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Chapter 15 - Channel and Waterway

15.1 Identifying Scour and Erosion – Waterway Mechanics

Scour that results in the undermining of foundation units is one of the most common causes of bridge failure. Streams are dynamic; they change position, shape and other characteristics with variation in flow and the passage of time. When a channel is modified near a bridge, or a new bridge/culvert is installed, this local change will often lead to a change in the channel characteristics both up and downstream of the bridge. Similarly, channel modifications up or downstream of a bridge can affect the channel characteristics at the bridge.

The tendency of a stream channel to scour and migrate is dependent on many factors, including:

- Stream Size
- Stream Velocity
- Flow Habit (Ephemeral, Flashy, Perennial)
- Bed and Bank Material
- Valley, Floodplain & Natural Levee configuration
- Channel Pattern (Meandering, Straight, Braided, Anabranched)

The amount of material that is transported, eroded, or deposited in a stream channel is a function of sediment supply and channel transport capacity. This concept is described in Figure 15.1 with a definition sketch of sediment continuity applied to a given channel reach over a given time period. Sediment supply is provided from the tributary watershed and erosion occurring in the upstream channel. Transport capacity is a function of the sediment size, stream velocity and geometric properties of the channel. When the transport capacity equals sediment supply, a state of equilibrium exists. When this equilibrium is disturbed, erosion, scour, or deposition will occur.

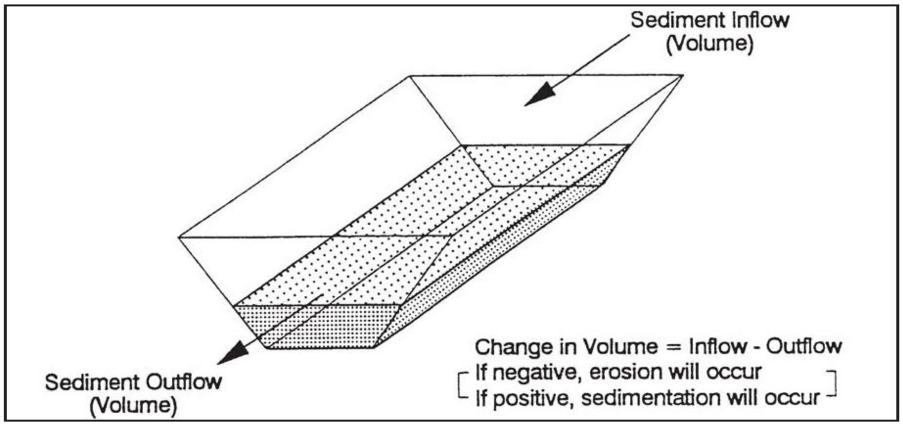


Figure 15.1 Definition Sketch of Sediment Continuity Concept

Migration occurs along a channel reach as bank materials are eroded at the outside of bends and deposited along the inside of bends, as shown in Figure 15.2. The figure shows modes of meander loop development, including (a) Extension, (b) Translation, (c) Rotation, (d)

Conversion to a Compound Loop, (e) Neck Cutoff by Closure, (f) Diagonal Cutoff by Chute, and (g) Neck Cutoff by Chute. Over time, migration can change the flow direction and alignment, thus affecting the efficiency of a bridge opening. Active bank erosion can be recognized by falling vegetation along the bank line, cracks along the bank surface, slump blocks (i.e., loosely consolidated materials or rock layers moving a short distance down a slope as a relatively coherent mass), increased turbidity, bent tree trunks and fresh vertical faces, as shown in Figure 15.3.

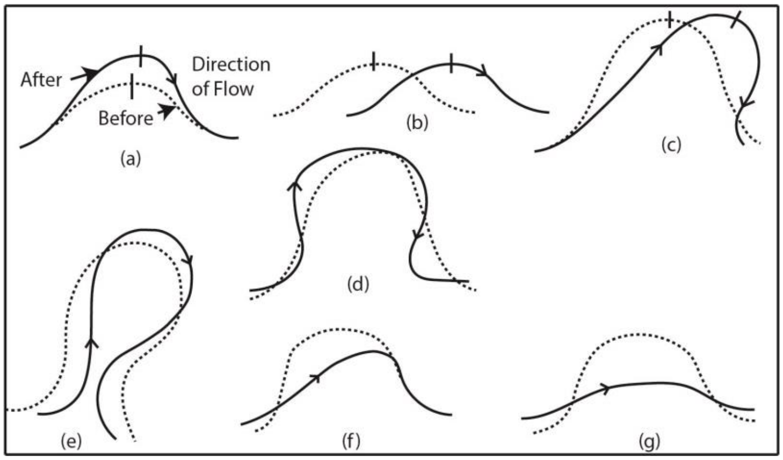


Figure 15.2 Modes of Meander Loop Development

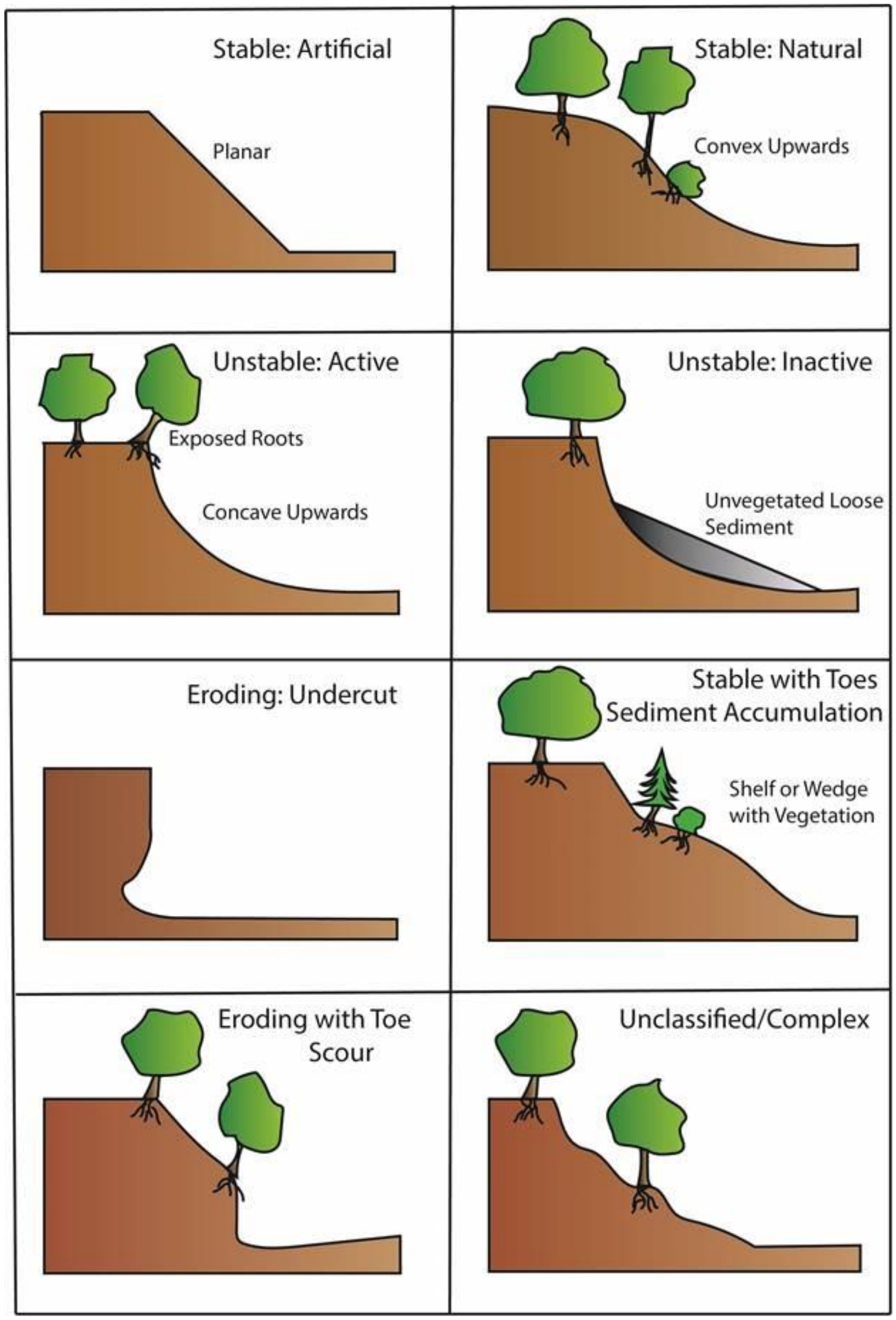


Figure 15.3 Classification and Morphology of Typical Bank Profiles

Aggradation and degradation are the vertical raising and lowering, respectively, of the streambed over relatively long distances and timeframes. The degree of aggradation and degradation are related to the sediment transport behavior of the waterway. Degradation can lead to the exposure and undermining of bridge foundations and increased susceptibility to local scour. Aggradation will reduce the hydraulic opening available at the bridge. Bed elevation changes can be recognized by taking periodic fascia sounding measurements from a fixed reference point and comparing the readings over time, i.e., channel profiles.

What To Look For

- Bank profiles that are not stable
- Evidence of scour around piers and abutments
- Evidence of debris creating problems around the bridge

Scour at bridges consists of three additive components :

1. Long term aggradation and degradation of the stream channel.
2. Contraction scour due to constriction or the location of the bridge, as shown in Figure 15.4. The figure shows an example of flow structure including macro-turbulence generated by floodplain/main channel flow interaction, flow separation around abutment, and wake region on the floodplain of a compound channel.
3. Local scour, as shown in Figure 15.5 for a cylindrical pier.

