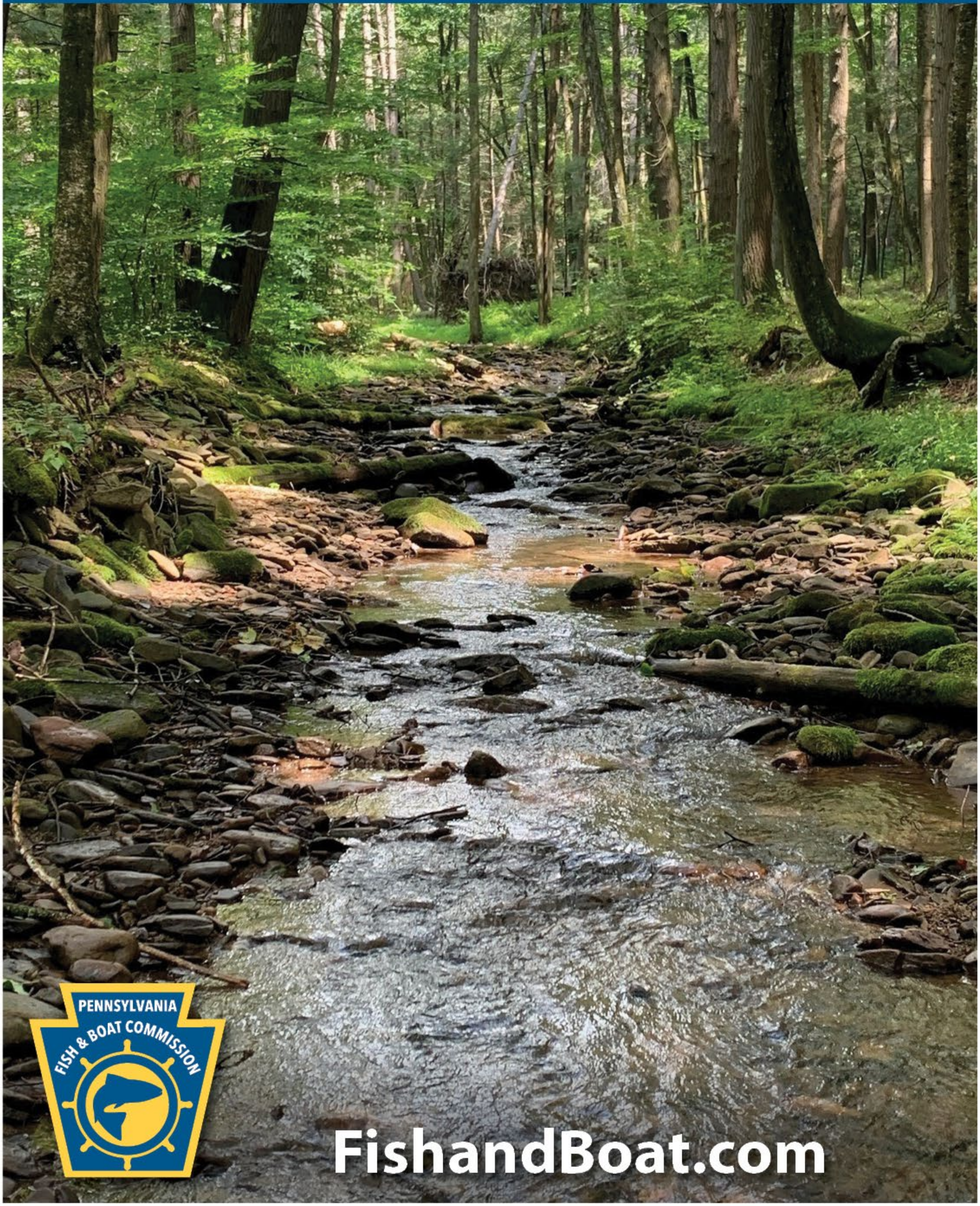
STREAM HABITAT IMPROVEMENT



Stream Habitat Improvement

Second Edition 2025

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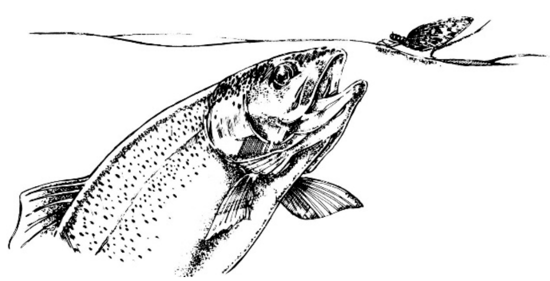


Introduction

The Pennsylvania Fish & Boat Commission (PFBC) has been conducting fish habitat improvement since the 1930's and the first version of this publication was printed in the 1950's. The majority of this early work was planned and implemented by PFBC crews. Early publications from this era (1959 -1969) were printed as a “do-it-yourself” guide for the public but urged PFBC assistance with the planning process. In the late 1970’s a Cooperative Program was developed, where the PFBC staff teamed up with volunteer groups to conduct habitat improvement projects together. This cooperative program went by various names over the years, but the Adopt-a-Stream/Adopt-a-Lake Programs, were named in the mid-1980’s. At first, work was done with PFBC staff and equipment. Later, the work developed into a cooperative program using conservation-minded volunteers from all over the Commonwealth.

In 2006, the PFBC elevated its commitment to restoring and improving aquatic habitats by creating the Division of Habitat Management within the Bureau of Fisheries. This new division built on decades of successful habitat work provided more expertise in the field, brought more funding to the table, and extended its outreach to those interested in improving the aquatic resource. Expanding existing partnerships with individuals, organizations, and other agencies is a vital part of completing the high-quality habitat work that will keep Pennsylvania a national leader in fish habitat initiatives. The Cooperative Habitat Improvement Program (CHIP) and the Technical Assistance Program (TAP) were created in 2007 and are currently active. Over the years, the designs and techniques have changed, but the mission remains the same for providing fishing and boating opportunities through the protection and management of aquatic resources.

Further expansion and partnerships reached a new level in 2019. The PFBC partnered with the Environmental Protection Agency (EPA) to expand our mission to improve the aquatic resource. This partnership allowed the PFBC to expand and develop a new unit called the Chesapeake Bay Watershed Habitat Unit. This unit has allowed the PFBC to implement more projects and reach more partnerships than ever before, further advancing our national leadership of stream habitat improvement.

Purpose

This publication is a second edition of the 2007 publication *Habitat Improvement for Trout Streams*. This edition still reinforces some basic understanding of stream ecology and management philosophy as it relates to habitat improvement as discussed in the first edition. This second edition brings the discovery of new design techniques and construction methods that have been successful in the past two decades. It discusses stream habitat assessment to help determine the “limiting factors” that may keep a stream from reaching its full potential. It offers some general guidance in determining which habitat structure is appropriate for a situation and how to construct the device. Permit requirements for these designs, which are administered by the Department of Environmental Protection (DEP), are also explained. The terms “fish habitat improvement” and “habitat restoration,” as discussed in this booklet, involve the enhancement of the existing stream channel. With these methods, there is only minor disturbance to the stream channel and every effort is made to use natural materials that allow fish habitat structures to blend with their surroundings.

Fish, like all living organisms, need a certain amount of space in which to live and grow. This space is called their habitat, and it must provide everything that they require for their survival and prosperity. The more diverse this habitat is, the greater potential it has to support a healthy, self-sustaining population. While nature does well on its own, the placement of artificial habitat structures can often enhance stream sections that lack naturally occurring habitat features. Lack of natural habitat can be the result of many situations, including stream channelization, poor agricultural practices, inadequate stormwater management, disconnected floodplain, and disturbances to the riparian zones bordering the stream.

The PFBC affirms that fish habitat improvement projects contribute to its mission of providing fishing and boating opportunities through the protection and management of aquatic resources. However, the design and placement of fish habitat improvement structures should not be a haphazard venture. There is a science, physics, and to some extent, an art to this process that should not be ignored. The science comes from very specific criteria that has been developed by the PFBC from decades of hands-on experience starting in 1930's and creating countless successful stream projects.

It is also important to understand how flowing water reacts to a habitat improvement structure under normal and significantly higher flows. The artistic process comes from developing a personal expertise and philosophy to design and place structures. And while there are standard designs for all the PFBC fish habitat improvement structures, there may be a necessity to use some creativity and imagination to modify a device or adjust the placement as the site dictates.

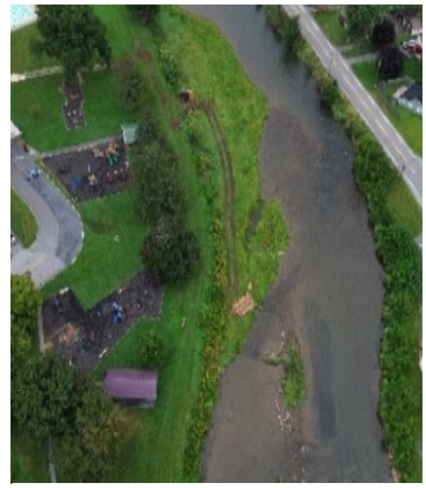
Stream bank stability is often a secondary benefit, but the primary objective should be resource based and should seek to provide better aquatic and riparian habitats. While there is certainly some overlap of purpose, other stream restoration methods, including fluvial geomorphology (FGM), or Natural Stream Channel Design (NSCD), have a primary goal of creating stream channel stability, which often involves a reconfiguration of the channel and often, with major disturbance. Determining what level of restoration is actually needed will determine the best approach.

Knowing the mechanics of flowing water, what has good and poor habitat value, and how a stream reacts to change are important elements to understanding and conducting habitat work. The PFBC has developed a Stream Habitat Visual Survey (see pages 26-27) to help identify key parameters for improvement.

Dynamic Nature of Streams

Whether a headwaters trout stream or a larger river, all waterways have something in common; they are dynamic systems, which means they are ever-changing and reacting to other processes, both natural and man-made. This is a natural process as the waterway tends to seek equilibrium with a stable pattern, profile, and dimension. If a stream is channelized and made wider, shallower, and straighter, it will inevitably begin to form islands and point bars in attempt to narrow and deepen itself again. As a stream changes, some features like deep pools, remembered as old fishing holes, may temporarily or permanently be lost, but they may appear elsewhere as the stream evolves through years of varying flows. The formation of split channels is also a natural process and often provides beneficial habitat variation for young trout and other wildlife. Even though it is human nature to try to "stabilize" streams, their natural evolution causes change and movement from one place to another across a valley floor. These changes can be subtle, taking decades to occur, or they can happen suddenly during a single highwater event. Successful stream restoration approaches should work with what the stream is trying to do, if possible, instead of working "against the flow."

Natural stream setting



Developed flood plain resulting in island and point bar formation

Stream Bank Stabilization

What causes a stream bank to become unstable and erode? There are several factors to consider. The surrounding land use must be examined. For example, is the land use agricultural or an urban area consistent with hard surface area? Is the stream gradient low or high? These are only a few examples that may increase the rate or erosion or are consideried erosion factors, but these still do not define where typical erosion takes place. Erosion takes place where the stream bank interesects the stream bottom. This interestion is refered to as the "toe-of-the-slope." Typically, this can be defined as a very small intersection of only several inches. This area is critical for causing stream bank erosion, regardless of the severety of the erosion. Erosion measuring one foot, five feet, or higher on the stream banks is caused from the instability at the "toe-of-the-slope." There is no vertical or horizontal limit to this area if unstable. When the "toe-of-the-slope" erodes, eventually the remaining vertical bank cannot support itself and the top of the bank falls into the stream. This principal is key to understanding erosion and

Illustration: toe-of-the-slope

Top of the bank falling in due to the erosion at the toe-of-the-slope preventing the catalyst of erosion factors. When preventing stream bank erosion, it is important to stablize the “toe-of-the-slope”, and not to focus your immediate attention to the vertical erosion.

The use of hard surface stream bank stabilization techniques like rip-rap (large stone), gabions (stone-filled wire baskets), and concrete-lined stream banks all provide good bank stabilization when properly used, but with the possible exception of rip-rap, they have little or no habitat value to the aquatic environment. A variety of more natural techniques discussed later in this publication can provide stream bank stability while improving fish habitat.

Hard surface concrete and rip-rap

Hard surface rip-rap

Flood Plains, Wetlands, and Storm Water

The importance of keeping the stream connected to its flood plain cannot be overstated. By allowing high flows to escape the channel and spread out across a wider area, the hydraulic energy is released in a more dispersed fashion. In contrast, constructing a barrier between the stream and its flood plain confines all the energy from raging high water to the stream channel. This results in scouring away existing habitats and causing extensive stream bank damage as it tries to escape. Evidence of this process can be readily seen in more urban areas, where flood plains have been developed and the destructive energy of high flows is compounded by poor stormwater practices. Developed flood plains coupled with ineffective stormwater management plans allow excess flows to reach the stream more quickly instead of absorbing into the ground, causing higher-than-normal flow events. Since there is less time for water to soak into the ground, a period of lower-than-normal flows can soon follow resulting in more severe drought conditions. Ground water retention of storm water will go a long way towards maintaining a normal water table and helping to retain natural aquatic and riparian habitats. Natural flood plains often contain wetland features that are not only valuable for wildlife habitat, but they also act as large sponges, soaking up higher flows and releasing them gradually, thus minimizing high-flow-damage. Eliminating wetlands not only hurts fish and wildlife habitat, but it also increases the likelihood of stormwater damage to human interests.

Results from poor stormwater management

Diversity of Habitats for Wild Trout

Initially, when many people think of improving wild trout habitat, they usually picture a large, easily fished hole that will be filled with "lunker" trout. However, the physical makeup of an ideal trout stream will have a diversity of habitat types for all size classes of trout and other aquatic organisms. Good fish habitat serves all the ecological needs of the species, including spawning areas, nursery habitats, foraging, resting, and hiding areas. Therefore, the objective of undertaking a fish habitat improvement project should address all aspects of the life cycle needs of the designated species.

Healthy age class distribution

The objective should not necessarily be to make every linear foot of stream fishable for adult trout. Habitat diversity is the key and will increase the potential for a healthy, self-sustaining ecosystem. It is also important to examine an extended stream stretch beyond the immediate treatment area and any artificial boundaries or property lines. For example, a good riffle stretch on one property may be the only available riffle habitat nearby and should not necessarily be converted to more pool habitat. Good habitat management values the protection of important existing habitats as well as the creation of new habitats.

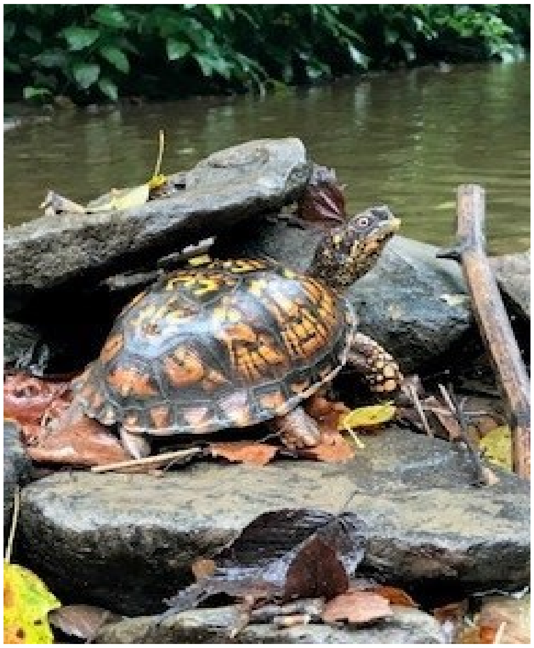
Woody Debris

To this day, it is often considered an acceptable practice to keep stream channels "clean" by cutting brush from the stream banks and by removing larger woody debris from the channel. Although these efforts seem pleasing to the eye, they usually prove detrimental to the aquatic environment. Large woody material (fallen trees, roots, log jams) and vegetative matter, such as leaves and twigs, which enter the stream channel, are an important and necessary component of the aquatic ecosystem. This material serves as a primary food source as well as habitat for many organisms throughout the food chain. Larger woody material helps to form and shape the stream channel and creates variability in habitat types. Woody material provides excellent trout habitat and is not easily duplicated. It also provides a buffer in high water events to slow down surges and can help deflect the water onto the flood plain to relieve energy and increase ground water retention time. Woody material provides many benefits to the stream ecosystem, but individual material jams may increase erosion or endanger roadways, bridges, and personal property. In these cases, it may be necessary to remove part or all the jam to alleviate the problem. Removal decisions are subjective and should be made individually, ultimately removing, or altering only what is necessary. In more wilderness areas, it can be argued to allow woody material to continually shape and change a stream channel as a natural process without interference. It should also be noted that good wild trout habitat in this form might not always be "pretty" or easily fished, but it remains a vital component of the stream ecosystem.

Complex large wood habitat

Stream Corridor Management

A stream is only as healthy as the land it flows through. In return, the land area adjacent to the stream (known as the riparian zone) derives nourishment from the stream's water. They are connected and depend on each other for their well-being. The waterway and its riparian area are a complete ecosystem and should be managed as a whole. Therefore, when considering aquatic habitat enhancement, managing the riparian area is just as important as placing artificial structures in the stream. Having a vegetated buffer zone between the waterway and other land uses has many benefits. Root systems help to keep stream banks stabilized, reducing the amount of silt that enters the stream. Shading from the tree canopy helps keep water temperatures cooler, which is necessary for the survival of many aquatic organisms. There is a direct increase in food, cover, and nesting habitat for a variety of terrestrial wildlife species. Woody debris and leaf litter, which end up in the stream, are a necessary element in a healthy aquatic ecosystem's "food chain." Many aquatic invertebrates use this material as habitat and as a food source. The aquatic invertebrates in turn create an ample forage base for fish. Larger trees absorb excess nutrients through their root systems, changing them into plant tissue, while some nutrients are broken down by organisms in the soil and leaf litter. Sediment can also be filtered out by thick, understory vegetation.



Eastern Box Turtle

A buffer of larger shrubs and trees helps to slow flood waters while deflecting or catching debris, thus protecting fences and other property. Depending on objectives, management of the buffer can either be as simple as letting nature take its course, or it can use a more specific approach. For example, wildflowers or flowering trees can be planted to improve aesthetics. Planting to attract wildlife or to improve water quality may be a priority, or planting fruit trees or managing for timber production to yield a future crop can be a goal. Planting materials should be native species that tolerate moist soils. Studies have shown that the survival of aquatic invertebrates feeding on native leaf litter was significantly higher than those consuming exotic plant species.

In the year 2000, the Pennsylvania Fish & Boat Commission established a riparian buffer policy to establish and/or preserve, wherever feasible, a stable, vegetated riparian buffer zone between waters of the Commonwealth and other land uses on all Commission property. An excerpt of the Commission's riparian buffer guidelines follows:

Existing riparian buffers will be protected and encouraged to develop naturally with a minimum of disturbance. Riparian buffers may be established by simply allowing an area to grow naturally, allowing natural succession to determine vegetative composition, or can be accelerated with plantings of native shrubs and/or trees. Buffer Composition: A forested buffer provides the most benefits and should be promoted whenever possible. However, a native shrub and/or grass community is also acceptable if it is a more amenable land use. Native vegetation should always be selected while the use of exotics and ornamentals should be avoided. Buffer Width: The width of the buffer area can be very subjective depending upon the use of the site. Forested buffers and areas of limited use should be a minimum of 35 feet wide, measured from the top of the bank or shoreline. On areas that have been routinely mowed for aesthetic reasons, a minimum five-foot strip of denser vegetation should be established along the top of the bank. Buffer Maintenance: Riparian buffer areas should be allowed to grow naturally and with a *minimum of disturbance. Any removal of noxious plant species and exotics should be done mechanically whenever possible. If chemicals are to be considered, they should be applied to specific target plants and they need to be approved for use near water. They also need to be used in accordance with label instructions and conform to all Federal, State and Local regulations. Grass buffers in more manicured areas can be maintained by occasional weed eating, but should remain considerably denser and higher than the adjacent mowed lawn. Larger woody debris found within the stream channel, on the stream banks or elsewhere in the riparian zone should be left as habitat for aquatic and terrestrial animals, unless it is causing property damage or posing a public health or environmental safety hazard.*

Even though the majority of streams in Pennsylvania can benefit from vegetated riparian buffer zones, some select streams without temperature-related problems could actually be enhanced by "daylighting" cuts of the thicker, shrubby vegetation. Typically, the streams that may fit into this category are the limestone spring streams with a constant water temperature. By maintaining a scattering of larger overstory trees and thicker grassy vegetation for stabilization and overhanging cover, the stream can be made more productive by having sunlight reach a portion of the stream channel. This technique should be considered only where water temperatures would not rise above the trout's tolerance. Addressing stream and riparian related concerns on agricultural land brings into focus some additional components of stream corridor management. Practices like streamside fencing and the construction of stable livestock access ramps and crossings are important in managing many farm properties. For more detailed information on these matters and other agricultural related concerns, see the Pennsylvania Fish & Boat Commission publication, Corridor Management for Pastureland Stream (Lalo, J., et al., 1994) and Riparian Buffer Guidelines on our website.

Improved farm stream with habitat structures, fencing, and tree plantings

Installed cattle crossing for access to opposite field and stable watering location

Improving a small stream stretch and its riparian corridor will show many benefits. However, to realize a goal of trout stream restoration, it is often necessary to extend the scope of the project to a watershed scale. By assessing the entire stream and all its tributaries, problem areas can be identified, priorities can be established, and an organized plan of improvements can be implemented.

Stream Assessment

Conducting pre-project assessments can be beneficial during the initial stages of habitat enhancement planning. Before beginning any design work, it is important to determine the problems, or limiting factors, that keep the stream from reaching its potential. By identifying these limiting factors and developing objectives, creating an effective work plan will be easier. The lack of good habitat is often the limiting factor and can easily be addressed, but sometimes more difficult problems need to be solved, such as water quality, stormwater issues and water temperature.


Designing

To evaluate habitat features, the Pennsylvania Fish & Boat Commission uses the PFBC Stream Habitat Visual Survey (see pages 26-27). The procedure is quick and simple to complete and is useful in identifying habitat limiting factors and making planning decisions to improve habitat. The assessment will also provide a numerical score to show justification for project proposals, and the evaluation can be compared with post-project assessments. The survey rates ten habitat and riparian related parameters on a scale of 0 to 20. Parameters examined include fish and aquatic insect available habitat, velocity depth regime, channel alteration, sediment deposition, substrate embeddedness, bank stability, bank vegetation, and riparian zone width. The cumulative score (xxx/200) categorizes the stream stretch as poor (0-55), marginal (56-105), sub-optimal (106-155) or optimal (156-200). Each parameter's scoring will also help determine specific limiting factors related to habitat in the stream stretch. For a more detailed explanation of these protocols, see the following reference: Sausser, Mark; Neimond, Tyler; Schmid, Jeff, Pennsylvania Fish and Boat Commission Stream Habitat Visual Survey Data Sheet Instructional Guide, 2018. This reference can be found online at PFBC's webpage.


Before


10 years later

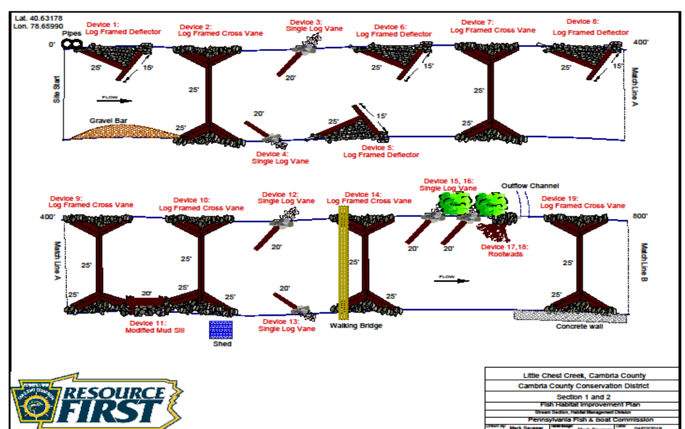
The Pennsylvania Fish & Boat Commission also uses fish surveys (electrofishing) and may conduct redd (trout nest sites) count surveys to assess habitat projects. Electrofishing surveys facilitate the calculation of wild trout population estimates and age/size class distributions. The presence or absence of other fish species is also noted during this procedure, because they are good indicators of aquatic diversity. Redd counts are performed during the spawning period to determine where trout are attempting to spawn and to determine any increase in spawning activity post project. The pre-project counts will also help determine where not to place improvement structures during the design phase, thus protecting preferred spawning sites.


Monitoring

Permit Requirements for Habitat Enhancement Structures

In 1981, the Pennsylvania Fish Commission (PFC) and the Department of Environmental Resources (DER) jointly developed the first General Permit. This General Permit-1 (GP-1) was titled Fish Enhancement Structures and was initially only for Commission use within their Cooperative Program. Shortly after, it was then opened for public use and was meant to provide a quick and simple way to authorize the construction of fish habitat improvement structures in Commonwealth waterways. When the GP-1 was added for public use, the DEP granted the PFBC the use of an abbreviated GP-1 application called the "Alternative Exhibit D" for use in its Cooperative Habitat Improvement Program. In the early 2010s, the Alternative Exhibit D was dissolved by DEP and all fish habitat enhancement activities are solely permitted by DEP within the Chapter 105 regulations as a GP-1.

The Chapter 105 GP-1 regulates the placement of any stream habitat improvement structure in Commonwealth waters. In this permit, habitat enhancement structures are considered an encroachment and/or water obstruction and therefore requires a permit to be constructed. The PFBC has set the standard for fish habitat improvement structures and within this booklet are all the PFBC stream habitat structures that are pre-reviewed by DEP for use with the GP-1. In cooperation with DEP, the PFBC has the initial review of the GP-1 applications for the placement and functionality of the proposed habitat structures. Once PFBC reviews the structure type and placement of the design, an acknowledgement letter will be issued to the applicant to proceed with the permit application process to DEP. Once final approval and authorization is acknowledged by DEP, they will send out an authorization letter which must be on site during construction. To ensure structures are suitable for in-stream habitat improvement, it is recommend using the structures found in the booklet when designing a project.



Design example

For construction activities that require earth disturbance, a Chapter 102 permit is also required. Chapter 102 addresses the control of accelerated soil erosion, and the resulting sedimentation in Commonwealth waters. All work performed under the GP-1, mentioned above, must comply with

Chapter 102. To address this, an Erosion and Sedimentation (E&S) Control Plan must be developed to minimize soil erosion resulting from earth disturbance during the construction of fish habitat enhancement projects. This plan must be approved by the county conservation district and must also be on site as part of the authorization. The PFBC has developed a sample E&S control plan on page 25 that has been pre-reviewed by DEP.

