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30 Años de Excelencia en el Adiestramiento de Oficiales de Transportación a Nivel Municipal, Estatal, y Federal en Puerto Rico e Islas Vírgenes

Diseño e Implantación de Medidas para el Control de la Erosión y la Sedimentación

Día 2

Instructor

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PLANNING PRINCIPLES FOR EROSION AND SEDIMENT CONTROL

Introduction

- The most important and most often neglected task is to provide effective soil stabilization throughout the duration of a construction project.
- Soil stabilization is based on a simple premise: If water cannot detach the soil, it cannot be transported (i.e., erosion does not occur).
- The easiest, most economical, and environmentally sound way to prevent detachment is by keeping a good vegetative cover in place. It can also be accomplished by other techniques such as mulching or use of erosion blankets.

Basic Rules

- Erosion control measures are required for construction areas where the ground surface will be disturbed by clearing, demolition, storage, grading, fills, excavations and other construction and related activities. When developing an effective ECSPP, there are several important concepts to consider:
  - Timing - schedule work to minimize overall impacts
  - Stage work - identify and process critical areas first
  - Minimize disturbance - create buffers and reduce mass grading
  - Pre-construction - during preliminary design and prior onsite grading
  - activities
  - Pictures/Video - documentation throughout life of project

Responsibilities

- A qualified designer, as defined in the existing regulation ("Reglamento para el Control de la Erosión y Prevención de la Sedimentación"), prepares the Erosion Control and Sediment Prevention Plan based upon information provided from resources obtained from local and regional agencies, and a detailed field site visit.

Elements of the Erosion Control and Sediment Prevention Plan

- Narrative
  - The narrative is a brief description of the overall strategy for erosion and sediment control. It should summarize the aspects of the project that are important for erosion control.
    - A brief description of the proposed land-disturbing activities
    - A description of critical areas on the site
  - A work schedule that includes the date grading will begin and the expected date of stabilization.
  - A brief description of the measures that will be used to minimize erosion and control sediment on the site, when they will be installed, and where they will be located.
  - A maintenance program; including frequency of inspection, provisions for repair of damaged structures, and routine maintenance of erosion and sediment control practices.

Elements of the Erosion Control and Sediment Prevention Plan

- Map/Site plan
  - The map is the key item in an Erosion Control and Sediment Prevention Plan.
- Construction Details, Specifications, and Notes
  - Construction details, often in large-scale, detailed drawings, provide key dimensions and spatial information that will not fit on the map.
- Calculations
  - Include the calculations used to size the control measures, particularly the data for the design storm

Preparing an Erosion Control and Sediment Prevention Plan

- Step 1: Collect Data
  - Topography
  - Drainage
  - Rainfall
  - Soils
  - Ground Cover
  - Adjacent Areas
- Step 2: Analyze Data
  - Drainage Areas
  - Rainfall and Runoff
  - Slope Steepness and Slope Length
  - Soils
  - Ground Cover
  - Adjacent Areas

Preparing an Erosion Control and Sediment Prevention Plan

- Step 3: Develop Site Plan
  - Fit Development to the Terrain
  - Restrict Construction Activities to the Least Critical Areas
  - Cluster Buildings Together
  - Minimize Impervious Areas
  - Retain the Natural Storm Water System
- Step 4: Develop the Erosion Control and Sediment Prevention Plan
  - Determine Limits of Clearing and Grading
  - Reexamine Drainage Areas
  - Apply the Principles of Erosion and Sediment Control
    1) Fit development to the terrain.
    2) Time grading and construction to minimize soil exposure.
    3) Retain existing vegetation wherever possible.
    4) Vegetate and mulch denuded areas.
    5) Divert runoff away from denuded areas.
    6) Minimize length and steepness of slopes.
    7) Keep runoff velocities low.
    8) Keep runoff velocities low.
    9) Keep runoff velocities low.
    10) Keep runoff velocities low.

Evaluating an Erosion Control and Sediment Prevention Plan

- Responsibility
- Communications
- Required Information
- Incomplete Plans
- First Review
- Plan Concept
- Schedule
- Site Storm Water
- Sediment Basins and Traps
- Erosion Control
- Channels and Outlets
- Miscellaneous

Evaluating an Erosion Control and Sediment Prevention Plan

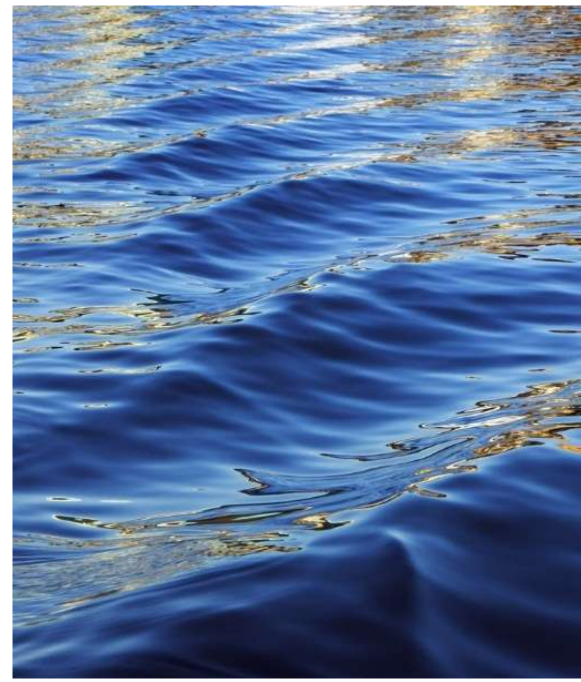
- Plan Details
- Structural Details
- Calculations
- Vegetation
- Maintenance
- Contingencies
- Technical Review
- Signature

Implementing the Plan

- Study the plan and the site.
- The pre-construction conference.
- Site preparation.
- Inspection and maintenance of erosion control measures.
- Grading and utility construction.
- Building construction.
- Permanent stabilization.

Erosion Control Practices

Part II
Vegetative Measurements



Vegetative Practices

- The primary objective of vegetative growth is stabilization on the area so that erosion is controlled and sediment losses are reduced to a minimum.
- Both permanent and temporary vegetative measures should be considered.

1. Dispose of excess water properly: waterways, subsurface drainage, stabilized outlets
2. Select plant species according to soil, climate and site conditions
3. Protect the area from heavy use until plants establish

Vegetative Practices

- Tree Preservation and Protection
- Topsoiling
- Mulching
- Erosion Control Matting
- Temporary Seeding
- Permanent Seeding and Planting
- Sodding
- Filter Strip
- Vegetative Barrier
- Riparian Forest Buffer

Vegetative Practice: Tree Preservation and Protection

- Purpose: To preserve and protect trees that have present or future value for their use in protection from erosion, for their landscape and aesthetic value, or for other environmental benefits such as endangered or threatened species.

Vegetative Practice: Tree Preservation and Protection

- BENEFITS of having trees
- Reduce storm water runoff by intercepting rainfall, promote infiltration, and lower the water table through transpiration.
- Moderate temperature changes, promote shade, and reduce the force of wind.
- Provide buffers and screens against noise and visual disturbance, providing a degree of privacy.
- Filter pollutants from the air, remove carbon dioxide from the air, and produce oxygen.
- Provide a habitat for animals and birds.
- Increase property values and improve site aesthetics.
- Must be preserved if classified as endangered or threatened species

Vegetative Practice: Tree Preservation and Protection

- BASIC DESIGN CRITERIA

1. Leave critical areas (such as water body banks, swales and wetlands buffers) with desirable trees in their natural condition or only partially cleared.
2. Locate roadways, storage areas, and parking pads away from valuable tree stands. Follow natural contours, where feasible, to minimize cutting and filling in the vicinity of trees.
3. Select trees to be preserved before sitting, roads, buildings, or other structures.
4. Minimize trenching in areas with trees. Place several utilities in the same trench.
5. Designate groups of trees and individual trees to be saved on the erosion and sedimentation control plan.
6. Do not excavate, traverse, or fill closer than the drip line, or perimeter of the canopy, of trees to be saved.

Vegetative Practice: Tree Preservation and Protection

- BASIC DESIGN CRITERIA: Landscape protection plan
- Mark construction boundaries
- Make a tree inventory on the site
- Select trees to be saved
- Use the Protected Root Zone (PRZ) to determine protection zone
- Protect the trees to be saved
- Monitor construction process

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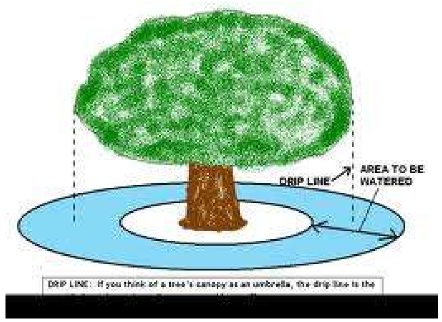
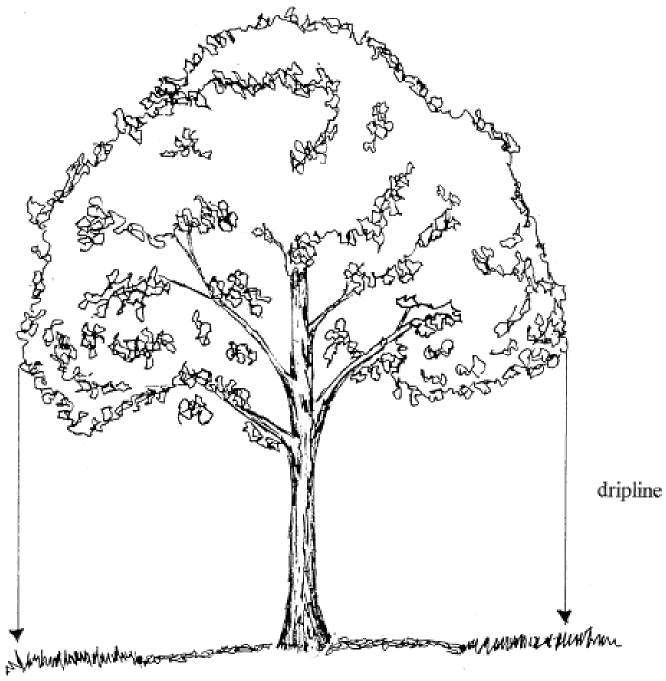
Vegetative Practice: Tree Preservation and Protection

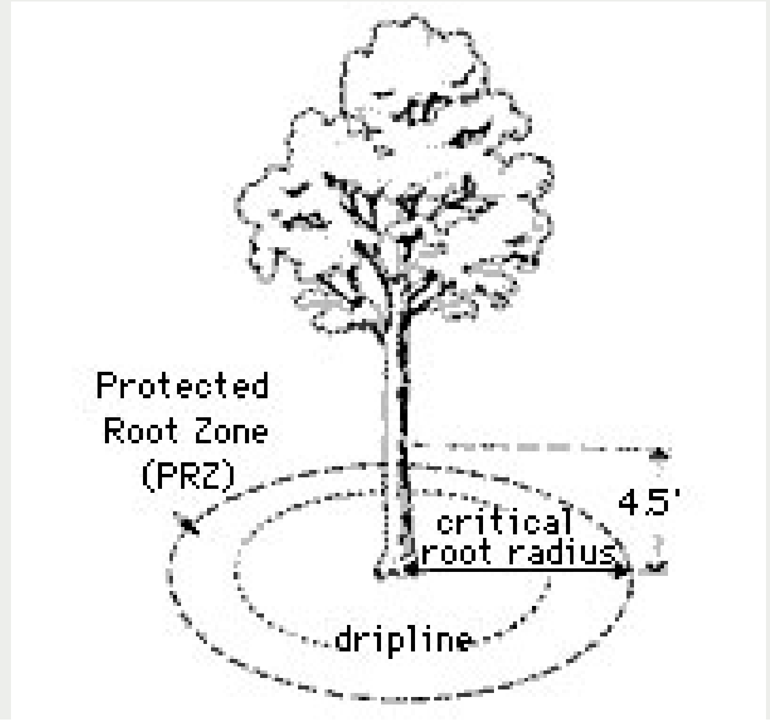
- Protect the trees you plan to save. Develop a map with the builder or architect showing the location of trees to be protected and the safest route for access to the building zone.
- One common method used to identify the tree's Protected Root Zone (PRZ) is to consider it to be the part of the roots that lie directly below its branches within an area known as the "drip line".





