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CONSTRUCTION ROAD STABILIZATION

Definition

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

Purpose

To control erosion on temporary construction routes and parking areas.

Conditions Where Practice Applies

All traffic routes and parking areas for temporary use by construction traffic.

Planning Considerations

Improperly planned and maintained construction roads can become a continual erosion problem. Excess runoff from roads causes erosion in adjacent areas, and an unstabilized road may become a dust problem. Construction vehicle traffic routes are especially susceptible to erosion because they become compacted, and collect and convey runoff water along their surfaces. Rills, gullies, and troublesome muddy areas form unless the road is stabilized.

During wet weather, unstabilized dirt roads may become so muddy they are virtually unusable, generating sediment and causing work interruption. Proper grading and stabilization of construction routes often saves money for the contractor by improving the overall efficiency of the construction operation while reducing the erosion problem.

Situate construction roads to reduce erosion potential, following the natural contour of the terrain. Avoid steep slopes, wet or rocky areas, and highly erosive soils.

Controlling surface runoff from the road surface and adjoining areas is a key erosion control consideration. Generally locate construction roads in areas where seasonally high water tables are deeper than 18 inches. Otherwise, subsurface drainage may be necessary. Minimize stream crossings and install them properly (Practices 6.70, *Temporary Stream Crossing* and 6.71, *Permanent Stream Crossing*).

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

Design Criteria

Road grade—A maximum grade of 10% to 12% is recommended, although grades up to 15% are possible for short distances.

Road width—14 feet minimum for one-way traffic
—20 feet minimum for two-way traffic

Side slope of road embankment—2:1 or flatter.

Ditch capacity—Roadside ditch and culvert capacities—10-year peak runoff.

Stone surface—Use a 6-inch course of "ABC" or "base course" or larger as specified in N.C. Department of Transportation Standard Specifications for Roads and Structures.

Permanent road standards—Design standards are available from the N.C. Department of Transportation Division of Highways District Engineer. Follow these specifications for all permanent roads.

Construction Specifications

1. Clear roadbed and parking areas of all vegetation, roots, and other objectionable material.

2. Ensure that road construction follows the natural contours of the terrain if it is possible.

3. Locate parking areas on naturally flat areas, if they are available. Keep grades sufficient for drainage, but generally not more than 2 to 3%.

4. Provide surface drainage, and divert excess runoff to stable areas by using water bars or turnouts (*References: Runoff Control Measures*).

5. Keep cuts and fills at 2:1 or flatter for safety and stability and to facilitate establishment of vegetation and maintenance.

6. Spread a 6-inch course of "ABC" crushed stone evenly over the full width of the road and smooth to avoid depressions.

7. Where seepage areas or seasonally wet areas must be crossed, install subsurface drains or geotextile fabric cloth before placing the crushed stone (Practice 6.81, *Subsurface Drain*).

8. Vegetate all roadside ditches, cuts, fills, and other disturbed areas or otherwise appropriately stabilize as soon as grading is complete (*References: Surface Stabilization*).

9. Provide appropriate sediment control measures to prevent off-site sedimentation.

Maintenance

Inspect construction roads and parking areas periodically for condition of surface. Topdress with new gravel as needed. Check road ditches and other seeded areas for erosion and sedimentation after runoff-producing rains. Maintain all vegetation in a healthy, vigorous condition. Sediment-producing areas should be treated immediately.

References

Surface Stabilization
6.10, Temporary Seeding
6.11, Permanent Seeding

Runoff Control Measures
6.20, Temporary Diversions
6.23, Right-of-way Diversions (Water Bars)

Runoff Conveyance Measures
6.30, Grass-lined Channels
6.31, Riprap-lined Channels

Other Related Practices
6.81, Subsurface Drain
6.84, Dust Control

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

6.81

SUBSURFACE DRAIN

Definition

A perforated conduit or pipe installed to a design depth and grade below ground surface to intercept, collect, and convey excess ground water to a satisfactory outlet.

Purpose

To improve soil-water conditions for vegetative growth, to improve slope stability, and to improve stability of structures with shallow foundations by lowering the water table.

Conditions Where Practice Applies

Subsurface drains apply where excess ground water must be removed to improve soil-water conditions for plant growth, to provide a stable base for construction, or to reduce hydrostatic pressure. The soil should have depth and sufficient permeability to permit installation of an effective drainage system at a depth of 2 to 6 feet.

An adequate outlet for the drainage system must be available either by gravity or by pumping. The quantity and quality of discharge should not damage the receiving stream.

This standard does not apply to subsurface drains for building foundations or deep excavations.

Planning Considerations

From a functional standpoint, subsurface drainage systems fall into two classes: relief drains and interceptor drains.

Relief drains are generally used to lower the water table in large, relatively flat areas that frequently become too wet to support desirable vegetation. Although surface water may also be carried through relief drains, it is generally better to install a separate drain for this purpose.

Relief drains may be installed in a grid, herringbone, or random pattern (Figure 6.81a), depending on specific site conditions. In locations where it is desirable to control the water table (raise or lower it) for optimum plant growth, the system may be designed as a combination subirrigation/drainage system. Special on-site investigations are needed, however, to design such dual-purpose systems.

Interceptor drains (Figure 6.81b) remove excess ground water from a slope, stabilize steep slopes and lower the water table immediately below a slope. They may also be used to stabilize shallow foundations such as paved channels or construction access roads.

Interceptor drains usually consist of a single pipe or a series of single pipes buried perpendicular to the slope.

The capacity of an interceptor drain is determined by calculating the maximum rate of ground water flow to be intercepted. Therefore, it is good practice to make complete subsurface investigations including hydraulic conductivity of the soil before designing a subsurface drainage system.