U. S. Army Corps of Engineers—Section 404 of the Clean Water Act

The U. S. Army Corps of Engineers (ACOE), under Section 404 of the Clean Water Act, requires a permit to place any material (or structure) in any stream with a flow greater than 5 cubic feet per second. The ACOE has issued a general permit (SPGP-6) for the construction and maintenance of approved habitat enhancement structures in Commonwealth waters. Essentially, the acknowledgement of and compliance with DEP's General Permit-1 satisfies the COE's Section 404 regulatory requirements. The exception is if the project impacts exceed one-half acre of permanent impacts or one acre of temporary impacts, in which case the ACOE will review the project and will issue a letter of authorization. Please note, it is important to double check the regulatory requirements as some may change periodically.

General Construction Guidelines

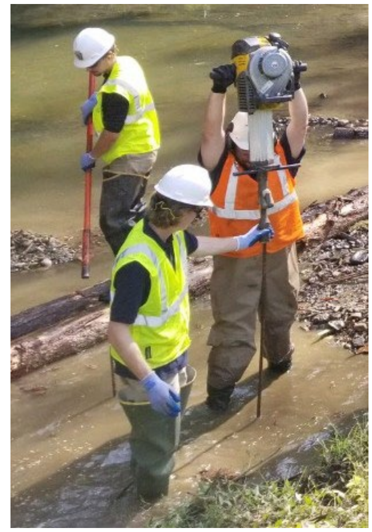
As mentioned previously, the design and placement of fish habitat enhancement structures should not be a haphazard venture. The Division of Habitat Management uses specific criteria for building these structures. The following guidelines include information on habitat structure designs, materials, and installation procedures. Building these structures is a challenging experience, and varying from these guidelines may be necessary as dictated by the uniqueness of the site.

Staging machinery and materials

All fish habitat enhancement structures should be built during normal to low-flow conditions, usually early summer through mid-fall. The completed structure should never be built at an elevation higher than the adjacent stream banks. The maximum structure height should be to the point of the bank known as "bankfull elevation," the height at which high water leaves the stream channel and enters the flood plain. If both stream banks are equally high, the bankfull elevation will be the top of the bank. If one bank is higher than the other, there will be a line of noticeable change in the slope and/or vegetation on the higher bank, indicating the bankfull elevation. High water events at bankfull elevation have the most effect on natural channel alteration and should therefore be used as a gauge when installing fish habitat improvement structures. PFBC "normal" construction activities recommend a structure height elevation of 3/4 "bankfull elevation" and the remaining top of the bank graded down onto the structure to allow for quicker vegetation growth.

Train car crane building habitat structures

Structures should be keyed into the stream bottom and banks. When using logs, the largest end of the log should be trenched a minimum of three feet to five feet into the stream bank. Logs are anchored to the stream bottom by drilling and pinning with 5/8-inch diameter rebar about every 3-5 feet along the log except for the last five feet of the log tip. Driving rebar through logs and into the stream bottom can be made much easier by using a 6-inch-long, 2-inch-diameter soft steel driving head with a 3/4 -inch-diameter hole drilled four inches deep. The driving head slips over the rebar and gives the sledgehammer a larger target to hit. More advanced methods currently being used is a gas-powered jackhammer with a rebar attachment to drive the rebar into stream bottom. In all cases, bend over the last four inches of the rebar pin parallel and flush with the log, pointing in a downstream direction. Bending over the rebar will prevent the log from lifting up from the rebar.



Safety first, using a jackhammer to drive a rebar pin

Safety is essential when building these structures. It's important to wear eye, ear, hand, toe, and head protection. Wearing a high visibility vest is also recommend when working around heavy machinery.

Construction Materials

Logs and timbers that average 6-12 inches in diameter generally fit most needs, although some situations may call for logs with larger diameters. Hemlock and larch are the preferred tree species of choice. Most hardwood and softwoods including oaks, hickory, aspen, birch, and white pine are not recommended choices. Red, scotch, and cedar pines maybe be substituted if hemlock or larch is not available. Fresh cut logs look more natural and blend well with the surroundings. Logs that have been left sitting for two or more years should not be used because rotting will decrease structure longevity. The use of treated or creosoted timbers is not permitted in the waterway.

Flooring

Rough-cut oak (2 inch x 6 inch x 8 foot) is used for flooring in the overhead cover structures. The design and implementation of these structures should allow for this flooring to be submerged as much as possible to slow rotting. Single oak boards should not span a distance greater than eight feet. Treated lumber should not be used.

Reinforcement Rods

Rebar rods are used to pin logs together or to secure logs to the stream bottom. Rods having a 5/8- inch diameter, cut in lengths of two, three, and four feet, should suit most needs for building habitat improvement structures. Two-foot pins are used to attach logs together. Three-foot pins are used to anchor large diameter logs together. Four-foot pins are used to anchor logs to stream bottom.

Nails

Whenever a board is to be attached to a log, use two nails equally spaced from the edge of the board. Galvanized nails are not necessary. Use 40d common nails when using 2-inch flooring. Ten-inch spikes can come in handy for attaching smaller-diameter logs.

Stone

Only clean, nonpolluting material should be used to construct fish habitat enhancement structures. Stone size depends on structure design and the stream's scouring ability. It is a good idea to examine deposits or point and gravel bars. These formations are caused from material moving in the system. A general rule to follow is examining the largest stone in these formations and selecting a stone size larger than what is observed. Another indicator whether a stone is moving or stationary is the presence of moss growing on the stone. Moss is slow-growing and is a good indicator that the stone is stationary.

Stone used in log frame structures can be smaller (usually 12-18 inch) and should be shingled in place if the stones are flat in shape. Structures made entirely of stone should use stone large enough so that it cannot be moved by high flows (usually 18-24 inch). Rock used for boulder placement (usually 24-36 inch) should not be moved by high flows. Construction of some devices (rock vanes, J-hooks, cross vanes) may require very large stone, sometimes as large as four to five feet in diameter (cube- shaped or rectangular-shape preferred).

When building structures by hand, one of the most important things that can be done to reduce future maintenance of structures is to “shingle” the stone fill in place. This technique involves hand-placing stone in an overlapping fashion (like shingles on a roof) by starting down- stream and working upstream. Even though it’s not always feasible or necessary to hand-place every stone, this procedure should be followed whenever possible.

Construction of Structures

Boulder Placement

Placing boulders (see page 38) in uniform stream stretches with little fish cover is probably one of the simplest ways to improve the aquatic habitat. Water flow will scour a deeper pocket around the boulders and fish will use the structures as “side” cover and as places to get out of the main flow. A scattering of boulders may also provide a travel corridor through open areas with minimal cover. Use boulders that are large enough so that they cannot be moved by normal high flows and should be typically seated in the stream bottom so not more or less than two inches stick above or below the water’s surface. Generally, they should be placed in the center third or middle of the stream channel so that they do not direct flows against the stream bank. They can be placed randomly or in a triangular or diamond pattern. They can also be placed just off the tip of a deflector or positioned to create a small run between the deflector and the boulder. They can also be placed at the down- stream tip of a single or multi-log structure as an added brace, which provides additional cover.

Random boulders just under the water surface

Deflectors

Deflectors are triangular structures that serve several purposes. They are most effective in stream sections that are over widened due to bank erosion or historical mechanical over widening. They narrow the existing stream channel, which causes a scouring and deepening effect along the outer face of the device. They will also naturally deposit substrate material along the bank below the device, which further helps narrow the channel as the structure rebuilds lost streambank. They create habitat value along the edges of the device, and they provide stream bank stability where the device is located. Deflectors can vary in design and construction materials, depending on the specific situation. Whatever the variation, some general guidelines of shape, size and spacing should be followed during construction of these structures.

The three angles of the triangle determine the overall shape of the deflector. The most effective design calls for an upstream angle of 30 degrees (to allow scouring to occur along the face of the structure while not causing a damming effect), a downstream angle of 60 degrees (to help deflect higher flows back toward the stream), and a 90 degrees angle at the tip of the structure (to provide strength at a critical point).

The deflector size depends on the stream channel's width. Generally, the distance from the stream bank to the tip of the structure should equal a third of the channel width. This measurement can vary depending on the situation but should never be more than half the channel width. If you know the distance measured from the tip of the device to the stream bank, you can figure out the other dimensions of the deflector (see page 28).

Single deflectors can be used to solve specific problems, but they are more often used in a pattern alternating from one stream bank to the other. This placement helps create a meandering low-flow channel in the existing channel. The spacing of these alternating deflectors varies from stream to stream, but a good place to start is to leave the length of one deflector (measured along the bank) between structures on opposite sides. Adjustments can be made as necessary.

Stone "saw tooth" deflectors

Stone "saw tooth" deflectors (see pages 40-41) are basically irregular rip- rap. They serve not only to stabilize stream banks, but also to create fish habitat in the nooks between the rocks and in the backwater area behind each point. Construction involves grading the bank, where possible, to a 3:1 slope (three feet of horizontal distance for every foot of vertical drop) and then blanketing the area with large stone up to bankfull height. The stone can be dumped in an irregular pattern, or a machine can be used to form the deflector shapes. Buried logs protruding out of the deflector can add additional habitat value. In most cases, the deflectors should extend only about five feet out into the stream channel.

Larger **stone deflectors** (see page 45) can also be constructed. Larger stone size should be used as the frame and keyed into the stream bottom and stream banks. Smaller stone can then be used to fill the frame's interior.

A **stone deflector with single log or stone deflector with root wads** (see page 42-43) is a variation of the standard stone deflector that adds a log for some additional fish cover. It is constructed by embedding the large end of a log into the deflector. The log is positioned parallel to the device's downstream edge and allowed to protrude out of the deflector's upstream face for several feet. The log may cause some extra scouring off the tip of the device, and the angle will help direct flows toward the middle of the stream channel.

Log faced stone deflector

A **log-faced stone deflector** (see page 34) is another variation of the stone deflector that uses logs to add an extra lip of cover along the outer face of the device. It is constructed by embedding two or more sill logs into the deflector, perpendicular to the upstream face of the device. Only a 1-2 foot section of these logs should extend out from this edge. A face log is then attached to the tips of the sill logs with a two foot piece of rebar. An additional one or two face logs can be used to increase the width of cover, if desired. Water depth should be close to two log diameters deep.

Log frame deflectors (see pages 35-36), as the name implies, use logs to frame out the device. The log frame allows for the use of smaller stone for construction. A sill log (upstream log) is first trenched into the stream bank at a 30 degrees angle and pinned to the stream bottom. The frame log (down-stream log) is then trenched into the bank at a 60 degrees angle and pinned to the stream bottom. The frame log can extend out into the stream channel to provide additional submerged habitat and further help deflect water into the middle of the channel. Face logs (20-foot length) are then attached on top of the sill and frame log using two foot rebar pins. Stone can now be placed into the frame, using larger stone to reinforce the areas where the logs meet the stream bank. Stone should also be placed behind the frame log and taper downstream to prevent a scouring effect in this area. The framing of this structure can be multiple log sections to fit the desired improvement area.

Log framed deflector

Log framed deflector using oak boards

The standard log frame deflector can be modified to increase overhead cover in stream sections that have depths of two to four feet by using boards. This is accomplished simply by nailing (2 inch x 6 inch) oak flooring onto the back face log and angling it down into the stream bed within the deflector frame. Only the outermost third of the main log should be floored and no rebar pins should be in this area.

Brush deflectors (see page 33) are as the name implies and is completely built out of brush. These devices are strictly recommended only for use in low gradient systems with high sediment loads. Brush deflectors are designed to capture sediment within the brush and narrow an over widen channel.

A **root wad deflector** (see page 39) is comprised of a mature tree stem cut to a minimum of eight feet in length with the root ball still attached. These devices provide excellent habitat and act to stabilize the stream bank as well. They are typically used along higher, eroding stream banks or deeper drop offs along the banks. To install this device, a trench is dug at an upstream angle of 30-45 degrees. The root wad is placed into the trench with the root ball extending into the stream channel. When laid in the trench, the root ball should rest on the stream bottom, or it should be one-third to one-half submerged in deeper water. The upstream side of the root ball should be tight against the stream bank. Large stone should be placed on the stem within the trench and used to backfill the gap between the root ball and the stream bank.

Root wads to restore lost stream bank

Root wad bench with cross logs to stabilize a 30-foot-high vertical cliff

Root wads can be installed in an overlapping fashion or can be spaced out over a length of stream bank. Also, they can be used to create a bench at the base of a vertical cliff and stacked atop cross logs to provide extra stability.

Single log vane deflectors (see pages 67-69) are most often used in riffles and runs to create and maintain small pockets of habitat and provide some stream bank stabilization. Construction is quite simple, requiring only the digging of a trench in the stream bank for placement of a log. The log should extend out from the stream bank as much as one-third the width of the stream channel, with at least as much in the trench or a minimum of five feet. The log should slope downward into the stream channel at a two percent to seven percent slope to ensure the tip of the log would be under water during low flow periods. A perpendicular measurement from the tip of the device to the stream bank should be one-third of the total bankfull width. It should be remembered that water tends to fall off objects at a 90-degree angle, so the placement of the log is important. The log is pointed upstream at a 20-30-degree angle. This will help direct flows toward the center of the stream. A log angled in a downstream direction will direct flows toward the stream bank, if desired. The water turning at a 90-degree angle towards the middle of the stream will cause a slow moving back eddy towards the bank. This action is extremely important to catch fine silt and sediment that will deposit along the bank. When the water flows over the log and drops off, this hydraulic drop will create a small pocket of habitat behind the log. It is important to note this action has a tendency over time to scour under the log. To prevent this from occurring you must place an apron of stone or secure matting to the upstream side of the log to prevent the under-scour (see the standard drawing for more detail). To finish the structure, large stone should be placed on the log within the trench and in the area where the log enters the stream bank. Stone should not be placed higher than the three-quarters bank full elevation. All dirt removed during excavation should be placed back onto the device to cover up as much rock as possible. While these devices can be used on straight stretches, they are also well suited for the outside of curves. However, it may not be practical to use them on outside bends that exceed a 70-degree radius of curvature. As a general rule, these devices should be spaced one device length apart. Placing the uppermost device and observing the water flow can also determine spacing. The device will redirect flows away from the bank, but it will tend to move back toward the bank at some point downstream. The next device should be placed at the point where flow begins hitting the bank again. In general, these structures will need to be closer together on an outside bend as opposed to a straighter stretch of stream.

Single log vane deflector

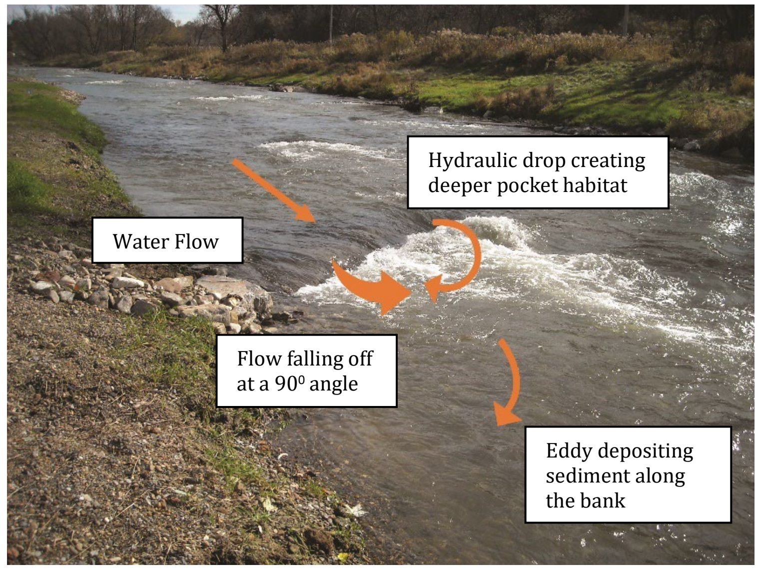


Illustration of water movement and hydraulic reaction to a single log vane structure

A **multi-log vane deflector** (see pages 61-62) is a heftier version of the single log structure and is typically used where there is a high stream bank or a deeper riffle or run. Construction is the same as a single log vane except that two logs are pinned together side- by-side, or three logs in the form of a pyramid. Refer to all construction notes from the single log vane deflector.

Multi-log vane deflector

Rock vanes and rock vanes with J-hook (see pages 65-66) are linear deflectors constructed entirely from large rock (as large as 4-5 foot diameter) and will usually require an excavator with a bucket "thumb" for placement. Rock vanes and J-hook vanes provide stream bank stabilization, help direct flows away from the stream bank and provide some plunge-pool habitat very similar to log vane deflectors. Rock vanes are recommended in stream sections that tend to dry up during summer conditions.

Rock vane deflector

The linear configuration of the rock vane structure runs in an upstream direction at a 20-degree to 30-degree angle to the stream bank. It begins at the three-quarter bank full height on the stream bank and drops at a two to seven percent slope down from the stream bank to just above normal low-flow water levels. A perpendicular measurement from the tip of the device to the stream bank should be one-third of the total bankfull width. To keep the device from falling into its own scour pool, the first step in construction is to embed a line of grade control rocks to their proper elevations. The second step in construction is to embed a line of footer rocks directly behind the grade control rocks into the stream bottom along the downstream edge of where the grade control rocks are placed. The tops of these footer rocks should be at or near stream bottom level. Refer to the additional diagram on the standard drawing.

These devices work by forcing higher flows to run slightly uphill along the stream bank, thus removing some of its energy. Since flowing water tends to fall off objects at a 90-degree angle, the device will also turn flows toward the center of the stream and away from stream banks. As the water falls, more energy is dissipated into the plunge pool.

A curved "**J-hook**" pattern can be added to the upstream end or the tip of deflectors and vanes to create a centered plunge pool effect. The rocks of this extension can have some space between them but should also have footer rocks. This extension should reach through the center one- third of the bankfull width.

J-hook off the tip of a log framed deflector

Cross Vanes

These structures extend completely across the stream channel. There are many new cross vane designs, and some are recommended for low flow and low gradient stream systems. Others are designed with a wider throat or opening intended to handle higher flow and high gradient systems. These structures are designed to provide pool habitat on the downstream side of the devices by using the stream's energy to create a hydraulic drop. These devices are designed and built to be placed just above stream bottom and never to be built to impound water or to create a dam. Regulations and permitting strictly prohibits the use of cross vanes to be constructed as a dam or impound water. A very important aspect of these devices is the use for grade control and for centering flows in the middle part of the channel. Grade control is essential, so the stream does not over scour or entrench itself during high flow periods. If adequate grade control is available the stream will be connected to its floodplain, which will allow water to flow onto the floodplain during seasonal runoffs or storm events. This is a natural function of a stream system by using the floodplain to reduce erosive forces to the stream channel and banks. Streams that are disconnected from the floodplain are prone to confining the erosive forces within the stream banks, resulting in bank erosion and possibly negative channel alterations.

Rock cross vane

Rock cross vane (see page 63) is built using two linear arms, one on each side of the bank, and a connecting rock throat in the middle. The arms should extend to one-third of the bankfull width each, with the middle portion taking up the center one-third. Each arm should be constructed with same guidelines as a rock vane as described above. These structures can be built in high or low gradient systems adjusting rock sizes accordingly. Typical rock sizes in low gradient systems should be R5-R6. While higher gradient systems rock sizes shouldn't be smaller than R7 up to 5x5 foot dimensions.

A **Rock riffle** (see page 64) is constructed the same way as a rock cross vane, but the rock riffle is constructed to provide riffle habitat instead of pool habitat. Both devices are intended to provide grade control.

Log cross vane (see page 57) can be constructed using a log trenched into each bank and meeting each other in the middle of the stream channel. The structures are only intended to be used in low gradient systems. This structure comes together in a V-point and directs all its energy into a small-scale pool. Too sharp of a V-point can lead to too much energy being focused on a central pool and structure failure may result. Log angles extending from the bank should not be less than a 45-degree angle. It's further recommended when constructing a cross vane that a l**og cross vane with rock throat** be designed instead. (see page 56) This design change helps spread out the energy more evenly in the middle third of the stream. **Cross log vane** (see page 55) is used to narrow stream width in low gradient systems. This structure uses one or two logs. Construction of these follows the same construction notes as a single log, but each end of the log is entrenched.

Log framed cross vane (see pages 58-60) were more recently designed for all stream systems. This structure's general purpose is to provide grade control and pool habitat with some overhead cover. The pool size is typically larger than a log cross vane because the energy and hydraulic drop is more evenly spread out over the entire middle third of the stream channel. These structures have proven to be very successful in higher gradient systems as compared to the V-style log and rock cross vanes. The first step to build this structure is to embed the two cross logs into the stream bottom. The elevation of these logs should always be set so they are under water during low flow periods, and typically the top of the log would not be more than 4-6 inches above stream bottom, as long as they remain underwater during low flow periods. These cross logs at a minimum should reach bank to bank.

Log framed cross vane

Log cross vane with rock throat

Log framed cross vane using existing fallen tree

For the best stability, the logs should be trenched 3-5 feet into both sides of the stream bank. The second step is to provide an upstream apron of rock to prevent any future under scour when the pool begins to deepen over time. The third step is to apply the upstream and downstream log wings. These wing sections can be continued beyond one section as the site conditions may vary. To finish the structure, fill in the frame with stone and grade with topsoil. The **log framed cross vane with extension wings** (page 60) helps to maximize the over headcover habitat as well keep substrate from depositing at the end of the pool. **Log framed cross vane with rock throat** (page 58) are used when the stream width is larger than the log length. The middle third of the stream is then connected to each side of the framed structure using rock. Typical log size for delivery is 25 feet up to 30 feet. Depending on site location you may request permission from the landowner to cut larger logs on site for your structure.

Streambank Cribbing and Overhead Cover Habitat

Modified mudsill (see pages 50-53) provides stream bank stability as well as overhead cover provided by two face logs. They are effective in reestablishing stream banks that have eroded away. They can be constructed on a straight stretch of stream, or they can follow the contour of an outside curve.

During construction of a modified mud sill

Completed modified mud sill

These devices are constructed in 20-foot sections by placing sill logs on the stream bottom spaced out 18 feet. Sill logs are usually 8-10 feet in length.

The first step is properly digging a trench. The trench should allow a sill log to sit in a level position with about two 2-4 inches of water over the log during low flow periods. If using an eight-foot sill log, five feet should be in the bank and 3 feet should extend out into the stream, and a six-foot and four-foot split, if using a 10-foot sill log. The sill logs are entrenched into the stream bank and secured with rebar and stone.

The second step is placing two face logs on top of the sill logs using two-foot rebar pins to connect the section. This process can be repeated multiple times to get the desired length needed. A key factor when constructing the device is to ensure the sill logs are embedded into the stream bottom deep enough, so the face logs remain touching the water during low flow periods. The face logs will last much longer if they are wet year-round.

Finally, backfill in with stone up to 3/4 bank full height and grade the remaining eroded bank onto the device establishing a 3:1 slope for grass seed and mulch.

Sawtooth modified mudsill (see page 53) is a unique variation to the standard modified mudsill. This device as its name implies is jagged which is important to provide more surface area to decrease stream energy as well as creating more pocket areas along the face logs. For these benefits, it's recommended to build this variation when the stream is 15 feet or wider.

Construction of a sawtooth modified mudsill waiting for bank grading

Toe log cribbing (see page 54) is a much smaller variation that only consist of one section. This device does not include sill logs, only face logs. The face logs must be entrenched into the stream banks a minimum of five feet. This device is only recommended in small low gradient streams.

Mud sill cribbing (see page 52) is an overhead cover device using oak boards. These are best suited for steep eroding banks that have three feet or more pool depth along the bank edge. They provide stream bank stability and create a stable undercut bank effect for fish cover.

The first and second steps of these devices follow the same instructions as above for a modified mud sill, but the sill logs are only spaced out every 6 feet to accommodate the length of the oak flooring.

The third step is to nail the (2 inch x 6 inch x 8 foot) oak flooring from sill to sill log. Continue placing the boards from the face log to the stream bank, to create an overhanging or "front porch" effect. If the sills are set properly, this flooring should remain slightly underwater.

To complete the framework, a wing log should be added to each end of the structure, running from the tip of the last sill to the bank. This log should slope slightly upward and enter a bank trench at a 30-degree angle. To provide some extra cover, oak flooring can be nailed to the wing logs, running at a downward angle toward the stream bank.

To finish, place stone over the flooring, up to the three-quarters bank full mark, fill the wings with stone, and grade the remaining eroded bank onto the structure to establish a 3:1 slope.


Construction of a bank cover waiting for stone and bank grading

The **bank cover crib** (see pages 47-48) is a simplified variation of the mudsill cribbing and provides similar benefits of stream bank stability and overhead cover. It is most suited to span an outside bend of an eroded stream bank and can be built in single or multiple sections.

This device differs from the mudsill cribbing because the boards are attached perpendicular to the device. This orientation of the boards allows you to space your sill logs out to 18 feet width (not six feet) resulting in less trench digging for your desired structure length.

The oak flooring slopes downward toward the stream bank at an angle no greater than 45 degrees. Using a sledgehammer, it is recommended that you pound the end of the board into the stream bank as much as you can before nailing to the face log. If there is excess board length, you can simply cut to fit using a chainsaw.

The next step is attaching a top log by using two-foot pins driven through the top log into the bottom face logs. The top log will still sit in the saddle of the two bottom logs and is intended to help protect the board edges. Finishing the device is as same as above.

Channel Blocks

Channel block structures (see pages 29-32) are designed to do just what the name implies—block off the flow of one channel and divert all the flow into another channel. It should be noted that every split channel does not necessarily need to be blocked. In fact, many side channels add to the variety of habits in the stream's ecosystem and are often used as nursery waters for young trout. They might be best used to direct normal flows away from a road, building or other property. However, remember that the blocked channel will still fill with water during higher flows as these structures are designed to divert normal and low flow conditions. Side channels are excellent avenues to take high water levels and help disperse energy from the main channel.

When deciding to modify a split channel with this structure, it is critical to choose the best channel to block off. Though many factors come into play, generally it is best to work with what the stream maybe trying to do.

There is simple **channel block with stone,** or they can be very complex as a **channel block with single logs and root wads**.

A **channel block with log frame** is best for smaller streams. It is started by placing two parallel logs into slight depressions across the stream bottom and into trenches in each stream bank. These logs are called the main logs and aids in grade control. The logs should be about four feet apart with the back log sitting slightly lower than the front log. Pin these two logs in the trenches using four-foot rebar pins.

Next, cut brace logs long enough to span the distance across the two main logs. Spaced about four feet to five feet apart, pin the brace logs in place by driving a four-foot pin through both logs and into the stream bottom.

Root wad framed channel block connected to a modified mud sill

Fill the frame and the trenches with stone, making sure that the overall height of the structure is no higher than ¾ quarters bank full. To complete the structure, place stone behind the back main log, tapering downstream like a ramp to prevent scouring in this area.

In some situations, especially larger streams with higher flows, it may be more feasible to build a **channel block with root wads** and/or single logs sticking out to provide extra stability and habitat. The key component to making these structures successful is to remember the lower the structure height the better the stability, but within respects to reach the desired goal.

Large Wood Devices (see page 46) are intended to provide habitat improvement where machinery access is limited, or where trenching into the bank is not recommended. These devices are only to be built by professionally trainer sawyers. Whole trees are cut on site and felled into the stream to provide habitat. If interested in using these types of devices, it's encouraged that you reach out to a state agency for consultation.