Vegetative Practice: Tree Preservation and Protection

- Critical Root Radius Method
  - For endangered or threatened tree species.
- Method:
  1. Measure the diameter at breast height (dbh). This is done by measuring the tree's trunk diameter (thickness) at a point 4.5 feet above the ground. The measurement should be done in inches.
  2. For each inch of dbh, allow for 1.5 feet of critical root radius for sensitive trees, or 1.0 feet for tolerant trees.
- Example: A tree's dbh is 10 inches, then its critical root radius is 15 feet (10 x 1.5 = 15).
- The PRZ is an area around the tree with a diameter of 30 feet (2 x radius), and is the area in which a critical amount of the tree's roots may be found. Whenever possible, isolate this area from construction disturbance.



Topsoiling

- Methods of preserving and using the surface layer of undisturbed soil often enriched in organic matter, in order to obtain a more desirable planting and growth medium.
- Used where:
  1. The available soil cannot provide an adequate growth medium for the desired vegetation.
  2. The soil is too shallow or will not supply necessary moisture and nutrients for growth of desired vegetation.
  3. The soil contains substances not desired for vegetation.
  4. Where high-quality grass or ornamental plants are desired.
  5. Only on slopes that are **2:1 or flatter unless other measures are taken to prevent** erosion and sloughing.

Topsoiling

- Advantages:
  - High organic matter and soft consistence
  - Promotes rapid root growth
  - Increases infiltration capacity and reduces runoff
- Disadvantages:
  - Stockpiling and spreading may no be cost-effective
  - Difficult to handle in some terrains
  - May contain undesirable weed seed
  - Water may creep along the junction between the soil layers and cause the topsoil to slough.
- Topsoiling is an integral component for preparing permanent cover to those areas where there is an unsuitable soil surface for plant growth.

Topsoiling

- If topsoil washes away erosion control practices must be provided.
- Cover piles with clear plastic covering until needed and avoid slopes and natural drainage ways
- Use sediment fences or other barriers where necessary to retain sediment.
- Compact the topsoil enough to ensure good contact with the underlying soil, but avoid excessive compaction, as it increases runoff and inhibits seed germination.
- Light packing with a roller is recommended where turf is to be established.

Mulching

- Applying plant residues or other suitable materials produced offsite, to the land surface
- Protects the soil surface from raindrop impacts and overland flow.
- Fosters the growth of vegetation, reduces evaporation, insulates the soil, moderates soil temperature, conserves soil moisture, suppresses weed growth, improves soil condition, and increases soil fertility.

Mulching

- This practice may be used alone or in combination with other practices to:
  - Establish temporary or permanent grass vegetation for disturbed soils after a construction project
  - Temporary stabilization of freshly seeded and planted areas, or during periods unsuitable for growing permanent vegetation.
  - Permanent stabilization around established plants, such as trees or shrubs, in order to prevent the growth of weeds and to maintain soil moisture conditions.
  - On poor or marginal soils, to add organic matter and retain moisture and fertilizer, as a strategy to speed establishment of permanent vegetative cover.
  - As a short-term ground cover on steep slopes to reduce rainfall impact, decrease the velocity of sheet flow, and settle out sediment.

Mulching

- Grass hay mulch is often selected due to the ease of application and good results.
- When mulching with straw or grass hay, apply in sufficient amounts to provide 70 % ground cover.
- Hydroseeding (including hydraulic application of mulch) is especially for steep slopes and locations, which require quick establishment of grass.
- Mulching is generally performed after grading, soil surface preparation and seeding and plantings are complete.
- Soil surface shall be prepared in order to achieve the desired purpose.

Mulching

- Specifications shall be prepared for each site and purpose:
  - Type of mulch material used (straw, hay, min. 6 inches fiber length)
  - Percent cover and/or thickness of mulch material (at least 80%)
  - Timing of application (depends on site)
  - Site preparation.
  - Listing of netting or method of anchoring
  - Operation and maintenance
- Common Trouble Points
  - The potential of introduction of weed-seed and unwanted plant material.
  - Can be easily blown or washed away by runoff if not secured.

Erosion Control Matting

- Provide a stable seedbed for one or more growing seasons (though some may be designed to last longer in extreme conditions), then to biodegrade as vegetal matter builds up to produce a healthy cover crop.
- The placing and securing of either *jute mesh*, *excelsior matting*, *erosion control fabric*, or other approved matting is used to prevent erosion on previously shaped and seeded drainage channels, slopes, or other critical areas.

Erosion Control Matting

- Erosion control Fabrics
  - Applied over mulch or sod in low size and low velocity ditches
- Excelsior Matting
  - American Excelsior Company is the inventor of biodegradable erosion control blankets. Developed in the 60's for large construction and highway projects
- Jute Matting:
- In general:
- Matts should be placed perpendicular to the slope if S > 2:1 and horizontal if S < 2:1 and less than 20 feet long
- Should be tucked and stapled. Details vary with the material.
- Follow instructions from the manufacturer
- Visit www.ectc.org

Erosion Control Matting

- Common Trouble Points
  - Inadequate coverage results in erosion, washout, and poor plant establishment.
  - Appropriate staple spacing not applied, or applied in insufficient amount; seed,
  - Topsoil, and mulch is lost to wind and runoff.
  - Channel grade and liner not appropriate for amount of runoff; this may result in erosion of the channel bottom. Modification may be necessary.
- If the fabric is not properly selected, **designed**, or installed the effectiveness may be reduced drastically.

Temporary Seeding

- Planting rapid-growing annual grasses, small grains, or legumes to provide initial, temporary cover for erosion control on disturbed areas.
- Provide temporary soil stabilization to areas that would remain bare for more than 7 days
- Temporary seeding controls runoff and erosion until permanent vegetation or other erosion control measures can be established.
- Reduces problems of mud and dust production from bare soil surfaces during construction.

Methods for Planting Seeds

- **Drill:** Seed is placed within the soil
- **Broadcast:** Seed is placed on the top of soil
  - Needs twice the drill application rates
- **Hydraulic**: Seed is within a slurry
  - May need up to 4 times the drill application rate
  - Higher rates for arid and semi-arid climates
- Fertilizers may be required

Temporary Seeding

- Use on any cleared, unvegetated, or sparsely vegetated soil surface where:
  - Permanent structures are to be installed or extensive re-grading of the area will occur prior to the establishment of permanent vegetation.
  - Areas which will not be subjected to heavy wear by construction traffic.
  - Areas sloping up to 10% for 100 feet or less
  - Applications of this practice include diversions, dams, temporary sediment basins, temporary road banks, and topsoil stockpiles.
- Proper seedbed preparation, selection of appropriate species, and use of quality seed are important

Seeding

- Apply seed uniformly on a firm, moist soil.
- Use seeding rates and planting method given in Table 1.
- Hand broadcasting is not recommended because of the difficulty in achieving a uniform distribution.
- Mulching will help ensure establishment under normal conditions and is essential to seeding success under harsh site conditions.
- Harsh site conditions include:
  - Seeding during the rainy season.
  - Slopes steeper than 3:1.
  - Adverse soils (shallow, rocky, or high in clay or sandy).
  - Areas receiving concentrated flow.

Seeding

- **Hydroseeding** (or hydraulic mulch seeding, hydro-mulching, hydraseeding) is a planting process that uses a slurry of seed and mulch.
- The slurry often has other ingredients including fertilizer, tackifying agents, fiber mulch, and green dye.
- Hydroseeding are appropriate for steep slopes where equipment cannot be driven.
- In Arid and Semi-Arid Climates apply seed prior to the application of mulch
  - Apply mulch after planting

- These plants were chosen for their wide adaptation and high degree of erosion control reliability.
- Others may be preferable for special applications.

Table 1. Recommended Species for Temporary Seeding

Species		Seeding Rate lbs/acres	Seeding Rate lbs/1000 sq.ft.	Planting Depth (in)
Grasses				
Ryegrass*	*Lolium perenne*	40	1	¼
Brown Top Millet*	*Urochloa ramosa*	40	1	¼
Legumes				
Habichuela de terciopelo Velvet bean	*Mucuna pruriens*	20	0.5	¼
Neonotonia wightii		5 [(a)]	0.12	¼

* Commercially available grasses which have been proven to perform well under prevailing conditions in Puerto Rico.
(a) deep in water 24 hrs before planting

Temporary Seeding

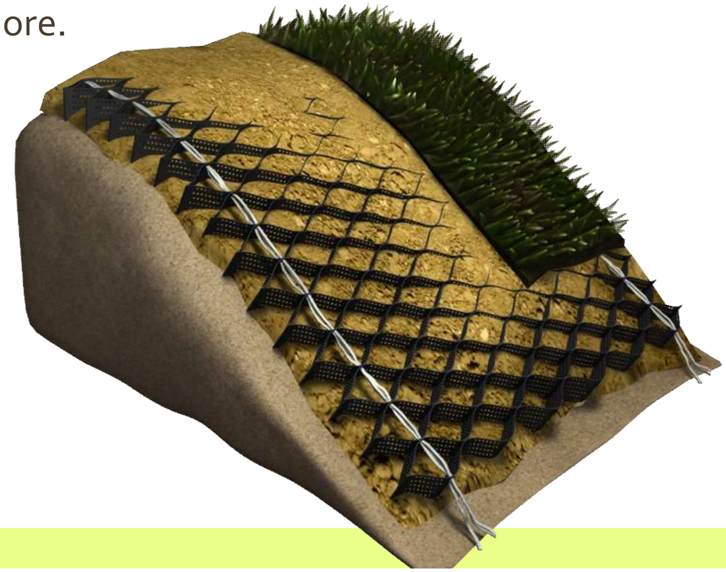
- Common Trouble Points
  - Seed not broadcasted evenly or application too low; either problems result in patchy growth and erosion.
  - Improper calculation of seeding rate
- Operation and Maintenance
  - Re-seed and mulch areas as soon as possible where seedling emergence is poor, or where erosion occurs. Do not mow. Protect from traffic as much as possible.
- All temporary erosion and sediment control measures should be removed within 30 days after final site stabilization is achieved or after the temporary practice is no longer needed

Permanent Seeding

- Vegetation controls erosion by protecting bare soil surfaces from raindrop impact and by reducing the velocity and volume of overland flow.
- Establishment of perennial vegetative covers on disturbed areas
- Reduce erosion and decrease sediment yield from disturbed areas, adapts to site conditions, and allows selection of the most appropriate plant materials.
- Advantages of seeding over other means of establishing plants: smaller initial cost, lower labor input, and greater flexibility.
- The probability of successful plant establishment can be maximized through:
  - good planning
  - knowledge of the soil characteristics
  - selection of suitable plant material for the site
  - good seedbed preparation
  - adequate fertilization, and timely planting and maintenance.

Permanent Seeding

- USE IN:
  - Where permanent, long-lived vegetative cover is the most practical or most effective method of stabilizing the soil
  - Areas with permanent vegetation must be seeded or planted within 30 days after final grade is reached, on a segment of the construction site
  - Graded, final graded or cleared areas where permanent vegetative cover is needed to stabilize the soil.
  - Areas that will not be brought to final grade for a year or more.
  - Vegetation-lined channels.
  - Retention or detention ponds as required.



Permanent Seeding

- Good mulching practices are critical to protect against erosion on steep slopes. Cover seeded areas with mulch or an appropriate rolled erosion control product to promote establishment of vegetation
- On slopes steeper than 2:1, jute, excelsior, or synthetic matting may be required to protect the slope.
- Condition soil and seed bed to improve growing
- Common Trouble Points
  - Inadequate seedbed preparation.
  - Unsuitable choice of plant materials.
- Inspect seeded areas for failure and make necessary repairs and re-seedings.
- If vegetation fails to grow, soil must be tested to determine if acidity or nutrient imbalance is responsible.