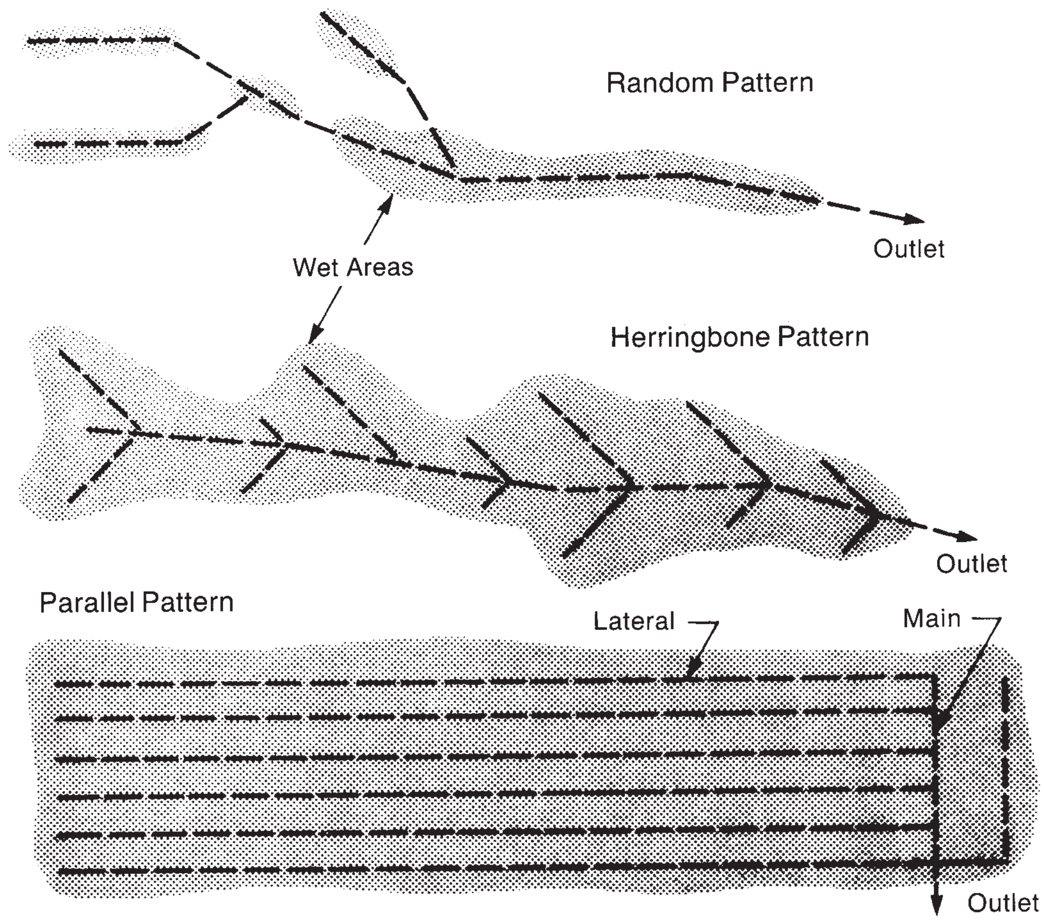

Figure 6.81a Subsurface relief drain layouts (source: USDA-SCS).

Design Criteria

Location—Do not install drain lines within 50 feet of trees to avoid tree roots that may clog the line. Use solid pipe with watertight connections where it is necessary to pass a subsurface drainage system through a stand of trees.

Arrange relief drains in a pattern that will drain the entire wet area evenly. Main lines are usually located through the lowest portion of the landscape (Figure 6.81a).

Locate interceptor drains to proper depth on the uphill side of wet, unstable areas and install on a positive grade across the slope.

Capacity of relief drains—Minimum removal rate is 1 inch of ground water in 24 hours (0.042cfs/acre). When surface water is allowed to enter directly into the drain, the design capacity must be increased accordingly. Design rates may be decreased if a good independent surface drainage system is installed.

Capacity of interceptor drains—Table 6.81a may be used to determine the capacity requirements for interceptor drains for most soils in North Carolina. Note the limitations in the chart.

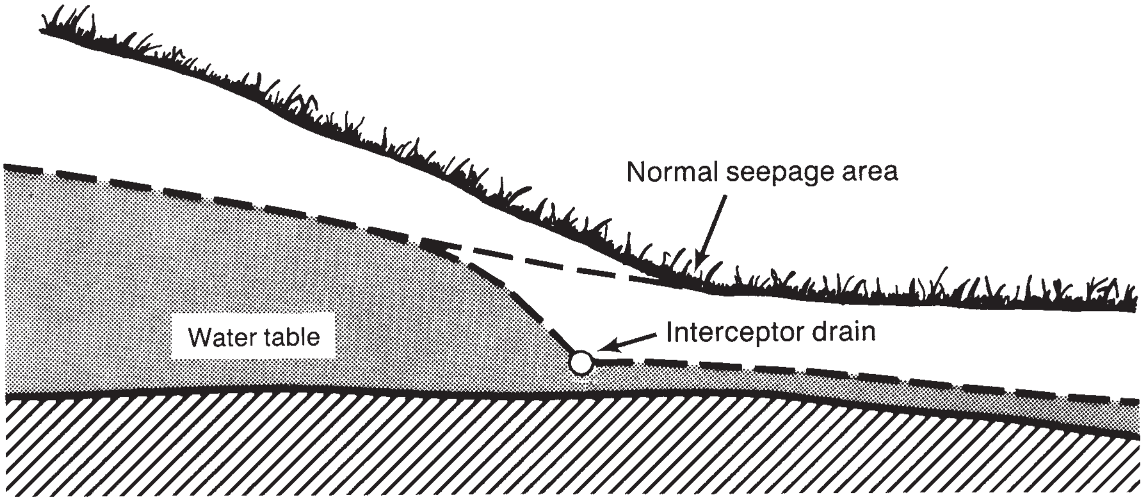

Figure 6.81b Interceptor drain to control seepage.

If spring flow or surface water enters the drain directly, the capacity must be increased to accommodate the excess. When anticipated seepage rates are high (greater than 20 inches/hour) or extensive drainage is require, an individual design may be based on the following equation:

$$Q_i = \frac{K\, i\, d_e\, L}{43{,}200}$$

where:

Q_i = design discharge in cfs,

K = hydraulic conductivity in inches/hour (sufficient in-place tests must be made to determine this value),

i = hydraulic gradient of the undisturbed water table in feet/feet (should be made during wet conditions),

d_e = the average effective depth in feet (the depth of the proposed drain invert below the undisturbed water table), and

L = length of the drain in feet.

Where hydraulic conductivity rates vary greatly, such as in gravel layers, a pilot trench may be dug to design depth and the actual flow rate measured under wet conditions.

Size of drain—Size subsurface drains to carry the required capacity without pressure flow. Minimum diameter for a subsurface drain is 4 inches.

Depth and spacing of relief drains—Relief drains should be installed in a uniform pattern with equal spacing between the drains and all drains at the same depth. The maximum depth is limited by the allowable load for the type of pipe, depth to an impermeable layer, and outlet conditions.

Spacing between drains depends primarily on soil hydraulic conductivity (permeability) and the depth of the drain. In most cases, a depth of 3 to 4 feet and a spacing of 50 feet is adequate.

Table 6.81a Design Flow Rates for Interceptor Drains in Sloping Land

Slope of Underground Water Surface[1]	Minimum Capacity[2]
<5%	0.3 cfs/1,000 ft
5 - 10%	0.6 cfs/1,000 ft
10 - 20%	1.0 cfs/1,000 ft
>20%	1.5 cfs/1,000 ft

[1] Use the slope of the land surface above the interceptor line if water table surface slope is not known.

[2] If hydraulic conductivity of the soil above the interceptor line exceeds 20 inches per hour, design should be based on specific site data.

When large areas are to be drained, specific site designs should be prepared. One reference for this purpose is the National Engineering Handbook, Section 16, Drainage of Agricultural Land, prepared by USDA, Soil Conservation Service.

Depth and spacing of interceptor drains—The depth of an interceptor drain is determined primarily by the depth to which the water table is to be lowered or the depth to a permeability-restricting layer. The maximum depth is limited by the allowable load for the type of pipe used and the depth to an impermeable layer. For practical reasons, the maximum depth is usually limited to 6 feet, with a minimum cover of 2 feet to protect the conduit.

