PART 1A – Nationwide Review of Best Management Practices for Stormwater Management (Construction Phase)

Florida Board of Professional Engineers

Approved Course No. 0010329

4 PDH Hours

A test is provided to assess your comprehension of the course material – 24 questions have been chosen from each of the above sections. You will need to answer at least 17 out of 24 questions correctly (>70%) in order to pass the overall course. You can review the course material and re-take the test if needed.

You are required to review each section of the course in its entirety. Because this course information is part of your Professional Licensure requirements it is important that your knowledge of the course contents and your ability to pass the test is based on your individual efforts.

Course Description:

Uncontrolled stormwater runoff from construction sites can significantly impact rivers, lakes, and estuaries. Sediment in waterbodies from construction sites can reduce the amount of sunlight reaching aquatic plants, clog fish gills, smother aquatic habitat and spawning areas, and impede navigation.

This course is part of a 4 course, 2-PART Series of a compilation of nationwide Best Management Practices (BMPs) published by the U.S. Environmental Protection Agency (EPA). The course includes BMP fact sheets describing practices that engineers involved with stormwater management may want to consider and the fact sheets generally provide applicability, implementation, and effectiveness information. Overall this series offers a total of 16 PDH credit hours (Parts 1A, 1B, and 2A, 2B)

Part 1 is further separated into 2 courses (Part 1A and 1B) and covers **Stormwater BMPs related to the Construction Phase** of projects and will cover areas of interest including:

- Construction Site Planning and Management
- Erosion Control
- Runoff Control
- Sediment Control
- Good Housekeeping/Materials Management

Part 2 is further separated into 2 courses (Part 2A and 2B)Part 2 is covers **Stormwater BMPs related to the Post-Construction Phase** of projects and will cover areas of interest including:

- Innovative BMPs for Site Plans
- Infiltration
- Filtration
- Retention/Detention

How to reach Us …

If you have any questions regarding this course or any of the content contained herein you are encouraged to contact us at Easy-PDH.com. Our normal business hours are Monday through Friday, 10:00 AM to 4:00 PM; any inquiries will be answered within 2 days or less. Contact us by:

EMAIL: bajohnstonpe@aol.com
Phone: 813-398-9380

Refer to Course No. 0010329

PART 1A – Nationwide Review of Best Management Practices for Stormwater Management (Construction Phase)

How the Course Works…

What do you want To do?	LOOK For This!
Search for Test Questions and the relevant review section	Q1 — Search the PDF for: Q1 for Question 1, Q2 for Question 2, Q3 for Question 3, Etc… (Look for the icon on the left to keep you ON Target!)

Easy-PDH.com (FBPE Approved Provider 442)
Britian Arthur Johnston PE (50603)
Johnston Service Corp
CA No. 30074
11909 Riverhills Drive, Tampa FL 33617
Email: bajohnstonpe@aol.com
Phone: 813-398-9380

24 QUESTIONS

Q1: In the construction planning stage of a project what should be done to ensure that sensitive areas are protected:

(A) identify natural features and sensitive areas
(B) mark the location of natural features and sensitive areas on maps and site plans
(C) flag natural features and sensitive areas on-site
(D) All of the Above

Q2: Erosion and sediment controls inspections fall into three categories EXCEPT:

(A) routine inspections
(B) inspections prior to construction sequencing
(C) inspections before rain events
(D) inspections after rain events

Q3: Preserving natural or existing vegetation is desirable in construction phases but if a tree is damaged during construction remove and replace with:

(A) a tree of the same or similar species with a 2 inch or larger caliper
(B) a tree of the same or similar species with a 1 inch or larger caliper
(C) at least 2 trees of the same or similar species with a 2 inch or larger caliper
(D) at least 2 trees of the same or similar species with a 1 inch or larger caliper

Q4: Preserving natural or existing vegetation can provide water quality benefits by reducing the load of stormwater discharges. Forest buffers can reduce total Nitrogen by what quantities:

(A) 5.9 to 12 lbs / square mile of buffer
(B) 5.9 to 12 lbs / acre of buffer
(C) 120 -1500 lbs / square mile of buffer
(D) 120 -1500 lbs / acre of buffer

Q5: Chemical stabilizers, also called soil binders, provide temporary soil stabilization. All of following design factors should be considered by designers before using chemical stabilizers EXCEPT:

(A) cure time
(B) on-site storage capability
(C) dosage or application rate
(D) soil compatability

Q6: On the steeper sloped surfaces (1:1), compost blankets should be used in conjunction with:

(A) netting or other confinement systems
(B) sod
(C) sprayed seed systems
(D) NA, on slopes that steep do not use compost blankets

Q7: A University of Georgia research study found that correctly applied compost blankets provide almost what percentage of soil surface coverage:

(A) 70
(B) 80
(C) 90
(D) 100

Q8: Dust control practices reduce the potential for construction activities to generate dust and which method is one of the most effective ways to control dust:

(A) application of stone
(B) installation of wind breaks
(C) sprinkling or irrigation
(D) spray on chemicals

Q9: Geotextile porous fabrics used for erosion and sediment control purposes are commonly called:

(A) filter fabrics
(B) synthetic fabrics
(C) construction fabrics
(D) All of the Above

Q10: An effective land grading activity that is a low-cost way to reduce stormwater discharge is:

(A) sloping to the highest elevation
(B) sloping to the lowest elevation
(C) preserving existing or established vegetation
(D) installation of diversion structures

Q11: Fine grading, soil treatment, and stabilization costs are approximately:

(A) 4 to 6 dollars per square yard
(B) 4 to 6 dollars per square foot
(C) 6 to 10 dollars per square yard
(D) 6 to 10 dollars per square foot

Q12: Mulching is an effective erosion control practice typical application rates for straw is:

(A) 5 to 8 tons per acre
(B) 1.25 to 2.5 tons per acre
(C) 1 to 2 tons per acre
(D) 0.50 to 1.0 tons per acre

Q13: Typical costs for mulching materials and labor vary but of the following which is the MOST expensive (dollars per acre):

(A) hay, 1 inch application
(B) stone, 3 inch application
(C) wood chips, 2 inch application
(D) hydromulch

Q14: What is the maximum steepness of the slope that riprap can be used before erosion and sliding occur:

(A) 4 to 1
(B) 3 to 1
(C) 2 to 1
(D) 1 to 1

Q15: Some states require that areas that are intended to stabilized with permanent vegetation are seeded within what time period:

(A) within 15 working days
(B) within 90 working days
(C) within 90 days after reaching final grade
(D) A and C

Q16: Actual Costs of sodding depend on many factors but a good cost range is:

(A) 25 to 100 dollars per square meter
(B) 25 to 100 dollars per square yard
(C) 100 to 150 dollars per square meter
(D) 100 to 150 dollars per square yard

Q17: Soil retention structures are commonly used to hold soil in place or keep it contained within a site boundary. The most common low cost method used for short term applications is:

(A) braced system
(B) cantilever system
(C) tie-back system
(D) trench box

Q18: Soil roughening is a temporary erosion control practice and works especially in what situations:

(A) slopes greater than 3 to 1
(B) piles of excavated soil
(C) areas with highly erodible soil
(D) All of the Above

Q19: Temporary slope drains should not exceed an area that is greater than:

(A) 1 acre
(B) 2 acres
(C) 5 acres
(D) 10 acres

Q20: In designing a temporary stream crossing where construction of a culvert is impractical what is the best crossing type to use:

(A) Bridge
(B) Ford
(C) Culvert
(D) Embankment

Q21: Wind fences are only effective when placed perpendicular or near perpendicular to prevailing winds and have an effective porosity of what percentage:

(A) 25
(B) 35
(C) 50
(D) 60

Q22: Check dams are temporary structures constructed within concentrated-flow areas such as swales, channels and ditches and should not be used if the drain area exceeds:

(A) 5 acres
(B) 10 acres
(C) 15 acres
(D) 20 acres

Q23: Grass-lined channels should be used in accordance with the natural drainage system and generally have the following limitations:

(A) do not cross ridges
(B) do not have sharp curves
(C) do not feature significant changes in slope
(D) All of the Above

Q24: During the growing season, grass-lined channels should be cut no shorter than:

(A) 1 inch
(B) 2 inches
(C) the level of the design flow
(D) NA, there is not minimum level

END OF TEST QESTIONS

Stormwater Best Management Practice

Construction Sequencing

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Construction Site Planning and Management

Description

Construction sequencing (also referred to as construction scheduling) involves following a specified schedule that coordinates the timing of earth-disturbing activities and the installation of erosion and sediment control (ESC) practices and post-construction stormwater controls. It is a cost-effective way to control erosion during construction. Construction procedures that limit land clearing, provide for timely installation of ESC practices, and quickly restore protective cover after completion can significantly reduce a site's erosion potential (WES, 2008). Construction sequencing disturbs only part of a site at a time to minimize erosion and sediment transport. Construction staff control and complete grading and earth-disturbing activities in portions of the site with active construction, allowing soil to stabilize there before commencing grading and construction at another part of the site. This sequencing limits the areas with active earth disturbance and promotes phasing of site clearing so that inactive portions of the site are less vulnerable to erosion. To be effective, design engineers and construction staff should incorporate sequencing into the overall site plan in the early stages of project planning.

Applicability

Construction sequencing can be used to plan earthwork and ESC activities at sites where earth disturbance might affect water quality in a receiving waterbody. This practice is particularly important for projects with large areas of earth disturbance.

Siting and Design Considerations

Construction staff should sequence construction projects to reduce the amount and duration of bare soil exposure while maintaining compatibility with the general

Aerial view of a subdivision construction project with sections completed in stages. Some areas are permanently stabilized while other areas are disturbed.

construction schedule. The construction schedule and associated sequencing should plan for an orderly listing of earth-disturbing activities in conjunction with appropriate ESC practices. Protecting existing natural features can help minimize the amount of clearing and grading as well as the amount of ESC practices required, in turn reducing costs (MDE, NRCS, & MASCD, 2011). If possible, earth-disturbing activities should coincide with the dry season to minimize erosion and sediment impacts to downstream waterbodies (MPCA, 2018). Construction staff should achieve final stabilization as quickly as possible after completing major phases.

Table 1 summarizes specific construction activity scheduling considerations. Note that construction staff should install and maintain all scheduling activities and associated ESC practices according to approved grading plans, ESC plans, and applicable regulations.

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Q1

Table 1. Scheduling considerations for construction activities (adapted from MPCA, 2018).

Construction Activity	Schedule Consideration
Construction planning	Before beginning construction activities, construction staff should identify natural features and sensitive areas (e.g., streams, wetlands, buffer zones), mark their locations on maps and site plans, and flag them on-site. ESC practices should be installed, as needed, to protect these features before construction activities. Additionally, construction staff should consider and coordinate the locations of cuts and fills of the land to minimize soil movement. ESC practices should be installed around areas where soil is stockpiled at the site.
Construction access, site entrance, construction routes, areas designated for equipment parking	As soon as construction begins, construction staff should stabilize any bare entrances and exits to the site and traffic routes with gravel and temporary vegetation. During construction sequencing for residential properties, residents who access recently constructed homes should be able to do so from a point that will not disturb active construction activities in another area of the site.
Sediment traps and barriers, basin traps, silt fences, inlet/outlet protection	Within the site, construction staff should install principal basins or other ESC practices—per approved plans—and add more traps and barriers as needed during grading. If existing inlets to the stormwater conveyance system are present on-site, construction staff should also apply ESC practices to these areas to prevent sediment and debris from entering the system during construction activities.
Stormwater control diversions, perimeter dikes, water bars, outlet protection	Construction staff should install ESC practices, per approved plans, during or before initial site access and before land grading. Additional stormwater control measures should be installed during grading, as needed.
Stormwater conveyance system, stabilization of stream banks, storm drains, channels, inlet and outlet protection, slope drains	If applicable, construction staff should stabilize stream banks as soon as possible and install a principal stormwater conveyance system with stormwater control measures. The remainder of the systems should be installed after grading.
Land clearing and grading, site preparation (cutting, filling, and grading; sediment traps; barriers; diversions; drains; surface roughening)	Construction staff should conduct major clearing and grading activities after installing principal ESC practices and key stormwater control measures. Additional ESC practices should be installed as grading continues. Construction staff should clear disposal areas as needed, and mark trees and buffer areas for preservation. Additional ESC practices should be installed as needed.
Surface stabilization, temporary and permanent seeding, mulching, sodding, riprap	Construction staff should immediately apply temporary or permanent stabilizing measures to any disturbed areas where work has either been completed or delayed.
Building construction, utilities installation, paving	During construction, staff should install any erosion and sediment control practices that are needed. These practices should be inspected regularly to ensure they are properly operating and adequately maintained.
Landscaping and final stabilization, topsoil application, trees and shrubs, permanent seeding, mulching, sodding, riprap	Construction staff should remove temporary ESC practices and stabilize all open areas to prevent erosion.

Limitations

Weather and other unpredictable variables might affect construction sequence schedules. However, the site plan should plainly state the proposed schedule and a protocol for making changes due to unforeseen problems.

Maintenance Considerations

Construction staff should follow the construction sequence schedule throughout the project and modify the written plan before changing any construction activities. They should also update the plan and implement additional erosion and sediment control practices if a site inspection indicates the need to do so. This should be a dynamic and ongoing process from project design to completion. Additionally, construction staff should ensure that temporary ESC practices are maintained and properly functioning throughout the project and that temporary and permanent stabilization techniques are effective.

Effectiveness

Construction sequencing effectively reduces erosion and sediment transport because it requires the strategic installation of ESC practices where necessary and appropriate. The sequencing schedule and construction documents should be updated if needed to maximize the effectiveness of the ESC practices under changing conditions. A comparison of sediment loss from a typical development project versus a phased project showed a 40 percent reduction in sediment export in the phased project (Claytor, 2000; NRCS, 2012).

Cost Considerations

Construction sequencing is a low-cost strategy when implemented early and executed correctly during a project. It requires a limited amount of a developer's time to write a plan that coordinates construction activities and management practices. When grading and clearing an entire site at one time, developers should use additional ESC practices to keep sediment from discharging off-site. By using construction sequencing, developers can better reduce costs, minimize maintenance activities and control sediment.

Application and Design Considerations

With very few exceptions (e.g., very small lots or lots with no landscaping), some sort of on-lot treatment applies to most sites. Traditionally, municipalities have encouraged but not widely adopted on-lot treatment of residential stormwater discharge, as the property owner is responsible for initial and maintenance costs. However, more local governments are offering financial incentives for on-lot treatment, such as reducing fees and supporting public outreach (see "Cost Considerations" below).

Although simpler than other types of stormwater controls, on-lot treatment still has certain design elements common to all practices. Pretreatment is important to ensure the controls do not clog with leaf litter or debris. For rainwater collection systems, a settling tank, first flush diverter, or debris-trapping grate or filter in the downspout is recommended.

Both infiltration- and storage-based on-lot treatment stormwater controls typically incorporate some type of bypass to direct heavy stormwater discharges away from buildings. In many cases, this simply entails allowing for an overflow route that will not cause erosion or flooding. For cisterns or rain barrels, emptying the container before large storm events helps prevent the container from overfilling. For example, property owners typically mount a hose at the bottom of the barrel or cistern to irrigate gardens or for landscaping; owners can use the hose to manually empty the tank or connect the hose to a drip tape to allow for slow drawdown after each rain event. In infiltration-based on-lot treatment, an aboveground opening in the downspout can serve as the bypass. Additionally, design engineers can design grassed swales and bioretention cells to absorb all but the largest of stormwater flows. In extreme cases, flows generally pass untreated over these stormwater controls.

