Construction Site Storm Water (Comprehensive)

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Credit: 9 PDH

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Construction Site Storm Water Runoff Control

Regulatory Text

- You must develop, implement, and enforce a program to reduce pollutants in any storm water runoff to your small MS4 from construction activities that result in a land disturbance of greater than or equal to one acre. Reduction of storm water discharges from construction activity disturbing less than one acre must be included in your program if that construction activity is part of a larger common plan of development or sale that would disturb one acre or more. If the NPDES permitting authority waives requirements for storm water discharges associated with small construction activity in accordance with Sec. 122.26(b)(15)(i), you are not required to develop, implement, and/or enforce a program to reduce pollutant discharges from such sites.

- Your program must include the development and implementation of, at a minimum:

(A) An ordinance or other regulatory mechanism to require erosion and sediment controls, as well as sanctions to ensure compliance, to the extent allowable under State, Tribal, or local law;

(B) Requirements for construction site operators to implement appropriate erosion and sediment control (ESC) best management practices;

(C) Requirements for construction site operators to control waste such as discarded building materials, concrete truck washout, chemicals, litter, and sanitary waste at the construction site that may cause adverse impacts to water quality;

(D) Procedures for site plan review which incorporate consideration of potential water quality impacts;

(E) Procedures for receipt and consideration of information submitted by the public, and

(F) Procedures for site inspection and enforcement of control measures.

Guidance

Examples of sanctions to ensure compliance include nonmonetary penalties, fines, bonding requirements, and/or permit denials for non-compliance. EPA recommends that procedures for site plan review include the review of individual pre-construction site plans to ensure consistency with local (ESC) requirements. Procedures for site inspections and enforcement of control measures could include steps to identify priority sites for inspection and enforcement based on the nature of the construction activity, topography, and the characteristics of soils and receiving water quality. You are encouraged to provide appropriate educational and training measures for construction site operators. You may wish to require a storm water pollution prevention plan for construction sites within your jurisdiction that discharge into your system. See Sec. 122.44(s) (NPDES permitting authorities' option to incorporate qualifying State, Tribal and local erosion and sediment control programs into NPDES permits for storm water discharges from construction sites). Also see Sec. 122.35(b) (The NPDES permitting authority may recognize that another government entity, including the permitting authority, may be responsible for implementing one or more of the minimum measures on your behalf).

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Land Grading

Construction Site Storm Water Runoff Control

Description


Soils exposed from land grading activities are very vulnerable to erosion

Land grading involves reshaping the ground surface to planned grades as determined by an engineering survey, evaluation, and layout. Land grading provides more suitable topography for buildings, facilities, and other land uses and helps to control surface runoff, soil erosion, and sedimentation during and after construction.

Applicability

Land grading is applicable to sites with uneven or steep topography or easily erodible soils, because it stabilizes slopes and decreases runoff velocity. Grading activities should maintain existing drainage patterns as much as possible.

Siting and Design Considerations

Before grading activities begin, decisions must be made regarding the steepness of cut-and-fill slopes and how the slopes will be

- Protected from runoff
- Stabilized
- Maintained.

A grading plan should be prepared that establishes which areas of the site will be graded, how drainage patterns will be directed, and how runoff velocities will affect receiving waters. The grading plan also includes information regarding when earthwork will start and stop, establishes the degree and length of finished slopes, and dictates where and how excess material will be disposed of (or where borrow materials will be obtained if needed). Berms, diversions, and other storm water practices that require excavation and filling also should be incorporated into the grading plan.

A low-impact development BMP that can be incorporated into a grading plan is *site fingerprinting*, which involves clearing and grading only those areas necessary for building activities and equipment traffic. Maintaining undisturbed temporary or permanent buffer zones in the grading operation provides a low-cost sediment control measure that will help reduce runoff and off-site sedimentation. The lowest elevation of the site should remain undisturbed to provide a protected storm water outlet before storm drains or other construction outlets are installed.

Limitations

Improper grading practices that disrupt natural storm water patterns might lead to poor drainage, high runoff velocities, and increased peak flows during storm events. Clearing and grading of the entire site without vegetated buffers promotes off-site transport of sediments and other pollutants. The grading plan must be designed with erosion and sediment control and storm water management goals in mind; grading crews must be carefully supervised to ensure that the plan is implemented as intended.

Maintenance Considerations

All graded areas and supporting erosion and sediment control practices should be periodically checked, especially after heavy rainfalls. All sediment should be removed from diversions or other storm water conveyances promptly. If washouts or breaks occur, they should be repaired immediately. Prompt maintenance of small-scale eroded areas is essential to prevent these areas from becoming significant gullies.

Effectiveness

Land grading is an effective means of reducing steep slopes and stabilizing highly erodible soils when properly implemented with storm water management and erosion and sediment control practices. Land grading is not effective when drainage patterns are altered or when vegetated areas on the perimeter of the site are destroyed.

Cost Considerations

Land grading is practiced at virtually all construction sites. Additional site planning to incorporate storm water and erosion and sediment controls in the grading plan can require several hours of planning by a certified engineer or landscape architect. Extra time might be required to excavate diversions and construct berms, and fill materials might be needed to build up low-lying areas or fill depressions.

References

State of Delaware. No date. *Delaware Erosion and Sediment Control Handbook for Development.* Department of Natural Resources and Environmental Control, Division of Water Conservation.

State of North Carolina. 1988. *Erosion and Sediment Control Planning and Design Manual.* North Carolina Sedimentation Control Commission and North Carolina Department of Natural Resources and Community Development, Raleigh, NC.

USEPA. 1992. *Storm Water Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices*. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

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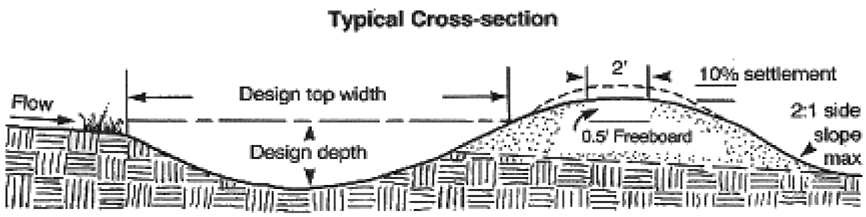
Permanent Diversions

Construction Site Storm Water Runoff Control

Description

Diversions can be constructed by creating channels across slopes with supporting earthen ridges on the bottom sides of the slopes. The ridges reduce slope length, collect storm water runoff, and deflect the runoff to acceptable outlets that convey it without erosion.



Site planners incorporate diversions into the overall grading plan to direct clean runoff away from exposed areas

Applicability

Diversions are used in areas where runoff from areas of higher elevation poses a threat of property damage or erosion. Diversions can also be used to promote the growth of vegetation in areas of lower elevations. Finally, diversions protect upland slopes that are being damaged by surface and/or shallow subsurface flow by reducing slope length, which minimizes soil loss.

Siting and Design Considerations

Ridge. A cross section of the earthen ridge must have side slopes no steeper than 2:1; a width at the design water elevation of at least 4 feet; a minimum freeboard of 0.3 feet; and a 10-percent settlement factor included in the design.

Outlet. Four acceptable outlets for the conveyance of runoff and their construction specifications include:

1. *Storm water conveyance channel*. A permanent designed waterway, containing appropriate vegetation, that is appropriately shaped and sized to carry storm water runoff away from developing areas without any damage from erosion. The following are general specifications that are required for channel construction:

    - All obstructions and unsuitable material, such as trees, roots, brush, and stumps, and any excess soil should be removed from the channel area and disposed of properly.
    - The channel must meet grade and cross-section specifications, and any fill that is used must be compacted to ensure equal settlement.
    - Parabolic and triangular-shaped, grass-lined channels should not have a top width of more than 30 feet.

- Trapezoidal, grass-lined channels may not have a bottom width of more than 15 feet unless there are multiple or divided waterways, they have a riprap center, or other methods of controlling the meandering of low flows are provided.
- If grass-lined channels have a base flow, a stone center or subsurface drain or another method for managing the base flow must be provided.
- All channels must have outlets that are protected from erosion.

2. *Level spreader*. A device used to prevent erosion and to improve infiltration by spreading storm water runoff evenly over the ground as shallow flow instead of through channels. It usually involves a depression in the soil surface that disperses flow onto a flatter area across a slight slope and then releases the flow onto level vegetated areas. This reduces flow speed and increases infiltration. Construction specifications for level spreaders include:

- Level spreaders should be constructed on natural soils and not on fill material or easily erodible soils.
- There should be a level entrance to the spreader to ensure the flow can be evenly distributed.
- Heavy equipment and traffic should not be allowed on the level spreader, as they can cause compaction of soil and disturbance of the slope grade.
- The spreader should be regraded if ponding or erosion channels develop.
- Dense vegetation should be sustained and damaged areas reseeded when necessary.

3. *Outlet protection*. This involves placing structurally lined aprons or other appropriate energy-dissipating devices at the outlets of pipes to reduce the velocity of storm water flows and thereby prevent scouring at storm water outlets, protect the outlet structure, and minimize potential for erosion downstream. Construction specifications for outlet protection practices require the following:

- No bends occur in the horizontal alignment.
- There is no slope along the length of the apron, and the invert elevations must be equal at the receiving channel and the apron's downstream end.
- No overfall at the end of the apron is allowed.
- If a pipe discharges into a well-defined channel, the channel's side slopes may not be steeper than 2:1.
- The apron is lined with riprap, grouted riprap, concrete, or gabion baskets, with all riprap conforming to standards and specifications, and the median-sized stone for riprap is specified in the plan
- Filter cloth, conforming to standards and specifications, must be placed between riprap and the underlying soil to prevent any soil movement through the riprap.

- All grout for grouted riprap must be one part Portland cement for every 3 parts sand, mixed thoroughly with water. Once stones are in place, the spaces between them are to be filled with grout to a minimum depth of 6 inches, with the deeper portions choked with fine material.
- All concrete aprons must be installed as specified in the plan.
- The end of the paved channel in a paved channel outlet must be smoothly joined with the receiving channel section, with no overfall at the end of the paved section.

4. *Paved flume. A* permanent paved channel that is constructed on a slope through which storm water runoff can be diverted down the face of the slope without causing erosion problems on or below the slope. Paved flumes are not recommended unless very high flows with excessive erosive power are expected, because increased runoff velocity might magnify erosion at the flume's outfall. Outfall protection must be provided to prevent damage from high-velocity flows. The paved flume also prevents infiltration of surface runoff, exacerbating offsite runoff problems. Where possible, vegetated channels should be used--additional stabilization can be provided with rip-rap, gabions, or turf reinforcement mats.

Construction specifications for paved flumes require that:

- The subgrade must be constructed to required elevations, with all soft portions and unsuitable material removed and replaced with suitable material, must be thoroughly compacted and smoothed to a uniform surface, and must be moist when the concrete is poured.
- The slope of the structure may be no more than 1.5:1.
- Curtain walls must be attached to the beginning and end of any paved flumes that are not adjoined to another structure, and the curtain walls should be the same width as the flume channel, at least 6 inches thick, and extend at least 18 inches into the soil under the channel.
- Anchor lugs must be spaced no more than 10 feet apart on center, continuous with the channel lining for the length of the flume; they must be the same width as the bottom of the flume channel, at least 6 inches thick, and extend at least 1 foot into the soil under the channel.
- There should be at least a 4-inch thickness of class A-3 concrete with welded wire fabric in the center of the flume channel for reinforcement.
- Traverse joints should be provided at approximately 20-foot intervals or when there are more than 45 minutes between consecutive concrete placements in order to control cracks.
- Expansion joints should be provided approximately every 90 feet.
- Outlets of the paved flumes should be protected from erosion through the use of an energy-dissipating device with outlet protection, as described previously.

Stabilization. Immediately after the ridge and channel are constructed, they must be seeded and mulched along with any disturbed areas that drain into the diversion. Sediment-trapping measures must remain in place in case the upslope area is not stabilized, to prevent soil from moving into the diversion. All obstructions and unsuitable material, such as trees, brush, and stumps, must be removed from the channel area and disposed of so the diversion may function properly. The channel must meet grade and cross-section specifications, and any fill that is used must be free from excessive organic debris, rocks, or other unsuitable material and must be compacted to ensure equal settlement. Disturbed areas should be permanently stabilized according to applicable local standards and specifications.

Limitations

The area around the channel that is disturbed by its construction must be stabilized so that it is not subject to similar erosion as the steep slope the channel is built to protect.

Maintenance Considerations

Diversions should be inspected after every rainfall and a minimum of once every 2 weeks before final stabilization. Channels should be cleared of sediment, repairs made when necessary, and seeded areas reseeded if a vegetative cover is not established.

References

Smolen, M.D., D.W. Miller, L.C. Wyatt, J. Lichthardt, and A.L. Lanier. 1988. *Erosion and Sediment Control Planning and Design Manual*. North Carolina Sedimentation Control Commission, North Carolina Department of Environment, Health, and Natural Resources, and Division of Land Resources Land Quality Section, Raleigh, NC.

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Virginia Department of Conservation and Recreation. 1995. *Virginia Erosion & Sediment Control Field Manual. Second Edition.* Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation, Richmond, VA.

Preserving Natural Vegetation

Construction Site Storm Water Runoff Control

Description


Natural vegetation is protected from heavy equipment with safety fencing

The principal advantage of preserving natural vegetation is the protection of desirable trees, vines, bushes, and grasses from damage during project development. Vegetation provides erosion control, storm water detention, biofiltration, and aesthetic values to a site during and after construction activities. Other benefits from preserving natural areas are because natural vegetation

- Can process higher quantities of storm water runoff than newly seeded areas
- Does not require time to establish
- Has a higher filtering capacity than newly planted vegetation because aboveground and root structures are typically denser
- Reduces storm water runoff by intercepting rainfall, promoting infiltration, and lowering the water table through transpiration
- Provides buffers and screens against noise and visual disturbance
- Provides a fully developed habitat for wildlife
- Usually requires less maintenance (e.g., irrigation, fertilizer) than planting new vegetation
- Enhances aesthetics.

Applicability

Preservation of natural vegetation is applicable to all construction sites where vegetation exists in the predevelopment condition. Areas where preserving vegetation can be particularly beneficial are floodplains, wetlands, stream banks, steep slopes, and other areas where erosion controls would be difficult to establish, install, or maintain. Only land needed for building activities and vehicle traffic needs to be cleared.

Siting and Design Considerations

Vegetation should be marked for preservation before clearing activities begin. A site map should be prepared with the locations of trees and boundaries of environmentally sensitive areas and buffer zones to be preserved. The location of roads, buildings, and other structures can be planned to avoid these areas. Preservation requires careful site management to minimize the impact of construction activities on existing vegetation. Large trees located near construction zones should be protected because damage during construction activities may result in reduced vigor or death after construction has ceased. The boundaries around contiguous natural areas and tree drip lines should be extended and marked to protect the root zone from damage. Although direct contact by equipment is an obvious means of damage to trees and other vegetation, compaction, filling, or excavation of land too close to the vegetation also can cause severe damage.

When selecting trees for preservation, the following factors should be considered:

- *Tree vigor*. Preserving healthy trees that will be less susceptible to damage, disease, and insects. Indicators of poor vigor include dead tips of branches, stunted leaf growth, sparse foliage, and pale foliage color. Hollow, rotten, split, cracked, or leaning trees also have less chance of survival.
- *Tree age.* Older trees are more aesthetically pleasing as long as they are healthy.
- *Tree species.* Species well-suited to present and future site conditions should be chosen. Preserving a mixture of evergreens and hardwoods can help to conserve energy when evergreens are preserved on the northern side of the site to protect against cold winter winds and deciduous trees are preserved on the southern side to provide shade in the summer and sunshine in the winter.
- *Wildlife benefits.* Trees that are preferred by wildlife for food, cover, and nesting should be chosen.

Other considerations include following natural contours and maintaining preconstruction drainage patterns. Alteration of hydrology might result in dieoff of preserved vegetation because their environmental requirements are no longer met.

The following are basic considerations for preservation of natural vegetation:

- Boards should not be nailed to trees during building operations.
- Tree roots inside the tree drip line should not be cut.
- Barriers should be used to prevent the approach of equipment within protected areas.
- Equipment, construction materials, topsoil, and fill dirt should not be placed within the limit of preserved areas.
- If a tree or shrub that is marked for preservation is damaged, it should be removed and replaced with a tree of the same or similar species with a 2-inch or larger caliper width from balled and burlaped nursery stock when construction activity is complete.
- During final site cleanup, barriers around preserved areas and trees should be removed.

Limitations

Preservation of vegetation is limited by the extent of existing vegetation in preconstruction conditions. It requires planning to preserve and maintain the existing vegetation. It is also limited by the size of the site relative to the size of structures to be built. High land prices might prohibit preservation of natural areas. Additionally, equipment must have enough room to maneuver; in some cases preserved vegetation might block equipment traffic and may constrict the area available for construction activities. Finally, improper grading of a site might result in changes in environmental conditions that result in vegetation dieoff. Consideration should be given to the hydrology of natural or preserved areas when planning the site.

Maintenance Considerations

Even if precautions are taken, some damage to protected areas may occur. In such cases, damaged vegetation should be repaired or replaced immediately to maintain the integrity of the natural system. Continued maintenance is needed to ensure that protected areas are not adversely impacted by new structures. Newly planted vegetation should be planned to enhance the existing vegetation.

Effectiveness

Natural vegetation (existing trees, vines, brushes, and grasses) can provide water quality benefits by intercepting rainfall, filtering storm water runoff, and preventing off-site transport of sediments and other pollutants.

Cost Considerations

A potential cost associated with preservation of natural vegetation is increased labor that might be required to maneuver around trees or protected areas.

References

Smolen, M.D., D.W. Miller, L.C. Wyall, J. Lichthardt, and A.L. Lanier. 1988. *Erosion and Sediment Control Planning and Design Manual*. North Carolina Sedimentation Control Commission, North Carolina Department of Environment, Health, and Natural Resources, and Division of Land Resources Land Quality Section, Raleigh, NC.

USEPA. 1992. Storm Water Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Construction Entrances

Construction Site Storm Water Runoff Control

Description

Stabilized construction entrances allow dirt to be removed from tire treads and collected as trucks leave construction sites

The purpose of stabilizing entrances to a construction site is to minimize the amount of sediment leaving the area as mud and sediment attached to motorized vehicles. Installing a pad of gravel over filter cloth where construction traffic leaves a site can help stabilize a construction entrance. As a vehicle drives over the gravel pad, mud and sediment are removed from the vehicle's wheels and offsite transport of soil is reduced. The gravel pad also reduces erosion and rutting on the soil beneath the stabilization structure. The filter fabric separates the gravel from the soil below, preventing the gravel from being ground into the soil. The fabric also reduces the amount of rutting caused by vehicle tires by spreading the vehicle's weight over a larger soil area than just the tire width.

In addition to removal of sediment by simple friction of vehicle tires on the gravel pad, a vehicle washing station can be established at the site entrance. Wash stations, if used on a routine basis, remove a substantial amount of sediment from vehicles before they leave the site. Diverting runoff from vehicle washing stations into a sediment trap helps ensure that sediment removed from vehicles is kept on-site and disposed of properly.

