey smaller stream flows.
- Some streams are too large to construct a diversion channel of pipe. In those cases, consider the use of alternative structures, such as cofferdams and geotextile tubes, in order for work to be conducted in dry conditions.
- There may be certain times of the year, especially in the summer, when rip rap or fabric-lined diversion channels may cause thermal pollution.
- The duration of the instream work should be minimized to the shortest period possible.
- Clearing of the streambed and banks should be kept to a minimum.
- Work that requires a stream diversion channel requires authorization from the Tennessee Division of Water Pollution Control and United States Army Corps of Engineers. All conditions of the ARAP and COE permit must be followed.

Design Criteria: Professionals familiar with the design of water conveyance systems should prepare construction plans and drawings for this technique. Several methods of diverting a stream are detailed below. There may be certain seasonal components to consider when attempting flow diversion of a stream, such as spawning times of individual fish species. Several other methods can be used to temporarily divert stream flows around an active work area. Regardless of the type of stream diversion chosen, the capacity of the diversion shall be designed to be equivalent to the bankfull capacity of the existing channel.

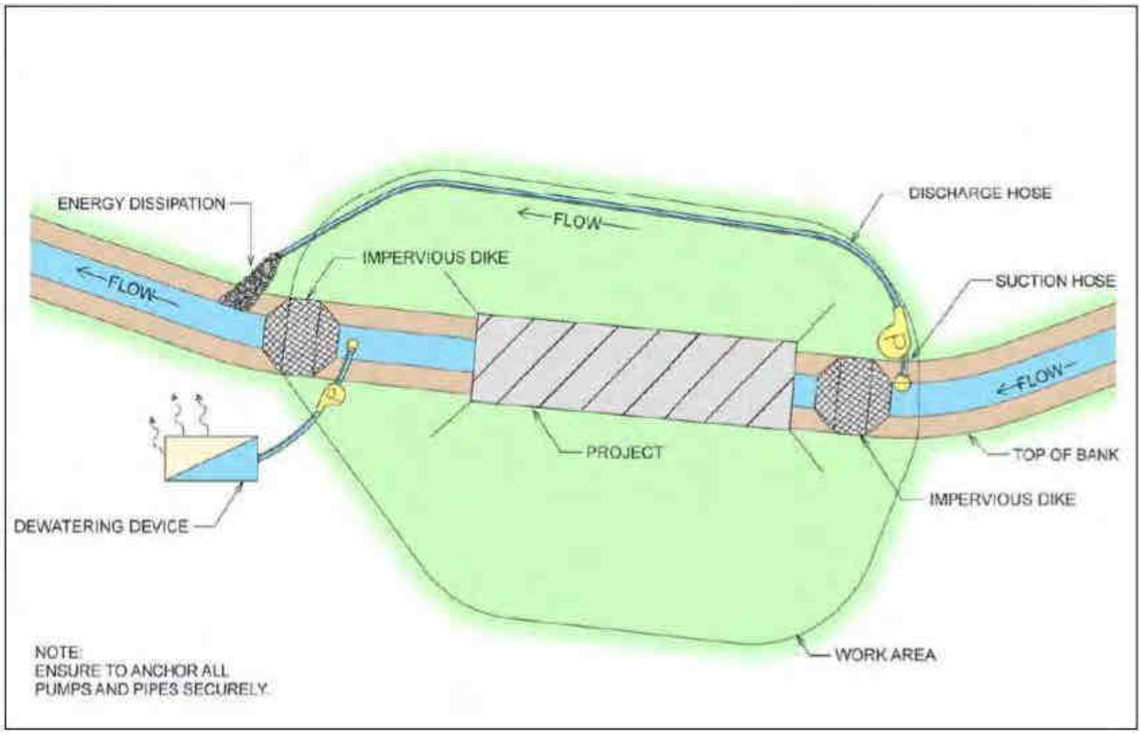


Figure 6.4-1 Bypass Pumping Design.

Bypass Pumping: A bypass pump and an impervious dike divert the flow of the watercourse from the inlet of the pipe to the outlet of the pipe (Figure 6.4-1). This is a water-to-water operation and care should be taken that the discharge is at a low flow rate to minimize turbidity and/or potential erosion of the stream channel at the outlet of the bypass pipe or hose. Use this practice when another type of diversion is not physically possible or practical or when the construction activities will not require pumping for an extended period. Do not use this practice when the discharge location cannot be adequately stabilized; when ponding of the stream to adequately submerge the pump suction line is not allowed or not practical; or when the normal flow of the stream cannot be handled by the typical bypass pump.

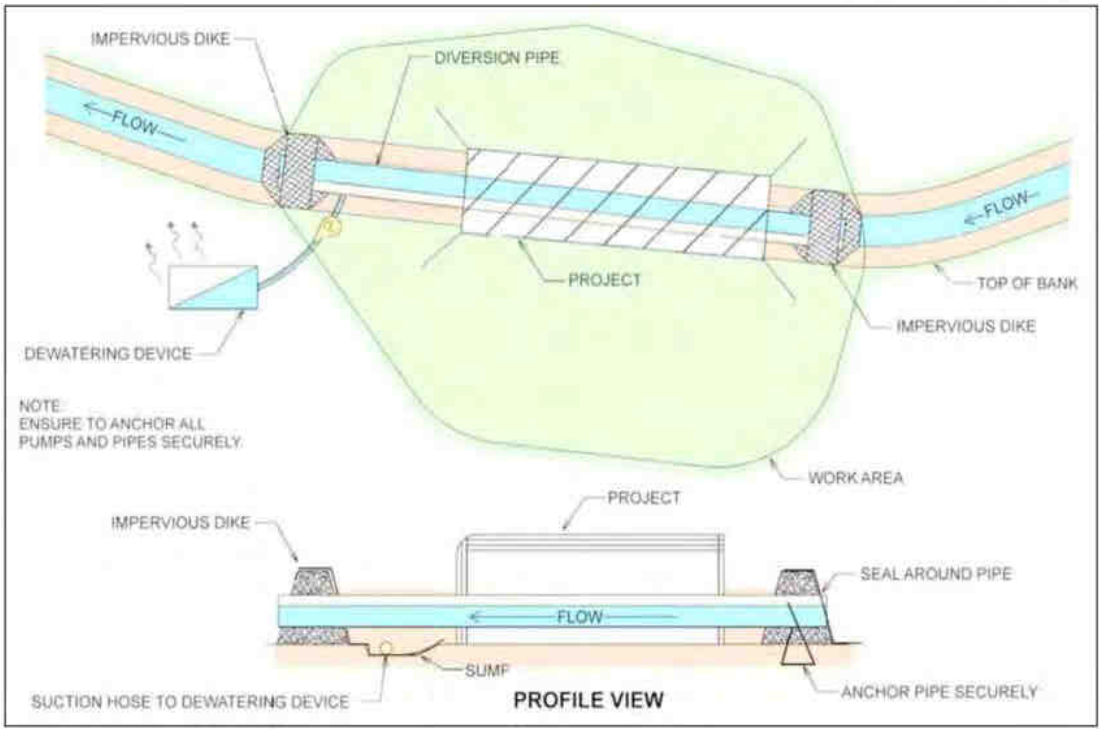


Figure 6.4-2 Suspended Bypass Pipe Design.

Suspended Bypass Pipe: The suspended bypass pipe is used where an existing pipe or culvert is extended. This bypass pipe is constructed inside the existing pipe or culvert to divert the watercourse through the work area while allowing the work area to remain dry (Figure 6.4-2). Use this practice when a pipe or culvert is being extended and is large enough to accommodate the bypass pipe or when space limitations do not allow for a fabric lined diversion channel (for example, widening grade and drain projects). Do not use this practice when the upstream ponding required to enter the suspended pipe inlet is unacceptable.

