INTRODUCTION AND PURPOSE OF THE DESIGN GUIDE

This Design Guide is intended to clarify the Chapter 1 of the Water Resources Infrastructure Protection Manual, section VIII, articles D-H (Outfalls, Pump stations and Site Drainage). This Design Guide describes how to address streambank erosion problems, and how to use bioengineered methods of bank protection and erosion repair.

This Design Guide is to be used by local permitting agencies, property owners and professionals who design projects on streamside parcels (i.e. civil engineers, land use planners, landscape architects, etc..) It is intended to:

- Provide guidance for how to design a variety of bank protection projects, in places where streambanks are, have, or may be eroding
- Promote proactive approach to preventing and resolving serious erosion problems

This document is a guide, not an instruction manual. Erosion repair activities within a stream channel will impact water quality, flood protection, the stability of adjacent properties, and the habitats of many stream-dependant species. It is for these reasons that these activities require several state and federal permits, as well as the involvement of qualified professionals to help design and construct the project in a way that addresses stability and long-term water resource protection. Examples of more detailed guidance manuals are listed at the end of this document for reference.

MOVING TOWARD SOFT, MORE SYSTEMIC METHODS OF BANK PROTECTION/EROSION REPAIR

Traditional methods of controlling erosion have relied on "hard" structural practices such as covering banks with interlocking concrete blocks and building retaining walls. However, these techniques often have negative impacts on streams. In many cases, these methods are also expensive and ineffective in the long run. Recommended instead are "soft" or bioengineered bank stabilization methods. A bioengineered approach involves the planting of native streamside or riparian vegetation combined with the strategic placement of logs or minimal rock, where necessary, and regrading of steep slopes wherever possible in order to produce living systems that minimize erosion, control sediment, and provide habitat. The natural attributes of plants, when combined with stabilized bank slopes, provide better dynamic stream systems than stationary hard structures.

An objective of this Design Guide is to protect, and where appropriate, restore streambanks and related stream resources. Where suitable, it encourages a systemic approach to streambank protection and stream restoration. This Design Guide starts by describing how streams function, typical features of a stream and importance of riparian vegetation. It then discusses typical causes of streambank erosion and recommends basic measures to be considered when planning and designing a bank protection erosion repair project. Finally, alternative methods of protecting a streambank are presented, starting with how to treat a reach of a stream in a more rural setting where there is room to use a more systemic approach, and continuing with a variety of treatments for smaller, urban parcels, which include a small reach of a stream.

GOALS/PURPOSE OF STREAMBANK PROTECTION ACTIVITIES

In general, the goals of any bank protection/ erosion repair activity should be to:

- Maintain or increase stream stability and facilitate transport of sediment and water;
- Avoid localized solutions that repair only a single erosion site but reduce the stability of neighboring stream banks

and cause erosion problems on upstream or downstream properties;

- Enhance and increase native vegetation both in extent and diversity to provide habitat value and help ensure long-term bank stability.

With these goals in mind, this Design Guide delineates some general guidelines and issues to consider when embarking on a bank-protection/erosion-repair project, as well as a description of various erosion-repair techniques. This guidance also provides agency staff and streamside property owners with a brief overview of how streams are formed, their common characteristics and features, and typical causes of streambank erosion

ORGANIZATION OF THIS DESIGN GUIDE

This Design Guide is organized into two parts and six subsections. The Technical Primer part includes useful background information that explains the causes of erosion. Homeowners and project developers will likely refer to the Techniques and Guidance part more frequently, because it outlines techniques and guidelines for erosion repair.

CONTENTS

PART ONE: TECHNICAL PRIMER ON STREAM FUNCTION AND FORM

SECTION 1 - HOW STREAMS FUNCTION

INTRODUCTION

Before considering bank protection or erosion repair, it is necessary to understand the process by which streams form and adjust to their surroundings. Streams are shaped by a combination of "forming forces" that include:

- Gravity, or the slope of the channel banks
- Friction, which is a function of vegetation, the soil's type and particle size, and the channel's pattern and profile.
- Velocity, the speed of the water flow.
- Quantity, the volume of water flowing and sediment moving through the stream.

Over time, streams move and shift in response to changes in these forming forces. That is why streams do not naturally tend to flow in a straight line. Instead, they meander in search of equilibrium with their forming forces, adjusting to changes in water flow and sediment transport. These changes can have both natural and non-natural causes.

CHARACTERISTICS AND HISTORY OF STREAMS IN SANTA CLARA COUNTY

Some streams in Santa Clara County are still in a natural condition, while others have been straightened or channelized in response to land development activities and flood control needs. Throughout the County, human-made channels were created to contain the flows that once naturally fanned out over the valley floor, carrying with them nutrients and sediment, and creating alluvial fans and fresh water marsh habitat. These human-made channels were created to accommodate the use of land for agriculture or urban development, and to ameliorate flooding conditions.

Experience has also shown, however, that significant problems arise when streams in the lower watershed are confined. By lining streams with levees or floodwalls, water that would otherwise slowly spread out over a large area of land in a beneficial way accumulates in the channel until it breaches its levee or floodwall, potentially causing catastrophic flooding. Even if this does not happen, a significant amount of sediment may be deposited in the channel after a storm event, raising the channel bed elevation. This sediment decreases the channel's capacity to handle subsequent storm flow. In other words, the chance of catastrophic flooding increases with every storm if the channel's sediment is not removed often enough.

Significant efforts are underway throughout the County to address these issues, and to maintain and enhance our remaining natural streams. There are also efforts being made to restore and enhance, where possible, channelized urban drainage ways. It is important to remember that even though a stream may be hardened or modified in a particular location, it may remain natural in other areas. Over time, it may be possible and even essential to restore these streams to a more natural state to improve stability and flood protection for nearby property owners.

In addition, the protection of water quality is critical in all types of Santa Clara County streams, both natural and unnatural, because they eventually convey water to either Monterey Bay or San Francisco Bay.

TYPICAL STREAM FEATURES

In a cross-sectional view, a stable natural stream can be defined by two significant features: the "bankfull" (or "active channel") and the "active floodplain."
See figure 1 below.

The bankfull or "active channel" can be defined by the elevation of the floodplain, which is formed by the most effective channel forming or "dominant" stream discharge. It is the part of the stream where sediment is actively transported and deposited, the part that is capable of containing the most frequent flows.

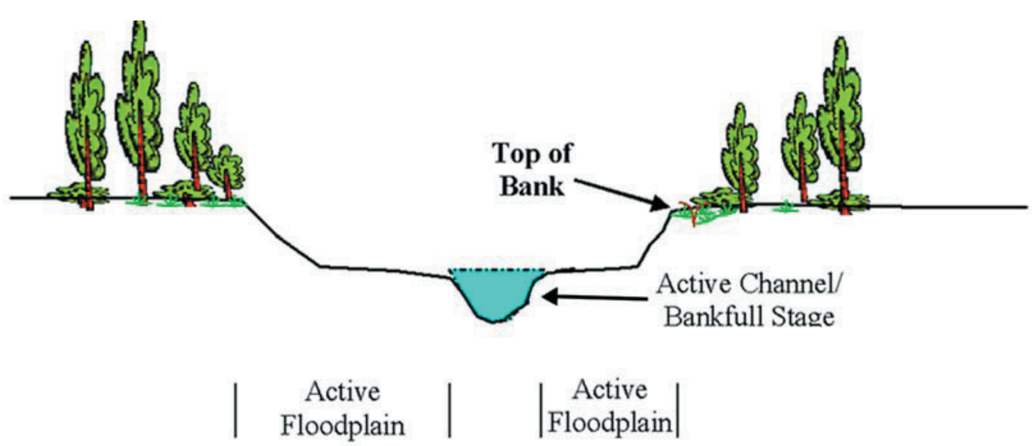
The active channel is an important feature because it transports the majority of the water and sediment in the stream system, and thus it influences the channel formation over time. As seen in Figure 1, the active channel is usually distinguished from the active floodplain by an abrupt change in the slope of the stream bank, usually from a vertically-sloped plane to the horizontally-sloped plane on top of the floodplain.

Active floodplains are the low-lying areas between Top of Bank (See Figure 1) and adjacent to the active channel that are subject to frequent inundation during moderate and high flows. This area is where sediment is deposited when the active channel's capacity is exceeded during high flows. In urban settings, active floodplains are often hard to identify, due to channel incision and erosion from increased urban runoff. On rural streams, the active floodplain normally fills approximately every year or two. Floodplain filling usually occurs more often in urban areas. Vegetation is typically present in the floodplain area, as it will become established between the alternating seasonal periods of inundation and sediment deposition.

(Section 2 of the Guidelines and Standards also includes more detailed definitions and sketches showing these features in a variety of settings).

Important Note: A stream's active floodplain is not to be confused with the delineation of floodplain used for flood insurance purposes. The floodplain defined for flood insurance purposes is the one percent (100-year) flood, or the area that has a one percent chance of being flooded to a depth of one foot or greater each year. For insurance purposes, this equates to a 26 percent chance of suffering some flood damage during the term of a 30-year mortgage.

FIGURE 1: CROSS-SECTIONAL VIEW OF A NATURAL STREAM



STREAM BELTWIDTH AND STREAM MEANDER WIDTH

A channel has a certain beltwidth within which it naturally moves. This beltwidth can be determined by studying: sections of the channel which have not been straightened; pre-development photographs; or, adjacent similar channels. Levees should not, for example, be constructed in a way that does not accommodate the beltwidth. Doing otherwise increases erosion potential and maintenance costs.

Meander width is the amplitude of the meander within the beltwidth. It is smaller than the beltwidth. At a minimum, the average meander width of a channel should not be compromised in the lower flood plains. In the mid to upper slopes above the valley floor, where the natural channel may be fairly straight, the beltwidth should also be respected.

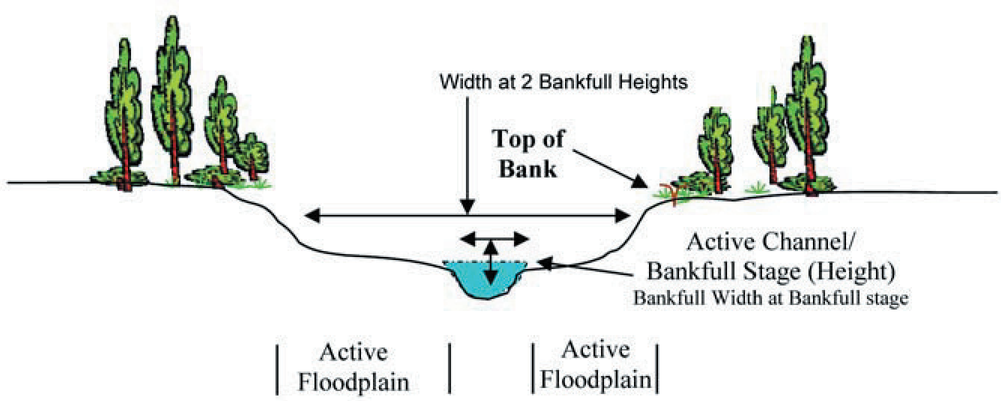
FACTORS THAT AFFECT STREAM STABILITY

Several factors affect stream stability. They include stream topography, the width-to-depth ratio, and extent of channel incision

The quantity and movement of both water and sediment in a stream are two of the primary influences on the topography of a stream. These materials tend to balance each other within the confines of the stream channel. For example, erosion on one bank is typically balanced by sediment deposition on the other. While the location and extent of the erosion and resulting deposition may change over time, the width and depth of a stable stream does not change much. Thus, any type of erosion repair project must be designed to maintain width-to-depth ratio in order to ensure long-term stream stability, while also allowing the streambed to erode and fill naturally.