Large wood devices also referred to as "chop and drop"

Closing

Stream habitat, whether it is natural or man-made, is a vital element to preserving our aquatic resource, including the animals living in the stream as well as protecting clean water for drinking. Its varying characteristic consisting of riffles, runs, and pools are what makes stream habitat and its ever-flowing system unique and healthy. Some habitats may not look pretty to some, but for others, it is home.

References

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PENNSYLVANIA FISH & BOAT COMMISSION
DIVISION OF HABITAT MANAGEMENT
STREAM & LAKE SECTIONS

EROSION & SEDIMENT CONTROL PLAN FOR THE CONSTRUCTION OF FISH ENHANCEMENT STRUCTURES

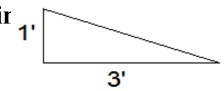
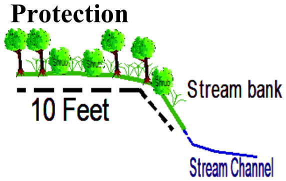
1. Maps and Plans:
   - Maps should show the location of the project with respect to municipalities, access roads, existing structures or other landmarks.
   - Work plans should show a detailed drawing of the specific work site including devices, lineal work limits, stream width, and other on-site features, such as access points, material storage and wetlands, narrative identifying the project, schedule, location, BMPs, and calculations can be included on the plan sheets with the drawings.
2. All work will be done during low-flow conditions, avoiding periods during or immediately following heavy precipitation.
3. Where practical, equipment work will be done from the stream bank, or shoreline, unless entry into the channel is determined necessary and appropriate by the site Habitat Manager. This will be considered appropriate only with minimal disturbance (hard bottom, limited area of travel, etc). Other factors to be considered for in-channel work include a heavily wooded bank, riparian areas (i.e. buffers) or wetlands on or near the bank. Certain Fluvial Geomorphic (FGM) structures such as rock vanes and cross vanes may require in-stream work for efficient and optimal project construction. Equipment should be inspected to ensure that there is no leaking of lubricants, fuel, hydraulic fluids, etc.
4. Excavation of waterway banks and/or bottom for the purpose of keying in stone and/or timbers, will be restricted to work that can be completed that same day.
5. Upon final completion of the earth disturbance activity, or any stage or phase, all disturbed areas will be immediately stabilized with rock, seeding, and mulching, or other suitable material, during the same day. Newly vegetated areas will be inspected and repaired (as needed) until grass is well established. E&S BMPs shall be implemented and maintained until permanent stabilization is completed/stabilized.
6. Grass seed mixtures used for permanent stabilization will either be a shade, conservation or slope variety depending upon the site requirements. Hand broadcasting of seed will average six pounds per 1,000 sq. yds. Mixtures must exclude Reed Canary grass or other known or potentially invasive plants.
7. Straw or hay mulch will be placed by hand to produce a loose layer three-fourths to one inch deep. (3 Tons/Acre)
8. Only clean, nonpolluting materials shall be used as fill, which should be shingled or keyed into the structures for longevity. Minimum stone size should be R-4, as rated by the National Stone Association.
9. Any material excavated during the installation of the structures should be deposited in a suitable site away from the floodplain or wetlands, and stabilized within 24 hours of initial excavation.
10. All enhancement structures shall be constructed according to approved Pennsylvania Fish & Boat Commission specifications. Other designs may be reviewed on a case-by-case basis.
11. Enhancement structures shall be maintained in a safe and functional condition, including necessary debris removal by the owner.
12. Unless there is earth disturbance, dredging or earthen fill used, no E & S plan will be required.
13. Additions to the E&S plan may be requested by DEP for atypical situations.

Revised 07-03-2023

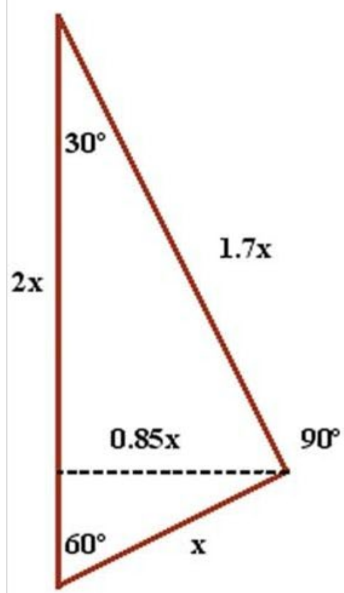
PENNSYLVANIA FISH AND BOAT COMMISSION
Stream Habitat Visual Survey Data Sheet

Stream Name and County:			Date:
Evaluators:	River mile_______________		Time:
Site #	Downstream Coordinates: Lat.	Lon.	Total Score:

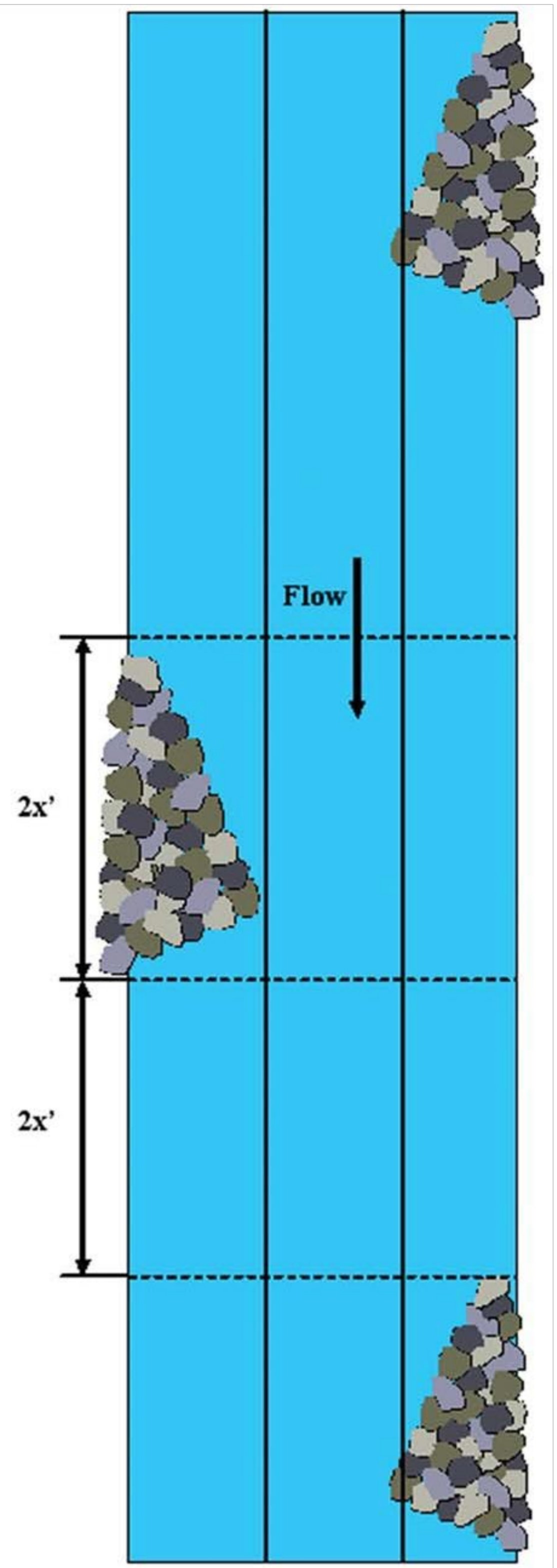
Habitat Parameter	*Condition Category*			
While scoring all parameters adjust to low flow stream conditions. Survey length is 300 meters	**Optimal**	**Suboptimal**	**Marginal**	**Poor**
1. Total Instream Fish Habitat Note: Ex. of habitat: snags, logs, undercut banks or bridge abutments, boulder, stream bottom etc.	Greater than 70% of the stream has fish habitat present in favorable substrate (gravel, cobble, boulder)	40-70% of the stream has fish habitat present in favorable substrate (gravel, cobble, boulder)	20-40% of the stream has fish habitat present in favorable substrate (gravel, cobble, boulder	Less than 20% of the stream has fish habitat present in favorable substrate (gravel, cobble, boulder
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Adult Instream Fish Habitat Note: Ex. of habitat: snags, submerged logs, undercut banks or bridge abutments, boulder, etc.	Greater than 50% of the available stable habitat occurs in 12 inches or greater water depth.	30-50% of the available stable habitat occurs in 12 inches or greater water depth.	10-30% of the available stable habitat occurs in 12 inches or greater water depth.	Less than 10% of the available stable habitat occurs in 12 inches or greater water depth.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Embeddedness and Macroinvertebrate Colonization Note: Evaluate in fastest moving water present.	Gravel, cobble and boulder particles are 0-25% surrounded by fine sediment and providing optimal diversity of niche space.	Gravel, cobble and boulder particles are 25-50% surrounded by fine sediment and still provides suboptimal diversity of niche spaces.	Gravel, cobble and boulder particles are 50-75% surrounded by fine sediment and provides marginal diversity of niche spaces.	Gravel, cobble and boulder particles are more than 75% surrounded by fine sediment and provides very little diversity of niche spaces.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Velocity/Depth Regime Equal lengths of Riffle, Run, Pool, and Glide Note: Pool= > 18" depth Note: Slow is < 0.3 m/s	All four regimes present with a 1:1:1:1 ratio of: slow-deep (Pool), slow-shallow (Glide), fast-deep (Run), fast-shallow (Riffle)	Only 3 of 4 present or 1 regime is not proportionate of: slow-deep (Pool), slow-shallow (Glide), fast-deep (Run), fast-shallow (Riffle)	Only 2 of 4 present or 2 regimes are not proportionate of: slow-deep (Pool), slow-shallow (Glide), fast-deep (Run), fast-shallow (Riffle)	Only 1 regime prevalent of: slow-deep (Pool), slow-shallow (Glide), fast-deep (Run), fast-shallow (Riffle)
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Alteration Note: Exclude habitat devices acting as streambank shoring structures	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization i.e., dredging, or old dams (greater than past 20 years), but recent channelization is not present.	Channelization may be extensive; 40-80% of stream reach channelized and disrupted. Embankments or shoring structures present on both banks i.e. rip-rap, dikes	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
6. Sediment Deposition: Island and Bar Formations Note: Exclude habitat devices from increasing deposition along banks	Little or no enlargement of new islands or point bars and less than 20% of the bottom affected by deposition.	Some new increase in island formation or point bars; 20-50% of the bottom affected by slight deposition in pools.	Moderate deposition on old and new bars or islands; 50-80% of the bottom affected by moderate deposition in pools.	Heavy deposits of material, increased bar and island development; greater than 80% of the bottom affected by heavy deposition; pools filling in with sediment.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Habitat Parameter	*Condition Category*			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
7. Bank Stability Note: Determine left & right banks by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. Less than 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5 – 30 % of bank in reach has areas of erosion.	Moderately unstable; 30 – 60 % of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; bare areas frequent along straight sections and bends; obvious bank sloughing; 60 – 100 % of bank has erosional scars.
Score (LB):	10 9	8 7 6	5 4 3	2 1 0
Score (RB):	10 9	8 7 6	5 4 3	2 1 0
8. Bank Slope and Connectivity to Flood Plair  **Note: a 3:1 slope or gradual incline is ideal for bank stability, vegetation, and flood plain access**	Greater than 80% of the bank has a minimum of a 3:1 slope and high water flow has easy to no restrictions to access the flood plain.	80-50% of the bank has a minimum of a 3:1 slope and high water flow has moderate access to the flood plain.	50-30% of the bank has a minimum of a 3:1 slope and high water flow has limited access to the flood plain.	Less than30% of the bank has a minimum of a 3:1 slope and high water flow has very limited to no access to the flood plain.
Score (LB):	10 9	8 7 6	5 4 3	2 1 0
Score (RB):	10 9	8 7 6	5 4 3	2 1 0
9. Immediate Riparian Zone and Vegetative Protection  **Note: Water's edge to the top of the bank and back 10 Feet**	Greater than 90% of the stream bank surfaces are covered by all three vegetation classes: non-woody plants, shrubs, and tress providing full canopy cover.	70 - 90% of the stream bank surfaces are covered by vegetation, but one plant class may not be represented, or tree canopy is lacking	50 - 70% of the stream bank surfaces are covered by vegetation; patches of bare soil obvious; or two plant classes not represented and/or tree canopy is greatly lacking.	Less than 50% of the stream bank surfaces are covered by vegetation; disruption and bare soil is highly visible. Or very little to no tree canopy present.
Score (LB):	10 9	8 7 6	5 4 3	2 1 0
Score (RB):	10 9	8 7 6	5 4 3	2 1 0
10. Riparian Zone Note: Riparian zone = 4 times stream width but not > 18 meters (59')	Vegetative disruption is minimal or not evident; almost all plants allowed to grow naturally. Human or farming activities not evident.	Vegetative disruption is present by human or farming activities but not affecting full plant growth potential to any great extent.	Vegetative disruption is obvious by human or farming activities; plant growth is moderately affected or prohibited to grow naturally.	Vegetative disruption by human or farming activities has severely impacted plant growth resulting in little or not existing; impervious surface or bare soil is present.
Score (LB):	10 9	8 7 6	5 4 3	2 1 0
Score (RB):	10 9	8 7 6	5 4 3	2 1 0
Notes:				**Optimal= 156-200** **Suboptimal= 106-155** **Marginal= 56-105** **Poor= 0-55**

Deflector Dimensions and Spacing

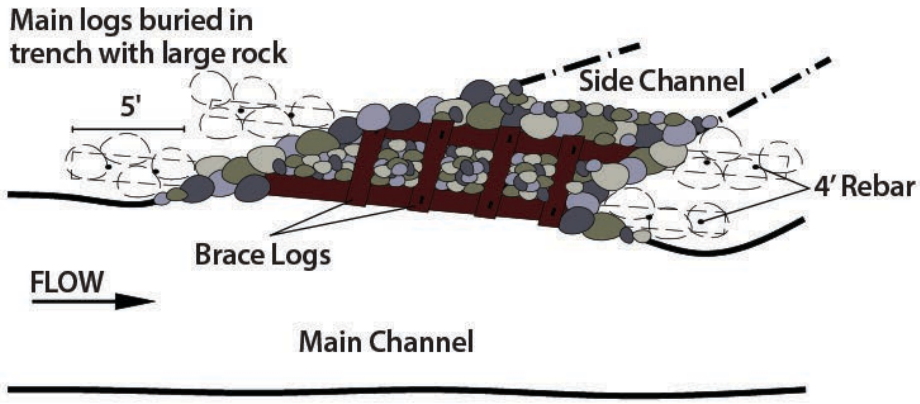


0.85x	x	1.7x
5'	6'	10'
7'	8'	14'
9'	11'	18'
11'	13'	22'
13'	15'	26'
15'	18'	30'
17'	20'	34'
19'	22'	38'
21'	25'	42'
23'	27'	46'
25'	29'	50'
27'	32'	54'
29'	34'	58'
31'	36'	62'
33'	39'	66'
35'	41'	70'

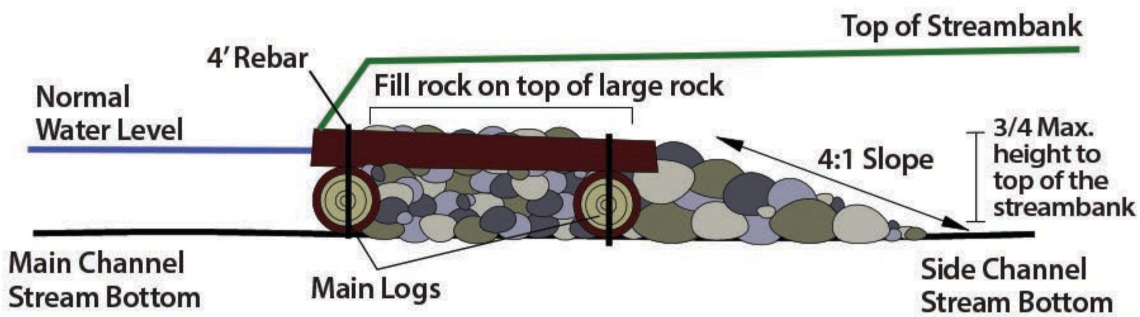


CHANNEL BLOCK WITH LOG FRAME

Plan View



Section View



Note: Channel block built lower than surrounding streambanks
while maintaining normal water level height
Maximum device height is 3/4 to the top of the bank

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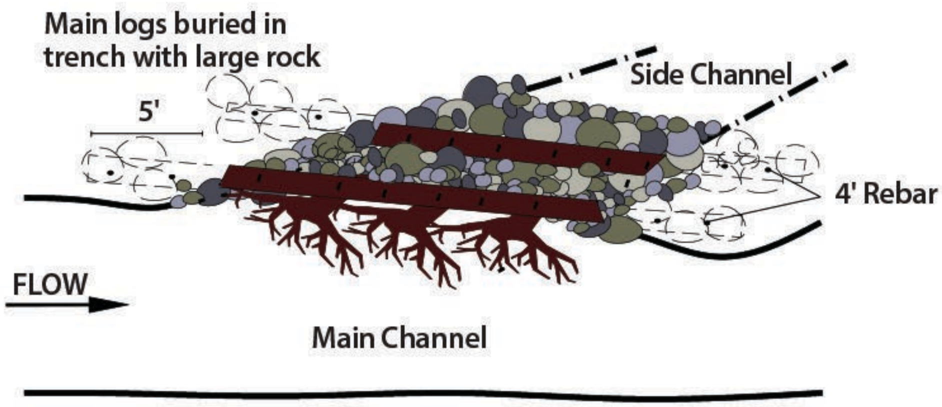
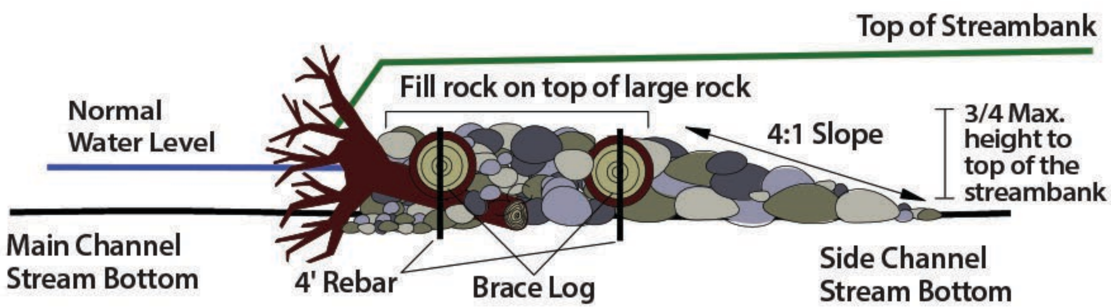
CHANNEL BLOCK WITH ROOT WADS

Plan View



Section View



Note: Channel block built lower than surrounding streambanks while maintaining normal water level height
Maximum device height is 3/4 to the top of the bank

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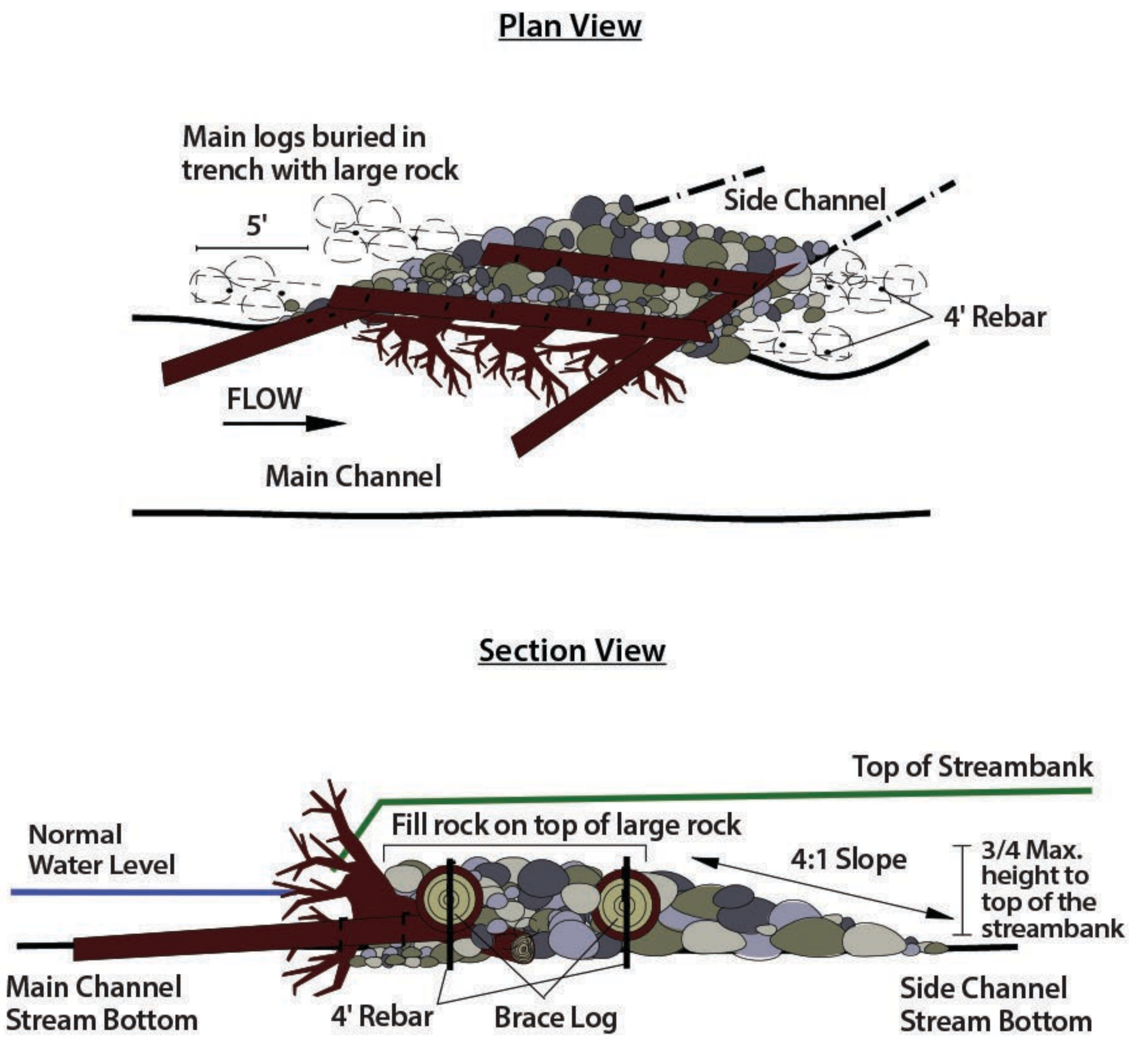
CHANNEL BLOCK WITH SINGLE LOGS AND ROOTWADS



Note: Channel block built lower than surrounding streambanks while maintaining normal water level height
Maximum device height is 3/4 to the top of the bank

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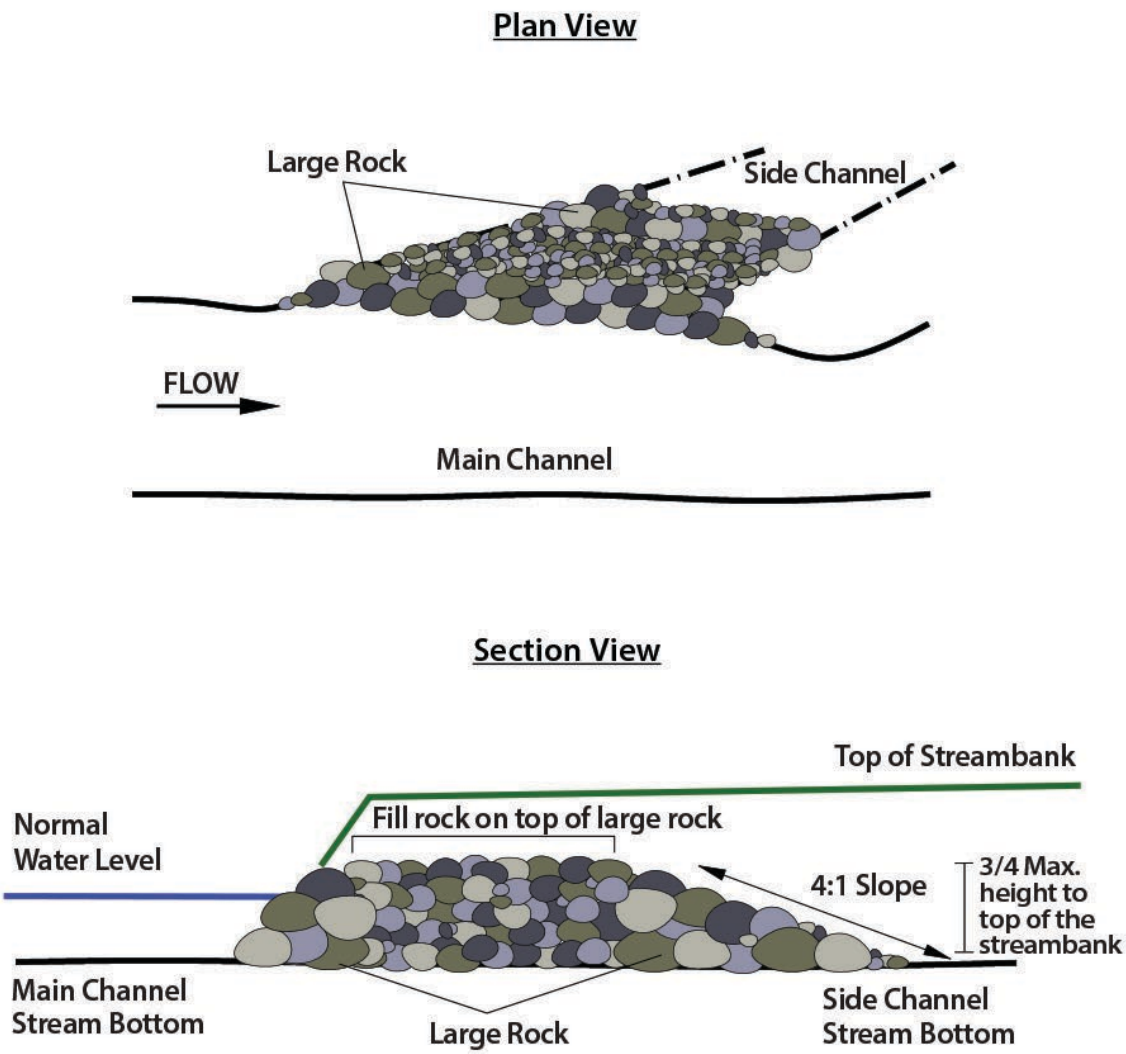
CHANNEL BLOCK WITH STONE



Note: Channel block built lower than surrounding streambanks while maintaining normal water level height
Maximum device height is 3/4 to the top of the bank

