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July 8, 2003

Chapter 8: Structural Measures for Erosion and Sediment Control

Introduction

Much of the information in this chapter is excerpted from Chapter 3 of the 1993 edition of the *Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas*, prepared by the Alabama Soil and Water Conservation Committee, USDA, Montgomery, AL. This handbook is currently being revised, with the new edition expected to be available in 2003. Therefore, it is possible that newer techniques and procedures are not included here, and local USDA offices and erosion control professionals should be consulted for updated information as it becomes available.

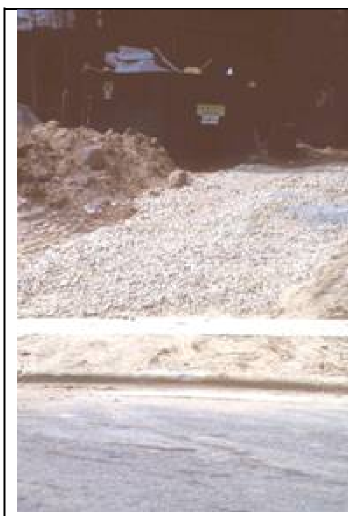
As stated in the *Alabama Handbook*, structural measures are not intended to stand alone. They should be employed as a system with vegetative measures, sequenced and sited to control erosion and sedimentation during development and to stabilize disturbed land as development is completed. By combining vegetative and structural measures into a comprehensive plan, successful erosion and sedimentation control can be achieved. Planners should consider the changing requirements of their site when determining the sequence in which measures are to be implemented.

The best way to prevent sediment from entering the storm sewer system is to stabilize the site as quickly as possible, preventing erosion and stopping sediment at its source. As much of the site as possible should be left undisturbed in the total site plan and land disturbance should be in small increments, if possible.

Specific Structural Controls for Construction Sites

The *Alabama Handbook*, along with other erosion control manuals, contain descriptions of many "structural" practices that can be used on construction sites to prevent erosion, or to capture sediment that has already eroded. The following excerpts from the *Alabama Handbook* are only a few that are included in this chapter, but are the most basic controls that should be considered: construction site exits, stormdrain inlet protection, use of riprap, check dams in channels, and protection of outlets from ponds. These sections contain recommendations for the use of these controls for Alabama conditions. As noted previously, this handbook is currently being revised, and local USDA extension offices should be consulted for updated recommendations. The erosion and sediment control benefits of most of these controls have not been measured in the field, but these controls are generally acknowledged to be needed as important elements of construction site erosion control programs.

Construction Site Exit (CE)



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Definition
A stone or rock stabilized pad located at points of vehicular ingress or egress to a construction site.

Purpose
To reduce or eliminate the transport of mud from the construction area onto public right-of-ways by motor vehicles or by runoff.

Conditions Where Practice Applies
This practice is applied where vehicular traffic will be leaving a construction site and move directly onto a public road or street.

Planning Considerations
Roads and streets adjacent to construction sites should be kept clean for the general safety and welfare of the public. A construction exit (Figure CE-1) should be provided where mud can be removed from construction vehicle tires before they enter a public road. If traveling over the rock stabilized pad does not remove the mud from construction vehicles, a wash area should be provided for that purpose. Whenever washing is used, the wash water needs to be collected in a sediment basin before leaving the site.

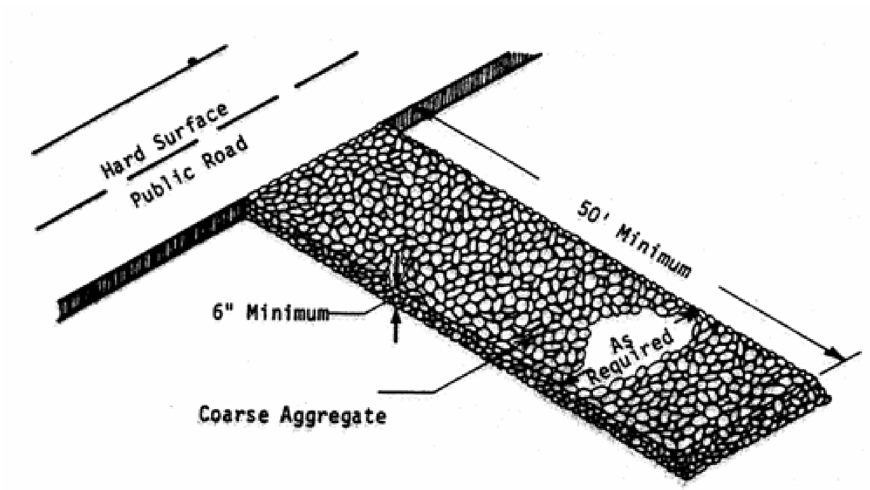

Figure CE-1. Gravel construction exit.

Construction of stabilized roads throughout the development site should be considered to lessen the amount of mud transported by vehicular traffic. The rock pad should be located to provide for maximum use by all construction vehicles. Consideration should be given to limiting construction vehicles to only one ingress and egress point. Measures may be necessary to make existing traffic use the construction exit.

Design Criteria
Aggregate Size: Aggregate should be Alabama Highway Department coarse aggregate gradation No. 1, or equivalent. AL DOT coarse aggregate No. 1 has the following size specifications:

Percent passing:

100 mm (4 in)	90 mm (3-1/2 in)	63 mm (2-1/2 in)	37.5 mm (1-1/2 in)	19 mm (3/4 in)
100	90-100	25-60	0-15	0-5

Entrance Dimensions: The rock pad shall be a minimum of six inches thick. It shall be at least 50 feet long or the length required to enter and park the longest anticipated construction vehicles. The width shall be at least 20 feet.

Geotextiles: A non-woven geotextile meeting the requirements of Soil Conservation Service Material Specification 592, Class IV should be used under the rock when the subgrade is soft or the blow count is less than 10.

Washing: A wash rack shall be provided as necessary to prevent mud from being transported to public streets and highways. It shall be constructed of concrete and/or other durable materials. Provisions shall be provided for the mud and other material to be carried away from the wash rack to a sediment basin to remove the mud from the water before release from the site.

Maintenance
The construction exit shall be maintained in such a way to prevent the movement of mud into public travel ways. Aggregate should be added to the pad whenever it will not serve as an all weather travel way for the construction vehicles. Sediment basins shall be cleaned out whenever one-half of the design storage volume is depleted.

Construction Specifications for Construction Exit
1. Remove all vegetation, roots and other objectionable material from the stone pad area.

2. Smooth the area to an even grade and fill in and recompact material in holes low places or over excavated areas. Recompacted material shall be as dense as the surrounding material.

3. Place any required geotextile over the area to be protected. Take care not to pull the geotextile tight, but leave sufficient slack for the fabric to conform to the ground after rock is placed and loaded with vehicles. The fabric shall be unrolled parallel to the roadway centerline. The recommended geotextile overlap is 24 inches when the blow count is 10, 36 inches when the blow count is four to nine and 48 inches when the blow count is three or less. Geotextiles that are the full width of the roadway are needed.

4. The stone pad should be dumped and spread in a full uniform thickness before vehicular traffic is permitted to travel on it.

5. Wash racks shall be installed in accordance with manufacturers recommendations.

6. Sediment basins or other related facilities constructed in conjunction with the wash rack shall be constructed in accordance with the plans and specifications. Sediment basins for wash racks shall be constructed before the wash rack is put into service.

Stormdrain Inlet Protection (NP)

 J. Voorhees photo	

	
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Definition
A sediment filter installed around a storm drain drop inlet or curb inlet to reduce sediment discharge.

Purpose
To prevent sediment from entering storm drainage systems during construction and prior to permanent stabilization of the disturbed area.

Conditions Where Practice Applies
Where storm drain inlets are to be made operational before permanent stabilization of the disturbed drainage area. Different types of structures are applicable to different situations.

Planning Considerations
Storm sewers which are made operational before their drainage area is stabilized can convey large amounts of sediment to natural drainageways. In cases of extreme sediment loadings, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to minimize that amount of sediment that enters the system at the inlets.