When designing infiltration-based on-lot treatment stormwater controls, it is important to locate the infiltration area far enough away from the building's foundation to prevent the undermining of the foundation or basement seepage. The infiltration area should be at least 10 feet away from the house.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

Claytor, R. (2000). Practical tips for construction site phasing. In T. R. Schueler & H. K. Holland (Eds.), *The practice of watershed protection* (pp. 317–322). Ellicott City, MD: Center for Watershed Protection.

Maryland Department of the Environment (MDE), Natural Resources Conservation Service (NRCS), & Maryland Association of Soil Conservation Districts (MASCD). (2011). *2011 Maryland standards and specifications for soil erosion and sediment control.* Baltimore, MD: Maryland Department of the Environment.

Minnesota Pollution Control Agency (MPCA). (2018). Planning, scheduling, and sequencing for construction. In *Minnesota stormwater manual.*

Natural Resources Conservation Service (NRCS). (2012). Revised universal soil loss equation, version 2. U.S. Department of Agriculture.

Water Environment Services (WES). (2008). *Erosion prevention and sediment control: Planning and design manual.*

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Stormwater Best Management Practice

Erosion and Sediment Control Inspection and Maintenance

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Construction Site Planning and Management

Description

Q2

Erosion and sediment controls (ESCs) need regular inspections to ensure their effectiveness, and many permitting authorities require construction staff to perform self-inspections. ESC inspections fall into three categories: routine inspections, inspections before rain events and inspections after rain events.

Routine Inspections

Routine inspections are an integral part of regular maintenance. They are necessary to ensure the integrity and effectiveness of ESCs and give construction staff an opportunity to correct any problems found. Furthermore, routine inspection and maintenance minimizes the work needed to prepare a site before a rain event and helps protect a site from unexpected storms.

Inspections Before Rain Events

It is critically important for construction staff to pay attention to weather forecasts. To prepare for a rain event, they should walk the construction site and ensure that ESCs are clear and operating properly. They should verify that they have covered all dumpsters, covered paint and other chemicals, and cleaned up any oil spills. Construction staff should perform these types of housekeeping practices routinely. They should also visually inspect all ESCs when the site will be inactive for several days, such as over weekends or holidays. This will help to prepare for rain when workers are off-site. These inspections also minimize the risk of on- or off-site property damage due to inoperative or malfunctioning ESCs.

Inspections After Rain Events

After a rain event, construction staff should prepare the site for the next event. Typically, within 48 hours after a rain event, they should inspect, clean and repair any damaged ESCs. This will keep the site “clean” and minimize complaints from nearby residents. To prevent health and safety hazards, staff should remove tracked-out sediment or mud in traffic areas and remove standing water to prevent mosquito breeding. They should also clean or repair any ESC clogged with mud or debris so it works properly the next time it rains.

Construction staff inspecting a storm drain with inlet protection in an active construction area.
Photo Credit: PG Environmental for USEPA

Applicability

Stormwater discharges from construction sites disturbing 1 or more acres are generally covered under a state or EPA permit. These permits typically require construction staff to conduct routine site inspections looking at, for example, installation, function, and operation and maintenance of controls. As well, local permits may impose ESC requirements—and other inspection requirements—on a site. Staff should design and inspect all ESC controls in accordance with applicable local, state and federal requirements. Adequate ESC performance requires not only proper installation, but also regular inspection and maintenance.

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Implementation

The construction site operator should ensure the site undergoes regular inspections. At small sites, the site superintendent or other qualified members of the construction team can perform and document inspection tasks. At large sites, the developers may hire a firm with ESC expertise to implement an inspection, maintenance and repair program for the site. Some permitting authorities require construction sites to undergo inspection by a certified inspector and/or offer inspector certification programs (e.g., the California Water Board's Qualified SWPPP Developer and Practitioner Training Program [CWB, 2020]).

Inspectors should be familiar with the location, design specifications, maintenance procedures and performance expectations of each ESC. Often, a site will have a stormwater pollution prevention plan (SWPPP), which should include specifications for ESC maintenance (e.g., remove sediment before it accumulates to half of the above-ground height of any silt fence or other perimeter control).

> For more information on contractor training programs, see EPA's Contractor Training and Certification fact sheet.

The frequency of required inspections will vary by state. Many permits require weekly inspections, or inspections once every 14 calendar days and within 24 hours of a storm. The inspection frequency may also increase in areas with a higher risk of sediment discharge, or where the site discharges to a sensitive water. The frequency may decrease to account for arid, semiarid, drought or freezing conditions.

At a minimum, inspections should assess the following areas of a site:

- All areas that construction staff have cleared, graded or excavated but not begun stabilizing.
- All ESCs and other types of stormwater controls implemented at the site.
- Material, waste and equipment storage and maintenance areas.
- All areas where stormwater typically flows within the site, including drainageways designed to divert, convey and/or treat stormwater.
- All points of discharge from the site.
- All disturbed locations where staff have begun implementing stabilization measures but have not completed stabilization.

During the inspection, construction staff should check for conditions that could lead to spills, leaks or other accumulations of pollutants on the site. They should check for visible signs of erosion or sediment deposition caused by site activities. They should also check the banks of any waters flowing within or immediately adjacent to the site to ensure site activities and plans are not polluting existing waters. Any areas of erosion or sedimentation may warrant new or modified stormwater controls.

If a discharge is occurring during the inspection, construction staff should identify all discharge points at the site; observe, photograph and document the visual quality of the discharge; and take note of the characteristics of the stormwater discharge (including color; odor; floating, settled or suspended solids; foam; and oil sheen).

Regardless of who does the inspections, it is critical to maintain proper documentation. Inspectors should use an inspection form or checklist to document the findings from each inspection. At a minimum, inspection documentation should include:

- Inspection date
- Name and title of personnel conducting the inspection
- A summary of inspection observations, including notes about required maintenance or corrective actions
- Weather station and rain gauge measurements, as applicable

During an audit, permitting authorities will generally review a construction site's self-inspection reports to assess compliance. Permitting authorities may also wish to see maintenance documentation for each specific ESC. Communities with regulated municipal separate storm sewer (MS4) systems develop programs that should include procedures for site inspection and enforcement of ESC control measures. Therefore, municipal inspectors may also perform inspections of sites to ensure compliance with MS4 and local regulations.

During the span of a construction project, more than one person may have been responsible for site inspections. Therefore, it is important to keep adequate documentation of inspection dates, findings, and maintenance and repair of all ESCs. Site operators should make sure that inspection reports are signed and certified in accordance with permit requirements, keeping a copy of each one at the site or at an easily accessible location so they make it available during an audit or upon request by an inspector.

See the following EPA fact sheets for more information on specific management practices for hazardous materials at construction sites:

- Concrete Washout
- General Construction Site Waste Management
- Spill Prevention and Control Plan
- Vehicle Maintenance and Washing Areas at Construction Sites

Routine Maintenance and Other Corrective Actions

Inspections provide an opportunity to determine where a site needs repairs or other corrections. A well-conducted inspection will identify whether stormwater controls need repair or replacement, or whether specific stormwater controls are absent or incorrectly installed. An inspector may also identify discharges that the permit does not allow, such as discharges from concrete washout areas or releases of fuels, oils, soaps, solvents, or toxic or hazardous pollutants. When inspection reveals conditions such as these, construction staff should take reasonable steps to address the problem, including cleaning up any contaminated surfaces so the material will not discharge in subsequent storms. They should complete minor corrective actions by the close of the next business day. If the corrective action involves significant repairs or installation of a new or replacement control, staff should finish the work within seven calendar days from the time of discovery or as soon as feasible after that. Construction staff should document any corrective actions taken in response to an inspection finding.

Limitations

The most common limitation that site operators will face is a lack of funding or time for regular site inspections and ESC maintenance. It is therefore critical to reserve resources from the start of every project to address these requirements.

Lack of adequate training can limit the success of an ESC inspection program. Those responsible for inspecting and maintaining ESCs should have training on their design and operation. This will help ensure that workers know when ESCs need cleaning, repair or replacement. Similarly, as site conditions change, ESC designs may prove inadequate in controlling erosion and sedimentation. A knowledgeable inspector will be able to identify these deficiencies and ensure that staff make necessary improvements.

Effectiveness

The effectiveness of self-inspection and maintenance programs vary according to the amount of resources allocated to the tasks. When made a priority, inspections and maintenance ensure that ESCs function properly and help prevent harmful discharges.

Education of on-site personnel is another important factor in an effective program. To recognize and preempt problems, those responsible for maintaining ESCs should be familiar with their design and installation. Additionally, making everyone at the site aware of general ESC principles can expedite identification of maintenance issues and repairs and decrease the chance that normal construction activities will damage ESCs (e.g., driving over a silt fence).

Cost Considerations

ESC inspection and maintenance requires dedicating both management and staff time to training, inspecting, cleaning, and repairing or replacing ESCs. Inspector training requirements for staff vary by region and state, but typically include 8 to 24 hours of training with classroom and field components (as well as passing an exam in some cases). If repairing an ESC is impossible, construction staff may need to buy additional materials. For example, a ripped silt fence can often need replacement.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

California Water Boards (CWB). (2020). *Storm water program—training.*

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Stormwater Best Management Practice

Preserving Natural or Existing Vegetation

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Construction Site Planning and Management

Description

Preserving natural or existing vegetation is the practice of protecting desirable trees, vines, bushes and grasses from damage during project development. This practice has benefits during and after construction because natural, existing or established vegetation generally:

- Can withstand greater quantities of stormwater flow than newly seeded areas.
- Does not require time to establish.
- Has a higher infiltration capacity than newly planted vegetation due to a more developed and deeper root structure.
- Reduces stormwater discharge through greater interception and evapotranspiration.
- Buffers and screens against noise and visual disturbance.
- Provides habitat for wildlife.
- Improves air quality.
- Usually requires less maintenance (e.g., irrigation, fertilizer) than planting new vegetation.
- Enhances aesthetics.

Applicability

Construction staff can preserve natural or existing vegetation at any construction site where vegetation exists in the predevelopment condition. This practice can be particularly beneficial for floodplains, wetlands, perennial and intermittent streams, environmentally sensitive areas, steep slopes, and other areas where erosion controls would be difficult to establish, install or maintain (SPU, 2017).

Siting and Design Considerations

As part of the project planning phase, design engineers should visit the site to identify and map site features that may influence natural or existing vegetation stabilization measures such as drainage ways, highly erodible soils and steep slopes (MDE, NRCS, & MASCD, 2011). They

A construction safety fence preserves existing grass near a paved area.

should prepare a site map with the location and extent of trees, environmentally sensitive areas, and buffer zones to be preserved. They should also plan the locations of roads, buildings and other structures to avoid sensitive areas. Before clearing activities begin, construction staff should clearly mark the vegetation and other natural features that are to be preserved. Successfully preserving natural or existing vegetation requires careful site design and construction management to minimize the impact of construction activities on existing vegetation.

Direct contact and adjacent compaction, filling or excavation activities can damage trees and other vegetation (SPU, 2017). Therefore, construction staff should protect large trees near construction zones, as damage during construction could result in reduced vigor or death after construction ends. It is important to extend and mark the boundaries around contiguous natural areas and tree drip lines to protect the root zone from damage. Construction staff should clearly set limits using orange safety fence and signs spaced 100 feet apart (WES, 2008). Design engineers should consult local regulation and design standards for buffer zone width requirements near streams and other environmentally sensitive areas.

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Q3

A certified arborist can help inform the choice of which trees to preserve, offering information on the following sorts of factors:

- *Tree vigor*. Preserve healthy trees that are less susceptible to damage, disease and insects. Indicators of poor vigor include dead branch tips, stunted leaf growth, sparse foliage and pale foliage color. Hollow, rotten, split, cracked or leaning trees also have a lesser chance of survival.
- *Tree age.* Choose older trees because they are more aesthetically pleasing as long as they are healthy.
- *Tree species.* Preserve species that are well suited to present and future site conditions. Keeping a mixture of evergreens and hardwoods can help conserve energy—specifically, keep evergreens on the northern side of the site to protect against cold winter winds and keep deciduous trees on the southern side to provide shade in the summer and sunshine in the winter.
- *Wildlife and aquatic species benefits.* Choose trees that wildlife prefer for food, cover and nesting. Protect low-hanging trees, bushes and grasses, which provide habitat for fish in streams.

Other considerations include following natural contours and maintaining preconstruction drainage patterns. Altered hydrology may no longer meet the environmental needs of preserved vegetation, which could lead to its death (SPU, 2017).

The following are best practices for preserving natural or existing vegetation:

- Do not nail boards to trees during building operations.
- Do not cut tree roots inside the tree drip line.
- Use barriers to prevent equipment from approaching protected areas.
- Keep equipment, construction materials, topsoil and fill dirt outside the limit of preserved areas.
- Keep the duff layer (partially decomposed organic matter), native topsoil and natural vegetation undisturbed to the maximum extent practicable (SPU, 2017).
- Consider assigning a monetary value for trees or vegetated areas and visibly post this value on fencing (SPU, 2017).
- If construction activities damage a tree or shrub marked for preservation, remove and replace it with a tree of the same or similar species with a 2-inch or larger caliper width from balled and burlap nursery stock when construction is complete.
- During final site cleanup, remove barriers from around preserved areas and trees.

Limitations

Several factors can limit the practicality of preserving natural or existing vegetation throughout the development process. First, the practice is only suitable for sites with ample existing stands of healthy vegetation. In many urban areas, existing vegetation may be patchy and unhealthy, providing little overall benefit to site hydrology or aesthetics. In these cases, new vegetation may provide greater benefit. During planning, design engineers should consider the footprint of proposed structures relative to the total footprint of the site; for high-density development or where land prices are high, preserving existing vegetation may not be cost-effective. During construction, staff may need to remove existing vegetation that would interfere with the maneuverability of construction equipment.

Maintenance Considerations

Even if workers take precautions, some damage to protected areas might occur. If this happens, construction staff should repair or replace damaged vegetation immediately to maintain the integrity of the natural system. They should also consider enhancing the preserved area (e.g., removing invasive species). If fertilization is needed, construction staff should minimize adverse water quality effects by using the following practices (MPCA, 2019):

- Apply fertilizers to the minimum area needed.
- Apply fertilizer in lower amounts and more often if necessary.
- Work the fertilizer deeply into the soil (without harming root structures) to reduce nutrients' exposure to stormwater.
- Limit hydroseeding (i.e., simultaneously applying lime and fertilizers).

- Ensure that erosion and sediment control practices are in place to prevent stormwater from transporting fertilizers and sediments off-site.
- Inspect fencing and signs to ensure they are secure and undamaged.
- Do not mow protected areas.

Effectiveness

Preserving natural or existing vegetation can provide water quality benefits by reducing the quantity and improving the quality of stormwater discharge that a construction site generates. The overall effectiveness varies depending on the size of the area preserved, the type of vegetation and the amount of stormwater directed to the preserved area. Table 1 lists load reductions from several practices that are similar to the conservation of natural or existing vegetation. Although they are specific to the Chesapeake Bay region, they provide an approximation of the range of effectiveness that could be achieved by these practices in other locations.

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Table 1. Range in annual load reductions provided by natural vegetation buffers.

Buffer Practice	Units	Total Nitrogen	Total Phosphorus	Total Suspended Solids
Forest buffer	lb/acre of buffer	5.9–12	0.36–1.5	120–1,500
Conservation landscaping practices	lb/acre treated	2.2–4.8	0.070–0.23	NA
Filter strip	lb/acre treated	1.1–2.5	0.15–0.49	68–900

Source: CPB, 2018

Cost Considerations

When implemented successfully, preserving natural or existing vegetation is a low-cost practice. Damaging existing vegetation (and needing to replace it) can increase costs. Preserving natural or existing vegetation can also require additional labor costs to maneuver around trees or protected areas.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Chemical Stabilization

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

Chemical stabilizers, also known as soil binders or soil palliatives, provide temporary soil stabilization. They are readily applicable to the surface of the soil, can stabilize areas that cannot establish vegetation, and provide effective protection from wind and stormwater erosion.