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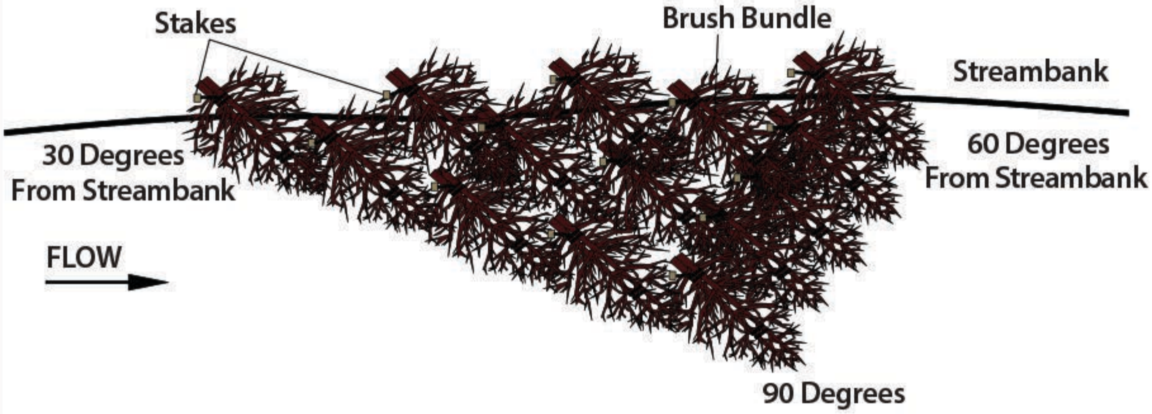
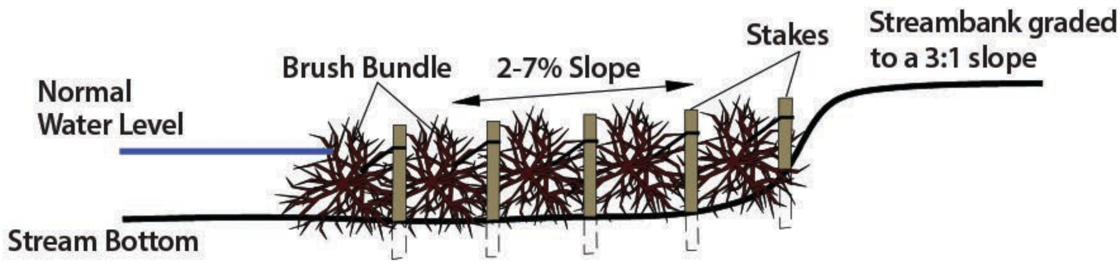
BRUSH DEFLECTOR
(LOW GRADIENT STRUCTURE)

Plan View



Section View



Note: Christmas tree/brush bundles attached to stakes and to other bundles with natural fiber twine
Stakes must be made of wood or other natural material

Note: Recommended only for use in low gradient systems

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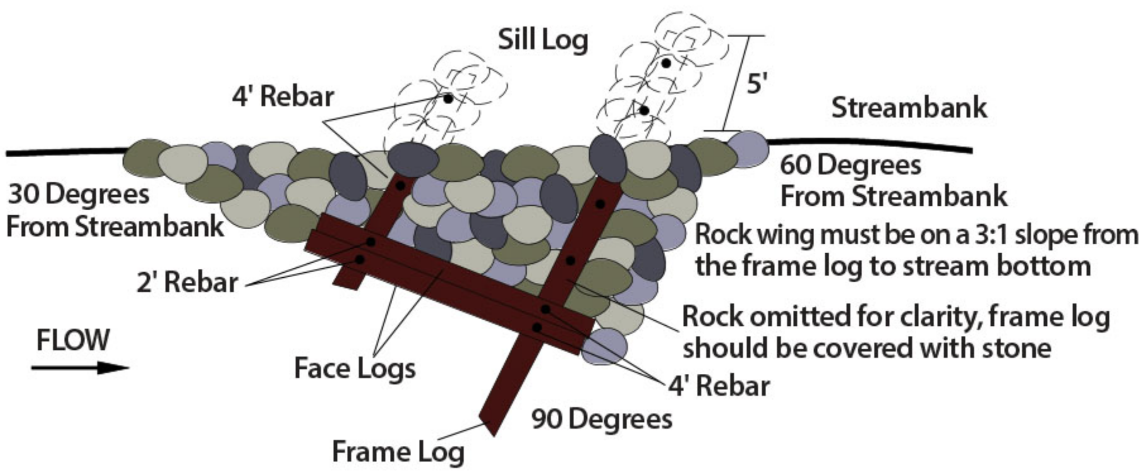
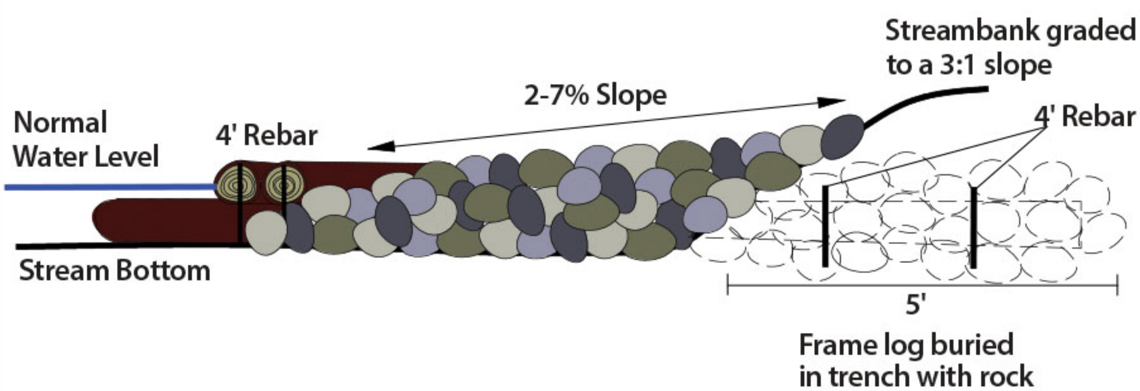
LOG FACED STONE DEFLECTOR

Plan View



Section View



Sill Logs = 10-15'
Face Logs = 20'
Frame Logs = 20-30'
Log Dia.= 8-12"

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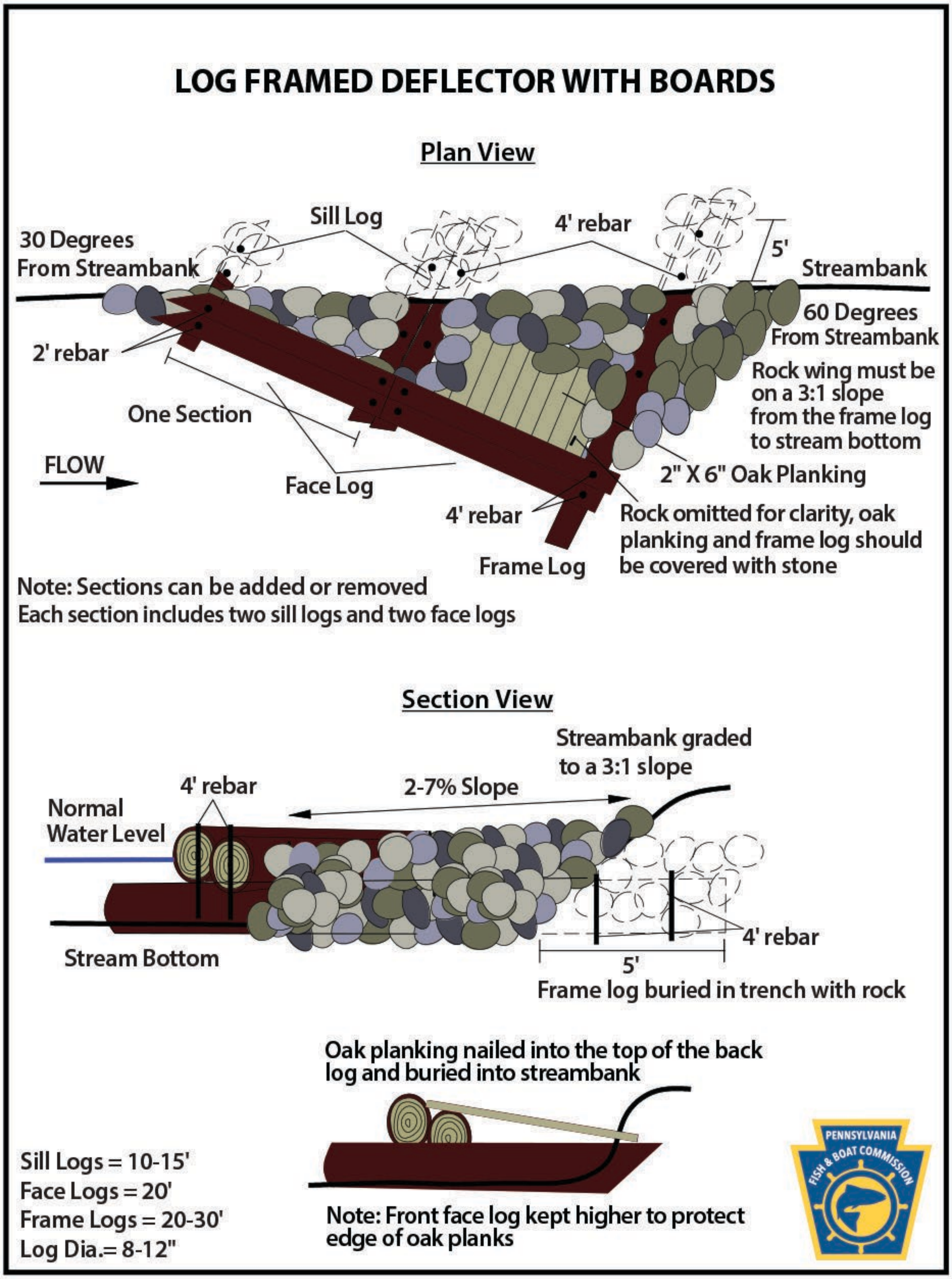
LOG FRAMED DEFLECTOR WITH BOARDS
Plan View
30 Degrees From Streambank
Sill Log
4' rebar
5'
Streambank
60 Degrees From Streambank
2' rebar
Rock wing must be on a 3:1 slope from the frame log to stream bottom
One Section
FLOW
Face Log
2" X 6" Oak Planking
4' rebar
Rock omitted for clarity, oak planking and frame log should be covered with stone
Frame Log
Note: Sections can be added or removed
Each section includes two sill logs and two face logs
Section View
Streambank graded to a 3:1 slope
4' rebar
2-7% Slope
Normal Water Level
4' rebar
Stream Bottom
5'
Frame log buried in trench with rock
Oak planking nailed into the top of the back log and buried into streambank
Sill Logs = 10-15'
Face Logs = 20'
Frame Logs = 20-30'
Log Dia.= 8-12"
Note: Front face log kept higher to protect edge of oak planks
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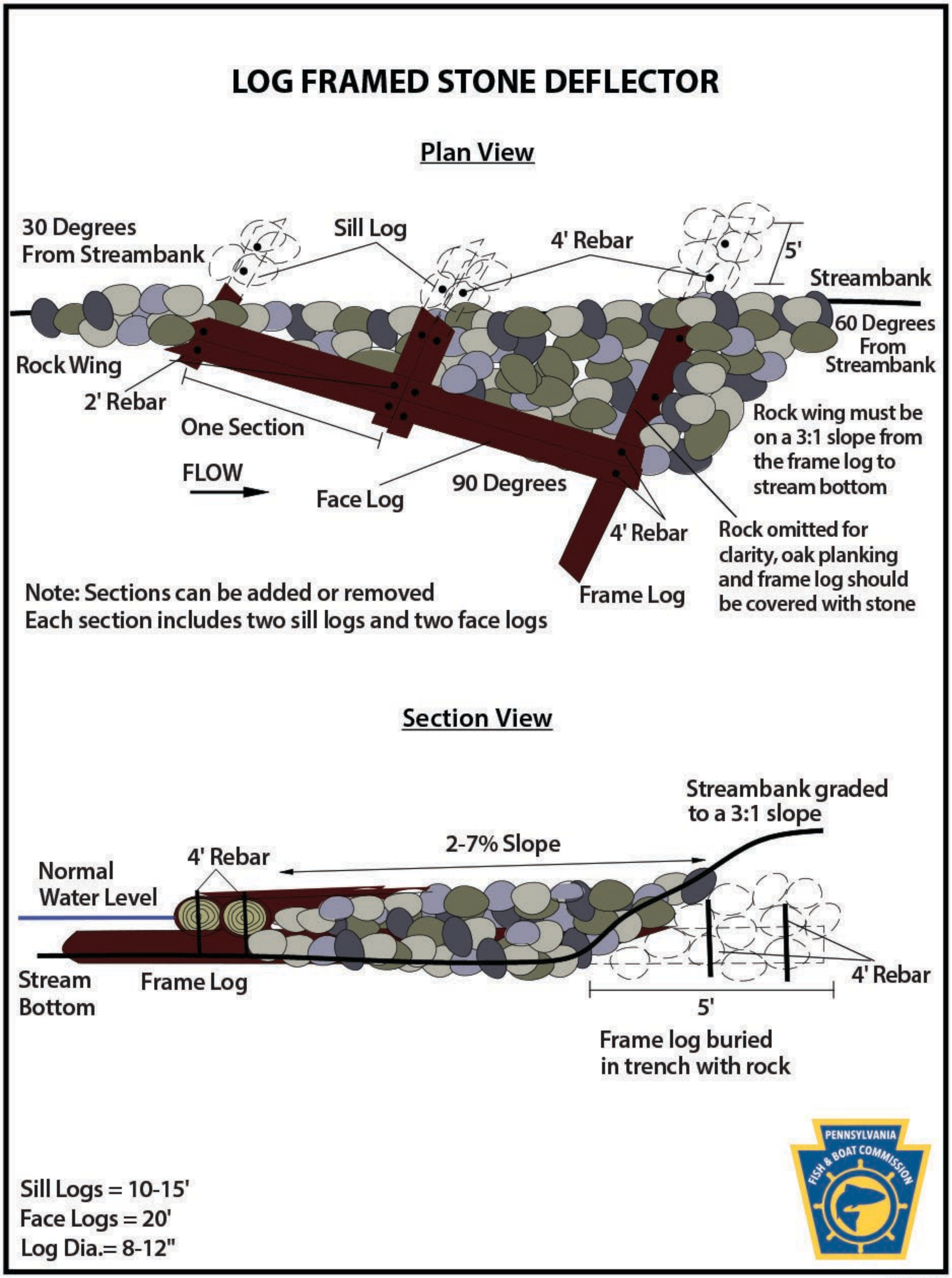
LOG FRAMED STONE DEFLECTOR
Plan View
30 Degrees From Streambank
Sill Log
4' Rebar
5'
Streambank
60 Degrees From Streambank
Rock Wing
2' Rebar
One Section
Rock wing must be on a 3:1 slope from the frame log to stream bottom
FLOW
Face Log
90 Degrees
4' Rebar
Rock omitted for clarity, oak planking and frame log should be covered with stone
Frame Log
Note: Sections can be added or removed
Each section includes two sill logs and two face logs
Section View
Streambank graded to a 3:1 slope
2-7% Slope
4' Rebar
Normal Water Level
Stream Bottom
Frame Log
4' Rebar
5'
Frame log buried in trench with rock
Sill Logs = 10-15'
Face Logs = 20'
Log Dia.= 8-12"
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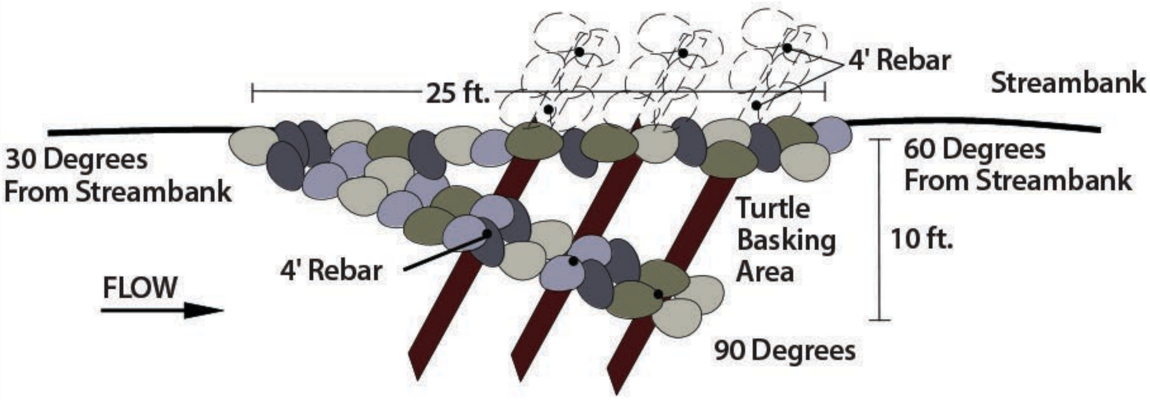
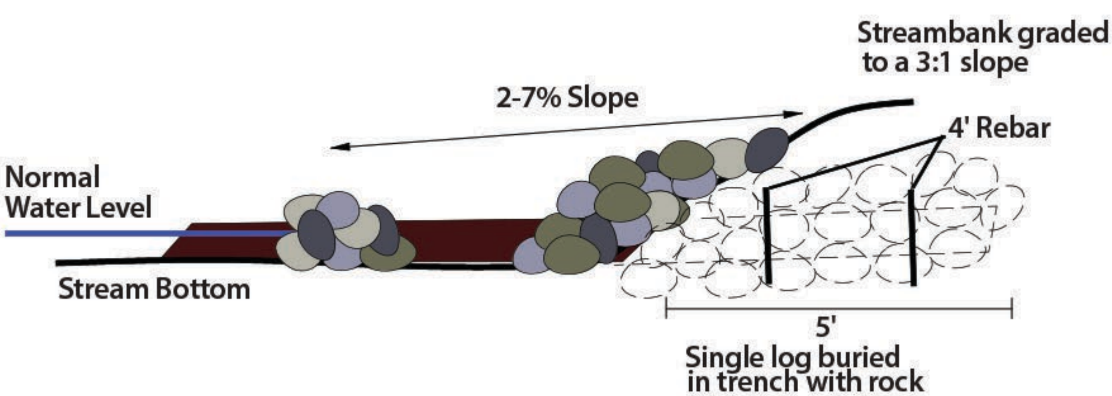
OPEN CENTER STONE DEFLECTOR WITH LOGS
(LOW GRADIENT STRUCTURE)

Plan View



Note: Length measurement is 2.5 times the width
Deflector sizes may vary

Section View



Log Length = 15-25'
Log Dia.= 8-12"
Note: Recommended only for use in low gradient systems

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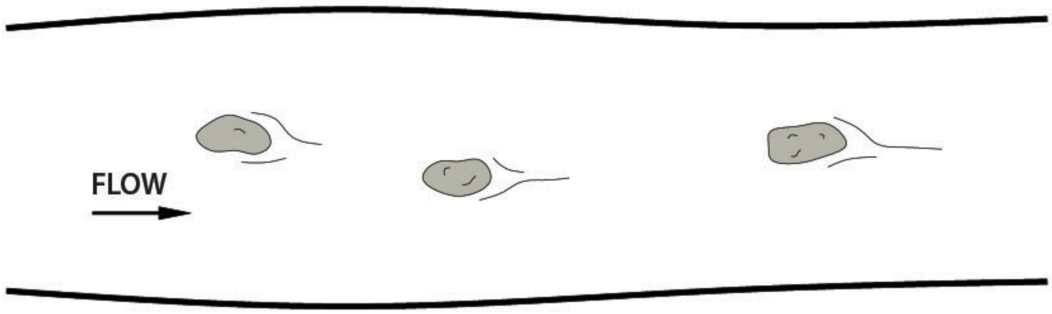
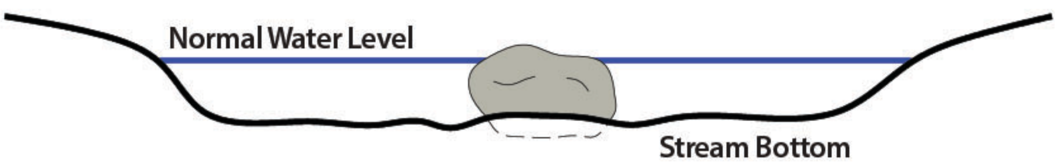
RANDOM BOULDER PLACEMENT

Plan View



Note: Place boulders in the middle third of the wetted width of the stream to prevent flow deflection into the streambanks

Section View



Note: Boulder should be large enough not to be displaced during high flow periods
Boulder height should be within 2" of normal water level

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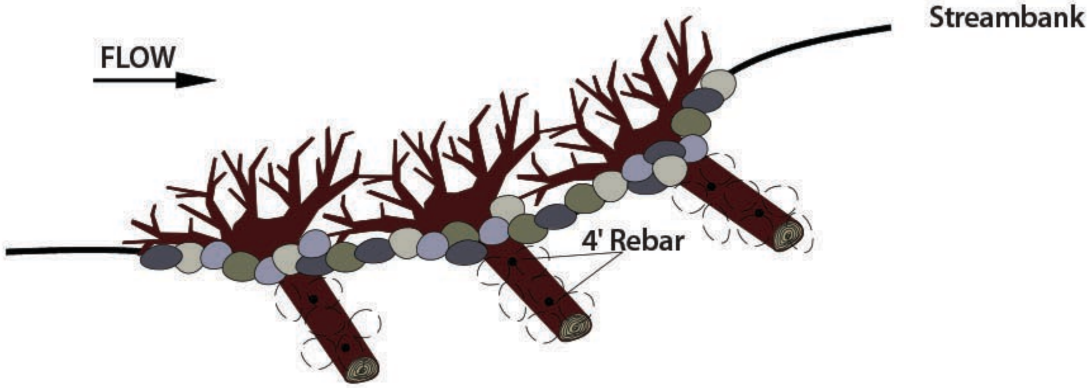
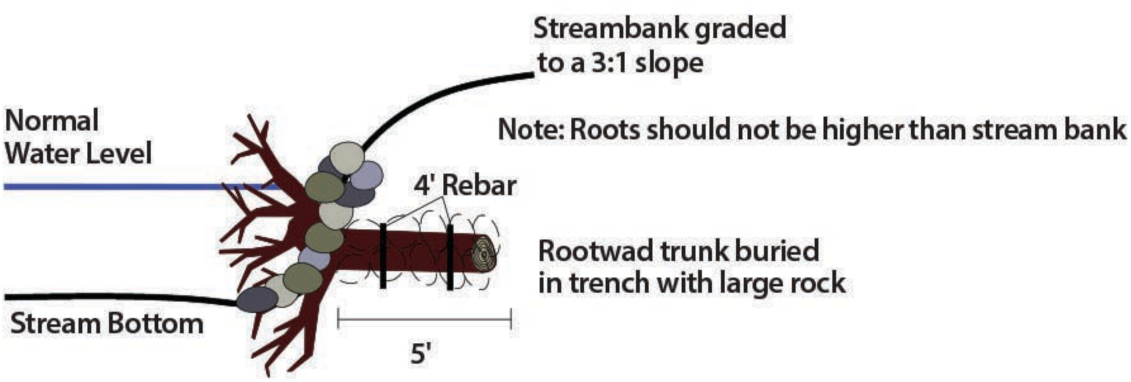
ROOTWAD DEFLECTOR

Plan View



Note: Can be placed as a single deflector or overlapping as shown

Section View



Rootwad Dia. = 3-6'
Rootwad Length = 10-15'

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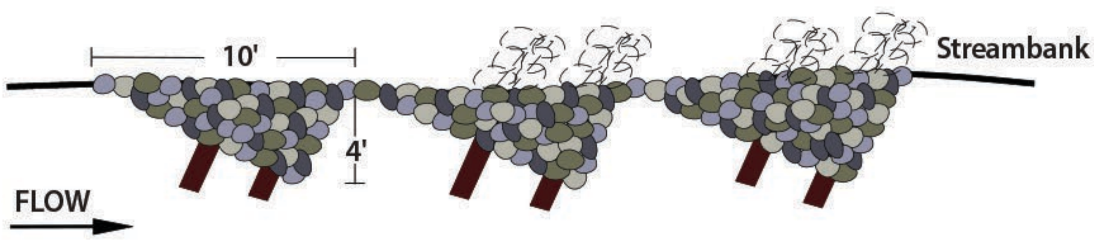
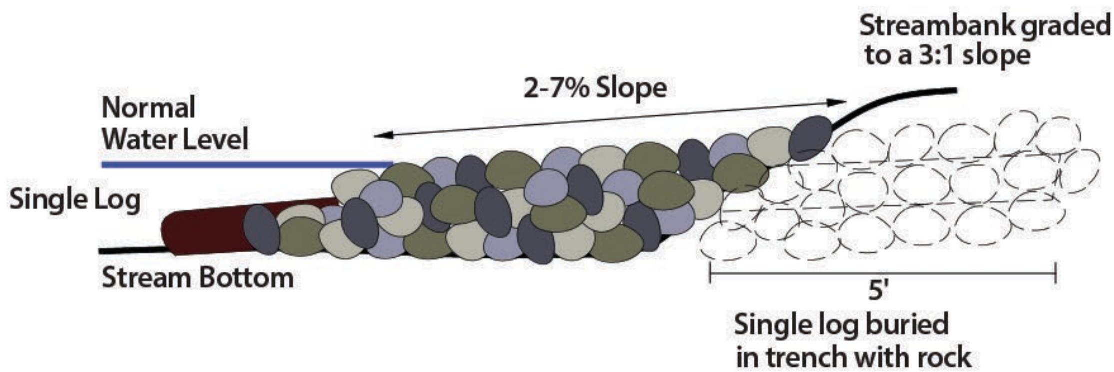
SAWTOOTH STONE DEFLECTORS WITH LOGS

Plan View



Note: Logs should be protruding 2 to 3 feet from rock face

Section View



Log Length = 10-15'
Log Dia.= 8-12"

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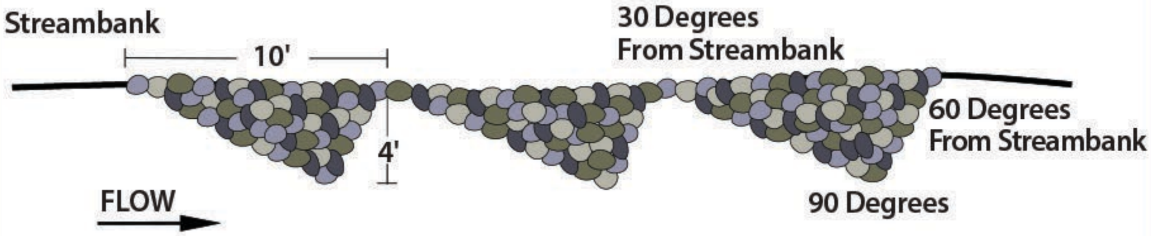
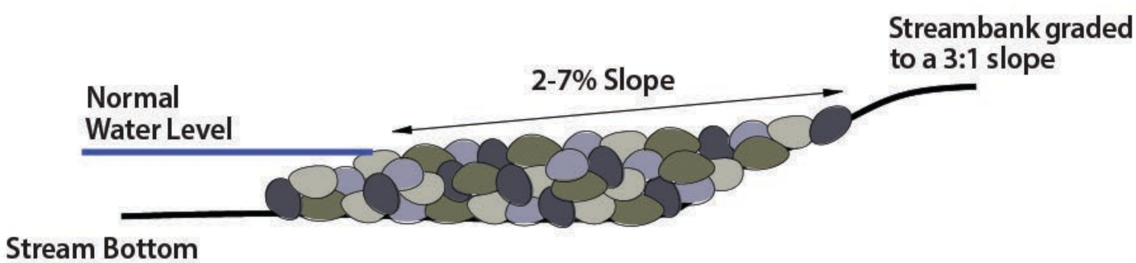
SAWTOOTH STONE DEFLECTORS