This practice contains several types of inlet filters and traps which have different applications dependent upon site conditions and type of inlet. These inlet protection devices are for drainage areas of less than one acre. Runoff from large disturbed areas should be routed through a sediment basin.

The best way to prevent sediment from entering the storm sewer system is to stabilize the site as quickly as possible, preventing erosion and stopping sediment at its source. Inlet protection devices likely have limited benefits for most of the eroding sediment, although they are more effective for the larger materials that may clog inlets and drainage systems. Sediment is best treated by preventing erosion. Leave as much of the site undisturbed as possible in the total site plan. Clear and disturb the site in small increments, if possible.

Design Criteria
1. The drainage area shall be no greater than 1 acre.

2. The inlet protection device shall be constructed in a manner that will facilitate cleanout and disposal of trapped sediment and minimize interference with construction activities.

3. The inlet protection devices shall be constructed in such a manner that any resultant ponding of stormwater will not cause excessive inconvenience or damage to adjacent areas or structures.

4. Design criteria more specific to each particular inlet protection device will be found with that construction specification.

5. Ponding of water or deposition of sediment on roadways that will create traffic hazards will be prevented.

Maintenance
1. The structure shall be inspected after each rain and repairs made as needed.

2. Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to 1/2 the design depth of the trap. Removed sediment shall be deposited in a suitable area and in such a manner that it will not erode. Stabilize all sediment disposal areas with appropriate vegetation.

3. Structures shall be removed and the area stabilized when the contributing drainage area has been properly stabilized.

Construction Specifications for Inlet Protection
1. Straw bale drop inlet structure. (Figure NP-1). This method of inlet protection is applicable where the inlet drains a relatively flat area (slopes no greater than 5 percent) where sheet or overland flows (not exceeding 0.5 cfs) are typical. The method shall not apply to inlets receiving concentrated flows, such as in street or highway medians.

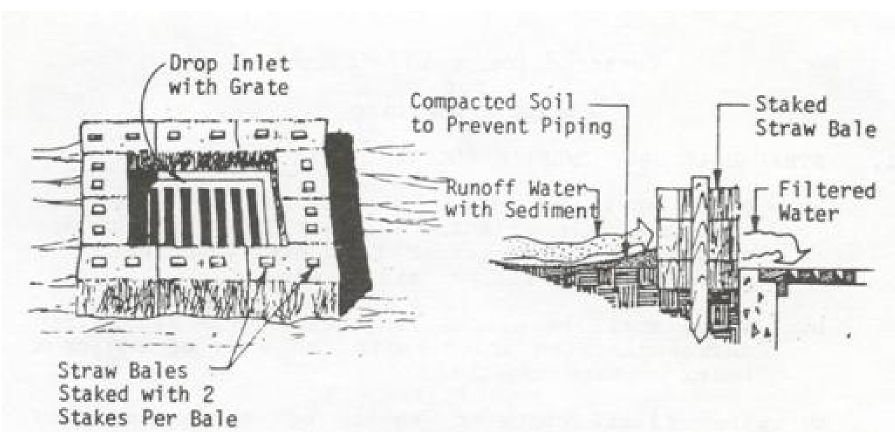

Figure NP-1. Straw bale drop inlet sediment trap.

a. Bales shall be either wire-bound or string-tied with the bale oriented so that the bindings are around the sides rather than over and under the bales. Bales will be laid on edge.

b. Bales shall be placed lengthwise in a single row surrounding the inlet, with the ends of adjacent bales pressed together.

c. The filter barrier shall be entrenched and backfilled. A trench shall be excavated around the inlet the width of a bale to a minimum depth of 4 inches. After the bales are staked, the excavated soil shall be backfilled and compacted against the filter barrier.

d. Each bale shall be securely anchored and held in place by at least two stakes or rebars driven through the bale.

e. Loose straw shall be wedged between bales to prevent water from entering between bales.

f. Stakes for anchorage shall be nominal 1” X 2” durable wood or equivalent. The wood shall be sound with a minimum actual dimension of ½”. The minimum embedment into the ground shall be 12”.

2. Gravel and wire mesh drop inlet sediment filter. (Figure NP-2). This method of inlet protection is applicable where heavy concentrated flows are expected, but not where ponding around the structure might cause excessive inconvenience or damage to adjacent structures and unprotected areas.

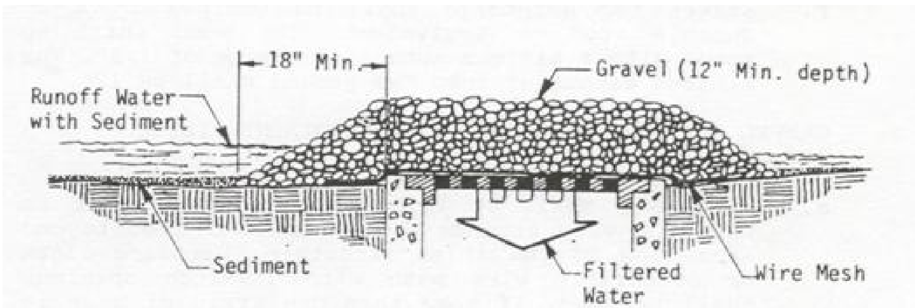

Figure NP-2. Gravel and wire mesh drop inlet filter.

a. Wire mesh shall be laid over the drop inlet so that the wire extends a minimum of l foot beyond each side of the inlet structure. Hardware cloth or comparable wire mesh with 1/2-inch openings shall be used. If more than one strip of mesh is necessary, the strips shall be overlapped and securely tied or wired together.

b. Alabama Highway Department No. 1 Coarse Aggregate, or equivalent, shall be placed over the wire mesh as indicated on Figure NP - 2. The depth of stone shall be at least 12 inches over the entire inlet opening. The stone shall extend beyond the inlet opening at least 18 inches in all directions.

c. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stones must be pulled away from the inlet, cleaned and replaced.

Warning: This filtering device has no overflow mechanism, therefore, ponding is likely, especially if sediment is not removed regularly. This type of device must never be used where overflow may endanger an exposed embankment slope. Consideration should also be given to the possible effects of ponding on traffic routes, nearby structures, working areas, adjacent property, etc.

4. Gravel curb inlet sediment filter. (Figure NP-3). This method of inlet protection is applicable at curb inlets where ponding in front of the structure is not likely to cause inconvenience or damage to adjacent structures and unprotected areas

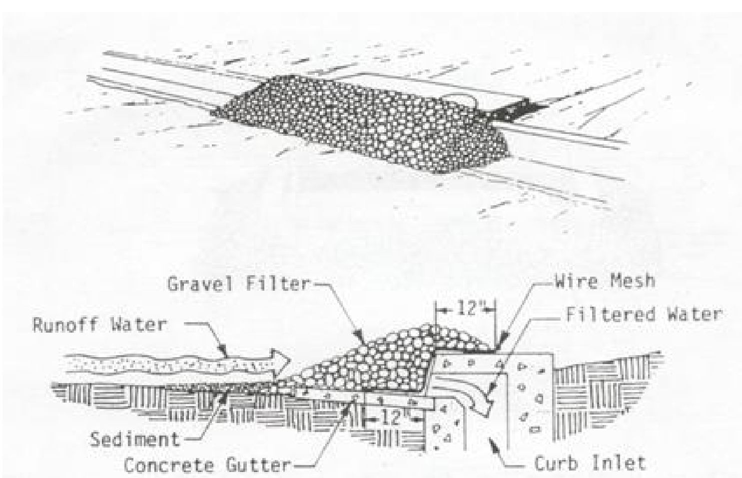

Figure NP-3. Gravel curb inlet sediment filter.

a. Hardware cloth or comparable wire mesh with 1/2inch openings shall be placed over the curb inlet opening so that at least 12 inches of wire extends across the inlet cover and at least 12 inches of wire extends across the concrete gutter from the inlet opening.

b. Stone shall be piled against the wire so as to anchor it against the gutter and inlet cover and to cover the inlet opening completely. Alabama Highway Department No. 1 Coarse Aggregate, or equivalent, shall be used.

c. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the block, cleaned and replaced. Do not hose the debris into the curb inlet!

