4.6 Drainage System Controls

General Information

Construction site ditches, curb inlets, drop inlets, inlets to culverts, and other areas where muddy runoff flows toward the stormwater conveyance system need to be protected. Ditches are protected with a variety of liners: grass-seeded turf reinforcement mats, riprap, gabions, pavement, or other material as appropriate. The long-term management of ditches and channels as stable, vegetated, *natural* drainage systems with native vegetation buffers is highly recommended because of the inherent stability offered by grasses, shrubs, trees, and other vegetation; greater visual and other aesthetic benefits provided by native plant buffers; and higher habitat and property values.

Ditches and Channels

During the construction phase, ditches and channels with gently sloping bottoms (less than 3 percent) can be stabilized with thick grass seedings and erosion control blankets if needed. Moderately sloping channels (3–6 percent slopes) will likely require TRMs and perhaps riprap if soils have high silt content. Steeply sloping channels (greater than 10 percent) need heavier armoring with concrete, riprap, gabions, geogrid, grade control structures, or other measures.

Silty soils are the most erodible, and clay is the least erodible. Steeper ditches and channels and those with highly erodible soils need more protection. Ditch or channel bank slopes should not exceed 2:1. If tractor mowers or other equipment will cross channels in the future, bank slopes should be 3:1 or flatter. Ditches and channels must be constructed and stabilized as soon as possible or before the channel receives incoming flows.

Culvert Inlets and Outlets

The basic approach for inlet protection is to create or install a structure that ponds or filters the flow, which facilitates sediment removal through settling or physical filtration. Outlet protection involves erosion prevention in the receiving ditch, channel, pond, or other area so that high-flow scour forces can be dissipated before localized erosion occurs.

A wide variety of ditch protection and ponding or filtration products have been developed for construction site applications. These products can provide excellent performance if used correctly, but often they are installed improperly, not maintained, or otherwise misused. Following the manufacturer's instructions is essential when using commercial products.

The following sections describe both rock and commercial ditch, inlet, and outlet protection approaches and devices. Rock of various sizes (see table below) is often used to stabilize ditches, construct inlet ponding dams, and armor pipe outlets to dissipate erosive flows. Commercial products are also gaining in popularity, and some (e.g., gravel-filled bags, commercial sediment dams, filter bags) can often be reused, if care is taken to protect them from vehicles and equipment during construction.

Good construction of drainage ditch, with riprap liner for steeply sloping section (background) and erosion control blanket over triple-seeding in flatter area. Ditches should be stabilized or seeded and mulched immediately after construction.

General Stabilization Approaches for Ditches and Channels

Channel Slope	Soil Type along Banks		
	Sandy	*Silty*	*Clays*
Steep > 10%	Pavement, gabions, or riprap with non-woven filter fabric	Pavement, gabions, or riprap with non-woven filter fabric	Riprap with non-woven filter fabric or gabions
Moderate ~ 10%	Riprap with non-woven filter fabric or gabions	Riprap or cellular geogrid or TRMs & seeding	Riprap or cellular geogrid or TRMs & seeding
Slight ~ 5%	Riprap or TRMs & seeding	Seeding & TRMs	Seeding & TRMs
Mostly Flat < 3%	Seeding & ECBs	Seeding & mulching	Seeding & mulching

Rock Sizing and Weight Information

KYTC coarse aggregate sizing	
Aggregate Size (KYTC Size No.)	***Mean Spherical Diameter (d50) (inches)***
1	3.5
2	2.5
23	2.5
3	2.0
357	2.0
4	1.5
467	1.5
5	1.0
57	1.0
610	1.0
67	0.75
68	0.75
710	0.75
78	0.50
8	0.375

This is a good example of a rock-lined ditch for conveying high velocity flows. Ditch was lined with rock after construction; surrounding areas should be seeded and mulched as quickly as possible to eliminate opportunities for sediment runoff.

4.6.1 Curb Inlet Sediment Barrier

Protect inlets with commercial dike products or site-fabricated ponding berms made of rock, wire, or other material. If structures and ponding within roadway areas are a problem, use inlet filter bags or other low-profile products. For best results, require that sediment be retained on landscaped areas and not discharged into roadways or parking lots.

Definition

Curb inlet sediment barriers are temporary dikes or barriers constructed from concrete block, gravel, gravel-filled fiber bags, filter fabric, or other material.

Purpose

Curb inlet sediment barriers are intended to reduce the sediment discharged into storm drains by ponding the runoff and allowing the sediment to settle out. The structures allow for overflow from high runoff events, and the gravel allows the area to dewater rapidly. Some proprietary curb inlet protection devices feature a frame that supports a geotextile that promotes physical filtration of sediment in muddy runoff. Most devices—proprietary or constructed on-site—will function appropriately if assembled and placed properly.

All inlet dams and filters are intended to provide temporary treatment (i.e., until the upslope catchment area is vegetated or otherwise stabilized). A feature in using inlet protection devices is to minimize the length of time they are needed by getting the upstream area to final grade and seeding and mulching as soon as possible.

Design Criteria

There is no formal design, though design notes should specify that dikes or filters intercept all muddy flows toward the inlet without bypasses. The sediment barriers can be used at curb inlets on gently sloping, paved streets where

- Water can pond and allow sediment to separate out of suspension
- Runoff is relatively low, less than 0.5 cubic feet per second

Once the small catchment areas behind the fiber bags or block and gravel fill with sediment, future sediment-laden runoff will enter the storm drain without being treated. Therefore, sediment must be removed from these structures after each storm. Additional storage can be obtained by constructing a series of sandbag barriers along the gutter so that each barrier traps small amounts of sediment.

Construction Specifications

General

Place the barriers on gently sloping streets where water can pond. Note that devices placed in the roadway or that cause ponding on roads open to traffic could present a safety hazard; if this will be a problem, use filters with frames that lay against the curb, drop inlet filter bags, or other low-profile devices.

The barriers must allow for overflow from a severe storm event. Slope runoff must be allowed to flow over blocks and gravel and not be bypassed over the curb. A spillway must be constructed with dike structures to allow overflow.

If using fiber bags filled with gravel, the bag should be of woven-type geotextile fabric because burlap bags deteriorate rapidly. The bags must be filled with three-quarter inch drain rock or one-quarter inch pea gravel. Fill fiber bags just over halfway so they can be packed tightly together without large gaps.

The fiber bags must be placed in a curved row from the top of curb at least 3 feet into the street. The row should be curved at the ends, pointing uphill, and be tied into the curbing to prevent bypasses. Several layers of bags should be overlapped and packed tightly. Leave a one-sandbag gap in the top row to act as a spillway.

Block and Gravel Type Barriers

Place two concrete blocks on their sides perpendicular to the curb at either end of the inlet opening. These will serve as spacer blocks.

Place concrete blocks on their sides across the front of the inlet and abutting the spacer blocks. The openings in the blocks should face outward, not upward.

Cut a 2 by 4 inch stud the length of the curb inlet plus the width of the two spacer blocks. Place the stud through the outer hole of each spacer block to help keep the front blocks in place.

Place wire mesh over the outside vertical face (open ends) of the concrete blocks to prevent stone from being washed through the blocks. Use chicken wire, hardware cloth with half inch openings, or filter fabric.

Place three-quarter to one and a third inch gravel against the wire to the top of the barrier.

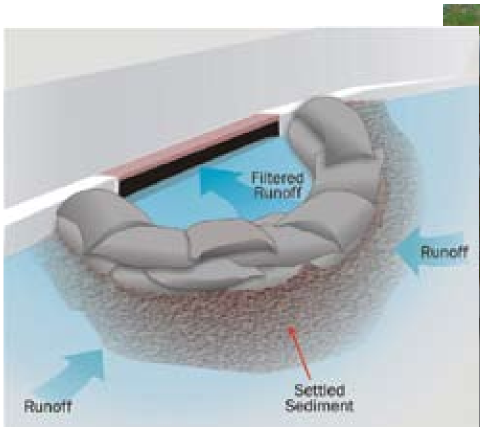
Inspection and Maintenance

Inspect and clean barrier weekly and after each rainfall greater than one-half inch, and remove sediment from behind the sandbag structure.

Immediately remove any sediment and gravel from the traveled way of roads.

Place the removed sediment where it cannot enter a storm drain, stream, or be transported off site.