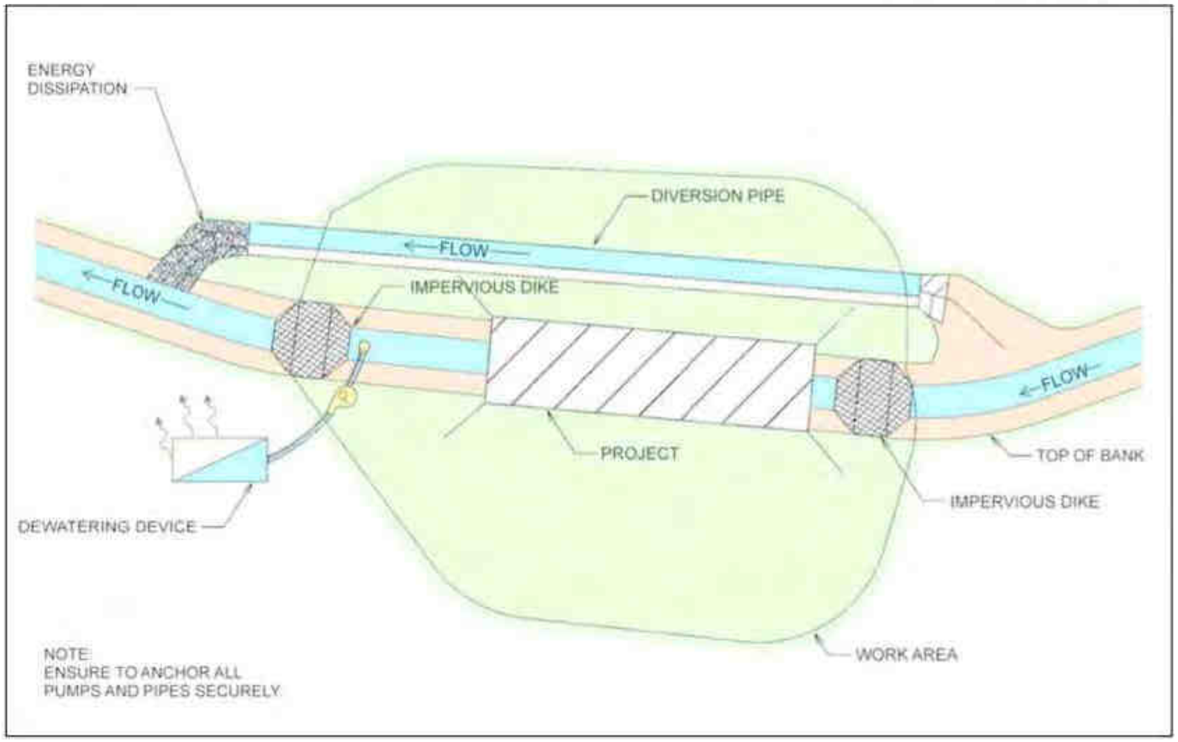


Figure 6.4-3 Piped Diversion Design.

Piped Diversion: Install a temporary pipe to divert the flow of the watercourse around the work area without the use of pumping operations (Figure 6.4-3). While the cost is higher for this operation than an open plastic lined channel, the probability of offsite 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. Do not use this practice where adequate space in unavailable, such as at pipe extensions, headwall installations and some pipe/culvert replacements.

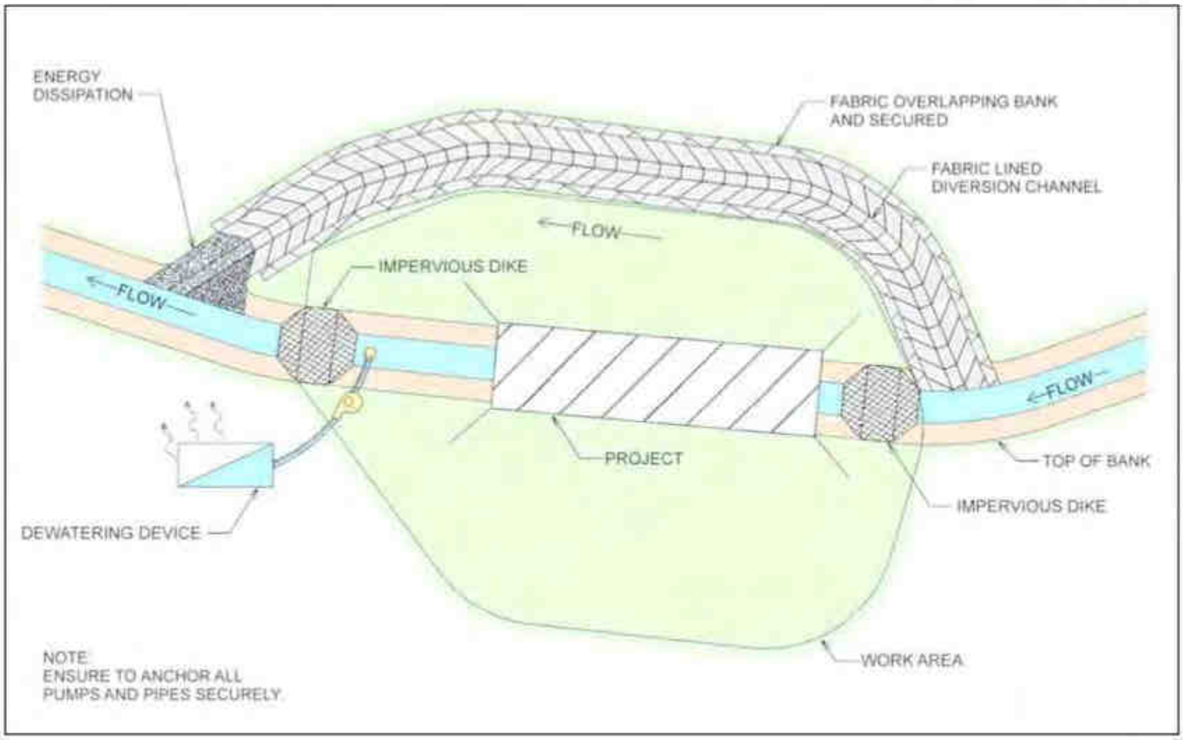


Figure 6.4-4 Fabric Lined Diversion Channel Design.

Fabric Lined Diversion Channel: A fabric lined temporary diversion channel is used to divert normal stream flow and small storm events around the work area without the use of pumping operations (Figure 6.4-4). The temporary diversion channel is typically constructed adjacent to the work area and is lined with a poly-fabric to minimize the potential for erosion within the temporary diversion channel. Use this practice where adequate space and slopes exist adjacent to the work area. Do not use this practice where adequate space is unavailable such as at pipe extensions, headwall installations and some pipe/culvert replacements.

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

Bypass Pumping:

- Set up bypass pump and temporary piping. Place outlet of temporary pipe to minimize erosion at discharge site or provide temporary energy dissipation measures. Firmly anchor pump and piping.
- Construct outlet protection if needed.
- Construct impervious dike upstream of work area to impound water for bypass pump intake. Use a floating intake for pumps where possible.
- Construct an impervious dike downstream, if necessary, to isolate work area.
- Check operation of pump and piping system.
- Upon completion of construction, remove impervious dike, bypass pump, and temporary pipe and stabilize disturbed area.

Suspended Bypass Pipe:

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

Piped Diversion:

- Install erosion and sediment controls.
- Install temporary pipe adjacent to work area. Excavation may be required to provide a positive drainage slope from the upstream to downstream side.
- Connect the downstream temporary pipe into the downstream existing channel.
- Place outlet of pipe to minimize erosion at the discharge site or provide temporary energy dissipation measures.
- Connect the upstream temporary pipe into the upstream existing channel.

- Construct an impervious dike at the upstream side of the existing channel to divert the existing channel into the temporary pipe.
- Construct an impervious dike at the downstream side of the bypass pipe to isolate work area.
- Upon completion of construction, remove the impervious dike and temporary pipe and stabilize the disturbed area.

Fabric Lined Diversion Channel:

- Install erosion and sediment controls.
- Excavate the diversion channel without disturbing the existing channel.
- Place poly-fabric liner in diversion channel with a minimum of 4 feet of material overlapping the channel banks. Secure the overlapped material using at least 1 foot of fill material.
- 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 in the existing channel at the upstream side to divert the flow into the diversion channel.
- Construct an impervious dike in the existing channel at the downstream side to isolate the work area.
- Upon completion of the culvert construction, remove the impervious dikes and divert the channel back into the culvert.
- Remove the poly-fabric liner and fill in the diversion channel.
- Establish vegetation on fill section and all other bare areas.

Maintenance and Inspection Points:

Bypass Pump:

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

Suspended Bypass Pipe:

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

Piped Diversion:

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

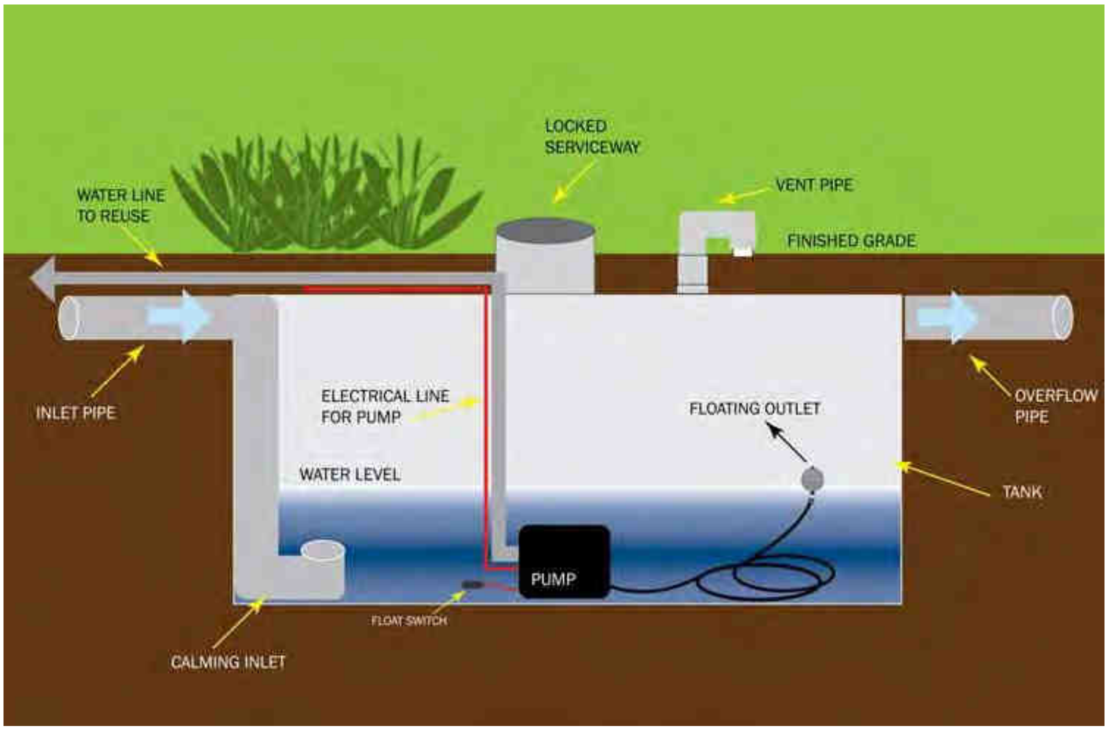
Fabric Lined Diversion Channel:

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

The stream diversion channel should be inspected at the end of each day to make sure that the stream flow control measures and construction material are positioned securely. This will ensure that the work area stays dry and that no construction materials float downstream. Inspect impounded work area to ensure water is not contaminated with construction materials or chemicals and that dewatering/treatment is adequate. All repairs should be made immediately.

Section 7: Stormwater Control Measures

Stormwater Control Measures 7.1: Stormwater Cistern/Rainwater Harvesting



Purpose and Application: Runoff capture and reuse may be implemented on a variety of sites in urban environments, institutional, and commercial properties. Potential applications include office buildings, schools, libraries, residential buildings, and mixed-use areas for irrigation, fire suppression systems, toilet flushing, or non-potable water uses. They can also be used on brownfield sites where the water collected from rooftops is captured and stored before becoming contaminated.
Rainwater harvesting systems can be useful in areas of steep terrain where other Stormwater treatments are inappropriate, provided the systems are designed in a way that protects slope stability. Cisterns should be located in level areas where soils have been sufficiently compacted to bear the load of a full storage tank. Harvested rainwater should not be discharged over steep slopes; rather, the rainwater should be used for indoor non-potable applications or outdoor irrigation.

Description: Rainwater can be used as a resource when it is captured from impervious surfaces, stored in cisterns or rain barrels, and reused as non-potable water. Captured rainwater can be used for landscape irrigation, firefighting needs, toilet flushing, or other non-potable water uses. Toilet flushing in high-use buildings (i.e., residence halls, classroom buildings, visitor centers) is one of the most effective reuse methods. Roof runoff is generally cleaner and more suitable than runoff from parking lots and roads, which require additional treatment and maintenance to address suspended solids. Runoff capture and reuse reduces the volume and peak flow associated with Stormwater runoff.

Limitations: Water treatment may be necessary depending on the contaminants in the contributing area and the reuse application.

Maintenance and Inspection Points: Inspections of gutters, downspouts, screen and filters for debris and remove them if necessary. Inspect the tank for leaks and accumulated sediment and address if necessary. Check flow control components and repair or replace if necessary.

Design Criteria: Many rainwater harvesting system variations can be designed to meet user demand and Stormwater objectives. This specification focuses on providing a design framework for addressing the design treatment volume. The actual runoff reduction rates for rainwater harvesting systems are based on tank size, configuration, demand drawdown, and use of secondary practices.

The size of the cistern required will be determined by the drainage area, the intended capture goal, and the usage needs of the reuse application. The designer must select a pump of adequate capacity to meet the flow requirements for the reuse system. A cistern provides volume management within the storage device only. The size of the storage device is dependent on the contributing drainage area.

Underground storage tanks must be above groundwater level. Certain roof materials may leach metals or hydrocarbons, limiting potential uses for harvested rainwater. Underground tanks should be set at least 10 feet from building foundations. Cistern overflows should be designed to avoid soil saturation within 10 feet of building foundations. Systems must be designed for consistent drawdown year round. Aboveground storage tanks should be UV resistant and opaque to inhibit algae growth. Underground storage tanks must be designed to support anticipated loads. Hookups to municipal backup water supplies must be equipped with backflow prevention devices.

Construction Specifications: Cisterns may be above- or below-ground tanks made from a variety of materials such as wood, concrete, plastic, fiberglass or metal. Storage devices should be sized to store the appropriate runoff volume from the contributing capture area and reuse needs should be adequate to drain the cistern within 72 hours to ensure that sufficient storage is available for subsequent rainfall events. A cistern provides volume management within the storage device only. The size of the storage device is dependent on the contributing drainage area.

There are six primary components of a rainwater harvesting system which are discussed below:

- **Roof surface:** The rooftop should be made of smooth, non-porous material with efficient drainage either from a sloped roof or an efficient roof drain system. Slow drainage of the roof leads to poor rinsing and a prolonged first flush, which can decrease water quality. If the harvested rainwater is selected for uses with significant human exposure (e.g. pool filling, watering vegetable gardens), care should be taken in the choice of roof materials. Some materials may leach toxic chemicals making the water unsafe for humans.

- **Collection and conveyance system:** The collection and conveyance system consists of the gutters, downspouts, and pipes that channel Stormwater runoff into storage tanks. Gutters and downspouts should be designed as they would for a building without a rainwater harvesting system. Aluminum, round-bottom gutters and round downspouts are generally recommended for rainwater harvesting. Minimum slopes of gutters should be specified. At a minimum, gutters should be sized with slopes specified to contain the 1-inch storm at a rate of 1-inch/hour for treatment volume credit.

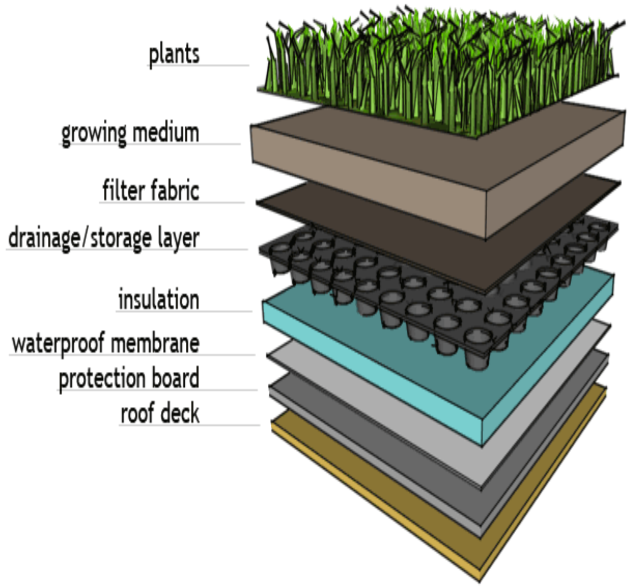
- **Pre-screening and first flush diverter:** Inflow must be pre-screened to remove leaves, sediment, and other debris. For large systems, the first flush (0.02 – 0.06 inches) of rooftop runoff should be diverted to a secondary treatment practice to prevent sediment from entering the system. Rooftop runoff should be filtered to remove sediment before it is stored. Pre-filtration is required to keep sediment, leaves, contaminants and other debris from the system.

- **Storage tank(s):** Storage tanks are sized based on consideration of indoor and outdoor water demand, long-term rainfall and rooftop capture area. The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. Cistern capacities can range from 250 to over 30,000 gallons. Multiple tanks can be placed adjacent to each other and connected with pipes to balance water levels and increase overall storage onsite as needed.

- **Distribution system:** The rainwater harvesting system should be equipped with an appropriately-sized pump that produces sufficient pressure for all end-uses. Distribution lines should be installed with shutoff valves and cleanouts, and should be buried beneath the frost line or insulated to prevent freezing. Most distribution systems require a pump to convey harvested rainwater from the storage tank to its final destination, whether inside the building, or an automated irrigation system. The rainwater harvesting system should be equipped with an appropriately-sized pump that produces sufficient pressure for all end-uses.

- **Overflow, filter path, or secondary runoff reduction practice:** The system must be designed with an overflow mechanism to divert runoff when the storage tanks are full. Overflows should discharge to pervious areas set back from buildings and paved surfaces, or to secondary BMPs. All cisterns must provide a safe way for water to exit the system when large it is full, such as when large storms generate more Stormwater runoff than the storage device is designed to hold. The cistern can be designed to slowly drain to the landscape between storm events to provide capacity. The overflow should convey runoff to an approved discharge point. The size of the overflow device or orifice should be equal in area to the total of all inlet orifices. An overflow mechanism should be included in the rainwater harvesting system design in order to handle an individual storm event or multiple storms in succession that exceed the capacity of the tank. Overflow pipes should have a capacity equal to or greater than the inflow pipe(s) and have a diameter and slope sufficient to drain the cistern while maintaining an adequate freeboard height. The overflow pipe should be screened to prevent access to the tank by rodents and birds.