Table 1. Recommended Species for Permanent Seeding

Seeding Mixtures	Seeding Rate	
	lbs/acres	lbs/1000 sq.ft.
Bermudagrass*	60	1.5
Ryegrass	40	1
Bermudagrass	60	1.5
Brown Top Millet	60	1.5

Seeding Mixtures	Seeding Rate	
	lbs/acres	lbs/1000 sq.ft.
Ciempiés*	20	0.5
Ryegrass	40	1
Ciempiés	20	0.5
Brown Top Millet	60	1.5

Seeding Mixtures	Seeding Rate	
	lbs/acres	lbs/1000 sq.ft.
Bahiagrass*	40	1
Ryegrass	40	1
Bahiagrass	40	1
Brown Top Millet	60	1.5

Seeding Mixtures	Seeding Rate	
	lbs/acres	lbs/1000 sq.ft.
Carpetgrass*	40	1
Ryegrass	40	1
Carpetgrass	40	1
Brown Top Millet	60	1.5

Seeding Mixtures	Seeding Rate	
	lbs/acres	lbs/1000 sq.ft.
Zoyzia*	40	1
Ryegrass	40	1
Zoyzia	40	1
Brown Top Millet	60	1.5

Seeding Mixtures	Seeding Rate	
	lbs/acres	lbs/1000 sq.ft.
Dallis*	20	0.5
Ryegrass	40	1
Dallis	20	0.5
Brown Top Millet	60	1.5

* Springgs planting rate 1,500 lb/acre

Maximum seeding depth should be 1/4 inch on clay soils and 1/2 inch on sandy soils.

Brown Top Millet and Ryegrass are annual grasses (commercially available) that will create favorable conditions for establishment of the perennial grasses.

Sodding

- Permanently stabilizing areas by laying a continuous cover of grass sod.
- Prevents erosion and damage from sediment and runoff
- Provides immediate vegetative cover of critical areas.
- Stabilize disturbed areas with a suitable plant material that cannot be established by seed.
- Stabilize drainage ways and channels and other areas of concentrated flow where flow velocities will not exceed that specified for a grass lining.

Sodding

- The practice of sodding for soil stabilization eliminates both the seeding and mulching operations and is a much more reliable method of producing adequate cover and sediment control.
- Advantages of properly installed sod include:
  - Immediate erosion and dust control.
  - Nearly year-round establishment capability.
  - Less chance of failure than with seedings.
  - More freedom from weeds.
  - Rapid stabilization of surfaces for traffic areas, channel linings, or critical areas.
  - Improve aesthetics.

Sodding

- The type of sod selected should be composed of plants adapted to both the site and the intended purpose.
- In Puerto Rico, these are limited to Bermuda grass, St. Augustine grass, Centipede grass, Bahía grass, Carpet grass and Zoyzia grass.

Sodding

- Common Trouble Points
  - Laid on poorly prepared soil or unsuitable surface; grass dies because it is unable to root.
  - Sod not adequately irrigated after installation; lack of water may cause root dieback or grass may not root properly because of dry conditions.
  - Sod not anchored properly; unanchored sod may be loosened by runoff.
  - Equipment allowed traveling over sodded area or materials are stored on sod.

Sodding

- Maintenance
  - Inspect sodded areas regularly, especially after large storm events. Re-tack, re-sod, or re-seed as necessary.
  - After the first week, water as necessary to maintain adequate moisture in the root zone and prevent dormancy of the sod.
  - Do not remove more than one-third of the shoot in any mowing. Grass height should be maintained between 2 and 3 inches unless otherwise specified.

Filter Strip

- Created or preserved vegetated strip located down slopes of disturbed areas and designed to remove sediment, other pollutants and to enhance the infiltration of surface water runoff.
- The principal purpose of this practice is to remove sediment and other pollutants from runoff water by filtration, deposition, infiltration, absorption, and vegetative uptake
- Another purpose is to reduce runoff quantities from impervious surfaces by infiltrating it into the ground.

Filter Strip

- Used:
  - Where surface water runoff is discharged as overland sheet flow; **not concentrated flows.**
  - **Filter strip,** when implemented as treatment control measure alone, requires significant land area.
  - Typical locations of vegetated filter strips include:
  - Construction sites and land undergoing development
  - Adjacent to roadways, parking lots, and other impervious surfaces
  - Lawns where roof downspouts are discharged to disperse and infiltrate runoff.
  - Adjacent to wetlands, streams, ponds or lakes, or conservation practices

Filter Strip

- Filter strip located on hydrologic soil groups C and D are less effective in treating runoff
- The maximum contributing upland **drainage area to a filter strip shall be 5 acres.**
- Should not be used on slopes greater than 15%.
- Should be sized according to the individual characteristics of the site, taking into account the size of the area to be drained and the slope of the land that they are located on.

Filter Strip

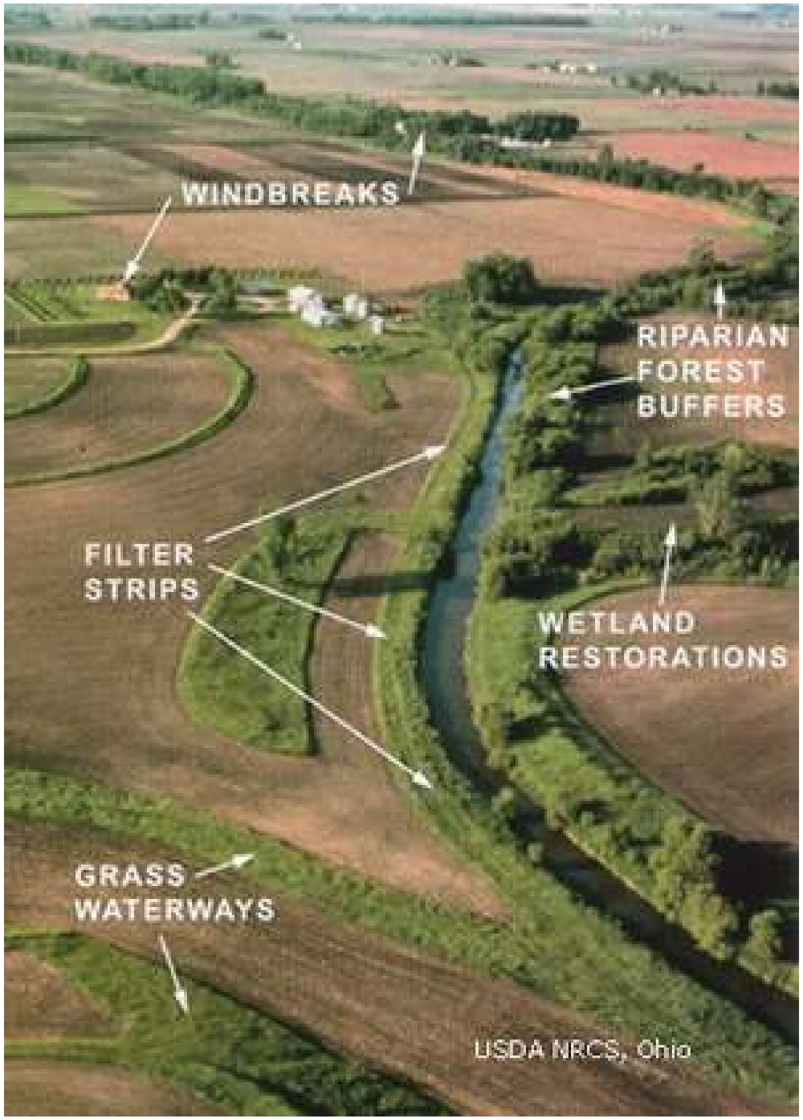
- For areas not adjacent to permanent water body, filter strip of 15 ft. (4.5m) for slope less than 10% will be maintained on perimeter of construction sites.
- Add additional 4 feet for each percent of slope at site up to 15%.
- Activities adjacent to permanent water body represent the most stringent requirement that applies to filter strips.
- Filter strip requires that vegetation densely established.

Filter Strip

- Common Trouble Points
  - Improper planting distance or strips have poor vegetative cover.
  - Inadequate irrigation.
  - Lack of remedial measures for repair and maintenance.
  - Design slope has exceeded the recommended fifteen percent.
  - Design width of slopes has been to narrow to adequately service the contributing area.

Filter Strip

- Maintain the vegetation dense stand.
- Caution when applying herbicides to filter strips or adjacent areas to minimize pollution to the water resources being protected.
- Mowing once every two to three years, after the vegetation is established.
- Filter strips that have accumulated so much sediment that they are higher than adjacent areas should be disked or graded as necessary to reestablish shallow sheet flow conditions, and be reseeded.


WINDBREAKS
RIPARIAN FOREST BUFFERS
FILTER STRIPS
WETLAND RESTORATIONS
GRASS WATERWAYS
USDA NRCS, Ohio

Vegetative Barriers

- Herbaceous vegetation established in strips or rows at determined intervals across the slope.
- Reduce erosion by water.
- Slow runoff flow.
- Entrap sediment.
- Produce forage and other vegetative materials.
- Increase water infiltration.

Vegetative Barriers

- Maximum slope to be established with vegetative row barriers is 50%.
- Barriers will be established at intervals across the slope as nearly as possible to the contour.
- Drainage ways will be left undisturbed except for elimination of undesirable plant species.
- Spacing along the horizontal distance:

Ave. Field Grade (Percent)	Maximum Spacing (Feet)
11 or less	40
12 - 24	35
24 - 40	25
41 - 50	20

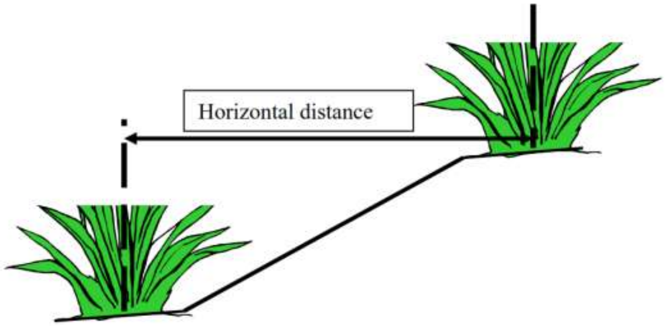
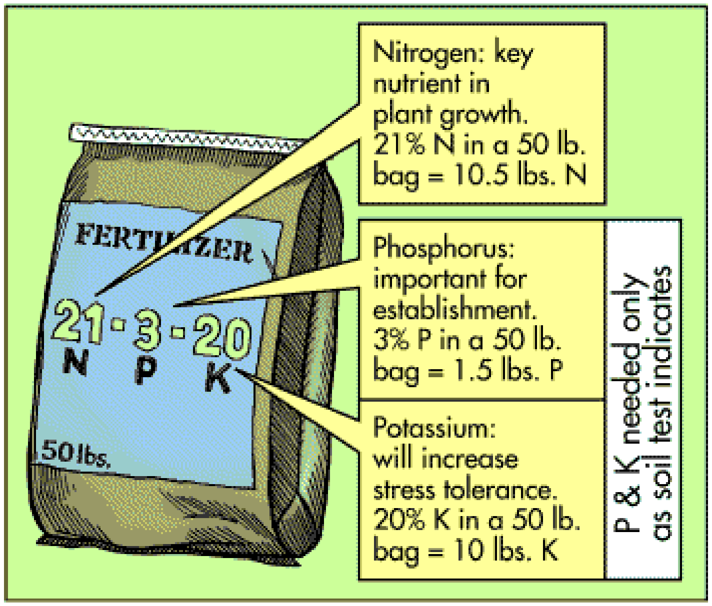


Figure 1. Horizontal Distance

Vegetative Barriers

- Fertility of the soil must be amended if needed
- Species must be adaptive to the site.
- Planting rate, density and method shall conform to the species. (See tables in Handbook)
- Common Trouble Points
  - Improper planting distance.
  - Inadequate irrigation.
  - Lack of remedial measures for repair and maintenance