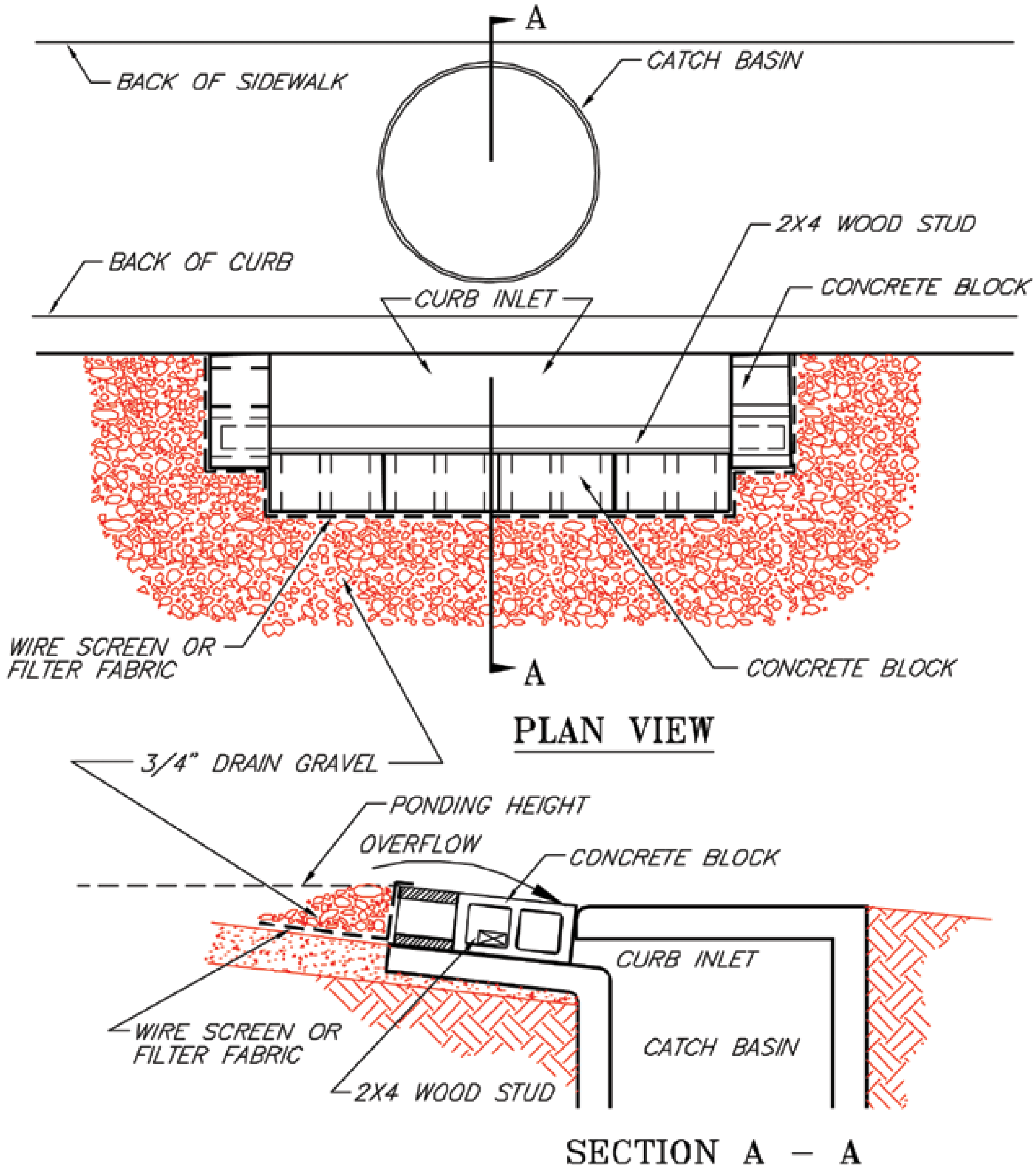
If the gravel becomes clogged with sediment, carefully remove it from the inlet and either clean or replace it.



Use half-filled stone bags to create a versatile and effective ponding berm in front of inlets. Make sure there are no bypasses.

This is a ponding dike fabricated from perforated, flexible plastic pipe and fabric sock appears to be trapping sediment—note deposits. Accumulated sediment should be removed after rains to ensure storage capacity for the next storm.

This shows poor maintenance on inlet protection device. Do not allow concrete truck washouts or other discharges into the storm sewer system—this is a direct violation of the KPDES stormwater permit!

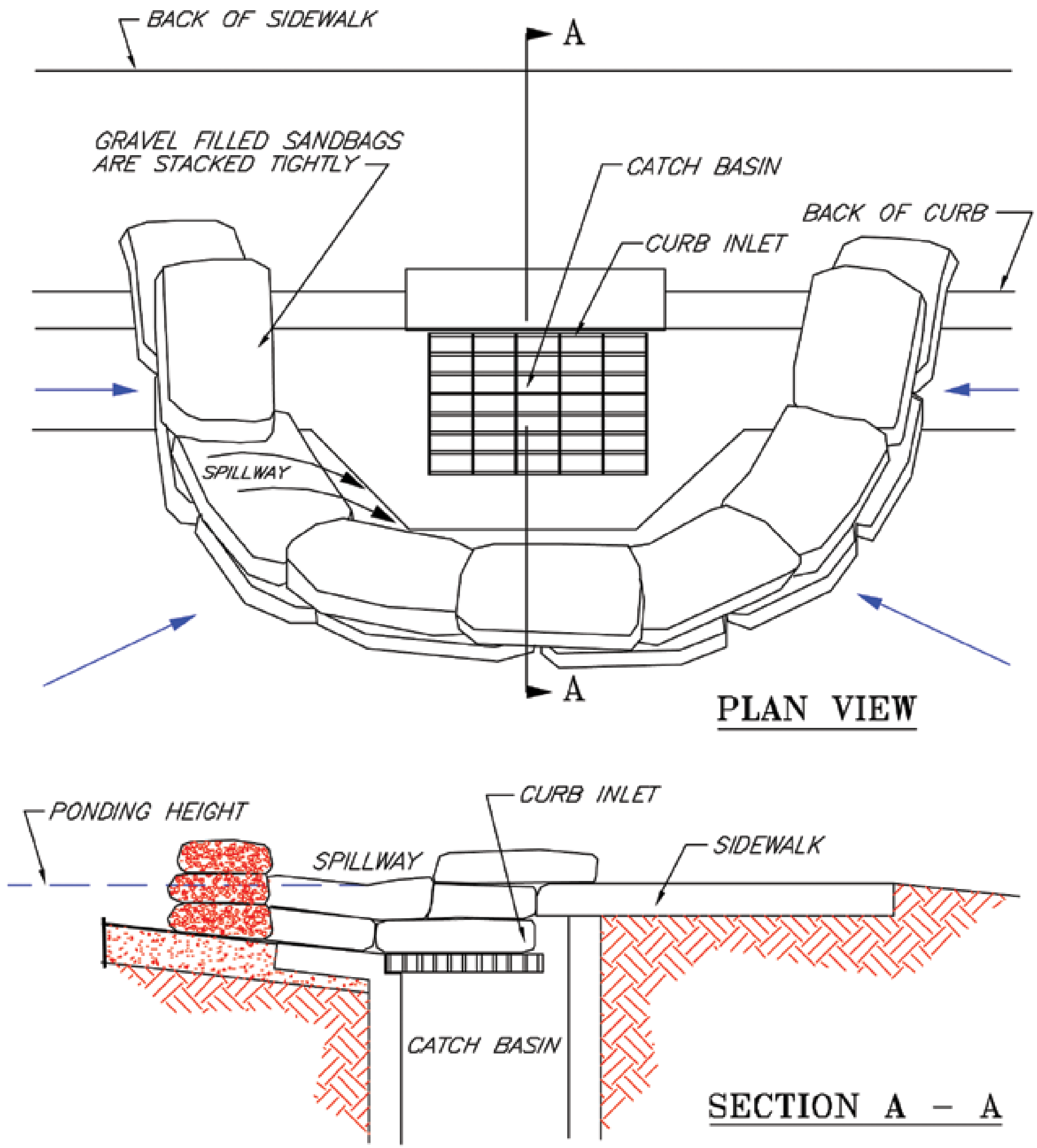


NOTES:

1. USE BLOCK AND GRAVEL TYPE SEDIMENT BARRIER WHEN CURB INLET IS LOCATED IN GENTLY SLOPING STREET SEGMENT, WHERE WATER CAN POND AND ALLOW SEDIMENT TO SEPARATE FROM RUNOFF.
2. BARRIER SHALL ALLOW FOR OVERFLOW FROM SEVERE STORM EVENT.
3. INSPECT BARRIERS AND REMOVE SEDIMENT AFTER EACH STORM EVENT. SEDIMENT AND GRAVEL MUST BE REMOVED FROM THE TRAVELED WAY IMMEDIATELY.

SOURCE: SALIX APPLIED EARTHCARE – EROSION DRAW 5.0

CURB INLET SEDIMENT BARRIER (BLOCK & GRAVEL)



NOTES:

1. PLACE CURB TYPE SEDIMENT BARRIERS ON GENTLY SLOPING STREET SEGMENTS WHERE WATER CAN POND AND ALLOW SEDIMENT TO SEPARATE FROM RUNOFF.
2. SANDBAGS, OF EITHER BURLAP OR WOVEN GEOTEXTILE FABRIC, ARE FILLED HALFWAY WITH GRAVEL, LAYERED AND PACKED TIGHTLY. NETTING BAGS CAN BE USED WITH BALLAST ROCK.
3. LEAVE ONE SANDBAG GAP IN THE TOP ROW TO PROVIDE A SPILLWAY FOR OVERFLOW.
4. INSPECT BARRIERS AND REMOVE SEDIMENT AFTER EACH STORM. SEDIMENT MUST BE REMOVED FROM ROADS IMMEDIATELY.

SOURCE: SALIX APPLIED EARTHCARE — EROSION DRAW 5.0

CURB INLET SEDIMENT BARRIER (SANDBAGS)

4.6.2 Drop Inlet Sediment Barrier

Plastic frames covered with silt fence fabric make good drop inlet protection devices. Stake frames down securely and trench in bottom of fabric to eliminate bypasses. Remove accumulated sediment before it reaches halfway to the top of the fabric. Use inlet barriers during the construction period until upland areas are stabilized (i.e., bare areas are covered with vegetation, gravel, or structures).

Definition

A drop inlet sediment barrier is a temporary barrier placed around or inside a drop inlet that promotes ponding, settling of sediment, or physical filtration of sediment from muddy inflows. The sediment barrier can be constructed of silt fence, geotextile, gravel and stone, or block and gravel. Straw bales should not be used because of their high failure rates caused by improper placement, rotting, and structural weakness.

Purpose

Drop inlet sediment barriers are intended to prevent sediment from entering the storm drains during construction operations. This practice allows early use of the storm drain system. Sediment-laden runoff is ponded or filtered before entering the storm drain, thus allowing some sediment to fall out of suspension or be removed through physical filtration.

Design Criteria

The contributing drainage area should be one acre maximum. The ponding area must be relatively flat (less than 1 percent slope) with a sediment storage of 35 cubic yards per disturbed acre.