A channel's width-to-depth ratio is calculated by dividing the width of the stream channel (at the bankfull level) by the mean channel depth. Width-to-depth ratio is part of a more complicated concept called entrenchment ratio, which is important because it calculates a channel's stability. Generally speaking, it calculates its stability in terms of its floodplain—the larger the floodplain, the higher the entrenchment ratio. Specifically the entrenchment ratio is equal to the width of the stream channel (at twice the maximum bankfull depth) divided by the width-to-depth ratio of the bankfull channel. In order to prevent channel incision and maintain a stable stream, the ratio of the width of the channel at 2 bankfull heights (see Figure 2) to the bankfull width should be a minimum of 2 where the channel is constrained. It should be a 3 to 4 ratio at other locations, both upstream and downstream. This provides sufficient relief, and thus prevents excessive erosion of streambed and bank. It also prevents damage to bankside properties during 1 year–10 year storm events.

FIGURE 2. DETERMINING THE APPROPRIATE WIDTH TO DEPTH RATIO



EFFECTS OF WATER AND SEDIMENT TRANSPORT ON BANK STABILITY

Streams adjust themselves to transport, as efficiently as possible, water and sediment from higher elevations to lower elevations. If the amount of sediment available to a creek is significantly increased or decreased, the creek adjusts its channel area or cross section to handle the change in sediment. In a normally-functioning gravel bed stream, for example, it is not uncommon for the stream channel (or portions of the stream channel) to downcut and refill significantly—from a few inches to 10 feet or more in a single storm event. This is one way streams transport their sediment loads, clean themselves, and temporarily increase their flow capacity.

With the expanded development in Santa Clara County, the time it takes for runoff to reach the streams has decreased, which leads to the increase in the amount of water in most streams. Some of the specific factors that have led to this increase in water flows are:

- Substantial increases in impervious surfaces such as pavement and roof tops.
- The routing of storm water runoff directly into streams through piped storm drain systems.
- Removal of large areas of streamside vegetation that would otherwise form buffers for runoff, and promote infiltration into the soil.

The stormwater management programs of local municipalities have efforts underway to address these long-term issues. In the interim, however, it is important that armoring the channel be avoided on individual properties whenever possible, for several reasons. First bank armoring prevents channels from adjusting to high flows, and can increase the probability of flooding. Bank armoring also causes accelerated flow velocities and turbulence along banks, which then induces more erosion on unarmored banks. Finally, because armored banks cannot adjust to changing stream conditions, they are prone to undercutting.

IMPORTANCE OF VEGETATION AND RIPARIAN BUFFERS

The roots of well-established vegetation not only protect the surface of stream banks, but also penetrate deeply into the ground, helping to stabilizing it. Lack of vegetation close to a creek bank can contribute to slope instability and failure due to overbank drainage or soil saturation. In addition to providing bank stability, streamside vegetation filters pollutants; shades and cools the stream; increases infiltration; reduces flash runoff; and provides habitat for wildlife. A variety of scientific studies of the minimum and optimum width of a vegetated buffer along a stream indicate that a width of 10 feet is not enough to provide adequate filtration or habitat. A study by U.S. Fish and Wildlife indicates that in order to effectively remove pollutants, a buffer of 50 feet is needed. Other sources recommend a vegetated buffer that is 2 to 5 times the width of the stream channel. While there is ongoing discussion about the most appropriate width for vegetated buffers, it is conclusive that at least some adequate buffer is necessary to protect stream resources. In terms of erosion repair projects, the use of live plants, either alone or in combination with dead or select rock materials, can be sufficient to prevent erosion, control sediment, and provide habitat.

STREAM FEATURES THAT ARE IMPORTANT TO FISH HABITAT

The movement of water through a streambed creates certain natural characteristics or that benefit fish habitat. Some of these important features are riffles, runs, glides and pools. Riffles are located in shallow areas or bends in a stream where water flows over rocks. Runs are the straight sections between riffles. Glides are the transition areas between the downstream end of pools and a run or riffle. Pools are usually formed on the outside of bends in a stream. Deep pools are particularly import ant in providing critical fish habitat and refuge areas. When the flow in the stream decreases in drought, fish can retreat to these pools to wait for the return of higher flows.

These stream features described above differ from stream to stream depending on a stream's geometry and location. For example, at higher elevations, stream channels are steeper, narrower, and drop at faster rates, and may contain series of step-pool cascades. At a lower elevation, however, a channel tends to be less steep, wider, and more sinuous, making riffles and pools more common. The combination of riffles, runs and pools is extremely important for fish because it provides different feeding, spawning and/or nursery areas. These stream characteristics should be preserved, restored, and enhanced where possible, as appropriate to the stream topography, in any type of erosion repair effort.

SECTION 2 - CAUSES OF STREAM BANK EROSION

All streams erode to some extent as a part of natural processes. Natural erosion is typically caused by:

1) Hydraulic forces that remove bank material;

2) Geotechnical instabilities;

3) Or, most commonly, a combination of both these two forces.

HYDRAULIC FAILURES

Hydraulic failures occur when the force or velocity of the water is greater than the natural cohesion of the soil. In other words, the forces that bind the soil together are overcome by the water. Some visible features of hydraulic failures are erosion near the bottom, (or at the "toe,") of a stream bank, or alteration of the streambed. Changes in the direction of flow, constrictions, increases or decreases in the amount of sediment, and increased amount and duration of flow from impervious areas can all accelerate erosion of the stream bank or alteration of the streambed, and in turn, hydraulic failure.

Some of the sediment that is introduced into the stream will naturally deposit on the bottom of the stream. Over time, this may raise the bottom of the stream and reduce the capacity of the active channel, forcing the water to spread out laterally. This causes erosion and steepening of the stream banks. This can also occur when a stream is starved of sediment (typically by dams or erosion control structures) and the excess energy that would have been used to transport sediment is now free to erode bed and banks. This condition typically occurs with the construction of hardened channel linings, or with the addition of other types of instream debris, sediment, or detention basins that trap sediment. In this case, the erosion (down-cutting and steepening) of the streambed and banks occurs below the lined section (or "instream basin"), causing the eroded sediment to settle farther downstream. Nonetheless, the impact on the stream is similar. Thus, for hydraulic failures, the most effective erosion repairs are accomplished by addressing the root cause of the failure, which may include installation of measures to redirect flow, increasing the erosion resistance of the bank, by planting vegetation on the bank or adding protection to the toe of the stream bank.

GEOTECHNICAL FAILURES

Geotechnical failures occur when gravitational forces are greater than the strength of the soil. These failures are usually caused by over steepened banks and/or excess moisture in the soil. This results in the movement of earth, better known as a landslide. Near a stream, the likely causes of this type of failure are a high groundwater table, poorly designed surface drainage systems (such as those that drain surface runoff directly over the top of the stream bank), leaking swimming pools, and leaking septic systems or water lines (which saturate the stream bank). Thus, for most geotechnical failures, what must be addressed is the source of the water that's causing excess moisture in the vicinity of the stream bank.

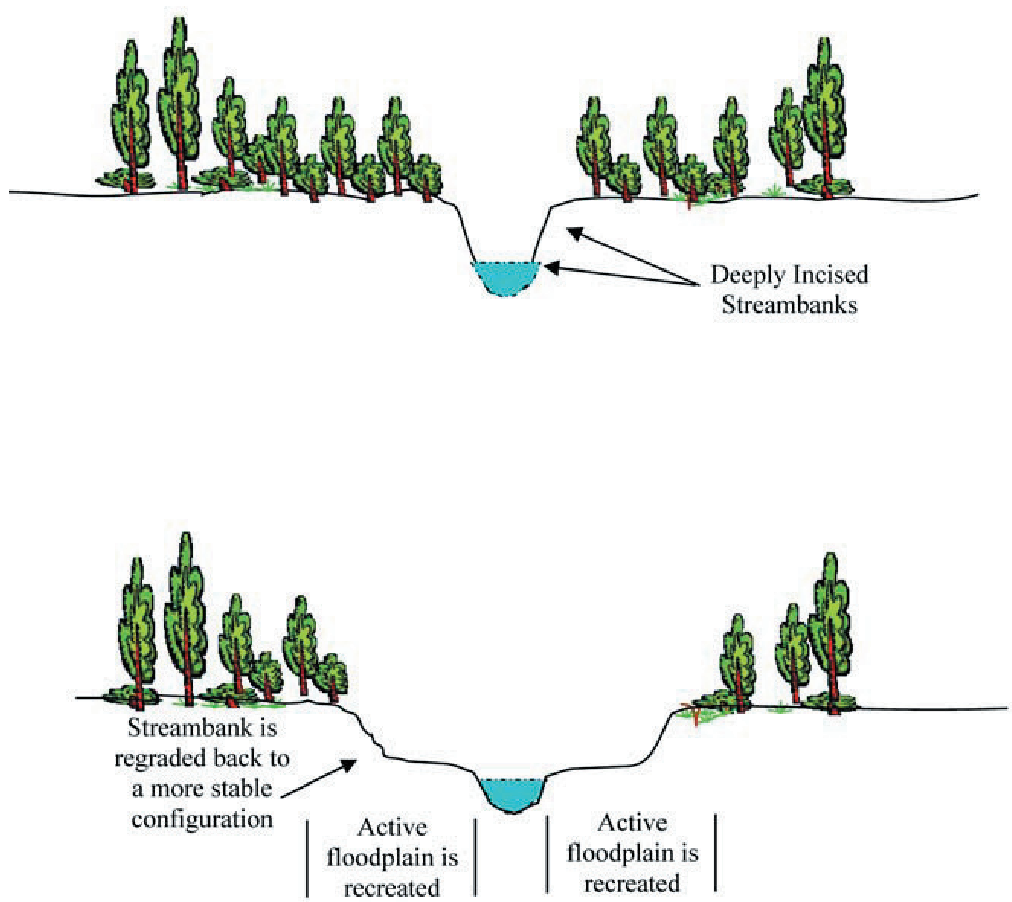
COMBINATION FAILURES

The third type of failure is a combination of hydraulic forces and geotechnical instabilities. Hydraulic failures often lead to geotechnical failures. As the toe of the stream bank erodes, or the channel cuts downward because of hydraulic forces, the bank effectively increases in height and becomes too steep and unstable. Sometimes, the upper portion of the stream bank fails from lack of support, and slides into the stream. This process is well described in the document Maintaining Corte madera Creek: A Citizen's Guide to Creek-side Property Protection, which was prepared by Phil Williams and Associates in Collaboration with H. T. Harvey and Associates for the San Francisquito Creek Joint Powers Authority. They write, "The higher a bank is, the flatter the angle must be to prevent slumping. For example, most soils will support a three-foot high vertical bank, but if the river cuts a deeper channel (say five feet) the bank will collapse under its own weight. A five-foot tall bank would need to be graded to a lower gradient to be as stable as a three-foot vertical bank, and a ten-foot high bank would have to be excavated to an even lower gradient to be stable. The higher the bank, the lower the stable gradient becomes." The best remedy for this problem—the problem of an over-steepened bank experiencing both hydraulic and geotechnical failures—combines several steps. The first step involves regrading the slope to a more stable angle, which is why it is called "laying it back."