Plan View



Note: Sections can be added or removed, and the length measurement is 2.5 times the width

Section View



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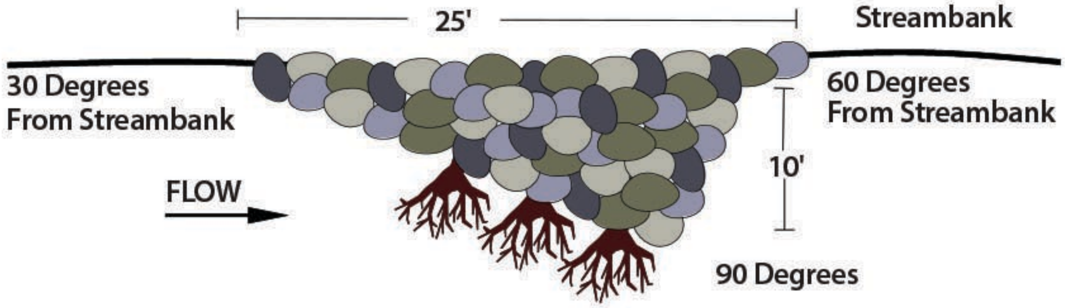
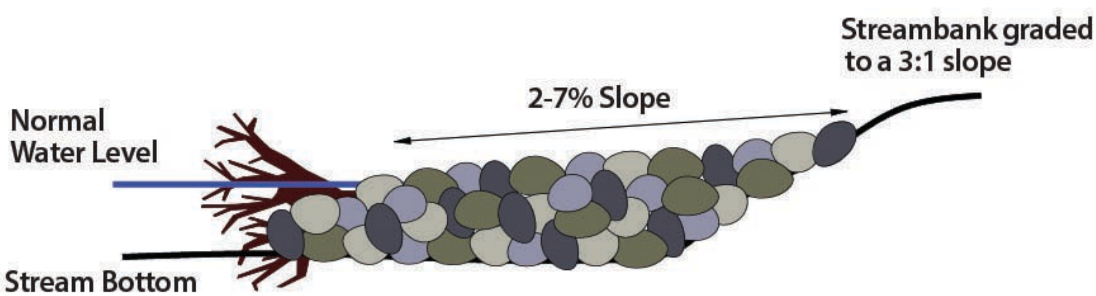
STONE DEFLECTOR WITH ROOTWADS

Plan View



Note: Length measurement is 2.5 times the width
Deflector sizes may vary

Section View



Rootwad Dia. = 3-6'
Rootwad Length = 10-15'

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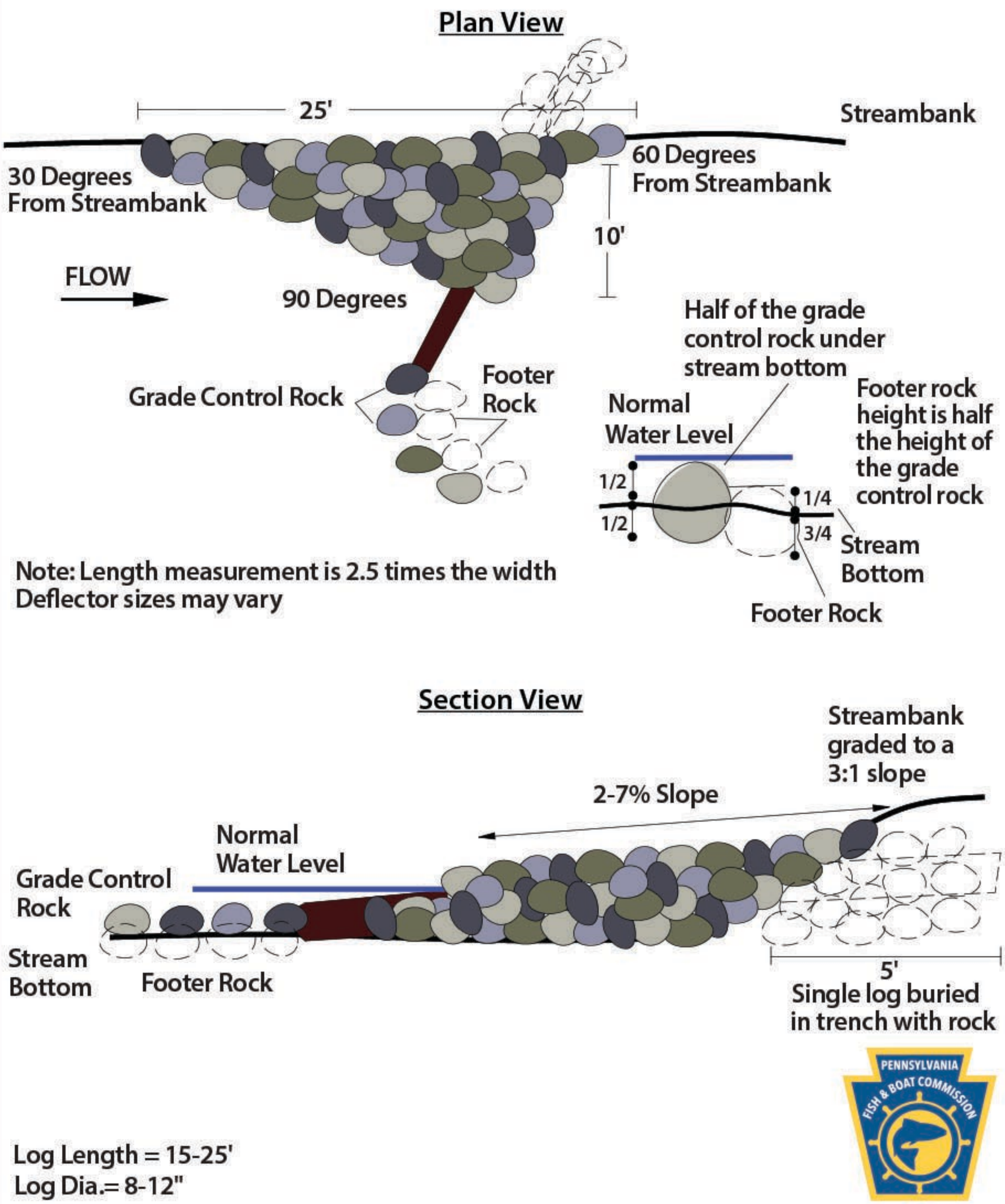
STONE DEFLECTOR WITH SINGLE LOG AND J-HOOK



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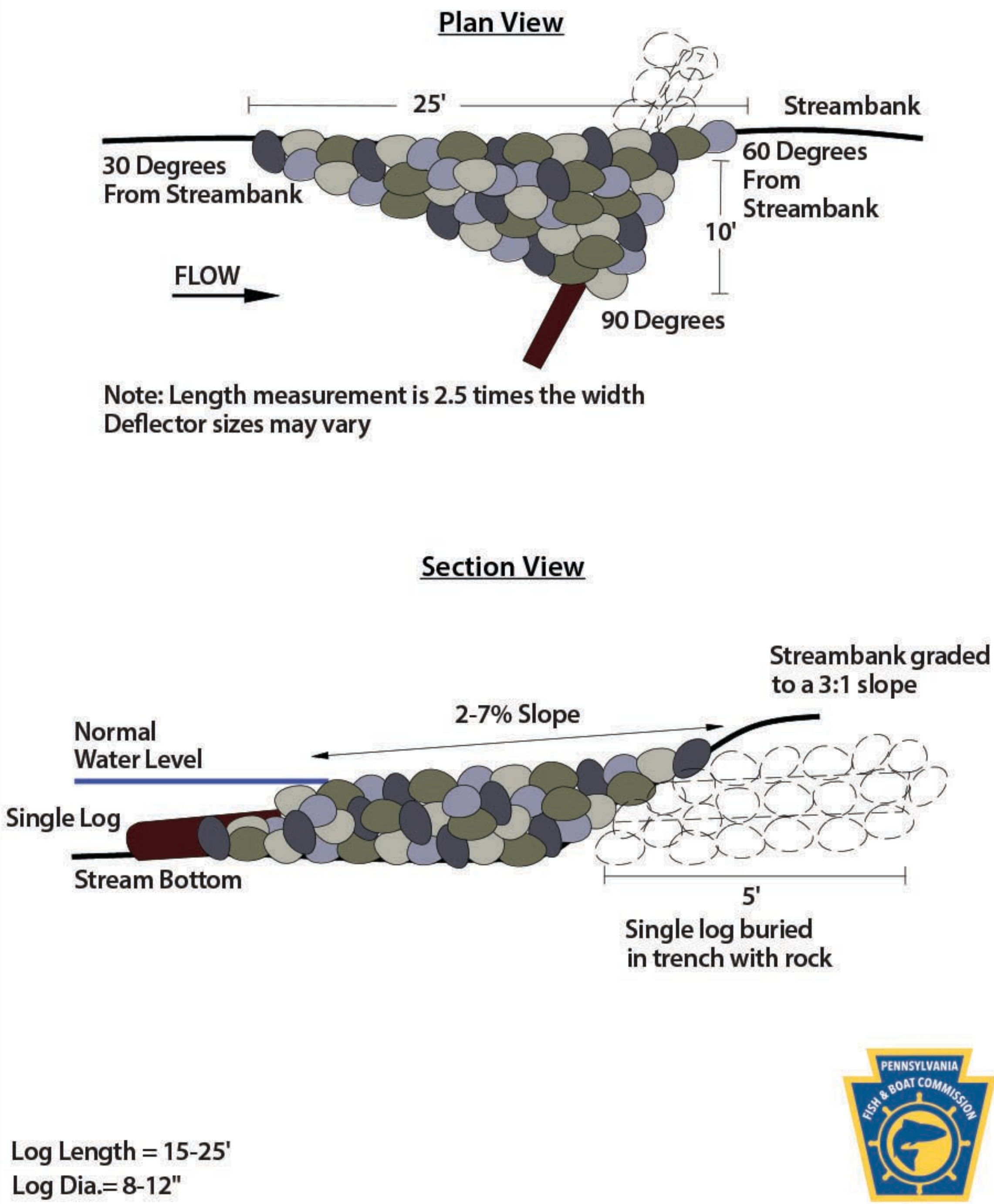
STONE DEFLECTOR WITH SINGLE LOG



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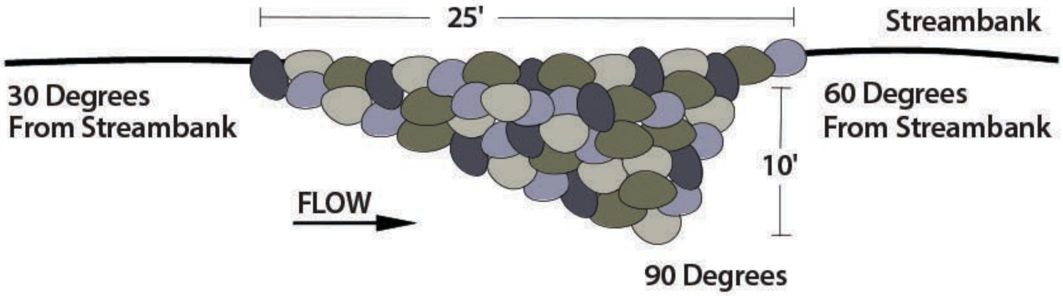
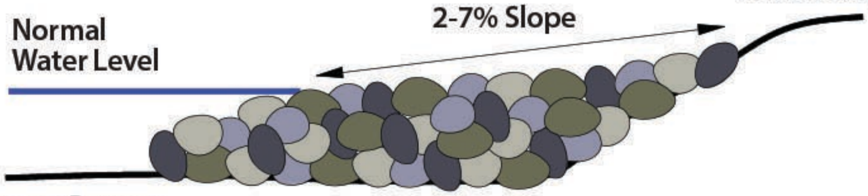
STONE DEFLECTOR

Plan View



Note: Length measurement is 2.5 times the width
Deflector sizes may vary

Section View



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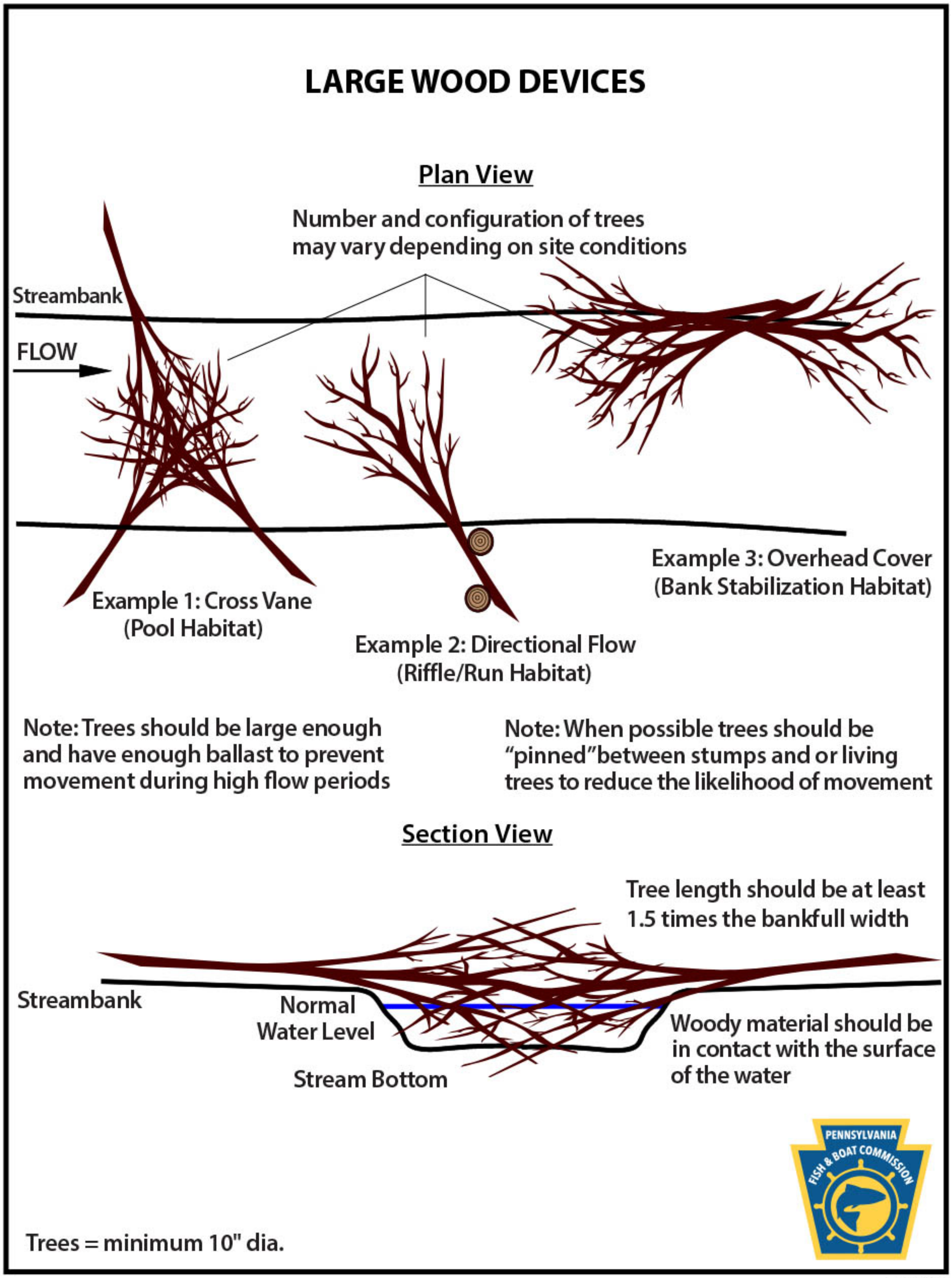
LARGE WOOD DEVICES
Plan View
Number and configuration of trees may vary depending on site conditions
Streambank
FLOW
Example 1: Cross Vane (Pool Habitat)
Example 2: Directional Flow (Riffle/Run Habitat)
Example 3: Overhead Cover (Bank Stabilization Habitat)
Note: Trees should be large enough and have enough ballast to prevent movement during high flow periods
Note: When possible trees should be "pinned" between stumps and or living trees to reduce the likelihood of movement
Section View
Tree length should be at least 1.5 times the bankfull width
Streambank
Normal Water Level
Stream Bottom
Woody material should be in contact with the surface of the water
Trees = minimum 10" dia.
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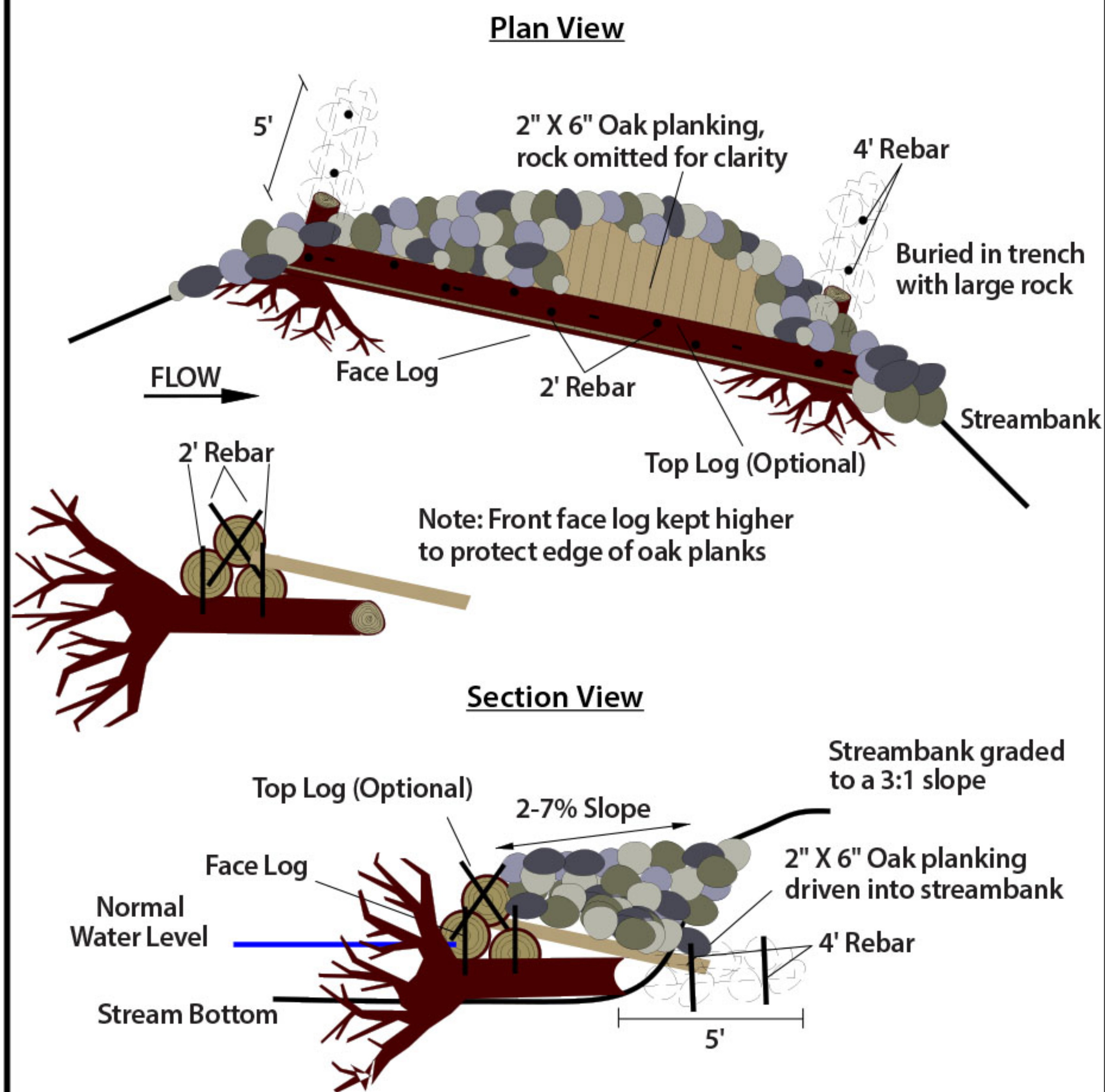
BANK COVER CRIBBING WITH ROOTWADS



Rootwad Length = 10-15'
Face Logs = 20'
Log Dia.= 8-12"

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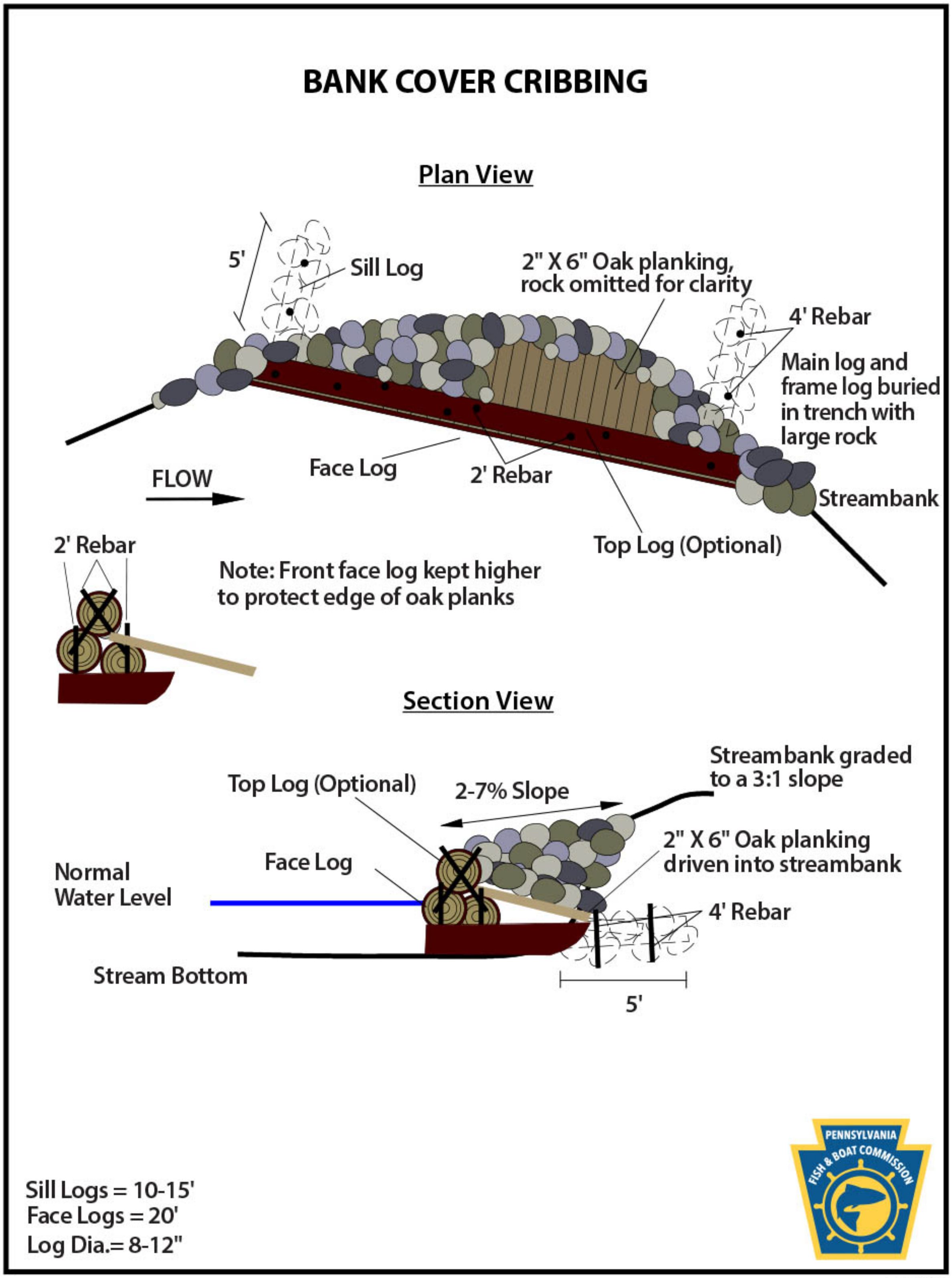
BANK COVER CRIBBING
Plan View
5'
Sill Log
2" X 6" Oak planking, rock omitted for clarity
4' Rebar
Main log and frame log buried in trench with large rock
Face Log
2' Rebar
FLOW
Streambank
Top Log (Optional)
2' Rebar
Note: Front face log kept higher to protect edge of oak planks
Section View
Streambank graded to a 3:1 slope
Top Log (Optional)
2-7% Slope
2" X 6" Oak planking driven into streambank
Face Log
Normal Water Level
4' Rebar
Stream Bottom
5'
Sill Logs = 10-15'
Face Logs = 20'
Log Dia.= 8-12"
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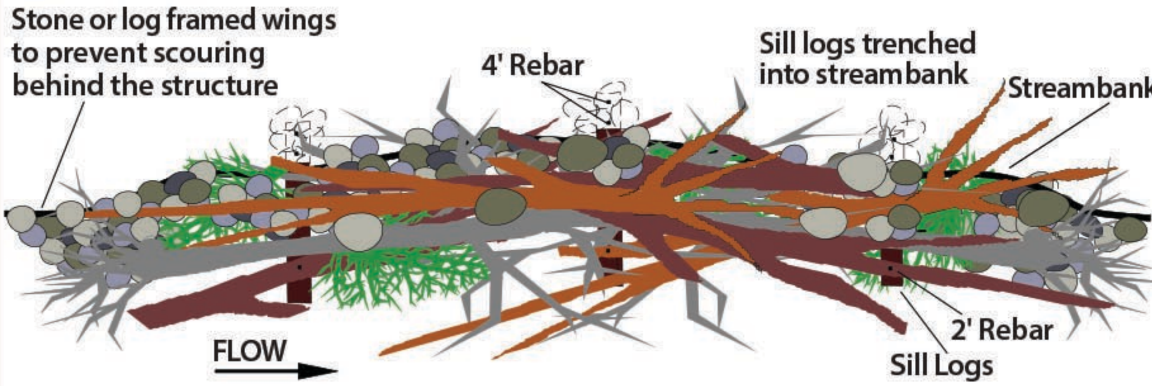
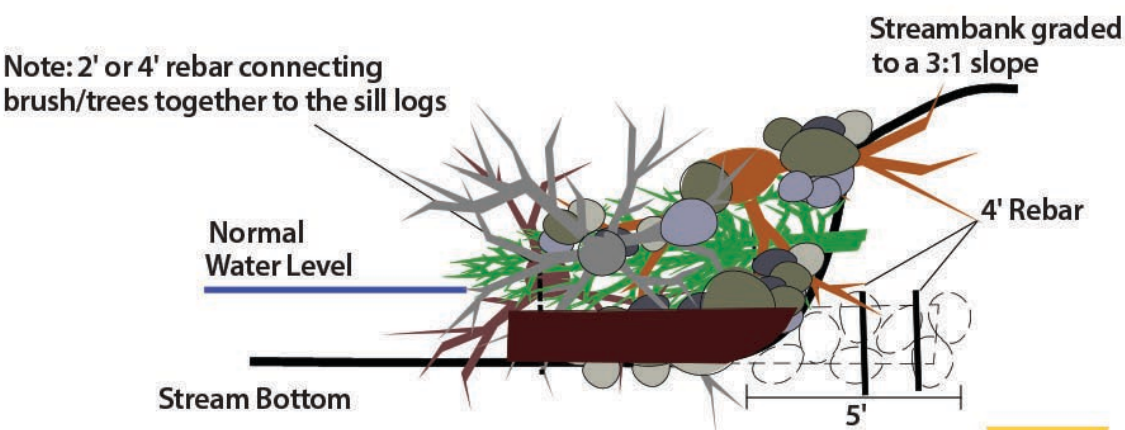
BRUSH REVETMENT