Categories of chemical stabilizers are as follows: water with surfactant, water-absorbing, organic non-petroleum, organic petroleum, synthetic polymer emulsion, concentrated liquid stabilizer and clay additive (Jones, 2017). Examples include calcium chloride, lignosulfonates, guar and polyacrylamide (PAM). In all cases, construction staff should follow local guidance regarding the suitability of individual products for specific applications.

A truck applies chemical stabilizers to a roadway for dust suppression.

Applicability

Construction staff can use chemical stabilizers in areas where other methods of stabilization are not effective due to site constraints, either alone or in combination with vegetative or perimeter practices to enhance erosion and sediment control.

Siting and Design Considerations

Construction staff should follow manufacturer recommendations for application procedures to prevent products from pooling and to ensure effective soil stabilization. Potential methods include spray-on treatment and mix-in applications. Where appropriate, construction staff should use proper personal protective equipment. Before selecting a chemical for soil stabilization, design engineers should consider environmental concerns, including toxicity and biodegradability. In most cases, local permitting authorities should provide guidance on product suitability, acceptability and use restrictions for environmentally sensitive areas. The latest EPA Construction General Permit also provide insights on the permitting requirements, use and storage of chemicals at construction sites covered under EPA's permit.

The following is a list of site and design factors that design engineers should consider before using chemical stabilization for erosion control:

- Chemical/soil compatibility
- Dosage or application rate
- Cure time
- Potential for export of unreacted chemical
- Degradation rate
- Reapplication rate

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Limitations

Chemical stabilization is usually more expensive than vegetative practices and generally creates environmental concerns. Cationic polymers can be highly toxic to aquatic organisms and require federal and local approval on a case-by-case basis (U.S. EPA, 2019). Chloride compounds are effective for stabilization but could limit vegetation establishment due to the toxicity of chloride to plants (MPCA, 2019). Glycerin-based stabilizers, lignosulfonates, molasses-based stabilizers and plant oil-based stabilizers can negatively impact aquatic life by increasing biological oxygen

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demand as they degrade in receiving waters (Jones, 2017). Petroleum-based chemical stabilizers adversely affect plants and water resources (MPCA, 2019).

Effectiveness

The effectiveness of chemical stabilization methods varies significantly based on site conditions and the chemical type. For example, chloride-based compounds require humidity for effective performance, and organic petroleum products do not perform as well in high-traffic areas. For any project considering chemical stabilization, its effectiveness depends on the consideration of all possible environmental interactions and close communication with local regulating authorities and chemical manufacturers.

Cost Considerations

The cost of chemical stabilization can vary widely depending on the site, chemical, application technique and application rate. For larger sites, truck-mounted applicators may be more cost-effective despite having higher equipment costs. The cost of the chemicals themselves also varies considerably. Polyacrylamide, one of the more common soil palliatives, costs around $6 per pound. Therefore, when using a minimum suggested application rate of 20 pounds per acre (McLaughlin, 2015), the chemical cost is at least $120 per acre. Calcium chloride costs around $0.50 per pound (RSMeans, 2019) but requires an application rate of 1 to 3 tons per acre, resulting in a chemical cost of $1,000 to $3,000 per acre.

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Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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EPA United States Environmental Protection Agency

Stormwater Best Management Practice

Compost Blankets

Permits for Clean Water NPDES

Minimum Measure

Construction Site Stormwater Runoff Control

Subcategory

Erosion Control

Figure 1. *Applying a compost blanket on a bare and eroding slope*

Figure 2. *Same slope after revegetation*

Purpose and Description

A compost blanket is a layer of loosely applied composted material placed on the soil in disturbed areas to reduce stormwater runoff and erosion. This material fills in small rills and voids to limit channelized flow, provides a more permeable surface to facilitate stormwater infiltration, and promotes revegetation. Seeds can be mixed into the compost before it is applied. Composts are made from a variety of feedstocks, including yard trimmings, food residuals, separated municipal solid waste, and municipal sewage sludge (biosolids). Controlling erosion protects water quality in surface waters, such as streams, rivers, ponds, lakes, and estuaries; and increasing stormwater infiltration replenishes groundwater aquifers. Applying a compost blanket also works well as a stormwater best management practice (BMP) because it:

- Retains a large volume of water, which aids in establishing vegetation growth within the blanket,
- Acts as a cushion to absorb the impact energy of rainfall, which reduces erosion,
- Stimulates microbial activity that increases the decomposition of organic matter, which increases nutrient availability and improves the soil structure,
- Provides a suitable microclimate with the available nutrients for seed germination and plant growth, and
- Removes pollutants such as heavy metals, nitrogen, phosphorus, fuels, grease and oil from stormwater runoff, thus improving downstream water quality (USEPA 1998).

Applicability and Limitations

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Compost blankets can be placed on any soil surface: flat, steep, rocky, or frozen. The blankets are most effective when applied on slopes between 4:1 and 1:1 (horizontal run:vertical rise); such as construction sites, road embankments, and stream banks; where stormwater runoff can occur as sheet flow. On the steeper slopes (1:1) the compost blanket should be used in conjunction with netting or other confinement systems to further stabilize the compost and slope, or the compost particle size and depth should be specially designed for this application. Compost blankets should not be placed in locations that receive concentrated or channeled flows either as runoff or a point source discharge. If compost blankets are placed adjacent to highways and receive concentrated runoff from the traffic lanes, they should be protected by compost berms, or a similar BMP that diffuses or diverts the concentrated runoff before it reaches the blanket (Glanville, Richard, and Persyn 2003). Because a compost blanket can be applied to the ground surface without having to be incorporated into the soil, it provides excellent erosion and sediment control on difficult terrain, such as steep or rocky slopes (Figures 3, 4). Projects where the cost of transporting and applying composts is most easily justified are situations that demand both immediate erosion control and growth of vegetative cover, such as projects completed too late in the growing season to establish natural vegetation before winter or areas with poor quality soils that don't readily support vegetative growth (Glanville, Richard, and Persyn 2003).

Figure 3. *Applying a compost blanket on a steep, rocky slope*

Figure 4. Same slope after revegetation

Office of Water, 4203M
www.epa.gov/npdes/pubs/compostblankets.pdf
www.epa.gov/npdes/stormwater/menuofbmps

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What Is Compost?

Compost is the product of controlled biological decomposition of organic material that has been sanitized through the generation of heat and stabilized to the point that it is beneficial to plant growth. It is an organic matter resource that has the unique ability to improve the biological, chemical, and physical characteristics of soils or growing media. Compost contains plant nutrients but is typically not characterized as fertilizer (USCC 2008).

This decomposition of organic material is produced by metabolic processes of microorganisms. These microbes require oxygen, moisture, and food in order to grow and multiply. When these three factors are maintained at optimal levels, the natural process of decomposition is greatly accelerated. The microbes generate heat, water vapor, and carbon dioxide as they transform the raw materials into a stable soil conditioner. Compost can be produced from many raw organic materials, such as leaves, food scraps, manure, and biosolids. However, the mature compost product bears little physical resemblance to the raw material from which it originated.

Figure 5. *Mature compost product*

How Is Compost Beneficial?

Biological Benefits

Provides an excellent substrate for soil biota. The activity of soil microorganisms is essential for productive soils and healthy plants. Their activity is largely based on the presence of organic matter. Soil microorganisms include bacteria, protozoa, and fungi. They are not only found within compost, but will also proliferate within the soil under a compost blanket. These microorganisms play an important role in organic matter decomposition, which leads to humus formation and nutrient availability. Some microorganisms also promote root activity; specific fungi work symbiotically with plant roots, assisting them in extracting nutrients from the soils.

Suppresses plant diseases. The incidence of plant diseases may be influenced by the level and type of organic matter and microorganism present in soils. Research has shown that increased populations of certain microorganisms may suppress specific plant diseases, such as pythium blight and fusarium wilt.

Chemical Benefits

Provides nutrients. Compost blankets contain a considerable variety of macro- and micronutrients essential for plant growth. Since compost contains relatively stable sources of organic matter, these nutrients are supplied in a slow-release form.

Modifies and stabilizes pH. The pH of composts differ. When necessary, a compost may be chosen that is most appropriate for revegetating a particular construction site.

Physical Benefits

Improved soil structure and moisture management.
In fine-textured soils (i.e., clay or clay loam), the addition of compost will increase permeability, and reduce stormwater runoff and erosion. The soil-binding properties of compost are due to its humus content. Humus is a stable residue resulting from a high degree of organic matter decomposition. The constituents of humus hold soil particles together, making them more resistant to erosion and improving the soil's ability to hold moisture.

Effectiveness of Compost, Topsoil, and Mulch

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Because of the biological, chemical, and physical benefits it can provide, compost makes a more effective erosion control blanket than topsoil. An Iowa State University study (Glanville, Richard, and Persyn 2003), sponsored by the Iowa Department of Natural Resources and Iowa Department of Transportation (DOT), compared the quantity of runoff from road embankments treated with topsoil and with compost blankets. The test plots were exposed to simulated, high intensity rainfall (3.7 inches/hour) lasting for 30 minutes. Results showed that the amount of runoff from the embankment treated with a compost blanket was far less than the runoff from the embankment treated with topsoil.

Mulch is a protective covering placed around plants for controlling weeds, reducing evaporation, and preventing roots from freezing. It is made of various substances usually organic, such as hardwood or pine bark. A compost blanket is a much more effective BMP for erosion control and revegetation than mulch. A University of Georgia research study (Faucette and Risse 2002) reported that correctly applied compost blankets provide almost 100 percent soil surface coverage, while other methods (e.g., straw mats and mulches) provide only 70 to 75 percent coverage. Uniform soil coverage is a key factor in effective erosion and sediment control because it helps maintain sheet flow and prevents stormwater from forming rills under the compost blanket.

Compost Quality

Compost Properties

Maturity. Maturity indicates how well the compost will support plant growth. One maturity test measures the percent of seeds that germinate in the compost compared to the number of seeds that germinate in peat based potting soil. For example, if the same number of seeds was planted in the potting soil (control) and in a marketed compost product, and 100 of them germinate in the potting soil and 90 germinate in the compost, the compost's maturity would be 90 percent. Another maturity test compares the growth and vigor of seedlings after they have been growing in both compost and potting soil.

Stability. Stability determines how "nice" the compost is. While microbial decay is actively transforming the feedstocks into compost, the unstable mixture may have unpleasant characteristics such as odors. However, after the decay process is completed, the stable compost product no longer resembles the feedstock or has offensive characteristics. During the composting process, CO_2 is produced because the microbes are actively respiring. So the microbial respiration (CO_2 evolution) rates can be measured and used to determine when the microbial decay is completed and the compost product has stabilized.

Presence of Pathogens. The pathogen count indicates how sanitary the compost is. EPA has defined processes for composting biosolids that reduce the number of pathogenic organisms to nondetectible levels and ensure the resulting compost will be sufficiently heat treated and sanitary. These processes to further reduce pathogens (PFRP) are defined in 40 CFR, Part 503, Appendix B, Section B. Compost quality specifications often require compost to be treated by a PFRP process, so there are no measurable pathogenic microorganisms present.

Other compost properties that may be found in compost quality specifications are plant nutrients and heavy metal concentrations, pH, moisture content, organic matter content, soluble salts, and particle size.

Compost Quality Testing

A compost testing, labeling, and information disclosure program, the Seal of Testing Assurance Program, has been established by the United States Composting Council (USCC), a private, nonprofit organization. Under this program testing protocols for determining the quality and condition of compost products at the point of sale have been jointly approved and published by the USCC and U.S. Department of Agriculture. These Test Methods for Evaluating Compost and Composting, the TMECC Testing Protocols are conducted by independent laboratories to help compost producers determine if their compost is safe and suitable for its intended uses, and to help users compare various compost products and verify the product safety and market claims. The goal of the program is to certify the compost products have been sampled and tested in accordance with these approved protocols. Compost producers who participate in this program have committed to having their products tested by an approved laboratory according to the prescribed testing frequency and protocols and to providing the test results to anyone upon request. The products of participating compost producers carry the USCC certification logo and product information label.

Compost Quality Specifications

The Federal Highway Administration supported developing specifications for compost used in erosion and sediment control through a cooperative agreement with the Recycled Materials Resource Center at the University of New Hampshire. The original compost blanket specifications (Alexander 2003) were developed under this grant. Working with the USCC and Ron Alexander (Alexander 2003), the American Association of State Highway and Transportation Officials finalized and approved these specifications (AASHTO 2010), which include: narrative criteria (e.g., no objectionable odors or substances toxic to plants), numerical specifications [e.g., pH, soluble salts, moisture content, organic matter content, particle size, stability, and physical contaminants (e.g., metal, glass, plastics)], and pathogen reduction using the EPA processes to further reduce pathogens. These AASHTO specifications also recommend the TMECC testing protocols. A number of states have now developed specifications for the compost they use in erosion and sediment control. Examples are the California DOT specifications and Texas DOT specifications.

Compost Blanket Installation

Once any trash and debris have been removed from a site, a compost blanket can be uniformly applied usually between 1 and 3 inches thick using a bulldozer, skid steer, manure spreader, or hand shovel. Application rates (thickness) are often included in compost blanket specifications. The compost blanket should extend at least 3 feet over the shoulder of the slope to ensure that stormwater runoff does not flow under the blanket (Alexander 2003). On very rocky terrain or if the slope is too steep for heavy equipment, a pneumatic blower truck is needed to apply the compost (Figure 6). If the slope is steep, a compost blanket may work best in conjunction with other BMPs, such as compost socks placed across the slope to reduce the runoff velocity (Figure 7) or compost berms placed at the top of the slope to divert or diffuse concentrated runoff before it reaches the compost blanket (Figure 8).

Figure 6. *Using a pneumatic blower truck to apply a compost blanket on a rocky 1:1 slope*

Figure 7. *Using compost socks to reduce the runoff velocity*

Figure 8. *Using a compost berm to divert or defuse highway runoff before it reaches the compost blanket*

Fabric netting can also be used to hold the compost blanket on steep slopes (Figure 9). The netting is usually stapled to the slope (Figure 10), and then the compost is blown on the slope and into the netting.

Mature compost for erosion control on moderate slopes is shown in Figure 11, with a red pen for size comparison. The compost in

Figure 9. *Netting stabilizing a compost blanket*

Figure 10. *Stapling netting to the slope*

Figure 5 is too fine for erosion control. Coarser compost should be avoided on slopes that will be landscaped or seeded, as it will make planting and crop establishment more difficult. But coarse and/or thicker compost is recommended for areas with higher annual precipitation or rainfall intensity, and even coarser compost is recommended for areas subject to wind erosion (Alexander 2003).

Figure 11. *Compost for erosion control on moderate slopes*

Grass, wildflower, or native plant seeds appropriate for the soil and climate can be mixed into the compost. Although seed can be broadcast on the compost blanket after installation, it is typically incorporated into the compost before it is applied, to ensure even distribution of the seed throughout the compost and to reduce the risk of the seed being washed from the surface of the compost blanket by stormwater. Wood chips may also be added to reduce the erosive effect of rainfall's impact energy.

Figure 12. *Impact of rainfall*

Inspection and Maintenance

The compost blanket should be inspected periodically and after each major rainfall. If areas of the compost blanket have washed out, another layer of compost should be applied. In some cases, it may be necessary to add another BMP to control the stormwater, such as a compost filter sock or silt fence. On slopes greater than 2:1, establishing thick, permanent vegetation as soon as possible is the key to successful erosion and sediment control. Restricting or eliminating pedestrian traffic on such areas is essential (Faucette and Ruhlman 2004).