All incoming storm flows must be intercepted and ponded or filtered by the structure, and pass over the structure and into the storm drain without bypasses. Temporary diking around the structure might be necessary to prevent bypass flow. Material can be excavated from inside the sediment storage area for this purpose.

Drop inlet bag and frame filters are available from commercial vendors. These devices work very well if installed and maintained properly. Specify frames or filters that fit tightly around inlets and eliminate bypass opportunities. Filters can be reused if they are not damaged and washed out after prior use.

Construction Specifications

Silt Fence Sediment Barrier

Support posts for a silt fence must be steel fence posts or 2 by 4 inch wood, length 3-foot minimum, spacing 3-foot maximum, with a top frame X-brace or other support recommended.

Excavate a trench 4 inches wide and at least 8 inches deep and bury the bottom of the silt fence in the trench.

Backfill the trench with gravel or soil. Compact the backfill well.

The height of the silt fence must be a 1.5-foot maximum, measured from the top of the inlet.

Gravel Doughnut

Keep the stone slope toward the inlet at 3:1 or flatter or use concrete blocks to help prevent the stone from being washed into the drop inlet. A minimum 1-foot-wide level area set 4 inches below the drop inlet crest will add further protection against the entrance of material.

Stone on the slope toward the inlet should be 3 inches or larger for stability, and 1 inch or smaller on the slope away from the inlet to control flow rate. Mix various size stone for best results.

Wire mesh with 2-inch openings can be placed over the drain grating, but it must be inspected frequently to avoid blockage by trash. If concrete blocks are used, the openings should be covered with wire screen or filter fabric.

Inspection and Maintenance

Inspect the barrier weekly and after each rainfall greater than one-half inch, and promptly make repairs as needed.

Remove sediment after each significant rainfall (one-half inch in 24 hours) to provide adequate storage volume for the next rain.

Deposit the removed sediment in an area that will not contribute sediment off-site and can be permanently stabilized.

For gravel filters: If the gravel becomes clogged with sediment carefully remove it from the inlet and either clean or replace it. Close monitoring of drop-down inlet filter bags is required to ensure that they do not become overfilled.

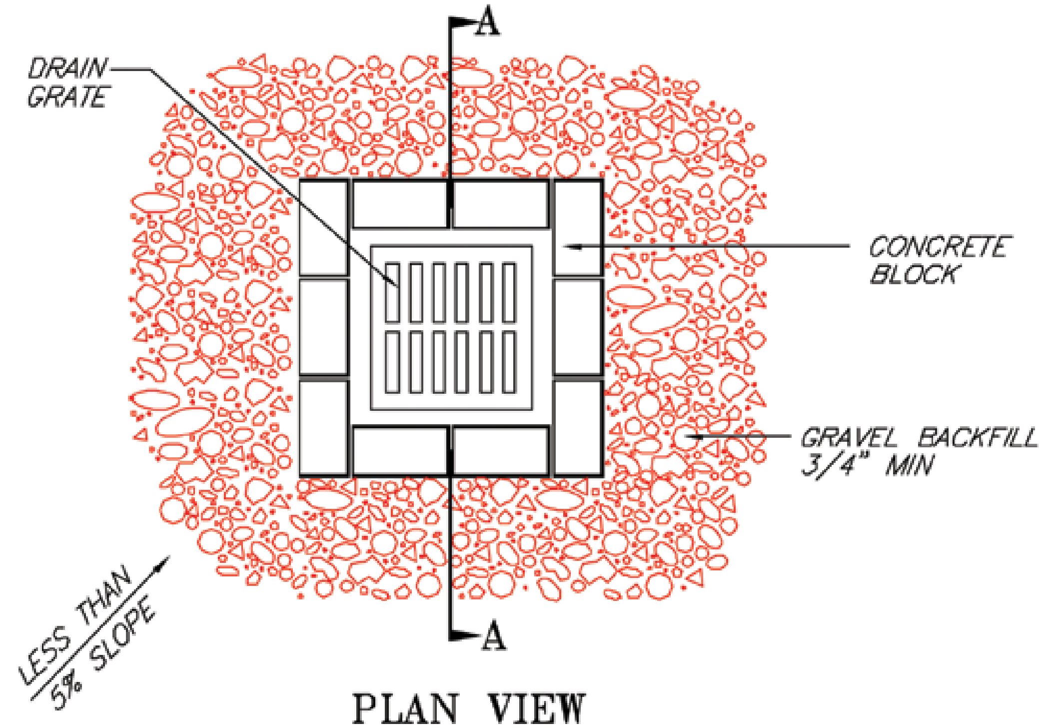
Tap filter fabric with a wooden stake when dry to remove caked-on fines, taking care not to tear the fabric.

Inlet protection berm constructed of half-filled stone bags. Use #57 rock, overlap bags to eliminate large openings and rapid flow-through.

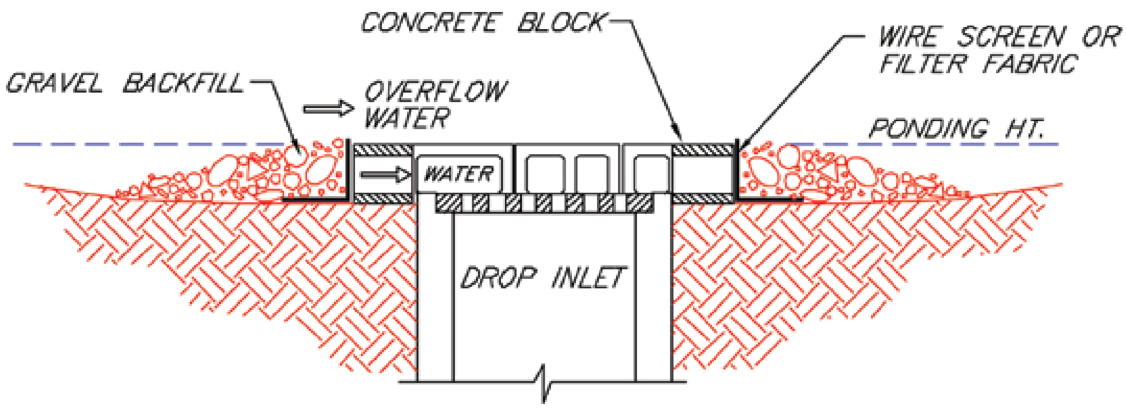
Silt fencing can be used as an inlet protection device if flow volumes and velocities are low. When using a silt fence frame to construction in inlet protection dike, add wire reinforcement and cross-bracing to prevent collapse in areas of heavy flows.

Commercial inlet frames and filters, ponding devices, and other products are often economical and effective approaches for inlet protection. Many can be cleaned and reused.

Side hole in drop inlet protected by half-round section of corrugated metal pipe with one-inch holes, held in place by stone berm. This modification can also be used on sediment basin outlet risers.



PLAN VIEW



SECTION A – A

NOTES:

1. DROP INLET SEDIMENT BARRIERS ARE TO BE USED FOR SMALL, NEARLY LEVEL DRAINAGE AREAS. (LESS THAN 5%)

2. EXCAVATE A BASIN OF SUFFICIENT SIZE ADJACENT TO THE DROP INLET.

3. THE TOP OF THE STRUCTURE (PONDING HEIGHT) MUST BE WELL BELOW THE GROUND ELEVATION DOWNSLOPE TO PREVENT RUNOFF FROM BYPASSING THE INLET. A TEMPORARY DIKE MAY BE NECESSARY ON THE DOWNSLOPE SIDE OF THE STRUCTURE.

SOURCE: SALIX APPLIED EARTHCARE – EROSION DRAW 5.0

DROP INLET SEDIMENT BARRIER BLOCK AND GRAVEL

4.6.3 Culvert Inlet Sediment Barrier

Stone berms placed in front of culvert inlets can trap large volumes of sediment. Make sure sediment is removed as it accumulates to preserve storage capacity for the next storm.

Definition

A culvert inlet sediment barrier is a temporary rock barrier at a culvert inlet.

Purpose

The purpose of the barrier is to reduce the amount of sediment that enters the culvert by creating a small ponding area for the sediment to settle out.

Design Criteria

The barrier should surround all sides of the culvert that receives runoff and should be placed a minimum of 4 feet from the culvert. The barrier must be designed to ensure that no bypasses occur and that adjacent property will not be damaged by the ponded water.

Control the location of the sediment barrier spillway by placing an overflow notch at a selected location in the middle portion of the barrier. The notch should be at least six inches lower than the rest of the barrier. The downgradient portion of the overflow notch should be protected from spillover scouring with rock, turf matting, or other appropriate energy dissipator.

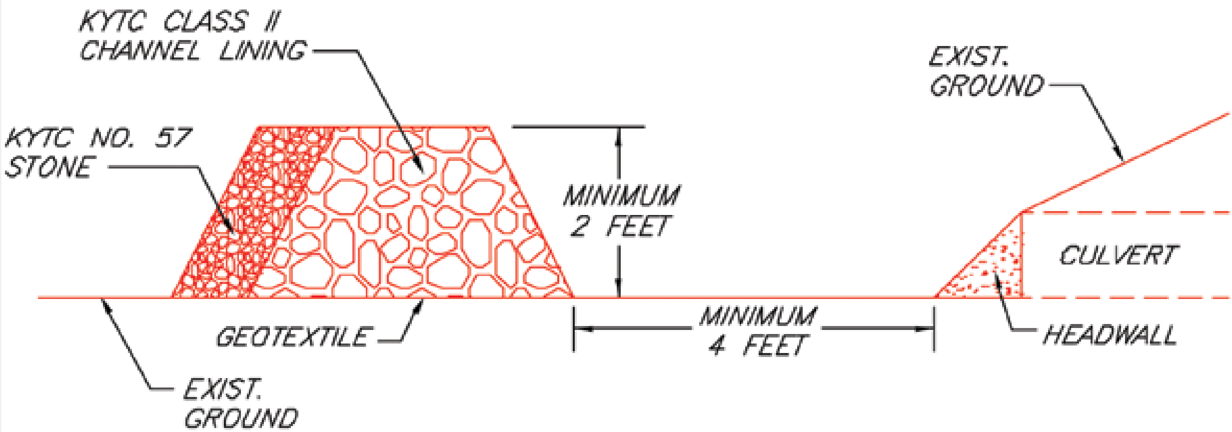
Construction Specifications

The stone should be KYTC Class II Channel Lining. The upstream face of the barrier should consist of smaller stone such as KYTC No. 57 to decrease the flow rate through the stone. A geotextile should be placed between the stone and the soil.