One interceptor drain is usually sufficient, especially when the drain can be located on or just above an impermeable layer. Where more than one interceptor drain may be needed, it may be acceptable to install only the upper drain—then if seepage problems occur downslope, additional drains can be installed in the same manner as the first line. An alternative approach is to make sufficient soil borings and hydraulic conductivity tests to define (1) the surface of the impervious layer, (2) the undisturbed slope of the water table during wet conditions, and (3) the in-place saturated hydraulic conductivity of the soil materials upslope of the problem area. The minimum number of individual interceptor lines can then be sized and placed to the proper depth and location to control the underground water level to a minimum depth of 2 feet below the ground surface.

Envelopes and filters—Bed all drains in gravel as shown in Figure 6.81c to improve flow into the drain. If soil material is used for the backfill, place filter cloth over the top of the gravel before backfilling to prevent soil from moving into the gravel. If sand is used, it should conform to NCDOT Standard size No. 2S subsurface drain material (NCDOT Section 905-3). Envelopes and filters should surround the drain to a minimum of 3-inch thickness.

Velocity limitations—The minimum velocity to prevent silt deposition in drain lines is 1.4 ft/sec. The maximum allowable velocity using a sand-gravel filter or envelope is 9 ft/sec.

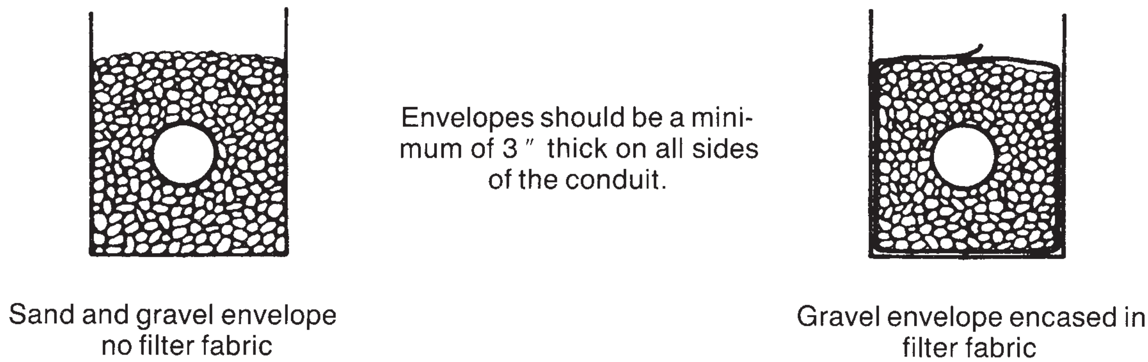

Figure 6.81c Drainage envelopes and filters (modified from USDA-SCS).

Outlet—Ensure that the outlet of a drain empties into a channel or other watercourse above the normal water level.

Use outlet pipe of corrugated metal, cast iron, steel pipe, or heavy-duty plastic without perforations and at least 10 feet long. Do not use an envelope or filter material around the outlet pipe, and bury at least two-thirds of the pipe length.

When outlet velocities exceed those allowable for the receiving stream, outlet protection must be provided (*References: Outlet Protection*).

Secure an animal guard to the outlet end of the pipe to keep out rodents.

Material—Acceptable materials for subsurface drains include perforated, continuous closed-joint conduits of corrugated plastic, corrugated metal, concrete, and bituminized fiber. Ensure that the strength and durability of the pipe meet the requirements of the site and are in keeping with the appropriate ASTM specification for the materials used.

Construction Specifications

1. Dig a trench to grade 3 inches below the design bottom elevation of the pipe to accommodate the envelope or filter material.

2. Stabilize any soft, yielding soils under the drain with gravel or other suitable material.

3. Lay pipe on the design grade and elevation avoiding reverse grade or low spots.

4. Do not use damaged, deformed, warped, or otherwise unsuitable pipe.

5. Place envelope or filter material around pipe with at least 3 inches of material on all sides.

6. Ensure that gravel for envelopes around flexible pipe does not exceed 3/4 inch in size to prevent damage to the pipe.

7. Place filter cloth over gravel envelopes to prevent movement of soil into the gravel.

8. Backfill immediately after placement of the pipe. Ensure that the backfill material does not contain rocks or other sharp objects and place it in the trench in a manner that will not damage or displace the pipe. Overfill the trench slightly to allow for settlement.

9. For the outlet section of the drain, use at least 10 feet of nonperforated corrugated metal, cast iron, steel, or heavy-duty plastic pipe. Cover at least two-thirds of the pipe length with well-compacted soil.

10. Keep the settled fill over the pipe outlet slightly higher than the surrounding ground to prevent erosion and wash-out from surface runoff.

11. Place a suitable animal guard securely over the pipe outlet to keep out rodents.

12. Cap the upper end of each drain with a standard cap made for this purpose or with concrete or other suitable material to prevent soil from entering the open end.

Maintenance

A properly designed and installed subsurface drain requires little maintenance. However, check drains periodically and especially after heavy rains to see that they are operating properly. Keep the outlet free of sediment and other debris, and keep the animal guard in place and functional. Investigate any wet areas along the line for possible cave-in due to vehicle traffic, blockage by roots, or other problems. Make all needed repairs promptly.

References

Runoff Conveyance Measures
6.30, Grass-lined Channels

Outlet Protection
6.41, Outlet Stabilization Structure

USDA Soil Conservation Service
National Engineering Handbook, Section 3,
Drainage of Agricultural Land

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

6.82

GRADE STABILIZATION STRUCTURE

Definition

A structure designed to reduce channel grade in natural or constructed watercourses.

Purpose

To prevent erosion of a channel that results from excessive grade in the channel bed. This practice allows the designer to adjust channel grade to fit soil conditions.

Conditions Where Practice Applies

This practice applies where structures are required to prevent head cutting or stabilize gully erosion. Specific locations are:

- Where head cutting or gully erosion is active in natural or constructed stream channels.
- Where beds of intersecting channels are at different elevations.
- Where a flatter grade is needed for stability in a proposed channel or water disposal system.

Planning Considerations

Grade stabilization structures are usually installed as part of a vegetated water disposal system. If the channel grade is erosive with a vegetative liner, the designer should consider using nonerodible channel liners (riprap or paving), or a vegetated channel in combination with grade stabilization structures. In deciding which type of system to use, the designer should consider:

- the differences in channel depths, widths, and spoil disposal,
- the effect the deeper channel will have on the water table, especially near the structure,
- entrance of surface water into the deeper channel system, and the need for an emergency bypass, at structure locations,
- side slope stability,
- outlet velocities,
- environmental impacts,
- site aesthetics, and
- cost comparisons including maintenance.

In general, shallow channels stabilized with riprap or concrete are preferred to deeper earth channels that require grade stabilization structures.

Grade stabilization structures are often used to stabilize progressive head cutting in an existing channel. Make an on-site evaluation to determine that the channel upstream and downstream from the proposed structure will be stable for the design flow conditions. Base the stability evaluation on clear water flow, as another head cut may begin below the structure once sediment sources upslope are controlled.

Grade stabilization structures may be vertical drop structures, concrete or riprap chutes, gabions, or pipe drop structures. Permanent ponds or lakes may be part of a grade stabilization system.

Where flows exceed 100 cfs and grade drops are higher than 10 feet, consider concrete chutes. This type of grade control structure is often used as an outlet for large water impoundments.