5. Block and gravel curb inlet sediment filter. (Figure NP-4). This method of inlet protection is applicable at curb inlets where an overflow capability is necessary to prevent excessive ponding in front of the structure.

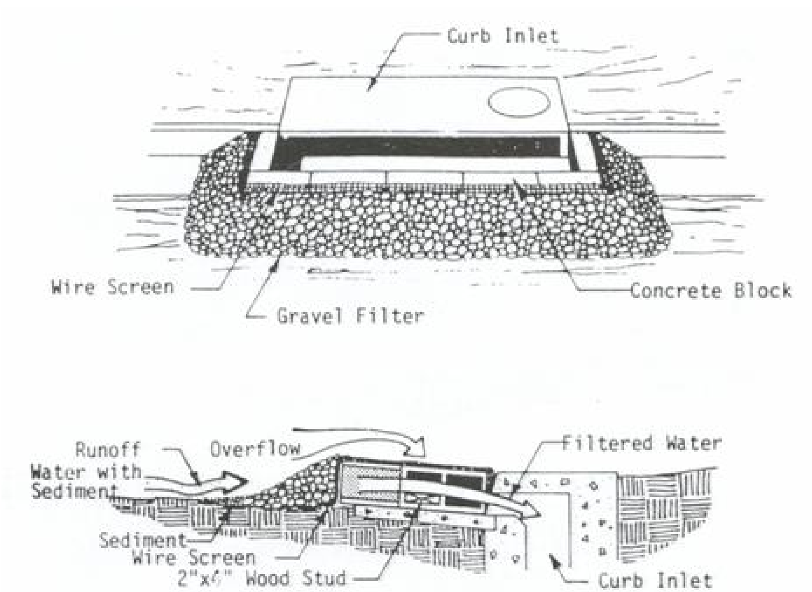

Figure NP-4. Block and gravel inlet filter.

a. Two concrete blocks shall be placed on their sides abutting the curb at either side of the inlet opening.

b. A 2-inch by 4-inch stud shall be cut and placed through the outer holes of each spacer block to help keep the front blocks in place.

c. Concrete blocks shall be placed on their sides across the front of the inlet and abutting the spacer blocks as illustrated in Figure NP-4.

d. Wire mesh shall be placed over the outside vertical face (webbing) of the concrete blocks to prevent stone from being washed through the holes in the blocks. Chicken wire or hardware cloth with 1/2-inch openings shall be used.

e. Alabama Highway Department No. 1 Coarse Aggregate, or equivalent, shall be piled against the wire to the top of the barrier as shown in Figure NP-4.

f. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and replaced.

6. Block and gravel drop inlet sediment filter. (Figure NP-5). This method of inlet protection is applicable where heavy flows are expected and where an overflow capacity is necessary to prevent excessive ponding around the structure.

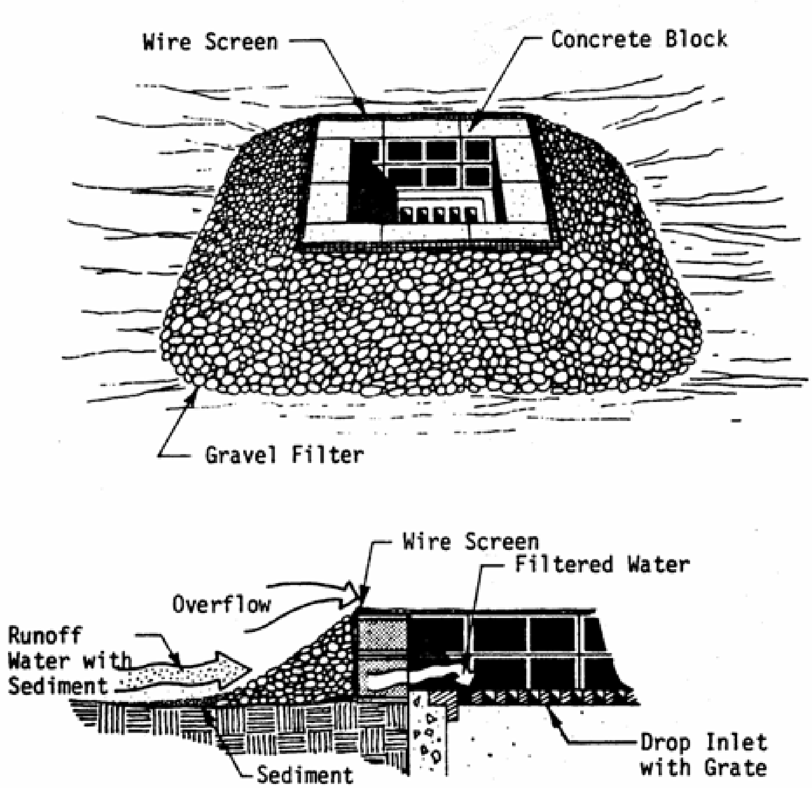

Figure NP-5. Block and gravel drop inlet filter.

a. Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, with the ends of adjacent blocks abutting. The height of the barrier can be varied, depending on design needs, by stacking combinations of 4-inch, 8-inch and 12-inch wide blocks. The barrier of blocks shall be at least 12 inches high and no greater than 24 inches high.

b. Wire mesh shall be placed over the outside vertical face of the concrete blocks to prevent stone from being washed through the holes in the blocks. Hardware cloth or comparable wire mesh with 1/2-inch openings shall be used.

c. Stone shall be piled against the wire to the top of the block barrier, as shown in Figure NP-5. Alabama Highway Department No. 1 Coarse Aggregate, or equivalent, shall be used.

d. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and replaced.

Riprap (RR)

Definition
A permanent, erosion-resistant ground cover of large, loose, angular stone.

Purpose
1. To protect the soil surface from the erosive forces of concentrated runoff.
2. To slow the velocity of concentrated runoff while enhancing the potential for infiltration.
3. To stabilize slopes with seepage problems and/or noncohesive soils.

Conditions Where Practice Applies
Soil-water interfaces where the soil conditions, water turbulence and velocity, expected vegetative cover, etc., are such that the soil may erode under the design flow conditions. Riprap may be used, as appropriate, at storm drain outlets, on channel banks and/or bottoms, roadside ditches, drop structures, at the toe of slopes, etc.

Planning Considerations
1. Graded vs. Uniform Riprap. Riprap is classified as either graded or uniform. A sample of graded riprap would contain a mixture of stones which vary in size from small to large. A sample of uniform riprap would contain stones which are all fairly close in size.

For most applications, graded riprap is preferred to uniform riprap. Graded riprap forms a flexible self-healing cover, while uniform riprap is more rigid and cannot withstand movement of the stones. Graded riprap is cheaper to install, requiring only that the stones be dumped so that they remain in a well-graded mass. Hand or mechanical placement of individual stones is limited to that necessary to achieve the proper thickness and line. Uniform riprap requires placement in a more or less uniform pattern, requiring more hand labor or mechanical effort.

Riprap sizes can be designated by either the diameter or the weight of the stones. It is often misleading to think of riprap in terms of diameter, since the stones should be rectangular instead of spherical. However, it is simpler to specify the diameter of an equivalent size of spherical stone. Table RR-1 lists some typical stones by weight, spherical diameter and the corresponding rectangular dimensions. These stone sizes are based upon an assumed specific weight of 165 lbs/ft .

Table RR-1. Size of Riprap Stones

Weight (lbs)	Mean Spherical Diameter (ft)	Rectangular Shape	
		Length (ft)	Width, Height (ft)
50	0.8	1.4	0.5
100	1.1	1.75	0.6
150	1.3	2.0	0.67
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1000	2.2	3.7	1.25
1500	2.6	4.7	1.5
2000	2.75	5.4	1.8
4000	3.6	6.0	2.0
6000	4.0	6.9	2.3
8000	4.5	7.6	2.5
20000	6.1	10.0	3.3

Since graded riprap consists of a variety of stone sizes, a method is needed to specify the size range of the mixture of stone. This is done by specifying a diameter of stone in the mixture for which some percentage, by weight, will be smaller. For example, d_{85} refers to a mixture of stones in which 85% of the stone by weight would be smaller than the diameter specified. Most designs are based on d_{50}. In other words, the design is based on the average size of stone in the mixture. The State of Alabama Highway Department classifies riprap according to Table RR-2.