The second step involves reinforcing the toe, where necessary, with biotechnical methods such as logs and rocks. The third step involves reducing erosive energy on the bank by planting the bank, so that it does not become over-steepened again.

For an illustration, see figure 3 below.

FIGURE 3: LAYING BACK A STREAMBANK TO INCREASE STABILITY



PART TWO:
TECHNIQUES AND GUIDANCE FOR DEVELOPING A WATERSHED-FRIENDLY EROSION REPAIR PROJECT.

SECTION 3 - EMBARKING ON YOUR BANK PROTECTION/EROSION REPAIR PROJECT

This section describes five initial steps to consider in undertaking an erosion repair project. This text borrows extensively from the guidance manual developed for the Guadalupe and Alamitos Creeks entitled "Stream-bank Repair Guidance Manual for the Private Landowner," which is cited in the references section.

INITIAL STEPS

Step 1: Establish the Purpose and Necessity of Your Project

Step 2: Hire Qualified Professionals

Step 3: Get to the Root of the Problem

Step 4: Seek Assistance from the Water District

Step 5: Secure Permits from the Appropriate State and Federal Agencies

STEP 1. ESTABLISH THE PURPOSE AND NECESSITY OF YOUR PROJECT

Repairing a stream or bank erosion problem is not a simple or routine task. The root cause of the bank failure must first be identified. Then, the most probable stable channel form and dimensions must be determined, based on geomorphology and hydrology, as well as hydraulic analyses. Only then can a proper solution or repair be recommended.

Before embarking on any bank stabilization/ erosion repair project, it is important to answer the following questions: What is the purpose of this project? What are its objectives? Is it necessary?

Some examples of objectives could include:

- Protecting property or structures
- Restoring eroded banks
- Protecting existing banks from erosion
- Restoring riparian habitat and improving stream function

Determination of the project's necessity must take into account the fact that some erosion is natural and acceptable. For example, the exposure of roots on a streamside tree is natural, and unless extreme, it will not hurt the tree. If the bank height is less than about eight feet, what is easily perceived as bank erosion may be only temporary, or even reverse itself as the stream meanders in its floodplain. Some erosion repair activities, such as bank armoring, can destabilize other areas erosive forces are transferred downstream, or onto opposite banks, eventually causing additional problems. A qualified professional may be needed to help determine whether, and to what extent, erosion is in need of repair.

STEP 2. HIRE A QUALIFIED EXPERT TO DETERMINE THE APPROPRIATE DESIGN

Designing an erosion repair project that maximizes stability and avoids unintended consequences is complicated. As noted earlier, a stream must have a properly dimensioned bankfull channel in order for it to have long-term stability. Other critical factors in proper channel design include: proper width to depth ratio, water velocity, sheer stress, and channel slope. Most property owners do not have the training or expertise necessary to incorporate all of these considerations into project design.

A walk along many Santa Clara County streams proves this point. It reveals many examples of how individual property owners, without professional help, tried to control streambank erosion by armoring the bank. These measures often fail to address the need to reduce shear stresses in order to keep the bed and banks from eroding. Eventually, the channel will downcut, and in most cases, fail. Professionals can help avoid this kind of failure-prone approach to streambank repair and help identify and address the root cause of the problem.

STEP 3. IDENTIFY THE SOURCE OF THE PROBLEM

It is important to identify and, if possible, address that the source of streambank or bed erosion. If it is not addressed, the erosion repair project may either need to be repeated or expanded in the future, or cause other erosion problems upstream, downstream, or across the stream. To identify a potential source, one should look for:

- Flow constrictions like bridges or debris that increase downstream velocities and shear stress,
- Existing hardscape, or paved over areas, that may be increasing velocities downstream,
- Natural or non-natural debris that may have redirected the flow into the bank,
- Drainage features that may be directing flow onto, or saturating, the bank,
- Watershed-wide increases in amount and duration of runoff that may be causing systematic degradation of the creek channel (incision), which leads to toe failures and bank slumps.

These underlying causes of erosion could be natural features or constrictions, but most likely, they are non-natural, i.e., human-made. Oftentimes, the source of the problem is an earlier effort to address an erosion problem upstream or downstream. Depending on the extent of the problem, it may be worthwhile for the property owner to consider a collective effort with neighboring property-owners, perhaps even including government and/or public agencies who own land or rights-of-way in or near the stream.

Because actions taken to address erosion in one place can cause problems elsewhere, permit applicants should consider the potential impacts on both the downstream and upstream streambed and banks when determining the type of erosion repair measure to use. To this end, property owners may be asked to provide professional analyses of stream geomorphology and/or hydraulics to determine potential negative impacts, and recommend ways to prevent them.

STEP 4. SEEK ASSISTANCE FROM THE SANTA CLARA VALLEY WATER DISTRICT (SCVWD)

For SCVWD's assistance in conducting repair or maintenance, contact the SCVWD's Watershed staff at 408.265.2600. There are three different scenarios related to ownership and easement that determine assistance eligibility:

SCVWD RIGHT OF WAY: If the District owns the property where the stream is located, District staff will visit the site to inspect the erosion, determine if and how it should be addressed, and then, if need be, take appropriate measures to do so.

SCVWD EASEMENT: If the District has an easement on the section of the stream needing repairs, District staff will visit the site to inspect the erosion. Easements generally provide the District with the necessary rights to perform the work. The District can make repairs within an easement after assessing the extent of the erosion, the infrastructure affected, the available funding, and the need to conduct other work on District property.

PRIVATE OWNERSHIP: If the stream is under private ownership, District staff is generally available for a visit to the site, however this availability will depend on the number of requests received and staff resources. Staff can provide advice on an approach to use but, the District will not design or construct the project.

Requests for technical assistance for minor erosion repair work can be submitted to the District via their web site at http://www.valleywater.org/Water/Watersheds_-_streams_and_floods/Taking_care_of_streams/Service_request_form.cfm. To negotiate an agreement for assistance on a substantial repair project, contact the District's Watershed staff at 408.265.2600.

STEP 5. SECURE PERMITS FROM FEDERAL, STATE AND/OR LOCAL RESOURCE AGENCIES

Most erosion repair projects will require permits from federal, state and/or local regulatory agencies if they entail construction between the banks of a stream. Please refer to the Resource Agency Referral List in Section 6 of this Design Guide for a list of all the agencies, the types of activities for which they should be contacted, and their contact information. The San Francisco Bay Area Joint Aquatic Resource Permit Application (JARPA) consolidates the information that permitting agencies require into a single application. The JARPA application can be found at:

http://www.abag.ca.gov/bayarea/sfep/projects/JARPA/JARPA.html

The permitting process can take as little as a few weeks to complete, but typically takes a few months, depending on the complexity of the project and the presence (or potential presence) of federal of state listed endangered, threatened or special status species of plants or animals. Typically, the U.S. Army Corps of Engineers, the Regional Water Quality Control Board, and California Department of Fish and Game will issue permits under federal and state laws, while the Santa Clara Valley Water District or the local municipality acts as the local permitting agency.

IMPORTANT NOTE: Bank repair designs that avoid or minimize hardscape and are based on sufficient analysis of the cause of failure and stable channel characteristics almost always receive permits more readily than those that do not. Do not hesitate to contact agency representatives early in the design process to determine whether you need a permit from their agency, and to discuss potential repair options if you do.

SECTION 4 – GENERAL GUIDANCE FOR WATERSHED FRIENDLY DESIGN

USE VEGETATION TO RESTORE AND MAINTAIN STABILITY

Revegetation of the streambank is one of the most common, and often the most effective, way to prevent erosion along a streambank. This is because roots bind soils together, which prevents erosion, while leaves provide protection from rain splash erosion. In addition, the exposed trunks and stalks provide resistance to stream flow because they slow the water and decrease its erosive energy. An added benefit is that vegetation provides ideal habitat for birds and other animals. Vegetation planting methods commonly used include cuttings, transplants, live staking, and direct seeding (including hydro-seeding).

- Maintain streamside trees. Avoid pruning trees unless it is necessary to the survival of the plant or the protection of existing property and/or infrastructure as trees can critical shelter and shade for stream wildlife.
- Do not remove affixed logs. Logs that have been permanently or securely affixed to the streambank provide valuable habitat. Their removal could negatively impact fish habitat, and might therefore require mitigation. However, downed trees and logs can often deflect high flows, causing serious bed and bank erosion, destroying fish habitat, and degrading water quality. For these reasons, downed trees and logs need to be removed quickly.
- Plant between October 15 and March 15. In order to minimize irrigation requirements and ensure that plants receive sufficient water for natural propagation, plant in the fall and early winter. Where soils are dry and water is limited, irrigate as needed until the rainy season.
- Do not introduce invasive non-native vegetation species into the watershed. Non-native invasive plants are a serious problem because they often inappropriately constrict water flows and overtake native plant species.(See Design Guide 2 for more on invasive non-natives).
- Instead, use locally collected native species for revegetation and replacement plantings. Plant selection and density should be informed by a survey of natural areas on the same creek that have a similar ecological setting. This can inform you as to what species would be found in the area and an approximate population density. See Design Guide 4 and 5.
- Plant according to moisture needs, using different types of vegetation on the upper and lower sections of the stream bank. Plants have different tolerances for the wet conditions at the toe of slope. They also vary in drought-tolerance and erosion-control effectiveness on the upper slopes. Some tree species, such as willows and cottonwoods, are more successful when they are closer to the stream. Others, like oaks, enjoy more success higher up the bank. Where stream capacity is an issue for flood protection purposes, choose vegetation that is flexible and that will not collect debris and slow high flows during flood events.
- Use fast-sprouting grass species for more immediate erosion control. A regraded slope can be seeded with fast-sprouting grass species such as sterile wheat, or better yet, a native grass/sedge seed mix combined with a biodegradable erosion control blanket. These species provide more immediate erosion control.

See Design Guides 4 and 5 for plant species.

- Do not use chemical fertilizers, herbicides or pesticides. These chemicals can be easily transported to the creek by wind or rain and degrade water quality, endangering aquatic life.

WATERSHED-FRIENDLY DESIGN: BEST MANAGEMENT PRACTICES

This section provides some tips for stream care during construction. Proper use of best management practices (BMPs) can have a tremendously beneficial impact on aquatic species and other wildlife, human health, environment, property, and public services.