Stormwater Control Measure 7.2: Green Roof



Description: A green roof consists of vegetated cover used to mimic the hydrologic performance of surface vegetation rather than the surface of an impervious roof. Green roofs are effective in reducing the volume of runoff from a roof as well as the rate at which runoff leaves a rooftop. Green roofs help to minimize thermal impacts to downstream receiving waters. Green roofs may be designed to accommodate functions ranging from solely rainfall management to more complex systems that integrate rainfall management with livable/usable space.

Purpose and Application: The goal for green roof systems designed for stormwater management is to establish a full and vigorous cover of low-maintenance vegetation that is self-sustaining and requires minimal mowing, trimming, or weeding. Green roofs are ideal for use on commercial, institutional, municipal and multi-family residential buildings. They are particularly well suited for use on ultra-urban development and redevelopment sites where space for infiltrative practices can be limited. Green roofs can be applied to most roof surfaces, although concrete roof decks are preferred. Certain roof materials, such as exposed treated wood and uncoated galvanized metal, may not be appropriate for green rooftops due to pollutant leaching.

Design Criteria: Green Roofs typically consist of layers which are designed to support plant growth and retain water for plant uptake while preventing ponding on the roof surface. The roofs are designed so that water drains vertically through the media and then horizontally along a waterproofing layer towards the outlet. Green roofs are designed to have minimal maintenance requirements. Plant species are selected so that the roof does not need supplemental irrigation or fertilization after initial establishment. Green roofs are typically designed to manage the rainfall that falls onto the vegetated area. They also may be sized to manage runoff from other roof areas where vegetation may not be established (e.g., areas of steeply pitched roofs, air conditioning units). Green roofs that receive drainage from more steeply sloped roof areas should include an area for velocity dissipation prior to runoff flowing onto the vegetated area. Regardless of the complexity of the system, green roofs may be designed and constructed to meet Stormwater management requirements. Green roof plant species generally have shallow root systems, good regenerative qualities, and resistance to direct solar radiation, drought, frost, and wind. In addition to Stormwater benefits, green roofs provide benefits in terms of increased longevity of the roofing system (by protecting the roof from temperature extremes) and insulation benefits that may reduce heating or air-conditioning energy costs. Green roofs always include one or more drainage layers, separation fabrics (which may include a root barrier), and a waterproofing system.

Functional Elements: A green roof is composed of up to eight different systems or layers, listed below from bottom to top, that are combined together to protect the roof and maintain a vigorous cover.

1. Deck Layer: The roof deck is the foundation of a green roof. It may be composed of concrete, wood, metal, plastic, gypsum, or a composite material. The type of deck material determines the strength, load bearing capacity, longevity and potential need for insulation in the green roof system. In general, concrete decks are preferred for green roofs, although other materials can be used as long as the appropriate system components are matched to them.
2. Waterproofing Layer: All green roof systems must include an effective and reliable waterproofing layer to prevent water damage through the deck layer. A wide range of waterproofing materials can be used, including built up roofs, modified bitumen, single-ply, and liquid-applied methods. The waterproofing layer must be 100% waterproof and have an expected life span as long as any other element of the green roof system.
3. Insulation Layer (optional): Many green rooftops contain an insulation layer, usually located above, but sometimes below, the waterproofing layer. The insulation increases the energy efficiency of the building and/or protects the roof deck (particularly for metal roofs).
4. Root Barrier: The next layer of a green roof system is an optional root barrier that protects the waterproofing membrane from root penetration. Chemical root barriers or physical root barriers that have been impregnated with pesticides,

metals or other chemicals that could leach into Stormwater runoff should be avoided.

5. Drainage Layer and Drainage System: A drainage layer is then placed between the optional root barrier and the growing media to quickly remove excess water from the vegetation root zone. The drainage layer should consist of synthetic or inorganic materials (e.g. gravel, recycled polyethylene, etc.) that are capable of retaining water and providing efficient drainage. A wide range of prefabricated water cups or plastic modules can be used, as well as a traditional system of protected roof drains, conductors and roof leader. The required depth of the drainage layer is governed by both the required Stormwater storage capacity and the structural capacity of the rooftop.
6. Root-Permeable Filter Fabric: A semi-permeable polypropylene filter fabric is normally placed between the drainage layer and the growing media to prevent the media from migrating into the drainage layer and clogging it.
7. Growing Media: The next layer is the growing media, which is typically 4 to 6 inches deep. The recommended growing media for extensive green roofs is composed of approximately 80% to 90% lightweight inorganic materials, such as expanded slates, shales, clays, pumice, scoria or other similar materials. The remaining media should contain no more than 15% organic matter, normally well-aged compost. The percentage of organic matter should be limited, since it can leach nutrients into the runoff from the roof and clog the permeable filter fabric.
8. Plant Cover: The top layer typically consists of slow-growing, shallow-rooted, perennial, succulent plants that can withstand harsh conditions at the roof surface. An experienced design professional should be consulted to select the plant species best suited to a given installation.

Maintenance and Limitations: More maintenance is required than a conventional roof. Watering, fertilizing, and weeding are essential; especially during the first two years of growth with plants are being established.

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Stormwater Control Measure 7.3: Stormwater Treatment Wetland

Description: Constructed wetlands, sometimes called Stormwater wetlands, are shallow depressions that receive Stormwater inputs for water quality treatment. Runoff from each new storm displaces runoff from previous storms, and the long residence time allows multiple pollutant removal processes to operate. The wetland environment provides an ideal environment for gravitational settling, biological uptake, and microbial activity. Constructed wetlands are the final element in the roof-to-stream runoff reduction sequence. They should only be considered for use after all other upland runoff reduction opportunities have been exhausted and there is still a remaining water quality or Channel Protection Volume to manage.

Design Criteria: Research and experience have shown that the internal design geometry and depth zones are critical in maintaining the pollutant removal capability and plant diversity of Stormwater wetlands. Wetland performance is enhanced when the wetland has multiple cells, longer flowpaths, and a high ratio of surface area to volume. Whenever possible, Stormwater wetlands should be irregularly shaped with long, sinuous flow paths. The following design elements are required for Stormwater wetlands:

1. Multiple-Cell Wetlands: Wetland should be divided into at least four internal sub-cells of different elevations: the forebay, at least two wetland cells, and a micro-pool outlet. The first cell (the forebay) is deeper and is used to receive runoff from the pond cell or the inflow from a pipe or open channel and distribute it evenly into successive wetland cells. The purpose of the wetland cells is to create an alternating sequence of aerobic and anaerobic conditions to maximize nitrogen removal. The fourth wetland cell is located at the discharge point and serves as a micro-pool with an outlet structure or weir. Each wetland sub-cell can be differentiated by sand berms (anchored by rock at each end), back-filled coir fiber logs, or forested peninsulas extending as wedges across 95% of the wetland cell width. If there are elevation drops greater than 1 foot between cells, then the designer should consider using an earthen berm with a spillway, concrete weir, gabion baskets, or other means that provide adequate freeboard to pass expected peak. In addition, stable conveyance between cells should be provided based on the elevation change and expected velocities.
2. Detention Storage Ponding Depth: Where a Stormwater Wetland basin incorporates detention storage for larger storms, the detention elevation above the permanent pool should be 1 vertical foot or less. Where a multiple-cell design is used, the detention storage limits are as follows:
    - Multi-cell wetlands must be designed so that the water level fluctuation associated with the maximum "Design Volume" storm (a 1-inch rainfall event) is limited to 6 to 8 inches.
    - The maximum water level fluctuation during the larger design storm associated with local detention requirements (as applicable) should be limited to 12 inches in the wetland cells. This can be achieved by using a long weir structure capable of passing large flows at relatively low hydraulic head. If this standard cannot be met within the Stormwater wetland footprint, the designer should use the pond/wetland combination design or an "off-line" design whereby the wetland receives only flow associated with the Design Volume, and larger flows are diverted to other detention facilities.
    - For the pond/wetland combination, the maximum detention storage depth may be up to 5 feet above the wet pond cell permanent pool (but not the wetland cells). Wetland designs may have a mean pool depth greater than 1 foot.
3. High marsh Zone: Approximately 70% of the wetland surface area must exist in the high marsh zone (-6 inches to +6 inches relative to the normal pool elevation).

4. Transition Zone: The low marsh zone (-6 to -18 inches below the normal pool elevation) is no longer an acceptable wetland zone, and is only allowed as a short transition zone from the deeper pools to the high marsh zone. In general, this transition zone should have a maximum slope of 5H:1V (or preferably flatter) from the deep pool to the high marsh zone. It is advisable to install biodegradable erosion control fabrics or similar materials during construction to prevent erosion or slumping of this transition zone.

Limitations: Must maintain an adequate water balance, meaning there must be enough water supplied from groundwater, runoff, or baseflow. Permeable soils or karst geology will need a liner. No constraints for water table and put strong consideration on the contaminant transport.