Plan View



Note: Sill logs should be placed every 15-20 ft and attached to other trees using rebar if necessary
Stone can be added on top of the brush/trees for structural integrity/ballast

Section View



Note: Structure material should not exceed bankfull height

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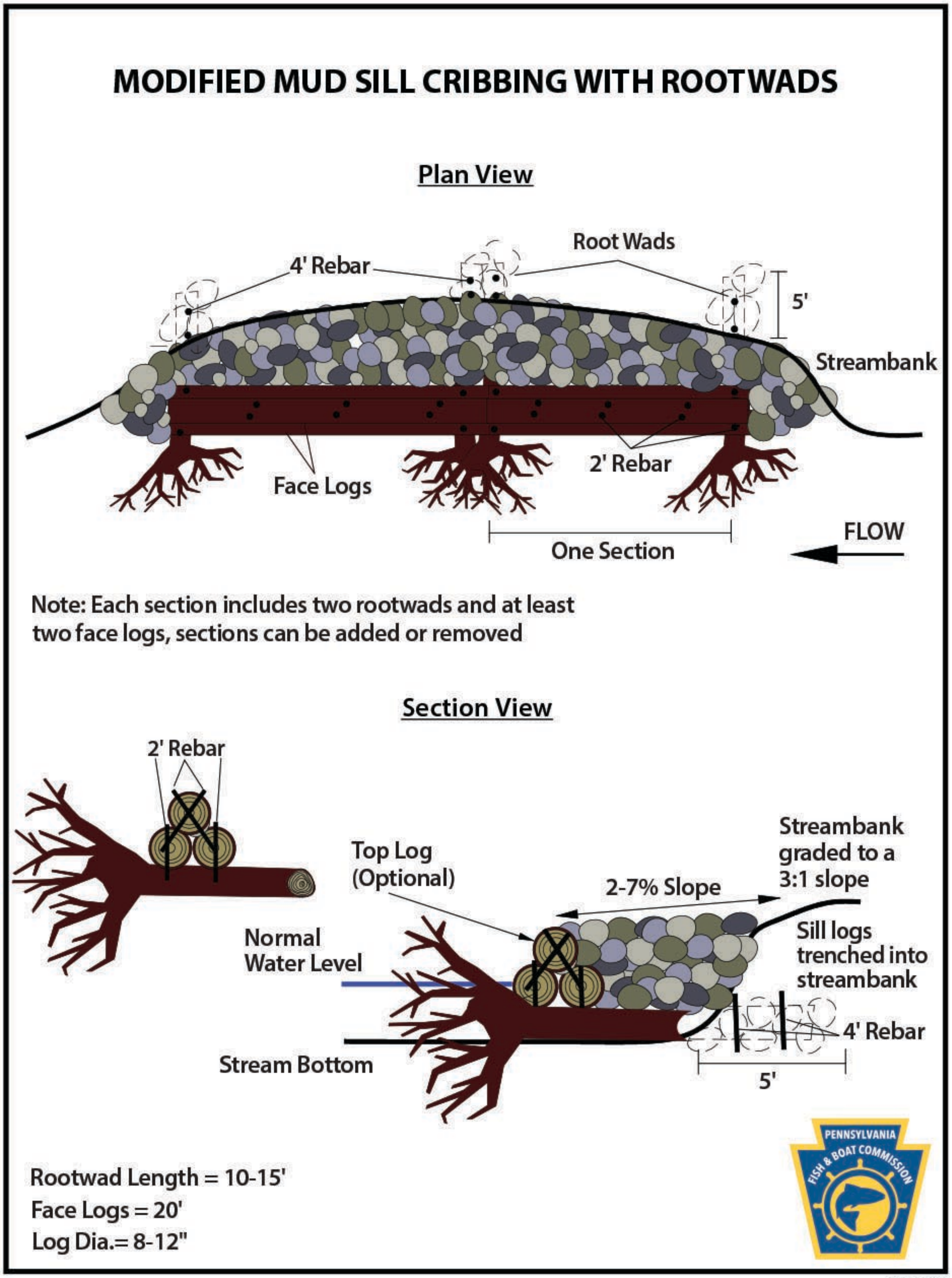
MODIFIED MUD SILL CRIBBING WITH ROOTWADS
Plan View
Root Wads
4' Rebar
5'
Streambank
Face Logs
2' Rebar
One Section
FLOW
Note: Each section includes two rootwads and at least two face logs, sections can be added or removed
Section View
2' Rebar
Top Log (Optional)
2-7% Slope
Streambank graded to a 3:1 slope
Normal Water Level
Sill logs trenched into streambank
4' Rebar
Stream Bottom
5'
Rootwad Length = 10-15'
Face Logs = 20'
Log Dia.= 8-12"
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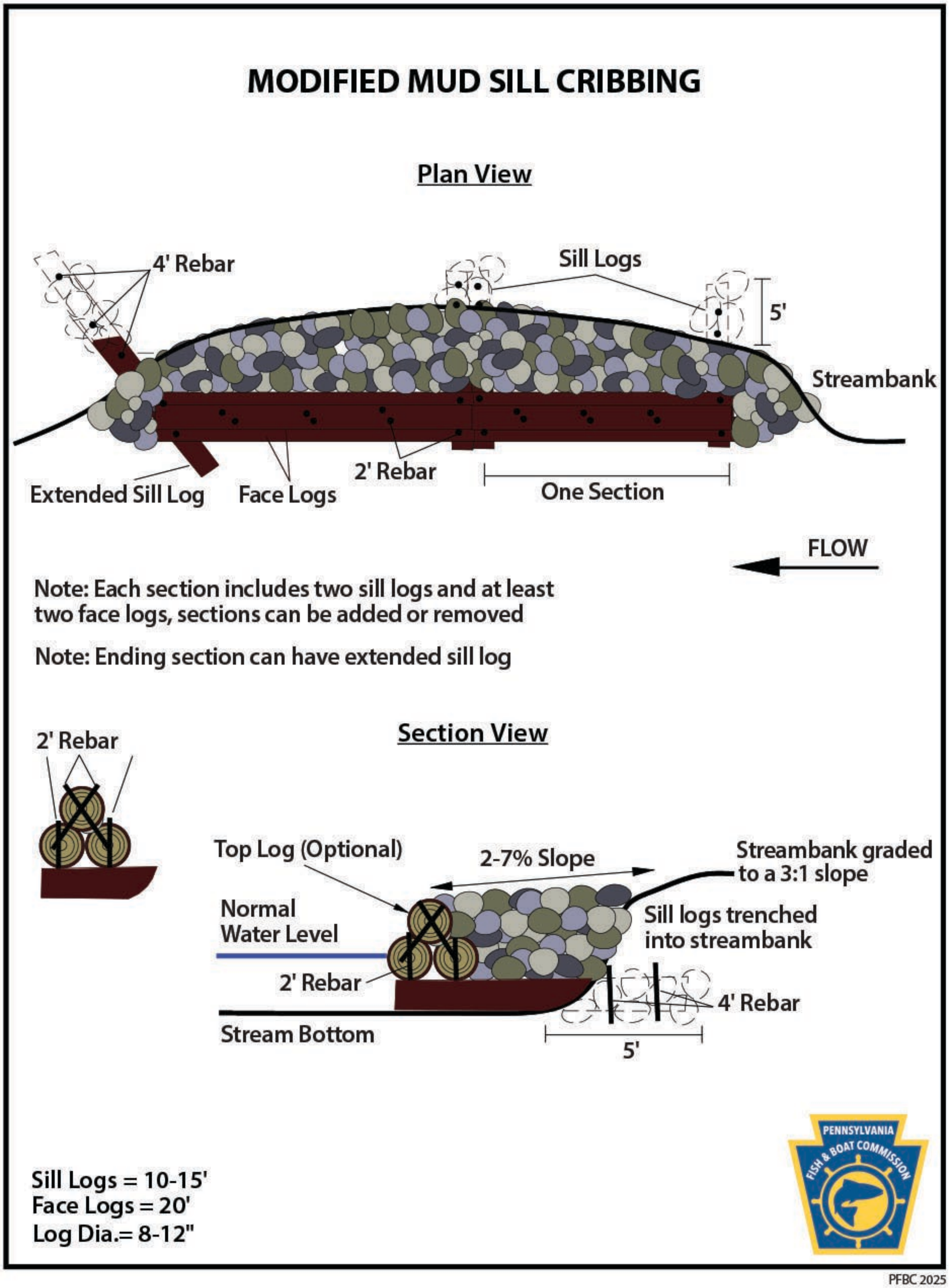
MODIFIED MUD SILL CRIBBING
Plan View
4' Rebar
Sill Logs
5'
Streambank
Extended Sill Log
Face Logs
2' Rebar
One Section
FLOW
Note: Each section includes two sill logs and at least two face logs, sections can be added or removed
Note: Ending section can have extended sill log
Section View
2' Rebar
Top Log (Optional)
2-7% Slope
Streambank graded to a 3:1 slope
Normal Water Level
Sill logs trenched into streambank
2' Rebar
4' Rebar
Stream Bottom
5'
Sill Logs = 10-15'
Face Logs = 20'
Log Dia.= 8-12"
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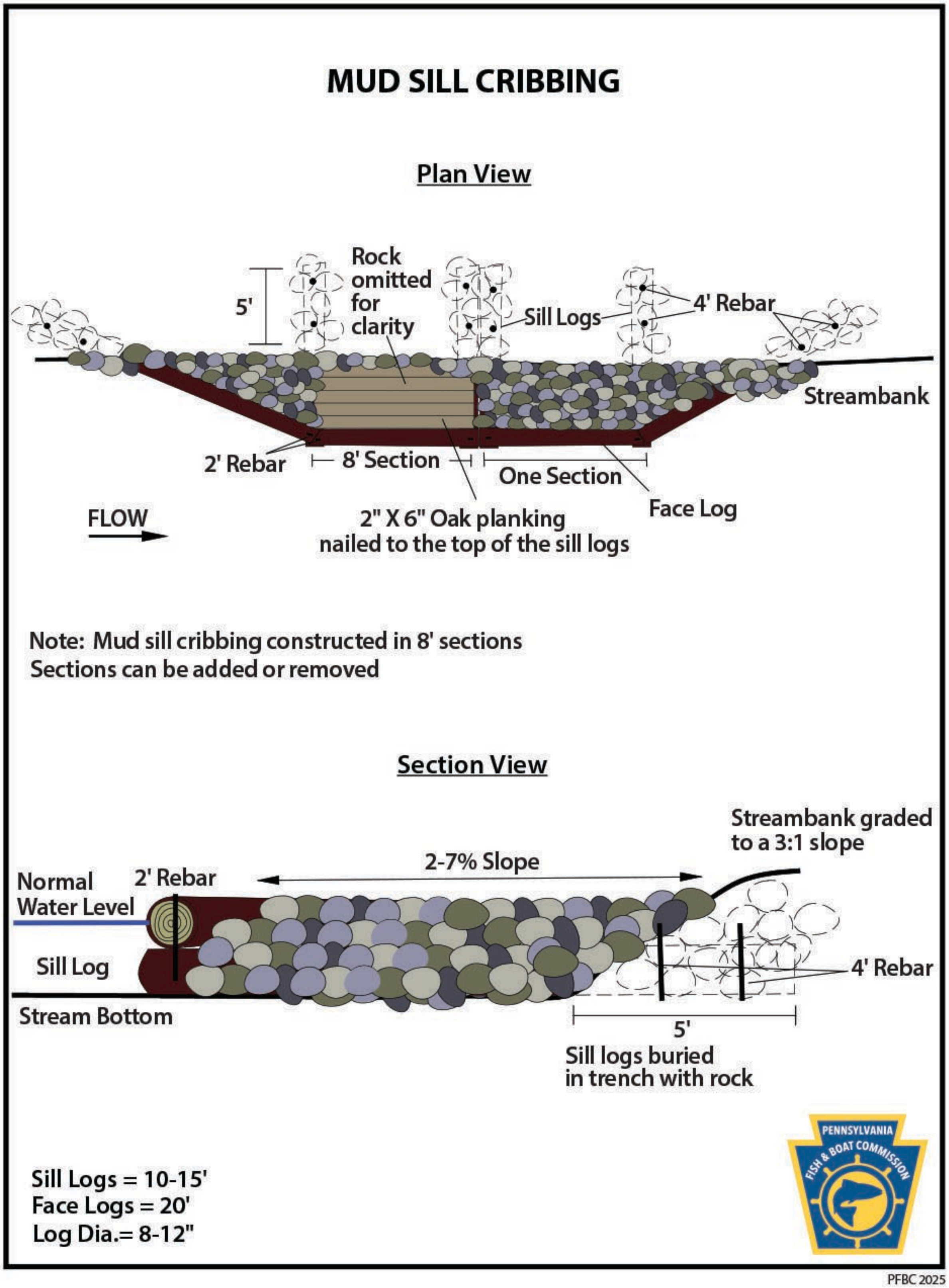
MUD SILL CRIBBING
Plan View
Rock omitted for clarity
5'
Sill Logs
4' Rebar
Streambank
2' Rebar
8' Section
One Section
Face Log
FLOW
2" X 6" Oak planking nailed to the top of the sill logs
Note: Mud sill cribbing constructed in 8' sections
Sections can be added or removed
Section View
Streambank graded to a 3:1 slope
2-7% Slope
Normal Water Level
2' Rebar
Sill Log
Stream Bottom
4' Rebar
5'
Sill logs buried in trench with rock
Sill Logs = 10-15'
Face Logs = 20'
Log Dia.= 8-12"
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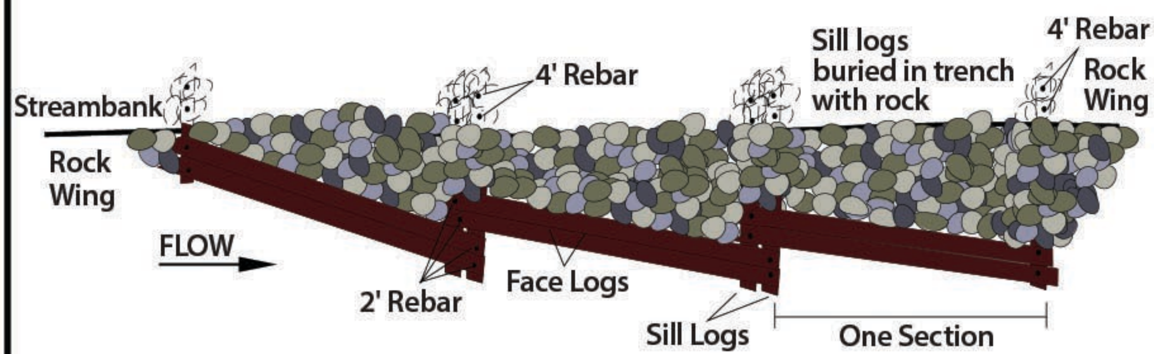
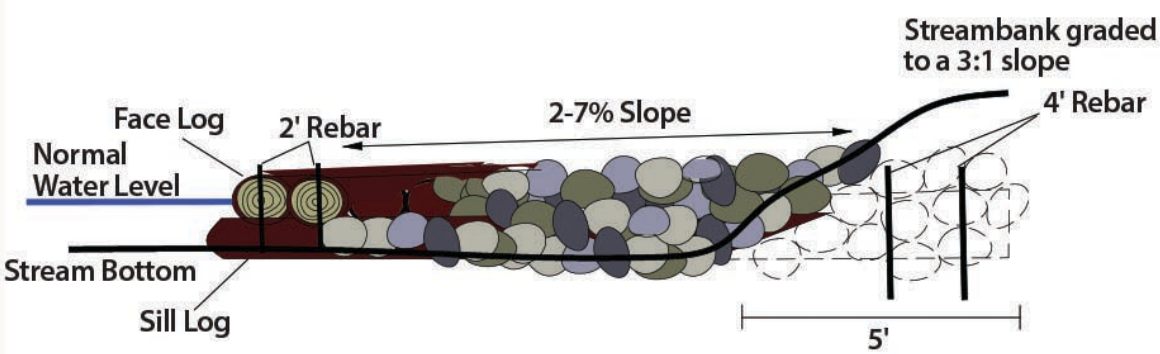
SAWTOOTH MODIFIED MUDSILL CRIBBING

Plan View



Note: Each section includes two sill logs and two face logs
Sections can be added or removed

Section View



Sill Logs = 10-15'
Face Logs = 20'
Log Dia.= 8-12"

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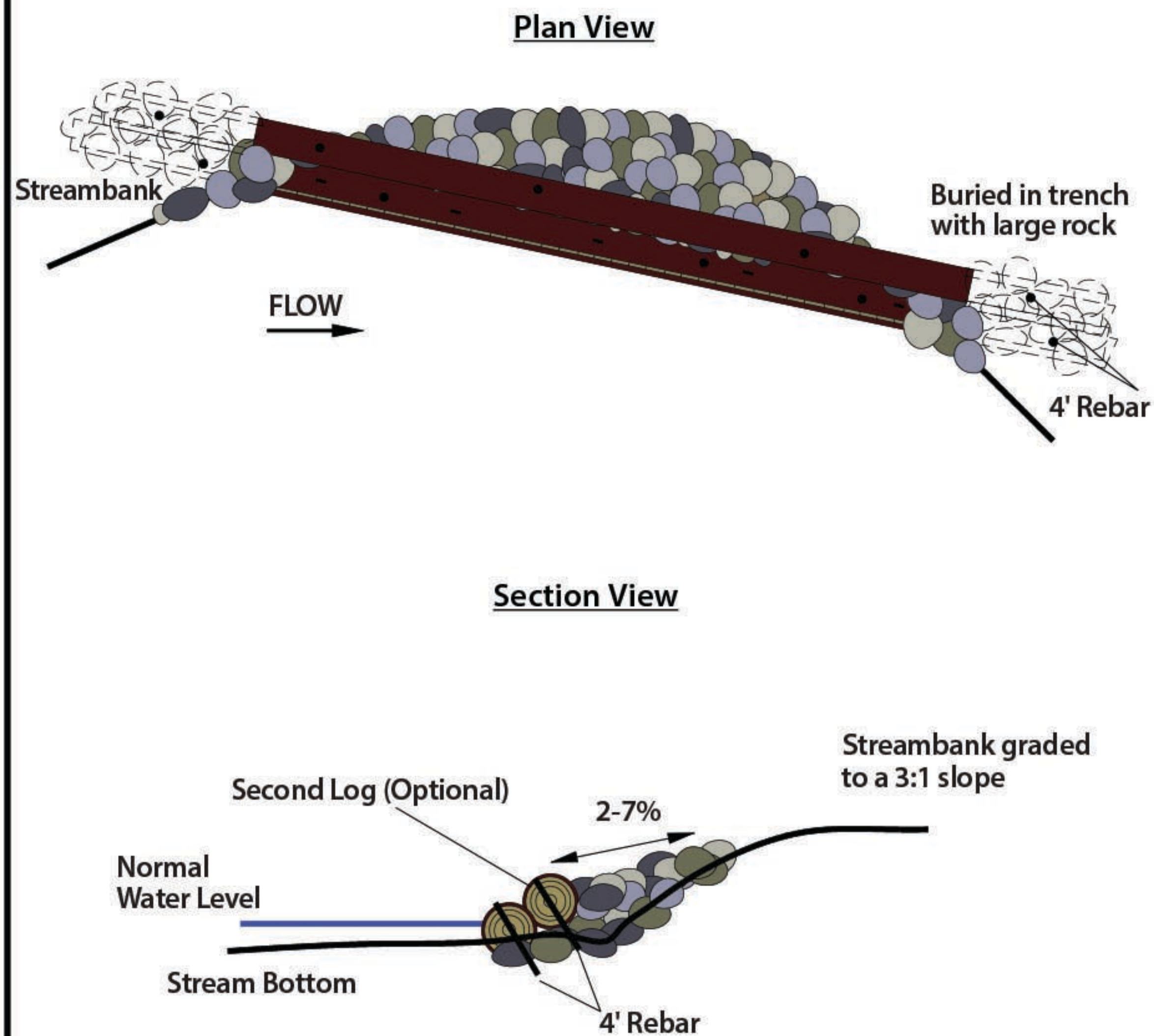
TOE LOG CRIBBING
(LOW GRADIENT STRUCTURE)



Log Dia.= 8-12"
Note: Recommended only for use in low gradient systems

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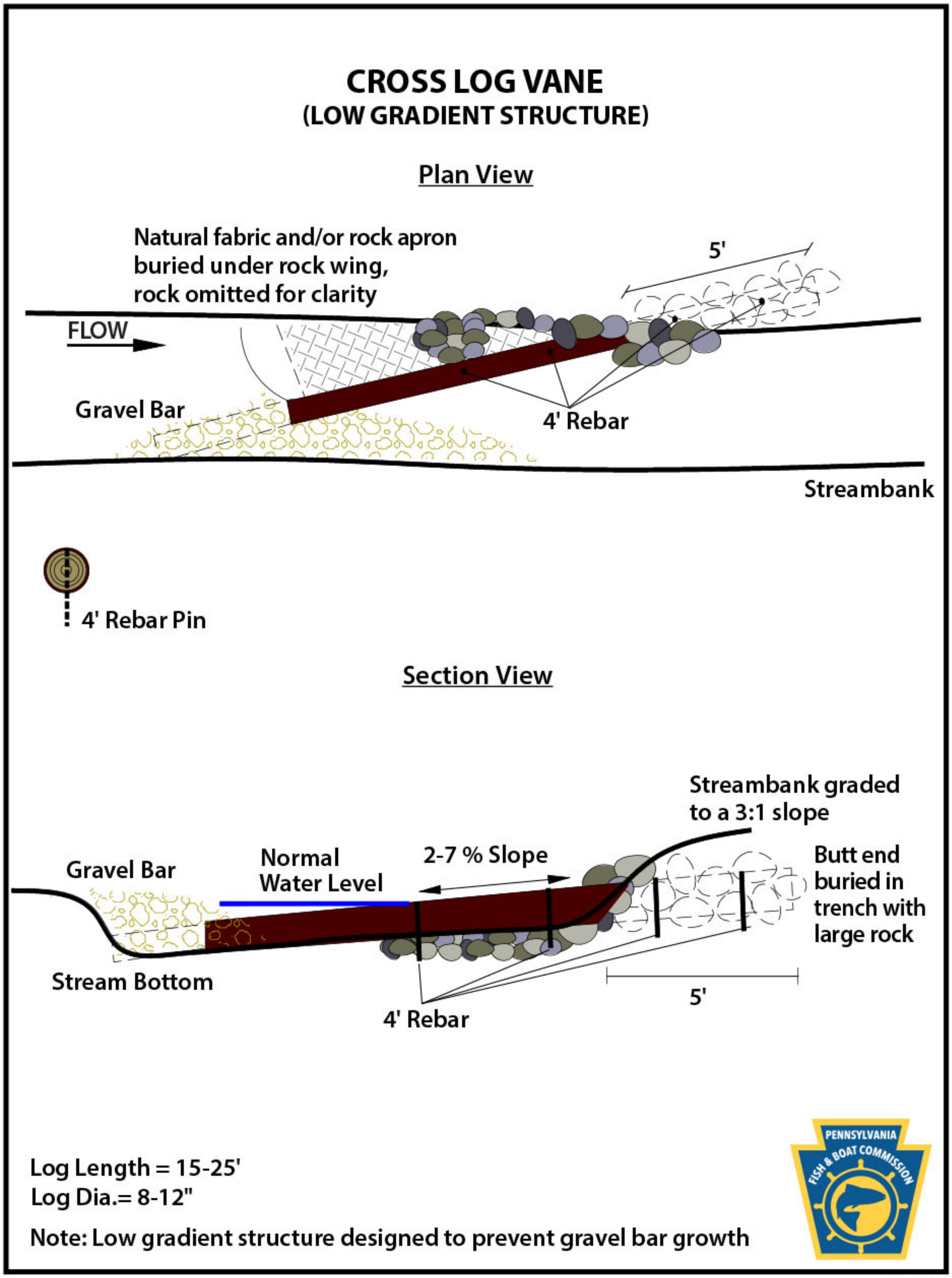
CROSS LOG VANE
(LOW GRADIENT STRUCTURE)
Plan View
Natural fabric and/or rock apron buried under rock wing, rock omitted for clarity
5'
FLOW
Gravel Bar
4' Rebar
Streambank
4' Rebar Pin
Section View
Streambank graded to a 3:1 slope
Normal Water Level
2-7 % Slope
Gravel Bar
Butt end buried in trench with large rock
Stream Bottom
5'
4' Rebar
Log Length = 15-25'
Log Dia.= 8-12"
Note: Low gradient structure designed to prevent gravel bar growth
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FISH & BOAT COMMISSION