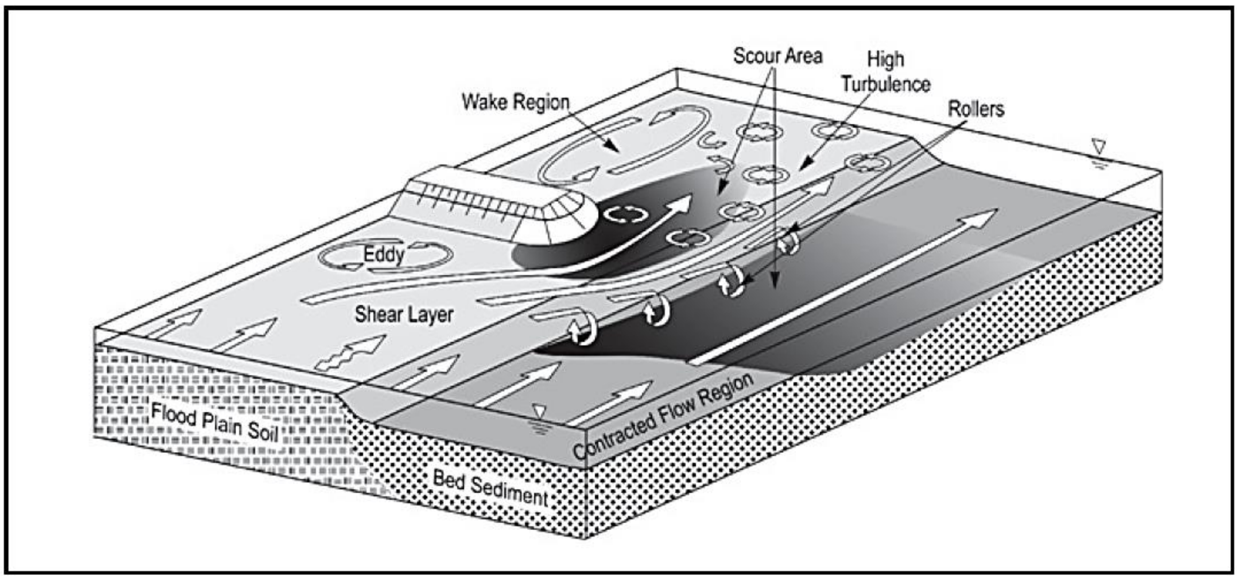


Figure 15.4 Construction Scour Example

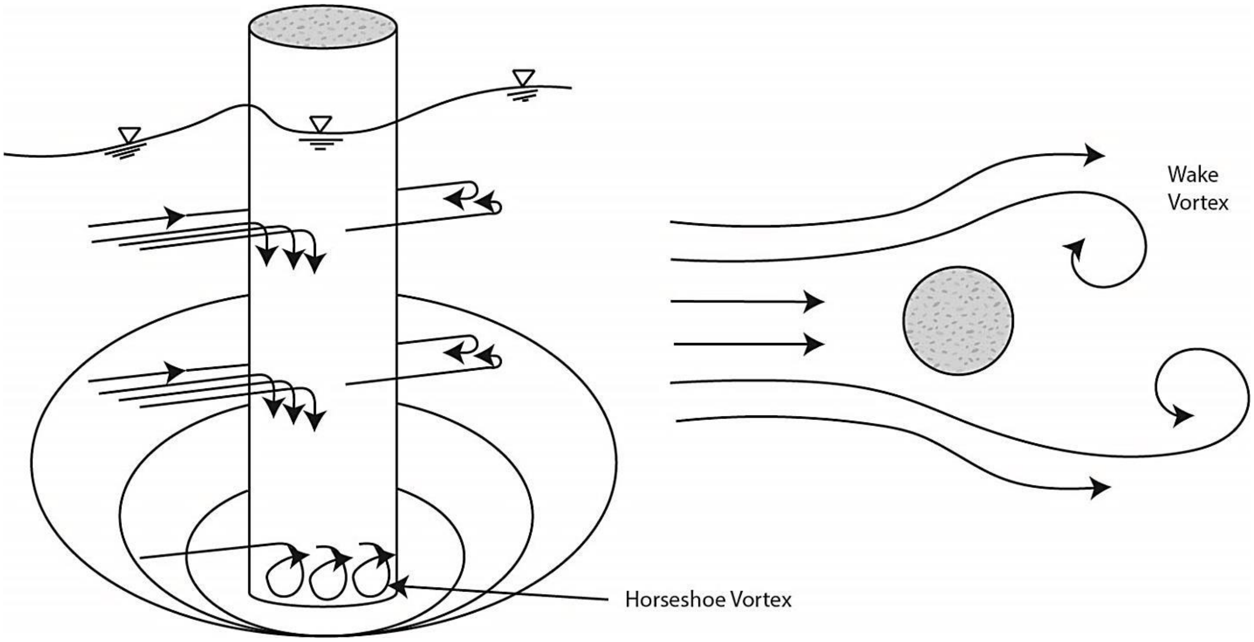


Figure 15.5 Schematic Representation of Scour at a Cylindrical Pier

The rate of scour depends on the erosive forces exerted on the channel boundary and the resistance of the material to erosion. Detailed information on waterway mechanics can be found in the FHWA Publication No. FHWA-NHI-12-004 *Stream Stability at Highway Structures* which can be downloaded from the FHWA web site. Additional resources include *Hydraulic Engineering Circular (HEC) 18* and *HEC 20*, the details of which are provided in the Reference List at the end of this chapter.

15.2 Preventive and Basic Maintenance for Channels and Waterway

15.2.1 Debris Removal

Waterborne debris (drift), composed primarily of tree trunks and large limbs, often accumulates at bridge piers, abutments and under-deck elements. High water events can increase the amount of debris in the waterway and accelerate debris accumulation. Accumulated debris restricts and redirects water flows through the bridge opening leading to flooding, damaging loads, and foundation scour, as shown by the example in Figure 15.6. Note that scour was defined and discussed in Section 4.8.3 Scour.

Consideration should be given to schedule debris removal to occur prior to NBIS regulated underwater bridge inspection operations. Accumulated debris is a diver safety hazard and will limit diver access to areas with high scour susceptibility.

Figure 15.6 Increased Scour at Bridge Piers as a Result of Debris

An effective debris removal program can improve the efficiency of the bridge opening and reduce scour potential during the next high water event.

Debris removal operations may be environmentally sensitive, as shown in Figure 15.7 and Figure 15.8. Coordination with local environmental regulatory agencies may be required for non-emergency work. Best management practices for debris removal include:

- Only cut material when necessary. Turn the debris to allow it to flow through the structure if downstream structures will not be affected; note this practice may not be environmentally acceptable for all bridge owners.
- Minimize machinery disturbance to the stream bank and bed materials. Where possible, use specialized equipment such as a crane, operated from the bridge deck.
- Perform any required work in flowing channels during the work window permitted for the specific stream body.
- Repair and restore bank areas which may be impacted by drift removal machinery.

Recommendation

Accumulated debris can create vortices and accelerate local scour. After debris removal, consider performing a scour inspection to determine if foundation exposure or undermining repairs are also required.

Figure 15.7 Debris Removal Operation
(Courtesy of the City of Rochester, New York - Department of Environmental Services)

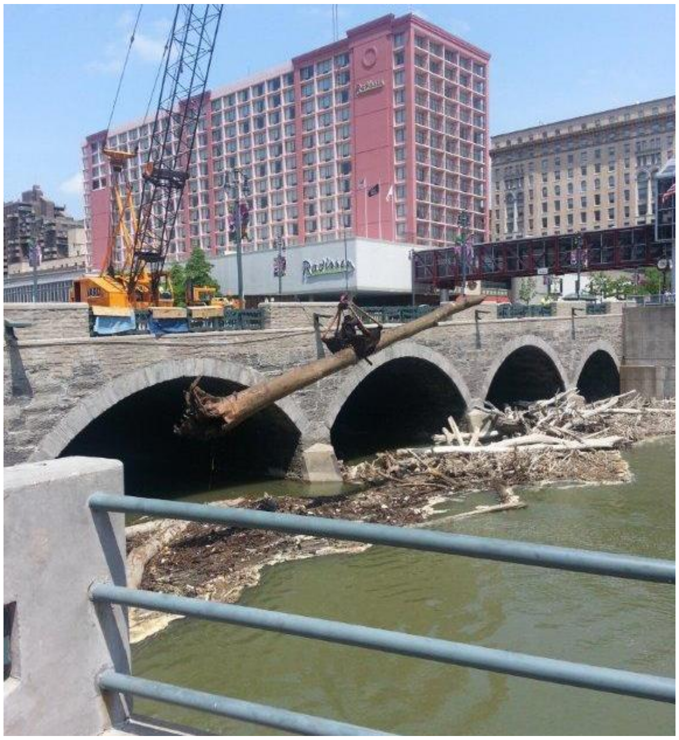


Figure 15.8 Debris Removal Operation
(Courtesy of the City of Rochester, New York - Department of Environmental Services)

If a structure has a tendency to accumulate debris and is configured such that debris removal is difficult, debris deflectors can be constructed near the structure. Alternatively, containment gates can be constructed at a convenient location upstream, as shown by the examples in Figure 15.9 and Figure 15.10. More specifically, Figure 15.9 shows a post and rail debris rack, in place for 35 years for light to medium floating debris, installed 100 feet upstream of the culvert. Figure 15.10 shows timber debris fins with sloping leading edge.