CHANNEL DESIGN

GRASS LINED WATERWAYS

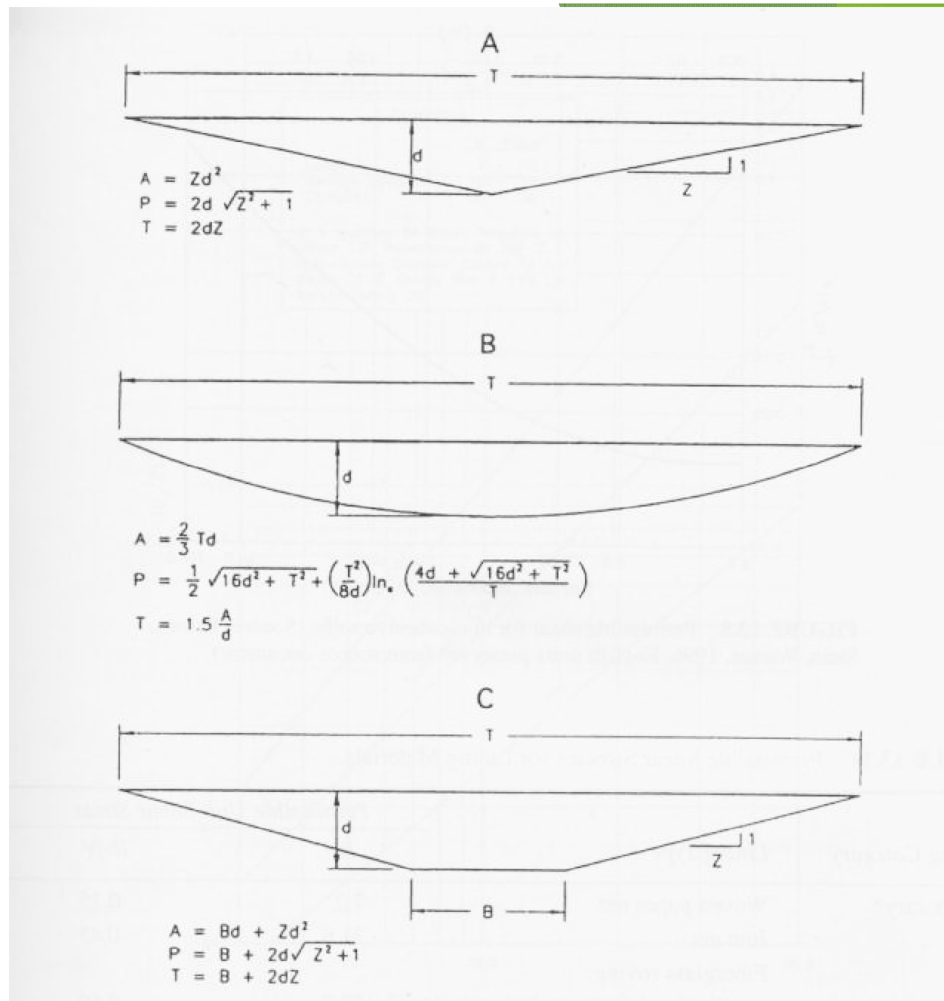
NRCS Vegetative Retardance Method

Basic Definitions

- **Depth of Flow**, y = perpendicular distance measured from the channel bed to the free surface
- **Flow Area**, A = cross section of the flow perpendicular to the flow direction
- **Wetted Perimeter**, P = length of the solid channel surface in contact with the liquid
- **Hydraulic Radius**, $Rh = A/P$
- **Top Width** , B = Surface width
- **Hydraulic Depth**, $D = A/B$

Basic Definitions

Geometric properties of grassed waterways



Channel geometries. (Source: Brown, Stein, Warner, 1996)

Computation of Normal Depth

Using Manning's equation

Computation of Normal Depth

- Fully Rough Regime
  - Using Manning's equation the discharge is given by:

$$Q = VA = \frac{K_n}{n} A R^{2/3} S_0^{1/2}$$

  - Depending on the known values, this equation could be solved directly or by iterative methods. A and R are functions of the flow depth. If the depth is known for a particular channel, the discharge can be solved directly. Calculation of the normal depth is more time consuming

Computation of Normal Depth

- Manning's equation may be written as:

$$Q = KS_0^{1/2}$$

- where K is the conveyance factor, defined as:

$$K = \frac{K_n}{n} AR^{2/3}$$

- The equation could also be written as:

$$AR^{2/3} = \frac{nQ}{K_n S_0^{1/2}}$$

- where the left hand term is called the section factor.

Computation of Normal Depth

For specified values of n, Q and S_0, we solve this equation using the following methods:

1) Design Charts

2) Trial and error procedure

3) Numerical methods

GRASS LINED CHANNELS

- Is the most desirable channel for urban drainage design
- Provides protection from erosion
- Has been done successfully by the Soil Conservation Service
- Vegetative linings are classified according to their degree of vegetal retardance as Class A, B, C, D, or E.
- Each class has a permissible shear stress as given in the next table

GRASS LINED CHANNELS

Retardance Class	Permissible τ_p , psf	Permissible τ_p , Pa	Degree of Retardance	Curve Index
A	3.70	177	Very high vegetal retardance	10
B	2.10	100	High vegetal retardance	7.64
C	1.00	48	Average vegetal retardance	5.60
D	0.60	29	Low vegetal retardance	4.44
E	0.35	17	Very low vegetal retardance	2.8

GRASS LINED CHANNELS

Grasses recommended for Puerto Rico and the Caribbean

Table 2. Classification of Vegetative Cover as to Degree of Retardance

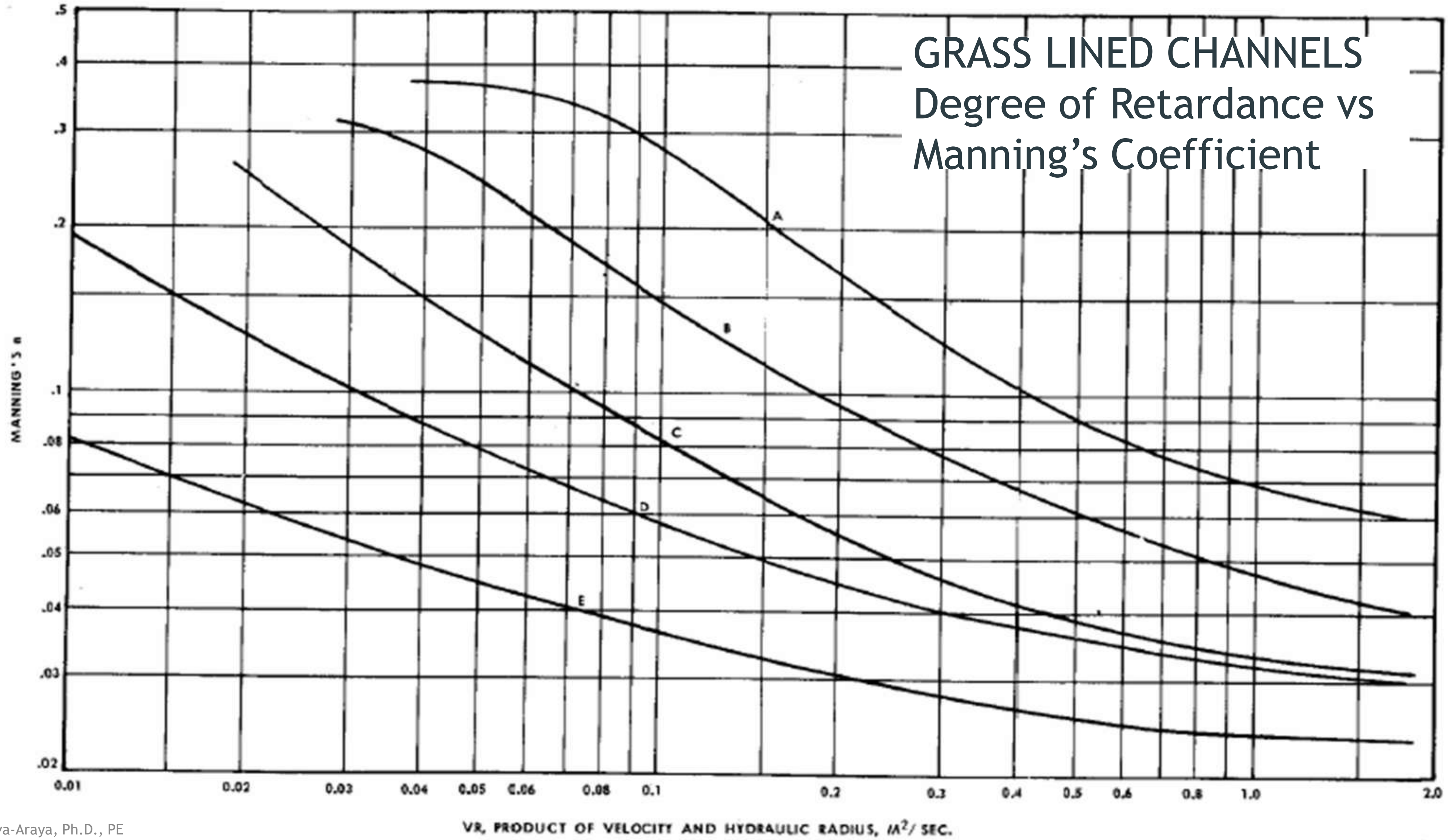
Name		Degree of Retardance	Percent of cover (%)			Average height (inches)
Spanish/English	Scientific		100-95	94-86	85-80	
Ciempiés/Centipede grass	Eremochloa ophiuroides	C		x		6
		D		x		2-6
		E			x	2
Grama colorada/Carpet grass	Axonopus compressus	D		x		2-6
		E		x		2
Mallojilla/Carib grass	Eriochloa polystachya	C		x		>20
Malojillo/Para grass	Urochloa mutica	C		x		11-24
Pajón/Railroad-track grass	Dichanthium annulatum	B		x		>20
		C			x	>20
Rhodes grass	Chloris gayana	B			x	>20
San Agustín/San Agustin grass	Stenotaphrum secundatum	C		x		6-10
		D			x	6-10
Signal/Signal grass	Urochloa brizantha	C			x	>20
Yerba Bahía/Bahia Grass	Paspalum notatum	B		x		>10
		C		x		6-10
		D			x	6-10
Yerba Bermuda/Common Bermuda	Cynodon dactylon	C		x		6-10
		D			x	2-6
		E			x	2
Yerba Buffel/Buffel grass	Pennisetum ciliare	B		x		11-24
		C		x		10-12
Yerba Dalis/Dallis grass	Paspalum dilatatum	C		x		6-12
Yerba Estrella/Star grass	Cynodon nlemfuensis	A	x			>30
		B		x		>30
		C			x	30
Yerba Huracán/Hurricane grass	Bothriochloa pertusa	B		x		>20
		C			x	>20
Yerba Pangola/Pangola grass	Digitaria eriantha	A	x			>30
		B		x		>30
		C			x	>30
Zoysia	Zoyzia spp	C		x		6
		E		x		2

From PR Erosion and Sediment Control Handbook, 2005

GRASS LINED CHANNELS

- Manning's n value is a function of the channel slope, the hydraulic radius, grass species and degree of cover.
- NRCS found good correlation between the Manning's *n* and the multiplication of the flow velocity (V) times the hydraulic radius (R).
- The *VR* vs *n* curves are shown in the next Figure

GRASS LINED CHANNELS
Degree of Retardance vs Manning's Coefficient



GRASS LINED CHANNELS

- Temple (1982) related the product VR with Manning's n using the following equation

$$n_R = e^{\left\{C_I\left[0.0133\,\left(ln(R_v)\right)^2 - 0.0954 ln(R_v) + 0.297\right] - 4.16\right\}}$$

- Where
- For SI units: $R_v = 10.753$ VR
- For EN units: $R_v =$ VR

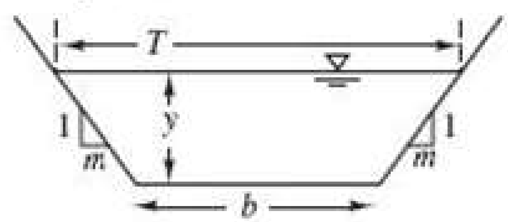
GRASS LINED CHANNELS – *Estimation of Discharge Capacity*

- ***Estimation of waterway discharge***

1. Choose vegetal retardance class (A, B, C, D or, E) and determine the permissible shear stress, τ_p .
2. Select the Curve Index for Retardance Class
3. Estimate a flow depth, y_0, for given bottom width, b, and side slopes, m, and calculate the hydraulic radius, R. Use the following equations for a trapezoidal channel.

$$A = y_0\left(b + my_0\right) \quad P = b + 2y_0\sqrt{1+m^2}$$

4. Other geometries could be used



GRASS LINED CHANNELS – *Estimation of Discharge Capacity*

4. Obtain the value R_v using the following relation proposed by Temple for submerged grass channel linings:

$$R_v = e^{\{(-b+\sqrt{b^2-4ac}/2a)\}}$$

$$a = 0.0133\,C_I$$

$$b = 1 - 0.094\,C_I$$

$$c = 0.297\,C_I - 4.16 + ln\left[0.093/(K_n R^{5/3} S^{1/2})\right]$$

Smooth graded, fine-grained soil

5. Solve for the velocity using the VR relation
6. Compute the discharge multiplying velocity times area

GRASS LINED CHANNELS – ***Estimation of Discharge Capacity***

6. Calculate the maximum bottom shear stress as

$$\tau_{max} = \gamma \; y_0 \; S_0$$

γ = 9,810 N/m3
γ = 64.4 lb/ft3

S_0 = Bottom slope, γ = specific weight of water, y_0 = water depth

6. Compare with the permissible stress τ_p (From Table)
7. Adjust the channel bottom width, slope, or vegetal retardance class until:

$$\tau_{max} \leq \tau_p$$

GRASS LINED CHANNELS – *Estimation of Discharge Capacity*

- Design procedures are available for temporary linings such as jute, fiberglass roving, straw with net, and synthetic mats that are usefull for stabilizing channels immediately after construction before a stand of grass develops.
- The Permissible shear stress criterion is preferable over the Permissible Velocity criterion.