Table RR-2. State of Alabama Highway Department Graded Riprap

Class	Weight (lbs.)					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

2. Sequence of Construction. Since riprap is used where erosion potential is high, construction must be sequenced so that the riprap is put in place with the minimum possible delay. Disturbance of areas where riprap is to be placed should be undertaken only when final preparation and placement of the riprap can follow immediately behind the initial disturbance. Where riprap is used for outlet protection, the riprap should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.

Design Criteria

Gradation. The riprap shall be composed of a well-graded mixture down to the one inch size particle such that 50% of the mixture by weight shall be larger than the d_{50} size as determined from the design procedure. A well-graded mixture as used herein is defined as a mixture composed primarily of the larger stone sizes but with a sufficient mixture of other sizes to fill the progressively smaller voids between the stones. The diameter of the largest stone size in such a mixture shall be 1.5 times the d_{50} size.

The designer, after determining the riprap size that will be stable under the flow conditions, shall consider that size to be a minimum size and then, based on riprap gradations actually available in the area, select the size or sizes that equal or exceed the minimum size. The possibility of damage by children shall be considered in selecting a riprap size, especially if there is nearby water to toss the stones into.

Thickness. The minimum thickness of the riprap layer shall exceed the maximum stone diameter by 6 inches and the total thickness cannot be less than 18 inches.

Quality of Stone. Stone for riprap shall consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone shall be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it shall be suitable in all other respects for the purpose intended. The specific gravity of the individual stones shall be at least 2.5.

Rubble concrete may be used provided it has a density of at least 150 pounds per cubic foot, and otherwise meets the requirements of this Standard and Specification.

Riprap at Outlets. Design criteria for sizing the stone and determining the dimensions of riprap pads used at the outlet of drainage structures are contained in outlet protection.

Riprap for Channel Stabilization. Riprap for channel stabilization shall be designed to be stable for the condition of full bank flow in the reach of channel being stabilized. The *Alabama Handbook* contains a procedure from the *Federal Highway Administration's Design of Stable Channels with Flexible Linings* that can be used for this design.

Riprap shall extend up the banks of the channel to a height equal to the maximum depth of flow or to a point where vegetation can be established to adequately protect the channel.

The riprap size to be used in a channel bend shall extend upstream from the point of curvature and downstream from the point of tangency a distance of at least 5 times the channel bottom width.

Where riprap is used only for bank protection and does not extend across the bottom, of the channel, riprap shall be keyed into the bottom of the channel to a minimum depth equal to the thickness of the blanket and shall extend across the bottom of the channel the same distance. (See Figure RR-1).

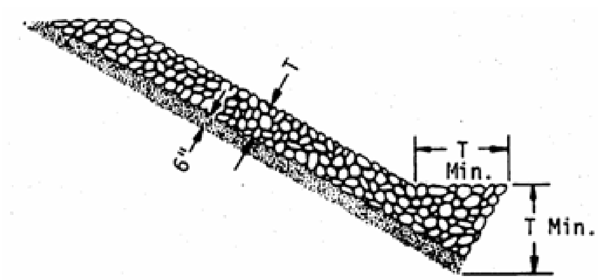

Figure RR-1. Riprap channel bank protection toe requirements.

Riprap for Slope Stabilization. Riprap for slope stabilization shall be designed so that the natural angle of repose of the stone mixture is greater than the gradient of the slope being stabilized.

Filter Blankets. A filter blanket is a layer of material placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap.

A filter blanket can be of two general forms: a gravel layer or a geotextile filter cloth. A determination of the need for a filter blanket is made by comparing particle sizes of the overlying material and the base material in accordance with the criteria below.

Gravel filter blanket. The following relationships must exist:

$$\frac{d_{50} filter}{d_{85} base} < 5 < \frac{d_{15} filter}{d_{15} base} < 40$$

and

$$\frac{d_{50}filter}{d_{50}base} < 40$$

In these relationships, filter refers to the overlying material and base refers to the underlying material. The relationships must hold between the filter material and the base material and between the riprap and the filter material. In some cases, more than one layer of filter material may be needed. Each layer of filter material should be approximately 6 inches thick.

Geotextile filter cloth: Geotextile filter cloth may be used in place of or in conjunction with gravel filters. The following particle size relationships must exist:

1. For filter cloth adjacent to granular materials containing 50 percent or less (by weight), of fine particles (less than 0.074 mm):

a) $$\frac{d_{85}base\ (mm)}{EOS^{*}\ filter\ cloth\ (mm)} > 1$$

b) Total open area of filter is less than 36 percent

2. For filter cloth adjacent to all other soils:

a) EOS* less than U. S. Standard Sieve No. 70.

b) Total open area of filter is less than 10 percent.

No filter cloth should be used with less than 4 percent open area or an EOS* less than U. S. Standard Sieve No. 100.

*EOS - Equivalent Opening Size to a U. S. Standard Sieve Size.

Filter blankets should always be provided where seepage from underground sources threatens the stability of the riprap.

Table RR. Selected U.S. Standard Sieve Sizes

U.S. Standard Sieve Sizes	Sieve Screen Opening (μm, unless otherwise noted)	Sieve Screen Opening (inch)
#4 in	100 mm	4.0
#3 in	75 mm	3.0
#2 in	50 mm	2.0
#1 in	25 mm	1.0
#3/4 in	19.0 mm	0.75
#5/8 in	16.0 mm	0.63
#3/8 in	9.5 mm	0.38
#1/2 in	12.5 mm	0.500
#1/4 in	6.3 mm	0.250
No. 4	4.75 mm	0.187
No. 6	3.35 mm	0.132
No. 8	2.36 mm	0.0929
No. 10	2.00 mm	0.0787
No. 12	1.70 mm	0.0669
No. 14	1.40 mm	0.0555
No. 16	1.18 mm	0.0465
No. 18	1.00 mm	0.0394
No. 20	850	0.0335
No. 25	710	0.0278
No. 35	500	0.0197
No. 40	425	0.0167
No. 45	355	0.0139
No. 50	300	0.0118
No. 60	250	0.0098
No. 70	212	0.0083
No. 80	180	0.0070
No. 100	150	0.0059
No. 120	125	0.0049
No. 140	106	0.0041
No. 170	90	0.0035
No. 230	63	0.0017
No. 270	53	0.0021

No. 325	45	0.0017
No. 400	38	0.0015
No. 450	32	0.0013
No. 500	25	0.0010
No. 635	20	0.0008

Maintenance
Once a riprap installation has been completed, it should require very little maintenance. However, it should be inspected periodically to determine if high flows have caused scour beneath the riprap or dislodged any of the stone. If repairs are needed, they should be accomplished immediately.

Construction Specifications for Riprap
Subgrade Preparation: The subgrade for the riprap or filter shall be prepared to the required lines and grades. Any fill required in the subgrade shall be compacted to a density approximating that of the surrounding undisturbed material. Brush, trees, stumps and other objectionable material shall be removed.

Filter Blanket: Placement of the filter blanket should be done immediately after slope preparation. For gravel filters the stone should be spread in a uniform layer to the specified depth. Where more than one layer of filter material is used, the layers should be spread so that there is minimal mixing of the layers.

For geotextile filter cloths, the cloth should be placed directly on the prepared slope. The edges of the sheets should overlap by at least 12 inches. Anchor pins, supplied by the manufacturer, should be spaced every 3 feet along the overlap. The geotextile material should not be stretched tight but should be loosely placed on the prepared surface. The upper and lower ends of the cloth should be buried a minimum of 12 inches deep. Care should be taken not to damage the cloth when placing the riprap. If damage occurs, that sheet should be removed and replaced. For large stone (12 inches or greater), a 4-inch layer of gravel may be necessary to prevent damage to the cloth.