Applicability

Typically, stabilized construction entrances are installed at locations where construction traffic leaves or enters an existing paved road. However, the applicability of site entrance stabilization should be extended to any roadway or entrance where vehicles will access or leave the site. From a public relations point of view, stabilizing construction site entrances can be a worthwhile exercise. If the site entrance is the most publicly noticeable part of a construction site, stabilized entrances can improve the appearance to passersby and improve public perception of the construction project.

Siting and Design Considerations

All entrances to a site should be stabilized before construction and further disturbance of the site area begins. The stabilized site entrances should be long and wide enough so that the largest construction vehicle that will enter the site will fit in the entrance with room to spare. If many vehicles are expected to use an entrance in any one day, the site entrance should be wide enough for the passage of two vehicles at the same time with room on either side of each vehicle. If a site entrance leads to a paved road, the end of the entrance should be "flared" (made wider as in the shape of a funnel) so that long vehicles do not leave the stabilized area when turning onto or off of the paved roadway. If a construction site entrance crosses a stream, swale, or other depression, a bridge or culvert should be provided to prevent erosion from unprotected banks. Stone and gravel used to stabilize the construction site entrance should be large enough so that they are not carried off site with vehicle traffic. In addition, sharp-edged stone should be avoided to reduce the possibility of puncturing vehicle tires. Stone or gravel should be installed at a depth of at least 6 inches for the entire length and width of the stabilized construction entrance.

Limitations

Although stabilizing a construction entrance is a good way to help reduce the amount of sediment leaving a site, some soil may still be deposited from vehicle tires onto paved surfaces. To further reduce the chance of these sediments polluting storm water runoff, sweeping of the paved area adjacent to the stabilized site entrance is recommended. For sites using wash stations, a reliable water source to wash vehicles before leaving the site might not be initially available. In this case, water may have to be trucked to the site at additional cost.

Maintenance Considerations

Stabilization of site entrances should be maintained until the remainder of the construction site has been fully stabilized. Stone and gravel might need to be periodically added to each stabilized construction site entrance to keep the entrance effective. Soil that is tracked offsite should be swept up immediately for proper disposal. For sites with wash racks at each site entrance, sediment traps will have to be constructed and maintained for the life of the project. Maintenance will entail the periodic removal of sediment from the traps to ensure their continued effectiveness.

Effectiveness

Stabilizing construction entrances to prevent sediment transport off-site is effective only if all entrances to the site are stabilized and maintained. Also, stabilization of construction site entrances may not be very effective unless a wash rack is installed and routinely used (Corish, 1995). This can be problematic for sites with multiple entrances and high vehicle traffic.

Cost Considerations

Without a wash rack, construction site entrance stabilization costs range from $1,000 to $4,000. On average, the initial construction cost is around $2,000 per entrance. Including maintenance costs for a 2-year period, the average total annual cost is approximately $1,500. If a wash rack is included in the construction site entrance stabilization, the initial construction costs range from $1,000 to $5,000, with an average initial cost of $3,000 per entrance. The total cost, including maintenance for an estimated 2-year life span, is approximately $2,200 per year (USEPA, 1993).

References

Corish, K. 1995. *Clearing and Grading Strategies for Urban Watersheds*. Metropolitan Washington Council of Governments, Washington, DC.

USEPA. 1992. *Storm Water Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices*. EPA 832-R-92-005. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. EPA 840-B-92-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Stabilize drainage ways

Check Dams

Construction Site Storm Water Runoff Control

Description

Check dams are used to reduce the energy of storm water to prevent erosion

Check dams are small, temporary dams constructed across a swale or channel. Check dams can be constructed using gravel, rock, sandbags, logs, or straw bales and are used to slow the velocity of concentrated flow in a channel. By reducing the velocity of the water flowing through a swale or channel, check dams reduce the erosion in the swale or channel. As a secondary function, check dams can also be used to catch sediment from the channel itself or from the contributing drainage area as storm water runoff flows through the structure. However, the use of check dams in a channel should not be a substitute for the use of other sediment-trapping and erosion control measures. As with most other temporary structures, check dams are most effective when used in combination with other storm water and erosion and sediment control measures.

Applicability

Check dams should be used in swales or channels that will be used for a short period of time where it is not practical to line the channel or implement other flow control practices (USEPA, 1993). In addition, check dams are appropriate where temporary seeding has been recently implemented but has not had time to take root and fully develop. Check dams are usually used in small open channels with a contributing drainage area of 2 to 10 acres. For a given swale or channel, multiple check dams, spaced at appropriate intervals, can increase overall effectiveness. If dams are used in a series, they should be spaced such that the base of the upstream dam is at the same elevation as the top of the next downstream dam (VDCR, 1995).

Siting and Design Considerations

Check dams can be constructed from a number of different materials. Most commonly, they are made of rock, logs, sandbags, or straw bales. When using rock or stone, the material diameter should be 2 to 15 inches. Logs should have a diameter of 6 to 8 inches. Regardless of the material used, careful construction of a check dam is necessary to ensure its effectiveness. Dams should be installed with careful placement of the construction material. Mere dumping of the dam material into a channel is not appropriate and will reduce overall effectiveness.

All check dams should have a maximum height of 3 feet. The center of the dam should be at least 6 inches lower than the edges. This design creates a weir effect that helps to channel flows away from the banks and prevent further erosion. Additional stability can be achieved by implanting the dam material approximately 6 inches into the sides and bottom of the channel (VDCR, 1995). When installing more than one check dam in a channel, outlet stabilization measures should be installed below the final dam in the series. Because this area is likely to be vulnerable to further erosion, riprap, geotextile lining, or some other stabilization measure is highly recommended.

Limitations

Check dams should not be used in live, flowing streams unless approved by an appropriate regulatory agency (USEPA, 1992; VDCR, 1995). Because the primary function of check dams is to slow runoff in a channel, they should not be used as a stand-alone substitute for other sediment-trapping devices. Also, leaves have been shown to be a significant problem by clogging check dams in the fall. Therefore, they might necessitate increased inspection and maintenance.

Maintenance Considerations

Check dams should be inspected after each storm event to ensure continued effectiveness. During inspection, large debris, trash, and leaves should be removed. The center of a check dam should always be lower than its edges. If erosion or heavy flows cause the edges of a dam to fall to a height equal to or below the height of the center, repairs should be made immediately. Accumulated sediment should be removed from the upstream side of a check dam when the sediment has reached a height of approximately one-half the original height of the dam (measured at the center). In addition, all accumulated sediment should also be removed prior to removing a check dam. Removal of a check dam should be completed only after the contributing drainage area has been completely stabilized. Permanent vegetation should replace areas from which gravel, stone, logs, or other material have been removed. If the check dam is constructed of rock or gravel, maintenance crews should be sure to clear all small rock and gravel pieces from vegetated areas before attempting to mow the grass between check dams. Failure to remove stones and gravel can result in serious injury from flying debris.

Effectiveness

Field experience has shown that rock check dams are more effective than silt fences or straw bales to stabilize wet-weather ditches (VDCR, 1995). For long channels, check dams are most effective when used in a series, creating multiple barriers to sediment-laden runoff.

Cost Considerations

The cost of check dams varies based on the material used for construction and the width of the channel to be dammed. In general, it is estimated that check dams constructed of rock cost about $100 per dam (USEPA, 1992). Other materials, such as logs and sandbags, may be less expensive, but they might require higher maintenance costs.

References

USEPA. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. EPA 840-B-92-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

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Washington State Department of Ecology. 1992. *Stormwater Management Manual for the Puget Sound Basin*. Technical manual. Washington State Department of Ecology, Olympia, WA.

Filter Berms

Construction Site Storm Water Runoff Control

Description

A gravel or stone filter berm is a temporary ridge made up of loose gravel, stone, or crushed rock that slows, filters, and diverts flow from an open traffic area and acts as an efficient form of sediment control. A specific type of filter berm is the continuous berm, a geosynthetic fabric that encapsulates sand, rock, or soil.

Applicability

Gravel or stone filter berms are most suitable in areas where vehicular traffic needs to be rerouted because roads are under construction, or in traffic areas within a construction site.

Siting and Design Considerations

The following construction guidelines should be considered when building the berm:

- Well-graded gravel or crushed rock should be used to build the berm.
- Berms should be spaced according to the steepness of the slope, with berms spaced closer together as the slope increases.
- Sediment that builds up should be removed and disposed of and the filter material should be replaced. Regular inspection should indicate the frequency of sediment removal needed.

Limitations

Berms are intended to be used only in gently sloping areas. They do not last very long, and they require maintenance due to clogging from mud and soil on vehicle tires.

Maintenance Considerations

The berm should be inspected after every rainfall to ensure that sediment has not built up and that no damage has been done by vehicles. It is important that repairs be performed at the first sign of deterioration to ensure that the berm is functioning properly.

Effectiveness

The effectiveness of a rock filter berm depends upon rock size, slope, soil, and rainfall amount. The continuous berm is not staked into the ground and no trenching is required. Effectiveness has been rated at up to 95 percent for sediment removal, but is highly dependent on local conditions including hydrologic, hydraulic, topographic, and sediment characteristics.

Cost Considerations

Construction materials for filter berms (mainly gravel) are relatively low cost, but installation and regular cleaning and maintenance can result in substantial labor costs. These maintenance costs are lower in areas of less traffic, gentler slopes, and low rainfall.

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Grass-Lined Channels

Construction Site Storm Water Runoff Control

Description

A grass-lined channel can be used to filter and convey runoff

Grass-lined channels convey storm water runoff through a stable conduit. Vegetation lining the channel reduces the flow velocity of concentrated runoff. Grassed channels usually are not designed to control peak runoff loads by themselves and are often used in combination with other BMPs, such as subsurface drains and riprap stabilization. Where moderately steep slopes require drainage, grassed channels can include excavated depressions or check dams to enhance runoff storage, decrease flow rates, and enhance pollutant removal. Peak discharges can be reduced through temporary detention in the channel. Pollutants can be removed from storm water by filtration through vegetation, by deposition, or in some cases by infiltration of soluble nutrients into the soil. The degree of pollutant removal in a channel depends on the residence time of water in the channel and the amount of contact with vegetation and the soil surface. As a result, removal efficiency is highly dependent on local conditions.

Applicability

Grassed channels should be used in areas where erosion-resistant conveyances are needed, including areas with highly erodible soils and moderately steep slopes (although less than 5 percent). They should only be installed where space is available for a relatively large cross section. Grassed channels have a limited ability to control runoff from large storms and should not be used in areas where flow rates exceed 5 feet per second.

Siting and Design Considerations

Grass-lined channels should be sited in accordance with the natural drainage system and should not cross ridges. The channel design should not have sharp curves or significant changes in slope. The channel should not receive direct sedimentation from disturbed areas and should be sited only on the perimeter of a construction site to convey relatively clean storm water runoff. Channels should be separated from disturbed areas by a vegetated buffer or other BMP to reduce sediment loads.

Basic design recommendations for grassed channels include the following:

- Construction and vegetation of the channel should occur before grading and paving activities begin.
- Design velocities should be less than 5 feet per second.

- Geotextiles can be used to stabilize vegetation until it is fully established.
- Covering the bare soil with sod, mulches with netting, or geotextiles can provide reinforced storm water conveyance immediately.
- Triangular-shaped channels are used with low velocities and small quantities of runoff; parabolic grass channels are used for larger flows and where space is available; trapezoidal channels are used with large flows of low velocity (low slope).
- Outlet stabilization structures should be installed if the runoff volume or velocity has the potential to exceed the capacity of the receiving area.
- Channels should be designed to convey runoff from a 10-year storm without erosion.
- The sides of the channel should be sloped less than 2:1, and triangular-shaped channels along roads should be sloped 2:1 or less for safety.
- All trees, brushes, stumps, and other debris should be removed during construction.

Effectiveness

Grass-lined channels can effectively transport storm water from construction areas if they are designed for expected flow rates and velocities and if they do not receive sediment directly from disturbed areas.

Limitations

Grassed channels, if improperly installed, can alter the natural flow of surface water and have adverse impacts on downstream waters. Additionally, if the design capacity is exceeded by a large storm event, the vegetation might not be sufficient to prevent erosion and the channel might be destroyed. Clogging with sediment and debris reduces the effectiveness of grass-lined channels for storm water conveyance.

Maintenance Considerations

Maintenance requirements for grass channels are relatively minimal. During the vegetation establishment period, the channels should be inspected after every rainfall. Other maintenance activities that should be carried out after vegetation is established are mowing, litter removal, and spot vegetation repair. The most important objective in the maintenance of grassed channels is the maintaining of a dense and vigorous growth of turf. Periodic cleaning of vegetation and soil buildup in curb cuts is required so that water flow into the channel is unobstructed. During the growing season, channel grass should be cut no shorter than the level of design flow.

Cost Considerations

Costs of grassed channels range according to depth, with a 1.5-foot-deep, 10-foot-wide grassed channel estimated between $6,395 and $17,075 per trench, while a 3.0-foot-deep, 21-foot-wide grassed channel is estimated at $12,909 to $33,404 per trench (SWRPC, 1991). Grassed channels can be left in place permanently after the construction site is stabilized to contribute to long-term storm water management. The channels, in combination with other practices that detain, filter, and infiltrate runoff, can substantially reduce the size of permanent detention facilities such as storm water ponds and wetlands, thereby reducing the overall cost of storm water management.

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Riprap

Construction Site Storm Water Runoff Control

Description

Riprap is a permanent, erosion-resistant layer made of stones. It is intended to protect soil from erosion in areas of concentrated runoff. Riprap may also be used to stabilize slopes that are unstable because of seepage problems.

Riprap can be used to stabilize drainageways and outlets to prevent erosion

Applicability

Riprap can be used to 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 and grades.

Siting and Design Considerations

Riprap may be unstable on very steep slopes, especially when rounded rock is used. For slopes steeper than 2:1, consider using materials other than riprap for erosion protection. If riprap is being planned for the bottom of a permanently flowing channel, the bottom can be modified to enhance fish habitat. This can be done by constructing riffles and pools which simulate natural conditions. These riffles promote aeration and the pools provide deep waters for habitats.

The following are some design recommendations for riprap installation, (Smolen et al., 1988):

- *Gradation*. A well-graded mixture of rock sizes should be used instead of one uniform size.
- *Quality of stone*. Riprap must be durable so that freeze/thaw cycles do not decompose it in a short time; most igneous stones such as granite have suitable durability.
- *Riprap depth*. The thickness of riprap layers should be at least 2 times the maximum stone diameter.
- *Filter material*. Filter material is usually required between riprap and the underlying soil surface to prevent soil from moving through the riprap; a filter cloth material or a layer of gravel is usually used for the filter.
- *Leaching Protection*. Leaching can be controlled by installing a riprap gradation small enough to act as a filter against the channel base material, or a protective filter can be installed between the riprap and the base material.
- *Riprap Limits*. The riprap should extend for the maximum flow depth, or to a point where vegetation will be satisfactory to control erosion.

- *Curves*. Riprap should extend to five times the bottom width upstream and downstream of the beginning and ending of the curve as well as the entire curved section.
- *Riprap Size*. The size of riprap to be installed depends on site-specific conditions.

Limitations

Riprap is limited by steepness of slope, because slopes greater than 2:1 have potential riprap loss due to erosion and sliding. When working within flowing streams, measures should be taken to prevent excessive turbidity and erosion during construction. Bypassing base flows or temporarily blocking base flows are two possible methods.

Effectiveness

When properly designed and installed, riprap can prevent virtually all erosion from the protected area.

Maintenance Considerations

Riprap should be inspected annually and after major storms. If riprap has been damaged, repairs should be made promptly to prevent a progressive failure. If repairs are needed repeatedly at one location, the site should be evaluated to determine if the original design conditions have changed. Channel obstructions such as trees and sediment bars can change flow patterns and cause erosive forces that may damage riprap. Control of weed and brush growth may be needed in some locations.

Cost Considerations

The cost of riprap varies depending on location and the type of material selected. A cost of $35 to $50 per square yard of nongrouted riprap has been reported, while grouted riprap ranges from $45 to $60 per square yard (1993 dollars; Mayo et al., 1993). Alternatives to riprap channel lining include grass, sod, and concrete, which cost $3, $7, $8, $12, and $25 to $30 per square yard, respectively (1993 dollars, Mayo et al., 1993).

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Erosion Control

Stabilize exposed soils

Chemical Stabilization

Construction Site Storm Water Runoff Control

Description

A truck applies chemical stabilizers to reduce soil erosion where vegetation can not be planted (Source: Terra Firma Industries, 1999)

Chemical stabilizers, also known as soil binders or soil palliatives, provide temporary soil stabilization. Materials made of vinyl, asphalt, or rubber are sprayed onto the surface of exposed soils to hold the soil in place and protect against erosion from runoff and wind. Chemicals used for stabilization are easily applied to the surface of the soil, can be effective in stabilizing areas where vegetative practices cannot be established, and provide immediate protection.

Applicability

Chemical stabilization can be used in areas where other methods of stabilization such as temporary seeding or permanent vegetation are not effective because of environmental constraints. They can also be used in combination with vegetative or perimeter practices to enhance erosion and sediment control.

Siting and Design Considerations

The application rates and procedures recommended by the manufacturer of a chemical stabilization product should be followed as closely as possible to prevent the products from forming ponds and to avoid creating impervious areas where storm water cannot infiltrate.

Limitations

Chemical stabilization can create impervious surfaces where water cannot infiltrate and which might increase storm water runoff. Overuse of chemical stabilizers might adversely affect water quality, although the chemicals' impacts on wildlife are still unknown. Additionally, chemical stabilization is usually more expensive than vegetative practices.

Maintenance Considerations

Chemically stabilized areas should be regularly inspected for signs of erosion. Stabilizers should be reapplied if necessary.

Effectiveness

Effectiveness of polymer stabilization methods ranges from 70 percent to 90 percent, although effectiveness of a particular polymer depends on soil type, application method, and individual chemical characteristics of the polymer (Aicardo, 1996).

Cost Considerations

Polyacrylamide, one of the more common soil palliatives, costs between $4 and $35 per pound; a pound can stabilize approximately 1 acre of land.

References

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Mulching

Construction Site Storm Water Runoff Control

Description


Grass mulching is applied to stabilize exposed soils and to reduce storm water runoff velocity

Mulching is a temporary erosion control practice in which materials such as grass, hay, wood chips, wood fibers, straw, or gravel are placed on exposed or recently planted soil surfaces. Mulching is highly recommended as a stabilization method and is most effective when used in conjunction with vegetation establishment. In addition to stabilizing soils, mulching can reduce storm water runoff velocity. When used in combination with seeding or planting, mulching can 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.

Mulch mattings are materials such as jute or other wood fibers that are formed into sheets and are more stable than loose mulch. Jute and other wood fibers, plastic, paper, or cotton can be used individually or combined into mats to hold mulch to the ground. Netting can be used to stabilize soils while plants are growing, although netting does not retain moisture or insulate against extreme temperatures. Mulch binders consist of asphalt or synthetic materials that are sometimes used instead of netting to bind loose mulches.