When to Call the Engineer

Containment gates can significantly affect upstream flood elevations. A hydraulic analysis should be performed prior to installing this type of countermeasure to assess the impact on upstream properties and structures.

Figure 15.9 Post and Rail Debris Rack Installed 100 Feet Upstream of Culvert

Figure 15.10 Timber Debris Fins with Sloping Leading Edge

15.2.2 Vegetation Removal

The condition of the vegetation and surroundings should be evaluated to determine the appropriate method and degree of vegetation removal. Depending on the type of channel and the conditions, the vegetation removal may be as simple as mowing the areas to keep them clear, without increasing erosion potential.

In areas where fast growing vegetation is a concern, or obstruction of the waterway with vegetation has been a recurring problem, mechanical removal (excavation of the roots) or use of herbicides may be appropriate. Use of herbicides will be governed by local environmental regulations.

15.3 Repair and Rehabilitation of Channel and Waterway

Knowledge of the mechanics of stream migration and erosion can be used to predict future conditions and implement repairs for observed problems. Effective countermeasures can be employed to control stream migration and to protect foundations from local scour. Extensive information on the selection and design of countermeasures can be found in FHWA Publication No. FHWA-NHI-09-112 (Bridge Scour and Stream Instability Countermeasures: Experience, Selection and Design Guidance) which can be downloaded from the FHWA web site.

Maintenance countermeasures typically consist of river training and armoring techniques which are designed either to modify the flow or resist erosive forces.

River Training Structures are those which modify the flow by altering stream hydraulics to mitigate undesirable erosional and or depositional conditions at a particular location or in a river reach. This type of structure is typically classified by its orientation to flow:

- **Transverse Structures** are countermeasures which project into the flow field at an angle or perpendicular to the flow (bendway weirs, groins, check dams)
- **Longitudinal Structures** are countermeasures which are oriented parallel to the flow or along a bank-line (bulkheads, toe-dikes, levees)
- **Areal Structures** are other countermeasure treatments such as channelization, flow relief, and sediment detention

Armoring Countermeasures resist the erosive forces caused by a hydraulic condition. This type of countermeasure is typically classified by the armoring material and location. These systems can be either rigid or flexible. Rigid systems are typically impermeable but are subject to undermining failure. Flexible systems can conform to changing conditions but are subject to removal and displacement failure. Types of armoring include:

- **Revetments** are designed to protect the channel bank.
- **Bed Armoring** is designed to protect the river bed.
- **Local Scour Armoring** is designed specifically to protect individual substructure elements from local scour.

Other countermeasure strategies include structural (e.g., foundation strengthening, pier geometry modification), biotechnical (e.g., vegetated geofabrics, woody mats, root wads) and monitoring. A convenient reference guide is provided in *Appendix B: References* of this manual on a wide range of countermeasures applicable to scour and stream stability problems. The table can also be used to identify and prioritize possible alternatives.

Contraction Scour Countermeasures–The most typical countermeasures used for preventing contraction scour are revetments placed on the embankment fill slopes and spur dike/guide bank construction at the upstream side of the abutments.

Local Scour Countermeasures–Countermeasures can include modifications to move the scour away from the foundations, pier nose streamlining as well as armoring. The practice of heaping stones around a pier is not recommended because experience has shown that continual replacement is usually required. An engineered armoring system (detailing size, location, shape, and filtering) will result in a more robust protection.

Aggradation / Degradation Countermeasures–Check dams and detention structures can effectively be used to control bank slipping and caving and sediment deposits near bridges. In lieu of permanent structures, continuing maintenance (dredging / clearing of deposited material) has been used effectively to remove deposited sediment and maintain the hydraulic openings at bridges, as shown in Figure 15.11.

When to Call the Engineer

An engineer should be contacted when designing any of these treatments.

(a) (b)

Figure 15.11 Deposited Sediment Removal to Maintain Hydraulic Opening (a) Before, (b) After (Courtesy of PA Department of Transportation)

Many countermeasure strategies involve work in streams which may be regulated by local environmental agencies. Consultation with these agencies is advised for non-emergency actions. Discharge of fill, placed within waters of the United States, is regulated through the United States Army Corps of Engineers (USACE) through Section 404 of the Federal Clean Water Act. Nationwide Permits are issued typically every four years to authorize common work items which have been determined to have minimal adverse impacts. The scope of proposed work items should be checked against the most recent issuance of Nationwide Permit No's 3 (Maintenance of Currently Serviceable Structures) and 13 (Bank Stabilization). If a bridge foundation has been determined to be scour critical as part of the bridge owner's scour evaluation program, the USACE will give priority to the bridge owner's request for authorization of the installation of scour countermeasures. Advanced notice of the proposed countermeasure design and construction schedule to the bridge owner and USACE is required.

In addition, the state environmental agency may also have jurisdiction over work done in and adjacent to waterways, so any channel or waterway work should also be reviewed for compliance with state environmental regulations. This not only applies to excavation and placement of fill (riprap), but may also apply to placement of cementitious materials in the waterway.

When to Call the Engineer

Call the Engineer to ensure countermeasures are adequately sized and located to perform correctly.

Countermeasures must be inspected periodically and after floods to check their performance. The design may need to be modified as a result of the inspection. The condition of the countermeasure should be documented with photographs to enable comparison between inspections. In most cases, countermeasures do not "cure" the scour or instability problem. Funding for continued maintenance of the countermeasures should be planned. Non-structural countermeasures are not considered permanent.

15.3.1 Placement of Riprap and Gabions

Riprap and gabion placements are flexible armoring techniques that can be used in various configurations to counter the erosive action of moving water. Riprap refers to a layer or facing of rock, placed on channel and structure boundaries to limit the effect of erosion. Gabions and mattresses refer to loose collections of stones encased in a wire framework (See Figure 15.12 through Figure 15.15).

- Revetments, bendway weirs and spur dikes to counter migration
- Bed armoring and check dams to counter degradation
- Revetments and guide banks to counter contraction scour
- Bed armoring to counter local scour

Riprap is a very common countermeasure due to its general availability, ease of installation, and relatively low cost. Riprap placements should be designed to resist particle erosion, substrate material erosion, and mass failure. Typical practices involve the use of filter fabric bedding, limiting slope angles, and trenching the toe below the anticipated contraction and degradation scour level.

The basis of protection provided by the riprap is the mass and interlocking of the individual rocks, therefore careful attention needs to be given to placement technique and mat thickness.

Riprap is not considered a permanent repair to scour and must be periodically monitored at a minimum on the two year inspection cycle.

The following figures are intended to present a basic insight into riprap and gabion uses. An extensive coverage of riprap and gabion countermeasures can be found in Chapter 5 of the FHWA publication, *Hydraulic Engineering Circular No. 23 – Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance*.