Stone Placement: Placement of riprap should follow immediately after placement of the filter. The riprap should be placed so that it produces a dense well-graded mass of stone with a minimum of voids. The desired distribution of stones throughout the mass may be obtained by selective loading at the quarry, controlled dumping of successive loads during final placing, or by a combination of these methods. The riprap should be placed to its full thickness in one operation. The riprap should not be placed in layers. The riprap should not be placed by dumping into chutes or similar methods which are likely to cause segregation of the various stone sizes. Care should be taken not to dislodge the underlying material when placing the stones.

The finished slope should be free of pockets of small stone or clusters of large stones. Hand placing may be necessary to achieve the required grades and a good distribution of stone sizes. Final thickness of the riprap blanket should be within plus or minus 1/4 of the specified thickness.

Check Dam (CD)

SCS photo

Definition
Small barriers or dams constructed across a swale, drainage ditch or areas of concentrated flow.

Purpose
To prevent or reduce erosion by lessening the gradient of the flow channel which reduces the velocity of storm water flows. Some sediment will be trapped upstream from the check dams, but its volume will be insignificant and should not be considered in off-site sediment reduction.

Conditions Where Practice Applies
This measure is limited to use in small open channels and drainageways which drain 10 acres or less. It should not be used in a live stream. Specific applications include:

1. Temporary ditches or water courses which, because of their short length of service, cannot establish a nonerodible lining but still need some protection against erosion.

2. Permanent ditches or water courses which for some reason cannot establish an enduring non-erodible lining.

3. Either temporary or permanent ditches or water courses which need protection during the establishment of protective linings.

Planning Considerations
Check dams may be constructed of rock, logs, hay bales or other suitable material. Most check dams would be constructed of rock. Rock may not be acceptable in some installations because of aesthetics and hay bales or logs may need to be considered.

Rock check dams (Figures CD-1 and CD-2) are easier to install with backhoes or other suitable equipment. The rock is usually purchased and would increase cost. Some locations may not have rock readily available. Rock should be handled carefully in areas to be mowed. Some rock may be washed downstream and should be removed before each mowing operation.

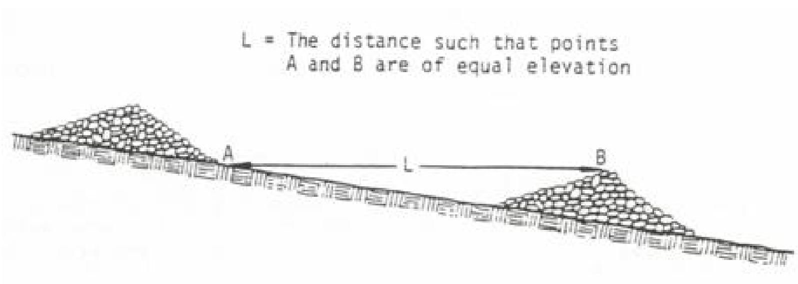

Figure CD-1. Spacing of typical rock check dams.

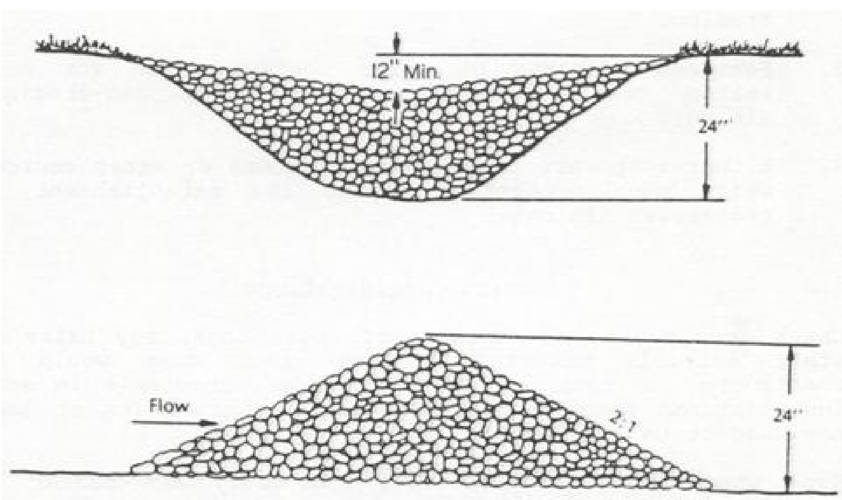

Figure CD-2. Cross sections of rock check dam.

Check dams should be planned to be compatible with the other features such as streets, walks, trails, sediment basins and rights-of-way or property lines. Check dams may be constructed in series and the dams should be located at a normal interval from other grade controls such as culverts or sediment basins. Needed hydraulic conveyance must also be confirmed.

Check dams constructed of hay bales (Figure CD-3) have the shortest life of the materials discussed. Hay bale check dams should not be used where permanent water course protection is needed. They should not be used where the drainage areas exceeds 5 acres.

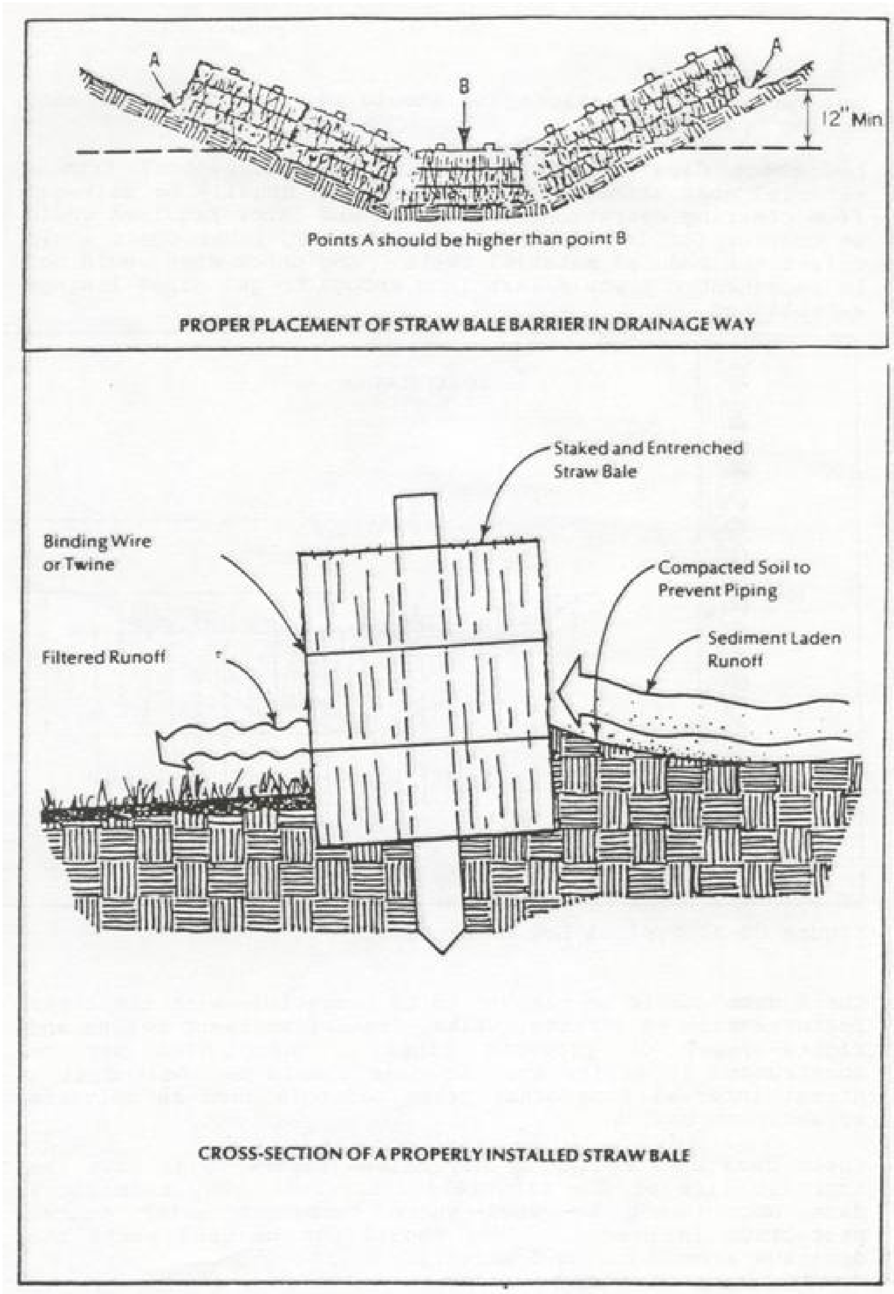

Figure CD-3. Typical hay bale check dam.