Climate Change Mitigation

In 2005 an estimated 246 million tons of municipal solid wastes were generated in the United States. Organic materials including yard trimmings, food scraps, wood waste, paper and paper products are the largest component of our trash and make up about two-thirds of the solid waste stream. When this organic matter decomposes in landfills, the carbon is converted to methane (CH_4) and other volatile organic compounds, which are released into the atmosphere and contribute to global warming. EPA has identified landfills as the single largest source of methane, a potent greenhouse gas that is 23 times more efficient at trapping heat than carbon dioxide (CO_2). Landfills contribute approximately 34 percent of all man-made methane released into the atmosphere in the United States (USEPA 2007). Two approaches for mitigating climate change are reducing carbon emissions and sequestering carbon in the atmosphere.

Reducing carbon emissions. When organic materials are composted and then recycled, the composting feedstocks are diverted from already burdened municipal landfills, and landfill-generated methane gas emissions are reduced.

Figure 13. *As compost like this is recycled, green house gasses are reduced*

Sequestering Carbon. Carbon sequestration is the act of removing carbon dioxide from the atmosphere and storing it in carbons sinks, such as oceans, plants and other organisms that use photosynthesis to convert carbon from the atmosphere into biomass. Forest ecosystems and permanent grasslands are prime examples of terrestrial carbon sinks that sequester carbon. We no longer have the vast expanses of prairies and eastern forests, but we are using compost blankets to revegetate construction sites, road banks, and green roofs; and this vegetation sequesters carbon.

Figure 14. *Compost blankets will nurture revegetation, which sequesters carbon and prevents erosion*

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Stormwater Best Management Practice

Dust Control

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

Dust control practices reduce the potential for construction activities to generate dust from disturbed soil surfaces. Construction sites can have large areas of soil disturbance and open space from which wind can pick up dust particles. Airborne particles pose a dual threat to the environment and human health. Dust that the wind carries off-site can impact nearby waterbodies due to direct deposition or transport by stormwater. In addition, dust from construction sites increases the levels of particle air pollution, also called particulate matter (PM), in the form of $PM_{2.5}$ (fine inhalable particles with diameters generally 2.5 micrometers and smaller) and PM_{10} (inhalable particles with diameters that are generally 10 micrometers and smaller) in surrounding areas (Azarmi et al., 2016; Muleski et al., 2005), which can contribute to respiratory health problems and create inhospitable working environments.

Applicability

Dust control measures apply to any construction site where major soil disturbances or heavy equipment construction activities—such as clearing, excavation, demolition or excessive vehicle traffic—occur. Earthmoving activities, particularly transport of cut and fill materials, are the major source of dust from construction sites (Muleski et al., 2005), but traffic and general disturbances can also be significant contributors (WA Dept. of Ecology, 1992). Dust control measures are especially important in arid or semiarid regions, where soil can become extremely dry and vulnerable to transport by high winds. The most effective dust control measures for a site depend on its topography and land cover, soil characteristics, and expected rainfall.

Siting and Design Considerations

The quantity of dust generation and transport depends on the amount of exposed soil. Therefore, when designing a dust control plan, design engineers and construction staff can greatly reduce dust generation by sequencing activities in a way that disturbs only small areas at a time. Construction staff responsible for dust control should determine which practices accommodate their needs according to specific site and weather conditions. The following is a brief list of example control measures and design criteria:

A truck equipped with a spray system can spray water throughout a construction site and prevent dust from being transported off-site.

- *Sprinkling/irrigation.* Sprinkling the ground surface with water until it is moist is an effective dust control method for most sites, particularly on haul roads and other traffic routes where other dust control methods may not be possible.
- *Vegetative cover.* In areas that construction staff do not designate for vehicle traffic, vegetative cover reduces wind velocity at the ground surface, thus reducing the potential for dust to become airborne.
- *Mulch.* Mulching can be a quick and effective dust control method for a recently disturbed area.
- *Wind breaks.* Wind breaks are barriers (either natural or constructed) that reduce the velocity of wind through a site, thereby reducing the number of particles the wind suspends. Wind breaks can be trees or shrubs that construction staff leave in place during site clearing or constructed barriers such as wind fences, snow fences, tarp curtains, hay bales, crate walls or sediment walls.

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- *Tillage.* Deep tillage in large open areas brings soil clods to the surface where they rest on top of dust, preventing it from becoming airborne.
- *Stone.* Stone can be an effective dust deterrent for construction roads and entrances or serve as mulch in areas that cannot establish vegetation.
- *Chemical soil stabilization (palliatives).* There are several different categories of chemical soil treatments: water absorbing, organic non-petroleum, organic petroleum, synthetic polymer emulsion, concentrated liquid stabilizer and clay additive (Jones, 2017). Factors to consider when selecting a chemical application for dust suppression include biodegradability, soil suitability, and impacts to wildlife and environmentally sensitive areas.

Limitations

Applying water to exposed soils can be time-intensive and—if done to excess—could result in discharge from the site or vehicles tracking mud onto public roads. Excessive use of water can also be inappropriate in water-scarce regions. Misuse of chemical applications can create hazardous working conditions, increase surface water pollution from discharges or contaminate groundwater. Excessive use of chemical applications might also present a health risk.

Maintenance Considerations

Inspection and maintenance requirements are unique for each site because dust controls depend on specific methods, site conditions and weather conditions. Generally, dust control measures involving the application of either water or chemicals require more monitoring than structural or vegetative controls to remain effective. Construction staff should consult manufacturer specifications for chemical stabilizers. If the site uses structural controls, regular inspection and maintenance are necessary to ensure that the controls remain effective.

Effectiveness

Q8

- *Mulch.* Mulch can reduce wind erosion by 75 to 95 percent compared to unstabilized soils, depending on the type of mulch and the application rate (MPCA, 2019). Mulch is effective on sites that will re-establish vegetation and in areas where slopes have less than 1 foot of elevation change for every 2.5 feet of horizontal change. Mulch can be effective in areas with steep slopes in combination with tackifiers or other stabilization methods.
- *Sprinkling/irrigation.* Water is one of the most common ways to control dust on a construction site. It is effective in heavily trafficked areas, such as construction roads where other methods are not feasible. However, water requires frequent reapplications to remain effective.
- *Wind breaks.* The effectiveness of wind breaks depends primarily on their size and permeability. As a general rule, for each foot of vertical height, an 8- to 10-foot deposition zone develops on the leeward side of the barrier. Highly permeable barriers are less effective than more impermeable barriers.
- *Stone.* Gravel can reduce soil losses by 95 percent compared to unstabilized soils (MPCA, 2019).
- *Spray-on chemical soil treatments (palliatives).* The effectiveness of polymer stabilization methods is highly variable and depends on site characteristics, climate and the specific chemical soil treatment. Sites should follow manufacturer specifications to achieve maximum effectiveness.

Cost Considerations

Costs for chemical dust control measures can vary widely depending on the specific needs of the site and the desired level of dust control. Water requires significantly more frequent reapplication than chemical stabilizers, as well as specialized machinery. Therefore, while water itself is inexpensive, costs associated with using water for dust control may be significantly higher than other methods (Jones, 2017). Chemical soil treatments typically only require seasonal or annual application, thus resulting in potential labor and equipment cost savings. However, depending on the type of chemical, the substance may require special storage and application equipment. Once established, vegetation can be more cost-effective for long-term stabilization.

Additional Resources

- Maryland Department of the Environment. (2011). 2011 *Maryland standards and specifications for soil erosion and sediment control*.
- Montana Department of Transportation. (2015). *Erosion and sediment control best management practices manual*.
- Ohio Department of Natural Resources. (2014). *Rainwater and land development—Ohio's standards for stormwater management, land development and urban stream protection* (3rd ed.).
- City of Portland Oregon. (2008). *Erosion and sediment control manual*.
- Washington State Department of Transportation. (2019). *Temporary erosion and sediment control manual*.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

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Disclaimer

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Stormwater Best Management Practice
Geotextiles, Matting and Netting

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Q9

Description

Geotextiles—also known as filter fabrics, synthetic fabrics, construction fabrics or fabrics—are porous fabrics used for erosion and sediment control purposes. Manufacturers create woven geotextiles by weaving fibers together and non-woven geotextiles by bonding fibers together. Non-woven geotextiles are more porous than woven geotextiles and typically break down faster. Geotextiles consist of synthetic materials such as polypropylene, polyester, polyethylene, nylon, polyvinyl chloride, glass and various mixtures of these materials.

Matting typically consists of jute, coir or other wood fibers that manufacturers have formed into sheets. Matting serves similar purposes as traditional loose mulch but is more stable. Netting typically consists of jute, wood fiber, plastic, paper or cotton and can hold mulching and matting to the ground. Netting alone can also stabilize soils and help establish vegetation.

Geotextiles, netting and matting come in a wide variety of materials and have specifications to match specific uses and site conditions.

Applicability

Geotextiles have multiple uses for erosion and sediment control on construction sites. Geotextiles can prevent erosion when construction staff apply them as liners to sediment traps and basins, post-construction stormwater control measures, and stone-lined stormwater conveyances—including spillways. Geotextiles can also serve as a separator between riprap and soil to prevent the soil from eroding beneath the riprap and maintain the riprap's base. When construction staff install geotextiles upright, geotextiles can serve as silt fences and inlet protection. Geotextiles may also serve as temporary protection for exposed soils—for example, as a cover for active piles of soil that construction staff have left overnight.

Design engineers should use woven geotextiles where impermeability is important, such as for silt fences or separation applications. They should use non-woven geotextiles where water passes through the device (e.g., storm drain inlet protection).

Geotextile matting protects bare soil from erosion caused by wind and stormwater.

Design engineers can use matting and netting to stabilize ground surfaces, including river and stream banks. Due to their porosity and biodegradability, matting and netting are particularly useful for temporarily holding seeds, fertilizers and topsoil in place while vegetation becomes established.

Siting and Design Considerations

Construction staff should consider site conditions and intended use before selecting a geotextile, netting or matting material. Due to the variety of material types and applications, construction staff should always consult and adhere to manufacturer specifications and local permitting authority specifications. A geotextile should have the appropriate tensile strength, tear strength, apparent opening size and other properties for its intended use. Many jurisdictions (e.g., the Maryland Department of the Environment and Washington State Department of Transportation) provide geotextile specifications for specific erosion and sediment control applications.

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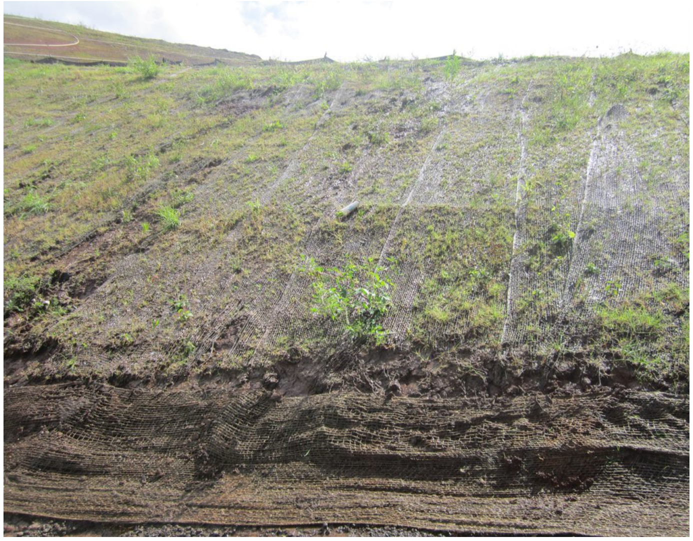
In addition to using the correct product for a given application, construction staff should properly install the geotextile, netting or matting to achieve maximum effectiveness. Proper installation depends on the type of material as well as the specific application. Typically, local jurisdictions provide guidance (e.g., Idaho Department of Environmental Quality stormwater best management practices) on installation requirements, such as material orientation, edge overlap, anchoring, and stake or staple spacing. In all cases, the material should maintain firm, continuous contact with the soil either through proper anchoring or use of sufficient cover material such as gravel or fill. If there is no contact, the material will not hold the soil, and erosion will occur underneath the material.



Geotextile matting can be used on slopes to help establish vegetation by protecting the soil surface and seedlings from erosion while still allowing vegetation to grow through the mat.
Credit: Anthony D'Angelo for USEPA, 2015

Limitations

Geotextiles are not biodegradable and are not appropriate for areas where their presence or appearance is aesthetically unacceptable. Many geotextiles degrade rapidly when exposed to sunlight. The wind might blow geotextiles away or the geotextiles might increase discharges if construction staff do not install them properly. It may be necessary to dispose of geotextiles as well as synthetic matting and netting in a landfill, which makes them less desirable than vegetative stabilization. Improper selection, design or installation of geotextile fabric, matting or netting may drastically reduce its effectiveness.

Maintenance Considerations

Maintenance requirements vary depending on the type of material and specific application. Geotextiles should undergo regular inspection to determine if cracks, tears or breaches have formed in the fabric. Construction staff should address defects in geotextiles immediately. For silt fences, construction staff should remove sediment buildup after each storm event or when a significant amount of buildup has accumulated. Where geotextiles, matting or netting have separated from the ground, additional cover material or staking may be necessary to maintain contact and ensure long-term effectiveness.

Cost Considerations

Installation costs for geotextiles—including materials and labor—typically range from $1 to $3 per square yard (Maryland SHA, 2019; RSMeans, 2019) but can be as high as $10 per square yard or more for advanced materials. Netting and matting costs typically range from $1 to $4 per square yard (RSMeans, 2019). Costs depend on material, strength, thickness and durability.

Additional Resources

- Idaho Department of Environmental Quality. (2005). BMP 17: Geotextile. In *Catalog of stormwater best management practices for Idaho cities and counties (Vol. 2)*. Water Quality Division, Idaho Department of Environmental Quality.
- Maryland Department of the Environment. (2011). 2011 Maryland standards and specifications for soil erosion and sediment control.
- Washington State Department of Transportation. (2019). *Standard specifications for road, bridge, and municipal construction 2022* (M 41-10).

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

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Disclaimer

Stormwater Best Management Practice

Land Grading

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

NPDES

Description

This land grading fact sheet includes information related to land grading, gradient terraces, permanent slope diversions and temporary diversion dikes. Land grading involves reshaping the ground surface to planned elevations, as approved construction drawings from a civil engineer or other qualified professional show. Land grading provides more suitable topography for buildings, facilities and other land uses and helps control stormwater, soil erosion and sedimentation during and after construction.

Land grading involves reshaping the ground surface to planned elevations.
Credit: Anthony D'Angelo for USEPA, 2012

Applicability

Land grading applies to all sites that require earthwork—particularly those with uneven topography or easily erodible soils—because it can stabilize slopes and decrease stormwater velocity.

Siting and Design Considerations

When preparing grading plans or other construction drawings that specify grading, a civil engineer or other qualified professional should account for:

- Existing soil types
- Existing slopes
- Existing drainage patterns
- Environmentally sensitive areas
- Proposed land use
- Proposed stormwater control measures

Grading plans should specify limits of disturbance, land elevations, slopes, drainage patterns and construction schedules. A grading plan should also describe erosion and sediment controls, including locations, dimensions, quantities and standard details.

Construction staff should perform land grading in ways that limit the extent and duration of soil-disturbing activities. When developing grading plans, design engineers should minimize the limits of disturbance and only include areas necessary for construction, utility installation and equipment traffic. Construction sequencing, the practice of minimizing unstabilized soils at any given time during construction, should be a consideration when scheduling and conducting land grading activities. Clearing and grading should never occur beyond the limits of disturbance that approved construction drawings specify.