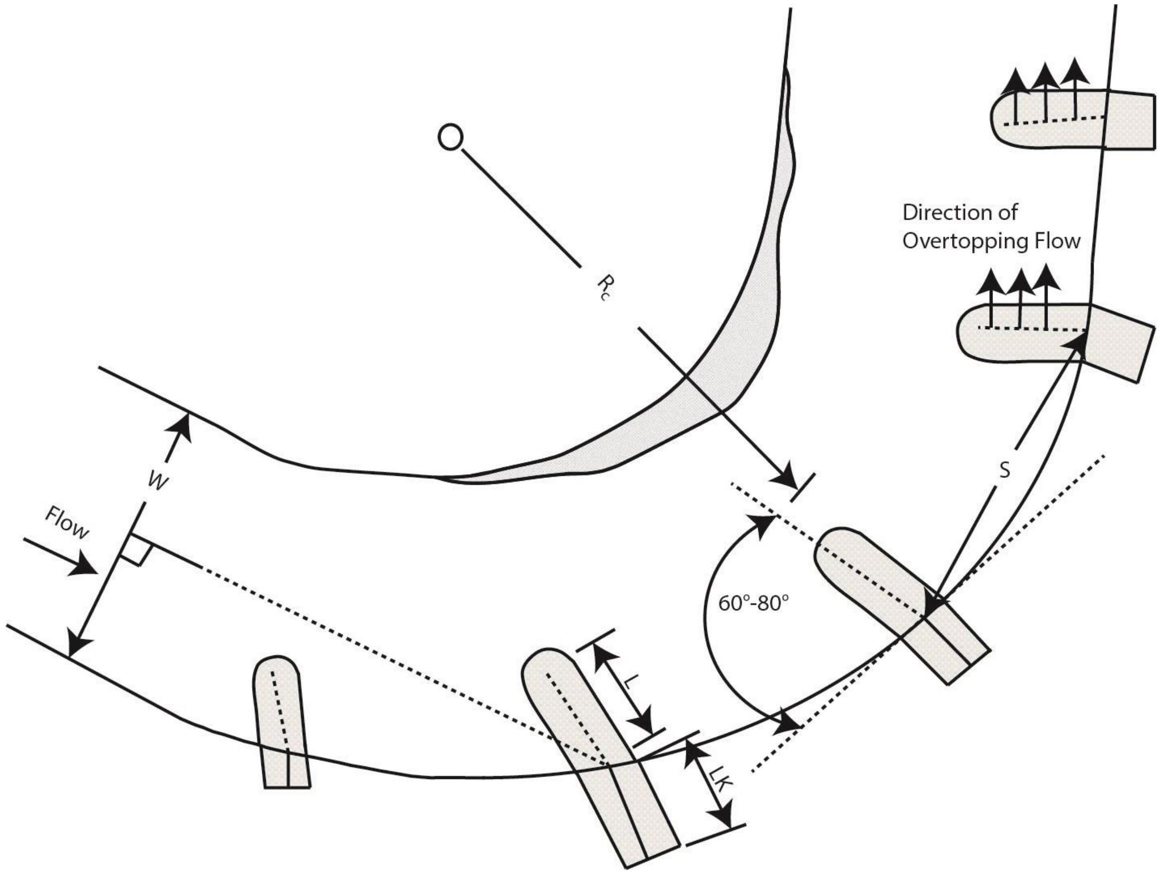


Figure 15.12 Bendway Weir Typical Plan View

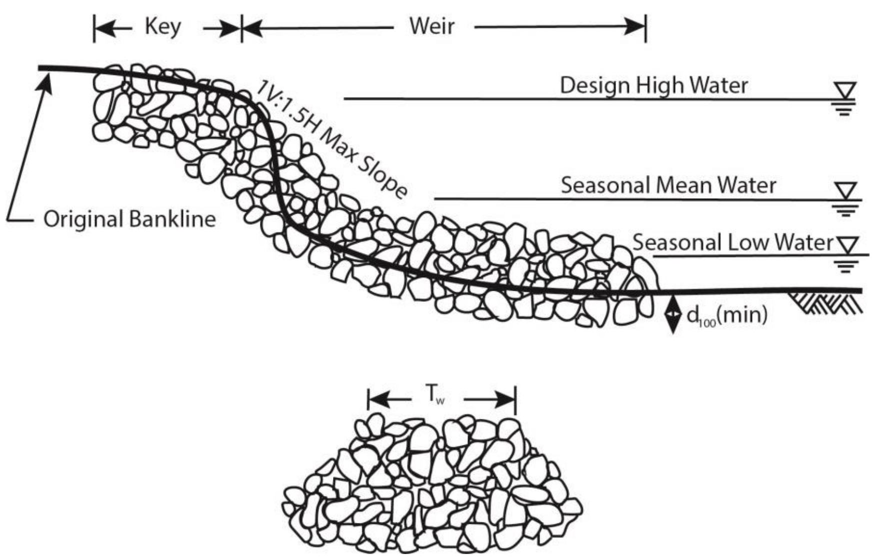


Figure 15.13 Bendway Weir Typical Cross Section

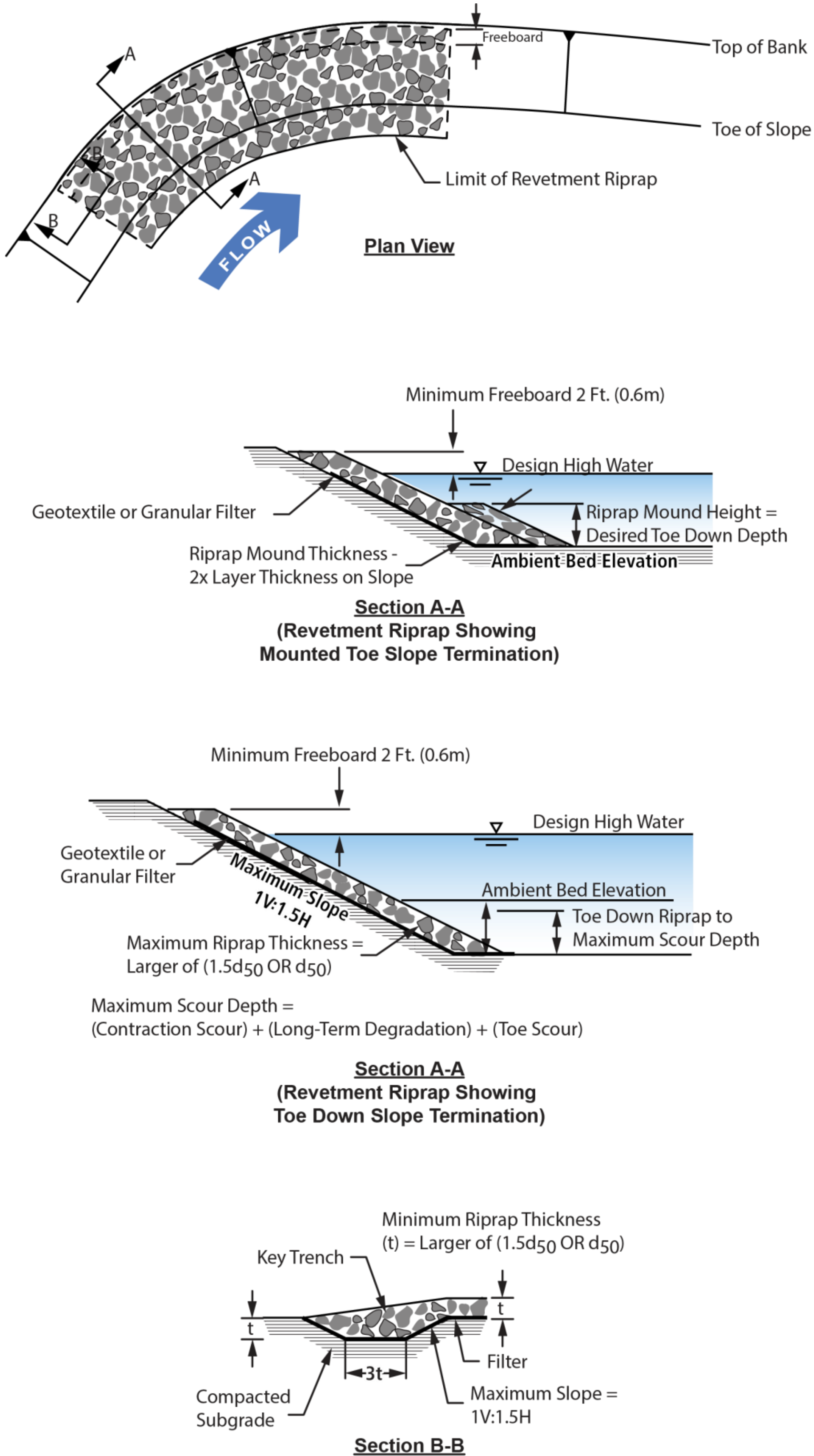
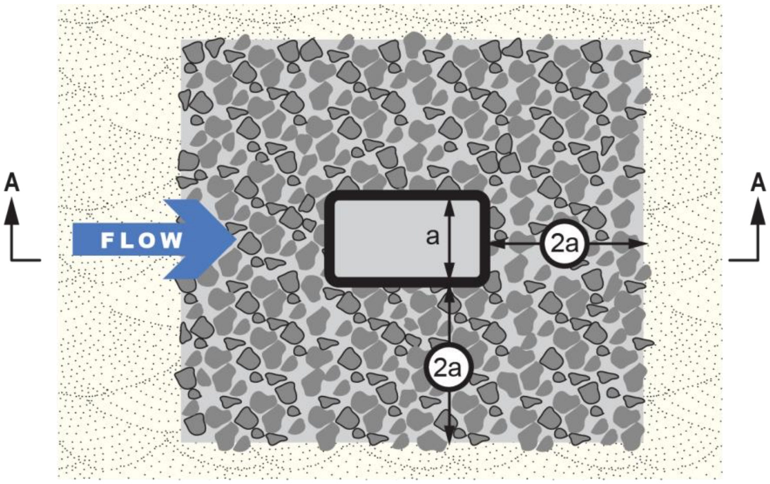
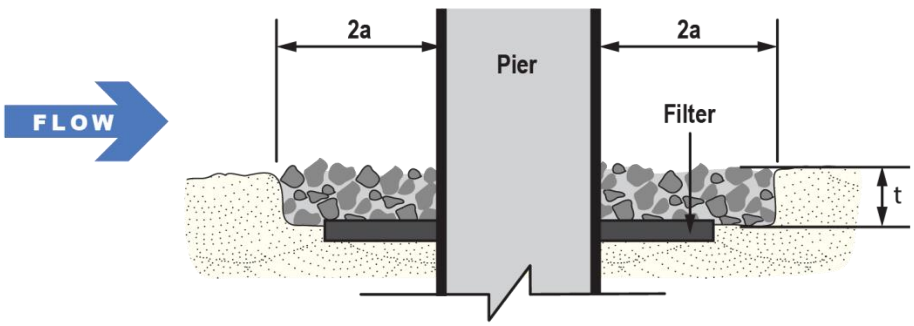


Figure 15.14 Riprap Revetment Details



Pier width = “a” (normal to flow)
Riprap placement = 2(a) from pier (minimum, all around)

Plan View



Minimum riprap thickness $t=3d_{50}$, depth of contraction scour and long-term degradation, or depth of bedform trough, whichever is greatest

Filter placement = 4/3(a) from pier (all around)

Section A-A

Figure 15.15 Riprap Layout Diagram for Pier Local Scour Protection

Because stone is produced and delivered in a range of sizes and shapes, the required size of stone is often stated in terms of minimum, mean, and maximum allowable size or weight. The shape of a stone can be generally described by designating three axes of measurement, as shown in Figure 15.16. Riprap stones should not be thin and platy, nor should they be long and needle-like. Therefore, specifying a maximum allowable ratio between the largest and smallest axis (i.e., shape factor) provides a suitable measure of particle shape. A maximum shape factor of 3.0 is recommended. Recommended tests for riprap rock quality are presented in Table 15.1.