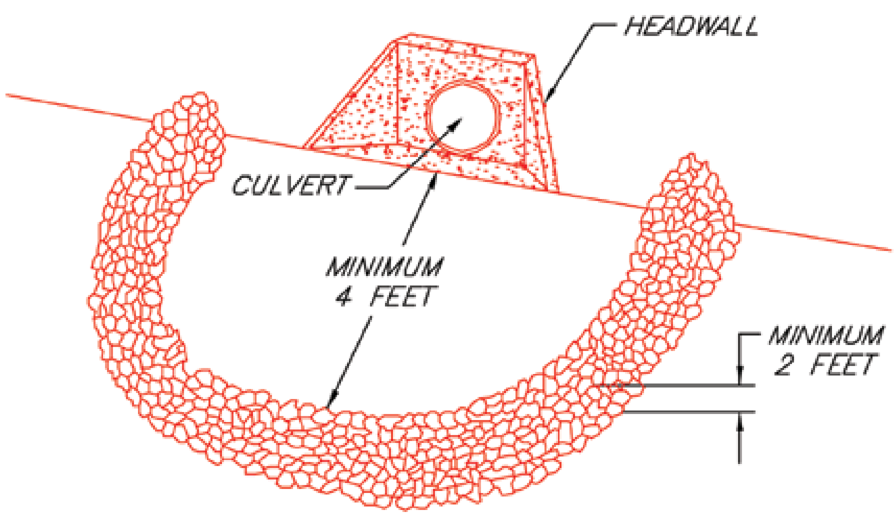
Inspection and Maintenance

The barrier should be inspected weekly and after every rainfall greater than one-half inch. The barrier must be kept free of trash and debris, and sediment should be removed when it reaches one-half the height of the barrier. The barrier should be removed after the disturbed area has been stabilized.

This is a good example of using smaller stone to face off ponding berm built of larger stone. The small rock ensures long ponding times, which maximizes sediment settling and removal.



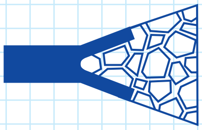
CROSS SECTION



CULVERT INLET SEDIMENT BARRIER

4.6.4 Culvert Outlet Energy Dissipator

Surging flows from culverts can erode large amounts of sediment from ditches and sidewalls near outlets. Rock, well-vegetated TRMs, or cellular products can be used to reduce this threat.



Definition

An energy dissipator is a rock, gabion, mat, or other structure designed to control erosion at the outlet of a channel or stormwater conveyance pipe.

Purpose

Energy dissipators are used to prevent erosion at the outlet of a channel or pipe by reducing the velocity of flow and dissipating the energy before discharge into the rest of the receiving channel or area. Applications include outlets of culverts, temporary slope drains, where lined ditches discharge into unlined ditches, and outlet or overflow areas for sediment traps and basins.

Design Criteria

Design considerations are the volume and velocity of flow to be controlled, characteristics of the bank or other area receiving the brunt of the flow, and the slope of the receiving channel or area, all of which will define the shape and structure of the energy dissipator. Dissipators designed for high-energy flows are usually rock aprons; those handling smaller flows with lesser velocities can consist of TRMs if shear and other stresses can be accommodated by the chosen product. The following criteria are key to dissipator design analysis:

Capacity—Design dissipators to handle the 10-year, 24-hour peak flow event

Tailwater Depth—Determine the depth of the tailwater immediately below the pipe outlet based on the design discharge plus other contributing flows. If the tailwater depth is less than half the diameter of the outlet pipe and the receiving stream is sufficiently wide to accept the divergence of flow, it is classified as a minimum tailwater condition. If the tailwater depth is greater than half the pipe diameter, it is classified as a maximum tailwater condition. Pipes that outlet onto broad flat areas with no defined channel may be assumed to have a minimum tailwater condition unless site conditions indicate otherwise.

Apron size—See the table below.

Grade—There should be no overfall at the end of the apron; that is, the elevation of the top of the apron at the downstream end should be the same as the elevation of the bottom of the receiving channel or the adjacent ground if there is no channel.

Alignment—The apron should be straight throughout its entire length, but if a curve is necessary to align the apron with the receiving stream, locate the curve in the upstream section of riprap. Additional armoring of the outside portion of the curve receiving the greatest scouring flows might be needed.

***Materials*—**Ensure that riprap consists of a well-graded mixture of stone. Larger stone should predominate, with sufficient smaller sizes to fill the voids between the stones. The diameter of the largest stone size should be no greater than 1.5 times the d50 size.

***Thickness*—**The minimum thickness of riprap must be 1.5 times the maximum stone diameter.

***Stone quality*—**Select stone for riprap from fieldstone or quarry stone. The stone should be hard, angular, and highly weather-resistant. The specific gravity of the individual stones should be at least 2.5.

***Filter*—**Install a non-woven geotextile liner (filter) under the rock to prevent soil movement through the openings in the riprap. Geotextile underliners for rock outlet energy dissipators are highly recommended to prevent erosion and undermining of the dissipator. Specify non-woven fabric tailored to the strength needed to support the rock load.

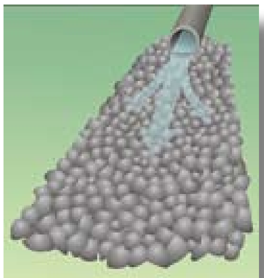
Construction Specifications

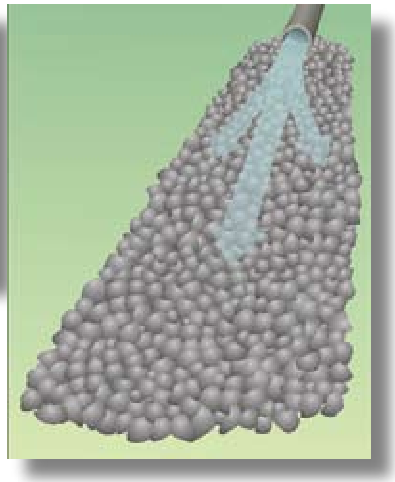
Ensure that the subgrade for the underliner and riprap follows the required lines and grades shown in the plan. Compact any fill required in the subgrade to the density of the surrounding undisturbed material. Low areas in the subgrade on undisturbed soil can also be filled by increasing the riprap thickness.

- The riprap and gravel underliner must conform to the specified grading limits shown on the plans.
- Filter (non-woven geotextile) cloth, when used, must meet design requirements and be properly protected from punching or tearing during installation. Repair any damaged fabric by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap a minimum of 1 foot. If the damage is extensive, replace the entire filter cloth.
- Riprap can be placed by equipment, but take care to avoid damaging the filter.
- The minimum thickness of the riprap should be 1.5 times the maximum stone diameter.
- Riprap may be field stone or rough quarry stone. It should be hard, angular, highly weather-resistant and well graded.
- Construct the apron with no overfall at the end. Make the top of the riprap at the downstream end level with the receiving area or slightly below it.
- Ensure that the apron is properly aligned with the receiving stream and preferably straight throughout its length. If a curve is needed to fit site conditions, place it in the upper section of the apron.
- Immediately after construction, stabilize all disturbed areas with vegetation.

Inspection and Maintenance

Inspect riprap outlet structures weekly and after every rainfall greater than one-half inch 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.





For low-pressure head outlets (above), shorter outlet dissipators can be used. When outlet flows are under a pressure head, however, lengthen the dissipator (right) to ensure flow velocities and possible channel erosion are reduced.

Table of Riprap Apron Dimensions

The tables below can be used to determine the length, width, and D50 stone size of a riprap apron based on circular culverts flowing full.