GRASS LINED CHANNELS – *Estimation of Discharge Capacity*

1. The maximum permissible velocity for the mayor storm event in a grass channel is 7.0 fps for cohesive soils; and 5.0 fps for non-cohesive soils. A minimum of 2.0 fps should be maintained for a minor event
2. Froude number for the design discharge should be less than 0.8
3. Where the natural topography is steeper than desired, drop structures are installed to control the channel grade.
4. The center of curvature in bends shall have a radius twice the top width of the design flow but no less than 100 ft.
5. The flow depth in a mayor event shall be kept less than 5 ft.

From Channel Design and Flow Analysis by J.C. Y. Guo, 1999

Erosion Control Practices

Part II
Structural Practices

Structural Practices

- Structural measures are used where vegetative measures are not adequate to prevent erosion, or where control of runoff is required to protect a facility or area of use.
- Require planning, design, and installation
- Designs are based on many factors: expected runoff, risk to life and property, expected sediment accumulation, future land use, and maximum allowable water velocity.

Structural Practices

- Stabilized Construction Entrance
- Temporary Sediment Trap
- Sediment Basin
- Silt Fences
- Straw Bale Barrier
- Land Grading
- Dust Control
- Construction Road Stabilization
- http://www.wayneswcd.org/Sediment%20and%20Erosion%20Control%20DOs%20and%20DON'Ts.html

Stabilized Construction Entrance

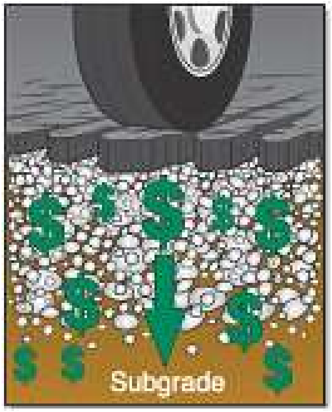
- A stabilized pad of aggregate underlain with filter fabric located at any point where traffic will be entering or leaving a construction site to or from a public right-of-way, street, alley, sidewalk, or parking area.
- Construction entrances are stabilized to reduce the amount of sediment (mud,dirt, rocks, etc.) transported onto paved roads by vehicles or equipment.
- All sediment shall be prevented from entering storm drains, ditches, watercourses, or surface waters including wetlands.
- If vehicles are washed, intercept the wash water and trap the sediment before it is carried offsite.

Stabilized Construction Entrance

- Fencing shall be installed as necessary to restrict traffic to the construction entrance.
- Whenever possible, the entrance shall be constructed on a firm, compacted subgrade.
- The area of the entrance should be cleared of all vegetation, roots, and other objectionable material.
- The aggregates shall be placed to the specified dimensions.

Stabilized Construction Entrance

- Stabilized construction entrance shall meet the following requirements.
  - Aggregate size – Place coarse aggregate 2 to 4 inches in size.
  - Thickness - 6 inches or more.
  - Width - 12 feet minimum but not less than the full width of ingress or egress points.
  - Length - As required, but not less than 50 feet.
  - A separation geotextile shall be used under the aggregate to minimize the migration of stone into the underlying soil by heavy vehicle loads.
  - Follow Geotextile Specifications



Sediment containment systems

- Hydraulic controls that modify the storm runoff hydrograph
- Provides conditions for sediment deposition by gravity
- The goal is to capture sediment from runoff waters
- Efficiency depends on the type of suspended sediment entering the containment
- Three Types of SCS are:
  - Retention Systems
  - Detention Systems
  - Flow-through system

RETETION SYSTEM

- Runoff waters are totally retained
- 100% effective for controlling pollutants
- EPA required to retain the two-year, 24 hr events
- Are not practical for large areas
- Drainage occurs by evaporation and seepage
- Safety and maintenance problems exist
- Could become a wetland

DETETION SYSTEM

- Is the most common system
- Temporary detention with controlled release
- General design criteria: Sufficient volume to contain sediment-laden runoff from contributing areas resulting from a 2-yr, 24 hrs event and
- Take at least 48 hours to drain (changes according to region)
- Drainage occurs through rock barriers, riser pipes, or skimmers.
- Are not 100% efficient
- Have to monitor discharge waters to ensure compliance with turbidity.

Sediment containment systems

- There are three types of SCS

1. Type-1 : Design Size particles <= 0.062 mm

2. Type 2 : 0.062 mm < Design Size Particles <= 041 mm

3. Type 3: Design Size Particles > 0.41

Sediment containment systems

1. Type-1 : Design Size particles <= 0.062 mm

   Highest efficiency. Sediment Basins and Sediment Traps. Controlled discharge

2. Type 2 : 0.062 mm < Design Size Particles <= 041 mm

   Single Chamber Flow Through Containments, Filter bags

   Could be highly effective

Sediment containment systems

1. Type 3: Design Size Particles > 0.41 mm
   1. Least effective methods
   2. Often BMPs found in construction sites
   3. Examples:
      1. Bale and silt fence barrier
      2. Inlet control structures
      3. Drainage ditch check structures
   4. Requires continuing maintenance
   5. Separation (spacing), length, flow and effectiveness of barriers can be determined as part of the design process

Temporary Sediment Trap

- Impoundments that allow sediment to settle out of construction runoff.
- Usually installed in a point of discharge from a disturbed area.
- Temporary diversions can be used to direct runoff to the sediment trap (USEPA, 1993).
- Sediment traps detain sediments in stormwater runoff to protect receiving streams, lakes, drainage systems, and the surrounding area.
- The 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).

Temporary Sediment Trap

- Sediment traps are used in association with sediment fences and/or diversion drains and banks to trap suspended sediment onsite.
- They may be used in most drainage situations to prevent excessive siltation of pipe structures.
- Sediment trap design and frequency of use will depend upon site topography, catchment area and the volume of sediment and water intercepted.
- Natural drainage patterns should be noted, and sites where runoff from potential erosion can be directed into the traps should be selected.
- Traps are not meant to control concentrated flows and store large volumes of sediment. Sediment basins perform this function.

Temporary Sediment Trap

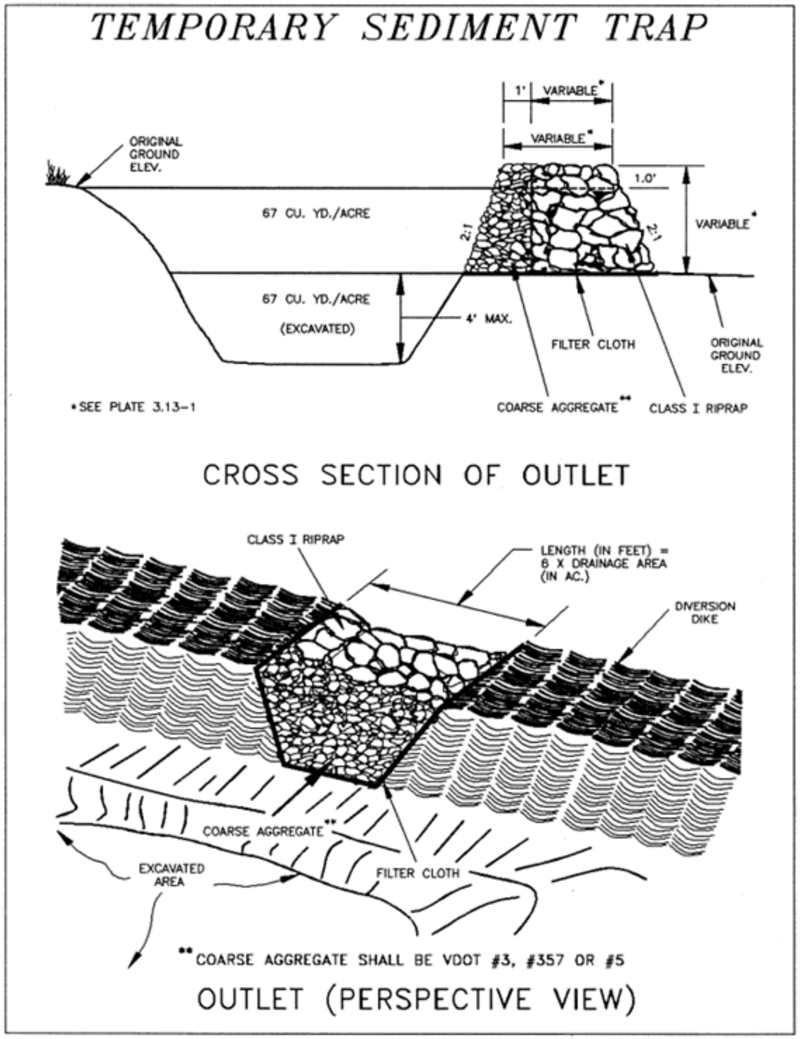
- Design a sediment trap to maximize the surface area for infiltration and sediment settling.
- The minimum storage capacity should be 1,800 ft^3 per acre of total drainage area
- The volume of a natural sediment trap can be approximated using the following equation (Smolen et al., 1988)(EPA):

  Volume (ft^3) = 0.4 x surface area (ft^2) x maximum pool depth (ft)
- When excavating an area for a sediment trap, make sure the side slopes are no steeper than 2:1 and the embankment height no more than 5 feet from the original ground surface.

Temporary Sediment Trap

- The temporary sediment trap volume can be found by computing the detention volume required for the 2-year, 24-hour design storm. (PR Handbook Design)
- Side slopes should not exceed 2:1.
- After determining the necessary volume, size the trap by adding an additional 1½ feet for sediment accumulation to the volume computed using the 2-year, 24-hour design storm.
- Care should be taken in the sitting and design phase to situate sediment traps for easy access by maintenance crews.
- All sediment structures should be at least twice as long as they are wide. A 3:1 aspect ratio between the trap length and width of the trap is desirable.

Temporary Sediment Trap

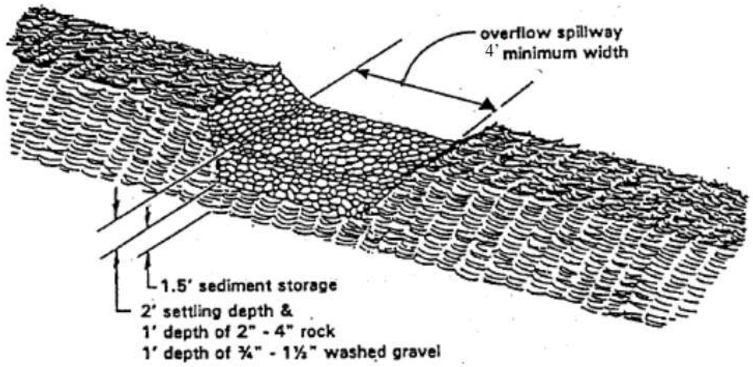


Temporary Sediment Trap




Temporary Sediment Trap

- Machine-compact all embankments to ensure stability.
- To reduce flow rate from the trap, line the outlet 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.
- The minimum depth of the spillway is 1 ft.
- Do not use sediment traps for drainage areas greater than 5 acres (USEPA, 1993).
- The effective life span of these structures is usually limited to 24 months (Smolen et al., 1988).
- Detention periods are too short for removing fine particles like silts and clays.