CONSTRUCTION BMPS:

- **When restoring a damaged section of a streambank, imitate natural stream features**, such as channel meanders, appropriate width and depth, and vegetation. This will stabilize the channel. Details of this concept are included in Section 5 of this Design Guide.
- **Observe work windows**. In-channel work should generally be conducted during the dry season, between June15th and October 15th, to minimize negative impacts to plant and wildlife. Sometimes these dates will vary depending on the wildlife species in the area. Do not use heavy equipment during spawning or migration seasons, as it can destroy fish habitat. If construction during periods of stream flow can not be avoided, include measures to separate area of disturbance from stream flow to minimize turbidity in stream.
- **Avoid removing in-stream gravel.** Avoid disturbing the creek bed, particularly spawning gravel. After project completion, replace or restore any gravel that was moved or removed to maintain spawning areas for fish.
- Take special care when establishing stream access points, because these points can contribute undesirable sediment to the stream. So
    - Use established access point wherever possible.
    - If it is necessary to create a temporary access point for construction, do so as close to the work area as possible in order to minimize adverse impacts. When the project is complete, restore the access Point to as natural and stable condition as possible.
    - Prevent soil at construction entrances from being tracked onto streets near work sites.
- **Control dust**. Dust can be a nuisance, and have an adverse impact on water quality.

    To control dust:

    - Water active maintenance areas so that they are sufficiently moist to prevent dust.
    - Sweep any paved access roads of visible soil material.
    - Cover trucks hauling sediment, ensure that their tailgates are closed, and brush off any excess dirt.
- **Store and secure materials.** Remove all building materials, debris, lumber, et cetera within 2 days of completing the project.
- **Be wary of mercury and other contaminants**. Disturbed or excavated soils in areas where soils are known to contain mercury or other contaminants should be removed or properly capped if the soil will be exposed to flood flows. In areas whose soils are known to contain mercury, remediate the disturbed or excavated soils if they are exposed to flood flows. Wear protective equipment. Consult the Santa Clara Valley Water District for disposal guidance.

FOLLOW-UP MAINTENANCE:

Do not neglect stream-bank repair after construction is over. Minor maintenance activities help ensure a project's success.

- **Remove trash and debris.** Sometimes, the accumulation of debris in the channel causes erosion on nearby banks. So:
    - Regularly remove debris such as trash and human-caused debris.
    - Do not put yard waste in the creeks or on the banks, where leaves and clippings can wash into the stream.
- **If mulching:**
    - Use biodegradable erosion control blankets on bare slopes or if it is too late in the season to establish vegetation. The blankets will last for 1 to 3 years while natives reseed.

      Monitor the success of natural revegetation before taking aggressive action to revegetate.
    - Woody debris from the site might make for suitable mulch.
    - Use bark and other wood products or fabric blankets above the high water line to prevent erosion of bare soil after construction is completed.
    - Use weed-free certified mulch.
    - Do not use Eucalyptus, Walnut, or Tree of Heaven. They produce an allelopathic compound that can be toxic to plants and aquatic organisms.
- **Be careful when trying to control rodents**. Burrowing rodents may be a nuisance and can damage levees on streams, but do not use rodenticides. Their effect on the local habitat is too destructive. Instead, consult County Vector Control.
- **Revegetate**. In areas that have been revegetated, replace dead or dying plants and weeds. Remove non-native plant colonizers. Ensure that all plants receive sufficient water.

SECTION 5 - DETAILED DESCRIPTIONS OF EROSION REPAIR TECHNIQUES

Described in this section are 16 different types of erosion repair methods. Each description contains a brief overview of the repair method, the circumstances in which it is most appropriate, its anticipated environmental value, its relative costs, and its potential impacts. Descriptions are not exhaustive, and should only be used in conjunction with consultation from a qualified erosion repair professional, the Santa Clara Valley Water District, and relevant regulatory agencies.

Even the most well-meaning erosion repair designs can have negative impacts on a stream if they are not planned, designed, and constructed properly. Poorly placed rocks or woody material can cause bed and bank scour/erosion, excessive sediment deposition, and/or decreased channel capacity. For this reason, it is essential that the project is designed to accommodate the site's particular geomorphic location, channel form and depth, flow velocity, and site constraints. This typically requires a physical, or "geomorphic" assessment by a trained professional.

To protect both your property and its value, the goals of any streamside bank protection or erosion repair project should be to restore stability and leave the site in a better ecological condition than it was before. The first erosion repair method, the modified flood plain, will provide the best long term, ecologically friendly and most stable results. Methods 2 through 8 use bioengineering methods. Bioengineered bank stabilization methods typically involve two components:

- Regrading the upper streambank to establish or re-establish a floodplain, with terraces where possible.
- Planting native riparian vegetation on the streambank and terraces in order to restore and provide long-term stability.

If soft methods of protection are not feasible due to highly erosive forces, then there is probably a channel dimension, hydrology and/or morphology problem.

Hard bank protection can cause more erosion and damage in the channel, along the downstream and/or upstream banks, as well as on the opposite bank of the repair site. Any consideration of the use of hardened materials should be with caution and with an assessment of the impacts that may occur.

Erosion repair methods 9 thorough 11, incorporate bank armoring which should be avoided. The use of log and rock flow deflecting structures as described in method 1 is less expensive and a more environmentally friendly way of protecting banks from erosion. Detailed guidance of these methods is beyond the scope of this Design Guide but should be considered by the design professional.

Erosion repair methods 12 through 16 are NOT recommended. However, they may be necessary when the site is constrained, or where the water volume, velocity, bank steepness, and resultant erosive forces necessitate the use of more extreme methods

TABLE 1: PREFERRED EROSION REPAIR METHODS

Repair Method	Appropriate Slope	Appropriate Water Velocity	Environ Value	Cost
1. Modified floodplain	Varies	Varies	Positive	Low
2. Slope Grading with Vegetation	2:1 or flatter for vegetation section, 1.5:1 or flatter for boulder section.	Low – typically up to 6 ft/sec	Positive	Low
3. Erosion Mats	2:1 or flatter for erosion mat section, 1.5:1 or flatter if boulders used.	Generally 1-7 ft/sec but can go up to12ft/sec if vegetated.	Positive, if planted.	Low
4. Contour Wattling		Low	Positive	Low
5. Brush Mattresses	2:1 or flatter for erosion mat section, 1.5:1 or flatter if boulders used.	Low	Positive	Low
6. Brush Layering	2:01	Medium	Positive	Low
7. Vegetated Geogrids or Soil Lifts	Up to 1:1	Medium	Positive	Low
8. Root wads and boulders		Medium: (10 ft/sec or less)	Positive, if planted	High
9. Boulder/ Rock Revetment	Up to 1:1, preferably 2:1.	High: up to 15 ft/sec; less where voids in boulders are planted.	Negative. Negative to Neutral, if planted	Medium
10. Cellular Confinement System	Up to 0.5 to 1	Medium to High:5-21 ft/sec depending on vegetation)	Neutral	Medium
11. Live Log Crib Walls	Up to 0.25:1	Medium: up to 12 ft/sec or less	Neutral to High, if planted	High

#1 MODIFIED FLOODPLAIN HOW TO CREATE A MODIFIED FLOODPLAIN

The modified flood plain design provides the optimum solution for long-term, ecologically-friendly, and less expensive stability. In urban areas property owners typically have short stretches of stream running through their property and often only on one side of the stream. The cooperative enlisting of neighbors to affect this approach is well worth the effort. The typical steps in creating a modified floodplain are:

Step 1: Identify the appropriate channel width and depth, at bankfull level. The active channel will contain flows resulting from small frequent rainfall events.

Step 2: Identify the appropriate elevation for the floodplain area, and determine how much space is available and appropriate for widening the banks.

Step 3: Regrade or lay back the existing bank above the floodplain to a flatter, more stable angle (usually a 2 horizontal to 1 vertical slope, or greater);

Step 4: Create terraces above the active floodplain to accommodate vegetation

Step 5: Plant the terraces with appropriate local, native, riparian vegetation to stabilize the bank(s) and create habitat.

HOW TO CREATE A MODIFIED FLOODPLAIN IN DEEPLY INCISED CHANNELS

A watershed-friendly design that recreates a natural floodplain is depicted in Figures 4 and 5 below:

FIGURE 4: STREAM CHANNEL WITH DEEPLY INCISED STREAMBANKS

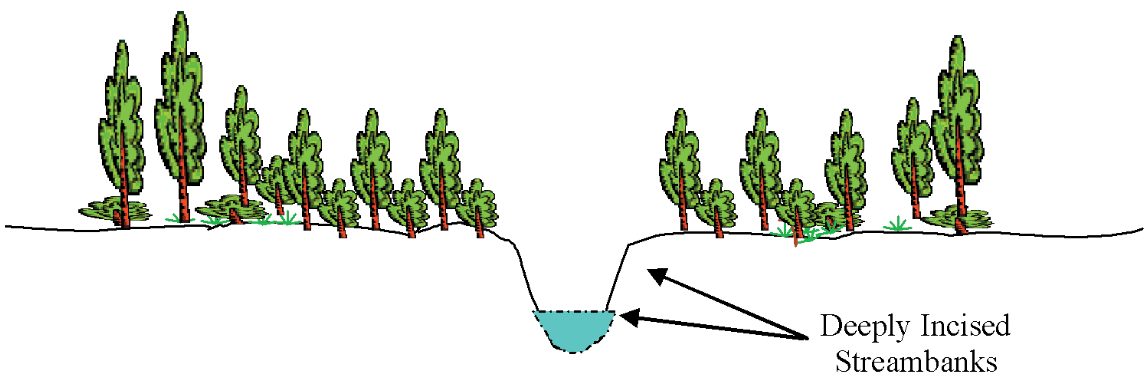
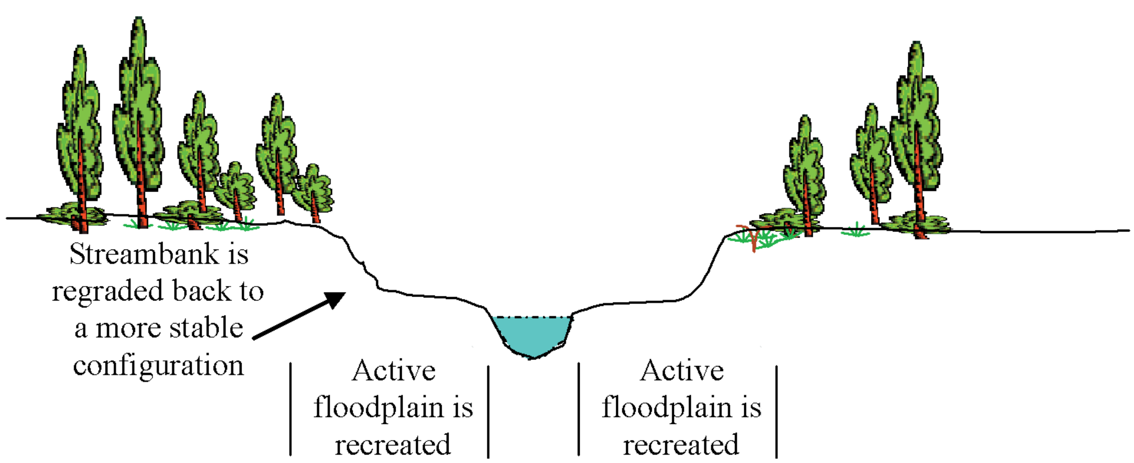