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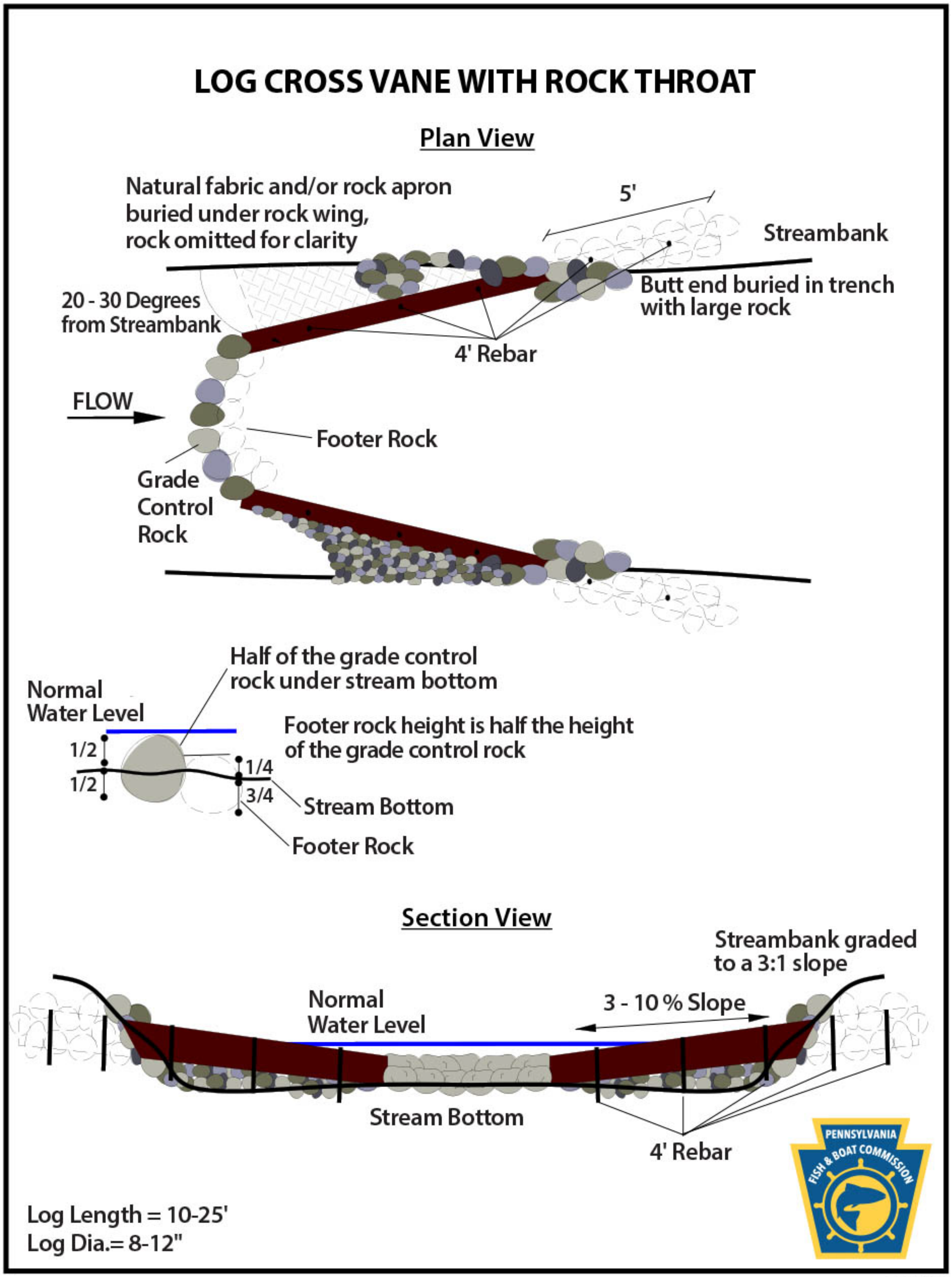
LOG CROSS VANE WITH ROCK THROAT
Plan View
Natural fabric and/or rock apron buried under rock wing, rock omitted for clarity
5'
Streambank
Butt end buried in trench with large rock
20 - 30 Degrees from Streambank
4' Rebar
FLOW
Footer Rock
Grade Control Rock
Half of the grade control rock under stream bottom
Normal Water Level
Footer rock height is half the height of the grade control rock
1/2
1/2
1/4
3/4
Stream Bottom
Footer Rock
Section View
Streambank graded to a 3:1 slope
Normal Water Level
3 - 10 % Slope
Stream Bottom
4' Rebar
Log Length = 10-25'
Log Dia.= 8-12"
PENNSYLVANIA FISH & BOAT COMMISSION

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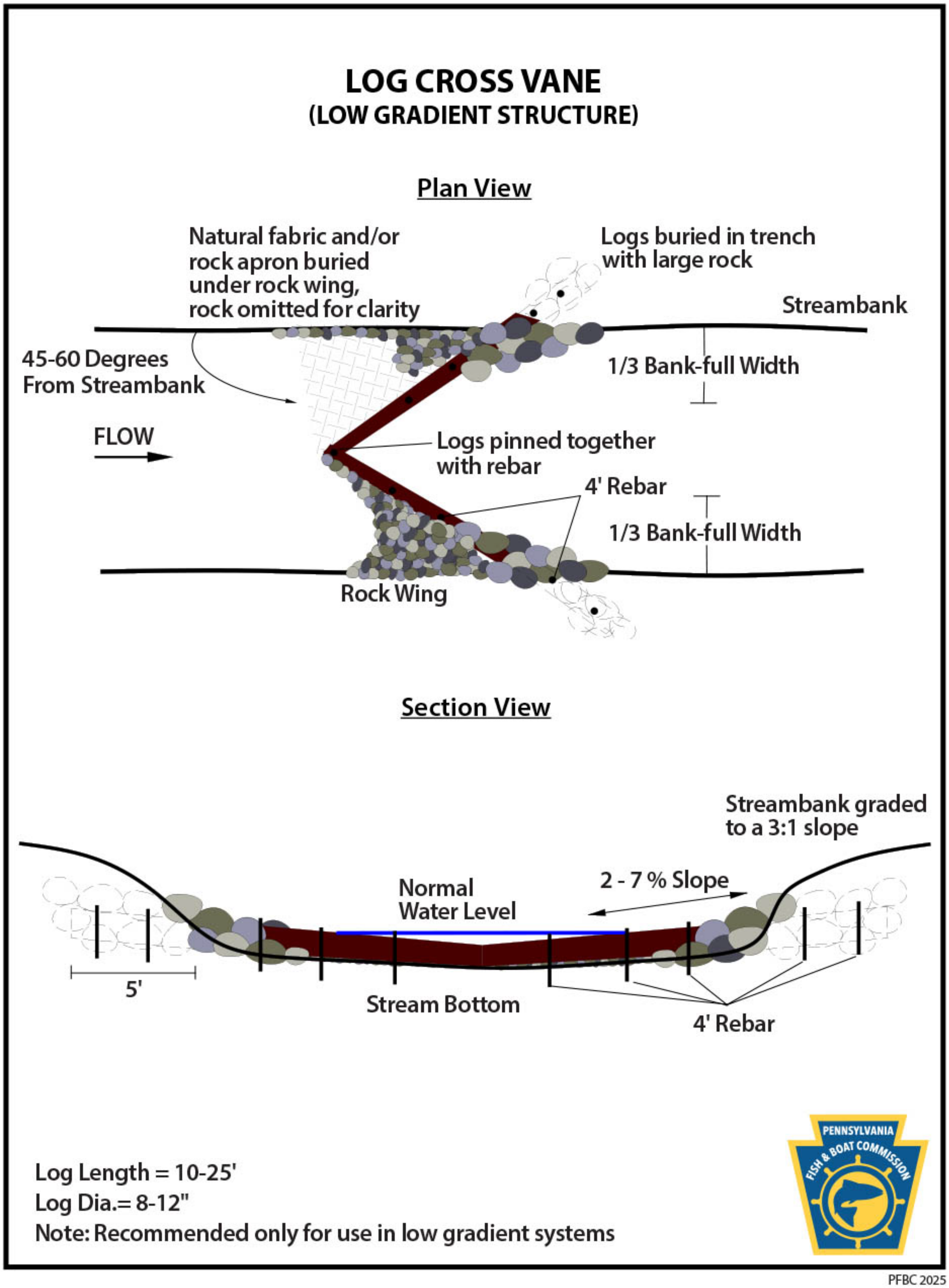
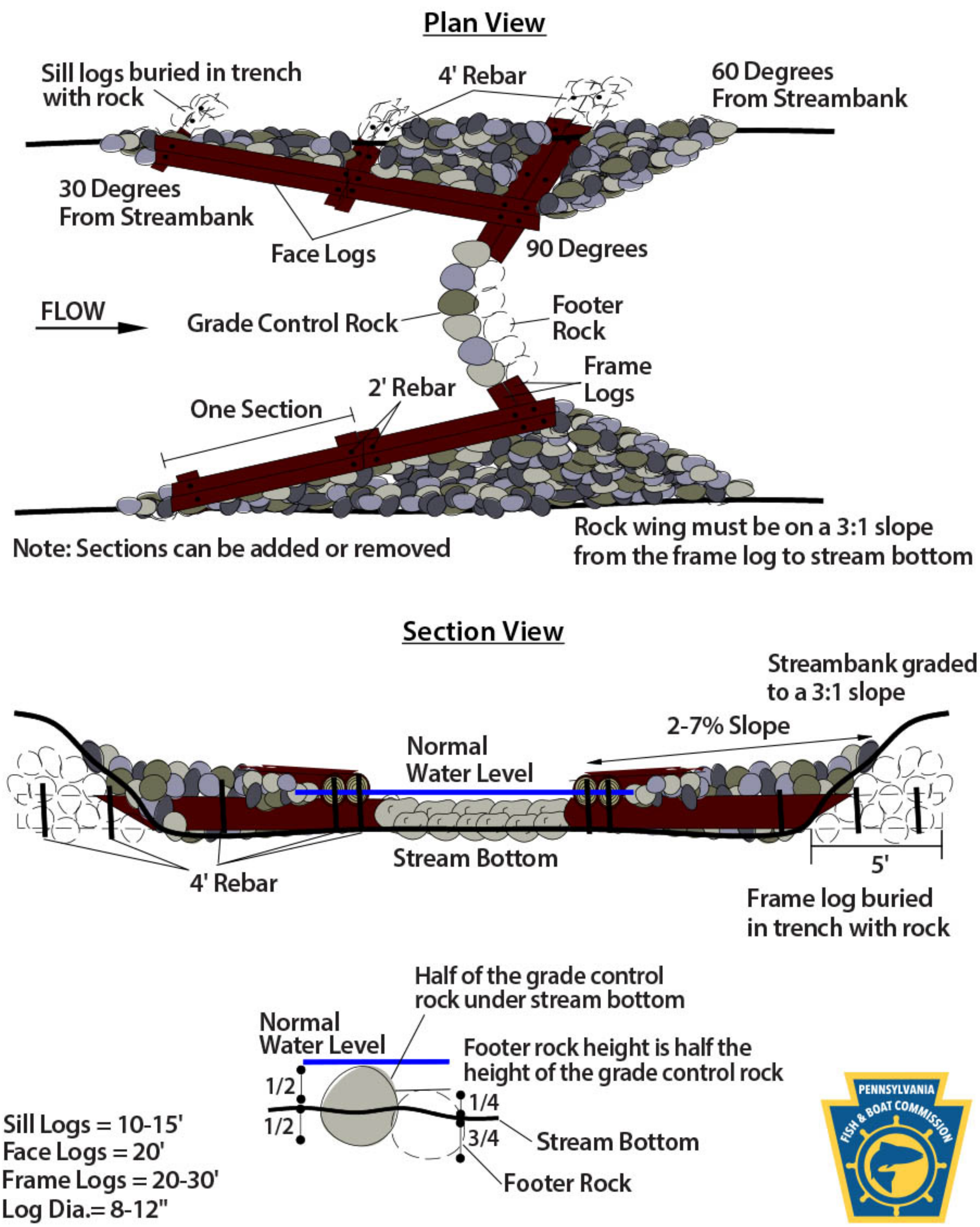

LOG CROSS VANE
(LOW GRADIENT STRUCTURE)
Plan View
Natural fabric and/or rock apron buried under rock wing, rock omitted for clarity
Logs buried in trench with large rock
Streambank
45-60 Degrees From Streambank
1/3 Bank-full Width
FLOW
Logs pinned together with rebar
4' Rebar
1/3 Bank-full Width
Rock Wing
Section View
Streambank graded to a 3:1 slope
Normal Water Level
2 - 7 % Slope
5'
Stream Bottom
4' Rebar
Log Length = 10-25'
Log Dia.= 8-12"
Note: Recommended only for use in low gradient systems
PENNSYLVANIA FISH & BOAT COMMISSION
PFBC 2025

LOG FRAMED CROSS VANE WITH ROCK THROAT



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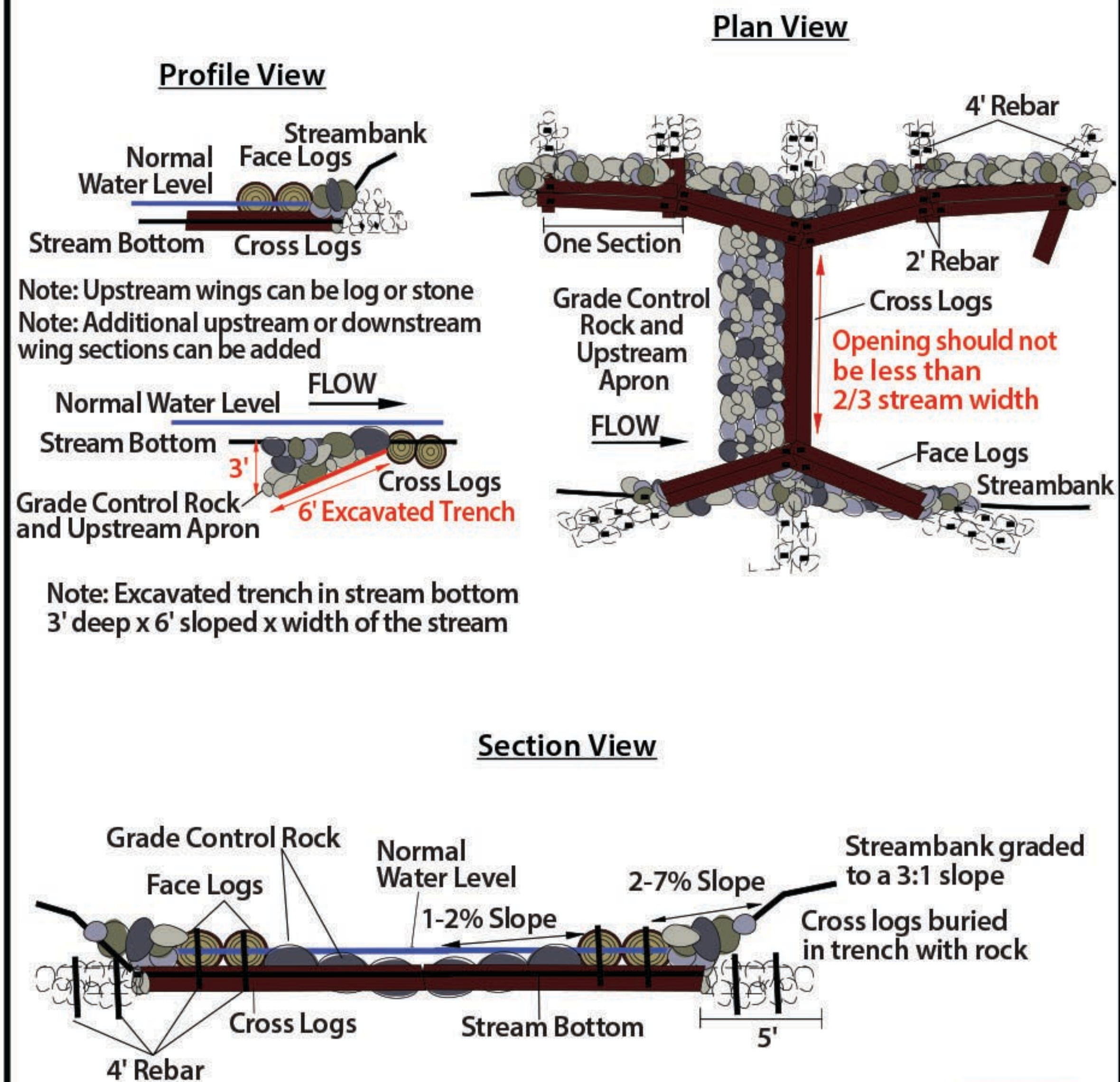
LOG FRAMED CROSS VANE



Sill Logs = 10-15'
Face Logs = 20'
Frame Logs = 20-30'
Log Dia.= 8-12"

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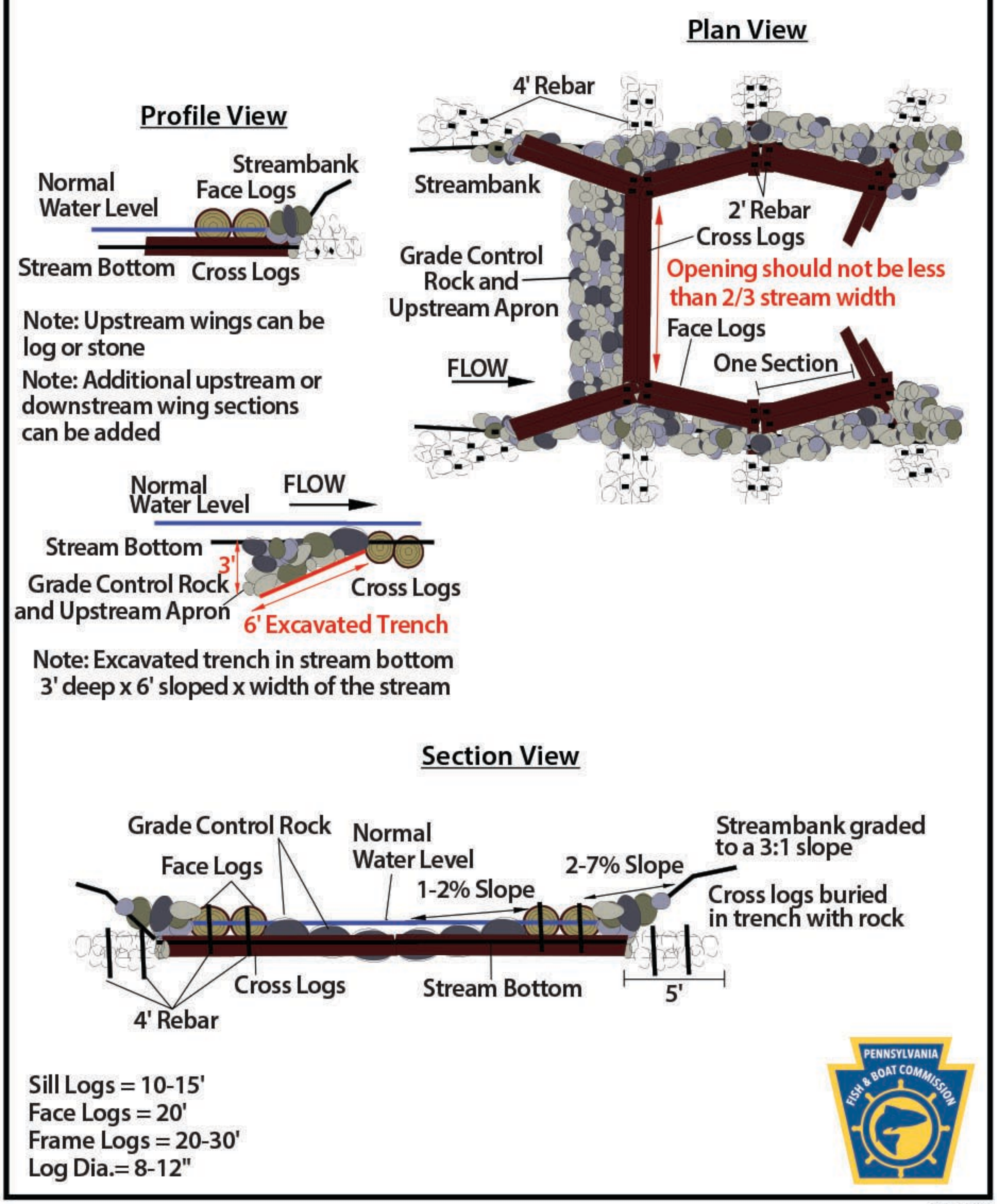
LOG FRAMED CROSS VANE WITH WING EXTENSIONS



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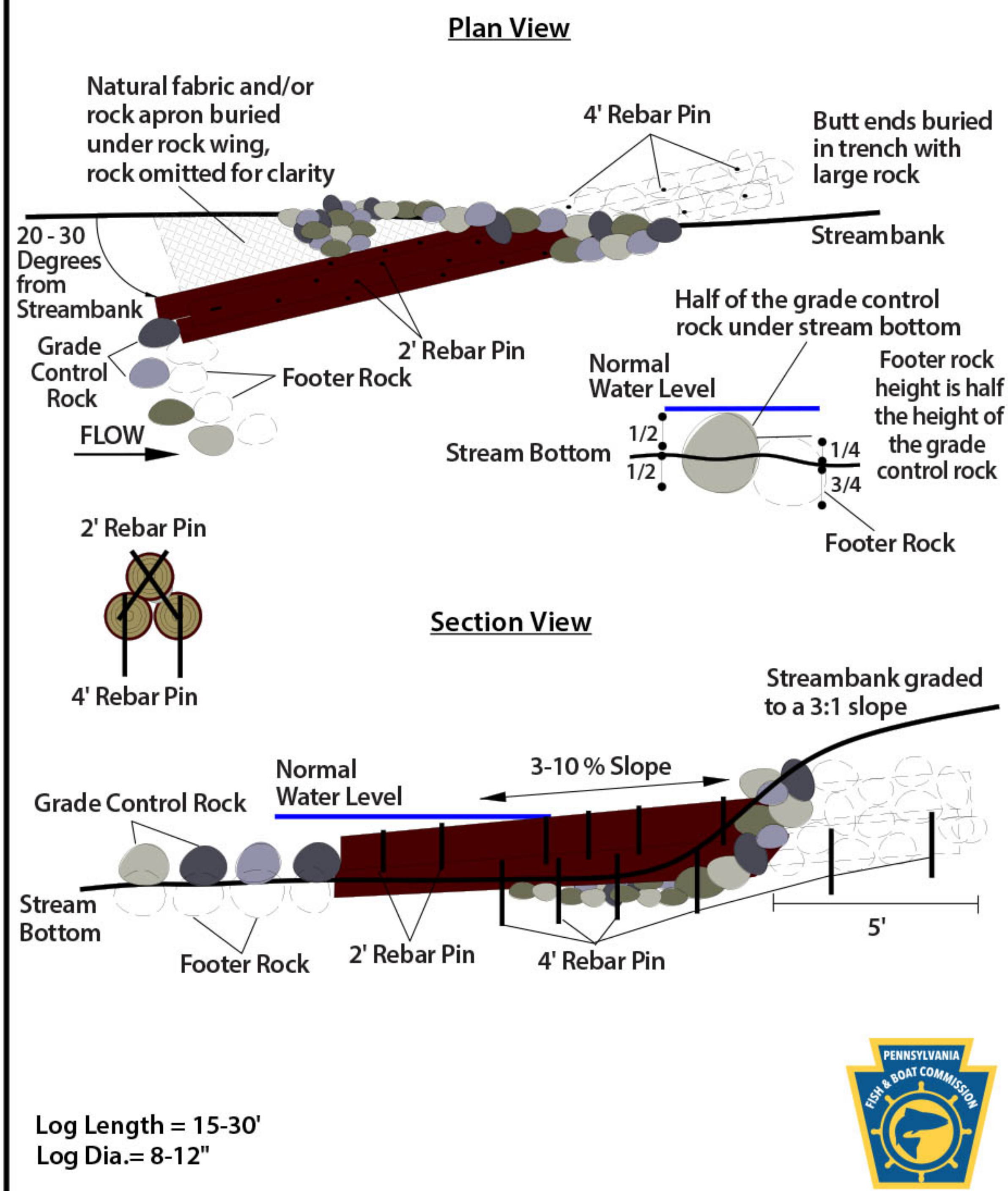
MULTI-LOG VANE DEFLECTOR WITH J-HOOK



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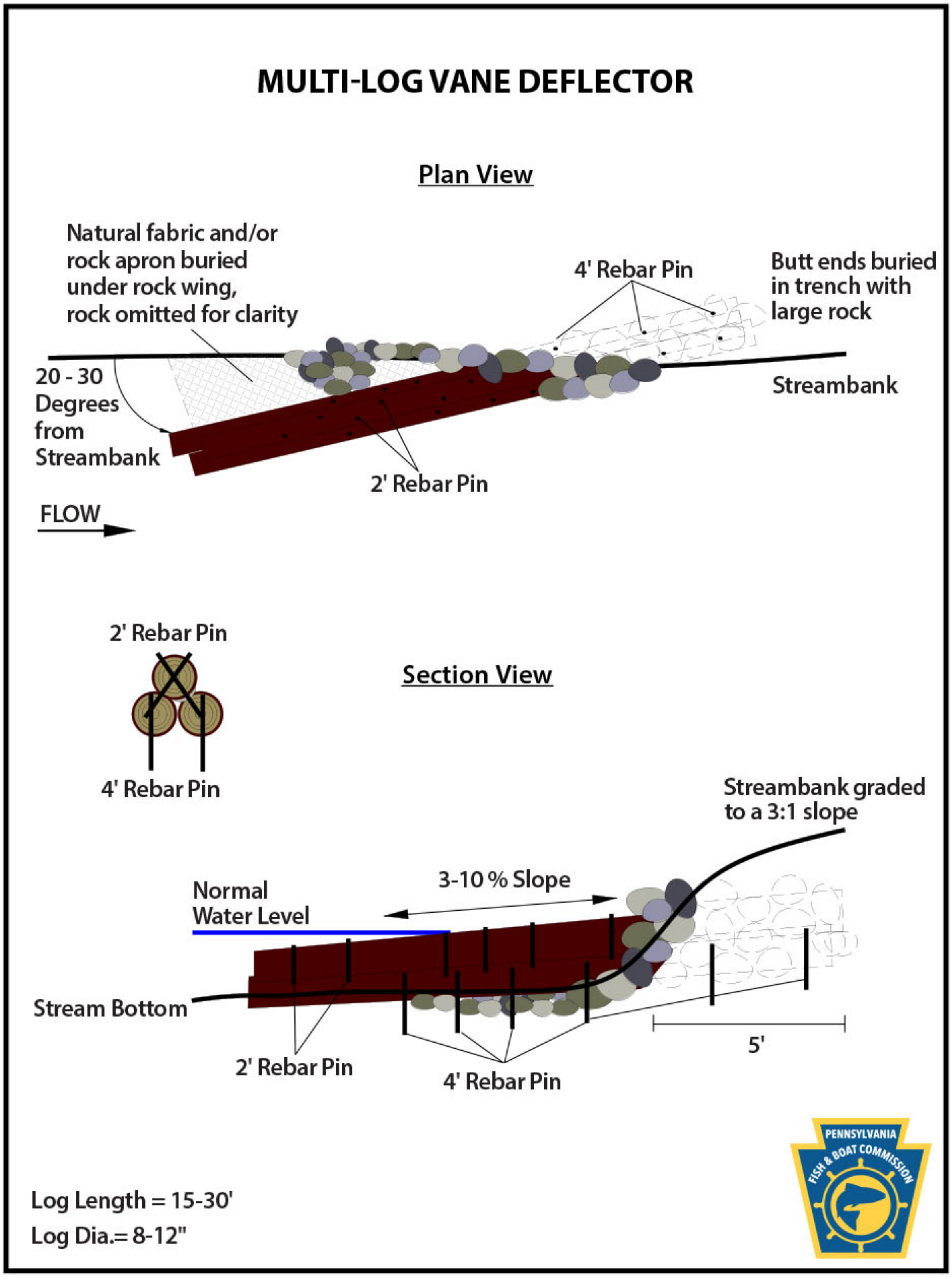