Design Criteria
Formal design is not required. The following limiting factors shall be adhered to when designing check dams:

- Drainage Area: 10 acres or less (Rock)
  5 acres or less (Hay bale Check Dam)

- Maximum Height: 2 feet when drainage area is less than 5 acres
  3 feet when drainage area is 5 to 10 acres

- Depth of Flow: 6 inches when drainage area is less than 5 acres
  12 inches when drainage area is 5 to 10 acres

- Side Slopes: 2:1 or flatter

- Max. Spacing between dams: Elevation of toe of upstream dam is at or below elevation of crest of downstream dam.

Top of dam, perpendicular to flow, should be parabolic. The center of the dam must be lower than the ends. The dam shall be constructed well into the abutment so that water cannot run around the dam.

Rock check dams should be constructed of durable rock riprap. Riprap gradation shall conform to the requirements of Class I Riprap, Alabama Highway Department, Standard Specification for Highway Construction, or equivalent.

Maintenance
Check dams may be removed when their useful life has been completed. Whenever check dams are removed, care shall be taken to minimize disturbance to the remainder of the watercourse.

The area where check dams are removed shall be shaped and smoothed to water course dimensions and seeded and mulched immediately. On rock check dams, care shall be taken to remove all rock if the area is to be mowed.

Periodic inspection is necessary on check dams. Repair should be done as soon as need is noted to minimize damage and expense of repair.

Pond Outlet Protection (OP)

Definition
Structurally lined aprons of riprap, concrete or other acceptable energy dissipating devices placed at the outlets of pipes or paved channel sections.

Purpose
To prevent scour at stormwater outlets and to minimize the potential for downstream erosion by reducing the velocity of concentrated stormwater flows.

Conditions Where Practice Applies
Applicable to the outlets of all pipes and paved channel sections where the velocity of flow at design capacity of the outlet will exceed the permissible velocity of the receiving channel or area. To prevent scour at stormwater outlets, a flow transition structure is needed which will absorb the initial impact of the flow and reduce the flow velocity to a level which will not erode the receiving channel or area.

Planning Considerations
The outlets of pipes and structurally lined channels are points of critical erosion potential. Stormwater which is transported through man-made conveyance systems at design capacity generally reaches a velocity which exceeds the ability of the receiving channel or area to resist erosion. To prevent scour at stormwater outlets, a flow transition structure is required which will absorb the initial impact of the flow and reduce the flow velocity to a level which will not erode the receiving channel or area.

The most common used structure for outlet protection is an erosion resistant lined apron. These aprons are generally lined with loose rock riprap, grouted riprap or concrete. They are constructed at zero grade for a distance which is related to the outlet flow rate and the tailwater level. Criteria for designing these structures are contained in this standard.

Where the flow is excessive for the economical use of an apron, excavated stilling basins may be used. Acceptable designs for stilling basins may be found in the following documents available from the U. S. Government Printing Office.

> *Hydraulic Design of Energy Dissipators for Culverts and Channels*, Hydraulics Engineering Circular No. 14, U. S. Department of Transportation, Federal Highway Administration.
>
> *Hydraulic Design of Stilling Basins and Energy Dissipators*, Engineering monograph No. 25 U. S. Department of Interior - Bureau of Reclamation.

Design Criteria
Structurally lined aprons at the outlets of pipes and paved channel sections shall be designed according to the following criteria:

Pipe Outlets (Figure OP-1)

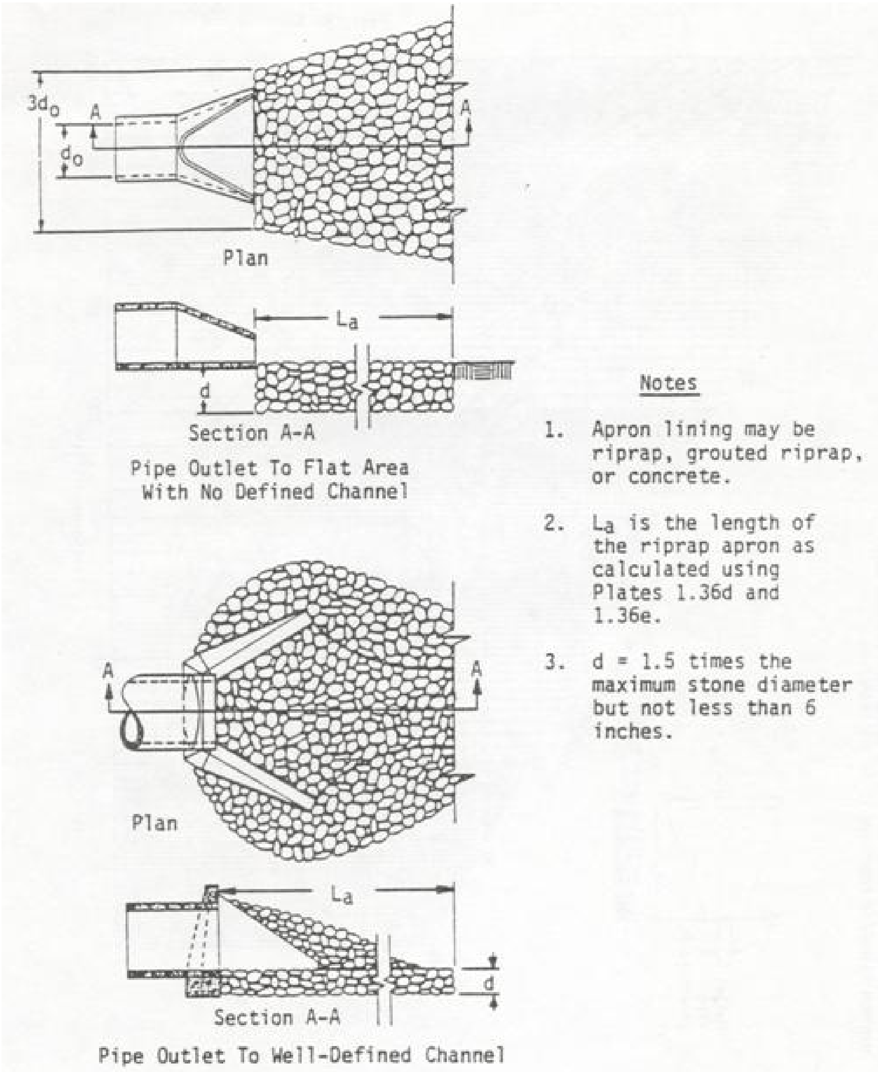

Figure OP-1. Pipe outlet conditions.

Tailwater - The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth. If the tailwater depth is less than half the diameter of the outlet pipe, it shall be classified as a Minimum Tailwater Condition. If the tailwater depth is greater than half the pipe diameter, it shall be classified as a Maximum Tailwater Condition. Pipes which outlet to flat areas with no defined channel may be assumed to have a Minimum Tailwater Condition.

Apron Length - The apron length shall be determined from Figure OP-2 or OP-3 according to the tailwater condition.