Where flows exceed 100 cfs and the drop is less than 10 feet, a vertical drop weir constructed of reinforced concrete or sheet piling with concrete aprons is generally recommended. Small flows allow the use of prefabricated metal drop spillways or pipe overfall structures.

Pipe drop grade stabilization structures are commonly used where channels intersect at different elevations, especially when flows are less than 50 cfs. Pipe drop structures also make convenient permanent channel crossings.

Design Criteria

Designs for grade stabilization structures can be complex and usually require detailed site investigations. Design of large structures (100 cfs) require a qualified engineer familiar with hydraulics and experienced in structure design. Advice on the control of stream channel erosion may be obtained from the local USDA Soil Conservation Service office serving each country.

Location of structure—Locate the structure on a straight section of channel with no upstream or downstream curves within 100 feet.

Ensure that the foundation material at the site is stable, relative homogenous, mineral soil with sufficient strength to support the structure without uneven settling. Piping potential of the soil should be low.

Ensure that flood bypass capability is available at the site to protect the structure from flows greater than design capacity. Protect the area where bypass flow enters the channel downstream (Figure 6.82a).

Consider diversion of flow for dewatering during construction as part of site evaluation.

Capacity—At a minimum, design the structure to control the peak runoff from the 10-year storm or to meet the bankfull capacity of the channel, whichever is greater.

Ensure that bypass capacity prevents structural failure from larger storms, based on the expected structure life and consequences of failure. **Large structures require greater design factors because of safety considerations**.

Grade elevations—Set the crest of the structure's inlet at an elevation that will stabilize the grade of the upstream channel. Set the outlet section at an elevation that will provide a stable grade downstream to assure stability.

Structural dimensions—The National Engineering Handbook (Drop Spillways, Section 11, and Chute Spillways, Section 14), prepared by the USDA Soil Conservation Service, gives detailed information useful in the design of grade stabilization structures.

Foundation drainage is needed to reduce hydrostatic loads on drop spillway structures. New products such as plastic, prefabricated drainage devices are available that provide positive drainage, are easy to install, and may be less costly than conventional drainage methods.

Outlet conditions—Keep the velocity of flow at the outlet within the allowable limits for the receiving stream (Table 8.05d). Place a transition section consisting of properly sized riprap at the toe of the structure to prevent erosion of the channel bed (Practice 6.41, *Outlet Stabilization Structure*).

Construction Specifications

1. Divert all surface runoff around the structure during construction so that the site can be properly dewatered for foundation preparation, construction of headwalls, apron drains, and other structural appertenances.

2. Ensure that the concrete conforms to standards for reinforced structural concrete. Make adequate tests, including breaking test cylinders to see that the concrete meets all design specifications for the job. Failure of a large grade stabilization structure may be costly and extremely hazardous.

3. Hand-compact backfill in 4-inch layers around the structure.

4. Make the end of the riprap section as wide as the receiving channel, and make sure the transition section of riprap between the structure end sill and the channel is smooth.

5. Ensure that there is no overfall from the end sill along the surface of the riprap to the existing channel bottom.

6. Locate emergency bypass areas so flood flow in excess of spillway capacity enters the channel below the structure without serious erosion or damage to the structure.

7. Stabilize all disturbed areas as soon as construction is complete.

Since these structures are located in watercourses, take special precautions to prevent erosion and sedimentation during construction of the structure.

Maintenance

Once a grade stabilization structure has been properly installed and the area around it stabilized, maintenance should be minimal. Inspect the structure periodically and after major storms throughout the life of the structure. Check the fill around the structure for piping, erosion, and settlement and to ensure that good protective vegetation is maintained. Check the channel at the structure entrance and outlet for scour and debris accumulation that may cause blockage or turbulence. Check the structure itself for cracking or spauling of the concrete, uneven or excessive settlement, piping, and proper drain functioning. Check emergency bypass areas around the structure for erosion, especially where flow re-enters the channel. Repair or replace failing structures immediately.

References

Runoff Conveyance Measures
6.31, Riprap-lined Channels

Outlet Protection
6.41, Outlet Stabilization Structure

Appendix
8.05, Design of Stable Channels and Diversions

USDA Soil Conservation Service
National Engineering Handbook, Sections 11 and 14.
Washington, D.C.

6.83

CHECK DAM

Definition

A small temporary stone dam constructed across a drainage way.

Purpose

To reduce erosion in a drainage channel by reducing the velocity of flow.

Conditions Where Practice Applies

This practice may be used as a temporary measure to limit erosion by reducing velocity in small open channels. When needed, they can be used in channels, roadside ditches, and temporary diversions.

Check dams may be used to:

- reduce velocity in small temporary channels that are degrading, but where permanent stabilization is impractical due to their short period of usefulness;
- reduce velocity in small eroding channels where construction delays or weather conditions prevent timely installation of nonerosive liners.

Do not use check dams in intermittent or perennial streams.

Planning Considerations

Check dams are an expedient way to reduce gullying in the bottom of channels that will be filled or stabilized at a later date. The dams should only be used while permanent stabilization measures are being put into place.

Check dams installed in grass-lined channels may kill the vegetative lining if submergence after it rains is too long and/or silting is excessive. All stone and riprap must be removed if mowing is planned as part of vegetative maintenance.

Design Criteria

The following criteria should be used when designing a check dam:

- The drainage area is limited to one half acre.
- Keep a maximum height of 2 feet at the center of the dam.
- Keep the center of the check dam at least 9 inches lower than the outer edges at natural ground elevation.
- Keep the side slopes of the dam at 2:1 or flatter.
- Ensure that the maximum spacing between dams places the toe of the upstream dam at the same elevation as the top of the downstream dam (Figure 6.83a).
- Stabilize outflow areas along the channel to resist erosion.
- Use NC DOT Class B stone and line the upstream side of the dam with NC DOT #5 or #57 stone.
- Key the stone into the ditch banks and extend it beyond the abutments a minimum of 1.5 feet to avoid washouts from overflow around the dam.

Construction Specifications

1. Place stone to the lines and dimensions shown in the plan on a filter fabric foundation.

2. Keep the center stone section at least 9 inches below natural ground level where the dam abuts the channel banks.

3. Extend stone at least 1.5 feet beyond the ditch bank (Figure 6.83b) to keep water from cutting around the ends of the check dam.

4. Set spacing between dams to assure that the elevation at the top of the lower dam is the same as the toe elevation of the upper dam.

5. Protect the channel after the lowest check dam from heavy flow that could cause erosion.

6. Make sure that the channel reach above the most upstream dam is stable.

7. Ensure that other areas of the channel, such as culvert entrances below the check dams, are not subject to damage or blockage from displaced stones.