SEDIMENT TRAP OUTLET
NO SCALE

Temporary Sediment Trap

Temporary Sediment Trap

- Common Problems:
  - Serves only limited areas.
  - Inadequate spillway size: overtopping of dam, poor trap efficiency, and possible failure of the structure.
  - Omission or improper installation of filter fabric (under riprap outlets): washout under sides or bottom of the stone outlet section (piping).
  - Low point in embankment caused by inadequate compaction and settling
  - Stone size too small: stone displacement.
  - Inadequate vegetative protection: erosion of embankment.
  - Inadequate storage capacity: the sediment is not removed from basin frequently.

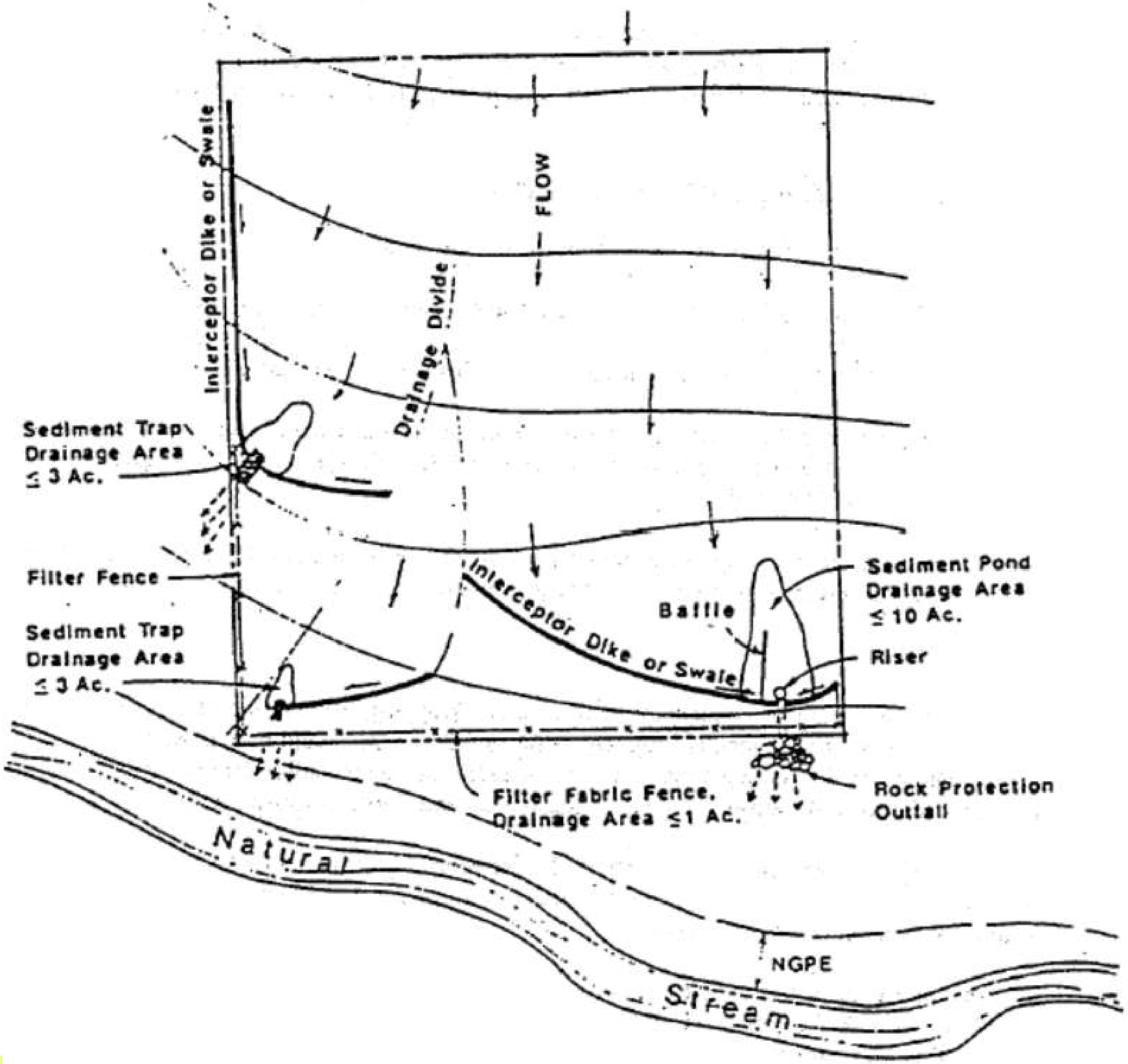
INCORRECT DESIGN

A Sediment Trap with no outlet (like the one shown above) will allow sediment to settle out in the inlet pipe (background), cause erosion downslope and jeopardize the integrity of the embankment when the pond overlows.

Temporary Sediment Trap

- **Maintenance**
- Inspect temporary sediment traps following each significant rainfall event and repair immediately any damage
- Trap should be cleaned out when sediment reaches 1/3 the design depth
- Sediment removal from the basin shall be deposited in a suitable area and in such a manner that will not erode and cause sedimentation problems.
- Check spillway depth periodically to ensure minimum 1-foot depth.
- Do not remove the sediment trap until all sediment producing areas have been permanently stabilized.
- The accumulated sediment in the trap should be removed, and all excavation should be backfilled and properly compacted.
- Smooth the site to blend with the terrain or as specified on plans.

Design Example



Sediment Basins

- Is a storm water detention structure formed by constructing a dam across drainage way or at other suitable locations and using it to intercept sediment-laden runoff.
- Consist of a settling pond with a controlled storm water release structure
- Sediment basins are generally larger and more effective in retaining sediment than temporary sediment traps.
- Sediment-laden runoff is intercepted by the basin reducing the amount of sediment leaving the disturbed area.

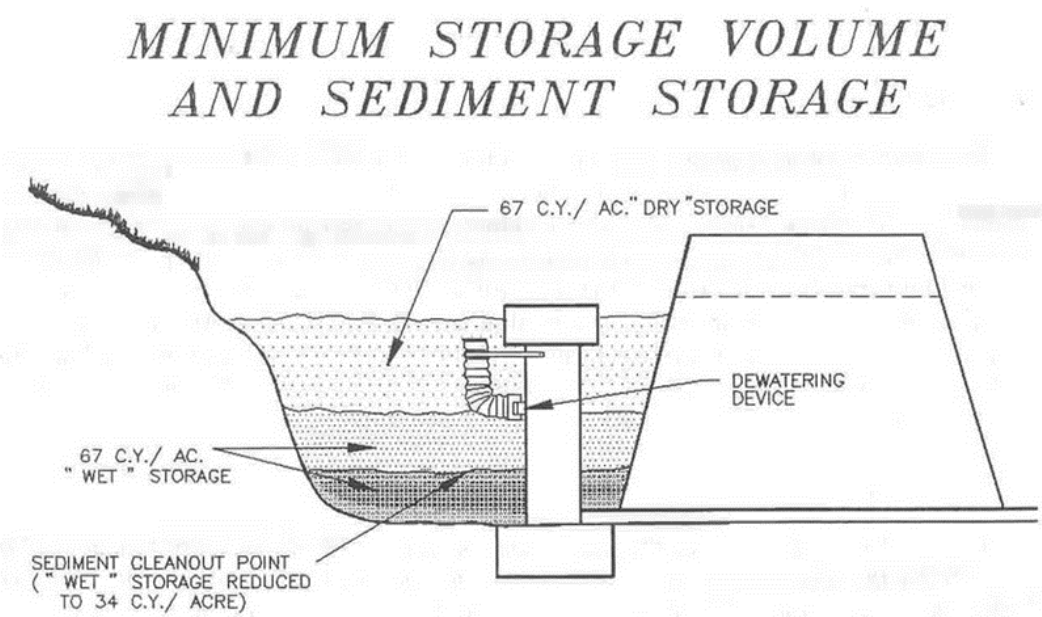
Sediment Basins

- Usually designed for disturbed areas larger than 5 acres
- Should be installed before clearing and grading is undertaken
- Used in combination with other control practices such as seeding or mulching it is especially effective in removing sediment.
- Designed such that failure of the structure would not result in loss of life, in damage to homes, commercial buildings, highways, and streets, or in interruption of the use of services or public utilities.

Sediment Basins

- Only 70-80% effective in trapping sediment that flows into them
- Should be used in conjunction with erosion control practices such as temporary seeding, mulching, diversion dikes, etc., to reduce the amount of sediment flowing into the basin
- Natural drainage patterns should be noted, and sites where runoff from potential erosion can be directed into the basin should be selected.
- Sediment basins can control concentrated flows and store large volumes of sediment.
- The best locations are low areas below disturbed areas.
- Diversion dikes and ditches can improve drainage into the basin.
- The basin should be located to trap sediment-laden runoff before it enters the stream

Sediment Basins



Sediment Basins

- The capacity of the sediment basin shall equal the volume of sediment expected to be trapped during the planned useful life
- The sediment storage volume may be determined by using the Revised Universal Soil Loss Equation (RUSLE) and gully erosion rates with an appropriate delivery ratio or by using other accepted sediment predictive procedures.
- Although site conditions will dictate specific design criteria, the storage capacity of a sediment basin should be at least 1,800 ft per acre of the drainage area.

Sediment Basins

Sediment Basins

- ***EPA BASELINE GENERAL PERMIT REQUIREMENTS***

Sediment Basin Requirements

Part IV.D.2.a(2).(a).

For common drainage locations that serve an area with 10 or more disturbed acres at one time, a temporary (or permanent) sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent control measures, shall be provided where attainable until final stabilization of the site. The 3,600 cubic feet of storage area per acre drained does not apply to flows from offsite areas and flows from onsite areas that are either undisturbed or have undergone final stabilization where such flows are diverted around the sediment basin.

- Dams that can store at least 30 acre-feet of runoff or are 20 feet or more in height must be designed as permanent ponds,according to the requirements in NRCS.

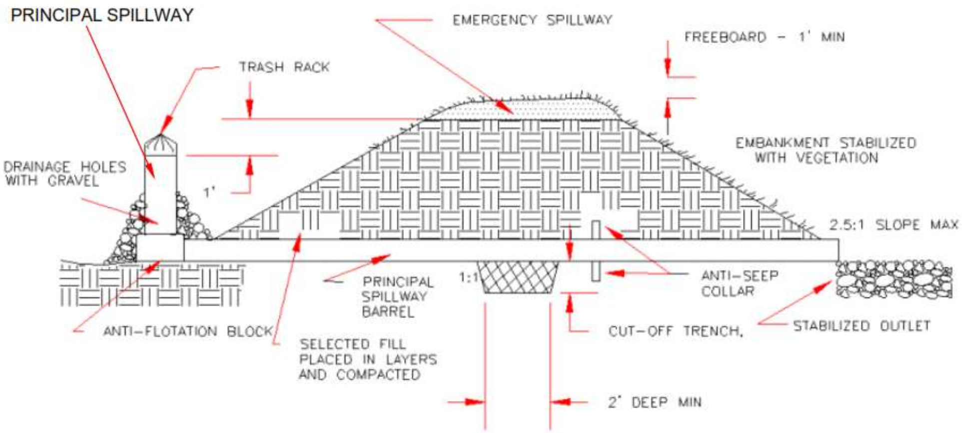
Sediment Basins

- The embankment shall have a minimum top width of 4 feet and side slopes of 2 horizontal to 1 vertical (2:1) or flatter.
- An outlet shall be provided of earth, pipe, stone, or other devices to handle the 10-year frequency discharge without failure or significant erosion.
- Sediment basins may be designed as permanent structures to remain in place after construction is completed for use as storm water detention ponds. Wherever these structures are to become permanent they must be designed as permanent.
- The drainage area for a sediment basin should not exceed 100 acres. (405. ha, 103 cuerdas)
- The basin is to be removed within 36 months after the beginning of construction of the basin.