Maintenance:

- Measure sediment accumulation levels in forebays and micropools.
- Monitor the growth and survival of emergent wetlands and tree/shrub species.
- Inspect the condition of Stormwater inlets to the wetland for material damage, erosion or undercutting.
- Inspect maintenance access to ensure it is free of woody vegetation.
- Inspect the condition of the principal spillway and riser for evidence of joint failure.
- Inspect internal and external side slopes of the wetland for evidence of erosion.
- Control invasive species.

Stormwater Control Measure 7.4: Permeable Pavement/Pavers

Description: Permeable pavements area alternative paving surfaces that allow Stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. Porous paving systems have several design variants.

The four major categories are:

1) pervious concrete
2) modular block paver systems
3) porous asphalt
4) grass and gravel pavers

All have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom.

Purpose and Application: The pavement course should be selected based on the project's budget and desired appearance as well as the types of loadings that will be applied to the permeable pavement. Designers may propose other types of pavement courses but they will be responsible for showing that their proposed design will function well both hydraulically and structurally in both short and long term. See below for a summary of the most commonly used pavement courses and some of the pros and cons of each.

Permeable Interlocking Concrete Pavers (PICP)	
PICPs are a type of unit paver system that maintains drainage through gaps between the pavers filled with small, uniformly graded gravel. The pavers are bedded on a gravel layer that provides uniform support and drainage.	
Pros	Well suited for plazas, patios, small parking areas, parking stalls and residential streets. Compared to PC and PA, PICP is easier and less costly to renovate if it becomes clogged or damaged. The Interlocking Concrete Pavement Institute offers a PICP Specialist Certification Program for contractors.
Cons	PICO often has the highest initial cost for materials and installation. The regular maintenance of PICP is more expensive than PC and PA because of the need to refill the gravel after street sweeping and the greater occurrence of weeds.

Pervious Concrete (PC)	
PC is produced by reducing the fines in a conventional concrete mix to maintain interconnected void space for drainage. Pervious concrete has a coarser appearance than standard concrete.	
Pros	PC is the most structurally sound permeable course, making it a good choice for travel lanes or larger vehicles in addition to parking areas, patios and residential streets. The regular maintenance costs are lower than PICP and CGP. PC has a design guide, construction specification and a contractor certification program managed by independent organizations (American Concrete Institute and National Ready Mixed Concrete Association).
Cons	Mixing and installation must be done correctly or the PC will not function properly. It may be difficult to restore permeability to the PC after a significant loss of initial permeability without removing it and installing a new course.
Porous Asphalt (PA)	
PA is very similar to standard asphalt except that the fines have been removed to maintain interconnected void space. PA may not be approved unless the designer shows that the design provides equal or better performance than PICP and PC.	
Pros	May be more economical in initial cost than PC for large scale operations (greater than 100,000 square feet).
Cons	PA does not offer the structural strength of PC and it has a much shorter design life, typically less than 15 years. There are also concerns about unknowingly using asphalt sealants or overlays that would eliminate the permeability of the PA. Mixing and installation must be done correctly or the PA will not function properly.

<table>
<tr><th colspan="3">Concrete Grid Pavers (CGP)</th></tr>
<tr><td colspan="2">CGPs are an "older cousin" to PICPs and have relatively larger open areas that are filled with gravel, sand, or even a loamy sand top soil. CGPs may not be approved for vehicular loads unless the designer shows that the design provides equal or better performance than PICP and PC.</td><td></td></tr>
<tr><td>Pros</td><td colspan="2">CGP is a somewhat less expensive paver option than PICP.</td></tr>
<tr><td>Cons</td><td colspan="2">The vast majority of sites observed by DWQ staff exhibited problems with waviness (differential settling) or clogging caused by soil and vegetation in the grids (or both). CGP should only be used for non-travel purposes or occasional use (fire lanes, police cut through lanes, etc).</td></tr>
<tr><th colspan="3">Plastic Turf Reinforcing Grid (PTRG)</th></tr>
<tr><td colspan="2">PRP is constructed of a large recycled crumb rubber granulate which creates a very porous open grid surface allowing for rapid rainwater dispersion and quick drying.</td><td></td></tr>
<tr><td>Pros</td><td colspan="2">Reduces hardscape expenses and maximizes lawn area.</td></tr>
<tr><td>Cons</td><td colspan="2">PTRG has less structural strength than the other pavement course options, especially if used under wet conditions. Also, the use of soil and vegetation between the grids makes it prone to clogging.</td></tr>
</table>

Pervious Rubber Pavement (PRP)	
PRP is constructed of a large recycled crumb rubber granulate which creates a very porous open grid surface allowing for rapid rainwater dispersion and quick drying.	
Pros	PRP has better slip resistance and shock absorption than traditional hardscape material.
Cons	When exposed to high temperature, PRP may give a strong rubber smell. Recycled rubber products may leach heavy metals and toxic chemicals into the soil, potentially damaging nearby plants.

Design Criteria: If permeable pavement will be used in a parking lot or other setting that involves vehicles, the pavement surface must be able to support the maximum anticipated traffic load. The structural design process will vary according to the type of pavement selected, and the manufacturer's specific recommendations should be consulted. The thickness of the permeable pavement and reservoir layer must be sized to support structural loads and to temporarily store the design storm volume (e.g., the water quality, channel protection, and/or flood control volumes). On most new development and redevelopment sites, the structural support requirements will dictate the depth of the underlying stone reservoir.

The structural design of permeable pavements involves consideration of four main site elements:

- Total traffic
- In-situ soil strength
- Environmental elements
- Bedding and Reservoir layer design

The resulting structural requirements may include, but are not limited to, the thickness of the pavement, filter, and reservoir layer. Permeable pavement is typically sized to store the complete runoff reduction volume) or another design storm volume in the reservoir layer. Modeling has shown that this simplified sizing rule approximates an 80% average rainfall volume removal for subsurface soil infiltration rates up to one inch per hour. More conservative values are given because both local and national experience has shown that clogging of the permeable material can be an issue, especially with larger contributing areas carrying significant soil materials onto the permeable surface.

The infiltration rate typically will be less than the flow rate through the pavement, so that some underground reservoir storage will usually be required. Designers should initially assume that there is no outflow through underdrains, to determine the depth of the reservoir layer, assuming runoff fully infiltrates into the underlying soil.

Design recommendations:

- For design purposes, the native soil infiltration rate should be the field-tested soil infiltration rate divided by a factor of 2. The minimum acceptable native soil infiltration rate is 0.5 inches/hr.
- Max drain time for the reservoir layer should be not less than 24 or more than 48 hours.

The use of underdrains is recommended when there is a reasonable potential for infiltration rates to decrease over time, when underlying soils have an infiltration rate of less than 1/2-inch per hour, or when soils must be compacted to achieve a desired density. Underdrains can also be used to manage extreme storm events to keep detained Stormwater from backing up into the permeable pavement.

Conveyance and Overflow: Permeable pavement designs should include methods to convey larger storms of 10-yr 24 hour to the storm drain system. The following is a list of methods that can be used to accomplish this:

- Place a perforated pipe horizontally near the top of the reservoir layer to pass excess flows after water has filled the base. The placement and/or design should be such that the incoming runoff is not captured (e.g., placing the perforations on the underside only).
- Increase the thickness of the top of the reservoir layer by as much as 6 inches (i.e., create freeboard). The design computations used to size the reservoir layer often assume that no freeboard is present.
- Create underground detention within the reservoir layer of the permeable pavement system.
- Set the storm drain inlets flush with the elevation of the permeable pavement surface to effectively convey excess Stormwater runoff past the system (typically in remote areas). The design should also make allowances for relief of unacceptable ponding depths during larger rainfall events. Route excess flows to another detention or conveyance system that is designed for the management of extreme event flows. Details below are possibilities of safe conveyance of the 10-year, 24 hour storm.

Limitations and Maintenance: Permeable pavements should not be used for high speed roads, hotspots, or areas with high sediment or trash/debris loads. Surface inspections of the pavement are necessary to look for evidence of sediment deposition, organic debris, staining or ponding that may indicate surface clogging. Area requires vacuum sweeping regularly. Check inlets, pretreatment cells and any flow diversion structures for sediment buildup.

Construction Planning:

- All permeable pavement areas should be fully protected from sediment intrusion by silt fence or construction fencing, particularly if they are intended to infiltrate runoff.
- Permeable pavement areas should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. Permeable pavement areas should be clearly marked on all construction documents and grading plans. To prevent soil compaction, heavy vehicular and foot traffic should be kept out of permeable pavement areas during and immediately after construction.
- During construction, care should be taken to avoid tracking sediments onto any permeable pavement surface to avoid clogging.
- Any area of the site intended ultimately to be a permeable pavement area should generally not be used as the site of a temporary sediment basin. Where locating a sediment basin on an area intended for permeable pavement is unavoidable, the invert of the sediment basin must be a minimum of 2 feet above the final design elevation of the bottom of the aggregate reservoir course. All sediment deposits in the excavated area should be carefully removed prior to installing the sub-base, base and surface materials.