Riprap Aprons for Low Tailwater (downstream flow depth < 0.5 x pipe diameter)

Culvert Diameter	Lowest Value			Intermediate Values to Interpolate From									Highest Value		
	Q Cfs	L_A Ft	D_{50} In	Q Cfs	L_A Ft	D_{50} In	Q Cfs	L_A Ft	D_{50} In	Q Cfs	L_A Ft	D_{50} In	Q Cfs	L_A Ft	D_{50} In
12"	4	7	6	6	10	6	9	13	6	12	16	7	14	17	8.5
15"	6.5	8	6	10	12	6	15	16	7	20	18	10	25	20	12
18"	10	9	6	15	14	6	20	17	7	30	22	11	40	25	14
21"	15	11	6	25	18	7	35	22	10	45	26	13	60	29	18
24"	21	13	6	35	20	8.5	50	26	12	65	30	16	80	33	19
27"	27	14	6	50	24	9.5	70	29	14	90	34	18	110	37	22
30"	36	16	6	60	25	9.5	90	33	15.5	120	38	20	140	41	24
36"	56	20	7	100	32	13	140	40	18	180	45	23	220	50	28
42"	82	22	8.5	120	32	12	160	39	17	200	45	20	260	52	26
48"	120	26	10	170	37	14	220	46	19	270	54	23	320	64	37

Source: Knoxville Engineering Department
L_A = Apron Length
Apron Width = L_A+ Culvert Diameter

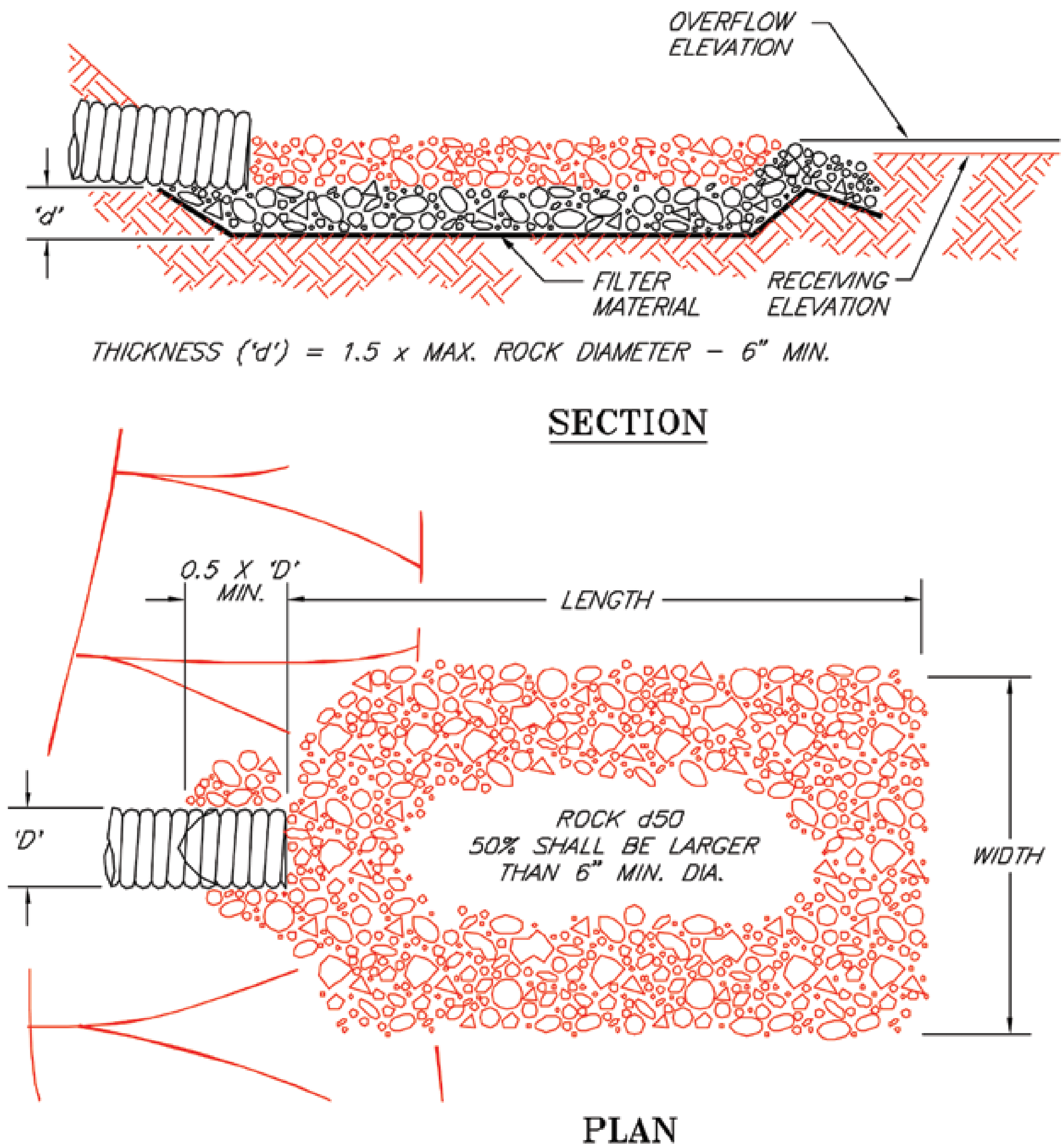
Riprap Aprons for High Tailwater (downstream flow depth > 0.5 x pipe diameter)

Culvert Diameter	Lowest Value			Intermediate Values to Interpolate From									Highest Value		
	Q Cfs	L_A Ft	D_{50} In	Q Cfs	L_A Ft	D_{50} In	Q Cfs	L_A Ft	D_{50} In	Q Cfs	L_A Ft	D_{50} In	Q Cfs	L_A Ft	D_{50} In
12"	4	8	6	6	18	6	9	28	6	12	36	7	14	40	8
15"	7	8	6	10	20	6	15	34	6	20	42	7.5	25	50	10
18"	10	8	6	15	22	6	20	34	6	30	50	9	40	60	11
21"	15	8	6	25	32	6	35	48	7	45	58	11	60	72	14
24"	20	8	6	35	36	6	50	55	8.5	65	68	12	80	80	15
27"	27	10	6	50	41	6	70	58	10	90	70	14	110	82	17
30"	36	11	6	60	42	6	90	64	11	120	80	15	140	90	18
36"	56	13	6	100	60	7	140	85	13	180	104	18	220	120	23
42"	82	15	6	120	50	6	160	75	10	200	96	14	260	120	19
48"	120	20	6	170	58	7	220	85	12	270	105	16	320	120	20

Source: Knoxville Engineering Department
L_A = Apron Length
Apron Width = 0.4 L_A+ Culvert Diameter

Good example of dissipator apron construction for low tailwater conditions.

Poor placement of outlet dissipator rock; poor ditch lining (no grass, mulch, or blanket); poor slope protection.



NOTES:

1. THE LENGTH AND WIDTH SHALL BE DETERMINED BY THE ENGINEER.
2. APRON SHALL BE SET AT A ZERO GRADE AND ALIGNED STRAIGHT.
3. FILTER MATERIAL SHALL BE FILTER FABRIC OR 6" THICK MINIMUM GRADED GRAVEL LAYER.

CULVERT OUTLET ENERGY DISSIPATOR

SOURCE: SALIX APPLIED EARTHCARE – EROSION DRAW 5.0

4.6.5 Rock-Lined Ditches and Channels

Rock is plentiful and relatively inexpensive in most locations in Kentucky and works well as a ditch liner. For a "greener" look, use grass with ECBs or TRMs (see the blanket/mat section in the "Slope Protection" chapter).

RRC RRC

Definition

Rock-lined channels are stormwater channels or ditches lined with rock or riprap.

Purpose

Rock-lined channels serve to convey concentrated surface runoff without erosion. Grass lining with ECBs or TRMs are recommended instead of rock. Rock lining may be necessary in the following conditions:

- There is not enough time to construct, seed, and establish a stabilized vegetated channel before the channel is expected to carry stormwater flows (i.e., construction during wet seasons).
- Design velocity exceeds 2 feet per second and conditions are not suitable for channel or ditch vegetation even if TRMs are used.
- Ditches or drainage channel slopes are greater than 2 percent and located in highly erodible soils that have a low-maximum permissible velocity that cannot be overcome with TRMs.
- Channel design velocity exceeds that allowable for a grass-lined channel with ECB or TRM liners.
- The channel will continue to down-cut without protection because it is adjusting to increased flow or a new base line (outlet elevation).

KYTC weight and size of riprap rock

Channel Lining Riprap Class	Corresponding Size
1A	Limestone with 100% passing a 5-inch sieve, and no more than 20% passing though square openings 1.5" by 1.5"
II	Limestone with 100% passing a 9-inch sieve, and no more than 20% passing though square openings 5" by 5"
III (Cyclopean Riprap)	> 80% by volume of individual stones ranging from ¼ to 1-½ cubic feet

Design Criteria

The channel must be designed to carry the 10-year, 24-hour peak flow using the formula below:

$Q = VA$, where

Q = flow

V = velocity

A = flow area

The Manning equation below must be used to determine the velocity:

$V = 1.486(R)^{2/3}S^{1/2}/n$, where

V=velocity

R=flow area/wetted perimeter

S=slope in feet/foot

$n = 0.0395\ (D_{50})^{1/6}$

The maximum depth must be determined from the following equation:

$D_{max} = \tau\ /\ (62.4 * S)$, where

D_{max} = maximum depth of flow

S = slope in feet/foot

τ = maximum tractive force of the liner in lbs/ft^2

The values for KYTC channel lining are shown below:

KYTC Channel Lining Rock Sizing

KYTC Channel Lining	D_{50}	Shear Lb/ft.^{2}	Manning's *n*
Class 1A	0.2	1.0	0.0302
Class II	0.5	2.5	0.0352
Class III	1.0	5.0	0.0395

Side slopes must be 2:1 or flatter

Riprap thickness**—**T = 1.5 times the largest stone diameter or as shown on the plans; 6-inch thick minimum

Foundation**—**Use extra-strength, non-woven filter fabric or an aggregate filter layer, if required.

The outlet must be stable with a suitable outlet stabilization energy dissipator.

Construction Specifications

Excavate the cross-section to the grades shown on plans. Overcut for thickness of rock and filter.

Place non-woven filter fabric or gravel filter layer, and place the rock as soon as the foundation is prepared.

Place rock so it forms a dense, uniform, well-graded mass with few voids. Hand placement might be necessary to obtain good size distribution.

No overfall of channel construction should exist. Grass-lined channels with riprap bottoms must have a smooth contact between riprap and vegetation.

Channel outlet must be stabilized with a suitable outlet stabilization energy dissipator.