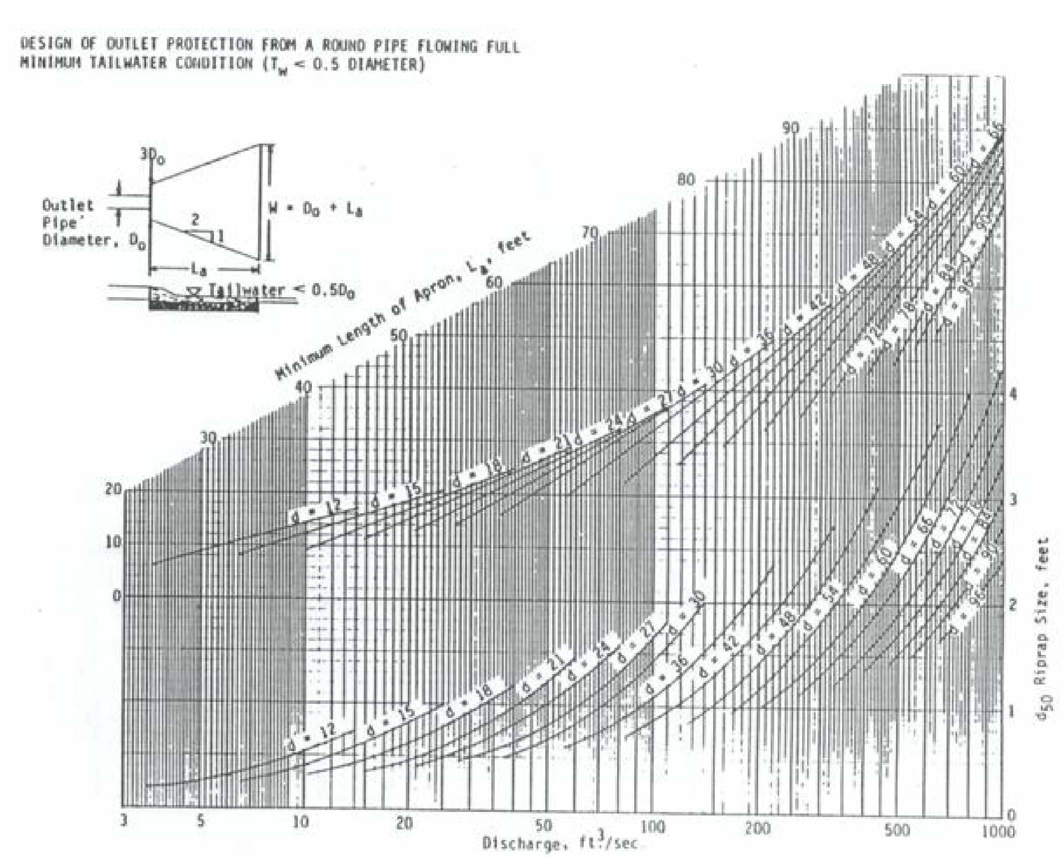

Figure OP-2. Outlet protection design for tailwater < 0.5 diameter.

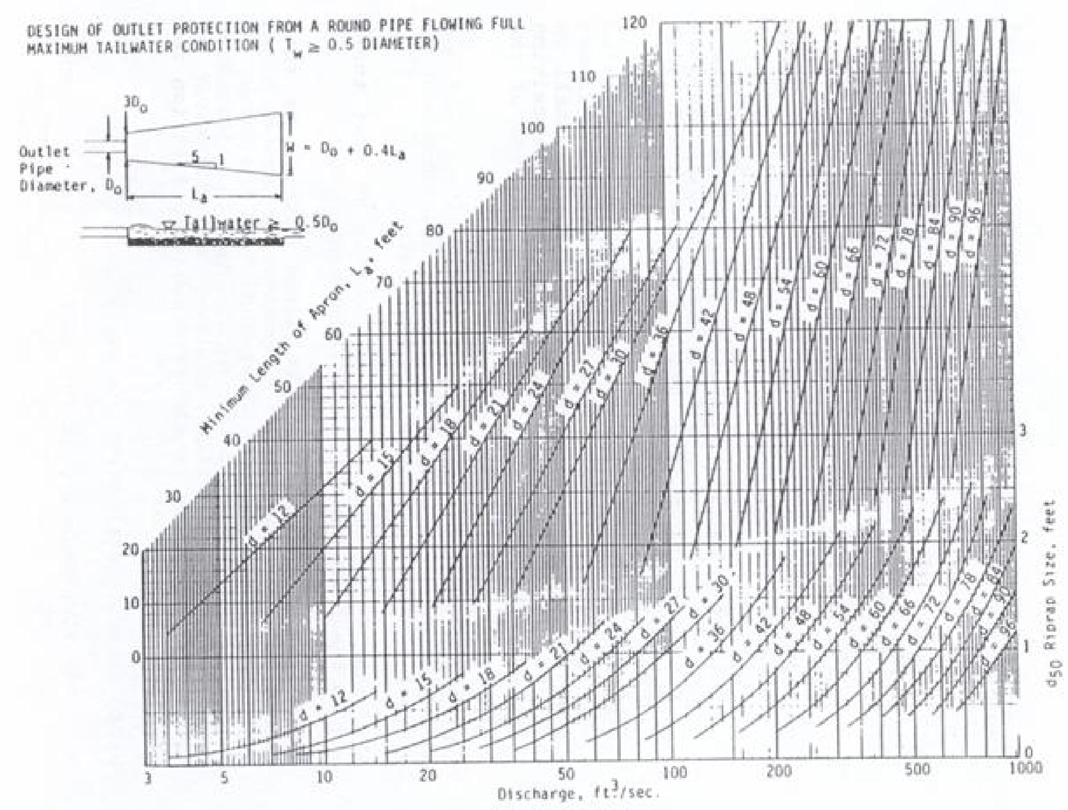

Figure OP-3. Outlet protection design for tailwater ≥ 0.5 diameter.

Apron Width - If the pipe discharges directly into a well-defined channel, the apron shall extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank (whichever is less).

If the pipe discharges onto a flat area with no defined channel, the width of the apron shall be determined as follows:

a. The upstream end of the apron, adjacent to the pipe, shall have a width three times the diameter of the outlet pipe.

b. For a Minimum Tailwater Condition, the downstream end of the apron shall have a width equal to the pipe diameter plus the length of the apron obtained from the figures.

c. For a Maximum Tailwater Condition, the downstream end shall have a width equal to the pipe diameter plus 0.4 times the length of the apron from Figures OP-2 or OP-3.

Bottom Grade - The apron shall be constructed with no slope along its length (0.0% grade). The invert elevation of the downstream end of the apron shall be equal to the elevation of the invert of the receiving channel. There shall be no overfall at the end of the apron.

Side Slope - If the pipe discharges into a well-defined channel, the side slopes of the channel shall not be steeper than 2:1 (Horizontal : Vertical).

Alignment - The apron shall be located so that there are no bends in the horizontal alignment.

Materials - The apron may be lined with loose rock riprap, grouted riprap, or concrete. The median sized stone for riprap shall be determined from the curves on Figure OP-2 and OP-3 according to the tailwater condition. The gradation, quality, and placement of riprap shall conform to Standard and Specification for Riprap presented earlier.

Paved Channel Outlets (Figure OP-4)

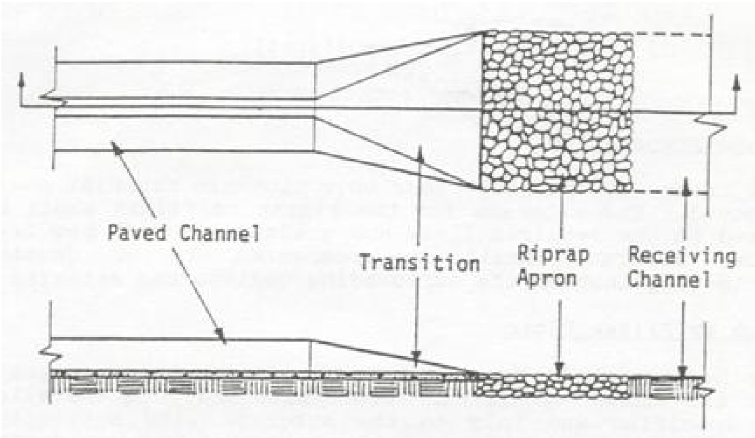

Figure OP-4. Paved channel outlet.