Table 15.1 Recommended Tests for Riprap Quality

Test Designation	Property	Allowable Value	Frequency[1]	Comments
AASHTO TP 61	Percentage of Fracture	< 5 percent	1 per 20,000 tons	Percentage of pieces that have fewer than 50% fracture surfaces
AASHTO T 85	Specific Gravity (S_g) and Water Absorption	Average of 10 pieces: $S_g > 2.5$ Absorption < 1.0%	1 per year	If any individual piece exhibits an $S_g < 2.3$ or water absorption greater than 3.0%, an additional 10 pieces shall be tested. If the second series of tests also exhibits pieces that do not pass, the riprap shall be rejected.
AASHTO T 103	Soundness by Freezing and Thawing	Maximum of 10 pieces after 25 cycles: <0.5%	1 per 2 years	Recommended only if water absorption is greater than 0.5% and the freeze-thaw severity index is greater than 15 per ASTM D 5312.
AASHTO T 104	Soundness by Use of Sodium Sulfate or Magnesium Sulfate	Average of 10 pieces: < 17.5%	1 per year	If any individual piece exhibits a value greater than 25%, an additional 10 pieces shall be tested. If the second series of tests also exhibits pieces that do not pass, the riprap shall be rejected.
AASHTO TP 58	Durability Index Using the Micro-Deval Apparatus	Value: Application > 90: Severe > 80: Moderate > 70: Mild	1 per year	Severity of application per Section 5.4, CEN (2002). Most riverine applications are considered mild or moderate.
ASTM D 3967	Splitting Tensile Strength of Intact Rock Core Specimens	Average of 10 pieces: >6 MPa	1 per year	If any individual piece exhibits a value less than 4 MPa, an additional 10 pieces shall be tested. If the second series of tests also exhibits pieces that do not pass, the riprap shall be rejected.
ASTM D 5873	Rock Hardness by Rebound Hammer	See Note (2)	1 per 20,000 tons	See Note (2)
Shape	Length to Thickness Ratio (A/C)	<10%, d_{50} < 24 inch <5%, d_{50} < 24 inch	1 per 20,000 tons	Percentage of pieces that exhibit A/C ratio greater than 3.0 using the Wolman Count method (Lagasse et al. 2006).
ASTM D 5519	Particle Size Analysis of Natural and Man-Made Riprap Materials		1 per year	See Note (3)
Gradation	Particle Size Distribution Curve		1 per 20,000	Determined by the Wolman Count method (Lagasse et al. 2006) where particle size "d" is based on the intermediate "B" axis.

(1) Testing frequency for acceptable of riprap from certified quarries, unless otherwise noted. Project-specific tests exceeding quarry certification requirements, either in performance value or frequency of testing, must be specified by the Engineer.

(2) Test results from D 5873 should be calibrated to D 3967 results before specifying quarry-specific minimum allowable values.

(3) Test results from D 5519 should be calibrated to Wolman Count (Lagasse et al. 2006) results before developing quarry-specific relationships between size and weight; otherwise assume W = 85 percent that of a cube of dimension “d” having a specific gravity S_g.

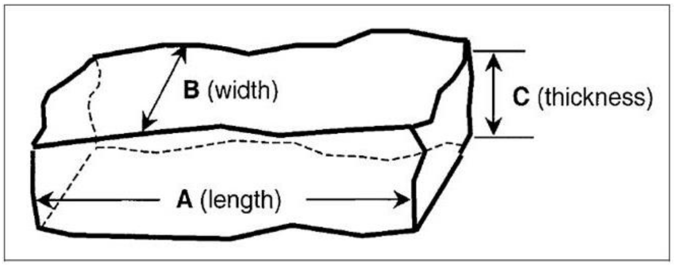


Figure 15.16 Riprap Shape Described by Three Axes

A general rule of thumb for riprap layer thickness is not less than the greater of the diameter of the largest allowable stone or 1.5 times the diameter of the median stone. Riprap placed underwater should be 50 percent thicker than the above noted criteria.

Advantages to gabions and mattresses are that the smaller stone (smaller than riprap) armoring can ease placement and is more resistant to removal by the waterway velocity. Mattresses are usually 1.0 foot or less in thickness, whereas gabions are thicker and nearly equidimensional. The use of these devices is most effective in transitory streams associated with an arid climate. Corrosion and abrasive failure of the cage wire is a concern for gabion construction in perennial streams. Galvanized and PVC coated wires are commonly used to extend the expected life span of gabions. Gabions are not recommended for use in gravel bed streams or in saline or acidic waterways. To improve anchorage, the cages can be anchored to steep slopes with railroad spikes. Examples of gabion mattress design details are presented in Figure 15.17 through Figure 15.20.