Stormwater Control Measure 7.5: Infiltration Area

Drainage from an impervious surface is directed to an infiltration area.

Description: Infiltration areas are properly sized engineered vegetated areas designated to receive runoff from disconnected roof downspouts, driveways, parking lots, and other impervious areas. Infiltration areas are low cost and have been proven to reduce the volume and flows associated with Stormwater runoff.

Purpose and Application: This method of Stormwater management provides a cost effective way to promote infiltration, and reduce runoff volume and peak discharge.

Maintenance: Remove sediment and debris from contributing impervious surfaces. Repair any areas that are eroding or where vegetation has died. Re-grade the soil to remove the gully and re-seed and water until fully established.

Design Criteria: An Infiltration Area is a vegetated area that is sized and graded to receive discharges runoff from built-upon area (usually a roof or a paved surface) to reduce runoff and pollutants. Much of the development across the state has been designed as connected impervious surface; that is, draining to pipes and ditches that rapidly convey Stormwater without runoff reduction or treatment. Infiltration Area can only work if impervious surfaces are disconnected and runoff is routed to it. Using Infiltration Area and Disconnected Impervious Surface (DIS) technique can help restore the hydrology of streams and reduce pollutant loadings. Major design elements include:

1. The Infiltration Area shall not include any impervious surface

2. The Infiltration Area shall have a maximum slope of 7% for B, C and D soils and 15% for A soils with land graded to promote diffuse flow in all directions. Vegetative cover shall be established dense lawn with no clumping species.
3. If the Infiltration Area is established on fill soils that are less permeable than the in-situ soils, then the soil type for crediting purposes shall be based on the fill soils. However, if the fill soils are more permeable than the in-situ soils, then the soil type for crediting shall reflect the in-situ soil type.
4. The vegetated cover shall be established dense lawn with no clumping species.
5. All sites built within the past fifty years shall be tilled to eight inches prior to vegetation establishment.
6. Recommended: There should be a minimum 5-foot distance between building foundation and Infiltration Area.
7. Some applications may require an overflow or outlet structure to covey Stormwater away from the infiltration area once it has reached the point of saturation.

Construction Specifications: For a new construction project, a preconstruction meeting is highly recommended to ensure contractors understand the locations and function of the Infiltration Area. Contractors will need to understand the need to construct the site drainage system according to the plans. Also, contractors shall grade and till the vegetated receiving areas as one of the last steps in the site construction process. A preconstruction meeting is also an opportunity to discuss other unique construction considerations for Infiltration Area.

Stormwater Control Measure 7.6: Filter Strip

Description: Filter strips are areas of dense vegetation located between runoff pollutant sources and other SCMs or receiving water bodies. Filter strips may be constructed of turf, meadow grasses, or other vegetation such as landscape plantings. Filter strips act to impede the velocity of Stormwater runoff (thereby allowing sediment to settle out), to reduce the impacts of temperature, and to encourage infiltration. Filter strips are a water quality BMP to slow the rate of runoff, reduce peak flows, and to allow for infiltration to a lesser extent.

Purpose and Application: Filter strips are vegetated areas that treat sheet flow delivered from adjacent areas by slowing runoff velocities and allowing sediment and attached pollutants to settle and/or be filtered by vegetation. Impervious areas are disconnected and runoff is routed over a level spreader to sheet flow over adjacent vegetated areas. This slows runoff velocities, promotes infiltration, and allows sediment and attached pollutants to settle and/or be filtered by the vegetation. Filter Strips may also be used as pretreatment for another Stormwater practice such as a grass channel, bioretention, or infiltration areas. If sufficient pervious area is available at the site, larger areas of impervious cover can be treated by filter strips, using an engineered level spreader to recreate sheet flow.

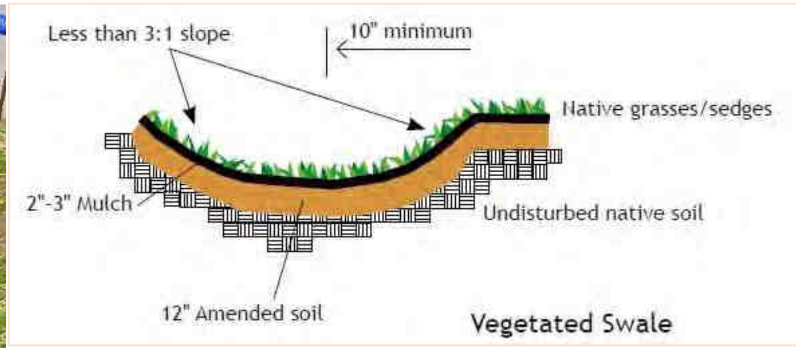
Maintenance: Watering, fertilizing, and weeding, especially in the first two years while plants are becoming established. Repair erosion and vegetation as necessary. Aerate soil as particulates accumulate to promote growth.

Design Criteria: Filter strips should be planted at such a density to achieve a 90% grass/herbaceous cover after the second growing season. Performance has been shown to fall rapidly as vegetative cover falls below 80%. Filter strips should be seeded, not sodded, whenever possible. Seeding establishes deeper roots, and sod may have muck soil that is not conducive to infiltration. The filter strip vegetation may consist of turf grasses, meadow grasses, other herbaceous plants, shrubs, and trees, as long as the primary goal of at least 90% coverage with grasses and/or other herbaceous plants is achieved. Designers should choose vegetation that stabilizes the soil and is salt tolerant. Vegetation at the toe of the filter, where temporary ponding may occur behind the permeable berm, should be able to withstand both wet and dry periods. The planting areas can be divided into zones to account for differences in inundation and slope.

Stormwater must enter the filter strip or conserved open space as sheet flow. If the inflow is from a pipe or channel, an engineered level spreader must be designed in accordance with the criteria contained herein to convert the concentrated flow to sheet flow.

Filter strips are best suited to treat runoff from small segments of impervious cover (usually less than 5,000 sf) adjacent to road shoulders, small parking lots, and rooftops. Human activity, slopes, and soil type influence the location of filter strips. Select a location to prevent vegetation damage and soil compaction from pedestrian traffic or unintended vehicle compaction. Optimum filter strip locations are often located to the side or downhill of high-volume vehicle or pedestrian traffic areas. Filter strips are generally most effective when used to manage a small capture area, or in conjunction with other BMPs.

Stormwater Control Measure 7.7: Vegetated Swale



Description: Designed to manage runoff primarily by reducing its velocity for increased treatment efficiency by a downstream practice. Vegetated surface provides water quality pretreatment through filtering, biological uptake mechanisms, and subsoil ion exchange capacity. Subsoil can also provide a relatively small amount of runoff volume reduction especially when check dams are used. These attributes, in addition to low installation and maintenance costs, make the vegetated swale preferable to the traditional system of curb and gutter, storm drains, and pipes for managing Stormwater runoff.

Purpose and Application: Vegetated swales are well suited as pretreatment structures for a volume reducing BMP such as upstream of an infiltration trench or bioretention area. Vegetated swales can also be used in residential, commercial, or institutional developments along parking lot edges or islands, around buildings, or along driveways. Vegetated swales should be applied in linear configurations parallel to the contributing impervious cover, such as roads and small parking areas to allow for level spreading and not concentrating flow at one inlet and similarly to prevent a bottleneck or clogging at said single inlet.

Limitations: Contributing Drainage Area: The development density of the contributing drainage area (CDA) affects peak runoff rates and the amount of land available for the footprint of the practice. Also note that the CDA for a single Vegetated swale must be 5 acres or less to reduce the occurrence of channel failure due to erosive velocities. When vegetated swales treat and convey runoff from drainage areas greater than 5 acres, the velocity and flow depth through the channel become too great to treat runoff or prevent channel erosion.

- Slopes: Vegetated swales are most effective on grades less than 5%. Vegetated swales should be designed on areas allowing for longitudinal slopes less than 4%.

Slopes greater than 4% create rapid runoff velocities that can cause erosion and do not allow enough contact time for filtering or infiltration unless check dams are used. However, terracing a series of Vegetated swale cells may work on slopes from 5% to 10%. The drop in elevation between check dams should be limited to 18 inches in these cases, and the check dams should be armored on the downslope side with properly sized stone to prevent erosion. Longitudinal slopes less than 2% are ideal and may eliminate the need for check dams. Channels having longitudinal slopes less than 1% must be monitored carefully during construction to ensure a continuous grade to avoid flat areas holding pockets of standing water, which could cause ancillary problems, i.e. mosquitos.

- Soils: Vegetated swales can be used in all hydrologic soil groups, but soil amendments may be required to enhance performance in C or D soils. Vegetated swales should not be used on soils with infiltration rates less than or equal to 0.5" per hour if infiltration of small runoff flows is intended.
- Depth to Water Table: The bottom of a vegetated swale must be at least 2 feet above the seasonally high water table to prevent water standing in the swale or cause the channel bottom to remain saturated and fail.