Q10

When developing grading plans, preserving natural, existing or established vegetation in temporary or permanent buffer zones is a low-cost way to reduce stormwater discharge and off-site sedimentation. In addition, design engineers should take care to ensure that land grading does not disturb steep slopes, wetlands, streams, stream valley buffers, forested areas or endangered species habitats.

To minimize off-site sediment transport, construction staff should divert stormwater from undisturbed areas away from areas that will be disturbed. Temporary diversion structures—such as check dams or temporary slope drains—should interrupt disturbed areas with long slopes to reduce stormwater velocities and divert stormwater from exposed areas.

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If construction staff uses blasting agents or explosives, they should take care to limit their emissions into the surrounding environment. These products may contain perchlorates, which are water-soluble chemicals. If construction staff must use explosives containing perchlorate, they should employ good housekeeping practices to ensure they properly dispose of any debris (MassDEP, 2006).

Limitations

Design engineers should develop grading plans to preserve existing drainage patterns as much as possible. Land grading that disrupts natural stormwater flow patterns might lead to poor drainage, high stormwater velocities or increased peak flows during storm events. Clearing and grading an entire site without maintaining a vegetated buffer or implementing adequate erosion and sediment control measures can promote off-site transport of sediments and other pollutants. If construction staff cannot use excavated material or store it on-site, they should make accommodations for off-site transport and disposal. Disposal costs increase if hazardous substances have contaminated the excavated material.

Maintenance Considerations

Construction staff should implement all land grading and erosion and sediment control practices per approved construction drawings and inspect them at frequencies in accordance with applicable permits and consistent with the site's stormwater pollution prevention plan. Construction staff should also inspect unstabilized areas and associated erosion and sediment controls after rainfall events. Necessary maintenance may include backfilling or stabilizing washouts and eroded areas or removing accumulated sediment from erosion and sediment controls.

Q11

Construction staff should stabilize areas where grading activities are complete and where they do not anticipate disturbance for 2 or more weeks, including any stockpiles that they will not actively use for 2 or more weeks (40 CFR 450.21[b]; U.S. EPA, 2019). Construction staff should also apply dust control measures in accordance with the permit and consistent with the site-specific stormwater pollution prevention plan.

Effectiveness

When sites properly implement land grading with appropriate stormwater management and erosion and sediment control practices, land grading can mitigate stormwater flow from steep slopes and stabilize highly erodible soils. Land grading can increase erosion and off-site sediment transport when it alters drainage patterns or when it leads construction staff to clear vegetated areas on the perimeter of the site (U.S. EPA, 2004).

Cost Considerations

Land grading incurs costs in both the design and construction phases. Even for small sites, a certified engineer or landscape architect may spend several hours establishing final grades and incorporating stormwater management and erosion and sediment controls into the development plan. These costs increase as sites become larger and more complex.

During construction, in addition to performing labor associated with grading activities, construction staff may need additional time to construct diversions and berms. The site may require off-site fill for low-lying areas or depressions. Where excavation is necessary, sites may need to remove and dispose of excess soil if on-site use or storage is not possible.

Costs of common land grading activities are as follows (RSMeans, 2019):

- Fine grading, soil treatment and stabilization costs are approximately \$4 to \$6 per square yard.
- Shallow excavation (1 to 4 feet deep) with a backhoe where dewatering is not necessary costs \$6 to \$10 per cubic yard of removed material.
- Larger-scale grading requires a site-specific assessment and a detailed earthworks analysis to retain as much soil on-site as possible and limit disposal costs.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

U.S. Environmental Protection Agency (U.S. EPA). (2015). *Model post-construction stormwater runoff control ordinance.* Washington, DC: U.S. Environmental Protection Agency.

Massachusetts Department of Environmental Protection (MassDEP). (2006). *The occurrence and sources of perchlorate in Massachusetts*.

RSMeans. (2019). Earthwork data from RSMeans [Online data file]. RSMeans data from Gordian.

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Stormwater Best Management Practice

Mulching

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

Mulching is an erosion control practice that uses materials such as grass, hay, wood chips, wood fibers, straw or gravel to stabilize exposed or recently planted soil surfaces. Mulching is advisable and most effective when sites use it with seeding or vegetation. In addition to stabilizing soils, mulching can reduce stormwater velocity and improve infiltration. Mulching can also aid plant growth by holding seeds, fertilizers and topsoil in place; preventing birds from eating seeds; retaining moisture; and insulating plant roots against extreme temperatures.

For areas with steep slopes or highly erodible soils, several options provide greater stability than loose mulch, including mulch matting, netting, tackifiers and hydromulch. Manufacturers make mulch matting from coir, jute or other fibers, which they form into sheets that are more stable than loose mulch. Construction staff can apply netting over loose mulch to keep it in place while plants are growing; this not only helps keep the mulch in place, but it also reduces the need for reapplication. Mulch tackifiers, which manufacturers make from asphalt or synthetic materials, are an alternative to mats and netting for binding loose mulch. Hydraulically applied erosion control product, or hydromulch, is another soil stabilization method that uses mulch. Hydromulch application uses a large tank, typically 1,000 to 3,000 gallons in volume, mounted on a truck or trailer to spray a mixture of water, mulch and tackifier onto soils to stabilize them. Hydromulch adheres to the top layer of soil, creating a crust that allows water to infiltrate while holding soil in place (WSDOT, 2019).

Applicability

Mulch is applicable to most construction sites and can provide immediate, inexpensive erosion control. Sites often use mulch with seeding to help establish vegetation and stabilize soils, and mulch can be effective in areas where it is difficult to establish vegetation, such as areas with steep slopes. Mulches are also effective in areas where sensitive seedlings need moisture retention

Straw and hydroseed applied to a slope.

or insulation from extreme temperatures. On steep slopes and in critical areas, such as those near waterways, construction staff should use netting, anchoring or tackifiers to stabilize the mulch. Alternatively, construction staff can apply hydromulches to stabilize soils in critical areas and areas with steep slopes.

Siting and Design Considerations

When possible, construction staff should use natural mulches for erosion control and plant material establishment. Suitable materials include loose straw, wood bark, wood cellulose or agricultural silage. Where available, sites can use ground tree trimmings or stumps that would otherwise end up in landfills, providing a beneficial reuse option. In most cases, mulch materials should have weed-free certification in accordance with applicable state requirements. Sites can use inorganic mulches, such as pea gravel or crushed granite, as an alternative to using mulches with anchoring or hydromulch in unvegetated areas and areas with steep slopes.

Construction staff should uniformly apply mulch at a rate appropriate for the type of mulch and in accordance with manufacturer specifications to prevent erosion, washout and poor plant establishment. Depending on slopes,

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wind conditions and mulch type, mulch application may require netting, tacking or other stabilization to reduce loss from wind and water erosion. Construction staff should stabilize loose hay or straw with netting, disking, crimping or tackifier. Materials that are heavy enough to stay in place (for example, gravel, bark or wood chips on flat slopes) do not need stabilization. Construction staff should use jute, coir or other biodegradable material netting or matting for mulch stabilization and should choose the material based on the length of time it requires for vegetation establishment. Construction staff should avoid plastic netting wherever possible. Hydromulch application should take place in spring, summer or fall so the site can establish plants before the material deteriorates. Table 1 provides typical mulch application rates and requirements.

Q12

Table 1. Typical mulching materials and application rates.

Material	Rate (Tons per Acre)	Requirements	Notes
Organic Mulches			
Bark	5–8[a]	Air dry; shredded, hammermilled or chips	Apply with mulch blower, with chip handler or by hand; do not use asphalt tack
Hydraulically applied mulches	1.25–2.5[a,b]	Apply via high-pressure pumping from mixing tank, through a hose and nozzle apparatus	Do not apply during rain or wind events or immediately before a storm event
Straw	1–2[c]	Dry, unchopped, unweathered; avoid weeds	Spread by hand or machine; tack or tie down
Wood chips	5–8[a]	Air dry, add 12 pounds of nitrogen fertilizer per ton of wood chips	Apply with blower, with chip handler or by hand; not suitable for fine turf areas
Wood fiber or wood cellulose	½–1		Use with hydroseeder; can use to tack straw; do not use in hot, dry weather
Inorganic Mulches			
Rock	200–500[a]		Can be costly; does not promote plant growth
Nets and Mats			
Coir net	Cover area	Apply heavily and uniformly; use with organic mulch	Withstands water flow
Excelsior (wood fiber) mat	Cover area		Anchoring only a requirement in critical areas or at sites subject to high winds; decomposes slowly[d]
Fiberglass roving	½–1	Continuous fibers of drawn glass that a non-toxic agent binds together	Apply with compressed air ejector; tacking may be necessary; consider end of life removal/disposal
Jute net	Cover area	Heavy, uniform; woven of single jute yarn; use with organic mulch	Withstands water flow

[a] Recommended application rate data source is MPCA, 2019.
[b] Recommended application rate data source is WSDOT, 2019.
[c] Recommended application rate data source is MDT, 2015.
[d] Application notes are from USDA, 2011.

Limitations

Mulching, matting and netting might delay seed germination because the cover changes soil surface temperatures. Mulches themselves are subject to erosion, and stormwater may wash them away during a rain event; sites should not use mulches in areas of concentrated flow without additional erosion and sediment control practices that are effective at reducing concentrated flow conditions.

Hydromulches need time to dry, and construction staff should apply them at least 24 hours before a storm. For long-term mulch application, construction staff should apply hydromulches in layers, with enough time between applications to allow each layer to dry. Refer to manufacturer specifications to determine actual application rates and drying times.

Maintenance Considerations

When mulches stabilize and protection is no longer necessary, remove netting or matting and compost or dispose of it as appropriate. Inspect mulched areas often in accordance with any applicable permit requirements and, where applicable, stormwater pollution prevention plan specifications to identify areas where mulch has loosened or where there has been mulch removal, especially after rain. Reseed these areas, if necessary, and replace the mulch cover immediately. If using mulch binders, reapply them at rates that the manufacturer recommends. If washout, breakage or erosion occurs, repair, reseed and reapply mulch. Inspections and maintenance activities should continue until firm vegetation establishment occurs.

Effectiveness

Mulching is effective at reducing soil loss. Effectiveness varies according to the type of mulch, but for most mulches, it increases as the application rate increases. For example, applying 0.5 tons of hay mulch per acre reduces soil loss by 75 percent, and applying 2.0 tons per acre reduces soil loss by 98 percent. Applying wood chips at a rate of 6 tons per acre reduces soil loss by 94 percent, applying wood cellulose at a rate of 1.75 tons per acre reduces soil loss by 90 percent, and applying gravel reduces soil loss by 95 percent (MPCA, 2019).

Cost Considerations

Table 2 shows costs that relate to various types of mulch, including material and labor costs. The high variability reflects differences in regional markets and raw material availability. When more than one product may be suitable for a particular application, using a more locally sourced option may realize cost savings.

Q13

Table 2. Typical costs for mulching materials and labor per acre.

Material Type	Cost (Dollars per Acre)[a]
Hay, 1-inch application depth	$2,000–$4,000
Oat, 1-inch application depth	$2,500–$4,500
Wood chips, 2-inch application depth	$13,000–$18,000
Stone, 3-inch application depth	$80,000–$100,000
Pea gravel, 3-inch application depth	$65,000–$95,000
Hydromulch	$10,000–$17,000
Jute netting	$7,500–$11,000

[a] Cost data source is RSMeans, 2019.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

Minnesota Pollution Control Agency (MPCA). (2019). Erosion prevention practices—natural and synthetic mulches. In *Minnesota stormwater manual*.

Montana Department of Transportation (MDT). (2015). Erosion and sediment control best management practices manual.

U.S. Department of Agriculture (USDA). (2011). *Mulching—Iowa job sheet*.

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Washington State Department of Transportation (WSDOT). (2019). *Temporary erosion and sediment control manual*.

Stormwater Best Management Practice

Riprap

Minimum Measure: Construction Site Stormwater Runoff Control;
Subcategory: Erosion Control

Description

Riprap is a layer of large stones that protects soil from erosion in areas of high or concentrated flows. It is especially useful for armoring channel and ditch banks, among other features. Construction staff may also pair riprap with other stormwater control measures to reduce stormwater flow rates.

Applicability

Riprap is useful in areas where other erosion control practices have exceeded their stabilization capacity (MPCA, 2019). For example, riprap can stabilize cut-and-fill slopes; channel side slopes and bottoms; inlets and outlets for culverts, bridges, slope drains, grade stabilization structures, and storm drains; and streambanks.

Siting and Design Considerations

Riprap can be unstable on very steep slopes, especially when site developers use rounded rock. For slopes steeper than 2:1, developers should consider using materials other than riprap for erosion protection. Construction sequencing is important, as construction staff that use riprap in high-flow locations often struggle to remove it after placement (WDE, 2014).

When installing riprap, construction staff should consider the following design recommendations (MDE, NRCS, & MASCD, 2011):

- *Gradation*. Use a well-graded mixture of rock sizes instead of one uniform size. Design engineers can determine a minimum size based on standard design equations and site-specific flow regimes.
- *Riprap size*. Riprap size depends on the shear stress of the flows that the riprap will be subject to, which design engineers can determine using standard design equations. Median stone diameters range from 9.5 to 23 inches, with no stones larger than 34 inches.

A riprap-lined bank surrounding a newly constructed detention pond.

- *Stone quality*. Stone for riprap should consist of field stone or quarry stone that is angular, variably sized and resistant to cracking during freeze and thaw cycles. Most igneous stones, such as granite, have suitable durability. Do not use crushed concrete for riprap.
- *Riprap depth*. Riprap minimum depths depend upon site flow regimes, median riprap size and local design requirements. Consult and appropriately implement local design standards.
- *Filter material*. To prevent underlying soil from moving through the riprap, apply a filter fabric, geotextile material or layer of gravel before applying the riprap.
- *Riprap upper limits*. Place riprap so it extends up to the maximum flow depth, or to a point where the land surface is stable or vegetation will be satisfactory to control erosion.
- *Curves*. Consult local design standards to ensure riprap extends far enough upstream and downstream of any curve.
- *Wire riprap enclosures*. Consider using chain link fencing or wire mesh to secure riprap installations, especially on steep slopes or in high-flow areas.

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This practice is typically referred to as a gabion. Consult local design standards for more information.

Limitations

Q14

The steepness of the slope limits the applicability of riprap, because slopes greater than 2:1 can cause riprap loss due to erosion and sliding. Improper use of riprap can increase erosion. Additionally, riprap can be hard to maintain if sediment inundates it; therefore, construction staff should not locate riprap downstream of an area with sediment-laden stormwater.

Maintenance Considerations

Inspect riprap areas annually and after major storms. If storms damage the riprap or geotextile material, repair it promptly to prevent a progressive failure. If a location repeatedly needs repairs, evaluate the site to determine if the original design conditions have changed. Also, weed and brush growth control may be necessary. Maintain the line, grade and cross section as designed. Remove accumulated sediment and debris if using riprap for energy dissipation (MDE, NRCS, & MASCD, 2011).

Effectiveness

Proper design and installation of riprap can reduce flow velocities and prevent erosion of the protected area.

Cost Considerations

The cost of riprap varies depending on location, material type, maintenance frequency and installation method. Hand-placed riprap can cost up to $750 per cubic yard, while random riprap can cost as little as $64 per cubic yard (MPCA, 2019).

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

Maryland Department of the Environment (MDE), Natural Resources Conservation Service (NRCS), & Maryland Association of Soil Conservation Districts (MASCD). (2011). *2011 Maryland standards and specifications for soil erosion and sediment control.* Baltimore, MD: Maryland Department of the Environment.