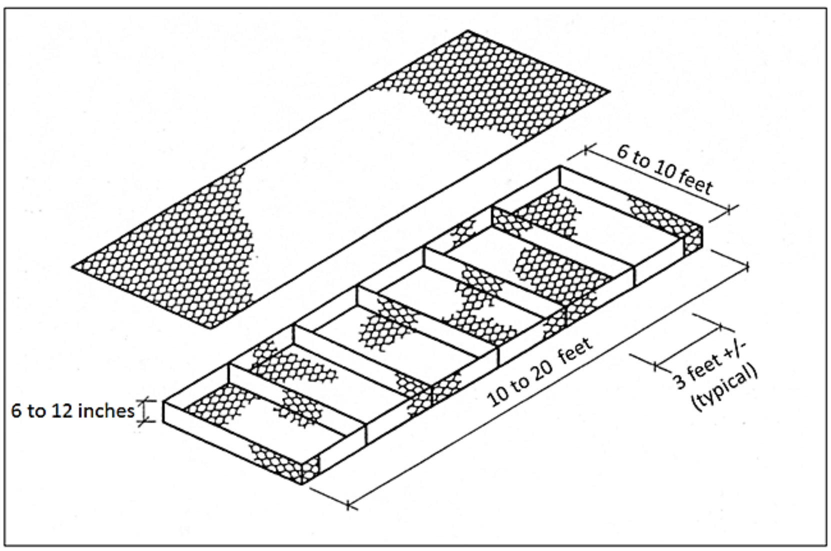


Figure 15.17 Gabion Mattress Showing Typical Dimensions

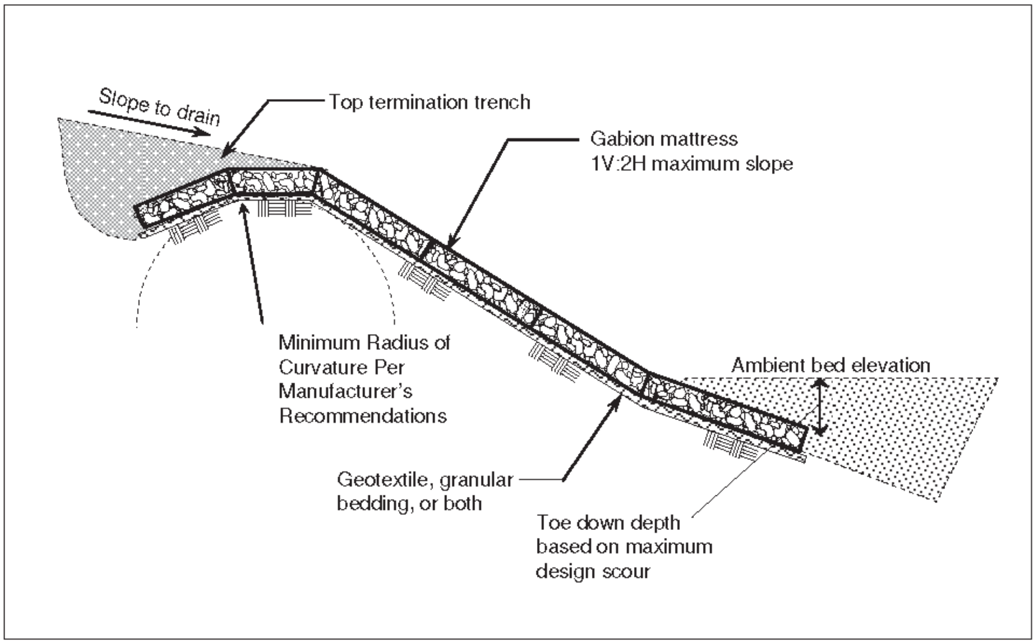


Figure 15.18 Suggested Installation Detail for Gabions Used as Bank Revetment

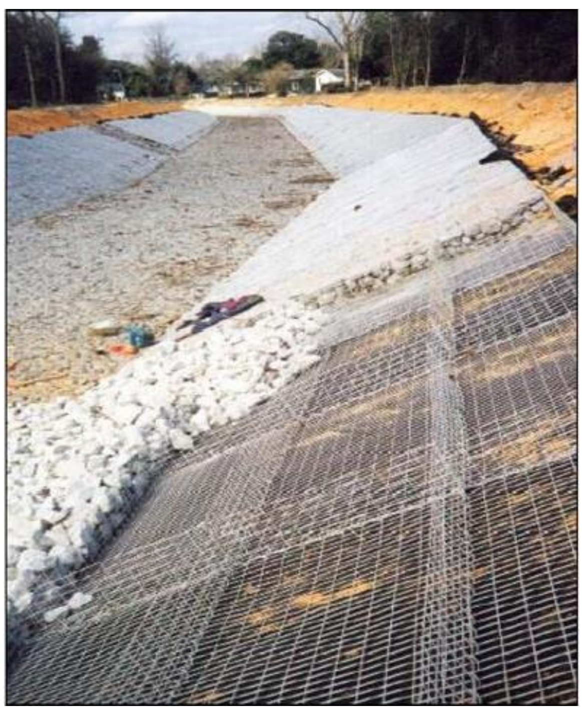


Figure 15.19 Field Installation of Gabion Mattresses on Channel Bed and Banks

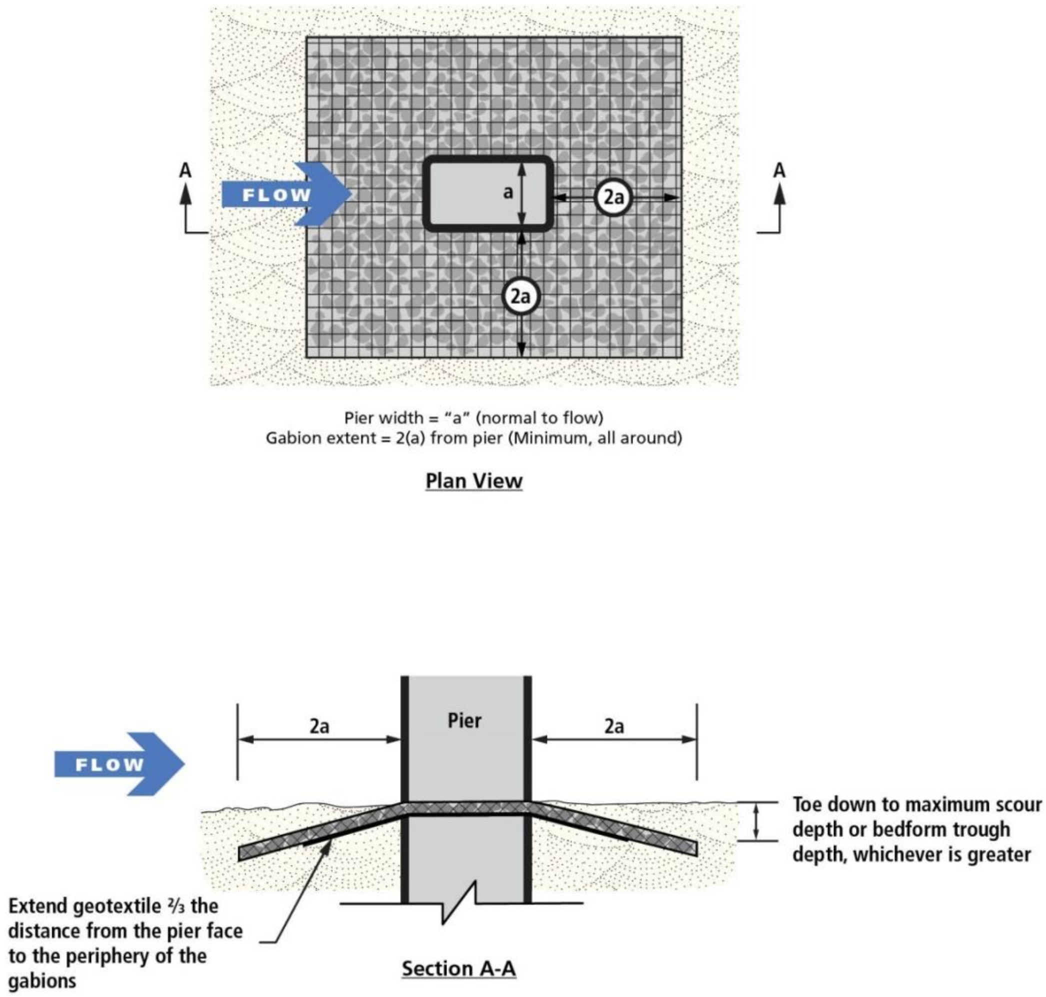


Figure 15.20 Gabion Mattress Layout Diagram for Pier Local Scour Counter Measures

Filters are essential to the successful long-term performance of porous armoring countermeasures such as riprap and gabions. The filter layer prevents excessive migration of the base soil particles through the voids in the armor layer, permits relief of water pressure under the armor, and distributes the weight of the armor to provide uniform settlement. There are two basic types of filters: granular and geotextile.

Subgrade soils should not be frozen and should be free of organic material. Divers should be used to verify underwater conditions are suitable for riprap placement. Filter placement should result in a continuous installation that maintains contact with the subgrade. Voids, gaps, and tears should be replaced or repaired.

Placing geotextiles under water is difficult. Some fabrics are buoyant and need to be anchored until the armor material is placed. Strong currents will create large forces on the fabric, causing the fabric to act like a sail, resulting in wavelike undulation. In deep water or strong currents, sand filled geotextile containers or proprietary mat systems can provide the filtering requirements. Geotextile should be placed so that upstream strips overlap downstream strips (1.5 feet dry / 3.0 feet underwater). Anchoring pins or weights can be used to keep the fabric in place.

Granular filters should be placed with front-end loaders with slopes limited to 1V:4H. Tremie tubes can be used to place granular filter material underwater at bridge piers.

Riprap may be placed underwater or in the dry from land or water based operations. Stones should be placed from the bottom working toward the top of the slope so that rolling and/or segregation does not occur. Riprap should be placed using methods that do not stretch, tear, puncture, or reposition the underlying fabric. Tracked and wheeled equipment should not be permitted to operate on lower lifts or finished application because they can destroy the interlocking integrity. Special purpose equipment, such as clamshells, orange-peel grapples, or hydraulic excavators, is available for installation. Sounding surveys, divers, sonar profiles, or remotely operated vehicles should be used to monitor and verify underwater placements.

Riprap and gabion mattresses can be grouted to control particle erosion and to create a smoother / more efficient hydraulic opening. Filters are not required for fully grouted riprap, however drainage of pore pressure must be provided. A significant disadvantage of complete grouting is that the grout converts a flexible revetment to a rigid cover, subject to toe undercutting, out-flanking, and the possibility of sudden catastrophic failure. Partially grouted systems have been used to maintain system flexibility while increasing stability (Figure 15.21). Guidance suggests that the grout should fill between 1/3 and 1/2 of the total void spaces. Additionally, a filter layer should be used with partially grouted rip-rap.

Figure 15.21 Close-Up View of Partially Grouted Riprap

Overhead restrictions should be considered when determining if riprap placement is a feasible alternative along abutment and pier faces obstructed by low superstructures. This is an example where gabions may be more practical than large riprap.

15.3.2 Tremie Concrete

Tremie concrete placement methods use a pipe or tube, through which concrete is placed below the water level. The lower end of the tube is kept immersed in fresh concrete, so that the rising concrete from the bottom displaces the water without washing out the cement content (see Figure 15.22). Tremie placements should be isolated from fast moving currents.

Figure 15.22 Tremie Placement (Courtesy of Underwater Engineering Services, Inc.)

The concrete mix should be designed to flow readily and the vertical fall distance should be minimized to prevent segregation. Concrete admixtures are available to improve the concrete mix performance for tremie applications. Examples are antiwashout admixtures and flow-improving admixtures.

Tremie placements can be effectively used to repair foundation undermining after a local scour event. An example is shown in Figure 15.23. A means should be provided to allow the trapped water to escape as the concrete surface rises.

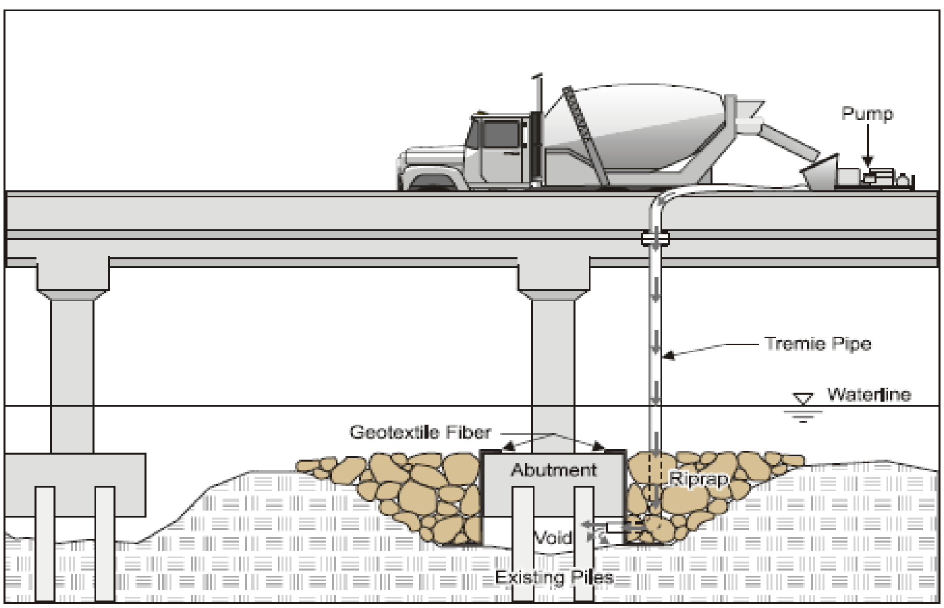


Figure 15.23 Tremie Concrete Placement used to Repair an Undermined Pile Cap (Courtesy Virginia DOT)

15.3.3 Grout Bag Placement

Concrete or grout filled bags and mattresses can be placed on dry bedding material or underwater by divers. The bags can be stacked and pinned together with rebar. The bags are fabricated in many shapes, sizes, and configurations with many proprietary systems available for a wide range of applications.

Common applications for grout filled bags include riprap substitution (revetment armoring, groin construction, local scour armoring, etc.) and as facing formwork for foundation undermining repairs. Examples are shown in Figure 15.24 through Figure 15.28.