Applicability

Mulching is often used in areas where temporary seeding cannot be used because of environmental constraints. Mulching can provide immediate, effective, and inexpensive erosion control. On steep slopes and critical areas such as waterways, mulch matting is used with netting or anchoring to hold it in place. Mulches can be used on seeded and planted areas where slopes are steeper than 2:1 or where sensitive seedlings require insulation from extreme temperatures or moisture retention.

Siting and Design Considerations

When possible, organic mulches should be used for erosion control and plant material establishment. Suggested materials include loose straw, netting, wood cellulose, or agricultural silage. All materials should be free of seed, and loose hay or straw should be anchored by applying tackifier, stapling netting over the top, or crimping with a mulch crimping tool. Materials that are heavy enough to stay in place (for example, gravel or bark or wood chips on flat slopes) do not need anchoring. Other examples include hydraulic mulch products with 100-percent post-consumer paper content, yard trimming composts, and wood mulch from recycled stumps and tree parts. Inorganic mulches such as pea gravel or crushed granite can be used in unvegetated areas.

Mulches may or may not require a binder, netting, or tacking. Effective use of netting and matting material requires firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material. Grading is not necessary before mulching.

There must be adequate coverage to prevent erosion, washout, and poor plant establishment. If an appropriate tacking agent is not applied, or is applied in insufficient amounts, mulch is lost to wind and runoff. The channel grade and liner must be appropriate for the amount of runoff, or there will be resulting erosion of the channel bottom. Also, hydromulch should be applied in spring, summer, or fall to prevent deterioration of mulch before plants can become established. Table 1 presents guidelines for installing mulches.

Table 1. Typical mulching materials and application rates

Material	Rate per Acre	Requirements	Notes
Organic Mulches			
Straw	1–2 tons	Dry, unchopped, unweathered; avoid weeds.	Spread by hand or machine; must be tacked or tied down.
Wood fiber or wood cellulose	½–1 ton		Use with hydroseeder; may be used to tack straw. Do not use in hot, dry weather.
Wood chips	5–6 tons	Air dry. Add fertilizer N, 12 lb/ton.	Apply with blower, chip handler, or by hand. Not for fine turf areas.
Bark	35 yd^3	Air dry, shredded, or hammermilled, or chips	Apply with mulch blower, chip handler, or by hand. Do not use asphalt tack.
Nets and Mats			
Jute net	Cover area	Heavy, uniform; woven of single jute yarn. Used with organic mulch.	Withstands water flow.
Excelsior (wood fiber) mat	Cover area		
Fiberglass roving	½–1 ton	Continuous fibers of drawn glass bound together with a non-toxic agent.	Apply with compressed air ejector. Tack with emulsified asphalt at a rate of 25–35 gal./1000 $ft.^2$

Limitations

Mulching, matting, and netting might delay seed germination because the cover changes soil surface temperatures. The mulches themselves are subject to erosion and may be washed away in a large storm. Maintenance is necessary to ensure that mulches provide effective erosion control.

Maintenance Considerations

Mulches must be anchored to resist wind displacement. Netting should be removed when protection is no longer needed and disposed of in a landfill or composted. Mulched areas should be inspected frequently to identify areas where mulch has loosened or been removed, especially after rainstorms. Such areas should be reseeded (if necessary) and the mulch cover replaced immediately. Mulch binders should be applied at rates recommended by the manufacturer. If washout, breakage, or erosion occurs, surfaces should be repaired, reseeded, and remulched, and new netting should be installed. Inspections should be continued until vegetation is firmly established.

Effectiveness

Mulching effectiveness varies according to the type of mulch used. Soil loss reduction for different mulches ranges from 53 to 99.8 percent. Water velocity reductions range from 24 to 78 percent. Table 2 shows soil loss and water velocity reductions for different mulch treatments.

Table 2. Measured reductions in soil loss for different mulch treatments (Source: Harding, 1990, as cited in USEPA, 1993)

Mulch Characteristics	Soil Loss Reduction (%)	Water Velocity Reduction (% relative to bare soil)
100% wheat straw/top net	97.5	73
100% wheat straw/two nets	98.6	56
70% wheat straw/30% coconut fiber	98.7	71
70% wheat straw/30% coconut fiber	99.5	78
100% coconut fiber	98.4	77
Nylon monofilament/two nets	99.8	74
Nylon monofilament/rigid/bonded	53.0	24
Vinyl monofilament/flexible/bonded	89.6	32
Curled wood fibers/top net	90.4	47
Curled wood fibers/two nets	93.5	59
Antiwash netting(jute)	91.8	59
Interwoven paper and thread	93.0	53
Uncrimped wheat straw, 2,242 kg/ha	84.0	45
Uncrimped wheat straw, 4,484 kg/ha	89.3	59

In addition, a study by Hetzog et al. (1998) concluded that mulching provides a high rate of sediment and nutrient pollution prevention. In addition, this study also found that seeding or mulching added value to a site in the eyes of the developers, real estate agents, and homebuyers that more than offset the cost of seeding or mulching.

Cost Considerations

Costs of seed and mulch average $1,500 per acre and range from $800 to $3,500 per acre (USEPA, 1993).

References

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Permanent Seeding

Construction Site Storm Water Runoff Control

Description

Hydroseeding is a popular technique for applying seeds, fertilizer, and chemical stabilizers in a single application (Source: Terra Firma Industries, 2000)

Permanent seeding is used to control runoff and erosion on disturbed areas by establishing perennial vegetative cover from seed. It is used to reduce erosion, to decrease sediment yields from disturbed areas, and to provide permanent stabilization. This practice is economical, adaptable to different site conditions, and allows selection of the most appropriate plant materials.

Applicability

Permanent seeding is well-suited in areas where permanent, long-lived vegetative cover is the most practical or most effective method of stabilizing the soil. Permanent seeding can be used on roughly graded areas that will not be regraded for at least a year. Vegetation controls erosion by protecting bare soil surfaces from displacement by raindrop impacts and by reducing the velocity and quantity of overland flow. The advantages of seeding over other means of establishing plants include lower initial costs and labor inputs.

Siting and Design Considerations

Areas to be stabilized with permanent vegetation must be seeded or planted 1 to 4 months after the final grade is achieved unless temporary stabilization measures are in place. Successful plant establishment can be maximized with proper planning; consideration of soil characteristics; selection of plant materials that are suitable for the site; adequate seedbed preparation, liming, and fertilization; timely planting; and regular maintenance. Climate, soils, and topography are major factors that dictate the suitability of plants for a particular site. The soil on a disturbed site might require amendments to provide sufficient nutrients for seed germination and seedling growth. The surface soil must be loose enough for water infiltration and root penetration. Soil pH should be between 6.0 and 6.5 and can be increased with liming if soils are too acidic. Seeds can be protected with mulch to retain moisture, regulate soil temperatures, and prevent erosion during seedling establishment.

Depending on the amount of use permanently seeded areas receive, they can be considered high- or low-maintenance areas. High-maintenance areas are mowed frequently, limed and fertilized regularly, and either (1) receive intense use (e.g., athletic fields) or (2) require maintenance to an aesthetic standard (e.g., home lawns). Grasses used for high-maintenance areas are long-lived perennials that form a tight sod and are fine-leaved. High-maintenance vegetative cover is used for homes, industrial parks, schools, churches, and recreational areas.

Low-maintenance areas are mowed infrequently or not at all and do not receive lime or fertilizer on a regular basis. Plants must be able to persist with minimal maintenance over long periods of time.

Grass and legume mixtures are favored 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.

Limitations

The effectiveness of permanent seeding can be limited because of the high erosion potential during establishment, the need to reseed areas that fail to establish, limited seeding times depending on the season, and the need for stable soil temperature and soil moisture content during germination and early growth. Permanent seeding does not immediately stabilize soils—temporary erosion and sediment control measures should be in place to prevent off-site transport of pollutants from disturbed areas.

Maintenance Considerations

Grasses should emerge within 4–28 days and legumes 5–28 days after seeding, with legumes following grasses. A successful stand should exhibit the following:

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

Seeded areas should be inspected for failure, and necessary repairs and reseeding should be made as soon as possible. If a stand has inadequate cover, the choice of plant materials and quantities of lime and fertilizer should be reevaluated. Depending on the condition of the stand, areas can be repaired by overseeding or reseeding after complete seedbed preparation. If timing is bad, rye grain or German millet can be overseeded to thicken the stand until a suitable time for seeding perennials. Consider seeding temporary, annual species if the season is not appropriate for permanent seeding. If vegetation fails to grow, soil should be tested 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. Soil tests can be used to determine if more fertilizer needs to be added. Do not fertilize cool season grasses in late May through July. Grass that looks yellow may be nitrogen deficient. Do not use nitrogen fertilizer if the stand contains more than 20 percent legumes.

Effectiveness

Perennial vegetative cover from seeding has been shown to remove between 50 and 100 percent of total suspended solids from storm water runoff, with an average removal of 90 percent (USEPA, 1993).

Cost Considerations

Seeding costs range from $200 to $1,000 per acre and average $400 per acre. Maintenance costs range from 15 to 25 percent of initial costs and average 20 percent (USEPA, 1993).

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Sodding

Construction Site Storm Water Runoff Control

Description

Grass sod is laid on exposed soil to stabilize the soil and to reduce the velocity of storm water runoff (Source: Landscape USA, no date)

Sodding is a permanent erosion control practice that involves laying a continuous cover of grass sod on exposed soils. In addition to stabilizing soils, sodding can reduce the velocity of storm water runoff. Sodding can provide immediate vegetative cover for critical areas and stabilize areas that cannot be vegetated by seed. It also can stabilize channels or swales that convey concentrated flows and can reduce flow velocities.

Applicability

Sodding is appropriate for any graded or cleared area that might erode, requiring immediate vegetative cover. Locations particularly well-suited to sod stabilization are:

- 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 and produces more reliable results with less maintenance. Sod can be laid during times of the year when seeded grasses are likely to fail. The sod must be watered frequently within the first few weeks of installation.

The type of sod selected should be composed of plants adapted to site conditions. Sod composition should reflect environmental conditions as well as the function of the area where the sod will be laid. The sod should be of known genetic origin and be free of noxious weeds, diseases, and insects. The sod should be machine cut at a uniform soil thickness of 15 to 25 mm at the time of establishment (this does not include top growth or thatch). Soil preparation and additions of lime and fertilizer may be needed; soils should be tested to determine if amendments are needed. Sod should be laid in strips perpendicular to the direction of waterflow and staggered in a brick-like pattern. The corners and middle of each strip should be stapled firmly. Jute or plastic netting may be pegged over the sod for further protection against washout during establishment. Areas to be sodded should be cleared of trash, debris, roots, branches, stones and clods larger than 2 inches in diameter. Sod should be harvested, delivered, and installed within a period of 36 hours. Sod not transplanted within this period should be inspected and approved prior to its installation.

Limitations

Compared to seed, sod is more expensive and more difficult to obtain, transport, and store. Care must be taken to prepare the soil and provide adequate moisture before, during, and after installation to ensure successful establishment. If sod is laid on poorly prepared soil or unsuitable surface, the grass will die quickly because it is unable to root. Sod that is not adequately irrigated after installation may cause root dieback because grass does not root rapidly and is subject to drying out.

Maintenance Considerations

Watering is very important to maintain adequate moisture in the root zone and to prevent dormancy, especially within the first few weeks of installation, until it is fully rooted. Mowing should not result in the removal of more than one-third of the shoot. Grass height should be maintained between 2 and 3 inches. After the first growing season, sod might require additional fertilization or liming. Permanent, fine turf areas require yearly maintenance fertilization. Warm-season grass should be fertilized in late spring to early summer, and cool-season grass, in late winter and again in early fall.

Effectiveness

Sod has been shown to remove up to 99 percent of total suspended solids in runoff. It is therefore a highly effective management practice for erosion and sediment control, but its trapping efficiency is highly variable depending on hydrologic, hydraulic, vegetation, and sediment characteristics.

Cost Considerations

Average construction costs of sod average $0.20 per square foot and range from $0.10 to $1.10 per square foot; maintenance costs are approximately 5 percent of installation costs (USEPA, 1993).

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Soil Roughening

Construction Site Storm Water Runoff Control

Description

Soil roughening is a temporary erosion control practice often used in conjunction with grading. Soil roughening involves increasing the relief of a bare soil surface with horizontal grooves, stair-stepping (running parallel to the contour of the land), or tracking using construction equipment. Slopes that are not fine graded and that are left in a roughened condition can also reduce erosion. Soil roughening reduces runoff 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.

Exposed soils can be temporarily stabilized by driving a tractor over the surface

Applicability

Soil roughening is appropriate for all slopes. Soil roughening works well on slopes greater than 3:1, on piles of excavated soil, and in areas with highly erodible soils. This technique is especially appropriate for soils that are frequently mowed or disturbed because roughening is relatively easy to accomplish. To slow erosion, roughening should be done as soon as possible after the vegetation has been removed form the slope. Roughening can be used with both seeding and planting and temporary mulching to stabilize an area. For steeper slopes and slopes that will be left roughened for longer periods of time, a combination of surface roughening and vegetation is appropriate. Roughening should be performed immediately after grading activities have ceased (temporarily or permanently) in an area.

Siting and Design Considerations

Rough slope surfaces are preferred because they aid the establishment of vegetation, improve infiltration, and decrease runoff velocity. Graded areas with smooth, hard surfaces might seem appropriate, but such surfaces may increase erosion potential. A rough soil surface allows surface ponding that protects lime, fertilizer, and seed. Grooves in the soil are cooler and provide more favorable moisture conditions than hard, smooth surfaces. These conditions promote seed germination and vegetative growth.

It is important to avoid excessive compacting of the soil surface, especially when tracking, because soil compaction inhibits vegetation growth and causes higher runoff velocity. Therefore, it is best to limit roughening with tracked machinery to sandy soils that do not compact easily and to avoid tracking on heavy clay soils, particularly when wet. Roughened areas should be seeded as quickly as possible. Proper dust control procedures also should be followed when soil roughening.

There are different methods for achieving a roughened soil surface on a slope. The selection of an appropriate method depends on the type of slope and the available equipment. Roughening methods include stair-step grading, grooving, and tracking. Factors to consider when choosing a method are slope steepness, mowing requirements, whether the slope is formed by cutting or filling, and available equipment. The following methods can be used for surface roughening

Cut slope roughening for areas that will not be mowed. Stair-step grades or groove-cut slopes should be used for gradients steeper than 3:1. Stair-step grading should be used on any erodible material that is soft enough to be ripped with a bulldozer. Slopes consisting of soft rock with some subsoil are particularly suited to stair-step grading. The vertical cut distance should be less than the horizontal distance, and the horizontal portion of the step should be slightly sloped toward the vertical wall. Individual vertical cuts should not be made more than 2 feet deep in soft materials or more 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. Grooves should be made using any appropriate implement that can be safely operated on the slope, such as disks, tillers, spring harrows, or the teeth on a front-end loader bucket. The grooves should be made more than 3 inches deep and less than 15 inches apart.

Fill slope roughening for areas that will not be mowed. Fill slopes with a gradient steeper than 3:1 should be placed in lifts less than 9 inches, and each lift should be properly compacted. The face of the slope should consist of loose, uncompacted fill 4 to 6 inches deep. Grooving should be used as described above to roughen the face of the slopes, if necessary. The final slope face should not be bladed or scraped.

Cuts, fills, and graded areas that will be mowed. Mowed slopes should be made no steeper than 3:1. These areas should be roughened with shallow grooves less than 10 inches apart and more than 1 inch deep using normal tilling, disking, or harrowing equipment (a cultipacker-seeder can also be used). Excessive roughness is undesirable where mowing is planned.

Roughening with tracked machinery. Roughening with tracked machinery should be limited to sandy soils to avoid undue compaction of the soil surface. Tracked machinery should be operated perpendicular to the slope to leave horizontal depressions in the soil. Tracking is generally not as effective as other roughening methods.

Limitations

Soil roughening is not appropriate for rocky slopes. Soil compaction might occur when roughening with tracked machinery. Soil roughening is of limited effectiveness in anything more than a gentle or shallow depth rain. If roughening is washed away in a heavy storm, the surface will have to be re-roughened and new seed laid.

Maintenance Considerations

Areas need to be inspected after storms, since roughening might need to be repeated. Regular inspection of roughened slopes will indicate where additional erosion and sediment control measures are needed. If rills (small watercourses that have steep sides and are usually only a few inches deep) appear, they should be filled, graded again, and reseeded immediately. Proper dust control methods should be used.

Effectiveness

Soil roughening provides moderate erosion protection for bare soils while vegetative cover is being established. It is inexpensive and simple for short-term erosion control when used with other erosion and sediment controls.

Cost Considerations

Soil roughening is inexpensive with respect to cost of materials but requires the use of heavy equipment.

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Protect steep slopes

Geotextiles

Construction Site Storm Water Runoff Control

Description

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

Geotextiles are porous fabrics also known as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or simply fabrics. Geotextiles are manufactured by weaving or bonding fibers made from synthetic materials such as polypropylene, polyester, polyethylene, nylon, polyvinyl chloride, glass, and various mixtures of these materials. As a synthetic construction material, geotextiles are used for a variety of purposes such as separators, reinforcement, filtration and drainage, and erosion control (USEPA, 1992). Some geotextiles are made of biodegradable materials such as mulch matting and netting. Mulch mattings are jute or other wood fibers that have been formed into sheets and are more stable than normal mulch. Netting is typically made from jute, wood fiber, plastic, paper, or cotton and can be used to hold the mulching and matting to the ground. Netting can also be used alone to stabilize soils while the plants are growing; however, it does not retain moisture or temperature well. Mulch binders (either asphalt or synthetic) are sometimes used instead of netting to hold loose mulches together. Geotextiles can aid in plant growth by holding seeds, fertilizers, and topsoil in place. Fabrics are relatively inexpensive for certain applications. A wide variety of geotextiles exist to match the specific needs of the site.

Applicability

Geotextiles can be used alone for erosion control. Geotextiles can be used as matting, which is used to stabilize the flow of channels or swales or to protect seedlings on recently planted slopes until they become established. Matting may be used on tidal or stream banks, where moving water is likely to wash out new plantings. They can also be used to protect exposed soils immediately and temporarily, such as when active piles of soil are left overnight. Geotextiles are also used as separators; for example, as a separator between riprap and soil. This "sandwiching" prevents the soil from being eroded from beneath the riprap and maintains the riprap's base.

Siting and Design Considerations

There are many types of geotextiles available. Therefore, the selected fabric should match its purpose. State or local requirements, design procedures, and any other applicable requirements should be considered. Effective netting and matting require firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil, and erosion will occur underneath the material.

Limitations

Geotextiles (primarily synthetic types) have the potential disadvantage of being sensitive to light and must be protected prior to installation. Some geotextiles might promote increased runoff and might blow away if not firmly anchored. Depending on the type of material used, geotextiles might need to be disposed of in a landfill, making them less desirable than vegetative stabilization. If the fabric is not properly selected, designed, or installed, the effectiveness may be reduced drastically.