Maintenance: Once established, vegetated swales have minimal maintenance needs outside of the spring cleanup, regular mowing, repair of check dams and other measures to maintain the hydraulic efficiency of the channel and a dense, healthy grass cover. Maintenance requirements for vegetated swales include the following:

1. Maintain grass height of 3 to 4 inches.
2. Remove sediment build up in channel bottom when it accumulates to 25% of original total channel volume.
3. Ensure that rills and gullies have not formed on side slopes. Correct if necessary.
4. Remove trash and debris build up.
5. Replant areas where vegetation has not been successfully established.

Design Criteria: The first step in designing Vegetated swales is to identify the size of the CDA to each channel. Once the CDA is identified, the cover type(s) must then be identified to determine the net runoff volume for the appropriate design storm. Using the cover type(s) to determine the CN for the CDA, the net runoff volume can be calculated from the regionally-specific design storm using the following procedure:

- This net runoff volume (or some smaller fraction if another practice will be used to handle the remaining volume) is the target volume to be handled by the vegetated swale. The Contributing Drainage Area to a single channel must be less than or equal to 5acres.
- Design Flow Rate: The primary design criterion for vegetated swales is flow rate. For relatively steeper slopes (2% – 4%), check dams may be necessary in order to meet the allowable max flow velocities.

- Channel Dimensions: The dimensions of a vegetated swale must convey the required flow at a velocity that is non-erosive. A channel should be sized to convey the 10 yr 24 hr storm (or 10-yr peak runoff if using the rational method) for channel sizing unless an alternate path for high flows is available. It is recommended that the velocity not exceed 1 fps unless supporting calculations are provided to demonstrate that erosive conditions will not occur through the use of TRMs or other methods.

Construction Specifications: Do not compact or subject existing subgrade in vegetated channels to excessive construction equipment traffic. Protect areas from vehicle traffic during construction with construction fence, silt fence, or compost sock. Excavating equipment should operate from the side of the channel and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an infiltration trench is not proposed) 18 inches shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil shall be thoroughly deep plowed into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores.

- Install overflow structure and other Stormwater structures: close and secure all inlets, pipes, trench drains, and other structures to prevent runoff from entering the vegetated channel prior to completion and site stabilization. Maintain drainage overflow pathways during construction while the vegetated channel is closed to provide for drainage during storm events.
- Vegetate Channel: Hydro-seed the bottom and banks of the grass channel, and peg in erosion control fabric or blanket where needed. After initial planting, a biodegradable erosion control fabric should be used. Prepare planting holes for any trees and shrubs, then plant materials as shown in the landscaping plan and water them weekly in the first two months.
- Inspections during construction are needed to ensure that the grass channel is built in accordance with these specifications. Some common pitfalls can be avoided by careful post-storm inspection of the grass channel:
- Make sure the desired coverage of turf or erosion control fabric has been achieved following construction, both on the channel beds and their contributing side-slopes.
- Inspect check dams and pre-treatment structures to make sure they are at correct elevations, are properly installed, and are working effectively.
- Make sure outfall protection/energy dissipation at concentrated inflows are stable.

Stormwater Control Measure 7.8: Bio-retention, Rain Gardens, and Silva Cells

Description: Bioretention areas are vegetated, shallow surface depressions that use the interaction of plants, soil, and microorganisms to store, treat, and reduce runoff volume, and to reduce the flow rate of Stormwater runoff. Bioretention areas are generally flat and include engineered or modified soils that allow drainage of Stormwater through soils; during storms, runoff temporarily ponds 6 to 12 inches above the mulch layer and then rapidly filters through the bed.

A Silva cell is an urban tree planter system that can be constructed as a bioretention system as well. A porous surface (such as porous pavers) are placed over a section of Silva cells drainage modules to allow for stormwater infiltration into the planting soil. Curb inlets also convey stormwater to the soil. The Silva cells reduce water discharge by soil retention and evapotranspiration, as well as remove pollutants by physical infiltration of particulates and suspended solids during movement through the soil profile.

Purpose and Application: Consider locating bioretention areas in places that are generally "not used" such as traffic islands; between parked cars in parking lots; along edges of public playgrounds, school yards, and plazas; in courtyards; and in place of traditional landscape planting areas. The following site-specific conditions should be considered:

- Select location to prevent vegetation damage and soil compaction from pedestrian traffic or unintended vehicle compaction. Ideal locations are often located to the side or downhill of high vehicle or pedestrian traffic areas. If necessary, provide for pedestrian passage and maintenance access.

Locate bioretention areas:

- Close to the source of runoff.
- To capture runoff from impervious areas and highly compacted pervious areas such as athletic fields and turf areas.
- To capture smaller drainage areas. If necessary, use several connected bioretention areas to address larger areas.

Limitations: Must be built in areas that are generally level (or graded level). Vegetation and soils must be protected from damage and compaction. Maintenance is required to maintain both performance and aesthetics.
Silva cells may be difficult to maintain vegetation under specific flow conditions, particularly during dry weather periods and may need supplemental irrigation. Other considerations for potential limitations include the depth to groundwater, subgrade permeability, soil type, and buried utilities.

Maintenance: Successful establishment of bioretention areas requires that the following tasks be undertaken in the first year following installation:

1. For the first 6 months following construction, the site should be inspected at least twice after storm events that exceed 0.5 inch of rainfall.
2. Spot reseeding. Inspectors should look for bare or eroding areas in the contributing drainage area or around the bioretention area, and make sure they are immediately stabilized with grass cover.
3. Fertilization. One-time, spot fertilization may be needed for initial plantings.
4. Watering. Depending on rainfall, watering may be necessary once a week during the first 2 months, and then as needed during first growing season (April-October), depending on rainfall.
5. Remove and replace dead plants. Since up to 10% of the plant stock may die off in the first year, construction crews should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction. The typical thresholds below which replacement is required are 85% survival of plant material and 100% survival of trees.

It is highly recommended that a spring maintenance inspection and cleanup be conducted at each bioretention area. The following is a list of some of the key maintenance problems to look for:

- Check to see if 75% to 90% cover (mulch plus vegetative cover) has been achieved in the bed, and measure the depth of the remaining mulch.
- Check for sediment buildup at curb cuts, gravel diaphragms or pavement edges that prevents flow from getting into the bed, and check for other signs of bypassing.
- Check for any winter- or salt-killed vegetation, and replace it with hardier species.
- Note presence of accumulated sand, sediment and trash in the pre-treatment cell or filter beds, and remove it.
- Inspect bioretention side slopes and grass filter strips for evidence of any rill or gully erosion, and repair it.
- Check the bioretention bed for evidence of mulch flotation, excessive ponding, dead plants or concentrated flows, and take appropriate remedial action.
- Check inflow points for clogging, and remove any sediment.
- Look for any bare soil or sediment sources in the contributing drainage area, and stabilize them immediately.
- Check for clogged or slow-draining soil media, a crust formed on the top layer, inappropriate soil media, or other causes of insufficient filtering time, and restore proper filtration characteristics.

Design Criteria: Filter Media to contain:

- 85%-88% sand
- 8%-12% soil fines
- 3%-5% organic matter in the form of leaf compost

The volume of filter media based on 110% of the plan volume, to account for settling or compaction. Mulch Layer is aged, shredded hardwood bark mulch. Lay a 2 to 3 inch layer on the surface of the filter bed.

Top Soil: Loamy sand or sandy loam texture, with less than 5% clay content, pH corrected to between 6 and 7, and an organic matter content of at least 2% at 3 inch surface depth.

Storage Layer: 1 inch stone should be double-washed and clean. 12 inches for the underdrain; 12 to 18 inches for the stone storage layer, if needed.

Underdrains, Cleanouts, and Observation Wells: Use 6 inch rigid schedule 40 PVC pipe (or equivalent corrugated HDPE for micro-bioretention), with 3/8-inch perforations at 6 inches on center; position each underdrain on a 1% or 2% slope located no more than 20 feet from the next pipe. Lay the perforated pipe under the length of the bioretention cell, and install non-perforated pipe as needed to connect with the storm drain system. Install T's and Y's as needed, depending on the underdrain

Plant Materials:

- Plant one tree per 250 square feet (15 feet on-center, minimum 1 inch caliper).
- Shrubs a minimum of 30 inches high planted a minimum of 10 feet on-center.
- Plant ground cover plugs at 12 to 18 inches on-center; Plant container-grown plants at 18 to 24 inches on-center, depending on the initial plant size and how large it will grow.

Establish plant materials as specified in the landscaping plan and the recommended plant list. In general, plant spacing must be sufficient to ensure the plant material achieves 80% cover in the proposed planting areas within a 3-year period. If seed mixes are used, they should be from a qualified supplier, should be appropriate for Stormwater basin applications, and should consist of native species (unless the seeding is to establish maintained turf).