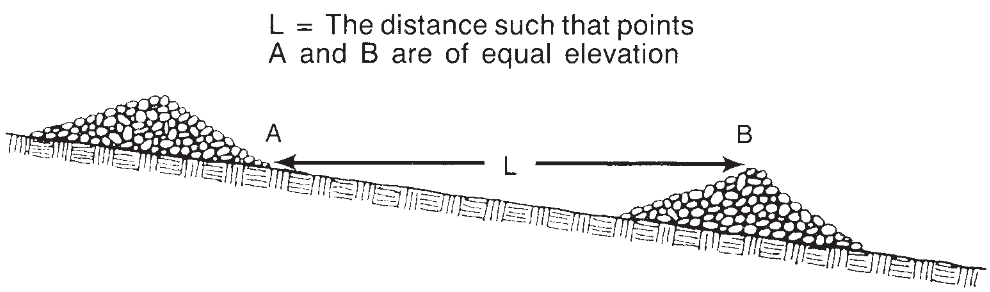

Figure 6.83a Space check dams in a channel so that the crest of downstream dam is at elevation of the toe of upstream dam.

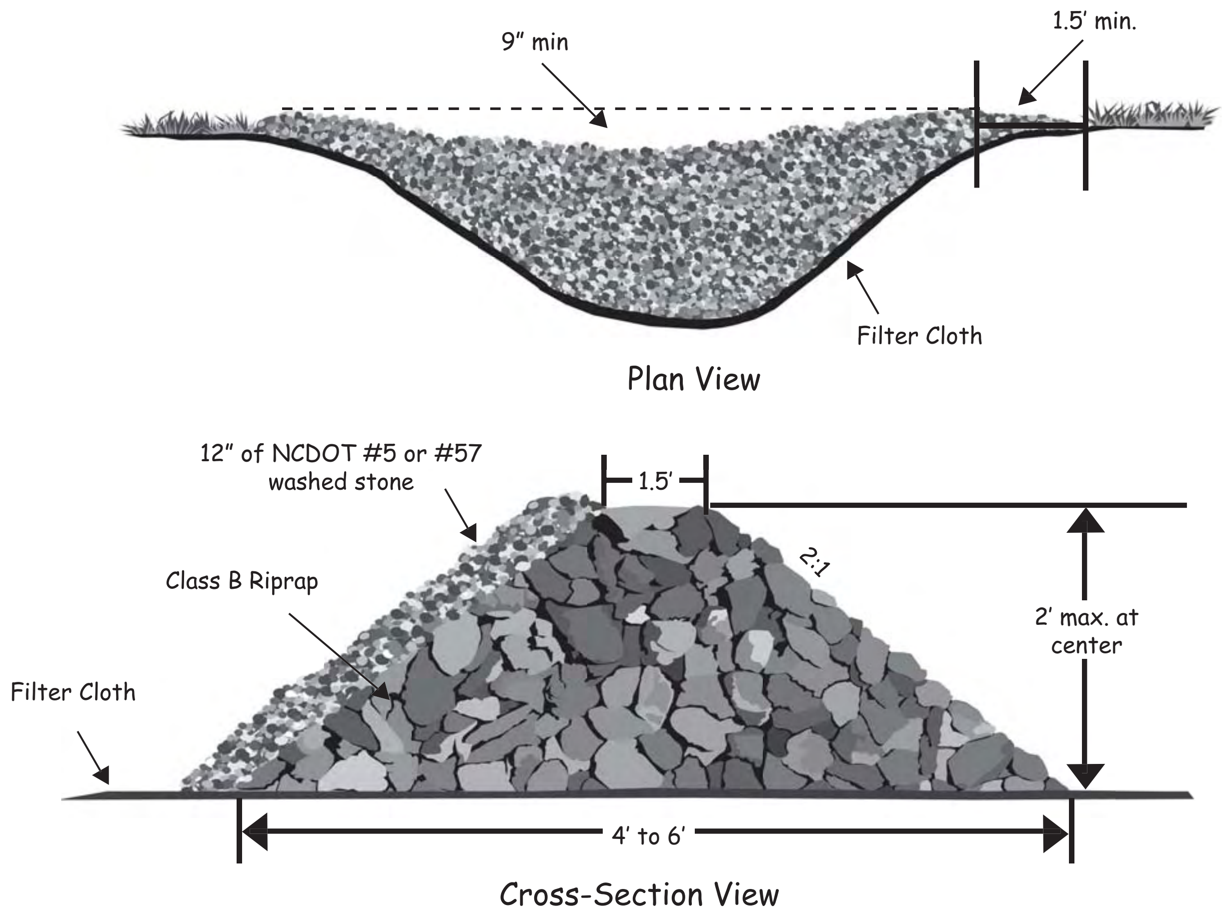

Figure 6.83b Stone check dam stone should be placed over the channel banks to keep water from cutting around the dam.

Maintenance

Inspect check dams and channels at least weekly and after each significant (1/2 inch or greater) rainfall event and repair immediately. Clean out sediment, straw, limbs, or other debris that could clog the channel when needed.

Anticipate submergence and deposition above the check dam and erosion from high flows around the edges of the dam. Correct all damage immediately. If significant erosion occurs between dams, additional measures can be taken such as, installing a protective riprap liner in that portion of the channel (Practice 6.31, *Riprap-line and Paved Channels*).

Remove sediment accumulated behind the dams as needed to prevent damage to channel vegetation, allow the channel to drain through the stone check dam, and prevent large flows from carrying sediment over the dam. Add stones to dams as needed to maintain design height and cross section.

References

Runoff Conveyance Measures
6.30, Grass-lined Channels
6.31, Riprap-lined and Paved Channels

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

6.84

DC

DUST CONTROL

Definition

The control of dust resulting from land-disturbing activities.

Purpose

To prevent surface and air movement of dust from disturbed soil surfaces that may cause off-site damage, health hazards, and traffic safety problems.

Conditions Where Practice Applies

On construction routes and other disturbed areas subject to surface dust movement, and dust blowing where off-site damage may occur if dust is not controlled.

Planning Considerations

Construction activities that disturb soil can be a significant source of air pollution. Large quantities of dust can be generated, especially in "heavy" construction activities such as land grading for road construction and commercial, industrial, or subdivision development.

In planning for dust control, it is important to schedule construction operations so that the least area is disturbed at one time.

Leave undisturbed buffer areas between graded areas wherever possible.

The greatest dust problems occur when the probability of rainfall erosion is least. Therefore, do not expose large areas of soil, especially during drought conditions.

Install temporary or permanent surface stabilization measures immediately after completing land grading.

Design Criteria

No formal design procedure is given for dust control. See Construction Specifications below for the most common dust control methods.

Construction Specifications

Vegetative cover—For disturbed areas not subject to traffic, vegetation provides the most practical method of dust control (*References: Surface Stabilization*).

Mulch (including gravel mulch)—When properly applied, mulch offers a fast, effective means of controlling dust.

Spray-on adhesive—Examples of spray-on adhesives for use on mineral soils are presented in Table 6.84a.

Table 6.84a
Spray-on Adhesive for Dust Control on Mineral Soil

	Water Dilution	Type of Nozzle	Apply Gallons/Acre
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

Calcium chloride may be applied by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist, but not so high as to cause water pollution or plant damage.

Sprinkling—The site may be sprinkled until the surface is wet. Sprinkling is especially effective for dust control on haul roads and other traffic routes.

Stone used to stabilize construction roads can also be effective for dust control.

Barriers—A board fence, wind fence, sediment fence, or similar barrier can control air currents and blowing soil. Place barriers perpendicular to prevailing air currents at intervals about 15 times the barrier height. Where dust is a known problem, preserve windbreak vegetation.