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Stormwater Best Management Practice

Permanent Seeding

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

Seeding establishes perennial vegetative cover, which helps control soil erosion on disturbed areas. It reduces erosion and sediment loss by protecting bare soil surfaces from displacement by raindrop impacts, reducing stormwater flow rates and volumes, and providing permanent stabilization. This practice is economical, is adaptable to different site conditions, and allows selection of a variety of plant materials.

Applicability

Seeding is well-suited to areas where permanent, long-lived vegetative cover is the most practical or most effective method of stabilizing the soil. These include roughly graded areas that construction staff will not regrade for at least a year. Seeding's advantages over other means of establishing plants include lower initial costs and labor needs.

Siting and Design Considerations

Q15

Some states require or at least recommend that construction staff seed or plant areas they intend to stabilize with permanent vegetation within 15 working days or 90 calendar days after reaching final grade, unless they apply temporary stabilization (Smolen et al. 2013).

Design engineers and construction staff can maximize successful vegetation establishment by:

- Careful planning
- Considering soil characteristics
- Selecting plant materials that are suitable for the site
- Planting at appropriate times
- Providing regular maintenance

Major factors that dictate the suitability of plants for a site include climate, soils and topography. Design engineers should consult state or local resources for recommendations on native, low-maintenance and low-water plant species.

Before seeding, construction staff should prepare and amend the soil on a disturbed site to provide sufficient nutrients for seed germination and seedling growth. This includes loosening the soil surface to allow for water

Hay and hydroseed can be used on a slope to establish vegetative cover.

infiltration and root penetration. If soils are too acidic, it also includes increasing the pH to between 6.0 and 6.5 with lime or choosing plants that are appropriate for acidic soils. Construction staff should apply seeds uniformly using hydroseeding, dry seeding, cultipacker seeding or manual seeding. They should protect seeds with mulch to retain moisture, regulate soil temperatures and prevent erosion during seedling establishment.

Grasses should emerge within 4–28 days and legumes 5–28 days after seeding, with legumes following grasses. A successful stand, or an area of continuous plantings, has the following characteristics:

- Vigorous dark green or bluish green (not yellow) seedlings
- Uniform density, with nurse plants, legumes and grasses well intermixed
- Green leaves that remain green throughout the summer—at least at the plant bases

Limitations

Limits on the effectiveness of seeding can include high erosion during establishment, the need to reseed areas that fail to establish, limited planting seasons, or unstable soil temperature and soil moisture content during germination and early growth. Seeding does not immediately stabilize soils; therefore, construction staff should use temporary erosion and sediment control measures to prevent pollutants from disturbed areas from being transported off the site.

Maintenance Considerations

Maintenance for seeded areas will depend on the type of vegetation and level of use expected. Long-lived, fine-leaved grass perennials that form a tight sod are suitable for areas that receive extensive use, such as homes, industrial parks, schools, churches and recreational areas. Less robust species may need frequent replanting. Native species that have adapted to local weather and soil conditions will reduce water and fertilizer requirements, thus reducing overall maintenance needs. This is especially important in arid areas, where irrigation requirements can be high. In these areas, using drought-adapted non-grass species (a major part of xeriscaping) can reduce or eliminate the need for watering.

Design engineers can also use seeding in low-maintenance areas that are mowed rarely or not at all and do not receive lime or fertilizer regularly. In these areas, plants should be able to persist with minimal maintenance over long periods. Design engineers should use grass and legume mixtures for these sites because legumes fix nitrogen from the atmosphere. Sites suitable for low-maintenance vegetation include steep slopes, stream or channel banks, some commercial properties, and “utility” turf areas such as road banks.

Construction staff should inspect seeded areas for failure and, if needed, reseed and repair them as soon as possible. If a stand has inadequate cover, they should reevaluate the choice of plant materials and quantities of lime and fertilizer. Depending on the condition of the stand, they should repair by overseeding or reseeding. Staff should perform complete seedbed preparation prior to reseeding the stand. If timing is bad, they can overseed with rye grain or German millet to thicken the stand until the time is right for seeding perennials. If the season is not appropriate for permanent seeding, construction staff can use temporary, annual species. If vegetation fails to grow, construction staff should test the soil to determine if low pH or nutrient imbalances are responsible.

On a typical disturbed site, full plant establishment usually requires refertilization in the second growing season. Construction staff can use soil tests to determine if they need to add more fertilizer. In most locations, construction staff should not fertilize cool season grasses in late May through July. Grass that looks yellow might be nitrogen deficient. Construction staff should not use nitrogen fertilizer if the stand contains more than 20 percent legumes.

Effectiveness

The effectiveness of seeding depends on a number of factors including site slopes, soils and vegetation health. Still, when properly implemented, permanent seeding often reduces soil loss by up to 99 percent (5C, 2012).

Cost Considerations

The cost of permanent seeding varies depending on many factors—availability and proximity of materials, application method, time of year, prevailing wage rates, and regional cost trends, to name a few. It is therefore difficult to develop cost estimates that apply nationwide and year-round. As a general example, seeding bluegrass with hydroseeding generally costs around $50 to $100 per thousand square feet (RSMeans, 2020).

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA’s National Menu of Best Management Practices (BMPs) for Stormwater website

References

Five Counties Salmonid Conservation Program (5C) (2012). *5C Roads Workshop Presentation, Understanding Erosion with the Revised Universal Soil Loss Equation.*

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Disclaimer

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Stormwater Best Management Practice

Sodding

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

Sodding is a permanent erosion control practice that involves laying a continuous cover of grass sod on exposed soils. Sodding can stabilize disturbed areas and slow down flowing stormwater. Sodding can provide immediate vegetative cover for critical areas and stabilize areas where seeding is not an option. It also can stabilize channels or swales that convey concentrated flows and reduce flow velocities. Sodding is an effective measure to provide stabilization on construction sites where construction activities have permanently ceased.

Sod can be used to quickly stabilize soil and reduce erosion

Applicability

Sodding is appropriate for any graded or cleared area that might erode, requiring immediate vegetative cover. Well-suited locations include:

- Residential or commercial lawns and golf courses where prompt use and aesthetics are important
- Steeply sloped areas
- Waterways and channels carrying intermittent flow
- Areas around drop inlets that require stabilization

Siting and Design Considerations

Sodding eliminates the need for seeding and mulching. Construction staff can lay sod during times of the year when seeded grasses are likely to fail. Staff should make sure to install sod no more than 36 hours after its producers harvest it to ensure that the sod is healthy and living. (If they cannot, they should inspect and approve the sod before installing it.) Staff should use only high-quality sod of known genetic origin, free of noxious weeds, disease and insect problems (Smolen et al., 2013). They should ensure that the sod is machine-cut at a uniform soil thickness of 0.5–2 inches (not including shoot growth or thatch) at the time of establishment. Local agricultural extension offices can be helpful resources for identifying sod sources and providing planting instructions for local conditions.

Sod installation generally entails the following steps:

- If a soil test determines the need based on local growing conditions, prepare the soil and add lime or fertilizer, as needed.
- Clear all trash, debris, roots, branches, stones and clods larger than 2 inches in diameter.
- Lay the sod in strips perpendicular to the direction of water flow. Stagger it in a brick-like pattern.
- Staple the corners and middle of each strip firmly.
- Peg jute or plastic netting over the sod to protect against washout during establishment.
- Water the sod often within the first few weeks of installation.

Limitations

Sod is more expensive than seed, and more difficult to obtain, transport and store. To ensure successful establishment, construction staff should prepare the soil and provide adequate moisture before, during and after installation. On poorly prepared soil or an unsuitable surface, the grass will die quickly because it cannot root. After installation, inadequate irrigation can cause root dieback or cause the sod to dry out.

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Maintenance Considerations

To maintain adequate moisture in the root zone and to prevent dormancy, construction staff should water the sod, especially within the first few weeks of installation. Staff should not mow the sod until it is firmly rooted. When mowing, they should not remove more than one-third of the shoot, keeping grass height between 2 and 3 inches. After the first growing season, staff should determine if the sod needs more fertilization or liming. Permanent, fine turf areas need yearly maintenance fertilization. Staff should fertilize warm-season grass in late spring to early summer; they should fertilize cool-season grass in late winter and again in early fall.

Effectiveness

The effectiveness of sod in reducing erosion is hard to quantify, as performance can vary depending on soil conditions, storm intensities and slope. Still, erosion over well-sodded areas is minimal in all but the largest storms (Beard & Green, 1994): many jurisdictions (e.g., 5C, 2012) credit sod as reducing soil loss by up to 99 percent.

Cost Considerations

Q16

The cost of sodding depends on many factors—availability and proximity of materials, time of year, prevailing wage rates, regional cost trends, and project size, to name a few. It is therefore difficult to develop cost estimates that apply nationwide and year-round. Including installation, costs can range from $25 to $100 per square yard (RSMeans, 2020).

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Soil Retention

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

Soil retention measures are structures or practices that hold soil in place or keep it contained within a site boundary. They can include grading or reshaping the ground to lessen steep slopes but most commonly include shoring excavated areas with wood, concrete or steel structures. Design engineers can use structural soil-retaining measures (sometimes referred to as shoring or retaining walls) to control erosion or protect workers during excavation projects.

Applicability

Before breaking ground on any construction site, design engineers and contractors should assess site conditions and, where possible, reduce steep slopes by grading. In some cases, regrading in conjunction with low impact practices such as mulching, seeding or chemical stabilization may be sufficient to protect against erosion. However, for sites with very steep slopes or loose, highly erodible soils, design engineers and contractors should consider soil-retaining structures.

Siting and Design Considerations

Q17

Even for temporary applications, qualified professionals should design and install soil-retaining structures according to local construction codes. If retaining walls serve trenching or excavation purposes, Occupational Safety and Health Administration Trenching and Excavation Safety standards may apply, requiring the use of acceptable support techniques.

General categories of soil retention structures are braced, cantilevered and tied back systems, which refer to their method of support. Braced systems consist of sheeting, which holds the soil in place, and external struts or boards, which hold the sheeting in place. Braced systems are the most common for low-cost, short-term construction site applications. Examples of braced systems include:

A retaining wall supporting soil along a steep slope.
Photo Credit: Washington State Department of Transportation/ Flickr

- ***Skeleton sheeting*** – An inexpensive soil-bracing system consisting of construction-grade lumber that supports the excavated face of a slope. This method requires the soil to be cohesive.
- ***Continuous sheeting*** – A system that involves using a material, such as face-steel, concrete or wood, to cover the entire slope continuously and placing struts and boards along the slope to support it.

Cantilevered and tied back systems tend to be stronger and often have larger or longer-term applications. Because of their strength and life spans, they are also applicable when the post-construction site layout requires soil retention. Cantilevered systems are L-shaped and get their support from the horizontal component that extends into the retained soil, using the weight of that soil to keep the wall in place. Tied back systems, or anchored systems, receive support from an anchor buried deep into the base of the retained soil. Cantilevered and tied back systems generally consist of concrete, masonry, steel or corrugated metal.

Design considerations for soil retention structures include the nature of the soil, location of the ground water table and expected loads. Chini and Genauer

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(1997) provides a comprehensive overview of technical considerations for construction site soil support systems. The *Wisconsin Department of Transportation Bridge Manual* also contains additional types of soil retention structures and a table to help with design selection according to project requirements.

Limitations

To be effective, soil retention structures should have designs that can handle expected loads. Heavy rains can damage or destroy these structures, especially temporary braced systems. As soil retention structures are generally holding back large quantities of soil, their failures can result in significant sediment input to waterbodies. Construction staff should properly install and maintain these structures to avoid failure.

Maintenance Considerations

Construction staff should regularly inspect soil retention structures, especially after rainstorms, to check for erosion, damage or other signs of deterioration. Staff should repair any damage to site features upslope of the retaining structure, such as washouts or breakages of other sediment control practices, before reinstalling materials for the soil retention structure.

Effectiveness

Soil retention structures with proper design and installation can effectively prevent erosion in areas with steep slopes and erodible soils. The potential for failure depends on the design, installation and maintenance of the structures, as well as the likelihood of catastrophic events such as heavy rains, earthquakes and landslides.

Cost Considerations

Soil retention practice costs depend on a number of factors. Land grading costs depend on the size of the area construction staff are regrading and the amount of soil they need to move. Soil retention structure costs vary widely depending on project requirements such as the topography of the surrounding area, excavation requirements, the type of soil that needs stabilizing and the amount of time the structure will be in place. Each of these factors affects the size and type of system that design engineers and contractors implement. A 5-foot-tall temporary wood skeleton sheeting can cost as little as $5 per linear foot (RSMeans, 2020a). A cast-in-place concrete retaining wall can cost from on the order of $100 per linear foot for smaller 5-foot to 10-foot walls, to more than $1,000 per linear foot for a 20-foot-high wall (RSMeans, 2020b).

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

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Stormwater Best Management Practice

Soil Roughening

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

Soil roughening is a temporary erosion control practice that often occurs in conjunction with grading. Soil roughening involves increasing the relief of a bare soil surface with horizontal grooves by either stair-stepping (running parallel to the contour of the land) or using construction equipment to track the surface. Slopes without fine-grading that remain in a roughened condition can also reduce erosion. Soil roughening reduces stormwater velocity, increases infiltration, reduces erosion, traps sediment, and prepares the soil for seeding and planting by giving seed an opportunity to take hold and grow. A rough soil surface allows surface ponding that protects lime, fertilizer and seed and decreases erosion potential. Grooves in the soil are cooler and provide more favorable moisture conditions than hard, smooth surfaces. These conditions promote seed germination and vegetative growth.

Soil roughened with tracked machinery can provide temporary erosion control.
Photo Credit: Anthony D'Angelo for USEPA, 2012

Applicability

Q18

Soil roughening is appropriate for all slopes but works especially well on slopes greater than 3:1, on piles of excavated soil and in areas with highly erodible soils (MDOT, 2015; Lake, 2016). This technique is a good option for soils that construction staff frequently disturb because roughening is relatively easy. To slow erosion, construction staff should roughen the soil as soon as possible after removing the vegetation from the slope or immediately after ceasing grading activities (temporarily or permanently). Use the practice in conjunction with seeding, mulching and chemical stabilization to stabilize an area. A combination of surface roughening and vegetation is appropriate for steeper slopes and slopes that will remain bare for longer periods of time.

Siting and Design Considerations

Certain soils are difficult to apply soil roughening to as they can compact easily. Construction staff should avoid excessive soil compaction as it inhibits vegetation growth and causes higher stormwater velocity. If using tracked machinery, staff should limit roughening to sandy soils that do not compact easily. Clay soils compact extremely easily, especially when wet. If clay soils or soils with high clay content require soil roughening, operators should consider lighter tools such as walk-behind tillers. Construction staff should seed roughened areas as quickly as possible to minimize the exposure of bare earth to rain. Dust control procedures can help reduce erosion while the site establishes vegetation.

Soil roughening methods depend on slope and project conditions. Methods include stair-step grading, grooving and tracking. When choosing a method, consider factors such as slope steepness, mowing requirements, whether the slope is formed by cutting or filling, and available equipment. Smolen et al. (2013) outlines soil roughening methods, which can include:

- ***Cut slope roughening for areas that construction staff will not mow*** – Stair-step grades or groove-cut slopes are suitable for gradients steeper than 3:1 or any erodible material that is soft enough for a bulldozer to rip. Stair-step grading is also suitable for slopes consisting of soft rock with some subsoil. The vertical cut distance should be less than the horizontal distance, with the slope of the horizontal portion of the step angling slightly down toward the vertical wall to slow stormwater and promote ponding and infiltration. Individual vertical cuts should be less than 2 feet deep in soft materials and less than 3 feet deep in rocky materials.