FIGURE 5: THE SAME STREAM CHANNEL AS FIGURE 4, BUT STREAM BANKS HAVE BEEN REGRADES TO CREATE TERRACES WHERE VEGETATION CAN BE PLANTED

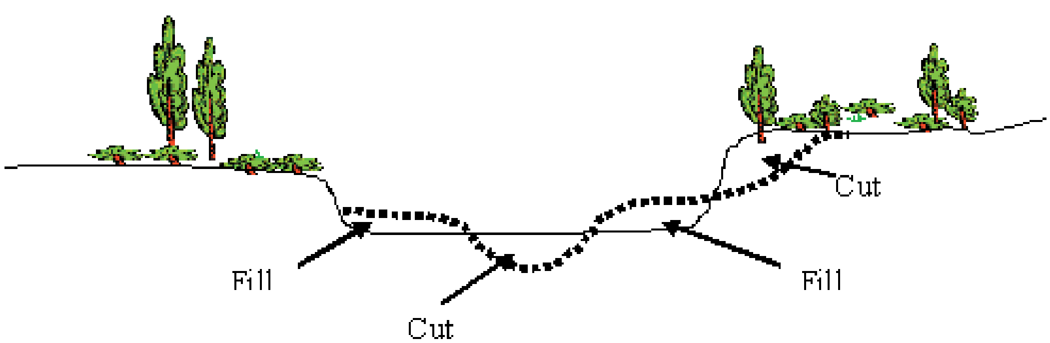


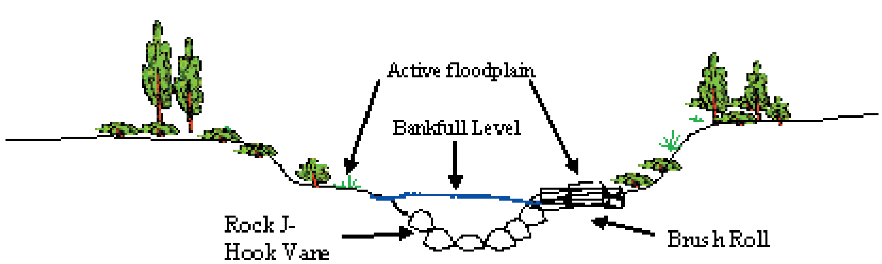
HOW TO CREATE A MODIFIED FLOODPLAIN IN BROAD FLAT STRETCHES WITH SEDIMENT DEPOSITION

In some cases, a stream may have experienced heavy sediment deposition over the years. In contrast to the deeply incised channels, with heavy sediment deposition tend to be wide, shallow and rather straight. Although there may have been fish present at one time, the shallow flows make it difficult for them to return. Where there is room, it is important to restore the nature meanders if possible.

Figures 6 below shows a stream prior to a stream restoration project. As you can see, the channel was wide, shallow and rather straight. The bottom drawing shows that the channel was made narrower and constructed with a proper width/depth ratio at the bankfull level. This helped assure the proper transport of sediment through the area by increasing velocities in the active channel. The active channel was moved away from the right bank and into the center of the channel corridor, creating deep pools for steelhead trout and salmon. Brush rolls were used on the top of the right floodplain to accumulate fine sediment and the right vertical stream bank was sloped back and vegetated.

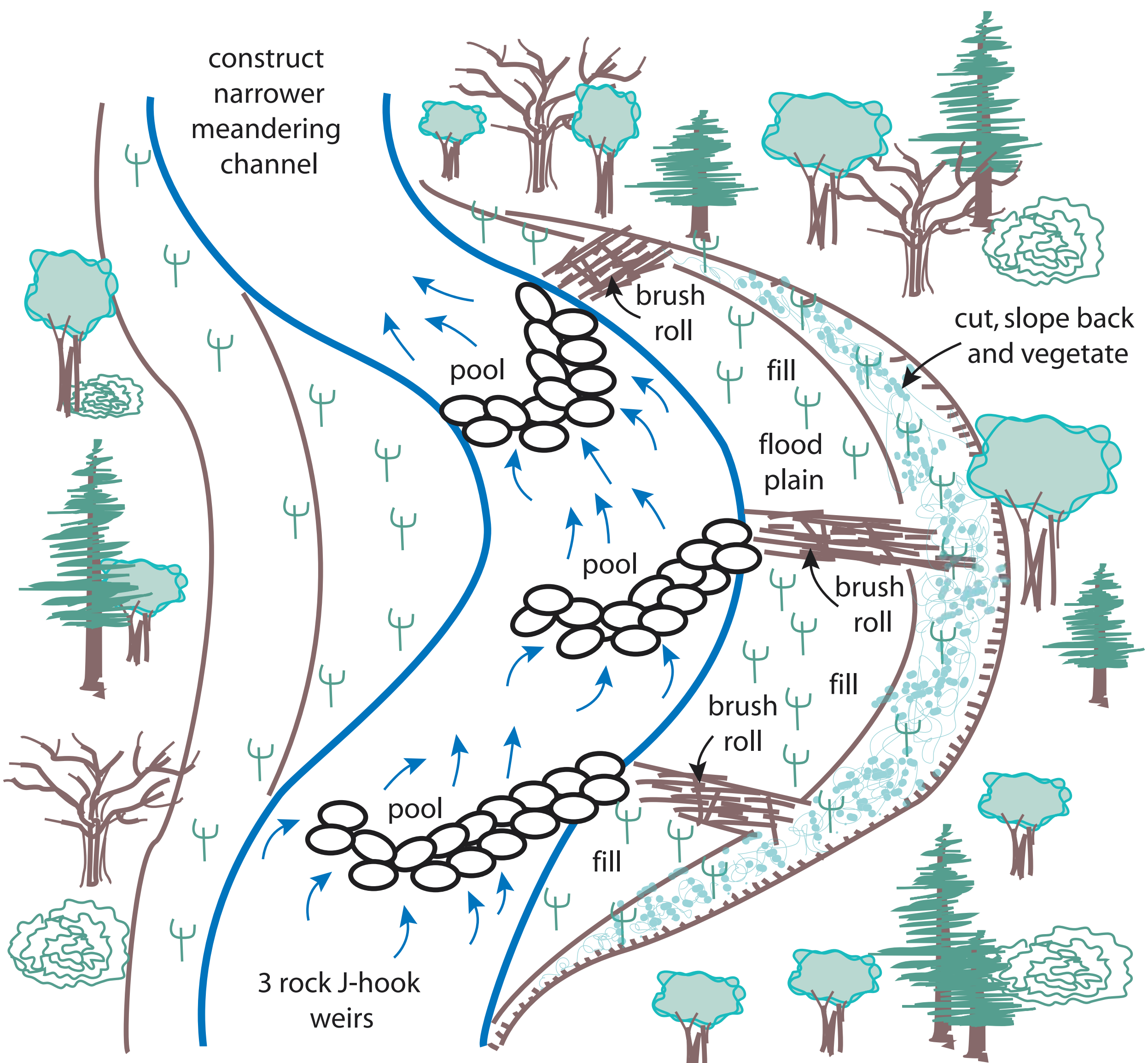
FIGURES 6: STREAM CHANNEL CROSS SECTION VIEW





POSSIBLE VARIATIONS ON THE FLOODPLAIN APPROACH: RESTORING NATURAL STREAM MEANDERS

Where there is sufficient room in the stream channel, it can be very helpful to modify the channel in a way that restores natural stream meanders. The diagram below shows how a creek channel can be narrowed and reformed with more meander. As noted earlier, a proper width/depth ratio at the bankfull level is created and a modified floodplain can be constructed. In this example, three J-Hook rock structures were installed with brush rolls on the right bank floodplain to divert the water away from the bank and into the center of the channel.



ADDITIONAL TOE AND BANK PROTECTION FOR HIGH FLOW VELOCITIES OR CONFINED AREAS

In the uncommon situations where water velocities are especially high, or where a structure is threatened by its proximity to the bank, additional protection or a hybrid approach may be desired. Placement of rock boulders at the toe of the slope, along with placement of riparian branch cuttings such as willows into the spaces between the boulders into the soil or earth-filled mats can accomplish this goal. Another hybrid approach is to use cellular confinement or rock on the lower slope, and the upper slope can be graded back to a less steep slope and revegetated The rock must be keyed into the streambed to prevent undercutting and failure of the rock slope protection.

In the cases noted above, the use of bank armoring is likely to cause more problems than it will solve, because it will not address the root cause of the problem. Instead, efforts should be made to reduce the water's velocity, or redirect it away from the bank using j-hook weirs or vanes.

USE OF GRADE CONTROL STRUCTURES

While efforts should be made to construct floodplains/flood benches and to consider hybrid alternatives, it is also important to consider whether a project should be addressed using a grade control structure. For example, sometimes bank erosion is a result of channel bed incision, which increases the height of a bank and reduces vertical support. If a channel is highly incised, simply regrading the slope may not be sufficient in the long-term, and the project will need to address grade control in order to stabilize the bank effectively. A variety of structures can be used, such as log or rock weirs, Newberry weirs, and vanes, in order to encourage sediment deposition and stabilization of the bed.

USE OF DEFLECTORS

Finally, in some cases it may be most appropriate to use smaller structures designed to

redirect high velocity flow away from eroding banks and into the center of the channel. Examples include spurs, kickers, deflectors, vane dikes, etc., and they should be considered as a way to train flows and reduce the amount of engineered bank protection. The photographs below provide some guidance on how and when these devices can be used. Detailed guidance of these methods, however, is beyond the scope of this Design Guide but should be considered by the design professional.

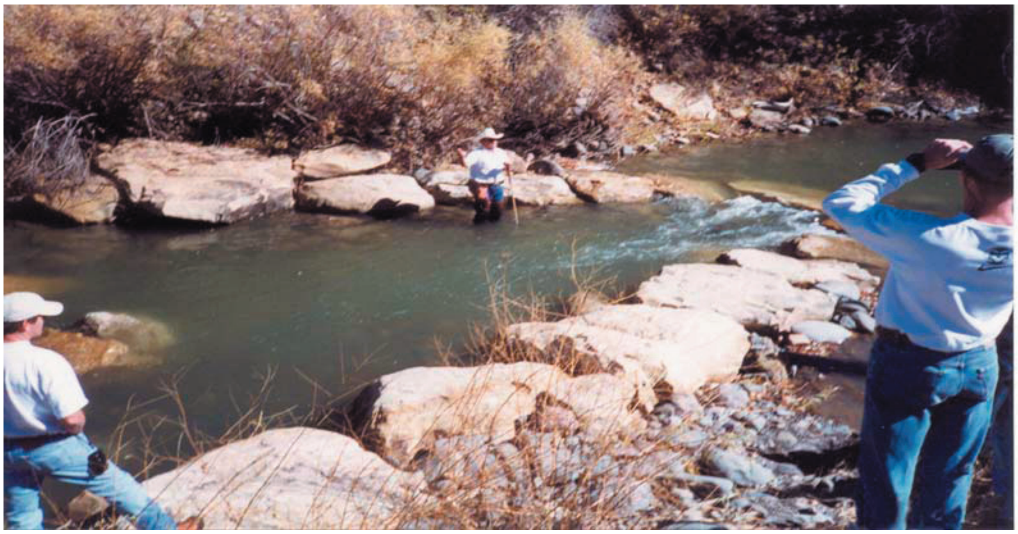
For a rock cross vane structure, boulders are placed in an upside down "V" shaped structure in the stream. This "V" shaped design serves to slow water velocities near the banks and direct the flow toward the center of the stream. The banks then become depositional areas, instead of erosion areas. At the same time, the increased velocities in the center of the channel actually increase the channel's flow and sediment transport capacity, reducing the risk for infrastructure flooding during high flow events. Finally, the rocks in the center serve as a channel grade control. The drop-off just downstream of the rocks creates a deep hole, which slows flows and can provide an excellent fish hold and hide habitat even at very low flows.