Maintenance Considerations

Regular inspections should be made to determine if cracks, tears, or breaches have formed in the fabric; if so, it should be repaired or replaced immediately. It is necessary to maintain contact between the ground and the geotextile at all times. Trapped sediment should be removed after each storm event.

Effectiveness

Geotextiles' effectiveness depends upon the strength of the fabric and proper installation. For example, when protecting a cut slope with a geotextile, it is important to properly anchor the fabric. This will ensure that it will not be undermined by a storm event.

Cost Considerations

Costs for geotextiles range from $0.50 to $10.00 per square yard, depending on the type chosen (SWRCP, 1991).

References

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Gradient Terraces

Construction Site Storm Water Runoff Control

Description

Terraces can be incorporated into the grading plan to shorten the length of the slope and to reduce the velocity of storm water flows (Source: Boaze et. al, 2000)

Gradient terraces are made of either earthen embankments or ridge and channel systems that are properly spaced and are constructed with an adequate grade. They reduce damage from erosion by collecting and redistributing surface runoff to stable outlets at slower speeds and by increasing the distance of overland runoff flow. They also surpass smooth slopes in holding moisture and help to minimize sediment loading of surface runoff.

Applicability

Gradient terraces are most suitable for use in areas with an existing or expected water erosion problem and no vegetation, and they are only effective when there are suitable runoff outlets provided. They are usually limited to use on long, steep slopes with a water erosion problem, or where it is anticipated that water erosion will be a problem. They should not be constructed on slopes containing rocky or sandy soil.

Siting and Design Considerations

Gradient terraces should be designed with adequate and appropriate outlets and should be installed according to a well-developed plan after conduction of an engineering survey and layout. Acceptable outlets include grassed waterways, vegetated areas, or tile outlets. Any outlet that is used should be able to redirect surface runoff away from the terraces and toward an area that is not susceptible to erosion or other damage.

General specifications require that:

- Whenever possible, vegetative cover should be used in the outlet.
- At the junction of the terrace and the outlet, the terrace's water surface design elevation should be no lower than the outlet's water surface design elevation when both are performing at design flow.
- During construction of the terrace system, dust control procedures should be followed.
- Proper vegetation/stabilization practices should be followed while constructing these features.

Limitations

Gradient terraces are not appropriate for use on sandy, steep, or shallow soils. If too much water permeates the soil in a terrace system, sloughing could occur, and cut and fill costs could increase substantially.

Maintenance Considerations

Regular inspections of the terraces should occur after any major storms and at least once a year to ensure that the terraces are structurally sound and have not been subject to erosion.

References

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Soil Retention

Construction Site Storm Water Runoff Control

Description

Soil retention measures are structures or practices that are used to hold soil in place or to keep it contained within a site boundary. They may include grading or reshaping the ground to lessen steep slopes or shoring excavated areas with wood, concrete, or steel structures. Some soil-retaining measures are used for erosion control, while others are used for protection of workers during construction projects such as excavations.

A permanent retaining wall prevents slope failure

Applicability

Grading to reduce steep slopes can be implemented at any construction site by assessing site conditions before breaking ground and reducing steep slopes where possible. Reinforced soil-retaining structures should be used when sites have very steep slopes or loose, highly erodible soils that cause other methods, such as chemical or vegetative stabilization or regrading, to be ineffective. The preconstruction drainage pattern should be maintained to the extent possible.

Siting and Design Considerations

Some examples of reinforced soil retaining structures include:

- *Skeleton sheeting*. An inexpensive soil bracing system that requires soil to be cohesive and consists of construction grade lumber being used to support the excavated face of a slope
- *Continuous sheeting*. Involves using a material that covers the entire slope continuously, with struts and boards placed along the slope to support the slope face - steel, concrete, or wood should be used as the materials
- *Permanent retaining walls*. Walls of concrete masonry or wood (railroad ties) that are left in place after construction is complete in order to provide continued support of the slope

The proper design of reinforced soil-retaining structures is crucial for erosion control and safety. To ensure safety of the retaining structure, it should be designed by a qualified engineer who understands all of the design considerations, such as the nature of the soil, location of the ground water table, and the expected loads. Care should be taken to ensure that hydraulic pressure does not build up behind the retaining structure and cause failure.

Limitations

To be effective, soil-retention structures must be designed to handle expected loads. However, heavy rains or mass wasting may damage or destroy these structures and result in sediment inputs to waterbodies. They must be properly installed and maintained to avoid failure.

Maintenance Considerations

Soil-stabilization structures should be inspected periodically, particularly after rainstorms, to check for erosion, damage, or other signs of deterioration. Any damage to the actual slope or ditch, such as washouts or breakage, should be repaired prior to any reinstallation of the materials for the soil-stabilization structure.

Effectiveness

Soil-retention structures, if properly designed and installed, can effectively prevent erosion and mass wasting in areas with steep slopes and erodible soils. Their potential for failure depends on their design, installation, maintenance, and the likelihood of catastrophic events such as heavy rains, earthquakes, and landslides.

Cost Considerations

Slope reduction can be accomplished during site development and might not incur any additional costs. Soil stabilization structures can be expensive because they require a professional engineer to develop a design (estimated to be 25 to 30 percent of construction costs [Ferguson et al., 1997]). Depending on the size of the proposed structure and the relief of the surrounding area, excavation and installation costs might be high. Capital costs include mobilization, grading, grooving, tracking and compacting fill, and installing the structures. Labor costs for regular inspection and repairs are also a consideration.

References

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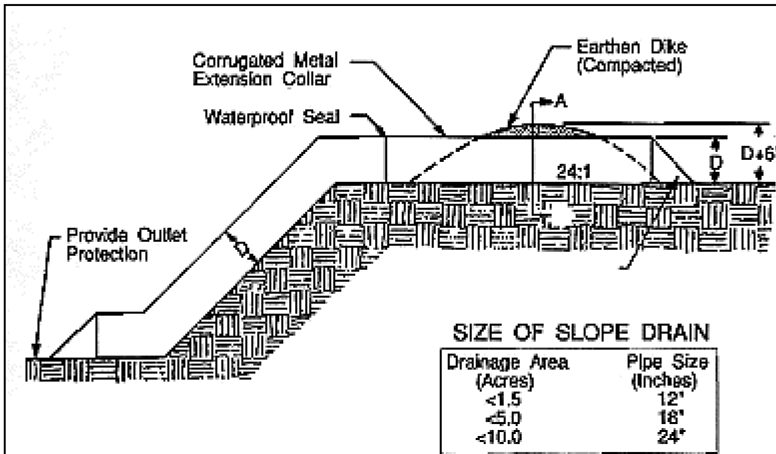
Temporary Slope Drain

Construction Site Storm Water Runoff Control

Description

A temporary slope drain is a flexible conduit extending the length of a disturbed slope and serving as a temporary outlet for a diversion. Temporary slope drains, also called pipe slope drains, convey runoff without causing erosion on or at the bottom of the slope. This practice is a temporary measure used during grading operations until permanent drainage structures are installed and until slopes are permanently stabilized. They are typically used for less than 2 years.



Drains can be installed along a steep exposed slope to divert runoff and prevent erosion (Source: Urban Drainage and Flood Control District, 1999)

Applicability

Temporary slope drains can be used on most disturbed slopes to eliminate gully erosion problems resulting from concentrated flows discharged at a diversion outlet.

Siting and Design Considerations

Recently graded slopes that do not have permanent drainage measures installed should have a temporary slope drain and a temporary diversion installed. A temporary slope drain used in conjunction with a diversion conveys storm water flows and reduces erosion until permanent drainage structures are installed.

The following are design recommendations for temporary slope drains:

- The drain should consist of heavy-duty material manufactured for the purpose and have grommets for anchoring at a spacing of 10 feet or less.
- Minimum slope drain diameters should be observed for varying drainage areas.
- The entrance to the pipe should consist of a standard flared section of corrugated metal; the corrugated metal pipe should have watertight joints at the ends; the rest of the pipe is typically corrugated plastic or flexible tubing, although for flatter, shorter slopes, a polyethylene-lined channel is sometimes used.
- The height of the diversion at the pipe should be the diameter of the pipe plus 0.5 foot.
- The outlet should be located at a reinforced or erosion-resistant location.

Limitations

The area drained by a temporary slope drain should not exceed 5 acres. Physical obstructions substantially reduce the effectiveness of the drain. Other concerns are failures from overtopping because of inadequate pipe inlet capacity, and reduced diversion channel capacity and ridge height.

Maintenance Considerations

The slope drain should be inspected after each rainfall to determine if capacity was exceeded or if blockages occurred. Repairs should be made promptly. Construction equipment and vehicular traffic must be rerouted around slope drains.

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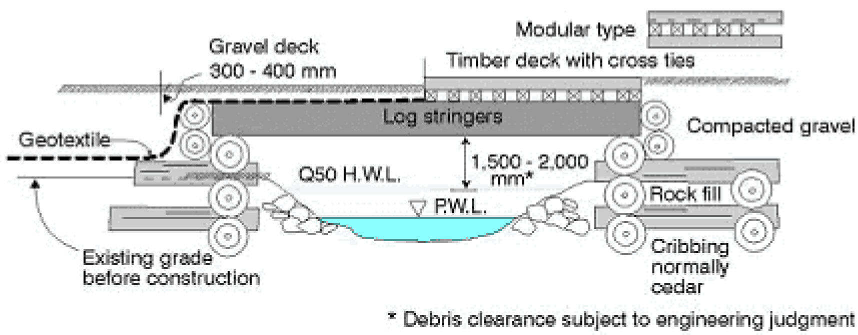
Protect waterways

Temporary Stream Crossings

Construction Site Storm Water Runoff Control

Description

A temporary steam crossing is a structure erected to provide a safe and stable way for construction vehicle traffic to cross a running watercourse. The primary purpose of such a structure is to provide streambank stabilization, reduce the risk of damaging the streambed or channel, and reduce the risk of sediment loading from construction traffic. A temporary stream crossing may be a bridge, a culvert, or a ford.



Properly installed stream crossings can prevent destruction of stream habitat (Source: British Columbia Ministry of Forests, no date)

Applicability

Temporary stream crossings are applicable wherever heavy construction equipment must be moved from one side of a stream channel to the other, or where lighter construction vehicles will cross the stream a number of times during the construction period. In either case, an appropriate method for ensuring the stability of the streambanks and preventing large-scale erosion is necessary.

A bridge or culvert is the best choice for most temporary stream crossings. If properly designed, each can support heavy loads and materials used to construct most bridges, and culverts can be salvaged after they are removed. Fords are appropriate in steep areas subject to flash flooding, where normal flow is shallow or intermittent across a wide channel. Fords should be used only where stream crossings are expected to be infrequent.

Siting and Design Considerations

Because of the potential for stream degradation, flooding, and safety hazards, stream crossings should be avoided on a construction site whenever possible. Consideration should be given to alternative routes to accessing a site before arrangements are made to erect a temporary stream crossing. If it is determined that a stream crossing is necessary, an area where the potential for erosion is low should be selected. If possible, the stream crossing structure should be selected during a dry period to reduce sediment transport into the stream.

If needed, over-stream bridges are generally the preferred temporary stream crossing structure. The expected load and frequency of the stream crossing, however, will govern the selection of a bridge as the correct choice for a temporary stream crossing. Bridges usually cause minimal disturbance to a stream's banks and cause the least obstruction to stream flow and fish migration. They should be constructed only under the supervision and approval of a qualified engineer.

As general guidelines for constructing temporary bridges, clearing and excavation of the stream shores and bed should be kept to a minimum. Sufficient clearance should be provided for floating objects to pass under the bridge. Abutments should be parallel to the stream and on stable banks. If the stream is less than 8 feet wide at the point a crossing is needed, no additional in-stream supports should be used. If the crossing is to extend across a channel wider than 8 feet (as measured from top of bank to top of bank), the bridge should be designed with one in-water support for each 8 feet of stream width.

A temporary bridge should be anchored by steel cable or chain on one side only to a stable structure on shore. Examples of anchoring structures include large-diameter trees, large boulders, and steel anchors. By anchoring the bridge on one side only, there is a decreased risk of downstream blockage or flow diversion if a bridge is washed out.

When constructing a culvert, filter cloth should be used to cover the streambed and streambanks to reduce settlement and improve the stability of the culvert structure. The filter cloth should extend a minimum of 6 inches and a maximum of 1 foot beyond the end of the culvert and bedding material. The culvert piping should not exceed 40 feet in length and should be of sufficient diameter to allow for complete passage of flow during peak flow periods. The culvert pipes should be covered with a minimum of 1 foot of aggregate. If multiple culverts are used, at least 1 foot of aggregate should separate the pipes.

Fords should be constructed of stabilizing material such as large rocks.

Limitations

Bridges can be considered the greatest safety hazard of all temporary stream crossing structures if not properly designed and constructed. Bridges might also prove to be more costly in terms of repair costs and lost construction time if they are washed out or collapse (Smolen et al., 1988).

The construction and removal of culverts are usually very disturbing to the surrounding area, and erosion and downstream movement of soils is often great. Culverts can also create obstructions to flow in a stream and inhibit fish migration. Depending on their size, culverts can be blocked by large debris in a stream and are therefore vulnerable to frequent washout.

If given a choice between building a bridge or a culvert as a temporary stream crossing, a bridge is preferred because of the relative minimal disturbance to streambanks and the opportunity for unimpeded flow through the channel.

The approaches to fords often have high erosion potential. In addition, excavation of the streambed and approach to lay riprap or other stabilization material causes major stream disturbance. Mud and other debris are transported directly into the stream unless the crossing is used only during periods of low flow.

Maintenance Considerations

Temporary stream crossings should be inspected at least once a week and after all significant rainfall events. If any structural damage is reported to a bridge or culvert, construction traffic should stop use of the structure until appropriate repairs are made. Evidence of streambank erosion should be repaired immediately.

Fords should be inspected closely after major storm events to ensure that stabilization materials remain in place. If the material has moved downstream during periods of peak flow, the lost material should be replaced immediately.

Effectiveness

Both temporary bridges and culverts provide an adequate path for construction traffic crossing a stream or watercourse.

Cost Considerations

Generally speaking, temporary bridges are more expensive to design and construct than culverts. Bridges are also associated with higher maintenance and repair costs should they fail. Additional costs may accrue to the site team in terms of lost construction time if a temporary structure is washed out or otherwise fails.

References

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Vegetated Buffer

Construction Site Storm Water Runoff Control

Description

Buffers at the perimeters of construction sites are similar to agricultural buffers in that they trap sediments and remove pollutants in runoff from exposed areas (Source: Nova Scotia Department of Agriculture and Fisheries, 2000)

Vegetated buffers are areas of either natural or established vegetation that are maintained to protect the water quality of neighboring areas. Buffer zones reduce the velocity of storm water runoff, provide an area for the runoff to permeate the soil, contribute to ground water recharge, and act as filters to catch sediment. The reduction in velocity also helps to prevent soil erosion.

Applicability

Vegetated buffers can be used in any area that is able to support vegetation but they are most effective and beneficial on floodplains, near wetlands, along streambanks, and on steep, unstable slopes. They are also effective in separating land use areas that are not compatible and in protecting wetlands or waterbodies by displacing activities that might be potential sources of nonpoint source pollution.

Siting and Design Considerations

To establish an effective vegetative buffer, the following guidelines should be followed:

- Soils should not be compacted.
- Slopes should be less than 5 percent.
- Buffer widths should be determined after careful consideration of slope, vegetation, soils, depth to impermeable layers, runoff sediment characteristics, type and quantity of storm water pollutants, and annual rainfall.
- Buffer widths should increase as slope increases.
- Zones of vegetation (native vegetation in particular), including grasses, deciduous and evergreen shrubs, and understory and overstory trees, should be intermixed.
- In areas where flows are concentrated and velocities are high, buffer zones should be combined with other structural or nonstructural BMPs as a pretreatment.

Limitations

Vegetated buffers require plant growth before they can be effective, and land on which to plant the vegetation must be available. If the cost of the land is very high, buffer zones might not be cost-effective. Although vegetated buffers help to protect water quality, they usually do not effectively counteract concentrated storm water flows to neighboring or downstream wetlands.

Maintenance Considerations

Keeping vegetation healthy in vegetated buffers requires routine maintenance, which (depending on species, soil types, and climatic conditions) can include weed and pest control, mowing, fertilizing, liming, irrigating, and pruning. Inspection and maintenance are most important when buffer areas are first installed. Once established, vegetated buffers do not require much maintenance beyond the routine procedures listed earlier and periodic inspections of the areas, especially after any heavy rainfall and at least once a year. Inspections should focus on encroachment, gully erosion, density of vegetation, evidence of concentrated flows through the areas, and any damage from foot or vehicular traffic. If there is more than 6 inches of sediment in one place, it should be removed.

Effectiveness

Several researchers have measured greater than 90 percent reductions in sediment and nitrate concentrations. Buffer/filter strips do a reasonably good job of removing phosphorus attached to sediment, but are relatively ineffective in removing dissolved phosphorus (Gilliam, 1994).

References

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Phase construction

Construction Sequencing

Construction Site Storm Water Runoff Control

Description

Construction sequencing requires creating and following a work schedule that balances the timing of land disturbance activities and the installation of measures to control erosion and sedimentation, in order to reduce on-site erosion and off-site sedimentation.

In sequenced construction, sites are completed in stages and completed portions are permanently stabilized before other areas are disturbed

Applicability

Construction sequencing can be used to plan earthwork and erosion and sediment control (ESC) activities at sites where land disturbances might affect water quality in a receiving waterbody.

Siting and Design Considerations

Construction sequencing schedules should, at a minimum, include the following:

- The ESC practices that are to be installed
- Principal development activities
- Which measures should be installed before other activities are started
- Compatibility with the general contract construction schedule

Table 1 summarizes other important scheduling considerations in addition to those listed above.

Limitations

Weather and other unpredictable variables may affect construction sequence schedules. However, the proposed schedule and a protocol for making changes due to unforeseen problems should be plainly stated in the ESC plan.

Table 1. Scheduling considerations for construction activities.

Construction Activity	Schedule Consideration
Construction access—entrance to site, construction routes, areas designated for equipment parking	This is the first land-disturbing activity. As soon as construction begins, stabilize any bare areas with gravel and temporary vegetation.
Sediment traps and barriers—basin traps, sediment fences, outlet protection	After construction site is accessed, principal basins should be installed, with the addition of more traps and barriers as needed during grading.
Runoff control—diversions, perimeter dikes, water bars, outlet protection	Key practices should be installed after the installation of principal sediment traps and before land grading. Additional runoff control measures may be installed during grading.
Runoff conveyance system—stabilize stream banks, storm drains, channels, inlet and outlet protection, slope drains	If necessary, stabilize stream banks as soon as possible, and install principal runoff conveyance system with runoff control measures. The remainder of the systems may be installed after grading.
Land clearing and grading—site preparation (cutting, filling, and grading, sediment traps, barriers, diversions, drains, surface roughening)	Implement major clearing and grading after installation of principal sediment and key runoff-control measures, and install additional control measures as grading continues. Clear borrow and disposal areas as needed, and mark trees and buffer areas for preservation.
Surface stabilization—temporary and permanent seeding, mulching, sodding, riprap	Temporary or permanent stabilizing measures should be applied immediately to any disturbed areas where work has been either completed or delayed.
Building construction—buildings, utilities, paving	During construction, install any erosion and sedimentation control measures that are needed.
Landscaping and final stabilization—topsoiling, trees and shrubs, permanent seeding, mulching, sodding, riprap	This is the last construction phase. Stabilize all open areas, including borrow and spoil areas, and remove and stabilize all temporary control measures.