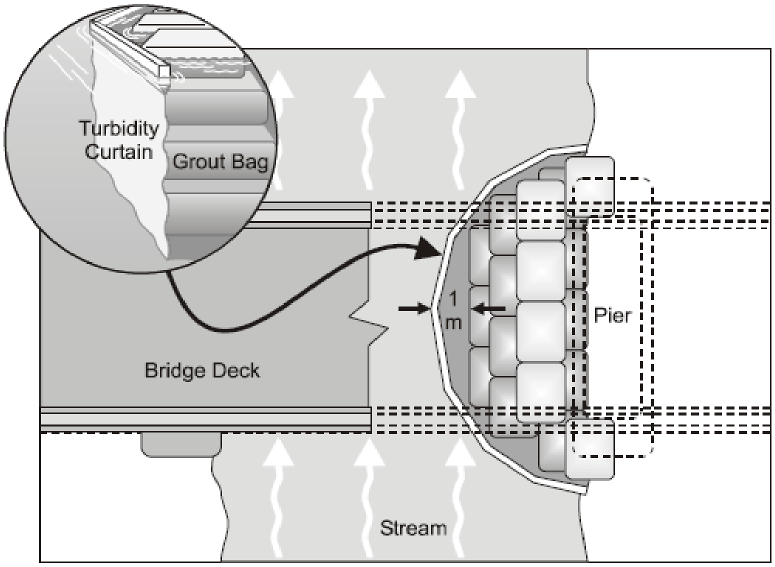


Figure 15.24 Grout Bags used for Local Scour Armoring (Riprap Substitution) (Courtesy Virginia DOT)

Figure 15.25 Grout Bags Installed around a Pier Nose (Courtesy Virginia DOT)

Figure 15.26 Grout-Filled Mat Used for Scour Protection at a Bridge Abutment

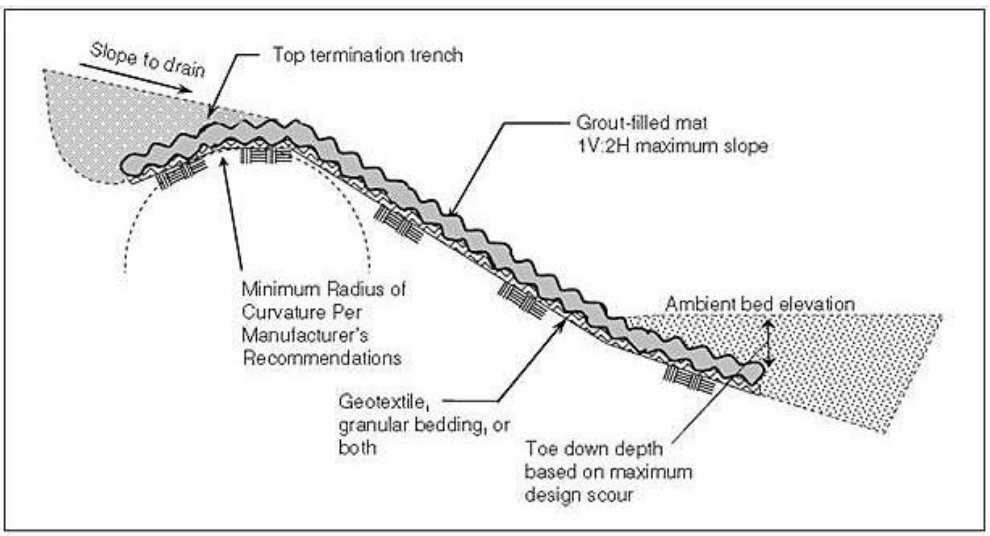
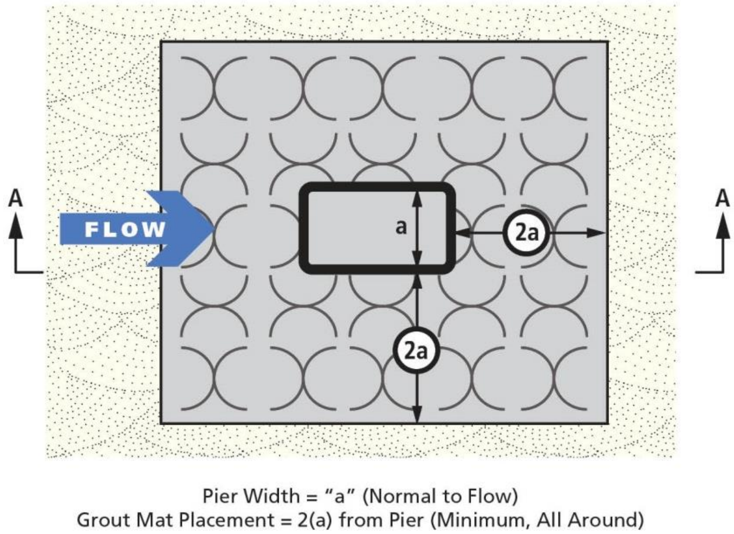


Figure 15.27 Suggested Installation Detail for Grout-Filled Mats Used as Bank Revetment



Plan View

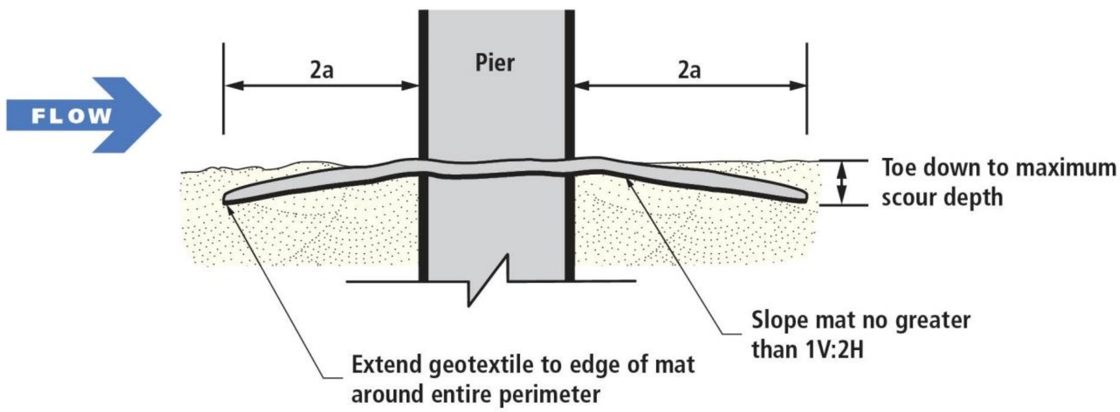


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Figure 15.28 Layout for Grout-Filled Mats at Bridge Piers (Local Scour Prevention)

The grout should be designed to be pumpable with compressive strengths of at least 2,500 psi at 28 days. Admixtures are available to improve the flowability of the grout mix.

When stacked as forms for undermining void repairs, joints should be staggered between rows and anchored with rod dowels. Lower level bags should be permitted sufficient set time to support the succeeding vertical course. Grout injection should be performed in a manner to avoid bag rupture, prevent cold joints from forming, and to prevent discharge of grout material into the waterway. Void injection and venting pipes should be inserted during bag installation and positioned to ensure that the enclosed volume can be completely filled, and the enclosed water displaced. A four foot maximum spacing of injection/vent pipes is recommended.

15.3.4 Sheet Piling

Sheet piling can be effectively used to contain tremie concrete placements at foundations and as a countermeasure against stream migration (Figure 15.29), degradation (Figure 15.30), and local scour protection.

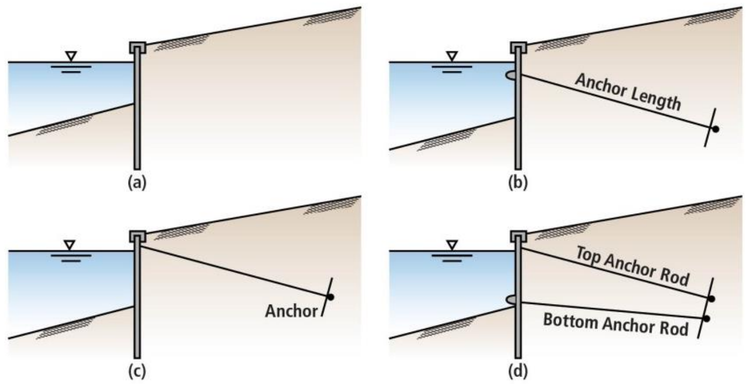


Figure 15.29 Anchorage Schemes for a Sheet Pile Bulkhead

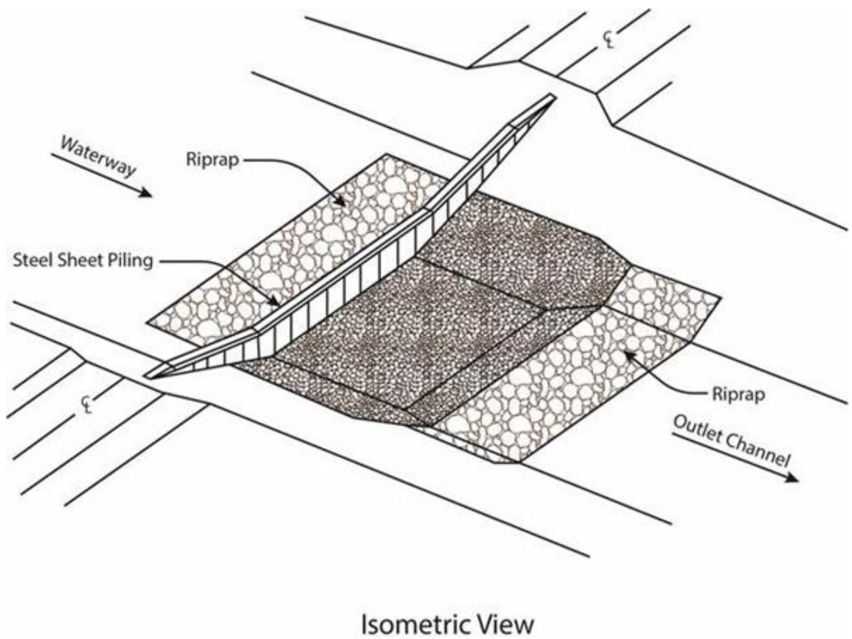


Figure 15.30 Isometric View of a Sheet Pile Check Dam

Sheet piling refers to the linear driving of adjacent pile elements into the existing soil to retain earth or prevent seepage. The piling can be constructed of interlocking steel, timber, or pre-cast concrete elements and can be configured with or without lateral anchorage. The pile elements are typically driven into the ground with crane mounted hammers, which are selected for the anticipated driving conditions.