Construction Specifications: The following is a typical construction sequence to properly install a bioretention measure. The construction sequence for micro-bioretention is more simplified. These steps may be modified to reflect different bioretention applications or expected site conditions:

Step 1. Construction of the bioretention area may only begin after the entire contributing drainage area has been stabilized with vegetation. It may be necessary to block certain curb or other inlets while the bioretention area is being constructed. The proposed site should be checked for existing utilities prior to any excavation.

Step 2. The designer and the installer should have a preconstruction meeting, checking the boundaries of the contributing drainage area and the actual inlet elevations to ensure they conform to original design. Since other contractors may be responsible for constructing portions of the site, it is quite common to find subtle differences in site grading, drainage and paving elevations that can produce hydraulically important differences for the proposed bioretention area. The designer should clearly communicate, in writing, any project changes determined during the preconstruction meeting to the installer and the plan review/inspection authority.

Step 3. Temporary erosion and sediment controls are needed during construction of the bioretention area to divert Stormwater away from the bioretention area until it is completed. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during the construction process.

Step 4. Any pre-treatment cells should be excavated first and then sealed to trap sediments.

Step 5. Excavators or backhoes should work from the sides to excavate the bioretention area to its appropriate design depth and dimensions. Excavating equipment should have scoops with adequate reach so they do not have to sit inside the footprint of the bioretention area. Contractors should use a cell construction approach in larger bioretention basins, whereby the basin is split into 500 to 1,000 sq. ft. temporary cells with a 10-15 foot earth bridge in between, so that cells can be excavated from the side.

Step 6. It may be necessary to rip the bottom soils to a depth of 8 to 12 inches to promote greater infiltration.

Step 7. Place geotextile fabric on the sides of the bioretention area with a 6-inch overlap on the sides. If a stone storage layer will be used, place the appropriate depth of #57 stone on the bottom, install the perforated underdrain pipe, pack #57 stone to 3 inches above the underdrain pipe, and add approximately 3 inches of choker stone/pea gravel as a filter between the underdrain and the soil media layer.

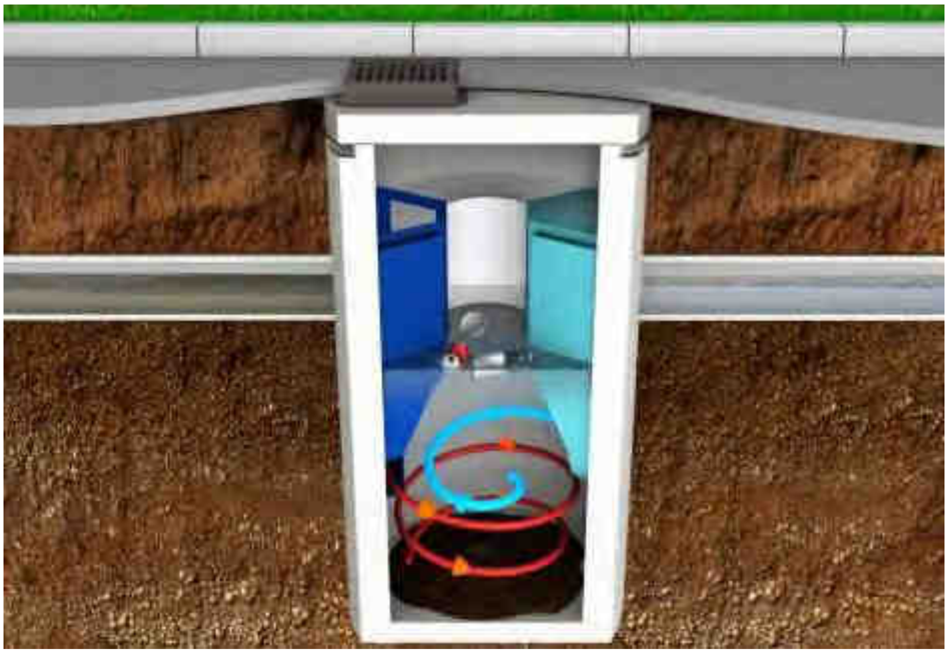
Step 8. Deliver the soil media from an approved vendor, and store it on an adjacent impervious area or plastic sheeting. Apply the media in 12-inch lifts until the desired top elevation of the bioretention area is achieved. Wait a few days to check for settlement, and add additional media, as needed, to achieve the design elevation.

Step 9. Prepare planting holes for any trees and shrubs, install the vegetation, and water accordingly. Install any temporary irrigation.

Step 10. Place the surface cover in both cells (mulch, river stone or turf), depending on the design. If coir or jute matting will be used in lieu of mulch, the matting will need to be installed prior to planting, and holes or slits will have to be cut in the matting to install the plants.

Step 11. Install the plant materials as shown in the landscaping plan, and water them during weeks of no rain for the first two months.

Stormwater Control Measure 7.9: Water Quality Devices



Description: Water Quality Devices are best management practices that use proprietary settling, filtration, absorption/adsorption, vortex principles, vegetation, and other processes to meet the Stormwater Management Standards. Although there are some proprietary devices that are used to control Stormwater quantity such as underground storage and cistern, the common purpose of proprietary devices is for TSS removal. There are two general types of Proprietary BMPs: hydrodynamic separators and filtering systems. Both of which are used to control Stormwater pollution using the movement of water and water's properties to settle or filter pollutants from the Stormwater. Commonly, this is accomplished in a large underground structure. Hydrodynamic devices are widely used flow-through structures that include a settling or separation unit to remove sediments and other pollutants. No outside power source is required, because the energy of the flowing water allows the sediments to efficiently separate. Depending on the type of unit, this separation may be by means of swirl action or indirect filtration. Units are designed to meet specific pollutant removal requirements.

Purpose and Application: In order for use as a limited application control, a proprietary system must have a demonstrated capability of meeting the Stormwater management goals for which it is being intended.

This means that the system must provide:

1. Independent third-party scientific verification of the ability of the proprietary system to meet water quality treatment objectives and/or to provide water quantity control (channel or flood protection);
2. Proven record of longevity in the field; and,
3. Proven ability to function in local conditions (e.g., climate, rainfall patterns, soil types, etc.).

For a proprietary system to meet item (1) listed above, the following monitoring criteria should be met for supporting studies:

- At least 15 storm events must be sampled
- The study must be independent or independently verified (i.e., may not be conducted by the vendor or designer without third-party verification)
- The study must be conducted in the field, as opposed to laboratory testing
- Field monitoring must be conducted using standard protocols which require proportional sampling both upstream and downstream of the device
- Concentrations reported in the study must be flow-weighted
- The propriety system or device must have been in place for at least one year at the time of monitoring

Although local data is preferred, data from other regions can be accepted as long as the design accounts for the local conditions. The University Stormwater program may submit a proprietary system to further scrutiny based on the performance of similar practices. A poor performance record or high failure rate is valid justification for not allowing the use of a proprietary system or device.

Construction Specifications: EPA has created the ETV Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

Maintenance: Maintenance is especially important with these devices. Clogging of devices not only can hinder removal of pollutants but may also create drainage problems. A general rule of thumb is that these devices must be cleaned out 1–2 times a year. Proper maintenance involves frequent inspections throughout the first year of installation. When the unit has reached capacity, it must be cleaned out. This may be performed with a sump vac or vacuum truck, depending on which unit is used.

Table 1: List of Proprietary Water Quality Devices with Pollutant Removal Rates

Manufactured Treatment Device Name	Certified TSS Removal Rate	Website
Aquafilter (AquaShield)	80.5%	http://www.aquashield.com/
Aqua-Swirl Concentrator (AquaShield)	80.5%	http://www.aquashieldinc.com/-aqua-swirl-resources.html
BayFilter (BaySaver Technologies, Inc)	82.9%	http://www.baysaver.com/products/BayFilter/index.html
Stormfilter (Contech)	80%	http://www.conteches.com/products/stormwater-management/treatment/stormwater-management-stormfilter
Media Filtration System MFS (Contech)	86%	http://www.conteches.com/products/stormwater-management/treatment/mfs
Water Quality Vault (Crystal Stream)	96%	http://crystalstream.com/products-overview/
Unistorm (Environment 21)	80%	http://www.env21.com/Unistorm.html
FloGard Dual Vortex Hydrodynamic Separator (KriStar)	80%	http://www.kristar.com/index.php/hydrodynamic-separators/flogard-dual-vortex
ecoStorm (Royal Enterprises)	80%	http://www.royalenterprises.net/prod/swtr_ecostormp_tpre.php
Terre Kleen Hydrodynamic Separator (Terre Hill)	86%	http://www.terrestorm.com/terre_kleen.php
Up-Flo Filter (Hydro International)	80%	http://www.hydro-int.com/us/products/up-flo-filter
Vortechnics, Inc. *Vortechs System, Model 11000* (Contech)	82%	http://www.conteches.com/Products/Stormwater-Management/Treatment/Vortechs
Arkal Pressurized Stormwater Filtration System (Zeta Technology, Inc.)	82%	http://archive.epa.gov/nrmrl/archive-etv/web/pdf/09_vs_arkal.pdf