Inspection and Maintenance

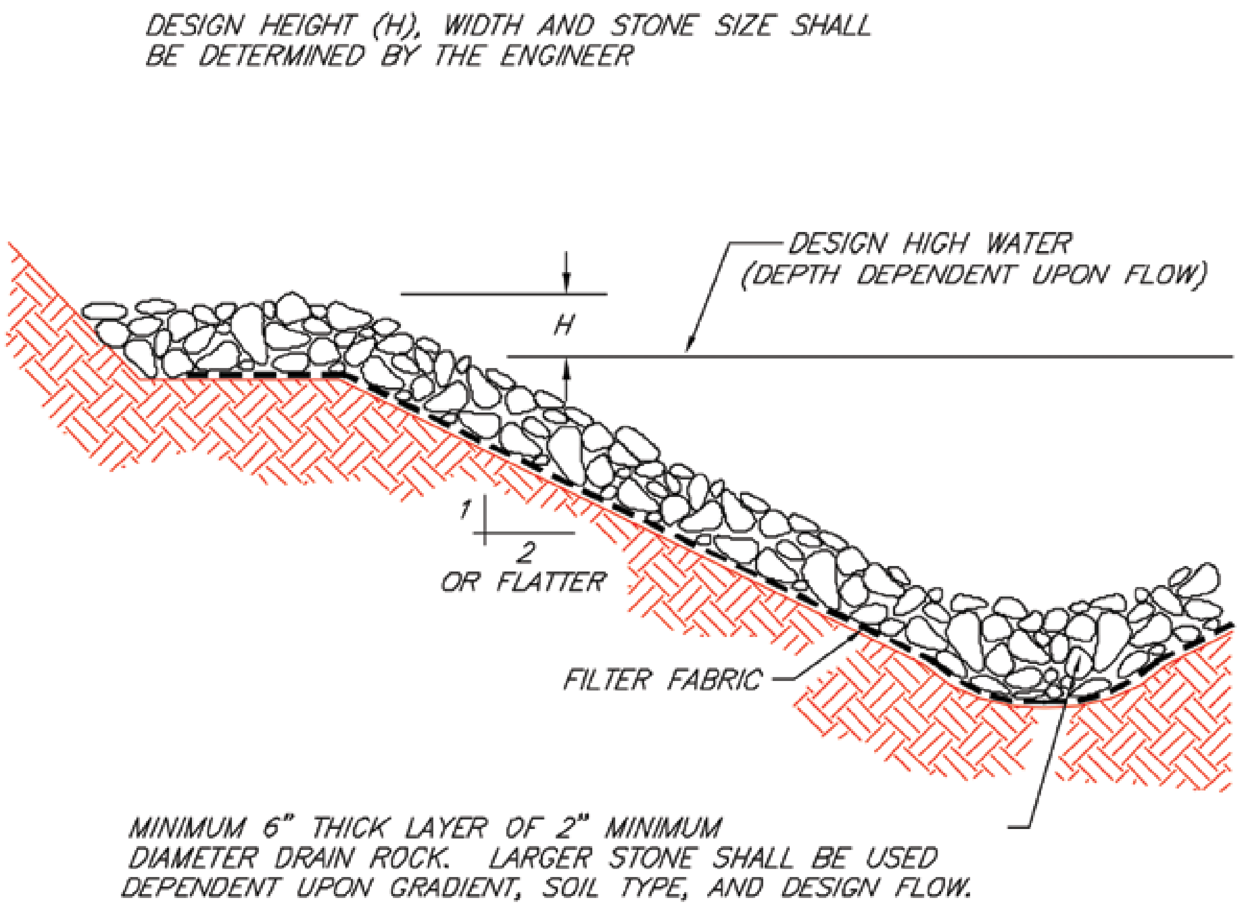
Inspect channels weekly and after rainfalls greater than one-half inch. Remove debris and make needed repairs where stones have been displaced. Take care not to restrict the flow area when stones are replaced.

Give special attention to outlets and points where any concentrated flow enters the channel. Repair eroded areas promptly. Check for sediment accumulation, piping, bank instability, and scour holes and repair promptly.

Here is a good example of rock-lined ditch. The seeding is a bit too thick on the side slopes.

This shows a very good stabilization of slope and ditch on highway project. Note the mix of large and small rock, which helps fills voids and deters undermining.

The rock is a little thin along this ditch, but could be acceptable because of the lack of visible channel erosion. Ditches should be monitored so that rock or other protective controls can be added if erosion becomes a problem.



TYPICAL SECTION

SOURCE: SALIX APPLIED EARTHCARE – EROSION DRAW 5.0

ROCK LINED CHANNEL

4.6.6 Grass-Lined Ditches and Channels

Wide and relatively flat ditches can be protected with triple-seeding and degradable ECBs or mulch. Steeper ditches (e.g., slopes of up to 5 percent and more in some cases) can also be seeded if TRMs are used (see the Blankets and Mats section in the Slope Protection chapter).

Definition

This consists of vegetation lining a ditch, channel, swale, or diversion berm to protect it from erosion.

Purpose

Grass protection of channels reduces erosion by lowering water velocity over the soil surface and by binding soil particles with roots. Grass-lined channels should be used where

- A vegetative lining can provide sufficient stability for the channel grade by increasing maximum permissible velocity.
- Slopes are generally less than 5 percent, with protection from sheer stress as needed through the use of mulch, ECBs, TRMs, or cellular/geogrid products.
- Site conditions required to establish vegetation (i.e., climate, soils, topography, and temporary/permanent protection for vegetation such as via mulch, ECBs, or TRMs) are present.

Design Criteria

Grass-lined channels resemble natural systems and are usually preferred where design velocities are suitable. Select appropriate vegetation and construct ditches or channels early in the construction schedule before grading and paving increase runoff rates.

- Generally, grass-lined channels are constructed in stable, low areas to conform with the natural drainage system, but they might also be needed along roadways or property boundaries. To reduce erosion potential, design the channel to avoid sharp bends and steep grades.
- For ditches and channels with slopes exceeding 3 percent, use the information in the Erosion Control Blankets and Turf Reinforcement Mats Fact Sheets to design and build grass-lined channels with appropriate scour and erosion protection (i.e., ensure that the ditch liner can appropriately resist sheer stresses, given the slope and length of the ditch).

The channel cross-section should be wide and shallow with relatively flat side slopes (e.g., 3H:1V) so surface water can enter over the vegetated banks without erosion. Riprap might be needed to protect the channel banks at intersections where flow velocities approach allowable limits and turbulence could occur.

Cross-section designs include:

V-shaped Channels

Generally these are used where the quantity of water is relatively small, such as roadside ditches. The V-shaped cross-section is desirable because of difficulty stabilizing the bottom, where velocities may be high. A sod or grass lining protected with ECBs or TRMs might suffice where velocities are low; use rock or riprap lining to protect against higher velocities.

Parabolic Grass Channels

Often these are used where larger flows are expected and sufficient space is available. The shape is pleasing and may best fit site conditions. Riprap should be used where higher velocities are expected and where some dissipation of energy (velocity) is desired. Combinations of grass with riprap centers or turf reinforcement mat centers are useful where there is a continuous low flow in the channel.

Trapezoidal Grass Channels

These are used where runoff volumes are large and slope is low so that velocities are non-erosive to vegetated linings. Low flow channel can be lined with turf reinforcement mats, erosion control blankets, riprap, or pavement if desired.

- Grass-lined channels must not be subject to sedimentation from disturbed areas.
- An established grass-lined channel resembles natural drainage systems and is usually preferred if design velocities are below 5 feet per second.
- Channels with design velocities greater than 2 feet per second will require that turf reinforcement mats or erosion control blankets be installed at the time of seeding to provide stability until the vegetation is fully established. It might also be necessary to divert water from the channel until vegetation is established or to line the channel with sod.
- Whenever design velocities exceed 4 feet per second a permanent type of turf reinforcement mat will be necessary.
- Sediment traps might be needed at channel inlets to prevent entry of muddy runoff and channel sedimentation.

Capacity

The channel must be designed to carry the 10-year, 24-hour peak flow using the formula below:

$Q = VA$, where

Q = flow

V = velocity

A = flow area

The Manning equation below must be used to determine the velocity:

$V = 1.486(R)^{2/3}S^{1/2}/n$, where

V=velocity

R=flow area/wetted perimeter

S=slope in feet/foot

n= 0.045 for grass

The maximum depth must be determined from the following equation:

$D_{max} = \tau / (62.4*S)$, where

D_{max} = maximum depth of flow

S = slope in feet/foot

τ = maximum tractive force of the liner in lbs/ft^2

The maximum shear stress for various liners is shown below:

Maximum Shear Stress of Liners

Material	Shear lb/ft²
Dense sod, fair condition (Class D/E), moderately cohesive soil	0.35
Bermuda grass, fair stand < 12 cm tall, dormant	0.9
Bermuda grass, good stand <12 cm tall, dormant	1.1
Bermuda grass, excellent stand 20 cm tall, dormant	2.7
Bermuda grass, excellent stand 20 cm tall, green	2.8
Bermuda grass, excellent stand >20 cm tall, green	3.2
Turf (immediately after construction)	0.2
Turf (after 3-4 seasons)	2.04
Turf reinforcement mat, permanent	8.0
Straw reinforcement mat, temporary	0.45
Jute mat	0.45
Straw with net	1.45
Curled wood net	1.55
Synthetic mat	2

Source: Salix Applied Earthcare – Erosion Draw 5.0

Cross-section

The channel shape may be parabolic, trapezoidal, or V-shaped, depending on need and site conditions.

Side Slopes

Grassed channel side slopes generally are constructed 3:1 or flatter to aid in the establishment of vegetation and for maintenance.

Grade

Generally restricted to slopes 5 percent or less. Either a uniform or gradually increasing grade is preferred to avoid sedimentation.

Construction Specifications

See the specifications for seeding and ECBs.

Inspection and Maintenance

During the initial establishment, grass-lined channels should be repaired and grass reestablished if necessary.

After grass has become established, check the channel periodically to determine if it is withstanding flow velocities without damage.