Design of a sheet piling system requires knowledge of the existing soil conditions, evaluation of forces and lateral pressures, determination of the required penetration depth, anchorage selection and anticipated driving conditions. Pile elements should be structurally designed to resist the driving forces, surcharge loading, and the lateral earth forces encountered during typical and maximum anticipated scour conditions.

Selection of sheet piling solutions should consider overhead clearances for driving equipment, clearances to overhead and underground utilities, depth to impenetrable soil/rock layers and vibratory effects on nearby structures and facilities.

15.3.5 Articulated Block

Articulated block concrete (ABC) systems provide a flexible alternative to riprap, gabions, and rigid revetments. These systems consist of preformed units which either interlock or are held together with cables (or both) to form a continuous blanket. Example of the preformed unit shapes used in these systems are shown Figure 15.31. Typical uses include revetment and bed armoring, where the mat is placed across the entire channel cross section and for pier scour protection (see Figure 15.32 and Figure 15.33).

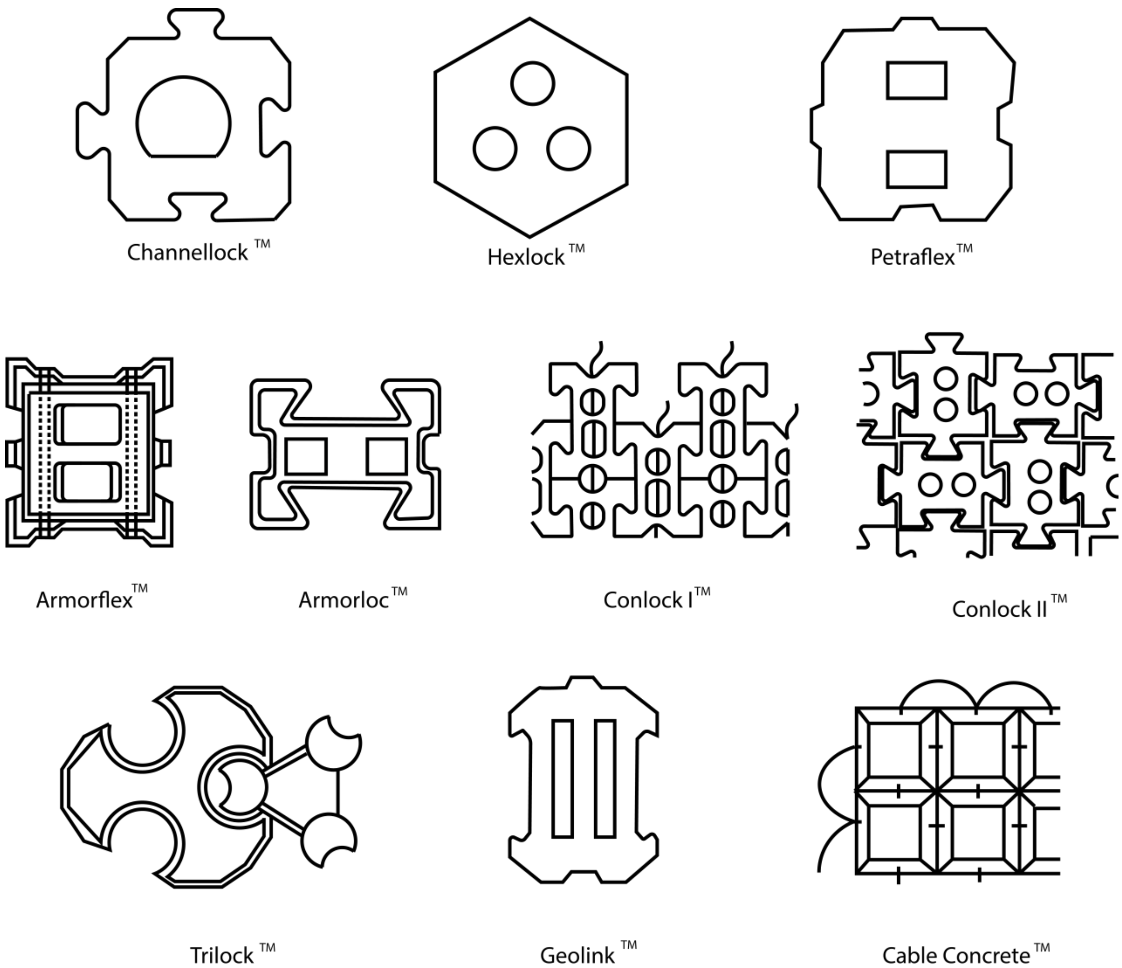


Figure 15.31 Examples of ACB Revetment Systems

Block systems vary in shape and size and will have unique design parameters suited to a range of anticipated hydraulic conditions. Block system should meet the physical requirements of ASTM D6684. In northern climates, the number of anticipated freeze/thaw cycles and corresponding weight loss cycles should be specified. Design and installation procedures should closely follow the manufacturer's recommendations to prevent uplift pressure and loss of subgrade soil through piping and liquefaction, which can lead to progressive plucking failure.

Articulated block systems are typically installed with a geotextile filter, although granular filtering can be used in certain situations. Installation in perennial streams will likely require stream diversions or cofferdams. Some systems maintain sufficient open spaces for the establishment of vegetation.

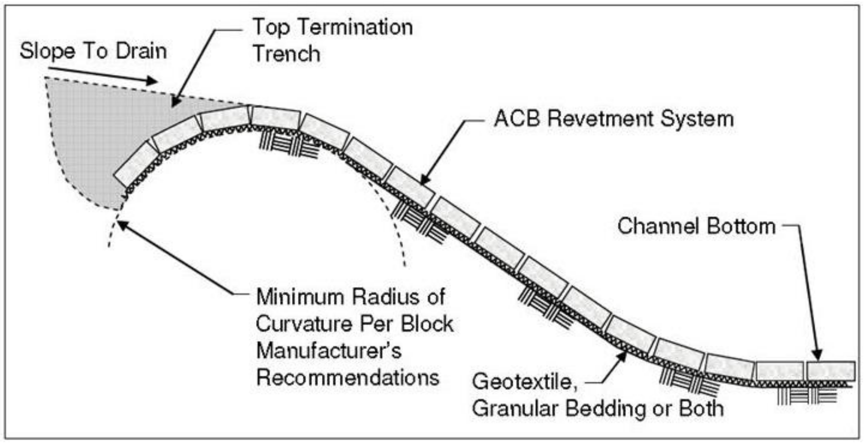
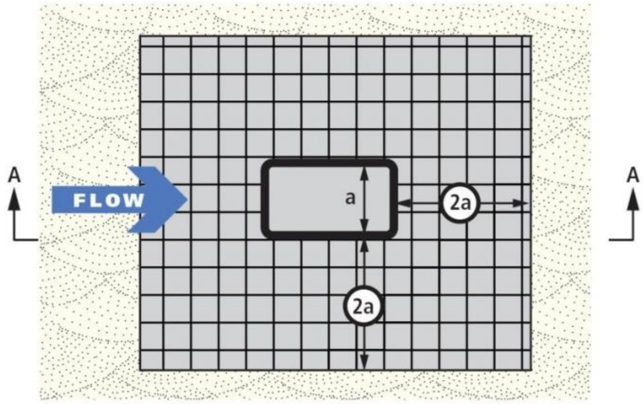


Figure 15.32 Recommended Layout Detail for Bank and Bed Armor



Pier width = "a" (normal to flow)
ACB placement = 2(a) from pier (Minimum, all around)

Plan View

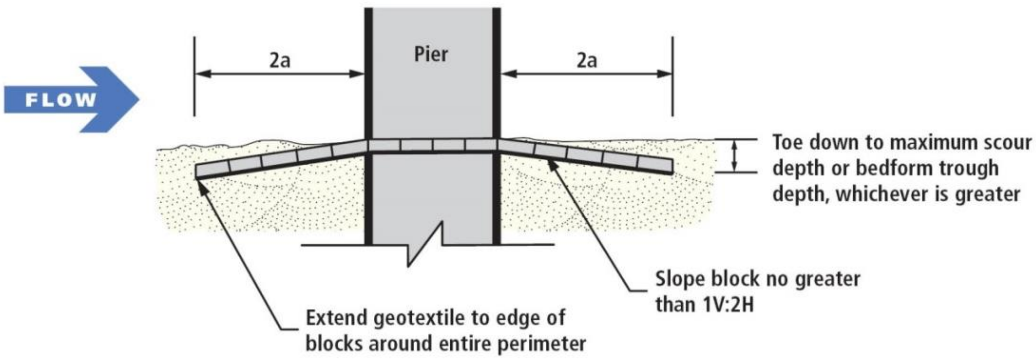


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Figure 15.33 ACB Layout Diagram for Pier Local Scour Counter Measures

15.4 Chapter 15 Reference List

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