Tillage—Deep plow large open undisturbed areas and bring clods to the surface. This is a temporary emergency measure that can be used as soon as soil blowing starts. Begin plowing on the windward edge of the site.

Maintenance

Maintain dust control measures through dry weather periods until all disturbed areas have been stabilized.

References

Surface Stabilization
6.10, Temporary Seeding
6.11, Permanent Seeding
6.14, Mulching

Other Related Practices
6.80, Construction Road Stabilization

6.85

SAND FENCE (Wind Fence)

Definition

An artificial barrier of evenly spaced wooded slats or approved fabric erected perpendicular to the prevailing wind and supported by posts.

Purpose

To reduce wind velocity at the ground surface, and trap blowing sand.

Conditions Where Practice Applies

Across open, bare, sandy soil areas subject to frequent winds, where the trapping of blowing sand is desired. Wind fences are used primarily to build frontal ocean dunes (to control erosion from wave overwash and flooding). They may also prevent sand from blowing off disturbed areas onto roads or adjacent property.

Planning Considerations

Soil movement by wind depends on the physical character and condition of the soil. Normally, only dry soils are moved by wind. The structure of soil in an air-dry state is the index to its erodibility. Loose, fine-textured soils are the most readily blown.

There are three types of soil movement operating simultaneously in the process of wind erosion:

- suspension—fine dust particles are carried and suspended in air,
- saltation—movement of particles in short bounces on the ground, and
- surface creep—movement of large particles on the ground by both direct wind and bombardment by smaller particles.

Sand fences act as barriers that catch and hold blowing sand in much the same way as a snow fence prevents snow drift. The fence consists of evenly spaced wooded slats. The spaces between slats allow wind and sand to pass through the fence, but the wind velocity is reduced, causing sand deposition along the fence and between rows of fence (Figure 6.85a).

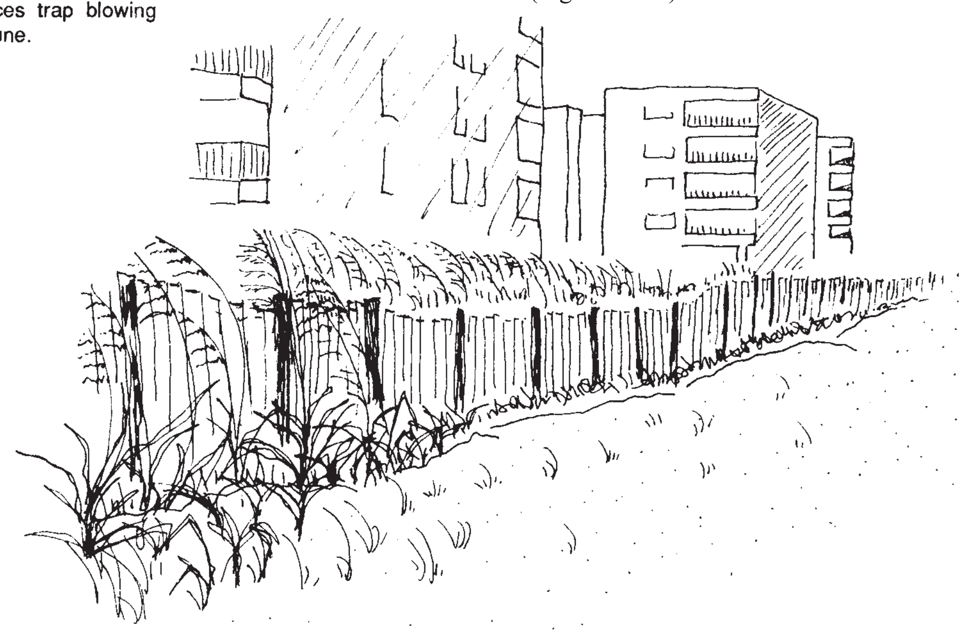

Figure 6.85a Sand fences trap blowing sand to rebuild frontal dune.

Sand fences, commonly used to build up low areas of frontal dunes along the coast line, can trap large amounts of sand. Their effectiveness depends on the source of sand and the frequency and velocity of onshore wind. As a windward fence is filling, some sand drifts to the next leeward fence. When the dune is sufficiently wide and fences are approximately two-thirds filled with sand, another series of fences may be erected. In this manner, 2 to 6 feet dunes are built in a single season.

There is a limit to how high the frontal dune will form. The natural process of the rise and fall of the tide with an onshore wind provides the sand source to build the dune. The high tide, driven by an onshore wind, carries sand onto the beach. As the tide recedes, the sun and wind dry the sand, and the wind blows it up the dune where it is caught by the fence. The process is repeated as the tides change. As the dune grows, it takes a progressively stronger wind to carry sand over the dune; but as the wind increases, the tides increase and water covers more of the beach. With less available beach sand, strong winds may remove sand along the fence instead of depositing it. In addition, the waves may reach the toe of the dune, causing it to cave and flatten. A change of wind direction more parallel to the coast will speed the erosion process because sand is carried along the beach instead of being deposited below the dune. Therefore, a wind fence must be located well above the expected high water mark to be effective.

When the dune has reached the level of other mature dunes in the area, stabilize it with vegetation. American beachgrass, sea oats, and other adapted vegetation will hold the captured sand in place and gradually capture more sand until the natural maximum dune height is reached. Dunes may be built by vegetation alone, but it usually takes a longer period of time (Practice 6.16, *Vegetative Dune Stabilization*).

Dunes built by wind fences and stabilized with appropriate beach vegetation do not provide permanent protection from beach erosion. However, they do speed up the rebuilding of the natural dune barrier and tend to reduce the average annual loss of frontal dunes.

Keep beach development at least 100 feet behind frontal dunes. Generally, do not attempt beach development in areas where the estimated average frontal dune loss is more than 2 ft/yr, or in particularly vulnerable locations, such as areas adjoining ocean inlets.

Sand fences also trap blowing sand at construction sites to prevent off-site damage to roads, streams, and adjacent property. Generally, locate them perpendicular to the prevailing wind and as near to parallel as possible on the leeward side of the area. Wind fences have been found to be effective up to 22 1/2 degrees from perpendicular to the wind.

Design Criteria

No formal design criteria have been developed for wind fences. Construction Specifications below describe typical wind fence installation.

Construction Specifications

1. Normally, locate sand fences perpendicular to the direction of the prevailing wind, but they may be as much as 22 1/2 degrees from perpendicular and still be very effective.

2. Commercial sand fences usually consist of wooden slats wired together with spaces between the slats. The distance between slats is approximately equal to the slat width (about 1 1/2 inches). Other materials such as discarded Christmas trees have been used to capture sand, but trees must be securely fastened in place and spaced to touch each other in the row.

3. Erect sand fences in parallel rows 20 to 40 feet apart and 2 to 4 feet high. The number of rows installed depends on the degree of protection needed. When fences are approximately two-thirds full, erect another series of fences.

4. In dune building, when the elevation of other mature dunes in the area is almost reached, or when the building process slows significantly, stabilize the dune immediately with appropriate vegetation.