Check the channel for debris, scour, or erosion and immediately make repairs. It is particularly important to check the channel outlet and all road crossings for bank stability and evidence of piping or scour holes and make repairs immediately.

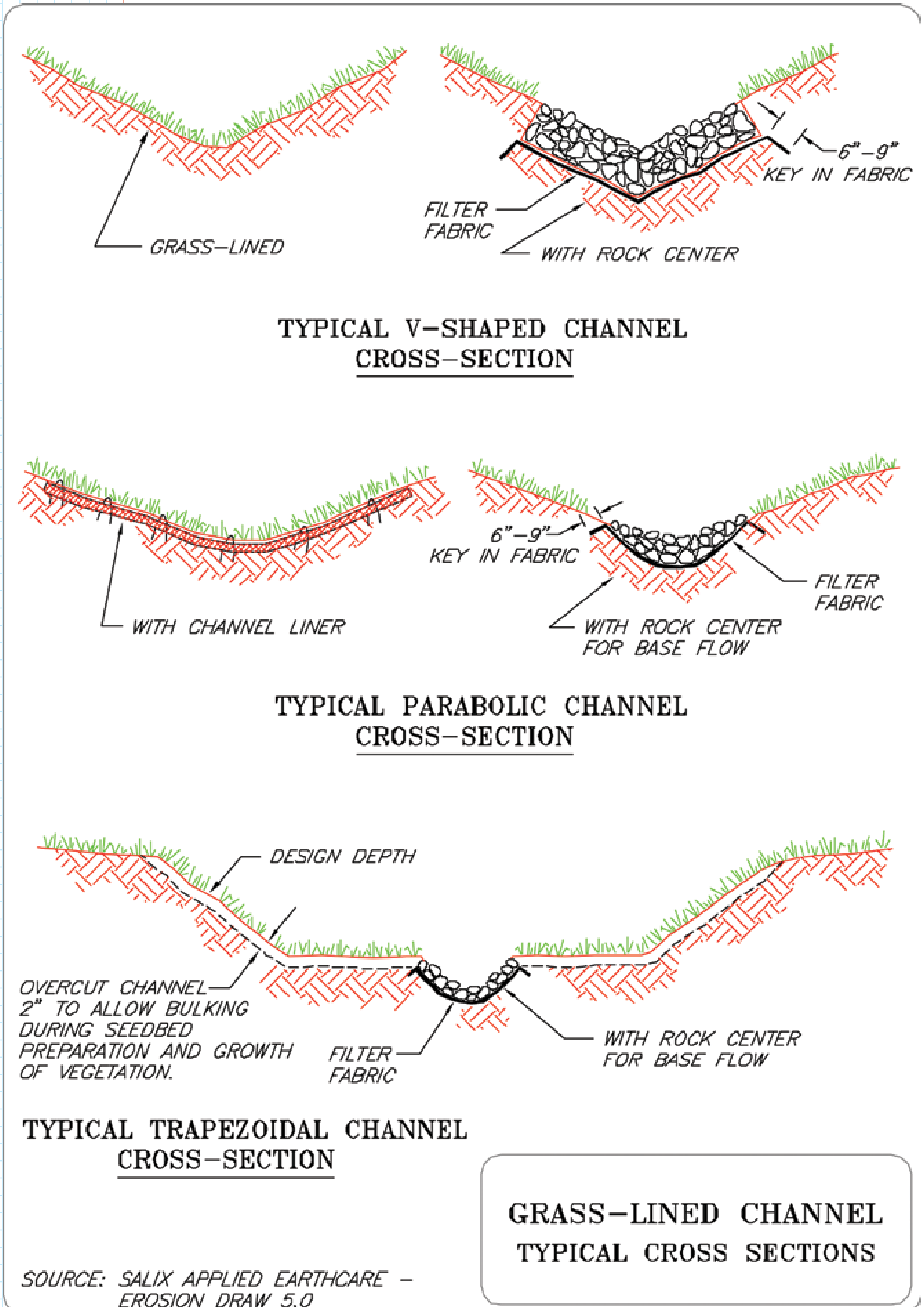
Remove all significant sediment accumulations to maintain the designed carrying capacity.

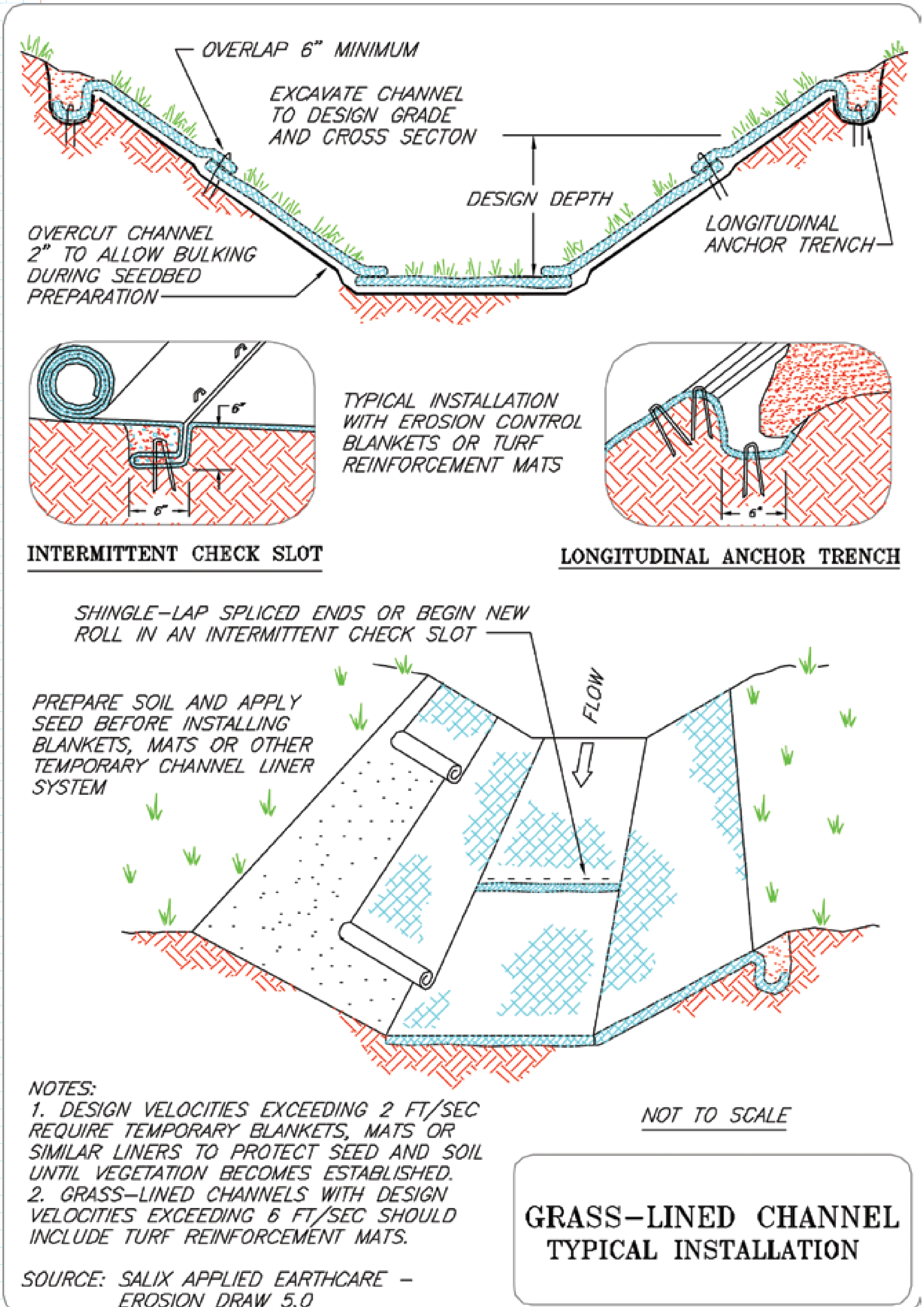
Keep the grass in a healthy, vigorous condition at all times, because it is the primary erosion protection for the channel.

Permanent grassed waterways should be seasonally maintained by mowing or irrigating, depending on the type of vegetation selected. The long-term management of ditches and channels as stable, vegetated, *natural* drainage systems with native vegetation buffers is highly recommended because of the inherent stability offered by grasses, shrubs, trees, and other vegetation; greater visual and other aesthetic benefits provided by native plant buffers; and higher habitat and property values.

Here is an excellent construction of triple-seeded ditch with excelsior blanket. Ditches should be stabilized, seeded, and mulched immediately after construction.

When using blankets and mats, make sure product has good soil contact throughout the ditch. Use plenty of staples to protect against surge flows during heavy rains. Blankets and mats are extremely vulnerable before seed germination, and can be dislodged by high-velocity flows if stapling is insufficient.