Maintenance Considerations

The construction sequence should be followed throughout the project and the written plan should be modified before any changes in construction activities are executed. The plan can be updated if a site inspection indicates the need for additional erosion and sediment control.

Effectiveness

Construction sequencing can be an effective tool for erosion and sediment control because it ensures that management practices are installed where necessary and when appropriate. The plan must be followed and updated if needed to maximize the effectiveness of ESC under changing conditions.

Cost Considerations

Construction sequencing is a low-cost BMP because it requires a limited amount of a contractor's time to provide a written plan for the coordination of construction activities and management practices. Additional time might be needed to update the sequencing plan if the current plan is not providing sufficient ESC.

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Dust Control

Construction Site Storm Water Runoff Control

Description

Dust control measures can be used to prevent dust from being transported by wind (Source: Dust Pro, Inc., no date)

Dust control measures are practices that help reduce surface and air movement of dust from disturbed soil surfaces. Construction sites are good candidates for dust control measures because land disturbance from clearing and excavation generates a large amount of soil disturbance and open space for wind to pick up dust particles. To illustrate this point, limited research at construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction (WA Dept. of Ecology, 1992). These airborne particles pose a dual threat to the environment and human health. First, dust can be carried off-site, thereby increasing soil loss from the construction area and increasing the likelihood of sedimentation and water pollution. Second, blowing dust particles can contribute to respiratory health problems and create an inhospitable working environment.

Applicability

Dust control measures are applicable to any construction site where dust is created and there is the potential for air and water pollution from dust traveling across the landscape or through the air. Dust control measures are particularly important in arid or semiarid regions, where soil can become extremely dry and vulnerable to transport by high winds. Also, dust control measures should be implemented on all construction sites where there will be major soil disturbances or heavy construction activity, such as clearing, excavation, demolition, or excessive vehicle traffic. Earthmoving activities are the major source of dust from construction sites, but traffic and general disturbances can also be major contributors (WA Dept. of Ecology, 1992). The particular dust control measures that are implemented at a site will depend on the topography and land cover of a given site, as well as the soil characteristics and expected rainfall at the site.

Siting and Design Considerations

When designing a dust control plan for a site, the amount of soil exposed will dictate the quantity of dust generation and transport. Therefore, construction sequencing and disturbing only small areas at a time can greatly reduce problematic dust from a site. If land must be disturbed, additional temporary stabilization measures should be considered prior to disturbance. A number of methods can be used to control dust from a site. The following is a brief list of some control measures and their design criteria. Not all control measures will be applicable to a given site. The owner, operator, and contractors responsible for dust control at a site will have to determine which practices accommodate their needs based on specific site and weather conditions.

- *Sprinkling/Irrigation*. Sprinkling the ground surface with water until it is moist is an effective dust control method for haul roads and other traffic routes (Smolen et al., 1988). This practice can be applied to almost any site.
- *Vegetative Cover*. In areas not expected to handle vehicle traffic, vegetative stabilization of disturbed soil is often desirable. Vegetative cover provides coverage to surface soils and slows wind velocity at the ground surface, thus reducing the potential for dust to become airborne.
- *Mulch*. Mulching can be a quick and effective means of dust control for a recently disturbed area (Smolen et al., 1988).
- *Wind Breaks*. Wind breaks are barriers (either natural or constructed) that reduce wind velocity through a site and therefore reduce the possibility of suspended particles. Wind breaks can be trees or shrubs left in place during site clearing or constructed barriers such as a wind fence, snow fence, tarp curtain, hay bale, crate wall, or sediment wall (USEPA, 1992).
- *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 may be an effective dust deterrent for construction roads and entrances or as a mulch in areas where vegetation cannot be established.
- *Spray-on Chemical Soil Treatments (palliatives)*. Examples of chemical adhesives include anionic asphalt emulsion, latex emulsion, resin-water emulsions, and calcium chloride. Chemical palliatives should be used only on mineral soils. When considering chemical application to suppress dust, consideration should be taken as to whether the chemical is biodegradable or water-soluble and what effect its application could have on the surrounding environment, including waterbodies and wildlife.

Table 1 shows application rates for some common spray-on adhesives, as recommended by Smolen et al. (1988).

Table 1. Application rates for spray-on adhesives (Source: Smolen et al., 1988)

Spray-on Adhesive	Water Dilution	Type of Nozzle	Application (gal/ac)
Anionic Asphalt Emulsion	7:1	Coarse Spray	1,200
Latex Emulsion	12.5:1	Fine Spray	235
Resin in Water	4:1	Fine Spray	300

Limitations

In areas where evaporation rates are high, water application to exposed soils may require near constant attention. If water is applied in excess, irrigation may create unwanted excess runoff from the site and possibly create conditions where vehicles could track mud onto public roads. Chemical applications should be used sparingly and only on mineral soils (not muck soils) because their misuse can create additional surface water pollution from runoff or contaminate ground water. Chemical applications might also present a health risk if excessive amounts are used.

Maintenance Considerations

Because dust controls are dependent on specific site and weather conditions, inspection and maintenance are unique for each site. Generally, however, dust control measures involving application of either water or chemicals require more monitoring than structural or vegetative controls to remain effective. If structural controls are used, they should be inspected for deterioration on a regular basis to ensure that they are still achieving their intended purpose.

Effectiveness

- *Sprinkling/Irrigation*. Not available.
- *Vegetative Cover*. Not available.
- *Mulch*. Can reduce wind erosion by up to 80 percent.
- *Wind Breaks/Barriers*. For each foot of vertical height, an 8-to 10-foot deposition zone develops on the leeward side of the barrier. The permeability of the barrier will change its effectiveness at capturing windborne sediment.
- *Tillage*. Roughening the soil can reduce soil losses by approximately 80 percent in some situations.
- *Stone*. The sizes of the stone can affect the amount of erosion to take place. In areas of high wind, small stones are not as effective as 20 cm stones.
- *Spray-on Chemical Soil Treatments (palliatives)*. Effectiveness of polymer stabilization methods range from 70 percent to 90 percent, according to limited research.

Cost Considerations

Chemical dust control measures can vary widely in cost, depending on specific needs of the site and level of dust control desired. One manufacturer of a chloride product estimated a cost of $1,089 per acre for application to road surfaces, but cautioned that cost estimates without a specific site evaluation are rather inaccurate.

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Sediment Control

Install perimeter controls

Temporary Diversion Dikes, Earth Dikes, and Interceptor Dikes

Construction Site Storm Water Runoff Control

Description

Diversion dikes can be used to contain storm water onsite

Earthen perimeter controls usually consist of a dike or a combination dike and channel constructed along the perimeter of a disturbed site. Simply defined, an earthen perimeter control is a ridge of compacted soil, often accompanied by a ditch or swale with a vegetated lining, located at the top or base of a sloping disturbed area. Depending on their location and the topography of the landscape, earthen perimeter controls can achieve one of two main goals.

Located on the upslope side of a site, earthen perimeter controls help to prevent surface runoff from entering a disturbed construction site. An earthen structure located upslope can improve working conditions on a construction site by preventing an increase in the total amount of sheet flow runoff traveling across the disturbed area and thereby lessen erosion on the site.

Alternatively, earthen perimeter control structures can be located on the downslope side of a site to divert sediment-laden runoff created onsite to onsite sediment trapping devices, preventing soil loss from the disturbed area.

These control practices can be referred to by a number of terms, including temporary diversion dikes, earth dikes, or interceptor dikes. Generally speaking, however, all earthen perimeter controls are constructed in a similar fashion with a similar objective—to control the velocity and/or route of sediment-laden storm water runoff.

Applicability

Temporary diversion dikes are applicable where it is desirable to divert flows away from disturbed areas such as cut or fill slopes and to divert runoff to a stabilized outlet (EPA, 1992). The dikes can be erected at the top of a sloping area or in the middle of a slope to divert storm water runoff around a disturbed construction site. In this way, earth dikes can be used to reduce the length of the slope across which runoff will travel, thereby reducing the erosion potential of the flow. If placed at the bottom of a sloping disturbed area, diversion dikes can divert flow to a sediment trapping device. Temporary diversion dikes are usually appropriate for drainage basins smaller than 5 acres, but with modifications they can be capable of servicing areas as large as 10 acres. With regular maintenance, earthen diversion dikes have a useful life span of approximately 18 months.

To prevent storm water runoff from entering a site, earthen perimeter controls can be used to divert runoff from areas upslope around the disturbed construction site. This is accomplished by constructing a continuous, compacted earthen mound along the upslope perimeter of the site. As an additional control measure, a shallow ditch can accompany the earthen mound.

Siting and Design Considerations

The siting of earthen perimeter controls depends on the topography of the area surrounding a specific construction site and on whether the goal is to prevent sediment-laden runoff from entering the site or to keep storm water runoff from leaving the site. When determining the appropriate size and design of earthen perimeter controls, the shape of the surrounding landscape and drainage patterns should be considered. Also, the amount of runoff to be diverted, the velocity of runoff in the diversion, and the erodibility of soils on the slope and within the diversion channel or swale are essential design considerations (WSDE, 1992).

Diversion dikes should be constructed and fully stabilized prior to commencement of major land disturbance. This will maximize the effectiveness of the diversion measure as an erosion and sediment control device.

The top of earthen perimeter controls designed as temporary flow diversion measures should be at least 2 feet wide. Bottom width at ground level is typically 6 feet. The minimum height for earthen dikes should be 18 inches, with side slopes no steeper than 2:1. For points where vehicles will cross the dike, the slope should be no steeper than 3:1 and the mound should be constructed of gravel rather than soil. This will prolong the life of the dike and increase effectiveness at the point of vehicle crossing.

If a channel is excavated along the dike, its shape can be parabolic, trapezoidal, or V-shaped. Prior to excavation or mound building, all trees, brush, stumps and other objects in the path of the diversion structure should be removed and the base of the dike should be tilled before laying the fill. The maximum design flow velocity should range from 1.5 to 5.0 feet per second, depending on the vegetative cover and soil texture.

Most earthen perimeter structures are designed for short-term, temporary use. If the expected life span of the diversion structure is greater than 15 days, it is strongly recommended that both the earthen dike and the accompanying ditch be seeded with vegetation immediately after construction. This will increase the stability of the perimeter control and can decrease the need for frequent repairs and maintenance.

Limitations

Earth dikes are an effective means of diverting sediment-laden storm water runoff around a disturbed area. However, the concentrated runoff in the channel or ditch has increased erosion potential. To alleviate this erosion capability, diversion dikes must be directed to sediment trapping devices, where erosion sediment can settle out of the runoff before being discharged to surface waters. Examples of appropriate sediment trapping devices that might be used in conjunction with temporary diversion structures include a sediment basin, a sediment chamber/filter, or any other structure designed to allow sediment to be collected for proper disposal.

If a diversion dike crosses a vehicle roadway or entrance, its effectiveness can be reduced. Wherever possible, diversion dikes should be designed to avoid crossing vehicle pathways.

Maintenance Considerations

Earthen diversion dikes should be inspected after each rainfall to ensure continued effectiveness. The dike should be maintained at the original height, and any decrease in height due to settling or erosion should be repaired immediately. To remain effective, earth dikes must be compacted at all times. Regardless of rainfall frequency, dikes should be inspected at least once every 2 weeks for evidence of erosion or deterioration.

Effectiveness

When properly placed and maintained, earth dikes used as temporary diversions are effective for controlling the velocity and direction of storm water runoff. Used by themselves, they do not have any pollutant removal capability. Diversion dikes must be used in combination with an appropriate sediment trapping device at the outfall of the diversion channel.

Cost Considerations

The cost of constructing an earthen dike can be broken down into two components: (1) site preparation, including excavation, placement and compacting of fill, and grading, and (2) site development, including topsoiling and seeding for vegetative cover. The Southeastern Wisconsin Regional Planning Commission (1991) estimated the total cost of site preparation to be $46.33 to $124.81 for a 100-foot dike with 1.5-foot-deep, 3:1 side slopes. The cost of site development was estimated at $115.52 to $375.44. The total cost was between $162 and $500.

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Wind Fences and Sand Fences

Construction Site Storm Water Runoff Control

Description


Sand fences are used to trap blowing sand and to reduce offsite movement of sand particles

A Sand fences are barriers of small, evenly spaced wooden slats or fabric erected to reduce wind velocity and to trap blowing sand. They can be used effectively as perimeter controls around open construction sites to reduce the off-site movement of fine sediments transported by wind. They also prevent off-site damage to roads, streams, and adjacent properties. The spaces between fence slats allow wind and sediment to pass through but reduces the wind velocity, which causes sediment deposition along the fence.

Applicability

Wind fences are applicable to areas with a preponderance of loose, fine-textured soils that can be transported off-site by high winds. They are especially advantageous for construction sites with large areas of cleared land or in arid regions where blowing sand and dust are especially problematic. Shorefront development sites also benefit from using wind fences because they promote the formation of frontal dunes.

Siting and Design Considerations

Effective trapping of sediment and reduction of wind velocity occurs only when the fence is erected perpendicular to the prevailing wind. Although wind fences have been shown effective up to 22.5 degrees from perpendicular, they should be erected as close to perpendicular to the movement of wind as possible (Smolen et al., 1988). Multiple fences can be erected to increase sediment-trapping efficiency, depending on the degree of protection desired. Linear rows of fence 2 to 4 feet high and spaced 20 to 40 feet apart can be installed. When used on shoreline beaches, wind fences should be installed well away from the incoming tide.

Limitations

A wind fence does not control sediment carried in storm water runoff. Wind fences should be installed in conjunction with other sediment and erosion control measures that capture sediment from runoff.

Maintenance Considerations

Wind fences require periodic inspection to ensure that there are no breaks or gaps. Repairs should be made immediately. Sand and sediment should be cleaned from the fence area periodically to prevent their mobilization by storm water runoff.

Effectiveness

Wind fences are very effective for promoting dune formation along shoreline areas, but are not adequate as a primary dust control or sediment-trapping measure for perimeters of construction sites. They should be used only in conjunction with other erosion and sediment control practices.

Cost Considerations

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

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Brush Barrier

Construction Site Storm Water Runoff Control

Description

Brush barriers trap sediment and remove pollutants from storm water

Brush barriers are perimeter sediment control structures used to prevent soil in storm water runoff from leaving a construction site. Brush barriers are constructed of material such as small tree branches, root mats, stone, or other debris left over from site clearing and grubbing. In some configurations, brush barriers are covered with a filter cloth to stabilize the structure and improve barrier efficiency.

Applicability

Brush barriers are applicable to sites where there is enough material from clearing and grubbing to form a sufficient mound of debris along the perimeter of an area. The drainage area for brush barriers must be no greater than 0.25 acre per 100 feet of barrier length. In addition, the drainage slope leading down to a brush barrier must be no greater than 2:1 and no longer than 100 feet. Brush barriers have limited usefulness because they are constructed of materials that decompose.

Siting and Design Considerations

A brush barrier can be constructed using only cleared material from a site, but it is recommended that the mound be covered with a filter fabric barrier to hold the material in place and increase sediment barrier efficiency. Whether a filter fabric cover is used or not, the barrier mound should be at least 3 feet high and 5 feet wide at its base. Material with a diameter larger than 6 inches should not be used, as this material may be too bulky and create void spaces where sediment and runoff will flow through the barrier.

The edge of the filter fabric cover should be buried in a trench 4 inches deep and 6 inches wide on the drainage side of the barrier. This is done to secure the fabric and create a barrier to sediment while allowing storm water to pass through the water-permeable filter fabric. The filter fabric should be extended just over the peak of the brush mound and secured on the down-slope edge of the fabric by fastening it to twine or small-diameter rope that is staked securely.

Limitations

Brush barriers are an effective storm water runoff control only when the contributing flow has a slow velocity. Brush barriers are therefore not appropriate for high-velocity flow areas. A large amount of material is needed to construct a useful brush barrier. For sites with little material from clearing, alternative perimeter controls such as a fabric silt fence may be more appropriate. Although brush barriers provide temporary storage for large amounts of cleared material from a site, this material will ultimately have to be removed from the site after construction activities have ceased and the area reaches final stabilization.

Maintenance Considerations

Brush barriers should be inspected after each significant rainfall event to ensure continued effectiveness. If channels form through void spaces in the barrier, the barrier should be reconstructed to eliminate the channels. Accumulated sediment should be removed from the uphill side of the barrier when sediment height reaches between 1/3 and 1/2 the height of the barrier. When the entire site has reached final stabilization, the brush barrier should be removed and disposed of properly.

Effectiveness

Brush barriers can be effective at reducing off-site sediment transport, and their effectiveness is greatly increased with the use of a fabric cover on the up-slope side of the brush barrier.

Cost Considerations

Creating brush barriers can range in cost from $390 to $620, depending upon the equipment used, vegetation type (heavy or light), fuel price, personnel, amount of filter fabric needed (if used), and the number of hours to perform the task. A common filter fabric, geotextile, can range in cost from $0.50 to $10.00/square yard, depending upon the type of geotextile used.

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Silt Fence

Construction Site Storm Water Runoff Control

Description

Silt fences prevent the offsite transport of sediment

Silt fences are used as temporary perimeter controls around sites where there will be soil disturbance due to construction activities. They consist of a length of filter fabric stretched between anchoring posts spaced at regular intervals along the site perimeter. The filter fabric should be entrenched in the ground between the support posts. When installed correctly and inspected frequently, silt fences can be an effective barrier to sediment leaving the site in storm water runoff.

Applicability

Silt fences are generally applicable to construction sites with relatively small drainage areas. They are appropriate in areas where runoff will be occurring as low-level shallow flow, not exceeding 0.5 cfs. The drainage area for silt fences generally should not exceed 0.25 acre per 100-foot fence length. Slope length above the fence should not exceed 100 feet (NAHB, 1995).

Siting and Design Considerations

Material for silt fences should be a pervious sheet of synthetic fabric such as polypropylene, nylon, polyester, or polyethylene yarn, chosen based on minimum synthetic fabric requirements, as shown in Table 1.

Table 1. Minimum requirements for silt fence construction (Sources: USEPA, 1992; VDCR, 1995)

Physical Property	Requirements
Filtering Efficiency	75–85% (minimum): highly dependent on local conditions
Tensile Strength at 20% (maximum) Elongation	Standard Strength: 30 lbs/linear inch (minimum) Extra Strength: 50 lbs/linear inch (minimum)
Ultraviolet Radiation	90% (minimum)
Slurry Flow Rate	0.3 gal/ft2/min (minimum)

If a standard strength fabric is used, it can be reinforced with wire mesh behind the filter fabric. This can increase the effective life of the fence. In any case, the maximum life expectancy for synthetic fabric silt fences is approximately 6 months, depending on the amount of rainfall and runoff for a given area. Burlap fences have a much shorter useful life span, usually only up to 2 months.