The rock J-hook structure is used to protect one side of the river bank by directing flows from that side to the center of the stream. As with the rock cross vane structure, the increased velocities in the center of the channel increase the channel's flow and sediment transport capacity and the deep hole is created for fish habitat.

ADDITIONAL TOE AND BANK PROTECTION FOR HIGH FLOW VELOCITIES OR CONFINED AREAS

In the uncommon situations where water velocities are especially high, or where astructure is threatened by its proximity to the bank, additional protection or a hybrid approach may be desired.

PHOTOGRAPH 1: ROCK CROSS VANE STRUCTURE:

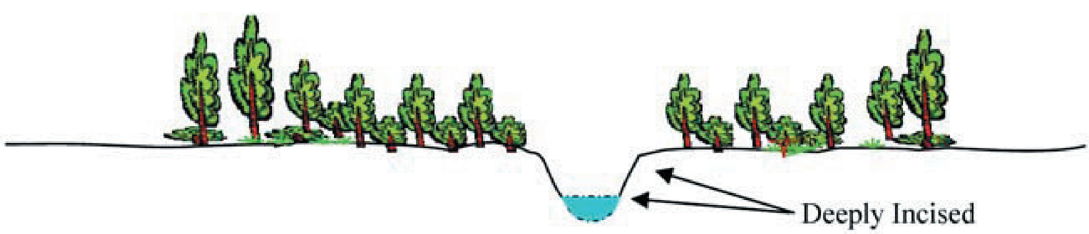


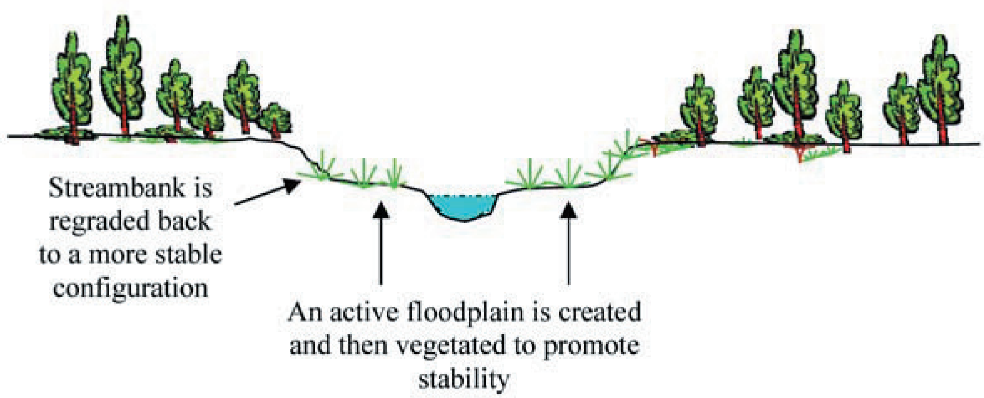
PHOTOGRAPH 2: ROCK J-HOOK STRUCTURE:

HOW TO CREATE A MODIFIED FLOODPLAIN IN BROAD FLAT STRETCHES WITH SEDIMENT DEPOSITION

In some cases, a stream may have experienced heavy sediment deposition over the years. In contrast to the deeply incised channels, channels with heavy sediment deposition tend to be wide, shallow and rather straight. Although there may have been fish present at one time, the shallow flows make it difficult for them to return. Where there is room, it is important to restore the nature meanders if possible.

Figures 6a and 6b below show a stream prior to a stream restoration project. As you can see, the channel was wide, shallow and rather straight. The bottom drawing shows that the channel was made narrower and constructed with a proper width/depth ratio at the bankfull level. This helped assure the proper transport of sediment through the area by increasing velocities in the active channel. The active channel was moved away from the right bank and into the center of the channel corridor, creating deep pools for steelhead trout and salmon. Brush rolls were used on the top of the right floodplain to accumulate fine sediment and the right vertical stream bank was sloped back and vegetated.





#2: SLOPE GRADING WITH VEGETATION AND FLOODPLAIN TERRACES SPACE PERMITTING

This is perhaps the least engineered, and often most effective, method of long-term bank repair, because it restores the natural contour and vegetative cover of the stream bank. If the bank is undercut or has slumped to a vertical face, consider matching the grade of a nearby stable slope. Usually a 2 horizontal to 1 vertical slope is considered stable for many soil types, and if space allows, a 3to 1 slope would be even better. Regrading the channel to create terraced banks (as described in Section 4) in order to include an active channel and floodplain area is appropriate wherever a more holistic approach to stream restoration is possible. As noted earlier, the stream bank should always be revegetated with appropriate native plants.

FIGURE 9A: SLOPE GRADING WITH VEGETATION

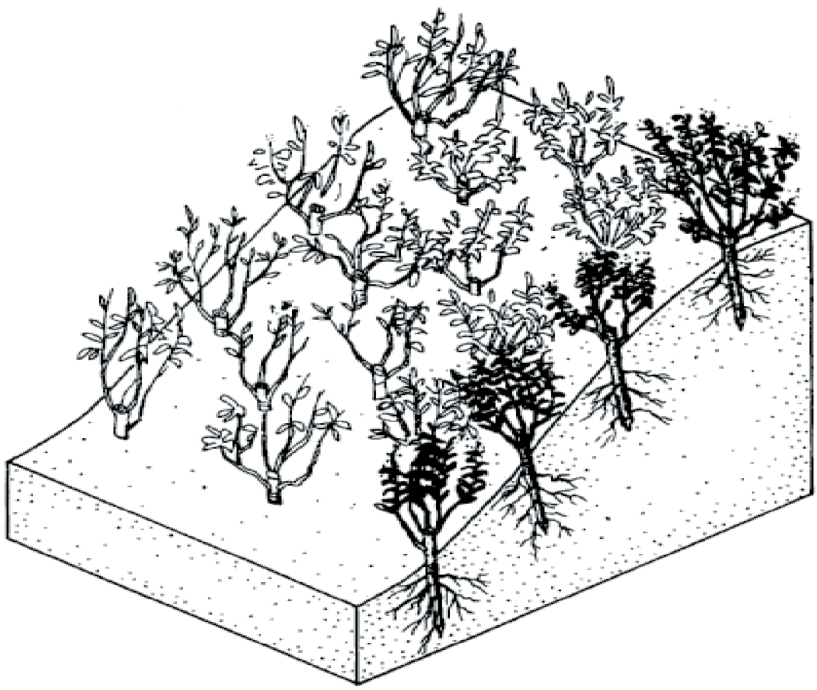
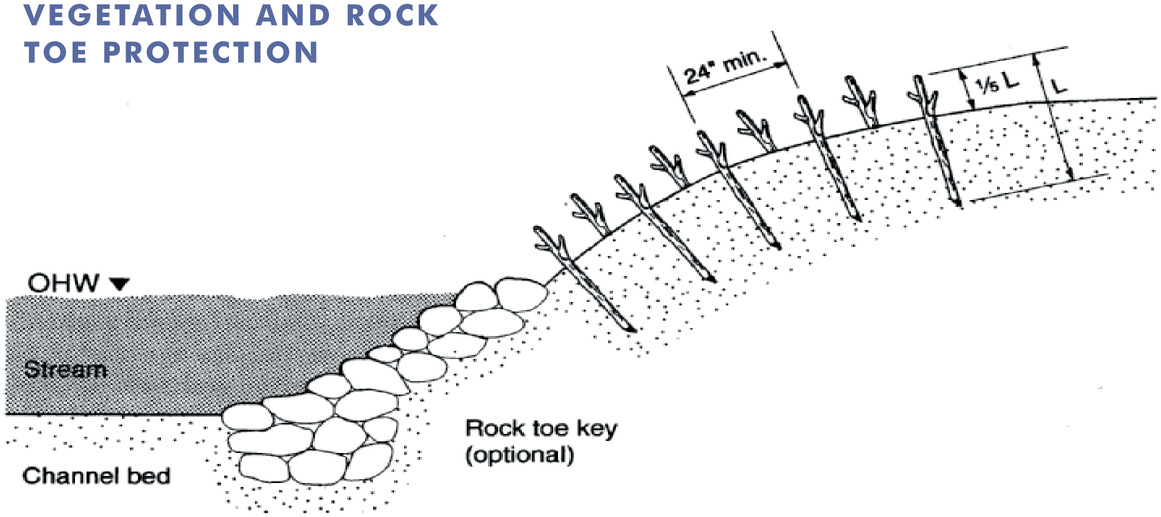


FIGURE 9B: CROSS SECTION OF SLOPE GRADING WITH VEGETATION AND ROCK TOE PROTECTION



#3: EROSION MATS

This method consists of securing geotextile blankets made of biodegradable materials like jute or coconut fiber to channel banks using stakes or staples. Biodegradable fabrics are preferable to plastic because they do not inhibit plant growth, or act like a net if they are dislodged during a storm. The erosion mats provide soft armor protection against erosive forces and are combined with live staking and direct seeding. Abrasive sediment, debris, foot traffic, and sunlight will slowly wear, snag, and tear these fabrics, potentially undermining the structure. That's why erosion mats are intended to be only the foundation of a vegetated erosion control system. In other words, the establishment of vegetation is crucial to the long-term success of erosion mats.

DESIGN CONSIDERATIONS:

- Toe protection may be required where significant toe scour is anticipated.
- The bank must be smooth before installing blankets to ensure adequate contact and prevent subsurface erosion.
- The erosion mats must be installed according to manufacturer's instructions in order to prevent failure.

#3A: EROSION MATS WITH BOULDER OR LOG TOE PROTECTION

This method consists of grading the lower portion of the eroded slope at a maximum of 1.5:1. The upper portion of the slope is then graded at a minimum slope of 2:1 and smoothed to ensure that the whole erosion mat contacts the soil. Appropriately-sized boulders are placed at the toe of the rebuilt bank up to the bankfull discharge water elevation, or even slightly higher. Voids between the boulders can be planted using live stakes.

DESIGN CONSIDERATIONS:

- Best for bank slopes of 3:1 or steeper
- Boulders must be keyed in (min. 3 feet) at the toe of the bank.
- Boulder placement must not constrict the channel cross section or reduce the width-to-depth ratio. Otherwise, the repair will likely destabilize the channel.
- The placement of boulders or armoring along the bank may increase turbulence in the area and other areas downstream. This could increase erosion.