GRASS–LINED
FILTER FABRIC
WITH ROCK CENTER
6"–9"
KEY IN FABRIC
TYPICAL V–SHAPED CHANNEL CROSS–SECTION
WITH CHANNEL LINER
6"–9"
KEY IN FABRIC
FILTER FABRIC
WITH ROCK CENTER FOR BASE FLOW
TYPICAL PARABOLIC CHANNEL CROSS–SECTION
DESIGN DEPTH
OVERCUT CHANNEL 2" TO ALLOW BULKING DURING SEEDBED PREPARATION AND GROWTH OF VEGETATION.
FILTER FABRIC
WITH ROCK CENTER FOR BASE FLOW
TYPICAL TRAPEZOIDAL CHANNEL CROSS–SECTION
GRASS–LINED CHANNEL
TYPICAL CROSS SECTIONS
SOURCE: SALIX APPLIED EARTHCARE – EROSION DRAW 5.0


OVERLAP 6" MINIMUM
EXCAVATE CHANNEL TO DESIGN GRADE AND CROSS SECTON
DESIGN DEPTH
OVERCUT CHANNEL 2" TO ALLOW BULKING DURING SEEDBED PREPARATION
LONGITUDINAL ANCHOR TRENCH
6"
6"
TYPICAL INSTALLATION WITH EROSION CONTROL BLANKETS OR TURF REINFORCEMENT MATS
6"
INTERMITTENT CHECK SLOT
LONGITUDINAL ANCHOR TRENCH
SHINGLE-LAP SPLICED ENDS OR BEGIN NEW ROLL IN AN INTERMITTENT CHECK SLOT
FLOW
PREPARE SOIL AND APPLY SEED BEFORE INSTALLING BLANKETS, MATS OR OTHER TEMPORARY CHANNEL LINER SYSTEM
NOTES:
1. DESIGN VELOCITIES EXCEEDING 2 FT/SEC REQUIRE TEMPORARY BLANKETS, MATS OR SIMILAR LINERS TO PROTECT SEED AND SOIL UNTIL VEGETATION BECOMES ESTABLISHED.
2. GRASS-LINED CHANNELS WITH DESIGN VELOCITIES EXCEEDING 6 FT/SEC SHOULD INCLUDE TURF REINFORCEMENT MATS.
NOT TO SCALE
SOURCE: SALIX APPLIED EARTHCARE – EROSION DRAW 5.0
GRASS-LINED CHANNEL
TYPICAL INSTALLATION

4.6.7 Check Dams for Ditches and Channels

Check dams, also known as "ditch checks," can help to control downcutting in drainage ditches before grass is well established. In this example, checks are working even though ditch seeding and mulching appears to be somewhat poor. Many contractors use half-filled fabric bags of stone for ditch checks because of their ease of handling, acceptability for reuse, and overall effectiveness.

Definition

A check dam (also known as a ditch check or silt check) is a small, temporary, center-overflow dam constructed across a ditch, swale, or channel, consisting of rock, gravel filled bags, fiber rolls, or other commercial products.

Purpose

The purpose of a check dam is to reduce the velocity of concentrated stormwater flows, thereby reducing erosion of the swale or channel. This practice also traps sediment.

Design Criteria

Check dams must be limited to use in small, open ditches that drain 10 acres or less. Check dams must not be used in streams. Straw bales are not to be used as check dams because of past high failure rates.

- Ditches lined with riprap do not usually require check dams; however they can be used in areas with highly erodible soils, steep slopes, and drainage areas of up to 5 acres. Check dams are especially applicable where the slope of ditches or channels is close to the maximum for a grass lining.
- The maximum height of a check dam must be 3 feet above the ground on which the rock is placed.
- The center of the check dam above the flat portion of the channel must be at least 6 inches lower than the outer edges.
- The maximum spacing between rock check dams in a ditch should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.
- Check dams for larger projects with greater slopes and wider drainage swales can be constructed of trees and brush cleared from the site, gabions, large rock, or other materials. Design and structural stability requirements for these applications, which can have significant benefits, are very site specific.

Construction Specifications

Stone check dams must be constructed of KYTC Class 2 channel lining. Fiber bags filled with gravel are also acceptable. Bags should be of woven-type geotextile fabric because burlap or cloth bags deteriorate rapidly. The fiber bags must be filled with three-quarter inch drain rock or one-quarter inch pea gravel. Fill fiber bags just over halfway, so they can be packed tightly together without large gaps.

- Commercial products such as fiber rolls, sediment dikes, and sediment fencing can be used in seeded and lined (or mulched) swales with bottoms not less than 4 feet wide and slopes not more than 3 percent, if appropriate. Follow the manufacturer's instructions for placement, staking, and maintenance. Applications in areas that exceed these parameters must be consistent with product design and performance information.

- Stone must be placed by hand or mechanically as necessary to achieve complete coverage of the ditch bottom and banks and to ensure that the center of the check dam is at least 6 inches lower than the outer edges.

- Gravel bag check dams must be placed in the ditch or channel by hand, with the tied ends of the bags pointing upstream and the center overflow area at least 6 inches lower than the outer edges.

- For all check dams, ensure that the higher elevation outer sidewalls tie into the upper portion of the ditch or channel bank to prevent bypasses.

- If stone check dams are used in grass-lined channels that will be mowed, take care to remove all stone from the channel when the dam is removed. This includes any stone that has washed downstream.

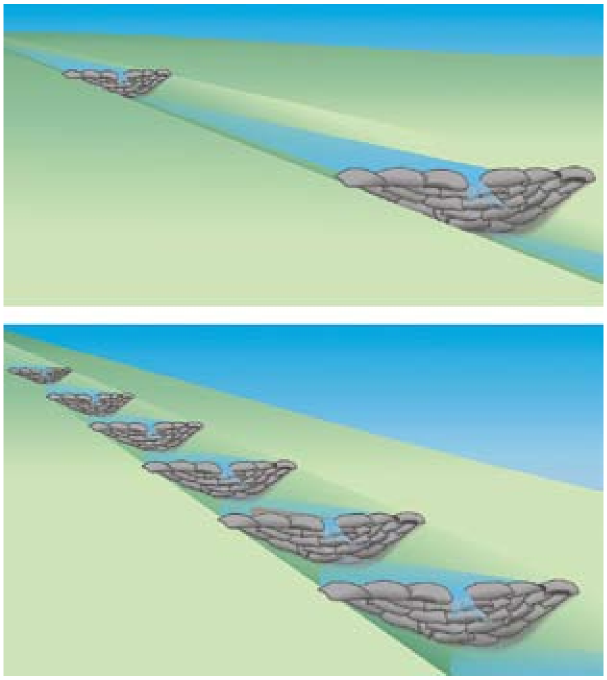
Inspection and Maintenance

Regular inspections must be made to ensure that check dams are in good working order and the center of the dam is lower than the edges. Erosion caused by high flows around the edges of the dam must be corrected immediately, and the dam must be extended upward beyond the repaired area.

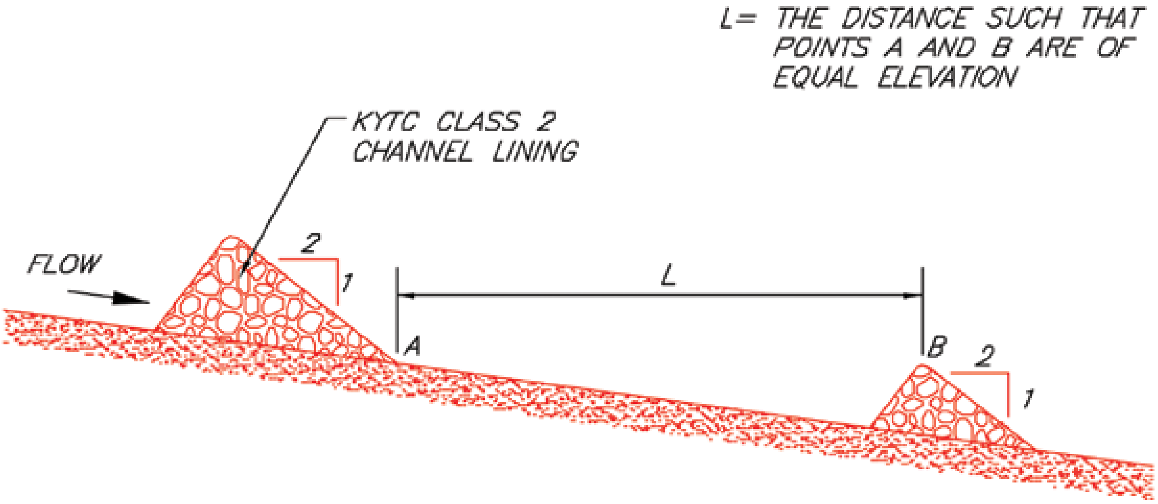
Inspect check dams for sediment accumulation weekly and after each rainfall greater than one-half inch. Sediment must be removed when it reaches one-half of the original height.

Check dams must remain in place and operational until the drainage area and channel are completely stabilized, or up to 30 days after the permanent site stabilization is achieved.

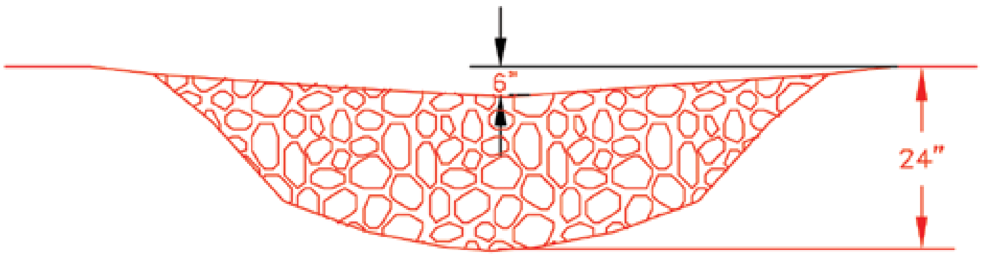
Check dams must be removed when their useful life has been completed. In temporary ditches and swales, check dams must be removed and the ditch filled in when it is no longer needed. In permanent channels, check dams must be removed when a permanent lining can be installed. In the case of grass-lined ditches, check dams must be removed when the grass has matured sufficiently to protect the ditch or swale. The area beneath the check dams must be seeded and mulched or sodded (depending upon velocity) immediately after check dams are removed.



Install check dams closer together in steep ditches (bottom) and farther apart in flatter ditches (top). Make sure overflow is in the center of the dam. Ditch checks are temporary controls, and should be removed when the ditch and upland areas are stabilized.



LONGITUDINAL SECTION SHOWING SPACING BETWEEN CHECK DAMS



SECTION ACROSS CHANNEL

CHECK DAM