Stakes used to anchor the filter fabric should be either wooden or metal. Wooden stakes should be at least 5 feet long and have a minimum diameter of 2 inches if a hardwood such as oak is used. Softer woods such as pine should be at least 4 inches in diameter. When using metal post in place of wooden stakes, they should have a minimum weight of 1.00 to 1.33 lb/linear foot. If metal posts are used, attachment points are needed for fastening the filter fabric using wire ties.

A silt fence should be erected in a continuous fashion from a single roll of fabric to eliminate unwanted gaps in the fence. If a continuous roll of fabric is not available, the fabric should overlap from both directions only at stakes or posts with a minimum overlap of 6 inches. A trench should be excavated to bury the bottom of the fabric fence at least 6 inches below the ground surface. This will help prevent gaps from forming near the ground surface that would render the fencing useless as a sediment barrier.

The height of the fence posts should be between 16 and 34 inches above the original ground surface. If standard strength fabric is used in combination with wire mesh, the posts should be spaced no more than 10 feet apart. If extra-strength fabric is used without wire mesh reinforcement, the support posts should be spaced no more than 6 feet apart (VDCR, 1995).

The fence should be designed to withstand the runoff from a 10-year peak storm event, and once installed should remain in place until all areas up-slope have been permanently stabilized by vegetation or other means.

Limitations

Silt fences should not be installed along areas where rocks or other hard surfaces will prevent uniform anchoring of fence posts and entrenching of the filter fabric. This will greatly reduce the effectiveness of silt fencing and can create runoff channels leading off site. Silt fences are not suitable for areas where large amounts of concentrated runoff are likely. In addition, open areas where wind velocity is high may present a maintenance challenge, as high winds may accelerate deterioration of the filter fabric. Silt fences should not be installed across streams, ditches, or waterways (Smolen et al., 1988).

When the pores of the fence fabric become clogged with sediment, pools of water are likely to form on the uphill side of fence. Siting and design of the silt fence should account for this and care should be taken to avoid unnecessary diversion of storm water from these pools that might cause further erosion damage.

Maintenance Considerations

Silt fences should be inspected regularly and frequently as well as after each rainfall event to ensure that they are intact and that there are no gaps at the fence-ground interface or tears along the length of the fence. If gaps or tears are found, they should be repaired or the fabric should be replaced immediately. Accumulated sediments should be removed from the fence base when the sediment reaches one-third to one-half the height of the fence. Sediment removal should occur more frequently if accumulated sediment is creating noticeable strain on the fabric and there is the possibility of the fence failing from a sudden storm event. When the silt fence is removed, the accumulated sediment also should be removed.

Effectiveness

USEPA (1993) reports the following effectiveness ranges for silt fences constructed of filter fabric that are properly installed and well maintained: average total suspended solids removal of 70 percent, sand removal of 80 to 90 percent, silt-loam removal of 50 to 80 percent, and silt-clay-loam removal of 0 to 20 percent. Removal rates are highly dependent on local conditions and installation.

Cost Considerations

Installation costs for silt fences are approximately $6.00 per linear foot (USEPA, 1992). SWRPC estimates unit costs between $2.30 and $4.50 per linear foot (SWRPC, 1991).

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Install sediment trapping devices

Sediment Basins and Rock Dams

Construction Site Storm Water Runoff Control

Description


Sediment basins are used to trap sediments and temporarily detain runoff on larger construction sites

Sediment basins and rock dams are two ways to capture sediment from storm water runoff before it leaves a construction site. Both structures allow a shallow pool to form in an excavated or natural depression where sediment from storm water runoff can settle. Basin dewatering is achieved either through a single riser and drainage hole leading to a suitable outlet on the downstream side of the embankment or through the gravel of the rock dam. In both cases, water is released at a substantially slower rate than would be possible without the control structure.

A sediment basin can be constructed by excavation or by erecting an earthen embankment across a low area or drainage swale. The basin can be either a temporary (up to 3 years) structure or a permanent storm water control measure. Sediment basins can be designed to drain completely during dry periods, or they can be constructed so that a shallow, permanent pool of water remains between storm events. However, depending on the size of the basin constructed, the basin may be considered a wet pond and subject to additional regulation.

Rock dams are similar in design to sediment basins with earthen embankments. These damming structures are constructed of rock and gravel and release water from the settling pool gradually through the spaces between the rock aggregate.

Applicability

Sediment basins are usually used for drainage areas of 5 to 100 acres. They can be temporary or permanent structures. Generally, sediment basins designed to be used for up to 3 years are described as temporary, while those designed for longer service are said to be permanent. Temporary sediment basins can be converted into permanent storm water runoff management ponds, but they must meet all regulatory requirements for wet ponds.

Sediment basins are applicable in drainage areas where it is anticipated that other erosion controls, such as sediment traps, will not be sufficient to prevent off-site transport of sediment. Choosing to construct a sediment basin with either an earthen embankment or a stone/rock dam will depend on the materials available, location of the basin, and desired capacity for storm water runoff and settling of sediments.

Rock dams are suitable where earthen embankments would be difficult to construct or where riprap is readily available. Rock structures are also desirable where the top of the dam structure is to be used as an overflow outlet. These riprap dams are best for drainage areas of less than 50 acres. Earthen damming structures are appropriate where failure of the dam will not result in substantial damage or loss of property or life. If properly constructed, sediment basins with earthen dams can handle storm water runoff from drainage basins as large as 100 acres.

Siting and Design Considerations

The potential sites for sediment basins should be investigated during the initial site evaluation. Basins should be constructed before any grading takes place within the drainage area. For structures that will be permanent, the design of the basin should be completed by a qualified professional engineer experienced in the design of dams.

Sediment basins with rock dams should be limited to a drainage area of 50 acres. Rock dam height should be limited to 8 feet with a minimum top width of 5 feet. Side slopes for rock dams should be no steeper than 2:1 on the basin side of the structure and 3:1 on the outlet side. The basin side of the rock dam should be covered with fine gravel from top to bottom for a minimum of 1 foot. This will slow the drainage rate from the pool that forms and allow time for sediments to settle. The detention time should be at least 8 hours.

Sediment basins with earthen embankments should be outfitted with a dewatering pipe and riser set just above the sediment removal cutoff level. The riser pipe should be located at the deepest point of the basin and extend no farther than 1 foot below the level of the earthen dam. A water-permeable cover should be placed over the primary dewatering riser pipe to prevent trash and debris from entering and clogging the spillway. To provide an additional path for water to enter the primary spillway, secondary dewatering holes can be drilled near the base of the riser pipe, provided the holes are protected with gravel to prevent sediment from entering the spillway piping.

To ensure adequate drainage, the following equation can be used to approximate the total area of dewatering holes for a particular basin (Smolen et al., 1988):

$$A_o = (A_s \text{ x } (2h) / (T \text{ x } C_d \text{ x } 20{,}428)$$

where

A_o = total surface area of dewatering holes, ft^2;

A_s = surface area of the basin, ft^2;

h = head of water above the hole, ft;

C_d = coefficient of contraction for an orifice, approximately 0.6; and

T = detention time or time needed to dewater the basin, hours.

In all cases, such structures should be designed by an appropriate professional based on local hydrologic, hydraulic, topographic, and sediment conditions.

Limitations

Neither a sediment basin with an earthen embankment nor a rock dam should be used in areas of continuously running water (live streams). The use of sediment basins is not intended for areas where failure of the earthen or rock dam will result in loss of life, or damage to homes or other buildings. In addition, sediment basins should not be used in areas where failure will prevent the use of public roads or utilities.

Maintenance Considerations

Routine inspection and maintenance of sediment basins is essential to their continued effectiveness. Basins should be inspected after each storm event to ensure proper drainage from the collection pool to determine the need for structural repairs. Erosion from the earthen embankment or stones moved from rock dams should be replaced immediately. Sediment basins must be located in an area that is easily accessible to maintenance crews for removal of accumulated sediment. Sediment should be removed from the basin when its storage capacity has reached approximately 50 percent. Trash and debris from around dewatering devices should be removed promptly after rainfall events.

Effectiveness

The effectiveness of a sediment basin depends primarily on the sediment particle size and the ratio of basin surface area to inflow rate (Smolen et al., 1988). Basins with a large surface area-to-volume ratio will be most effective. Studies have shown that the following equation relating surface area and peak inflow rate gives a trapping efficiency greater than 75 percent for most sediment in the Coastal Plain and Piedmont regions of the Southeastern United States (Barfield and Clar, in Smolen et al., 1988):

$$A = 0.01q$$

where A is the basin surface area in acres and q is the peak inflow rate in cubic feet per second.

USEPA (1993) estimates an average total suspended solids (TSS) removal rate for all sediment basins from 55 percent to 100 percent, with an average effectiveness of 70 percent.

Cost Considerations

If constructing a sediment basin with less than 50,000 ft^3 of storage space, the cost of installing the basin ranges from $0.20 to $1.30 per cubic foot of storage (about $1,100 per acre of drainage). The average cost for basins with less than 50,000 ft^3 of storage is approximately $0.60 per cubic foot of storage (USEPA, 1993). If constructing a sediment basin with more than 50,000 ft^3 of storage space, the cost range of installing the basin ranges from $0.10 to $0.40 per cubic foot of storage (about $550 per acre of drainage). The average cost for basins with greater than 50,000 ft^3 of storage is approximately $0.30 per cubic foot of storage (USEPA, 1993).

References

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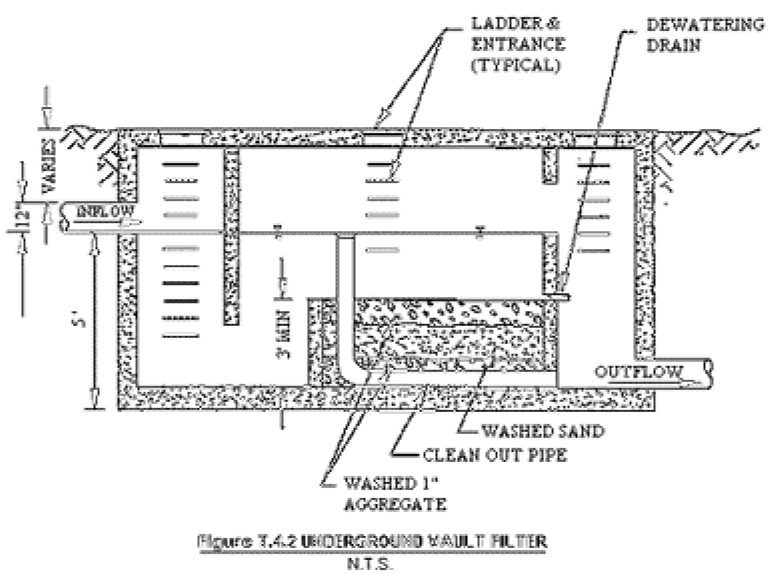
Sediment Filters and Sediment Chambers

Construction Site Storm Water Runoff Control

Description

Sediment filters are a class of sediment-trapping devices typically used to remove pollutants, primarily particulates, from storm water runoff. Generally speaking, sediment filters have four basic components: (1) inflow regulation, (2) pretreatment, (3) filter bed, and (4) outflow mechanism. Sediment chambers are merely one component of a sediment filter system.

Inflow regulation refers to the diversion of storm water runoff into the sediment-trapping device. After runoff enters the filter system, it enters a pretreatment sedimentation chamber. This chamber, used as a preliminary settling area for large debris and sediments, usually consists of nothing more than a wet detention basin. As water reaches a predetermined level, it flows over a weir into a filter bed of some filter medium. The filter medium is typically sand, but it can consist of sand, soil, gravel, peat, compost, or a combination of these materials. The purpose of the filter bed is to remove smaller sediments and other pollutants from the storm water as it percolates through the filter medium. Finally, treated flow exits the sediment filter system via an outflow mechanism to return to the storm water conveyance system.



Schematic representation of a sediment filter

Sediment filter systems can be confined or unconfined, on-line or off-line, and aboveground or belowground. Confined sediment filters are constructed with the filter medium contained in a structure, often a concrete vault. Unconfined sediment filters are constructed without encasing the filter medium in a confining structure. As one example, sand might be placed on the banks of a permanent wet pond detention system to create an unconfined filter. On-line systems are designed to retain storm water in its original stream channel or storm drain system. Off-line systems are designed to divert storm water.

Applicability

Sediment filters may be a good alternative for smaller construction sites where the use of a wet pond is being considered as a sediment-trapping device. Their applicability is wide ranging, and they can be used in urban areas with large amounts of highly impervious area. Because confined sand filters are man-made soil systems, they can be applied to most development sites and have few constraining factors (MWCOG, 1992). However, for all sediment filter systems, the drainage area to be serviced should be no more than 10 acres.

The type of filter system chosen depends on the amount of land available and the desired location within the site. Examples of sediment filter systems include the "Delaware" sand filter and the "Austin" sand filter. The Austin sand filter, so named because it first came into widespread use in Austin, Texas, is a surface filter system that can be used in areas with space restrictions. If space is at a premium, an underground filter may be the most appropriate choice. For effective storm water sediment control at the perimeter of a site, the Delaware sand filter might be a good choice. This configuration consists of two parallel, trench-like chambers installed at a site's perimeter. The first trench (sediment chamber) provides pretreatment sediment settling before the runoff spills into the second trench (filter medium).

Siting and Design Considerations

Available space is likely to be the most important siting and design consideration when choosing an appropriate sediment-filtering system. As mentioned previously, the decision as to which configuration is implemented on a particular site is dependent on the amount of space on a site. Another important consideration when deciding to install sediment-filtering systems is the amount of available head. Head refers to the vertical distance available between the inflow of the filter system and the outflow point. Because most filtering systems depend on gravity as the driving force to move water through the system, if a certain amount of head is not available, the system will not be effective and might cause more harm than good. For surface and underground sand filters, a minimum head of 5 feet is suggested (Claytor and Schueler, 1996). Perimeter sand filters such as the two-chambered Delaware sand filter should have a minimum available head of 2 to 3 feet (Claytor and Schueler, 1996).

The depth of filter media will vary depending on media type, but for sand filters it is recommended that the sand (0.04-inch diameter or smaller) be at least 18 inches deep, with a minimum of 4 to 6 inches of gravel for the bed of the filter. Throughout the life of a sediment filter system, there will be a need for frequent access to assess continued effectiveness and perform routine maintenance and emergency repairs. Because most maintenance of sediment filters requires manual rather than mechanical removal of sediments and debris, filter systems should be located to allow easy access.

Limitations

Sediment filters are usually limited to the removal of pollutants from storm water runoff. They must be used in combination with other storm water management practices to provide flood protection. Sediment filters should not be used on fill sites or near steep slopes (Livingston, 1997). In addition, sediment filters are likely to lose effectiveness in cold regions because of freezing conditions.

Maintenance Considerations

Maintenance of storm water sediment filters can be relatively high compared to other sediment-trapping devices. Routine maintenance includes raking the filter medium and removal of surface sediment and trash. These maintenance chores will likely need to be accomplished by manual labor rather than mechanical means. Depending on the medium used in the structure, the filter material may have to be changed or replaced up to several times a year. This will depend, among other things, on rainfall intensity and the expected sediment load.

Sediment filters of all media types should be inspected monthly and after each significant rainfall event to ensure proper filtration. Trash and debris removal should be removed during inspections. Sediment should be removed from filter inlets and sediment chambers when 75 percent of the storage volume has been filled. Because filter media have the potential for high loadings of metals and petroleum hydrocarbons, the filter medium should be periodically analyzed to prevent it from reaching levels that would classify it as a hazardous waste. This is especially true on sites where solvents or other potentially hazardous chemicals will be used. Spill prevention measures should be implemented as necessary. The top 3 to 4 inches of the filter medium should be replaced on an annual basis, or more frequently if drawdown does not occur within 36 hours of a storm event.

Effectiveness

Treatment effectiveness will depend on a number of factors, including treatment volume; whether the filter is on-line or off-line, confined or unconfined; and the type of land use in the contributing drainage area. MWCOG (1992) state that sand filter removal rates are "high" for sediment and trace metals and "moderate" for nutrients, BOD, and fecal coliform. Removal rates can be increased slightly by using a peat/sand mixture as the filter medium due to the adsorptive properties of peat (MWCOG, 1992). Estimated pollutant removal capabilities for various storm water sediment filter systems is shown in Table 1.

Table 1. Pollutant removal efficiencies for sand filters.

Source	Filter System	TSS[a] (%)	TP[a] (%)	TN[a] (%)	Other Pollutants
Claytor and Schueler, 1996	Surface Sand Filter	85	55	35	Bacteria: 40-80% Metals: 35-90%
	Perimeter Sand Filter	80	65	45	Hydrocarbons: 80%
Livingston, 1997	Sand Filter (general)	60–85	30–75	30–60	Metals: 30–80%

[a]TSS=total suspended solids; TP=total phosphorus; TN=total nitrogen

Cost Considerations

MWCOG (1992) estimates cost of construction for sand filters to be between $3.00 and $10.00 per cubic foot of runoff treated. Annual costs are estimated to be approximately 5 percent of construction costs.

References

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Sediment Trap

Construction Site Storm Water Runoff Control

Description

Sediment traps are used to collect sediment-laden runoff from disturbed areas on construction sites

Sediment traps are small impoundments that allow sediment to settle out of runoff water. They are usually installed in a drainageway or other point of discharge from a disturbed area. Temporary diversions can be used to direct runoff to the sediment trap (USEPA, 1993). Sediment traps are used to detain sediments in storm water runoff and trap the sediment to protect receiving streams, lakes, drainage systems, and the surrounding area.

Sediment traps are formed by excavating an area or by placing an earthen embankment across a low area or drainage swale. An outlet or spillway is often constructed using large stones or aggregate to slow the release of runoff (USEPA, 1992).

Applicability

Sediment traps are generally temporary control measures to slow concentrated runoff velocity and catch sediment, and they can be used with other temporary storm water control measures. They are commonly used at the outlets of storm water diversion structures, channels, slope drains, construction site entrance wash racks, or any other runoff conveyance that discharges waters containing erosion sediment and debris. Sediment traps can also be used as part of a storm water drop intake protection system when the inlet is located below a disturbed area and will receive runoff with large amounts of sediment.

Siting and Design Considerations

Sediment traps can simplify the storm water control plan design process by trapping sediment at specific spots at a construction site (USEPA, 1992). Therefore, they should be installed as early in the construction process as possible. Natural drainage patterns should be noted, and sites where runoff from potential erosion can be directed into the traps should be selected. Sediment traps should not be located in areas where their failure due to storm water runoff excess can lead to further erosive damage of the landscape. Alternative diversion pathways should be designed to accommodate these potential overflows.