MULTI-LOG VANE DEFLECTOR
Plan View
Natural fabric and/or rock apron buried under rock wing, rock omitted for clarity
4' Rebar Pin
Butt ends buried in trench with large rock
20 - 30 Degrees from Streambank
Streambank
2' Rebar Pin
FLOW
2' Rebar Pin
Section View
4' Rebar Pin
Streambank graded to a 3:1 slope
Normal Water Level
3-10 % Slope
Stream Bottom
5'
2' Rebar Pin
4' Rebar Pin
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Log Length = 15-30'
Log Dia.= 8-12"

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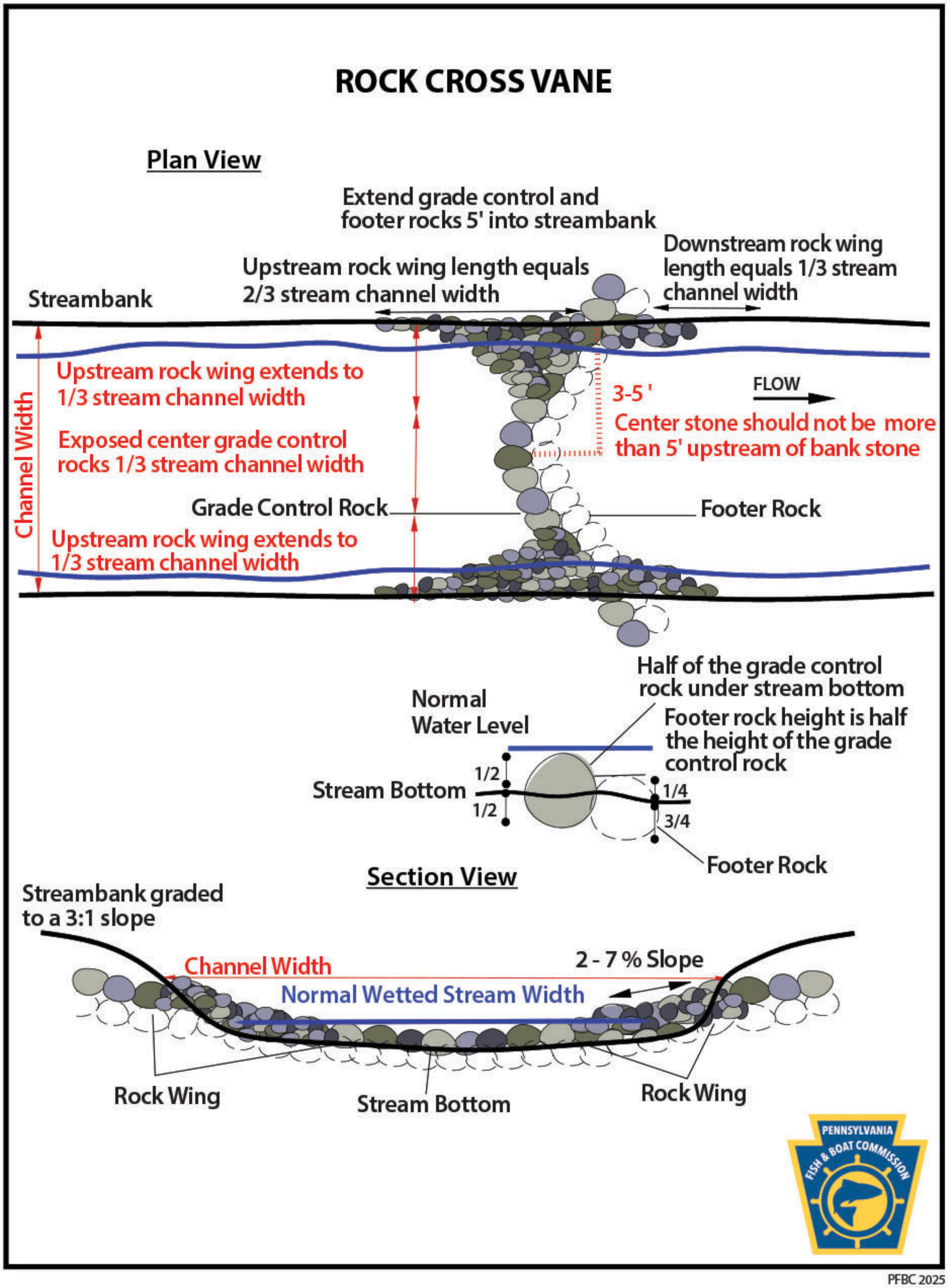
ROCK CROSS VANE
Plan View
Extend grade control and footer rocks 5' into streambank
Downstream rock wing length equals 1/3 stream channel width
Upstream rock wing length equals 2/3 stream channel width
Streambank
Upstream rock wing extends to 1/3 stream channel width
3-5 '
FLOW
Center stone should not be more than 5' upstream of bank stone
Channel Width
Exposed center grade control rocks 1/3 stream channel width
Grade Control Rock
Footer Rock
Upstream rock wing extends to 1/3 stream channel width
Half of the grade control rock under stream bottom
Normal Water Level
Footer rock height is half the height of the grade control rock
1/2
Stream Bottom
1/2
1/4
3/4
Footer Rock
Section View
Streambank graded to a 3:1 slope
Channel Width
2 - 7 % Slope
Normal Wetted Stream Width
Rock Wing
Stream Bottom
Rock Wing
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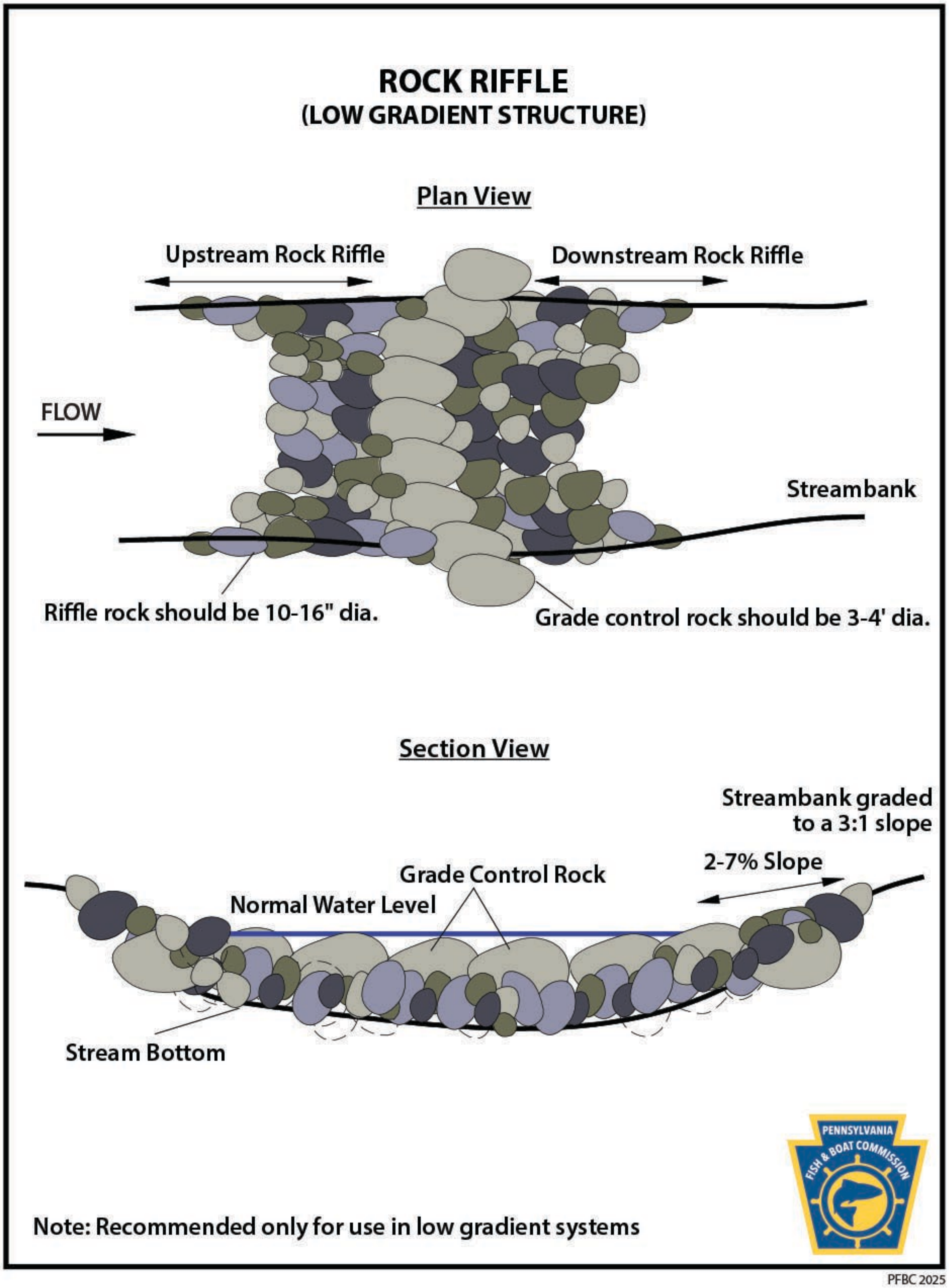
ROCK RIFFLE
(LOW GRADIENT STRUCTURE)
Plan View
Upstream Rock Riffle
Downstream Rock Riffle
FLOW
Streambank
Riffle rock should be 10-16" dia.
Grade control rock should be 3-4' dia.
Section View
Streambank graded to a 3:1 slope
2-7% Slope
Grade Control Rock
Normal Water Level
Stream Bottom
PENNSYLVANIA FISH & BOAT COMMISSION
Note: Recommended only for use in low gradient systems
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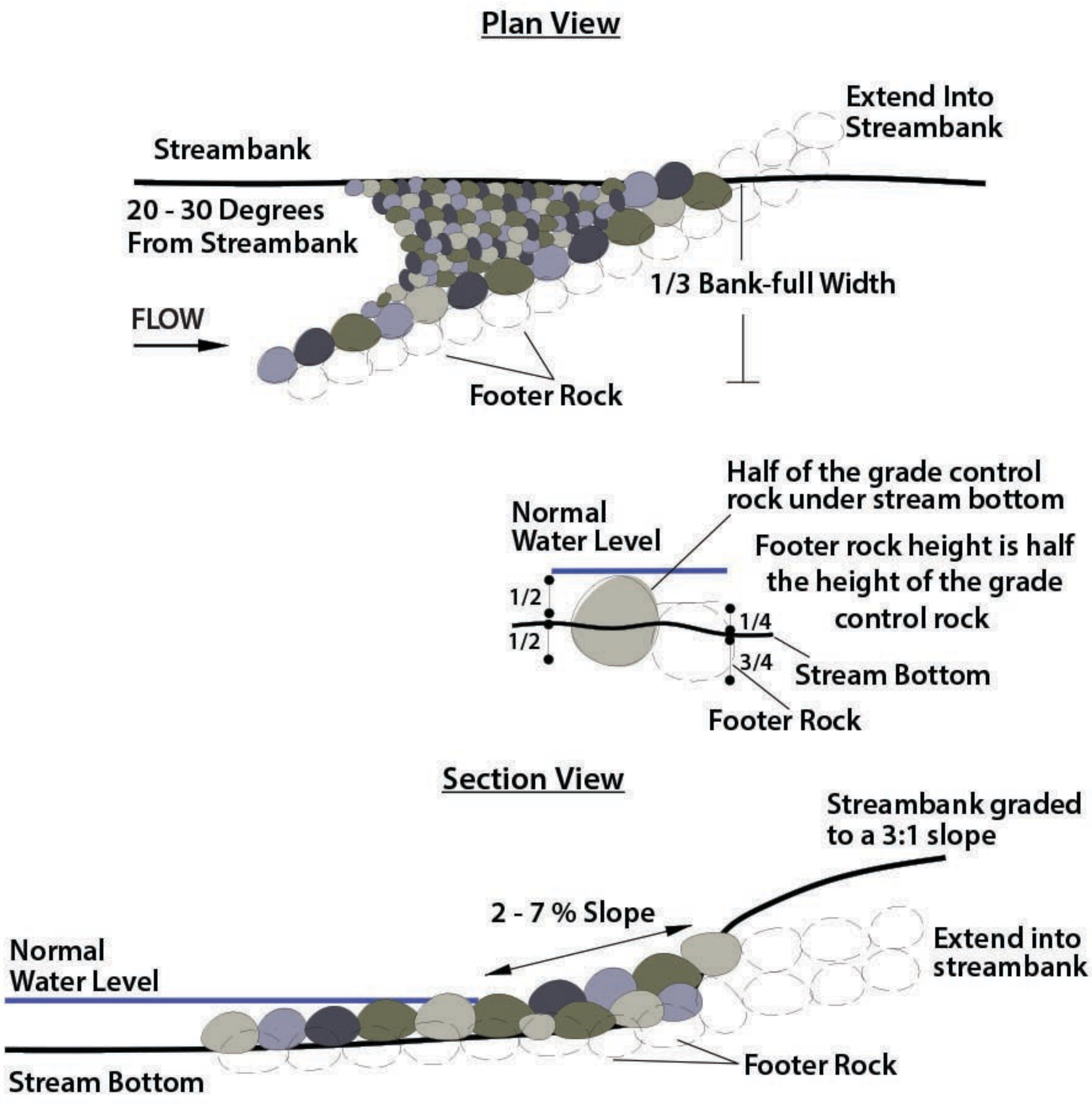
ROCK VANE DEFLECTOR



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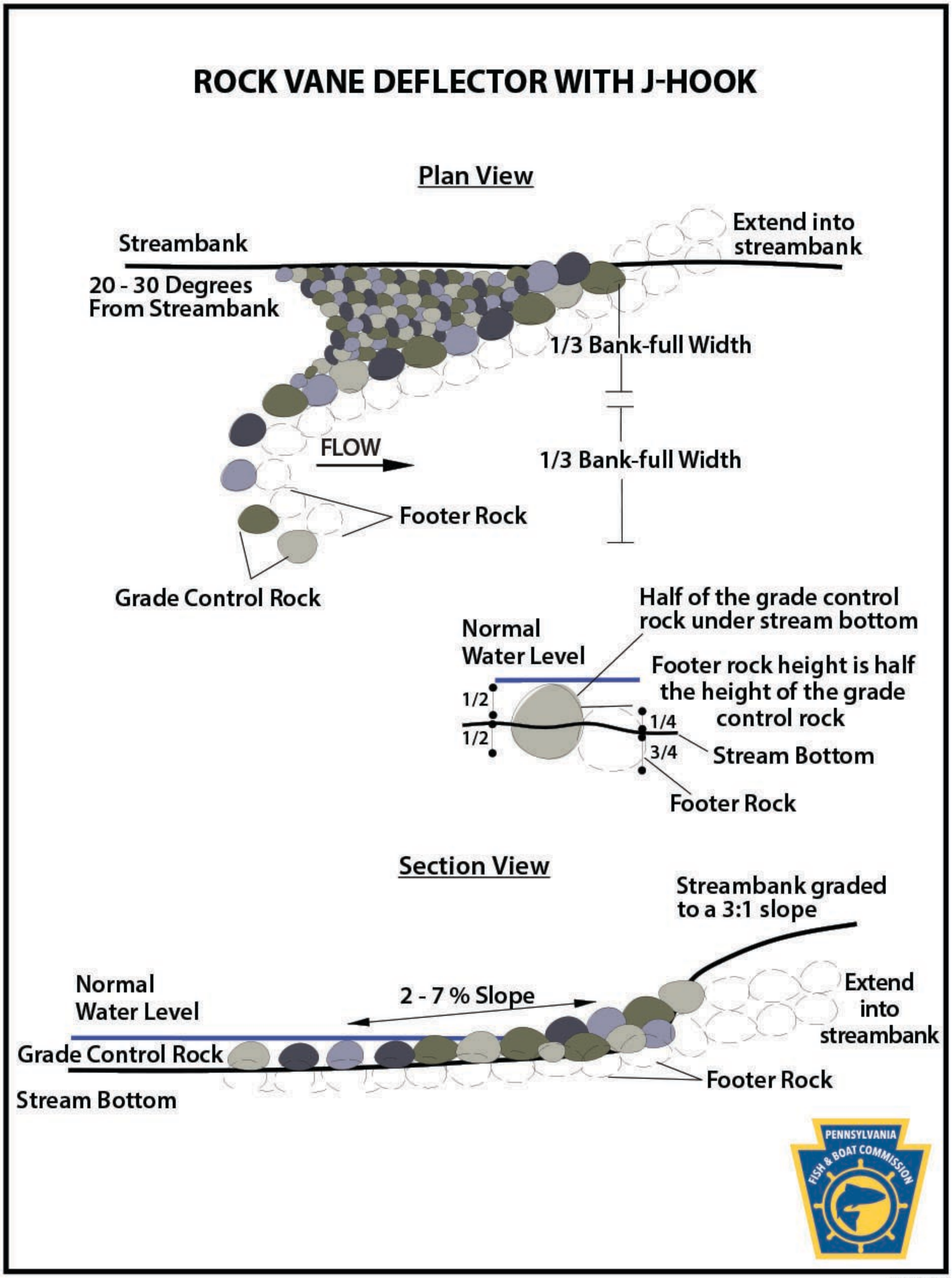

ROCK VANE DEFLECTOR WITH J-HOOK
Plan View
Streambank
Extend into streambank
20 - 30 Degrees From Streambank
1/3 Bank-full Width
FLOW
1/3 Bank-full Width
Footer Rock
Grade Control Rock
Normal Water Level
Half of the grade control rock under stream bottom
Footer rock height is half the height of the grade control rock
1/2
1/2
1/4
3/4
Stream Bottom
Footer Rock
Section View
Streambank graded to a 3:1 slope
Normal Water Level
2 - 7 % Slope
Extend into streambank
Grade Control Rock
Stream Bottom
Footer Rock
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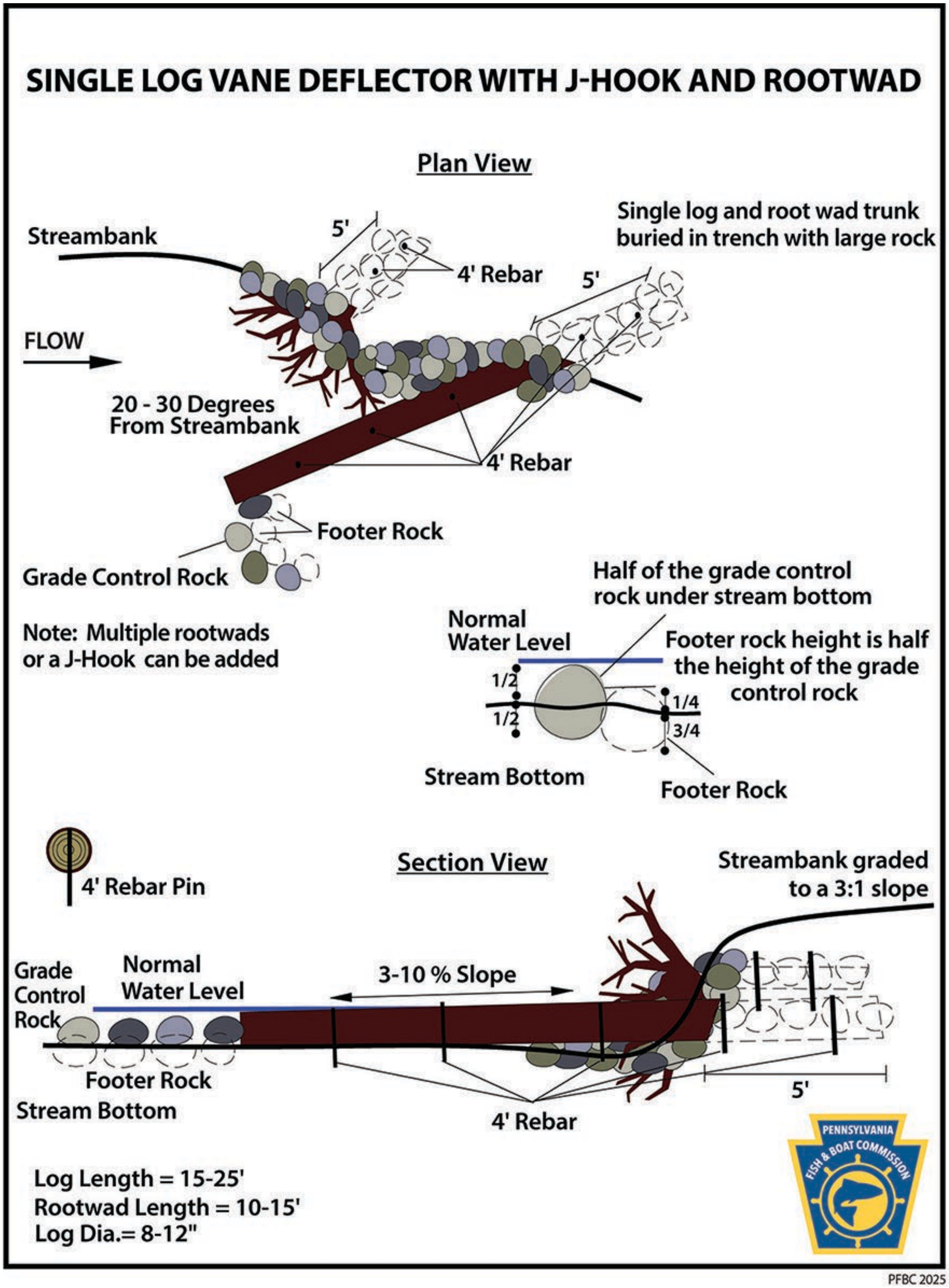
SINGLE LOG VANE DEFLECTOR WITH J-HOOK AND ROOTWAD
Plan View
Streambank
5'
4' Rebar
5'
Single log and root wad trunk buried in trench with large rock
FLOW
20 - 30 Degrees From Streambank
4' Rebar
Footer Rock
Grade Control Rock
Note: Multiple rootwads or a J-Hook can be added
Half of the grade control rock under stream bottom
Normal Water Level
Footer rock height is half the height of the grade control rock
1/2
1/2
1/4
3/4
Stream Bottom
Footer Rock
4' Rebar Pin
Section View
Streambank graded to a 3:1 slope
Grade Control Rock
Normal Water Level
3-10 % Slope
Footer Rock
Stream Bottom
4' Rebar
5'
PENNSYLVANIA FISH & BOAT COMMISSION
Log Length = 15-25'
Rootwad Length = 10-15'
Log Dia.= 8-12"
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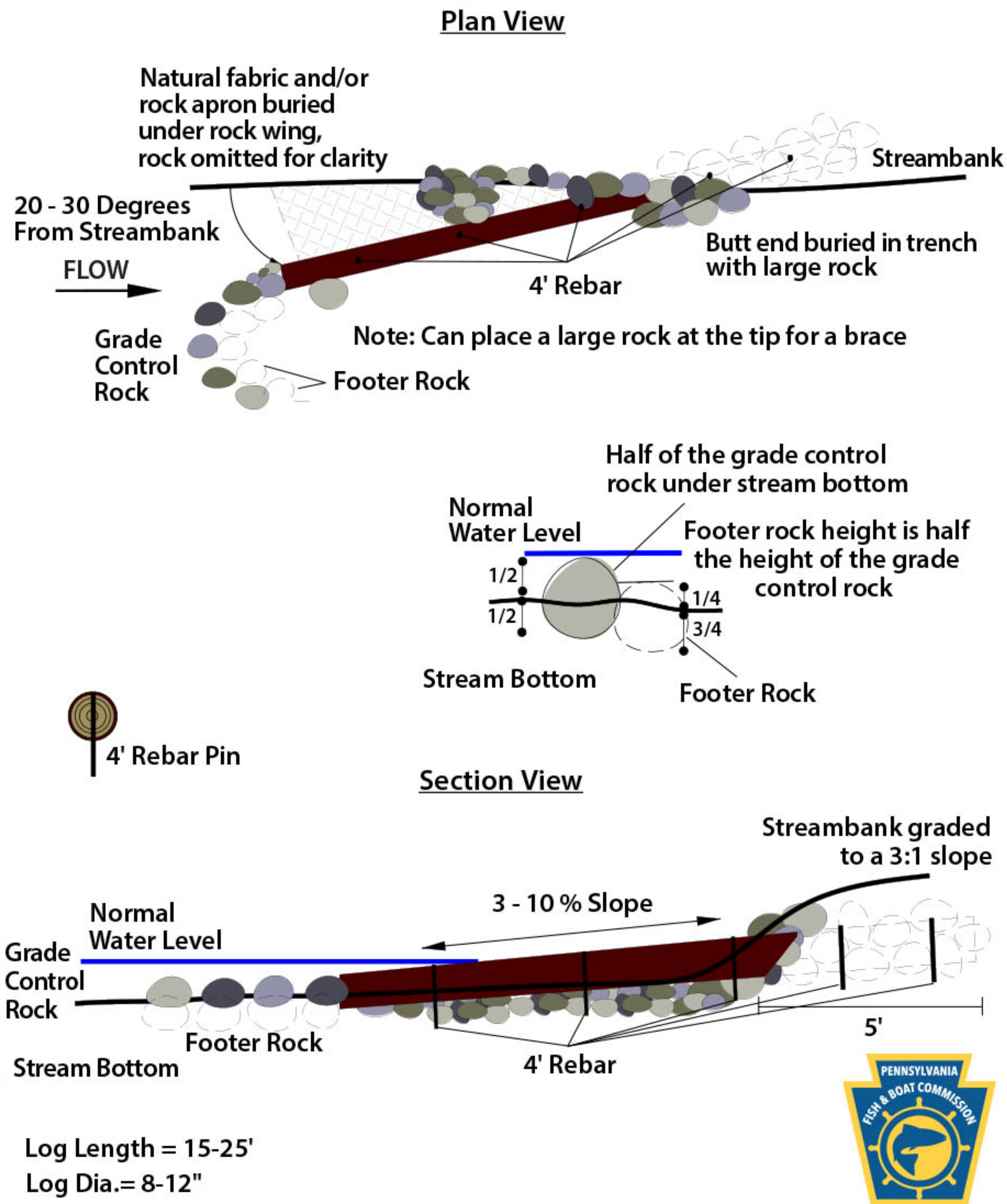
SINGLE LOG VANE DEFLECTOR WITH J-HOOK



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SINGLE LOG VANE DEFLECTOR