- ***Grooving*** – This technique uses machinery to create a series of ridges and depressions that run across the slope along the contour. Construction staff can make grooves using any appropriate implement that they can safely operate on the slope, such as disks, tillers, spring harrows or the teeth on a front-end loader bucket. Grooves should have a maximum depth of 3 inches and be less than 15 inches apart.
- ***Fill slope roughening for areas that construction staff will not mow*** – Staff should place fill slopes with a gradient steeper than 3:1 in lifts less than 9 inches. They should compact each individual lift according to design specifications. The face of the slope should consist of loose, uncompacted fill 4 to 6 inches deep. If necessary, construction staff can roughen slope faces by grooving the surface using the above techniques. They should not smooth, scrape or compact slope faces because it would limit the ability of the site to establish vegetation.
- ***Cuts, fills and graded areas that staff will mow*** – Mowed slopes should be no steeper than 3:1. Construction staff can roughen mowed slopes with shallow grooves less than 10 inches apart and deeper than 1 inch using normal tilling, disking or harrowing equipment (they can also use a cultipacker-seeder). Excessive roughness is undesirable where staff plan to mow.
- ***Roughening with tracked machinery*** – To avoid undue compaction of the soil surface, construction staff should only conduct roughening with tracked machinery in sandy soils. If staff implement roughening with tracked machinery, they should make track routes perpendicular to the slope so that the grooves of the tracks align with the contour. Tracking is generally not as effective as other roughening methods.

Limitations

Soil roughening is not appropriate for rocky slopes. Tracked machinery can excessively compact the soil. Typically, roughened surfaces only withstand gentle or shallow depth rains. If a heavy storm washes away roughening, construction staff typically have to re-roughen and reseed surfaces.

Maintenance Considerations

Construction staff should inspect roughened areas after storms to see if re-roughening is necessary. Regular inspection should indicate where additional erosion and sediment control practices are necessary. Staff should immediately fill, regrade and reseed any rills (small watercourses that have steep sides and are usually only a few inches deep) that appear.

Effectiveness

Soil roughening provides moderate erosion protection for bare soils while the site establishes vegetative cover. It is an inexpensive and simple temporary erosion control, and it is effective in use with other erosion and sediment control practices.

Cost Considerations

Soil roughening requires minimal materials but requires using equipment that varies in price. Rental costs of smaller pieces of equipment, such as hand tillers or disk harrows, are generally $50 to $100 per day (RSMeans, 2020). Larger sites generally require larger, more expensive equipment. However, heavy equipment, like a bulldozer, is often already present on construction sites, and rented attachments such as rippers or scarifiers can accomplish soil roughening. The cost of such attachments also tends to be in the range of $50 to $100 per day (RSMeans, 2020). In all cases, also consider the cost of labor, which varies according to the size of the area construction staff are roughening.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Temporary Slope Drains

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

A temporary slope drain is a conduit used to convey stormwater down a disturbed slope while preventing erosion. At the top of the slope, a channel or swale diverts flow to the pipe entrance for conveyance down the slope. The discharge end of the pipe requires outlet protection. This erosion control practice is a temporary measure that construction staff typically use for less than 2 years during grading operations until they can install permanent drainage structures or permanently stabilize slopes.

Applicability

Construction staff can use temporary slope drains on most disturbed slopes to eliminate gully erosion from concentrated flows. Properly designed slope drains are easy to install and maintain.

Siting and Design Considerations

Design engineers often consider the following for the siting and design of temporary slope drains (WDE, 2014):

- The conduit should consist of heavy-duty material that staff can anchor at a spacing of 10 to 20 feet depending on the size of pipe and expected flow volume. Conduit material typically includes corrugated metal, corrugated plastic or flexible tubing.
- The area upstream of the conduit should be stable and large enough to direct flow to the conduit inlet.
- The size of the conduit should be able to handle flow from a 10-year, 24-hour storm event.
- A conduit 12 inches wide or wider should have a standard flared section to prevent stormwater from undercutting the inlet. Construction staff should thoroughly compact and stabilize the soil around the conduit inlet with gravel or riprap.
- Construction staff may use sandbags near the conduit inlet as temporary reinforcement.

A temporary slope drain made from corrugated pipe. A "T" fitting at the downstream end slows discharge and prevents erosion.

- The conduit inlet should have at least 6 inches of freeboard.
- The conduit outlet should have suitable erosion protection or be in an erosion-resistant location.

- Construction staff should re-route equipment and vehicular traffic around slope drains to avoid damage.

Limitations Q19

The area that a temporary slope drains should not exceed 5 acres. Physical obstructions substantially reduce the conduit's effectiveness. Other concerns include failures from overtopping because of inadequate inlet capacity, leakage at joints and mudslides (WES, 2008).

Maintenance Considerations

Inspect the slope drain after each rainfall to determine whether it exceeded capacity, blockages occurred, leakages developed, anchoring is secure and positioning is appropriate for the site. Also check inlet and outlet structures for undercutting. Conduct repairs immediately, as needed (WES, 2008).

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

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Disclaimer

Stormwater Best Management Practice

Temporary Stream Crossings

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

A temporary steam crossing can provide a safe, stable way for construction vehicle traffic to cross a watercourse. Temporary stream crossings provide streambank stabilization, reduce the risk of damage to the streambed or channel, and minimize sediment loading from construction traffic. The crossing may be a bridge, culvert or ford. Stream crossings in most cases require a permit from the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act.

Applicability

Temporary stream crossings are appropriate where heavy construction equipment needs to move from one side of a stream channel to the other. They are also appropriate where lighter construction vehicles will cross the stream repeatedly during construction. Table 1 provides conditions for when each type of stream crossing is appropriate.

A bridge or culvert is the best choice for most temporary stream crossings because each can support heavy loads and regular traffic, as well as cause minimal disturbance. Bridges require the highest level of engineering and generally are the most expensive option; however, they provide the most functionality and protection to the stream that vehicles cross. Construction staff can salvage bridge and culvert construction materials after they remove the structures. A ford is a shallow area in a stream that vehicles can cross safely, and it generally has no load limits. However, fords can result in significant stream disturbances. Fords are only appropriate where stream crossings are infrequent and culverts or bridges are infeasible. When used, fords are appropriate where normal flow is shallow or intermittent and the channel is wide.

Q20

Table 1. Conditions affecting suitability of stream crossing type.

Crossing Type	Applicability
Bridge	■ Streams with high flow velocities, steep gradients and/or areas where regulations do not allow temporary restrictions in the channel. ■ Streams that do not have time-of-year restrictions.
Culvert	■ Perennial or intermittent streams. ■ Most common type of temporary stream crossing. ■ Creates less disturbance than a ford.
Ford	■ Dry washes, ephemeral streams or low-flow perennial streams in arid climates during the dry season. ■ Areas where stream banks are less than 4 feet high or construction of a culvert or bridge is impractical. ■ Most appropriate for short-term use.

Sources: IDT, 2014; MPCA, 2019

Siting and Design Considerations

Because of the potential for stream degradation, flooding and safety hazards, construction staff should avoid stream crossings whenever possible. Construction staff should consider alternative routes to accessing a site before planning to erect a temporary stream crossing. If a stream crossing is necessary, they should select an area where the potential for erosion is low and, if possible, construct the stream crossing during a dry period. In all cases, after removal of the temporary stream crossing, construction staff should return impacted banks and streambeds to their original condition and grade (USACE, 2015). Construction staff should minimize the disturbance or removal of vegetation to facilitate rapid regrowth after removing the temporary structure.

Bridges

If over-stream bridges are necessary, construction crews should only construct them under the supervision and approval of a qualified engineer.

Culverts

Culverts should be of an appropriate size for the site hydrology and drainage area. A qualified engineer may need to perform the hydrologic analysis and design. Construction staff should use filter cloth to cover the streambed, stream banks and approach to reduce settlement and make the culvert structure more stable. The filter cloth should extend at least 6 inches and no more than 1 foot beyond the end of the culvert and bedding material. The culvert piping should be of sufficient diameter to allow flow to pass completely during peak flow periods and to pass debris (USACE, 2015). Aggregate should cover pipes by at least 1 foot or one-half the pipe diameter, whichever is greater (MPCA, 2019). If necessary, construction staff should install energy-dissipating devices downstream of the culvert to prevent scour. Regional time-of-year restrictions may exist and should be a consideration (USACE, 2015).

Fords

Fords may be appropriate when a bridge or culvert is not feasible; the natural streambed and banks consist of a ledge, rock, or sand that help minimize erosion; and a stable gradual approach exists (USACE, 2015). Construction staff should construct fords using stabilizing material such as large rocks or clean, native gravel. Some streams, such as salmonid streams or streams and rivers below reservoirs, may even benefit from an influx of gravel (IDT, 2014). Cellular confinement systems or prefabricated mats may also be appropriate where the addition of gravel may be problematic (MECA, 2010). Ford construction should ideally occur during periods of little to no flow to minimize erosion. If construction has to occur during periods of flow, construction staff should use a temporary stream diversion. They should also use appropriate erosion and sediment controls along the stream banks and approach to the ford until stabilization occurs (MPCA, 2019).

Limitations

Bridges can be expensive to design and install, and sites should avoid them if less obtrusive measures are possible.

Culvert construction and removal usually disturbs the surrounding area, leading to erosion and sediment export. Therefore, some localities may prohibit the practice in sensitive streams. Culverts can also obstruct flow in a stream and get in the way of migrating fish. Depending on the culvert's size, large debris in a stream can block the culvert, and culverts are vulnerable to frequent washout (IDT, 2014).

Approaches to fords are likely to erode without sufficient stabilization. In addition, excavating the streambed and approach to lay riprap or other stabilization material causes major streambed and bank disturbances that construction staff should repair. The crossing can transport mud and other debris directly into the stream unless construction staff use it only during periods of low flow or use a temporary stream diversion (USACE, 2015).

Developers should be cautious when considering stream crossing measures that require disturbing area below the stream's high-water mark. A Section 401 State Certification of Water Quality, Section 404 dredge and fill permit or state permit may be a requirement for a temporary stream crossing (IDT, 2014). Additionally, a permit with the U.S. Fish and Wildlife Service may be a requirement if authorities know endangered or threatened species or critical habitat to be present in the work area (MPCA, 2019). For any project, developers should contact local authorities to ensure they have obtained all required permits.

Maintenance Considerations

Construction staff should inspect temporary stream crossings and maintain them in compliance with all applicable federal, state and local permit requirements. Inspections should occur at least once a week and after all significant rainfall events for staff to remove debris, repair areas of erosion or replace eroded material. If inspectors report any structural damage to a bridge or culvert, construction staff should not use the structure until they repair it. Following completion of the construction project, construction staff should promptly remove temporary stream crossings and stabilize disturbed areas (IDT, 2014).

Effectiveness

The effectiveness of a temporary stream crossing depends on the applicability of the crossing type, proper design and installation, siting, and adherence to long-term maintenance plans (MPCA, 2019). In an experiment that reviewed the effectiveness of stream crossings during and after construction of the crossing, Morris et al. (2016) found that the construction of fords and culverts results in nearly 10 times more sediment transport than the construction of bridges. They also found that, for any crossing type, protecting slopes with rock or gravel could reduce regular sediment export by about half compared to bare slopes, and they found that incorporating a geotextile could reduce sediment export further compared to rock alone.

Cost Considerations[1]

Implementation costs vary widely for a temporary stream crossing depending on the site needs, crossing type, maintenance needs and other site-specific factors. Typically, temporary bridges are more expensive to design and construct than culverts. Bridges also have higher maintenance and repair costs if they fail. Table 2 shows cost ranges of temporary stream crossings based on a survey of actual construction costs, including materials and installation, from 70 Virginia logging contractors (McKee et al., 2012).

[1] Prices are in 2019 dollars. Inflation data is from the Bureau of Labor Statistics CPI Inflation Calculator.

Table 2. Average total construction costs for stream crossings.

Crossing Type	Cost
Ford	$1,200
Culvert	$900–$1,900
Wooden bridge	$3,300–$3,500
Steel bridge	$11,000–$13,700

Source: McKee et al., 2012

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Wind Fences and Sand Fences

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

Wind fences (also called sand fences) are barriers made of permeable fabric or small, evenly spaced wooden slats. Construction staff erect wind fences to reduce wind velocity and to trap blowing sand. Wind fences can also serve as perimeter controls around open construction sites to keep the wind from blowing sediments off-site. In doing so, they prevent off-site damage to roads, streams and adjacent properties. The spaces between the fence slats allow wind to pass through but reduce its speed, causing sediment to deposit along the fence.

Applicability

Q21

Wind fences are appropriate for areas with loose sands that high winds can transport off-site. They can be helpful for construction sites with large areas of cleared land or in arid regions where blowing sand is problematic. Shorefront development sites also benefit because wind fences help to form frontal dunes. Wind fences are not an appropriate control measure for fine sediment or dust, though they can be more effective in combination with dust control practices. For control of fine sediment, see Dust Control.

Siting and Design Considerations

Wind fences are only effective when construction staff place them perpendicular or near perpendicular to the prevailing wind. They should be at least 3 to 4 feet high with an effective minimum porosity of 50 percent. For wooden slat fences, this means the gap between slats should equal the slat width. For prefabricated commercial products, such as woven polyethylene, the manufacturer should specify the porosity and the material should be ultraviolet-resistant. Construction staff should also install woven fences with a gap of 1 to 2 feet between the fabric bottom and ground surface to prevent breakage during high winds. Erecting multiple rows of fences, spaced 20 to 40 feet apart, increases their overall sediment-trapping efficiency (DOWL, 2015; GSWCC, 2016; NCDEQ, 2013).

A wind fence that has trapped sand along a beach dune.

To protect stockpiles, construction staff should place wind fencing upwind of the stockpiles at a distance of approximately three times the height of the stockpile (DOWL, 2015).

In coastal dune areas, construction staff should place wind fences away from the mean high tide line. Using native vegetation can enhance fence integrity (GSWCC, 2016).

Limitations

Wind fences do not control sediment carried in stormwater discharges and are not effective for dust control. Where erosion control and dust control are necessary, install wind fences with other erosion and sediment control practices (see Dust Control, Brush Barrier, Chemical Stabilization, Geotextiles, Land Grading, Preserving Natural or Existing Vegetation, Riprap, etc.).

Maintenance Considerations

Periodically inspect wind fences to ensure no tears or breaks exist. Repair any broken fences immediately.

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Periodically clean sand and sediment from the fence area to prevent stormwater from transporting them.

Effectiveness

The effectiveness of wind fences depends on several factors, including the soil type, local climate conditions, wind condition, and presence of other soil stabilization or dust control practices. Wind fences tend to be more effective for controlling heavier sands that stormwater transports near the ground surface. Wind fences do not effectively control finer sediment that becomes easily airborne (i.e., dust). Wind fences are most effective for slowing dune migration in coastal areas.

Cost Considerations

Wind fences are relatively inexpensive to purchase, install and maintain because they are small, easy to transport, lightweight and made of low-cost materials.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

DOWL. (2015). Erosion and sediment control best management practices manual. Montana Department of Transportation.

Georgia Soil and Water Conservation Commission (GSWCC). (2016). *Manual for erosion and sediment control in Georgia.*

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Stormwater Best Management Practice

Check Dams

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Runoff Control

Description

Check dams are relatively small, temporary structures constructed within concentrated-flow areas such as swales, channels and ditches. Check dams are primarily an erosion and sediment control practice and are most effective when combined with other erosion and sediment control practices.

Applicability

Check dams are appropriate where temporary or permanent channels are not yet vegetated, or channel lining is infeasible. Placing dams at regular intervals—so that the base of the upstream dam is at the same elevation as the top of the downstream dam—can reduce a conveyance feature's effective slope (SPU, 2017). Check dams reduce erosion by reducing flow velocities. Sediment trapping can occur at lower flow velocities, but construction staff should not use check dams solely for this purpose.