A sediment trap should be designed to maximize surface area for infiltration and sediment settling. This will increase the effectiveness of the trap and decrease the likelihood of backup during and after periods of high runoff intensity. Although site conditions will dictate specific design criteria, the approximate storage capacity of each trap should be at least 1,800 ft^3 per acre of total drainage area

(Smolen et al., 1988). The volume of a natural sedimentation trap can be approximated by the following equation (Smolen et al., 1988):

$$\text{Volume (ft}^3\text{)} = 0.4 \text{ x surface area (ft}^2\text{) x maximum pool depth (ft)}$$

Care should be taken in the siting and design phase to situate sediment traps for easy access by maintenance crews. This will allow for proper inspection and maintenance on a periodic basis. When excavating an area for sediment trap implementation, side slopes should not be steeper than 2:1 and embankment height should not exceed 5 feet from the original ground surface. All embankments should be machine compacted to ensure stability. To reduce flow rate from the trap, the outlet should be lined with well-graded stone.

The spillway weir for each temporary sediment trap should be at least 4 feet long for a 1-acre drainage area and increase by 2 feet for each additional drainage acre added, up to a maximum drainage area of 5 acres.

Limitations

Sediment traps should not be used for drainage areas greater than 5 acres (USEPA, 1993). The effective life span of these temporary structures is usually limited to 24 months (Smolen et al., 1988). Although sediment traps allow for settling of eroded soils, because of their short detention periods for storm water they typically do not remove fine particles such as silts and clays.

Maintenance Considerations

The primary maintenance consideration for temporary sediment traps is the removal of accumulated sediment from the basin. This must be done periodically to ensure the continued effectiveness of the sediment trap. Sediments should be removed when the basin reaches approximately 50 percent sediment capacity. A sediment trap should be inspected after each rainfall event to ensure that the trap is draining properly. Inspectors should also check the structure for damage from erosion. The depth of the spillway should be checked and maintained at a minimum of 1.5 feet below the low point of the trap embankment.

Effectiveness

Sediment trapping efficiency is a function of surface area, inflow rate, and the sediment properties (Smolen et al., 1988). Those traps that provide pools with large length-to-width ratios have a greater chance of success. Sediment traps have a useful life of approximately 18 to 24 months (USEPA, 1993), although ultimately effectiveness depends on the amount and intensity of rainfall and erosion, and proper maintenance. USEPA (1993) estimates an average total suspended solids removal rate of 60 percent. An efficiency rate of 75 percent can be obtained for most Coastal Plain and Piedmont soils by using the following equation (Barfield and Clar, in Smolen et al., 1988):

$$\text{Surface area at design flow (acres)} = (0.01) \text{ peak inflow rate (cfs)}$$

Cost Considerations

The cost of installing temporary sediment traps ranges from \$0.20 to \$2.00 per cubic foot of storage (about \$1,100 per acre of drainage). The average cost is approximately \$0.60 per cubic foot of storage (USEPA, 1993).

References

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Inlet protection

Storm Drain Inlet Protection

Construction Site Storm Water Control

Description

Storm drain inlet protection measures are controls that help prevent soil and debris from site erosion from entering storm drain drop inlets. Typically, these measures are temporary controls that are implemented prior to large-scale disturbance of the surrounding site. These controls are advantageous because their implementation allows storm drains to be used during even the early stages of construction activities. The early use of storm drains during project development significantly reduces the occurrence of future erosion problems (Smolen et al., 1988).

Coarse gravel and cinder blocks are often used to keep sediment and other pollutants out of storm drains

Three temporary control measures to protect storm drain drop inlets are

- Excavation around the perimeter of the drop inlet
- Fabric barriers around inlet entrances
- Block and gravel protection.

Excavation around a storm drain inlet creates a settling pool to remove sediments. Weep holes protected by gravel are used to drain the shallow pool of water that accumulates around the inlet. A fabric barrier made of porous material erected around an inlet can create an effective shield to erosion sediment while allowing water flow into the storm drain. This type of barrier can slow runoff velocity while catching soil and other debris at the drain inlet. Block and gravel inlet protection uses standard concrete blocks and gravel to form a barrier to sediments while permitting water runoff through select blocks laid sideways. In addition to the materials listed above, limited temporary storm water drop inlet protection can also be achieved with the use of straw bales or sandbags to create barriers to sediment. For permanent storm drain drop inlet protection after the surrounding area has been stabilized, sod can be installed as a barrier to slow storm water entry to storm drain inlets and capture erosion sediments. This final inlet protection measure can be used as an aesthetically pleasing way to slow storm water velocity near drop inlet entrances and to remove sediments and other pollutants from runoff.

Applicability

All temporary controls should have a drainage area no greater than 1 acre per inlet. It is also important for temporary controls to be constructed prior to disturbance of the surrounding landscape. Excavated drop inlet protection and block and gravel inlet protection are applicable to areas of high flow where overflow is anticipated into the storm drain. Fabric barriers are recommended for smaller, relatively flat drainage areas (slopes less than 5 percent leading to the storm drain). Temporary drop inlet control measures are often used in combination with each other and other storm water control techniques.

Siting and Design Considerations

With the exception of sod drop inlet protection, these controls should be installed before any soil disturbance in the drainage area. Excavation around drop inlets should be dug a minimum of 1 foot deep (2 feet maximum) with a minimum excavated volume of 35 yd^3 per acre disturbed. Side slopes leading to the inlet should be no steeper than 2:1. The shape of the excavated area should be designed such that the dimensions fit the area from which storm water is anticipated to drain. For example, the longest side of an excavated area should be along the side of the inlet expected to drain the largest area.

Fabric inlet protection should be staked close to the inlet to prevent overflow on unprotected soils. Stakes should be used with a minimum length of 3 feet, spaced no more than 3 feet apart. A frame should be constructed for fabric support during overflow periods and should be buried at least 1 foot below the soil surface and rise to a height no greater than 1.5 feet above ground. The top of the frame and fabric should be below the down-slope ground elevation to prevent runoff bypassing the inlet.

Block and gravel inlet barrier height should be 1 foot minimum (2 feet maximum), and mortar should not be used. The bottom row of blocks should be laid at least 2 inches below the soil surface flush against the drain for stability. One block in the bottom row should be placed on each side of the inlet on its side to allow drainage. Wire mesh (1/2 inch) should be placed over all block openings to prevent gravel from entering the inlet, and gravel (3/4 to 1/2 inch in diameter) should be placed outside the block structure at a slope no greater than 2:1.

Sod inlet protection should not be considered until the entire surrounding drainage area is stabilized. The sod should be laid so that it extends at least 4 feet from the inlet in each direction to form a continuous mat the around inlet, laying sod strips perpendicular to the direction of flows. The sod strips should be staggered such that strip ends are not aligned, and the slope of the sodded area should not be steeper than 4:1 approaching the drop inlet.

Limitations

Storm water drop inlet protection measures should not be used as stand-alone sediment control measures. To increase inlet protection effectiveness, these practices should be used in combination with other measures, such as small impoundments or sediment traps (USEPA, 1992). Temporary storm drain inlet protection is not intended for use in drainage areas larger than 1 acre. Generally, storm water inlet protection measures are practical for relatively low-sediment, low-volume flows. Frequent maintenance of storm drain control structures is necessary to prevent clogging. If sediment and other debris clog the water intake, drop intake control measures can actually cause erosion in unprotected areas.

Maintenance Considerations

All temporary control measures must be checked after each storm event. To maintain the sediment capacity of the shallow settling pools created from these techniques, accumulated sediment should be removed from the area around the drop inlet (excavated area, around fabric barrier, or around block structure) when the sediment capacity is reduced by approximately 50 percent. Additional debris should be removed from the shallow pools on a periodic basis. Weep holes in excavated areas around inlets can become clogged and prevent water from draining out of shallow pools that form. Should this happen, unclogging the water intake may be difficult and costly.

Effectiveness

Excavated drop inlet protection may be used to improve the effectiveness and reliability of other sediment traps and barriers, such as fabric or block and gravel inlet protection. However, as a whole, the effectiveness of inlet protection is low for erosion and sediment control, long-term pollutant removal, and low for habitat and stream protection.

Cost Considerations

The cost of implementing storm drain drop inlet protection measures will vary depending on the control measure chosen. Generally, initial installation costs range from $50 to $150 per inlet, with an average cost of $100 (USEPA, 1993). Maintenance costs can be high (up to 100 percent of the initial construction cost annually) due to frequent inspection and repair needs. The Southeastern Wisconsin Regional Planning Commission has estimated that the cost of installation of inlet protection devices ranges from $106 to $154 per inlet (SEWRPC, 1991).

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Good Housekeeping

Other wastes

General Construction Site Waste Management

Construction Site Storm Water Runoff Control

Description

Building materials and other construction site wastes must be properly managed and disposed of to reduce the risk of pollution from materials such as surplus or refuse building materials or hazardous wastes. Practices such as trash disposal, recycling, proper material handling, and spill prevention and cleanup measures can reduce the potential for storm water runoff to mobilize construction site wastes and contaminate surface or ground water.

Applicability

The proper management and disposal of wastes should be practiced at any construction site to reduce storm water runoff. Waste management practices can be used to properly locate refuse piles, to cover materials that may be displaced by rainfall or storm water runoff, and to prevent spills and leaks from hazardous materials that were improperly stored.

Siting and Design Considerations

The following steps should be taken to ensure proper storage and disposal of construction site wastes:

- Designate a waste collection area onsite that does not receive a substantial amount of runoff from upland areas and does not drain directly to a waterbody.
- Ensure that containers have lids so they can be covered before periods of rain, and keep containers in a covered area whenever possible.
- Schedule waste collection to prevent the containers from overfilling.
- Clean up spills immediately. For hazardous materials, follow cleanup instructions on the package. Use an absorbent material such as sawdust or kitty litter to contain the spill.
- During the demolition phase of construction, provide extra containers and schedule more frequent pickups.
- Collect, remove, and dispose of all construction site wastes at authorized disposal areas. A local environmental agency can be contacted to identify these disposal sites.

The following steps should be taken to ensure the proper disposal of hazardous materials:

- Local waste management authorities should be consulted about the requirements for disposing of hazardous materials.
- A hazardous waste container should be emptied and cleaned before it is disposed of to prevent leaks.
- The original product label should never be removed from the container as it contains important safety information. Follow the manufacturer's recommended method of disposal, which should be printed on the label.
- If excess products need to be disposed of, they should never be mixed during disposal unless specifically recommended by the manufacturer.

State or local solid waste regulatory agencies or private firms should be consulted to ensure the proper disposal of contaminated soils that have been exposed to and still contain hazardous substances. Some landfills might accept contaminated soils, but they require laboratory tests first.

Paint and dirt are often removed from surfaces by sandblasting. Sandblasting grits are the byproducts of this procedure and consist of the sand used and the paint and dirt particles that are removed from the surface. These materials are considered hazardous if they are removed from older structures because they are more likely to contain lead-, cadmium-, or chrome-based paints. To ensure proper disposal of sandblasting grits, a licensed waste management or transport and disposal firm should be contracted.

The following practices should be used to reduce risks associated with pesticides or to reduce the amount of pesticides that come in contact with storm water:

- Follow all federal, state, and local regulations that apply to the use, handling, or disposal of pesticides.
- Do not handle the materials any more than necessary.
- Store pesticides in a dry, covered area.
- Construct curbs or dikes to contain pesticides in case of spillage.
- Follow the recommended application rates and methods.
- Have equipment and absorbent materials available in areas where pesticides are stored and used in order to contain and clean up any spills that occur.

The following management practices should be followed to reduce the contamination risk associated with petroleum products:

- Store petroleum products and fuel for vehicles in covered areas with dikes in place to contain any spills.
- Immediately contain and clean up any spills with absorbent materials.
- Have equipment available in fuel storage areas and in vehicles to contain and clean up any spills that occur.

Phosphorous- and nitrogen-containing fertilizers are used on construction sites to provide nutrients necessary for plant growth, and phosphorous- and nitrogen-containing detergents are found in wash water from vehicle cleaning areas. Excesses of these nutrients can be a major source of water pollution. Management practices to reduce risks of nutrient pollution include the following:

- Apply fertilizers at the minimum rate and to the minimum area needed.
- Work the fertilizer deeply into the soil to reduce exposure of nutrients to storm water runoff.
- Apply fertilizer at lower application rates with a higher application frequency.
- Limit hydroseeding, which is the simultaneous application of lime and fertilizers.
- Ensure that erosion and sediment controls are in place to prevent fertilizers and sediments from being transported off-site.
- Use detergents only as recommended, and limit their use onsite. Wash water containing detergents should not be dumped into the storm drain system—it should be directed to a sanitary sewer or be otherwise contained so that it can be treated at a wastewater treatment plant.

Limitations

An effective waste management system requires training and signage to promote awareness of the hazards of improper storage, handling, and disposal of wastes. The only way to be sure that waste management practices are being followed is to be aware of worker habits and to inspect storage areas regularly. Extra management time may be required to ensure that all workers are following the proper procedures.

Maintenance Considerations

Containers or equipment that may malfunction and cause leaks or spills should be identified through regular inspection of storage and use areas. Equipment and containers should be inspected regularly for leaks, corrosion, support or foundation failure, or any other signs of deterioration and should be tested for soundness. Any found to be defective should be repaired or replaced immediately.

Effectiveness

Waste management practices are effective only when they are regularly practiced at a construction site. Guidelines for proper handling, storage, and disposal of construction site wastes should be posted in storage and use areas, and workers should be trained in these practices to ensure that everyone is knowledgeable enough to participate.

Cost Considerations

The costs associated with construction site waste management are mainly attributed to purchasing and posting signs, increased management time for oversight, additional labor required for special handling of wastes, transportation costs for waste hauling, and fees charged by disposal facilities to take the wastes.

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Spill Prevention and Control Plan

Construction Site Storm Water Runoff Control

Description

Absorbent snakes can be used to protect storm drains from spills (Spill911, no date)

Spill prevention and control plans should clearly state measures to stop the source of a spill, contain the spill, clean up the spill, dispose of contaminated materials, and train personnel to prevent and control future spills.

Applicability

Spill prevention and control plans are applicable to construction sites where hazardous wastes are stored or used. Hazardous wastes include pesticides, paints, cleaners, petroleum products, fertilizers, and solvents.

Siting and Design Considerations

Identify potential spill or source areas, such as loading and unloading, storage, and processing areas, places where dust or particulate matter is generated, and areas designated for waste disposal. Also, spill potential should be evaluated for stationary facilities, including manufacturing areas, warehouses, service stations, parking lots, and access roads.

Define material handling procedures and storage requirements, and take actions to reduce spill potential and impacts on storm water quality. This can be achieved by

- Recycling, reclaiming, or reusing process materials and thereby reducing the amount of process materials that are brought into the facility
- Installing leak detection devices, overflow controls, and diversion berms
- Disconnecting any drains from processing areas that lead to the storm sewer
- Performing preventative maintenance on storm tanks, valves, pumps, pipes, and other equipment
- Using material transfer procedures or filling procedures for tanks and other equipment that minimize spills
- Substituting less or non-toxic materials for toxic materials.

Provide documentation of spill response equipment and procedures to be used, ensuring that procedures are clear and concise. Give step-by-step instructions for the response to spills at a particular facility. This spill response plan can be presented as a procedural handbook or a sign. The spill response plan should

- Identify individuals responsible for implementing the plan
- Define safety measures to be taken with each kind of waste
- Specify how to notify appropriate authorities, such as police and fire departments, hospitals, or publicly owned treatment works for assistance
- State procedures for containing, diverting, isolating, and cleaning up the spill
- Describe spill response equipment to be used, including safety and cleanup equipment.

Limitations

A spill prevention and control plan must be well planned and clearly defined so that the likelihood of accidental spills can be reduced and any spills that do occur can be dealt with quickly and effectively. Training might be necessary to ensure that all workers are knowledgeable enough to follow procedures. Equipment and materials for cleanup must be readily accessible and clearly marked for workers to be able to follow procedures.

Maintenance Considerations

Update the spill prevention and control plan to accommodate any changes in the site or procedures. Regularly inspect areas where spills might occur to ensure that procedures are posted and cleanup equipment is readily available.

Effectiveness

A spill prevention and control plan can be highly effective at reducing the risk of surface and ground water contamination. However, the plan's effectiveness is enhanced by worker training, availability of materials and equipment for cleanup, and extra time spent by management to ensure that procedures are followed.

Cost Considerations

Spill prevention and control plans are inexpensive to implement. However, extra time is needed to properly handle and dispose of spills, which results in increased labor costs.

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Vehicle Maintenance and Washing Areas

Construction Site Storm Water Runoff Control

Description

Trucks should be washed in designated washing areas to prevent untreated wastewater from being discharged to surface or ground waters

Maintenance and washing of vehicles should be conducted using environmentally responsible practices to prevent direct, untreated discharges of nutrient-enriched wastewater or hazardous wastes to surface or ground waters. This involves designating covered, paved areas for maintenance and washing, eliminating improper connections from these areas to the storm drain system, developing a spill prevention and cleanup plan for shop areas, maintaining vehicles and other equipment that may leak hazardous chemicals, covering fuel drums and other materials that are stored outdoors, and properly handling and disposing of automotive wastes and wash water.

Applicability

Environmentally friendly vehicle maintenance and washing practices are applicable for every construction site to prevent contamination of surface and ground water from wash water and fuel, coolant, or antifreeze spills or leaks.

Siting and Design Considerations

Construction vehicles should be inspected for leaks daily and repaired immediately. All used products, including oil, antifreeze, solvents, and other automotive-related chemicals, should be disposed of as directed by the manufacturer. These products are hazardous wastes that require special handling and disposal. Used oil, antifreeze, and some solvents can be recycled at a designated facility, but other chemicals must be disposed of at a hazardous waste disposal site. A local environmental agency can help to identify such facilities.

Special paved areas should be designated for a vehicle repair area and a separate vehicle washing area in which runoff and wastewater from these areas is directed to the sanitary sewer system or other treatment facility as industrial process waste. Vehicle washing facilities should use high-pressure water spray without any detergents as water can remove most dirt adequately. If detergents must be used, phosphate- or organic-based cleansers should be avoided to reduce nutrient enrichment and biological oxygen demand in wastewater. Only biodegradable products should be used—they should not contain halogenated solvents. If possible, blowers or vacuums should be used instead of water to remove dry materials from vehicles. Washing areas must be clearly marked and workers should be informed that all washing must occur in this area. No other activities, such as vehicle repairs, should be conducted in the wash area. If vehicles or equipment are heavily greased or soiled, the area should be bermed and covered to prevent contamination of runoff from these pollutants.

Limitations

Limitations for vehicle maintenance areas include the cost of waste disposal (a fee may be charged by a hazardous waste disposal facility), the cost of providing an enclosed maintenance area with proper connections to an industrial sanitary sewer, and extra labor required to follow proper storage, handling, and disposal procedures. Vehicle wash areas might require permits, depending on the volume of wastewater produced and the type of detergents used, and it might be expensive to designate an area for vehicle washing with proper connections to the industrial waste handling system.

Maintenance Considerations

Vehicle maintenance areas produce a substantial amount of hazardous waste that requires regular disposal. Spills must be cleaned up and cleanup materials disposed of immediately. Equipment and storage containers should be inspected regularly to identify leaks or signs of deterioration. Maintenance of vehicle wash areas is minimal and involves maintenance of berms and drainage to the sanitary sewer system.