1. The flow velocity at. the outlet of paved channels flowing at design capacity must not exceed the permissible velocity of the receiving channel.

2. The end of the paved channel shall merge smoothly with the receiving channel section. There shall be no overfall at the end of the paved section. Where the bottom width of the paved channel is narrower than the bottom width of the receiving channel, a transition section shall be provided. The maximum side divergence of the transition shall be 1 in 3F where:

F = Froude number = V/gD
V = Velocity at beginning of transition (ft/sec)
d = depth of flow at beginning of transition (ft)
g = 32.2 ft/sec^2

3. Bends or curves in the horizontal alignment of the transition are not allowed unless the Froude number (F) is 0.8 or less (implying supercritical flow), or the section is specifically designed for turbulent flow.

Maintenance
Inspect riprap outlet after heavy rains to see if any erosion around or below the riprap has taken place or if stones have been dislodged. Immediately make all needed repairs to prevent further damage.

Construction Specification for Outlet Protection
Subgrade Preparation. Brush, trees, stumps, and other objectionable material shall be removed. The subgrade for the riprap or filter shall be prepared to the required lines and grades. Any fill required in the subgrade shall be compacted to a density approximating that of the surrounding undisturbed material.

Bedding or Filter Cloth. Filter bedding shall be placed to the depth, line and grade and in the manner specified. Geotextile shall be installed where specified and laid on the subgrade with sufficient slack so that it will not suffer extreme tension during placement of riprap or other linings.

Stone Placement. Placement of riprap should follow immediately after subgrade preparation. The riprap should be placed so that it produces a dense well-graded mass of stone with a minimum of voids. The desired distribution of stones throughout the mass may be obtained by selective loading at the quarry, controlled dumping of successive loads during final placing, or by a combination of these methods.

The riprap should be placed to its full thickness in one operation, not in layers. The riprap should not be placed by dumping into chutes or similar methods which are likely to cause segregation of the various stone sizes. Care should be taken not to dislodge the underlying material when placing the stones. Some hand placing may be necessary to achieve the required grades and a good distribution of stone sizes.

Use of Newly Developed Erosion Controls
The following presents some brief information concerning new products for controlling soil erosion at construction sites. This is a rapidly expanding area, but these two product categories (chemicals to bind soil particles and inlet protection devices) seem to

have the most products being developed. Few of these products have been evaluated in comprehensive field tests, but it is hoped they will offer additional tools to the erosion control professional. The following are only examples of a few of these alternatives, many more exist and this listing is not intended to be comprehensive, or an endorsement.

Chemical Treatment of Exposed Soils

There are a number of new products being developed and sold for the control of erosion and sediment at construction sites. One emerging area is the use of chemical polymers and coagulant agents. Older chemical products were mostly soil binding agents, including light asphalts. These newly developed materials act by chemically combining small soil particles into larger discrete particles that are more effective in settling in ponds and in channels. Polyacrylamide (PAM) is the most common chemical being sold now. The following information is from the Internet sites from several distributors or manufactures of some of these chemicals. This list is very short and is not intended to include all products.

JRM Chemicals, Inc. (http://www.soilmoist.com/agerosion.html)

Products:

1) FI-1000 Soil Erosion Polymer: FI-1000 is an anionic high molecular weight polymer designed to reduce soil loss and silt loss in furrow irrigation applications. FI-1000 will increase water infiltration and reduce fertilizer and other chemical runoff. The anionic polymer bonds the suspended particles in the water and they fall to the bottom of the water. Its application rate is one pound per acre (into 12,000 gallons of water).

2) FI-2000: FI-2000 is an anionic high molecular weight water-soluble polymer designed to reduce soil loss and silt loss in all aspects of agricultural irrigation. FI-2000 is an emulsion that can be applied to furrow, gated pipe, sprinkler and pivotal irrigation systems. Its application rate is 30 ppm.

Polyacrylamide (PAM)
The University of Nebraska Cooperative Extension service (http://www.ianr.unl.edu/pubs/water/g1356.htm) provides the following information on PAM. Polyacrylamide (PAM) is a long-chain synthetic polymer that acts as a strengthening agent, binding soil particles together. It is harder for water to move these larger, heavier particles of soil. USDA researchers in Kimberley, Idaho began working with PAM in the early 1990s as a method to reduce erosion in furrow irrigation. Their tests indicated PAM applied in the irrigation water reduced soil erosion in furrows by over 95 percent, when compared to irrigation without the polymer.

Polyacrylamide used for erosion control should have a negative (anionic) molecular charge. Historically, similar compounds have been used in other industries like potable water treatment, food processing, paper manufacturing and wastewater treatment. Research conducted in Idaho showed that less than 5 percent of PAM applied during an irrigation left fields in the runoff water. This research also showed that after leaving the field, the PAM concentration in the runoff quickly fell below detectable limits (>1,500 yards). There is no indication of any adverse impact on soil, plant or aquatic systems when anionic PAM is used to control soil erosion. Because PAM limits soil erosion, using it can prevent attached pollutants from also leaving the area.

Many companies distribute PAM. HYDROSORB (1390 N. Manzanita St., Orange, CA 92867) presents the following information for their products. SOILFLOC™ is a water-soluble, linear polyacrylamide (PAM) polymer that was designed to be used for erosion control, soil structure improvement and dust abatement. SOILFLOC™ works by aggregating soil particles, increasing pore space and infiltration capacity, resulting in soils that are less susceptible to raindrop and scour erosion. SOILFLOC™ is environmentally safe and non-toxic. A variety of PAM products have been approved by NSF International for potable water clarification. They will naturally degrade with UV light and are consumed by microbiological attack. This product is compatible with almost all irrigation systems. PAM products are now registered throughout the western United States. MSDS and TDS available upon request. SOILFLOC™ is available in a dry granule form, liquid emulsion, and tablets.

HydroGrass Technologies (http://www.hydrograsstech.com/cleansing.php) also supplies PAM. The following describes their products:

APS 600 Series Silt Stop®
Polyacrylamide Erosion Control Emulsion
A soil specific tailored polyacrylamide copolymer liquid emulsion for erosion control. It reduces and prevents erosion of fine particles and colloidal clays from water. Applied with a water truck of hydroseeder or other spraying devices at a rate of 1 1/2 gallons per acre.

APS 700 Series Silt Stop®
Polyacrylamide Erosion Control Powder
A soil specific tailored polyacrylamide copolymer powder for erosion control. Used to reduce and prevent erosion of fine particles.

Settles our suspended particles of sediment and colloidal clays from water. Applied with a hand spreader, mechanical disc or can be mixed with water and applied with a spraying device at a rate of approximately 10 pounds per acre.

APS Floc Log®
Polyacrylamide Semi-hydrated Gel Block
A soil and water chemistry tailored gel block, that when placed within stormwater or construction site damages will remove fine colloidal particles and reduce NTU values. Floc Logs are staked in place in a location close to active earth moving activities and can also be used in drop inlets, storm drains, retrofits and slope drains. The APS Floc Log will treat a flow rate of 60 to 75 gallons per minute.

Proprietary Inlet Protection Devices

Nutec Supply:
http://www.nutec-supply.com/erosion/inlet/#post

Crow Company:
http://www.geosyntheticproducts.com/Erosion_Control/erosion_control.html

EarthSaver Company:
http://www.earth-savers.com/index.html?Main%20Window=applictn.html

EPA discussion on inlet protection:
http://www.epa.gov/npdes/menuofbmps/site_17.htm

References

Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulics Engineering Circular No. 14, U. S. Department of Transportation, Federal Highway Administration.

Hydraulic Design of Stilling Basins and Energy Dissipators, Engineering monograph No. 25 U. S. Department of Interior - Bureau of Reclamation.

USDA. *Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas*, prepared by the Alabama Soil and Water Conservation Committee, Montgomery, AL. 1993