Maintenance

Maintain sand fences, and erect additional fences as needed until the eroding area has been permanently stabilized, or in the case of dune building, until the dune has reached the desired height and is properly vegetated.

References

Surface Stabilization
6.11, Permanent Seeding
6.16, Vegetative Dune Stabilization

6.86

F

FLOCCULANTS

Definition

Flocculation is the process of causing small, suspended materials to stick to each other to form "flocs". These flocs more readily settle out compared to the individual particles.

Purpose

When soil is exposed during construction, stormwater runoff can pick up soil particles and carry them to the nearest water conveyance. The larger particles, such as pebbles and sand, will fall quickly to the bottom once the flow rate slows. However, clays and fine silts will tend to stay suspended because they are much lighter and slower to settle out. The resulting suspended sediment can travel many miles in streams or keep ponds and lakes muddy looking for a long time after a storm. Suspended sediment reduces the biological productivity of the affected waters, decreases recreational value, and increases water treatment costs for industrial or drinking water plants. The purpose of flocculants is to treat the water so that suspended clays and fine silts will settle out of the water quickly before leaving the construction site.

Conditions Where Practice Applies

Construction sites over one acre are required to install measures to retain sediment within the site. These measures include silt fence, sediment traps, storm drain inlet protection, and others. However, water discharged from these devices can have high concentration of suspended clays and fine silts that are very difficult to settle out. There are three ways to reduce suspended sediment: (1) store the runoff long enough for the materials to settle, (2) store and filter runoff, or (3) treat water with chemical flocculants. Filtering water can be high maintenance and expensive. The most practical and least expensive option for most situations is flocculation. A chemical called polyacrylamide (PAM) can create flocs in many sediment types found in North Carolina. Gypsum or moulding plaster can coagulate or bridge clay particles, which also accelerates settling. Flocculants should be used to prevent damage to sensitive water resources such as ponds, lakes and trout streams or whenever turbidity control is required. However, sediment at each site has to be evaluated individually for responsiveness to PAM, gypsum, or other flocculant/coagulants. The use of flocculants is very soil-type dependent and requires a screening process to determine the best chemical for each specific location.

Planning Considerations

PAM is a term describing a wide variety of chemicals based on the acrylamide unit. When linked in long chains, a portion of the acrylamide units can be modified to result in a net positive, neutral, or negative charge on the PAM molecule. The positively charged (cationic) PAM's have not been widely used because they can be toxic to fish and other aquatic organisms if they enter water bodies in sufficient concentrations. The negatively charged (anionic) PAM's are much less toxic to aquatic organisms and are widely used in furrow irrigation agriculture. This is the type of PAM which is commonly allowed for use in stormwater treatment. PAM is available as a crystalline powder, emulsion, solution, or as a solid block or "log." One of the ingredients used to make PAM is acrylamide, which is a known carcinogen, so the PAM's available for public uses are required to have <0.05% free acrylamide. This purity allows them to be used in food processing, drinking water treatment, and other uses where human exposure is likely.

Figure 6.86a Flocculation of sediment with PAM.

PAM is water soluble, but it dissolves slowly and requires considerable agitation and time to dissolve. Water with over 0.1% PAM is often noticeably viscous and most PAM's have a maximum concentration of 0.5-1% in water. When dry PAM becomes wet, it is very slippery and sticky. As a result, it can create a slip hazard.

Gypsum is a natural mineral deposited widely around the earth. It is made up of calcium sulfate and water in the formula $Ca(SO_4)*2(H_2O)$. Moulding plaster is similar, but has a slightly different formula $Ca(SO_4)*0.5(H_2O)$. The largest use of gypsum is in the manufacture of wallboard, but it is also used in water, wastewater treatment, and other industrial processes.

Design Criteria

PAM's mixed with water with high suspended solid loads can greatly reduce turbidity and suspended solid concentrations. It may be used in dewatering operation discharge from borrow pits or construction excavations, from discharge settling ponds, or from stormwater from land disturbance. It is critical that an application system be in place that minimizes the chances of malfunctions that could result in over-application of PAM's and subsequent adverse effects to aquatic life. It is especially important to be cautious near sensitive streams, such as those classified as "High Quality" or "Outstanding Resource Waters."

In using any form of PAM, several basic guidelines should be followed:

1. PAM's should be used **only** after all appropriate physical BMP's have been implemented at a particular site.

2. Only PAM's that pass the chronic toxicity testing requirements, established by the Division of Water Quality, may be used. A laboratory that is certified to conduct NC DWQ whole effluent toxicity (WET) testing must perform a multi-dilution (five test concentrations plus the control) chronic Ceriodaphnia test to determine the IC25 endpoint of the product. For products that are intended for use in NC waters that are not classified as Trout waters, this testing may be performed in water with a turbidity of 60 Nephelometric Turbidity Units (NTU). For products that are intended for use in NC waters classified as Trout waters, this testing must be performed in water not exceeding 20 NTU's. The test protocol utilized may be either the NC DWQ or the standard EPA protocol. The approved maximum application rate must be less than the IC25.

3. PAM's must not be applied directly to surface waters of the state.

4. A sediment basin or similar structure between the application point of PAM's and surface waters is required. Choose the appropriate PAM for the soil type.

5. Before specifying the use of powder or liquid application of PAM's to a settling basin or run-off conveyance, submit a particular product's label, application instructions, and Material Safety Data Sheet (MSDS) to the Division of Water Quality Aquatic Toxicology Unit for evaluation and determination of the product's safe application rate. The product's vendor should be able to provide the required information. PAM information should be submitted to the Aquatic Toxicology Unit, NC DENR Division of Water Quality, 1621 Mail Service Center, Raleigh, NC 27699-1621, fax number (919) 733-9959, and phone (919) 733-2136, Currently the Division of Water Quality Wetlands and Stormwater Branch maintains a list of PAM's with established application rates.

Construction Specifications

One of the key factors in making a flocculant work is to ensure that it is dissolved and thoroughly mixed with the runoff water, which can be accomplished in several ways. Introducing the PAM to the runoff at a point of high velocity will help to provide the turbulence and mixing needed to maximize the suspended sediment exposure to the large PAM molecules. Examples include a storm drain junction box where a pipe is dropping water, inside a slope drain, or other areas of falling or fast moving water upslope from a sediment trap or basin.

As mentioned before, PAM can be purchased as a powder, an emulsion, or a solid block. Because it dissolves slowly, introducing the powder directly into runoff is not effective. The granules will not dissolve fast enough before the water leaves the site. Instead, the powders need to be dissolved in water and metered into the runoff. This solution is often used in PAM furrow irrigation using a PAM solution of 5mg/L (parts per million). However, there is little information on this type of PAM use for storm runoff. Tests in North Carolina have consistently shown that 1-5mg/L (parts per million), or 1-5oz PAM/1,000 cubic feet of water is the optimal dose for effective flocculation (Table 6.86a). Some of the technical challenges include: ways to adjust the amount of solution added to runoff flow to maintain proper PAM concentrations, the stability of the PAM once in solution, and freezing of the PAM solution during colder months.