Effectiveness

The techniques mentioned above are very effective at reducing discharges of untreated automotive wastes and wash water to receiving waters. Their effectiveness is highly dependent on the training and level of commitment of personnel to follow procedures.

Cost Considerations

Costs associated with vehicle maintenance and wash areas include building enclosed structures, establishing connections to the sanitary sewer system, grading wash areas to drain only to sanitary sewers, and increased labor associated with special handling of hazardous wastes.

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Education and awareness

Contractor Certification and Inspector Training

Construction Site Storm Water Runoff Control

Description

Municipalities can establish training programs to educate contractors about erosion and sediment control practices

In many municipalities, erosion and sediment control (ESC) plans are required under ordinances enacted to protect water resources. These plans describe how a contractor or developer will reduce soil erosion and contain and treat runoff that is carrying eroded sediments. Plans typically include descriptions and locations of soil stabilization practices, perimeter controls, and runoff treatment facilities that will be installed and maintained before and during construction activities. In addition to special area considerations, the full ESC plan review inventory should include (Smolen et al., 1988):

- Topographic and vicinity maps
- Site development plan
- Construction schedule
- ESC plan drawings
- Detailed drawings and specifications for practices
- Design calculations
- Vegetation plan.

One of the most important factors determining whether or not erosion and sediment controls will be properly installed and maintained on a construction site is the knowledge and experience of the contractor. Many communities require certification for key on-site employees who are responsible for implementing the ESC plan.

Several states have contractor certification programs. The State of Delaware requires that at least one person on any construction project be formally certified. The Delaware program requires certification for any foreman or superintendent who is in charge of onsite clearing and land-disturbing activities for sediment and runoff control associated with a construction project. Responsible personnel are required to obtain certification by completing a training program sponsored or approved by the Department of Natural Resources and Environmental Control (DNREC). All applicants seeking approval of a sediment and runoff plan must certify that all personnel involved in the construction project will have a certificate of attendance at a Department-sponsored or approved training course before initiation of any land-disturbing activity (DNREC, no date). A description of this certification requirement can be found at the DNREC web site at http://www.dnrec.state.de.us/newpages/ssregs14.htm.

The Maine Department of Environmental Protection offers a Voluntary Contractor Certification Program (VCCP) that is a nonregulatory, incentive-driven program to broaden the use of effective erosion control techniques. The VCCP is open to any contractor who is involved with soil-disturbance activities, including filling, excavating, landscaping, and other types of earthworks. For initial certification, the program requires attendance at two 6-hour training courses and the successful completion of a construction site evaluation. To maintain certification, a minimum of one 4-hour continuing education course within every 2-year period is required thereafter. Local soil and water conservation district personnel will complete construction site evaluations during the construction season. Certifications are valid until December 31 of the second year after issuance. Certification will entitle the holder to advertise services as a "DEP Certified Contractor" (MDEP, 1999). More information about this program can be found on the MDEP web site at http://janus.state.me.us/dep/blwq/training/ip-vccp.htm.

Municipalities often do not have the funding and staffing resources to support a construction site inspection program. Municipalities can implement a private inspector program in which individuals can receive stormwater management and ESC training to become certified inspectors to reduce the burden on the governing agency. These private inspectors can be hired directly by the contractor when the governing agency anticipates that a larger, more complicated site will require substantial agency resources.

Contractor certification programs are supplements to a municipal inspection and enforcement program. Such programs will not work if the contractors and inspectors are not held accountable, even without certification. Because there is a potential for contractors and private inspectors to abuse their certification, states such as Delaware require spot checks by county enforcement agents.

Applicability

Contractor certification programs are applicable for municipalities that require erosion and sediment control plans for construction sites. Training and certification will help to ensure that the plans are properly implemented and that best management practices are properly installed and maintained. Inspector training programs are appropriate for municipalities with limited funding and resources for ESC program implementation. The inspectors will lighten the financial and staffing burden of governing agencies to ensure compliance on construction sites.

Implementation

Contractor certification can be accomplished through municipally sponsored training courses, or more informally, municipalities can hold mandatory pre-construction or pre-wintering meetings and conduct regular and final inspection visits to transfer information to contractors (Brown and Caraco, 1997). Information that should be covered in training courses and meetings includes the importance of ESC for water quality protection; developing and implementing ESC plans; the importance of proper installation, regular inspection, and diligent maintenance of ESC practices; and recordkeeping for inspections and maintenance activities. To implement an inspector training program, the governing agency would need to establish a certification course with periodic recertification, review reports submitted by private inspectors, conduct spot checks for accuracy, and institute fines or other penalties for noncompliance.

Effectiveness

Although the effectiveness of training and certification programs has not been discretely measured, there has been a large response to Delaware's inspector certification program. Within 6 years of implementing the program, 340 people had been certified (CWP, 1997).

Benefits

Contractors are the individuals ultimately responsible for the proper installation and maintenance of ESC practices on construction sites. A contractor certification program will help to improve compliance with ESC programs and foster better relationships between contractors and regulators. Inspector training programs can help to enforce compliance by limiting the burden of inspection for local regulatory agencies. By freeing up staff and other resources, more frequent and thorough inspections can be made.

Limitations

Contractor certification and inspector training programs require a substantial amount of effort on the part of the municipality or regulatory agency. They need to develop curricula for training courses, dedicate staff to teach courses, and maintain a report review and site inspection staff to ensure that both contractors and inspectors are fulfilling their obligations and complying with the ESC program.

Cost Considerations

Costs for contractor certification and inspector training can vary widely depending on the type of training and certification programs that are implemented. However, cost savings can be seen in a decreased need for remedial action because contractors have more ESC experience. Additionally, there will a reduced need for site visits by agency staff because private inspectors can handle the especially time-consuming projects.

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Construction Reviewer

Construction Site Storm Water Runoff Control

Description

Construction reviewers periodically inspect construction sites to ensure that contractors have installed and maintained their erosion and sediment controls properly (Source: University of Connecticut Cooperative Extension System, 2000)

According to some state's regulations, the construction reviewer should be able to perform routine inspections of construction sites. According to the state of Delaware, the following guidelines should be followed by the construction reviewer:

- Perform a construction review of active construction sites at least once a week.
- Within five calendar days, inform the person engaged in the land-disturbing activity, and the contractor, by a written construction review report of any violations of the approved plan or inadequacies of the plan. Inform the plan approval agency, if the approved plan is inadequate, within five working days. In addition, send the appropriate construction review agency copies of all construction review reports.
- Refer the project through the delegated inspection agency to the proper department for appropriate enforcement action if the person engaged in the land-disturbing activity fails to address the items contained in the written construction review report. Give verbal notice to the proper department.

Applicability

Construction reviewer training is considered an extremely important aspect of erosion and sediment control and stormwater enforcement. Construction reviewer training allows for third-party inspections of construction permits and BMP implementation. Third-party inspections free up state personnel from the time-consuming efforts to inspect each construction site. However, construction site reviewer training is still in its infant stages and is not yet a nationwide program.

Limitations

Several states do not have enough enforcement officers to inspect a large number of construction sites. The regulatory agency that oversees permits relies heavily on notifications by the public for permit noncompliance at construction sites. Because of some state's dependence on public involvement, numerous construction sites are not inspected.

Effectiveness

If the permit is reviewed by a regulatory agency or third party and the site is inspected on a regular basis, then it is assumed that the contractor certification is a success. For construction reviewers, the state of Delaware has produced a program that has proven both beneficial in protecting the environment and cost effective. The Delaware Department of Natural Resources and Environmental Control's (DNREC) Sediment and Storm Water Program illustrates how an aggressive inspection program depending on privately employed inspectors can limit the water quality impacts of construction. The result is a win-win situation in which the environment is protected, developers have less downtime, DNREC's workload is more reasonable, and local jobs are created. To obtain the mandated construction inspection, developers can hire one of the hundreds of private inspectors licensed under the state's Certified Construction Reviewer (CCR) program, first implemented in 1992.

In New Castle County, Delaware, a Phase I permitted county, the CCR program has been a successful component of the overall storm water management program. The county is enjoying economic growth and related commercial and residential development. Approximately 400 construction sites per year in Delaware require development and implementation of a detailed Sediment and Storm Water Plan. Limited to only three county government inspectors, the county has used the CCR program to leverage greater inspection coverage and increase compliance with federal, state, and local construction requirements. Of the 400 construction starts, more than 75 percent are being inspected by CCRs for at least a portion of the site development. The CCRs inspect active sites weekly and submit a report to the developer/contractor and to the county. County staff time once spent inspecting construction sites can now be spent overseeing the private CCR inspection process. Through the CCR program, New Castle County has saved approximately $100,000 annually, while the rate of compliance with Delaware's Sediment and Storm Water Program requirements has increased.

Cost Considerations

Inspector training costs vary from state to state.

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BMP Inspection and Maintenance

Construction Site Storm Water Runoff Control

Description

To maintain the effectiveness of construction site storm water control best management practices (BMPs), regular inspection of control measures is essential. Generally, inspection and maintenance of BMPs can be categorized into two groups--expected routine maintenance and nonroutine (repair) maintenance. Routine maintenance refers to checks performed on a regular basis to keep the BMP in good working order and aesthetically pleasing. In addition, routine inspection and maintenance is an efficient way to prevent potential nuisance situations (odors, mosquitoes, weeds, etc.), reduce the need for repair maintenance, and reduce the chance of polluting storm water runoff by finding and correcting problems before the next rain.

Routine inspection should occur for all storm water and erosion and sediment control (ESC) measures implemented at a site. These measures may include, but are not limited to, grass-covered areas, seeded areas, mulched areas, areas stabilized with geotextiles or sod, silt fences, earth dikes, brush barriers, vegetated swales, sediment traps, sediment basins, subsurface drains, pipe slope drains, level spreaders, storm drain drop inlet protection measures, gabions, rain barrels, and road and site entrance stabilization measures. Nonroutine maintenance refers to any activity that is not performed on a regular basis. This type of maintenance could include major repairs after a violent storm or extended rainfall, or replacement and redesign of existing control structures.

In addition to maintaining the effectiveness of storm water BMPs and reducing the incidence of pests, proper inspection and maintenance is essential to avoid the health and safety threats inherent in BMP neglect (Skupien, 1995). The failure of structural storm water BMPs can lead to downstream flooding, causing property damage, injury, and even death.

Applicability

All storm water BMPs should be inspected for continued effectiveness and structural integrity on a regular basis for the life of the construction project. Generally, all BMPs should be checked after each storm event in addition to the regularly scheduled inspections. Scheduled inspections vary between BMPs. Structural BMPs like storm drain drop inlet protection might require more frequent inspection than other BMPs to ensure proper operation. Inspection and maintenance of BMPs should continue until all construction activities have ended and all areas of a site have been permanently stabilized. During each inspection, the inspector should document whether the BMP is performing correctly, any damage to the BMP since the last inspection, and what should be done to repair the BMP if damage has occurred.

Siting and Design Considerations

In the case of vegetative or other infiltration BMPs, inspection of storm water management practices following a storm event should occur after the expected drawdown period for a given BMP. This approach allows the inspector to see whether detention and infiltration devices are draining correctly. Inspection checklists should be developed for use by BMP inspectors. The checklists might include each BMP's minimum performance expectations, design criteria, structural specifications, date of implementation, and expected life span. In addition, the maintenance requirements for each BMP should be listed on the inspection checklist. This checklist will aid the inspector in determining whether a BMP's maintenance schedule is adequate or needs revision. Also, a checklist will help the inspector determine renovation or repair needs.

Limitations

Routine maintenance materials such as shovels, lawn mowers, and fertilizer can be obtained on short notice with little effort. Unfortunately, not all materials that might be needed for emergency structural repairs are obtained with such ease. Thought should be given to stockpiling essential materials in case immediate repairs must be made to safeguard against property loss and to protect human health.

Maintenance Considerations

When considering a maintenance schedule for BMPs to control storm water runoff from construction activities, care should be taken to factor in increased erosion and sedimentation rates for construction sites. Clearing, grading, or otherwise altering the landscape at a construction site can increase the erosion rate by as much as 1,000 times the preconstruction rate for a given site (USEPA, 1992). Depending on the relative amount of disturbed area at a site, routine maintenance might have to occur on a more frequent basis.

It is important that routine maintenance and nonroutine repair of storm water and erosion control BMPs be done according to schedule or as soon as a problem is discovered. Because many BMPs are rendered ineffective for storm water runoff control if not installed and maintained properly, it is essential that maintenance schedules are maintained and repairs are performed promptly. In fact, in some cases BMP neglect can have detrimental effects on the landscape and increase the potential for erosion. However, "routine" maintenance such as mowing grass should be flexible enough to accommodate varying need based on weather conditions. For example, more harm than good might be caused by mowing during a drought or immediately after a storm event.

Effectiveness

The effectiveness of BMP inspection is a function of the familiarity of the inspector with each particular BMP's location, design specifications, maintenance procedures, and performance expectations. Documentation should be kept regarding the dates of inspection, findings, and maintenance and repairs that result from the findings of an inspector. Such records are helpful in maintaining an efficient inspection and maintenance schedule and provide evidence of ongoing inspection and maintenance.

Because maintenance work for storm water BMPs (mowing, removal of sediment, etc.) is usually not technically complicated, workers can be drawn from a large labor pool. As structural BMPs increase in their sophistication, however, more specialized maintenance training might be needed to sustain BMP effectiveness.

Cost Considerations

Mowing of vegetated and grassed areas may be the costliest routine maintenance consideration (WEF, 1998). Management practices using relatively weak materials (such as filter fabric and wooden posts) may mean more frequent replacement and therefore increased costs. The use of more sturdy materials (such as metal posts) where applicable may increase the life of certain BMPs and reduce replacement cost. However, the disposal requirements of all materials should be investigated before BMP implementation to ensure proper handling after the BMP has become ineffective or when it needs to be disposed of after the site has reached final stabilization.

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Model Ordinances

Construction Site Storm Water Runoff Control

Description

Erosion and sedimentation from construction sites can lead to reduced water quality and other environmental degradation. Municipalities can enact erosion and sediment control (ESC) ordinances for construction sites. These local regulations are intended to safeguard the public, protect property, and prevent damage to the environment.

Applicability

Ordinances promote the public welfare by guiding, regulating, and controlling the design, construction, use, and maintenance of any development or other activity that disturbs or breaks the topsoil or results in the movement of earth on land. ESC ordinances consist of permit application and review, and they can require an erosion and sediment control plan. A number of communities have dealt with construction sites by using an ordinance requiring permits, review and approval, ESC plans, design requirements, inspections, and enforcement. A model ordinance is available on EPA's web site at *www.epa.gov/nps/ordinance/mol2.htm*.

Siting and Design Considerations

Ordinances can set design requirements for grading, erosion control practices, sediment control practices, and waterway crossings. They can set limits for clearing and grading, and they can require action within a certain time frame. For example, soil stabilization might be required to be completed within 5 days of clearing or inactivity in construction.

The following are ways to ensure compliance:

- *Nonmonetary penalties*. Some municipalities require violators to perform restoration work or implement a BMP rather than pay a fine.
- *Fines*. ESC ordinances can set penalties for violations of a permit. For example, a maximum fine might be set for various types of violations. In all cases, the permittee would be fined upon conviction of the violation. Sample text for violations and penalties can be found in a model ordinance on EPA's web site at *www.epa.gov/nps/ordinance/mol2.htm*.
- *Stop work orders*. A stop work order or a permit revocation might be issued when a permit is violated or when development is implemented in a manner found to adversely affect the health, welfare, or safety of persons residing or working in the neighborhood or at development sites, or when there is a risk of injury to persons or property.
- *Bonding requirements*. Bonding requirements are allowances that are set aside specifically to repair damage to temporary construction site erosion and sediment controls (e.g., silt fences) caused by severe storm flows, high winds, or fallen trees. Funds can be used only if documented inspections that show erosion and sediment controls are installed and maintained

as required. This allowance helps to ensure 100-percent compliance by contractors (Deering, 1999).

Limitations

Site inspections are required for an adequate ESC process. An adequate staff of inspectors must be available to review permit applications and proposed ESC plans. Site inspections must be conducted on each construction site. The number of site visits will depend on available staff. Timing for site visits might be based on

- Start of construction
- Installation of ESC measures
- Completion of site clearing
- Completion of rough grading
- Completion of final grading
- Close of the construction season
- Completion of final landscaping.

Maintenance Considerations

Keeping up-to-date with construction projects is a major part of enforcement maintenance. Some municipalities rely on information submitted by the public. The city of Jacksonville, Florida, has a citizen complaint form on its web page at *http://www.coj.net/pub/resd/airwater/CCFORM.HTM*. Some of the categories of complaints are "Discharge of pollutants to storm drains, ditches, rivers, or creeks," "Overflowing manholes or pump stations," "Uncontrolled erosion from land clearing activities," and "Pumping of muddy water into creeks, storm drains, or ditches." City staff have established a goal of contacting complaint submitters within 24 hours (City of Jacksonville, 2000). In the Fresno-Clovis metropolitan area of California, storm water inspections on construction sites are generally sparked by complaints, proximity to the San Joaquin River, and direct discharges to the river or other receiving waterbodies (FMFCD).

Procedures for Site Plan Review

Existing staff should spend as much time as allowed in the field at the construction sites. This allows them a better idea of how controls are being implemented (if at all) and whether another approach should be taken. It is also recommended that existing staff spend as much as 10 percent of their time assigned to contractor training or public outreach (Brown and Caraco, 1997). One firm, Stormwater Services Group, can train construction contractor staff to perform site inspections or can perform one site visit per week and prepare the required weekly written report. Their services start at $75 per week (Stormwater Services Group, 2000).

The Center for Watershed Protection (CWP) surveyed 80 ESC programs in 1997. Responses to the survey showed that each ESC inspector was responsible for an average of 150 sites annually, indicating a lack of inspectors needed. The state of Delaware created a program that requires developers to hire a private inspector under any of three circumstances (CWP, 1997):

- All sites with more than 50 acres of disturbed area
- Any site, as determined by the state's resource agency
- Sites under construction that present significant management problems.

The state set requirements for private inspectors, such as certification, submission of weekly reports to the contractors, and other qualifications. To prevent bias on the part of inspectors (i.e., not reporting violations because they were hired by the contractors), the state set two provisions-spot checks are conducted by the local ESC agency, and the inspector must be supervised by a Professional Engineer (P.E.). Any discrepancy can lead to an inspector or P.E. losing his license (CWP, 1997).

Brown and Caraco (1997) list 10 elements reviewers should look for in an effective plan:

- Minimize needless clearing and grading
- Protect waterways and stabilize drainage ways
- Phase construction to limit soil exposure
- Stabilize exposed soils immediately
- Protect steep slopes and cuts
- Install perimeter controls to filter sediments
- Employ advanced sediment settling controls
- Certify contractors on ESC plan implementation
- Adjust ESC plan at construction site
- Assess ESC practices after storms.

Effectiveness

Ordinances are only as effective as the degree to which they are enforced.

Cost Considerations

Municipalities that enact erosion and sediment control ordinances must budget for the drafting and enforcement of the regulation.

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