Sediment Basins

- The basin should not be located where its failure would result in the loss of life or interruption of the use or service of public utilities or roads.
- There are other conditions for the operation spillway, the emergency spillway design and the embankment materials.
- Points of entrance of surface runoff into excavated sediment basins shall be protected to prevent erosion.
- The sediment basin plans shall indicate the method(s) of disposing of the sediment removed from the basin.
- The sediment basin plans shall also show the method of disposing of the sediment

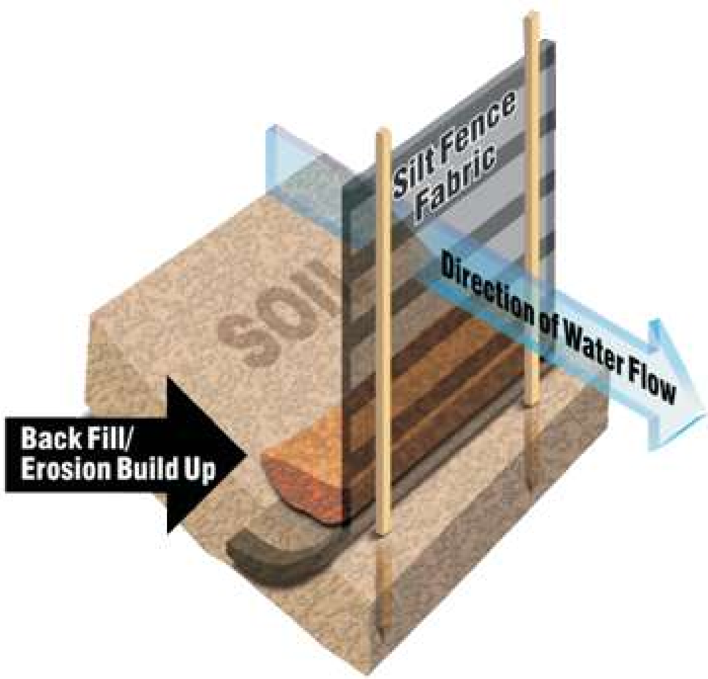
Sediment Basins

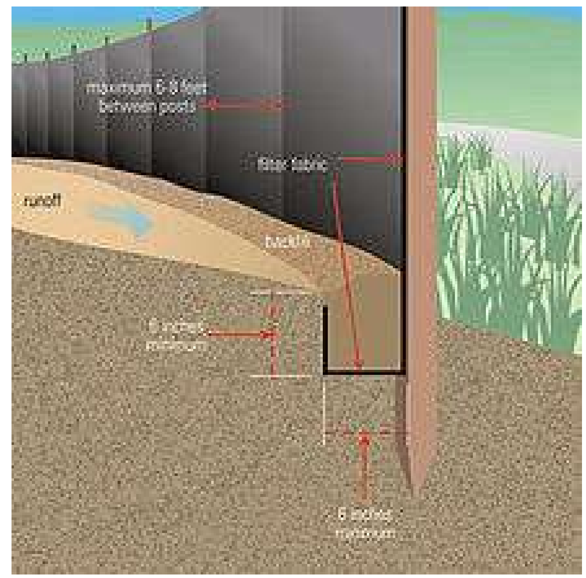


Silt Fences

- Is a temporary barrier of geotextile fabric (filter cloth), entrenched into the soil and attached to supporting posts, used to intercept sediment-laden runoff from small drainage areas.
- Installed below small disturbed areas or at the toe of a slope at a construction site or new development.
- The expected life span is normally six months or less and is dependent on ultraviolet stability and type of fabric.
- Very effective in sheet flow conditions and usually ineffective with concentrated flows.
- Woven and nonwoven synthetic fabrics are available.
- Woven fabric is generally stronger than nonwoven fabric and usually does not require the additional support of a wire mesh.
- Silt fence is a sediment control practice. It is not intended to be an erosion control practice.
- A silt fence can be used to promote sheet flow, to reduce runoff velocity, and retain transported sediment
- They are inexpensive, relatively easy to construct, and effective.

Silt Fences


Silt Fence Fabric
SOIL
Direction of Water Flow
Back Fill/
Erosion Build Up


maximum 6-8 feet between posts
filter fabric
runoff
backfill
6 inches minimum
6 inches minimum

Silt Fences

- **Woven:**
  advantages - cost, strength, stiffness; does not requires additional support
  disadvantages - easily "opened" by angular aggregate; poor filter, so it may not keep layers separate

  Non-woven:
  advantages - excellent filtration and separation properties
  disadvantages - more expensive than a woven (only a little); not as stiff (but can be strengthened and stiffened by making it thicker and reinforcing it)

Silt Fences

- Used
- FOR SLOPE PROTECTION
- There is no concentration of water in a channel or other drainage way above the barrier.
- Erosion will occur in the form of sheet and rill erosion.
- Protection of adjacent property or areas beyond the limits of grading is needed (perimeter control).
- Contributing drainage area is no more than .25 acre per 100 linear feet of silt fence
- The maximum flow path length above the barrier is 100 feet.
- The slope should be 50% or less.

Silt Fences

- A silt fence may be used around or downslope of soil stockpiles and along the sides of streams and ponds.
- Maximum allowable slope lengths

Slope Steepness	Maximum Slope Length (Feet)
2:1	20
3:1	40
4:1	60
5:1	80
Flatter than 5:1	100

Silt Fences

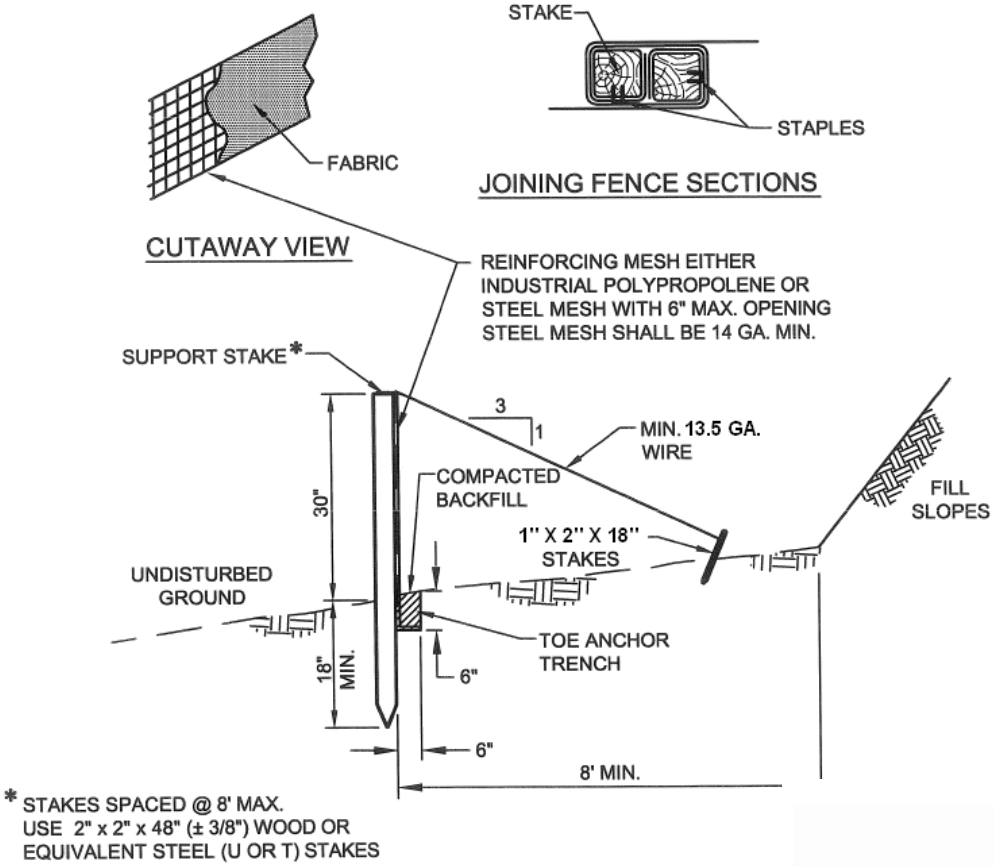
- FOR CHANNEL APPLICATIONS
- Filter fences may be used in minor swales or ditch lines where the maximum contributing drainage area is no greater than 1 acre.
- They are not for use in perennial channels.
- Filter fences should be used only where the volume of runoff water is not expected to exceed 0.5 cubic feet per second.

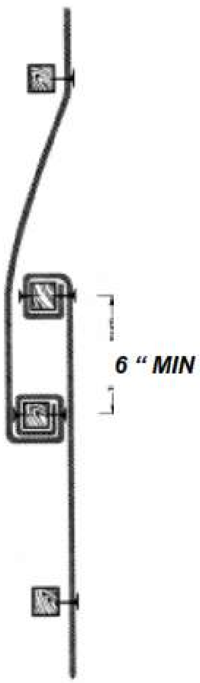
Silt Fences

- FOR CHANNEL APPLICATIONS

Silt Fences: Installation

- Continuous and transverse to the flow.
- Follow the contours of the site.
- Water cannot run off around the end of the fence.
- Silt fence ditch checks should be placed perpendicular to the flow line of the ditch.
- Silt fence should extend far enough so that the ground level at the ends of the fence is higher than the top of the low point of the fence.
- Minimum height above ground for the silt fence shall be 2.5 ft.
- Minimum embedment depth shall be 0.5 ft (6 inches).
- Height of a silt fence shall not exceed 3 ft.
- Storage height and ponding height not exceed 18 inches.

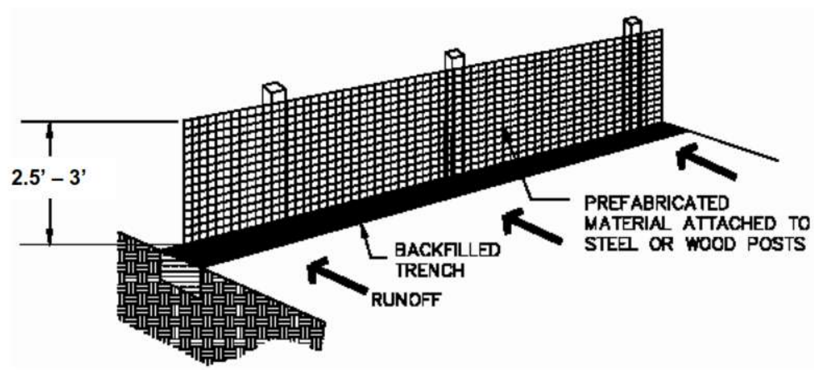


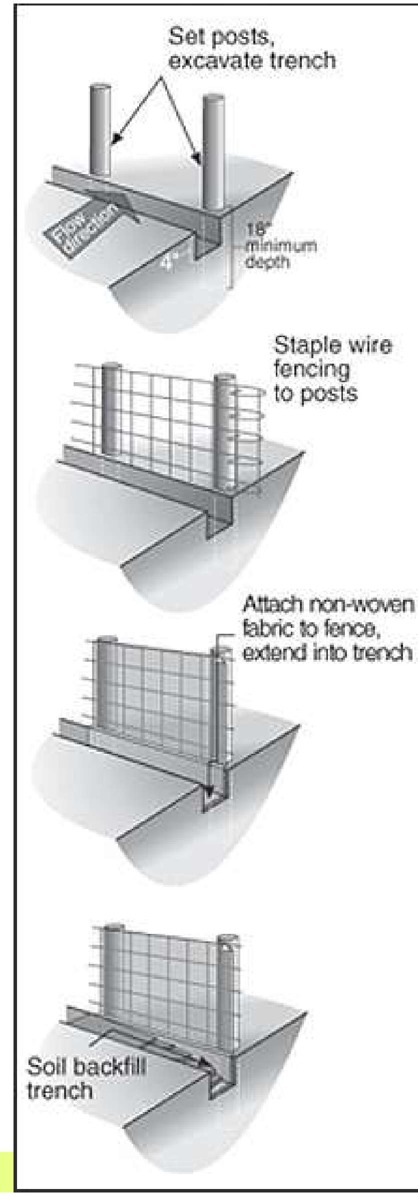


PR Handbook Join Detail

PR Handbook:
Max Stakes space @ 6 "

Tensor wire is optional





Silt Fences: Common problems

- Drainage area too large; break up into smaller areas.
- Concentration of flow
- Too much sediment accumulation allowed before clean out
- Upstream slope too steep or too long
- Fence not adequately supported
- Fence located across a drainage way; flows may be in excess of the silt fence's capability.
- Undercutting occurs; fence was not buried at least 6 inches or the trench was not backfilled and compacted properly.
- Erosion around barrier ends due to endpoints being lower than top of temporary pool elevation
- Do not place silt fence barriers in areas with shallow soils underlain by rock. If the barrier is not anchored sufficiently, it will wash out.