#4: CONTOUR WATTLING (FASCINES)

This method consists of tying long bundles of plant cuttings (typically willows or cottonwood) together with twine and anchoring them in shallow trenches, parallel to the stream, with wooden stakes. When the cuttings develop root systems and mature, the plants provide structural soil stability. This technique is generally used to manage surface erosion. It works well in straight stream sections and wherever flow velocity is low.

DESIGN CONSIDERATIONS:

- The long bundles trap and hold soil on banks by creating small, dam-like structures, effectively segmenting the slope length into a series of shorter slope lengths.
- This method enhances the opportunities for locally native species to colonize and therefore should, where appropriate, be used with other soil bioengineering systems and live plantings.
- Reinforcement at the toe of bank may be a limiting factor.
- Contour wattling does not work well in locations where slopes are undergoing geotechnical failure.

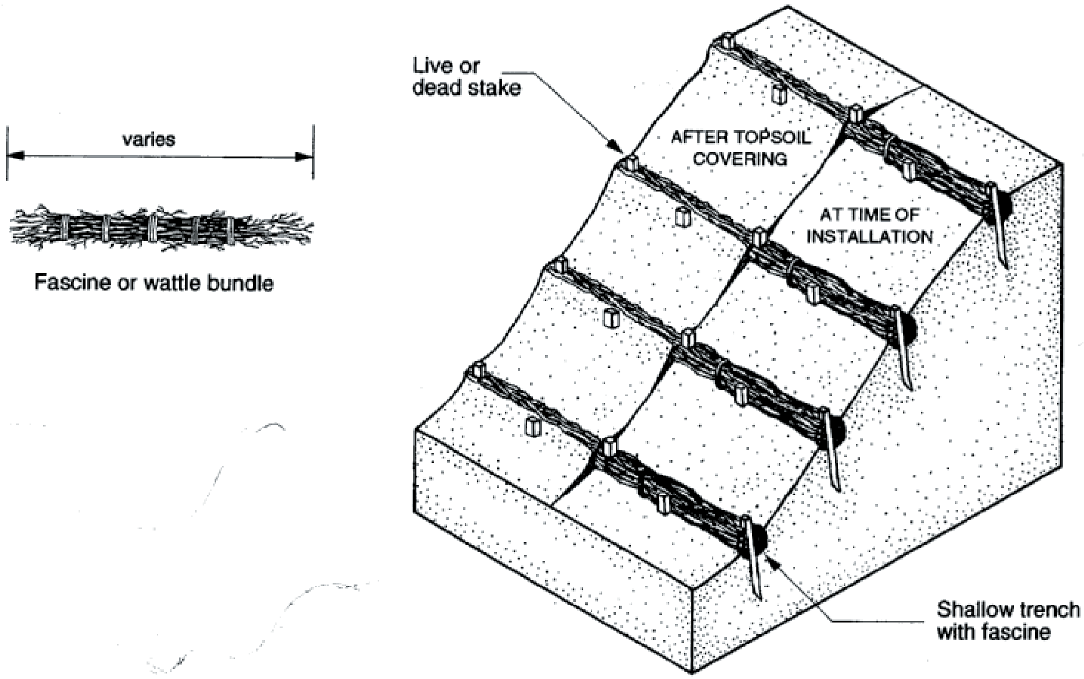
#4A: CONTOUR WATTLING WITH BOULDER OR LOG TOE PROTECTION

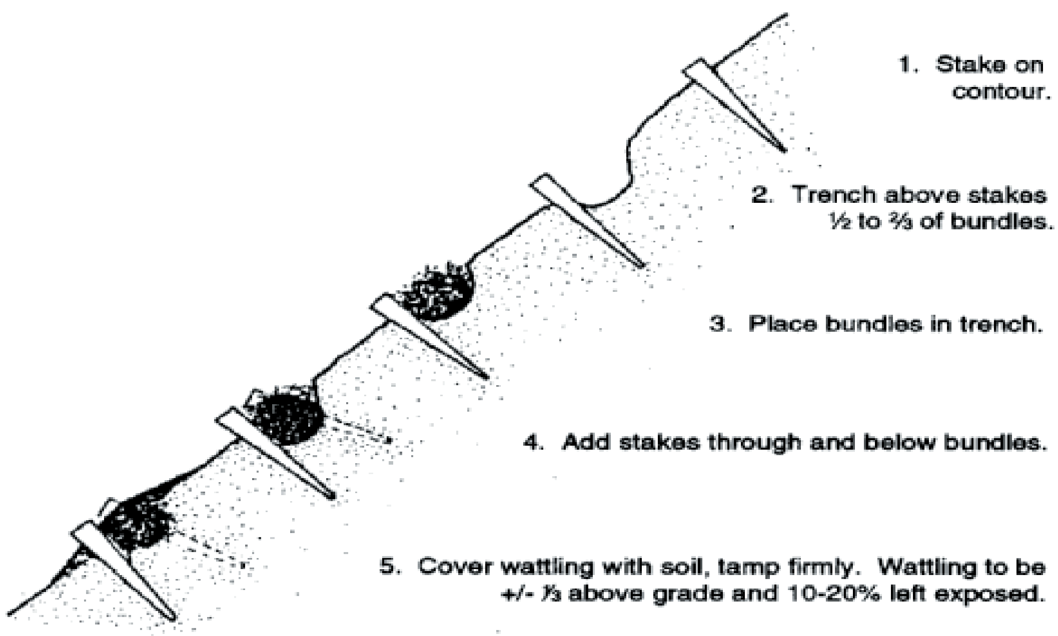
Appropriately-sized boulders are placed at the toe of the rebuilt bank up to the bankfull discharge water elevation or slightly higher. Voids between the boulders can be planted using live stakes.

DESIGN CONSIDERATIONS:

- Boulder placement must not constrict the channel cross-section or reduce the width-to-depth ratio. Otherwise, the repair will ` likely destabilize the channel.
- The placement of boulders or armoring along the bank may increase turbulence in the area and other areas downstream, which could increase erosion.

FIGURE 10: CONTOUR WATTLING





#5: BRUSH MATTRESS

First, the bank must be prepared. The eroded slope is graded and smoothed to ensure that all willows are in contact with the soil. Then, a deep trench (2 ft. min) is dug at the toe of the bank for the butt ends of the willow branches. Wood, steel, or live willow stakes are partially driven into the soil in rows, on three foot centers, in the area that will be covered by the mattress. After the stakes have been placed, live willow branches are put on the bank with their butt ends in the trench. Straight branches no shorter than four-feet in length and .5 to 1" in diameter are used. If the branches are not long enough to reach the upper end of mattress, several laye rs may be used; however, it is necessary to "shingle" the layers by lapping each new layer over the one below by at least 18".

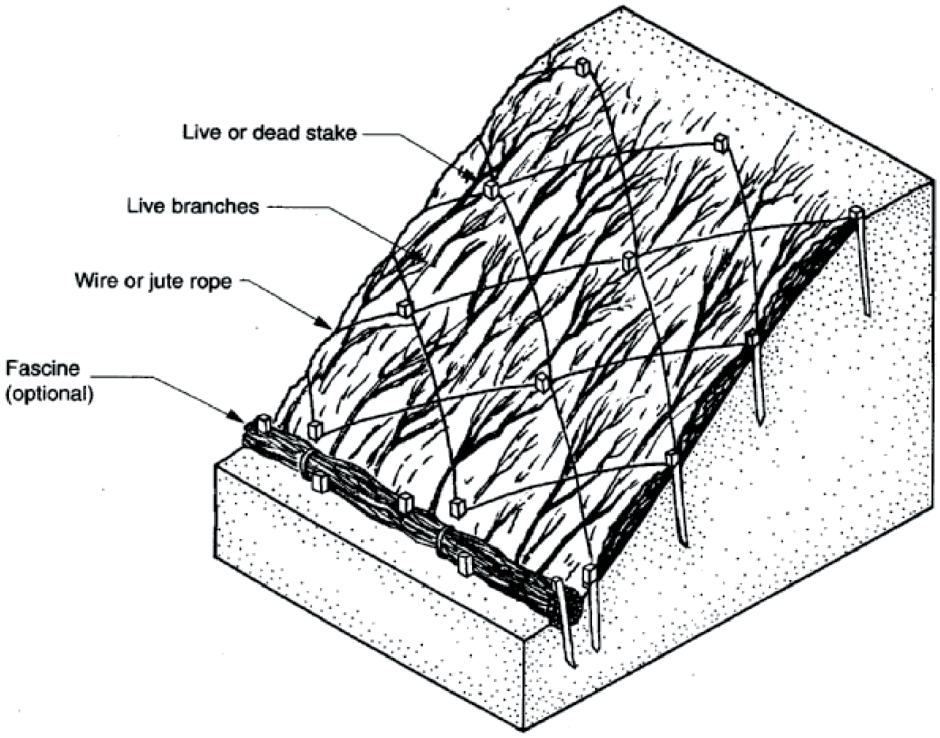
Once the bank is covered by a thick layer of willows, cross branches are placed horizontally over the bottom layer. These branches are placed against the stakes and then tied to the stakes using wire or string. The stakes are then driven into the bank at least two feet deep. After the completion of the mattress, the toe trench is filled with appropriately-sized boulders and rocks to anchor the butt ends of the branches. The brush mattress should be covered with an amount of soil sufficient to ensure a good contact surface between the mattress and the soil, leaving some buds and twigs exposed.

This method forms an immediate protective cover over the stream bank, captures sediment during flood flows, and rapidly restores riparian vegetation and streamside habitat. This measure is not appropriate where toe scour is anticipated, in which case boulders may need to be added at the toe.

DESIGN CONSTRAINTS AND CONSIDERATIONS:

- Branches should be tamped down before tying to create a good contact surface between the soil and the mattress.
- Butt or basal ends of branches must be covered with soil so they can root and to prevent them from drying out.
- Branches should be partially covered with soil.
- **This method should not be used on slopes that are experiencing geotechnical failures or other slope instability.**