Table 6.86a Volume of concentrated PAM solution

Final PAM Concentration Desired In Basin	Volume Needed (Gallons concentrated PAM mix/1000 cubic feet water treated)
1 ppm	6.7
5 ppm	33

Another option for introducing PAM into runoff involves running the water over a solid form of PAM. Powders can be sprinkled on various materials, such as jute, coir, or other geotextiles. When wet, PAM granules become very sticky, and bind to the geotextile fabric. The product binds to the material, and resists removal by flowing water rendering it ineffective for turbidity control. PAM's may also be purchased as solid blocks or 'logs". The logs are designed to be placed in flowing water to dissolve the PAM from the log somewhat proportionately to flow. While using these solid forms of PAM does not have the same challenges as liquid forms, they do have drawbacks. The amount of PAM released is not adjustable and is generally unknown, so the user has to adjust the system by moving or adding logs to get the desired effect. Because the PAM is sticky when wet, it can accumulate materials from the runoff and become coated, releasing little PAM. The solid forms also tend to harden when allowed to dry. This causes less PAM to be released initially during the next storm until the log becomes moist again.

To avoid these problems, the user must do two things to ensure PAM releases from the solid form:

- Reduce sediment load in the runoff upstream of the PAM location. This avoids burying the PAM under accumulated sediment.
- Create constant flow across or onto the solid PAM. The flow will help dissolve and mix the PAM as well as prevent suspended solids from sticking to the PAM product.

Once the PAM is introduced into the runoff and thoroughly mixed, the runoff needs to be captured in a sediment trap or basin in order for the flocs to settle out. It is important that the inlet of this structure be stabilized with geotextile or stone to prevent gully erosion at the upper end of the basin. Such erosion can contribute significantly to the turbidity in the basin and overwhelm the treatments. Other modifications may also be useful such as installing baffles across the basin or dewatering from the surface using a skimmer or similar device. Baffles using jute or coconut fiber are highly effective in reducing velocity and turbulence in sediment basins. Other, similar porous materials may also be effective, such as 700 g/m^2 coir matting.

Because sediment characteristics are very different across the state, it is important that the correct PAM is matched to the sediment type at the site. Large sites, may require more than one PAM formulation in order to flocculate sediment at different places on the site. At present, the only way to match sediment type to the PAM formulation is to test a number of PAM's for effectiveness. This testing can be done by mixing a small amount of PAM in a jar of water with a small amount of sediment, shaking, and then determining which PAM clears the water the quickest. This process is usually done by the

PAM dealer or supplier because they can maintain a large stock of different PAM's. The appropriate application rate for a product should be determined to provide effective treatment while remaining non-toxic. It is extremely important not to over apply the PAM; it may actually decrease the effectiveness of the product.

Moulding plaster and gypsum have also been demonstrated to settle solids in sediment basins. The material is applied by hand directly to the water after each storm. The dose rate of 20-30lb/1,000 cubic feet of water, spread evenly to the surface, has been found to reduce suspended sediments. This application has not been widely tested, but is one option. The obvious drawback is that the material has to be spread by hand after each storm, which is not only labor intensive, but also means the basin has to be large enough to store the runoff. Otherwise, a major portion of the runoff will be missed before treatment. The dose to result in less than 250mg SO_4/L, as required in North Carolina, is 25lb/1,000 cubic feet for moulding plaster (66% SO_4) and 30lb/1,000 cubic feet for gypsum (56% SO_4).

Maintenance

1. Dosing systems using pumps should be checked daily.

2. Floc logs should be checked at least weekly or after a rainfall event of ½ inch or greater to make sure the logs remain in place, are moist, and are not covered in sediment.

References

SoilFacts: Using Polyacrylamide (PAM) to Control Turbidity, Richard McLaughlin, North Carolina State University Cooperative Extension Service Fact Sheet AGW-439-59.

6.87

CHECK DAM WITH A WEIR

Definition

A small stone dam structure with a weir outlet with a sediment storage area on the upper side.

Purpose

To reduce erosion in a drainage channel by restricting the velocity of flow. This structure also has some ability to provide sediment control.

Conditions Where Practice Applies

This temporary practice may be used in the following locations:

- At outlets of temporary diversions, graded channels, and temporary slope drains;
- In small natural drainage turnouts; and
- In locations where the dams can be easily cleaned and maintained on a regular basis.

Do not use a check dam with a weir in intermittent or perennial streams.

Planning Considerations

Check dams are an expedient way to reduce gullying in the bottom of channels that will be filled or stabilized at a later date. The dams should only be used while permanent stabilization measures are being put into place.

Check dams installed in grass-lined channels may kill the vegetative lining if submergence after it rains is too long and/or sedimentation is excessive. All stone and riprap must be removed if mowing is planned as part of vegetative maintenance.

Design Criteria

The following criteria should be used when designing a check dam with a weir:

- Keep the weir at least 9 inches lower than the outer edges at natural ground elevation. The weir length is variable to the size of the drainage area and peak runoff. The weir length may be sized as:

$$L\ (\text{ft}) = \frac{Q\ \text{peak (csf)}}{0.88}$$

- Keep the side slope of the stone at 2:1 or flatter.
- The apron length (lower side of dam) should be approximately three times the height of the dam with a minimum length of 4 feet. Stabilize outflow areas along the channel to resist erosion.
- The maximum spacing between dams places the toe of the upstream dam at the same elevation as the top of the downstream dam (Figure 6.84a).
- Use NC DOT Class B stone and line the upstream side of the dam with NC DOT #5 or #57 stone.
- Key the stone into the ditch banks and extend it beyond the abutments a minimum of 1.5 feet to avoid washouts from overflow around the dams.
- Sediment storage area should be sized for the anticipated volume of sedimentation.

Construction Specifications

1. Place structural stone (Class B) to the lines and dimensions shown on the plan on a filter fabric foundation. The crest width of the dam should be a minimum of 2 feet.

2. Keep the center stone section at least 9 inches below the end where the dam abuts the channel banks.

3. Place sediment control stone (#5 or #57) on the upstream side of the dam that is a minimum of 1 foot thick.

4. Provide an apron that is 3 times the height of the dam. The apron width is at least 4 feet long. Undercut the apron so that the top of the apron is flush with the surrounding grade.

5. Extend the stone at least 1.5 feet beyond the ditch bank to keep water from cutting around the ends of the check dam.

6. Excavate sediment storage area to the dimensions shown on the plan

Maintenance

Inspect check dams and channels at least weekly and after each significant (1/2 inch or greater) rainfall event and repair immediately. Clean out sediment, straw, limbs, or other debris that could clog the channel when needed.

Anticipate submergence and deposition above the check dam and erosion from high flows around the edges of the dam. Correct all damage immediately. If significant erosion occurs between dams, additional measures can be taken such as, installing a protective riprap liner in that portion of the channel (Practice 6.31, *Riprap-line and Paved Channels*).

Remove sediment accumulated behind the dams as needed to prevent damage to channel vegetation, allow the channel to drain through the stone check dam, and prevent large flows from carrying sediment over the dam. Add stones to dams as needed to maintain design height and cross section.

References

Runoff Conveyance Measures
6.31, Riprap-lined and Paved Channels

North Carolina Department of Transportation
Standard Specifications for Roads and Structures