Siting and Design Considerations

Q22

Construction staff can build check dams using a variety of materials: most commonly rock, sand- or gravel-filled bags, or fiber logs. They should not use straw bales or silt fences, which are not suitable for concentrated-flow areas (MPCA, 2019). They should use check dams in concentrated-flow areas that drain areas of 10 acres or less (WES, 2008) and where velocity exceeds 4 feet per second as measured during a 2-year, 24-hour storm event (MDE, NRCS, & MASCD, 2011).

Check dam dimensions depend on slope and expected flow velocities. When installing them in series, construction staff should space check dams so the crest of the downstream dam is at the same elevation as the toe of the upstream dam (MPCA, 2019). A check dam should extend from bank to bank, with a center lower than the banks, to create a weir. The center of the dam should not be more than 24 inches high and should be at least 6 inches lower than the check dam edges (MDE, NRCS, & MASCD, 2011). To make dams more stable, construction staff can implant the material at least 6 inches into the sides and bottom of the channel. Combining check dam materials with stabilization measures, such as geotextile lining, can prevent further erosion.

A rock check dam in a channel.
Credit: Kort Kirkeby for USEPA, 2012

Before installing check dams, construction staff should impound and bypass upstream flow away from the work area. They should not install check dams in streams (SPU, 2017) or other waterways without approval from an appropriate regulatory agency.

Limitations

Check dams mainly serve to slow stormwater flow in a channel—they are not suitable as standalone substitutes for other erosion and sediment-trapping devices. Ponded water above check dams may kill established vegetation or prevent vegetation from establishing. Check dams may reduce the hydraulic capacity of the channel and create turbulent flow downstream, which may increase erosion unless the channel is protected with geotextile fabric or riprap (WES, 2008).

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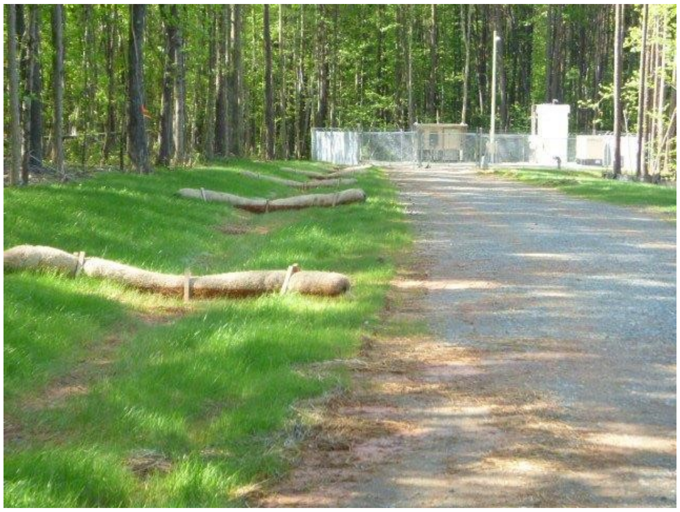

A series of filter sock check dams placed in a grass swale.
Credit: Jared Richardson for USEPA, 2015

Maintenance Considerations

Construction staff should inspect check dams after each storm event to ensure their structural integrity and to look for scour underneath the check dam and bypass on the sides. If the center of a check dam is not lower than its edges, staff may need to add additional stone to restore the correct height. During inspection, they should remove large debris, trash and leaves (MPCA, 2019). When sediment has reached about one-third the original height of the dam (measured at the center of the upstream side), staff should remove the accumulated sediment (WES, 2008). If significant erosion occurs between check dams, they should install a geotextile fabric liner or riprap in that portion of the channel (SPU, 2017).

Before removing a check dam, construction staff should completely stabilize the contributing area and remove all accumulated sediment. When removing check dams, staff should take care to remove all dam materials to ensure proper flow within the channel. Immediately after removal, they should stabilize any disturbed area with seed, soil stabilization matting or sod (MDE, NRCS, & MASCD, 2011).

Effectiveness

For long channels, check dams are most effective when used in series. They effectively prevent erosion in concentrated-flow regimes but have limited sediment settling capacity. If sediment transport is a concern, construction staff can use check dams in conjunction with other practices. Check dams are relatively easy to install (WES, 2008).

Cost Considerations[1]

Check dams are generally inexpensive (WES, 2008). The cost of a check dam depends on its composition and the width of the dammed channel. A 1-foot-deep rock check dam constructed using the minimum dimensions specified by MDE, NRCS and MASCD (2011) requires roughly 2 cubic yards of stone. With an installed cost for stone or gravel ranging from $50 to $200 per cubic yard (RSMeans, 2019), the resulting material cost alone is at least $100 to 400, which does not include excavation, maintenance or removal. By comparison, the Minnesota Department of Transportation's 2014 summary of average bid prices for awarded projects indicated an average cost per rock check dam of $1,400. Smaller versions or check dams using different materials may cost much less. For example, sediment control logs varied in price from $2.52 to $13.25 per linear foot (MPCA, 2019).

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

[1] Prices updated to 2019 dollars. Inflation rates obtained from the Bureau of Labor Statistics CPI Inflation Calculator website: https://data.bls.gov/cgi-bin/cpicalc.pl.

References

Maryland Department of the Environment (MDE), Natural Resources Conservation Service (NRCS), & Maryland Association of Soil Conservation Districts (MASCD). (2011). *2011 Maryland standards and specifications for soil erosion and sediment control.* Baltimore, MD: Maryland Department of the Environment.

Minnesota Pollution Control Agency (MPCA). (2019). Sediment control practices—Check dams (ditch checks, ditch dikes). In *Minnesota stormwater manual.* Retrieved from

RSMeans. (2019). Stone and gravel data from Gordian [Online data file]. Greensville, SC: RSMeans data from Gordian.

Seattle Public Utilities (SPU). (2017). *City of Seattle stormwater manual* (Vol. 2).

Water Environment Services (WES). (2008). *Erosion prevention and sediment control: Planning and design manual.*

Disclaimer

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Stormwater Best Management Practice

Grass-Lined Channels

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Runoff Control

Description

A grass-lined channel is a graded, vegetated channel that collects and conveys stormwater while encouraging infiltration into the ground. Vegetation lining the channel slows down concentrated flow. Because grassed channels usually cannot control peak flows by themselves, construction staff typically use them with other stormwater control measures, such as riprap stabilization. Small grass-lined channels can also be used to transport stormwater—via gravity—from one stormwater control measure to another. For example, a grass-lined channel can connect a series of check dams or energy disruption devices to a sediment basin.

Where moderately steep slopes require drainage, grassed channels can include excavated depressions to increase storage, decrease flow rates and further enhance the sediment settling. Grass-lined channels with extra storage can also reduce peak discharges by temporarily holding stormwater in the channel.

Grass-lined channel in a construction area.
Credit: Anthony D'Angelo for USEPA, 2017

Applicability Q23

Grass-lined channels primarily provide stormwater conveyance and velocity control. Although they also provide limited filtration capacity, construction staff should not use grass-lined channels as a primary sediment control practice. If the velocity in the channel would erode the grass or sod, construction staff can use riprap, concrete or gabions (U.S. EPA, 2009). Geotextile materials can be combined with either grass or riprap linings to provide additional protection at the soil-lining interface. Grass-lined channels are applicable to areas that need erosion-resistant conveyances, including areas with highly erodible soils and moderately steep slopes (only up to 5 percent). Construction staff should only install grass-lined channels where space is available for an adequately large cross section.

Siting and Design Considerations

Developers should site grass-lined channels in accordance with the natural drainage system. The channel design should not cross ridges, have sharp curves or feature significant changes in slope. The channel should not receive direct sedimentation from disturbed areas, and designers should site them only on the perimeter of a construction site to convey relatively clean stormwater discharge. To reduce sediment loads, developers can separate channels from disturbed areas using a vegetated buffer or another primary sediment control practice.

In addition to any local design specifications and requirements, basic design recommendations for grass-lined channels generally specify that construction staff should (WDE, 2014):

- Construct and vegetate the channel before site grading and paving activities begin, allowing vegetation to fully stabilize before stormwater is conveyed.
- Base maximum design velocities on soil conditions, vegetation type and expected flow rates and ensure that velocities do not exceed 5 feet per second. If design velocities are expected to exceed 2 feet per second before vegetation is established, construction staff should install a temporary liner.

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- Use triangular channels for low velocities and small quantities of stormwater and parabolic or trapezoidal channels for larger flows.
- Install riprap lining or subsurface drainage, if necessary, in areas that experience prolonged wet conditions.
- Install outlet stabilization structures if the discharge velocity is expected to be high.
- Ensure that side slopes are 2:1 or flatter for safety and erosion purposes.

Limitations

Q24

If construction staff do not properly install grass-lined channels, the channels can change the natural flow of surface water and adversely affect downstream waters. Also, if a large storm event exceeds the design capacity, the vegetation might not be adequate to prevent erosion, which might damage or destroy the channel. Clogging with sediment and debris reduces the effectiveness of grass-lined channels for stormwater conveyance. Increased infiltration could be a concern for buildings near the grass-lined channel with below-grade basements or downgradient slope failure (MPCA, 2019).

Maintenance Considerations

The maintenance requirements for grass-lined channels are relatively minimal. During the establishment of vegetation, inspect the channels after every storm. After vegetation establishment, mow it, remove litter and perform spot vegetation repair. Check for areas of scour or undercutting near outlet and inlet structures. The most important objective in grass-lined channel maintenance is to maintain a dense and vigorous growth of turf because it is the primary erosion protection for the channel. Remove vegetation and soil buildup to eliminate water flow obstructions within the channel. During the growing season, cut the channel grass no shorter than the level of the design flow (WDE, 2014).

Cost Considerations

Installation costs will vary greatly depending on the amount of earthwork the channel requires, the use of seed or sod, and any required additional protection measures such as lining or riprap. However, installation is generally quick, and (after vegetation establishment) the channel will need minimum maintenance if the channel is appropriately sited and designed by developers. Developers can design grass-lined channels as post-construction stormwater controls that are permanently left in place after construction staff stabilize the construction site. The channels, in combination with other practices that detain, filter or infiltrate stormwater, can substantially reduce the size of permanent detention facilities like stormwater ponds and wetlands, thereby reducing the overall cost of post-construction stormwater management.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

MPCA (Minnesota Pollution Control Agency). (2019). Sediment control practices—Buffer zones. In *Minnesota stormwater manual*.

U.S. Environmental Protection Agency (U.S. EPA). (2009). *Development document for final action for effluent guidelines and standards for the construction and development category*. (EPA-821-B-04-001).

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Stormwater Best Management Practice

Land Grading

Minimum Measure: Construction Site Stormwater Runoff Control
Subcategory: Erosion Control

Description

This land grading fact sheet includes information related to land grading, gradient terraces, permanent slope diversions and temporary diversion dikes. Land grading involves reshaping the ground surface to planned elevations, as approved construction drawings from a civil engineer or other qualified professional show. Land grading provides more suitable topography for buildings, facilities and other land uses and helps control stormwater, soil erosion and sedimentation during and after construction.

Applicability

Land grading applies to all sites that require earthwork—particularly those with uneven topography or easily erodible soils—because it can stabilize slopes and decrease stormwater velocity.

Siting and Design Considerations

When preparing grading plans or other construction drawings that specify grading, a civil engineer or other qualified professional should account for:

- Existing soil types
- Existing slopes
- Existing drainage patterns
- Environmentally sensitive areas
- Proposed land use
- Proposed stormwater control measures

Grading plans should specify limits of disturbance, land elevations, slopes, drainage patterns and construction schedules. A grading plan should also describe erosion and sediment controls, including locations, dimensions, quantities and standard details.

Construction staff should perform land grading in ways that limit the extent and duration of soil-disturbing activities. When developing grading plans, design engineers should minimize the limits of disturbance and only include areas necessary for construction, utility installation and equipment traffic. Construction sequencing, the practice of minimizing unstabilized soils at any given time during construction, should be a consideration when scheduling and conducting land grading activities. Clearing and grading should never occur beyond the limits of disturbance that approved construction drawings specify.

Land grading involves reshaping the ground surface to planned elevations.
Credit: Anthony D'Angelo for USEPA, 2012

When developing grading plans, preserving natural, existing or established vegetation in temporary or permanent buffer zones is a low-cost way to reduce stormwater discharge and off-site sedimentation. In addition, design engineers should take care to ensure that land grading does not disturb steep slopes, wetlands, streams, stream valley buffers, forested areas or endangered species habitats.

To minimize off-site sediment transport, construction staff should divert stormwater from undisturbed areas away from areas that will be disturbed. Temporary diversion structures—such as check dams or temporary slope drains—should interrupt disturbed areas with long slopes to reduce stormwater velocities and divert stormwater from exposed areas.

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If construction staff uses blasting agents or explosives, they should take care to limit their emissions into the surrounding environment. These products may contain perchlorates, which are water-soluble chemicals. If construction staff must use explosives containing perchlorate, they should employ good housekeeping practices to ensure they properly dispose of any debris (MassDEP, 2006).

Limitations

Design engineers should develop grading plans to preserve existing drainage patterns as much as possible. Land grading that disrupts natural stormwater flow patterns might lead to poor drainage, high stormwater velocities or increased peak flows during storm events. Clearing and grading an entire site without maintaining a vegetated buffer or implementing adequate erosion and sediment control measures can promote off-site transport of sediments and other pollutants. If construction staff cannot use excavated material or store it on-site, they should make accommodations for off-site transport and disposal. Disposal costs increase if hazardous substances have contaminated the excavated material.

Maintenance Considerations

Construction staff should implement all land grading and erosion and sediment control practices per approved construction drawings and inspect them at frequencies in accordance with applicable permits and consistent with the site's stormwater pollution prevention plan. Construction staff should also inspect unstabilized areas and associated erosion and sediment controls after rainfall events. Necessary maintenance may include backfilling or stabilizing washouts and eroded areas or removing accumulated sediment from erosion and sediment controls.

Construction staff should stabilize areas where grading activities are complete and where they do not anticipate disturbance for 2 or more weeks, including any stockpiles that they will not actively use for 2 or more weeks (40 CFR 450.21[b]; U.S. EPA, 2019). Construction staff should also apply dust control measures in accordance with the permit and consistent with the site-specific stormwater pollution prevention plan.

Effectiveness

When sites properly implement land grading with appropriate stormwater management and erosion and sediment control practices, land grading can mitigate stormwater flow from steep slopes and stabilize highly erodible soils. Land grading can increase erosion and off-site sediment transport when it alters drainage patterns or when it leads construction staff to clear vegetated areas on the perimeter of the site (U.S. EPA, 2004).

Cost Considerations

Land grading incurs costs in both the design and construction phases. Even for small sites, a certified engineer or landscape architect may spend several hours establishing final grades and incorporating stormwater management and erosion and sediment controls into the development plan. These costs increase as sites become larger and more complex.

During construction, in addition to performing labor associated with grading activities, construction staff may need additional time to construct diversions and berms. The site may require off-site fill for low-lying areas or depressions. Where excavation is necessary, sites may need to remove and dispose of excess soil if on-site use or storage is not possible.

Costs of common land grading activities are as follows (RSMeans, 2019):

- Fine grading, soil treatment and stabilization costs are approximately $4 to $6 per square yard.
- Shallow excavation (1 to 4 feet deep) with a backhoe where dewatering is not necessary costs $6 to $10 per cubic yard of removed material.
- Larger-scale grading requires a site-specific assessment and a detailed earthworks analysis to retain as much soil on-site as possible and limit disposal costs.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

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