Silt Fences: Common problems

- Silt fence slope barrier should be inspected every 7 days for damage (such as tearing by equipment, undercutting, bulge, excessive sag, fabric detached from the posts) and repair or replacement shall be made promptly as needed.
- An inspection should be made within 24 hours of each significant rainfall (0.5 inches or more) or daily during periods of prolonged rainfall.
- Sediment should be removed when they reach 1/3 to ½ the height of the barrier (18 inches maximum).
- Sediment deposits shall be removed when heavy rain is anticipated.
- *When removing sediment from behind a silt fence slope barrier or working around with a bulldozer or backhoe, take care not to undermine the entrenched silt fence.*

Silt Fences: Common problems

Straw Bales

- A temporary entrenched and anchored barrier installed across or at the toe of a slope of a construction site or new development.
- The expected life span is normally three months or less.
- Intercept and retain sediment from small unprotected drainage areas.
- Can be used to promote sheet flow and to reduce runoff velocity

Straw Bales

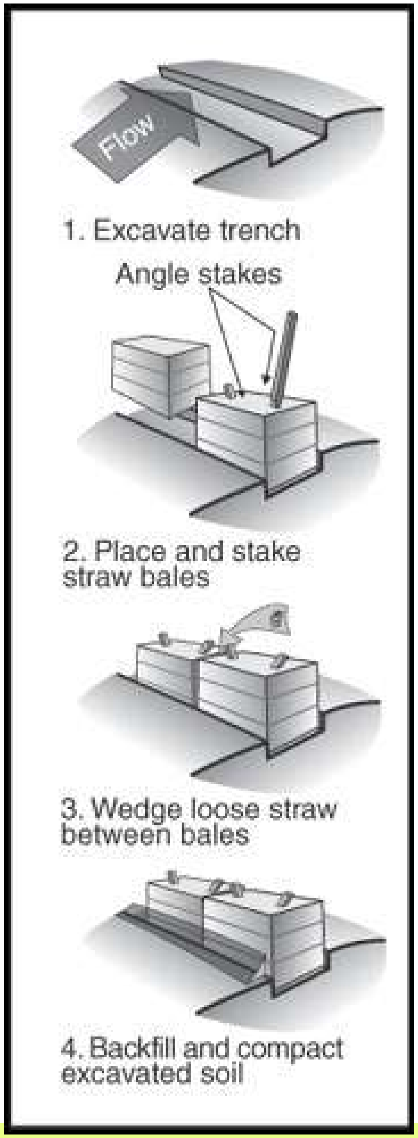
- Used:
- For slope Protection if:
  1) There is no concentration of water in a channel or other drainage way above the barrier.
  2) Erosion will occur in the form of sheet and rill erosion.
  3) Contributing drainage area is less than ½ acre and the length of slope of the contributing area is less than 200 feet. The slope should be 15% or less.
- The maximum length of slope behind the barrier is 100 feet

Straw Bales

- An average straw bale should be 30 inches in length, weight at least 50 pounds, and contain 5 cubic feet or more of material
- All bales shall be placed on the contour and should be tied with either wire or nylon strings if available.
- Excavate a 4- to 6-inch deep trench to the length of the barrier and the width of the bale.
- Make sure that the trench is excavated along a single contour to avoid concentration of flow.
- Excavated material is to be placed on the upstream side of the trench for later use.
- Place the bales in the trench, making sure that they are butted tightly.

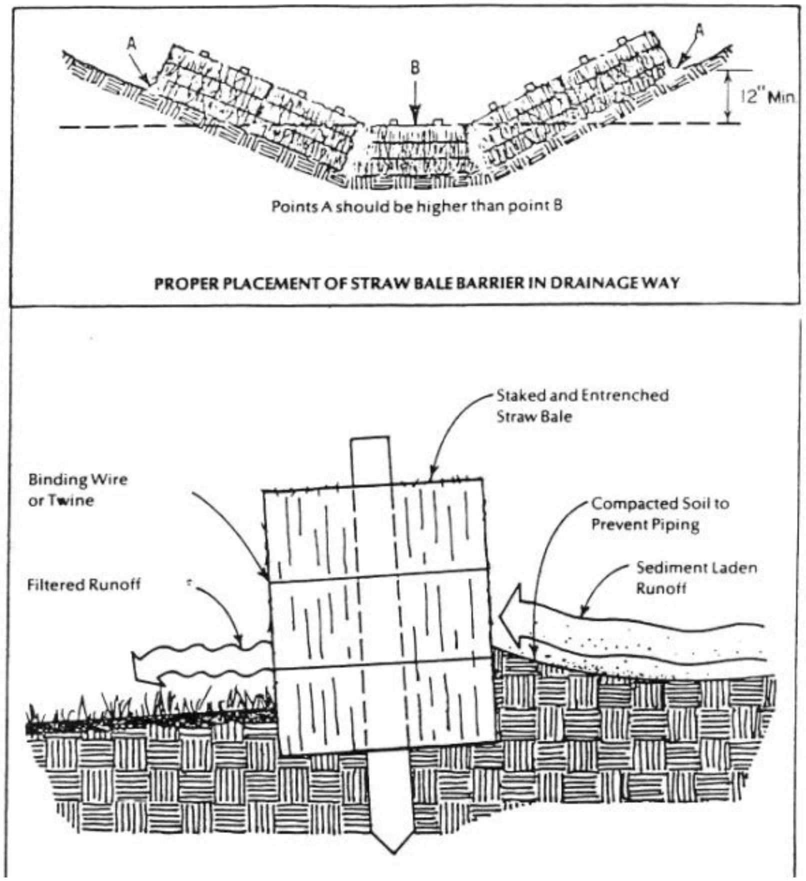
Straw Bales

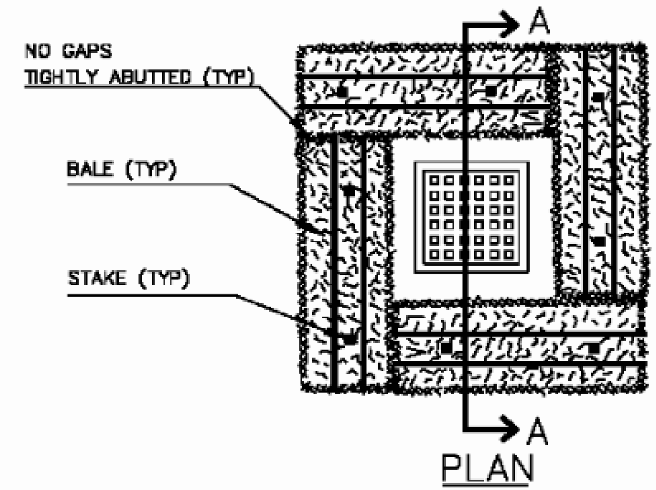
- Bales shall be securely anchored in place by two 2 x 2 wooden stakes or rebar steel driven through the bales into the underlying soil at a slight upstream angle to help prevent the bale from overturning.
- Stakes should be driven at least 18 inches into the ground.
- The first stake in each bale shall be driven toward previously laid bale to force bales together.
- Spacing between the bales should be tightly chinked with loose straw.

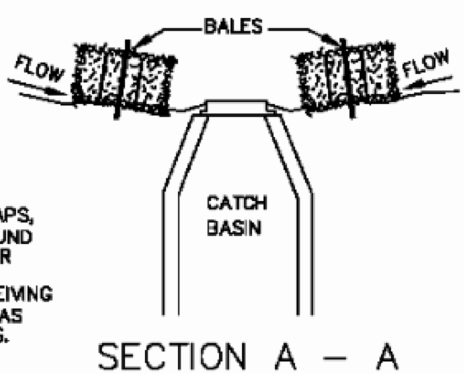


Straw Bales

- Straw bale check dams in swales or ditches: the barrier is placed perpendicular to the contour.
- The same installation procedure is followed with the barrier extended up the sides of the ditch until the tops of the end bales are higher than the top of the lowest middle bale.

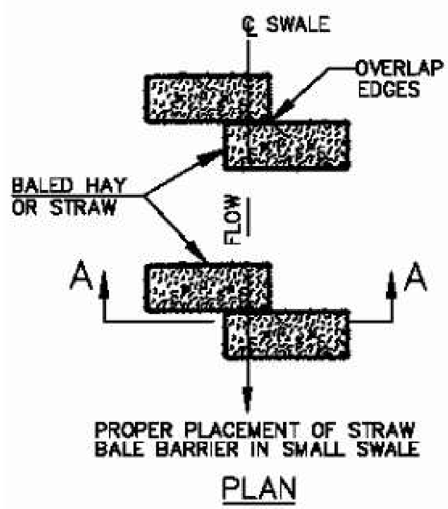


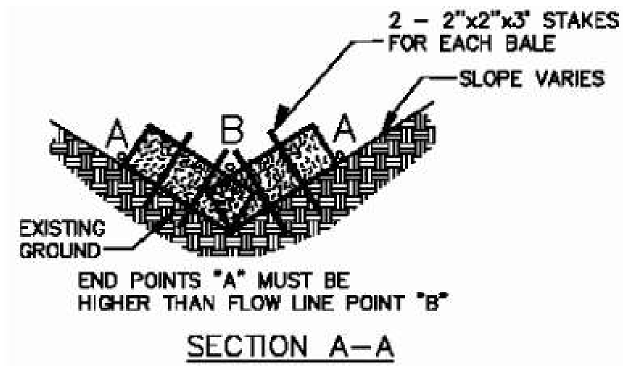




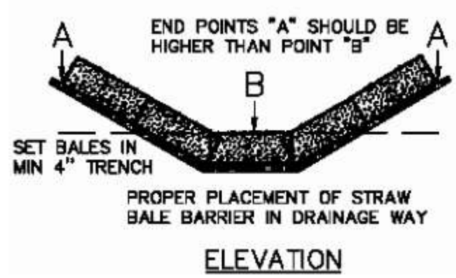
NOTES:
1. BALES ARE TO BE PLACED 4 INCHES IN THE SOIL, TIGHTLY ABUTTING WITH NO GAPS, STAKED AND BACKFILLED AROUND THE ENTIRE OUTSIDE PERIMETER
2. NOT RECOMMENDED FOR RECEIVING CONCENTRATED FLOWS, SUCH AS STREETS OR HIGHWAY MEDIANS.

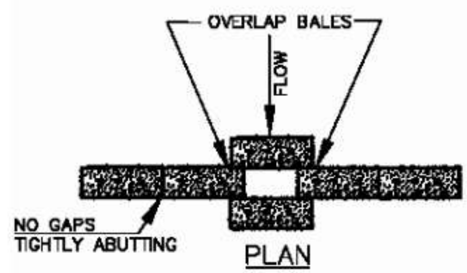
Straw Bale Sediment Control at Catch Basins



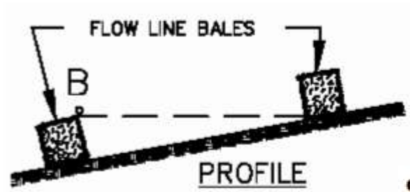


SMALL SWALE





DRAINAGE WAY



PLACE DOWNSTREAM BALES SUCH THAT POINT "B" IS APPROXIMATELY LEVEL WITH THE LOWEST ELEVATION OF THE UPSTREAM BALE

Straw Bale Check Dams Installation

Straw Bales

- Common Trouble Points
  - Drainage area too large; break up into smaller areas.
  - Too much sediment accumulation allowed before clean out
  - Upstream slope too steep or too long; break up length with additional rows of barriers.
  - Undercutting occurs; bales were not trenched at least 4 inches or compacted properly.
  - Loose spots or spacing not tightly chinked with loose hay; insufficient trap efficiency.
  - Bales located across a drainage way; flow may be in excess of bale's capacity.
  - Erosion around barrier ends due to endpoints being lower than top of temporary pool elevation
  - Do not place bale slope barriers in areas with shallow soils underlain by rock. If the barrier is not anchored sufficiently, it will wash out.
  - Bales at ground level do not work because they allow water to flow under the barrier.