FIGURE 11: BRUSH MATRESS



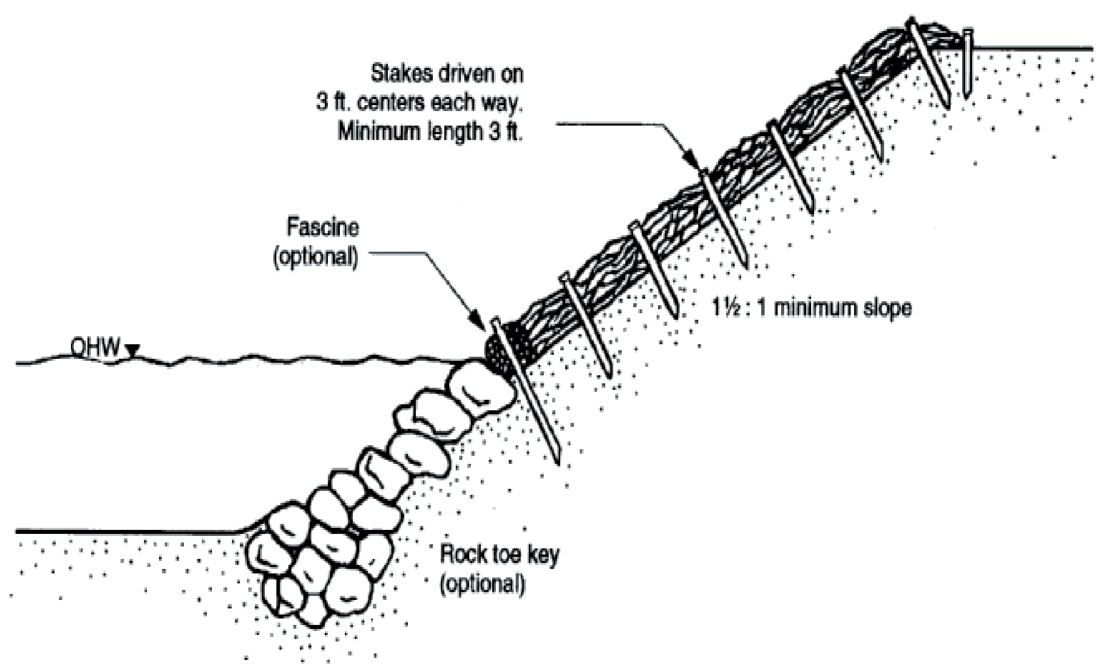
#5A: BRUSH MATTRESS WITH BOULDER OR LOG TOE PROTECTION

First, the lower portion of the eroded slope is graded at a maximum slope of 1.5:1. Then the upper portion of the slope is graded at a minimum of 2:1 and smoothed to ensure all willows are in contact with soil. Appropriately-sized boulders are placed at the toe of the rebuilt bank, up to the bankfull discharge water elevation or even slightly higher. Live stakes can be placed between the boulders to establish vegetation. This method requires a lot of branches. Therefore, needs to be installed during low flow conditions so that growth can be established. Otherwise, the branches will wash away.

DESIGN CRITERIA:

- Boulders must be keyed in (min. 3 feet) at toe of bank.
- Boulders placement must not constrict the channel cross-section or reduce the width-to-depth ratio. Otherwise, the repair will likely destabilize the channel.
- The placement of boulders or armoring along the bank will increase turbulence in the area and downstream, which could cause increased erosion.

FIGURE 12: BRUSH MATTRESS WITH BOULDER OR LOG TOE PROTECTION



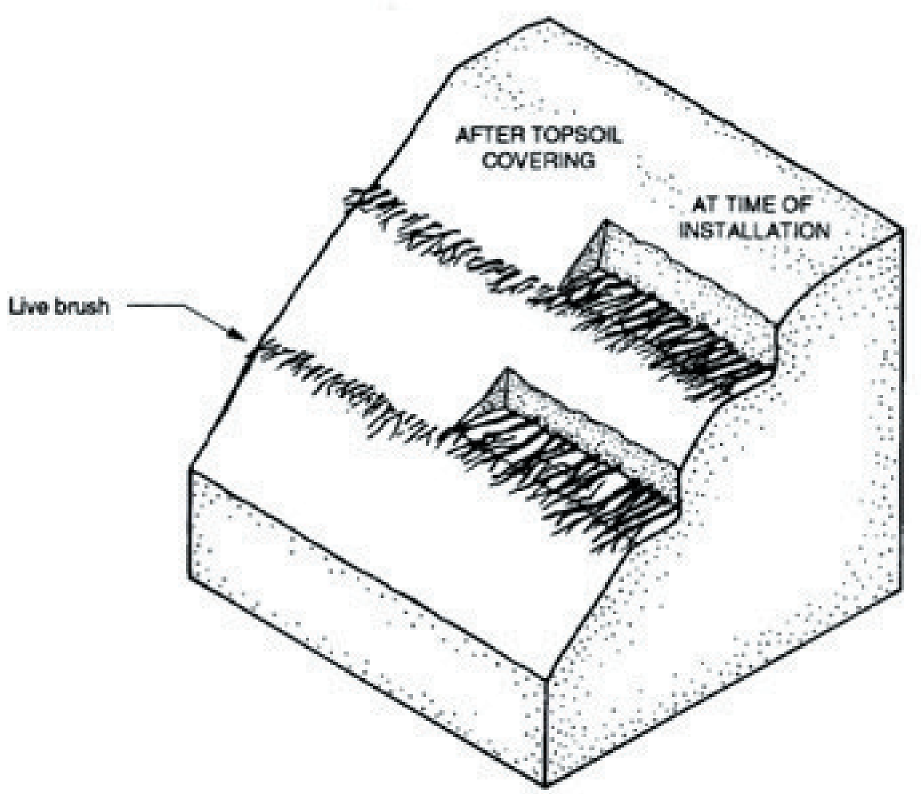
#6: BRUSH LAYERING

In this method, alternating layers of soil and live branches are installed in horizontal rows on the streambank. This method is more substantial than brush mattresses and can be used to repair erosion gullies, scour holes, and other significantly scoured areas. The buried branches take root to reinforce the substrate, while the tips produce vegetative top growth that protects the bank surface. This method can also be used in combination with a rock toe, vegetated geogrid or live cribwall as described later in this section.

DESIGN CONSTRAINTS AND CONSIDERATIONS:

- Installation is best done during dry periods or low flow conditions since construction requires earthwork.
- A large amount of branches are needed for this method.

FIGURE 13 : BRUSH LAYERING



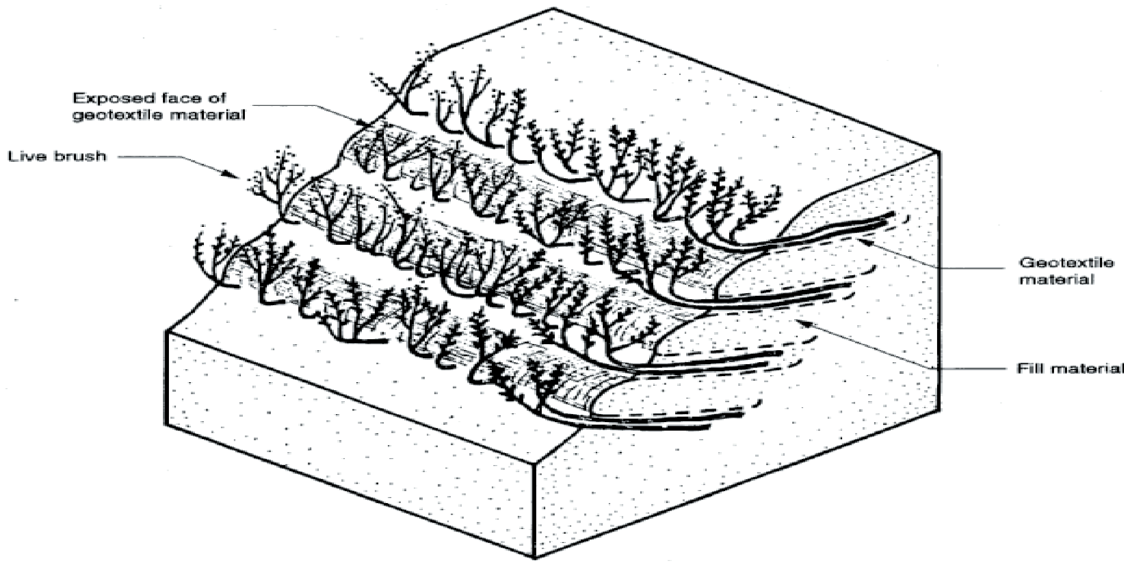
#7: VEGETATED GEOGRIDS OR SOIL LIFTS

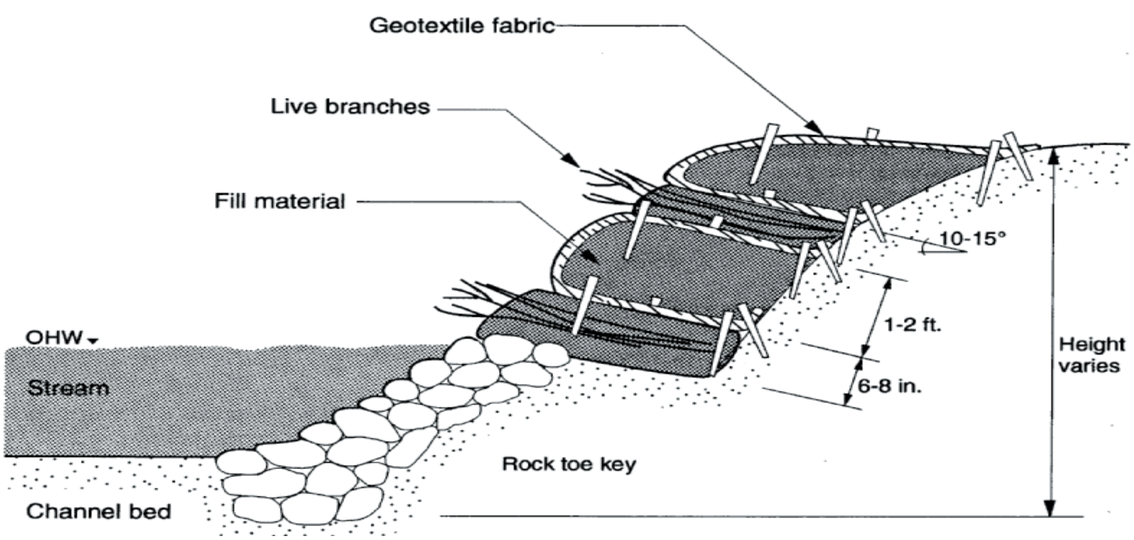
This method is similar to brush layering, but adds even more stability by wrapping engineered soil lifts in biodegradable erosion control fabric or geotextiles between layers of live branches. This method is useful where site constraints don't allow the slope to be laid back. Boulder or log toe-protection can also be incorporated into the design where site conditions warrant.

DESIGN CONSIDERATIONS:

- Boulder placement must not constrict the channel cross-section or reduce the width-to-depth ratio. Otherwise, the repair will likely destabilize the channel.
- Armoring or the placement of boulders along the bank will increase turbulence in the area andother areas downstream, which could increase erosion.

FIGURE 14: VEGETATED GEOGRIDS OR SOIL LIFTS





#8: ROOT WADS AND BOULDERS

This method consists of using a combination of boulders, logs, and live plant material to armor a stream bank. It enhances fish habitat, and creates a natural-looking bank stabilization structure [1]. Footer logs are set in a toe trench below the thalweg line (the line of maximum depth in a stream), with the channel end pointed downstream and the butt end angled 45 to 60 degrees upstream. A second log (with a root wad) is set on top of the footer log diagonally, forming an "X".

The root wad end is set pointing upstream and the butt end lying downstream 45 to 60 degrees. The apex of the logs are anchored together using boulders, re-bar or cables. Large boulders are placed on top and between the logs at each apex. After all the logs and boulders are set in place, live plant material, such as willows, is placed within the spaces of the structure behind the boulders. Excavated gravel and stream materials can then be placed over the bank end portion of the structure1.

This method will tolerate high boundary shear stresses if logs and root wads are well anchored. This method should, where appropriate, be used in conjunction with soil bioengineering or live vegetation plantings in order to stabilize the upper bank and ensure a regenerative source of streambank vegetation. The endurance of the structure depends on the species of logs used; it might need replacement if vegetative colonization does not take place.

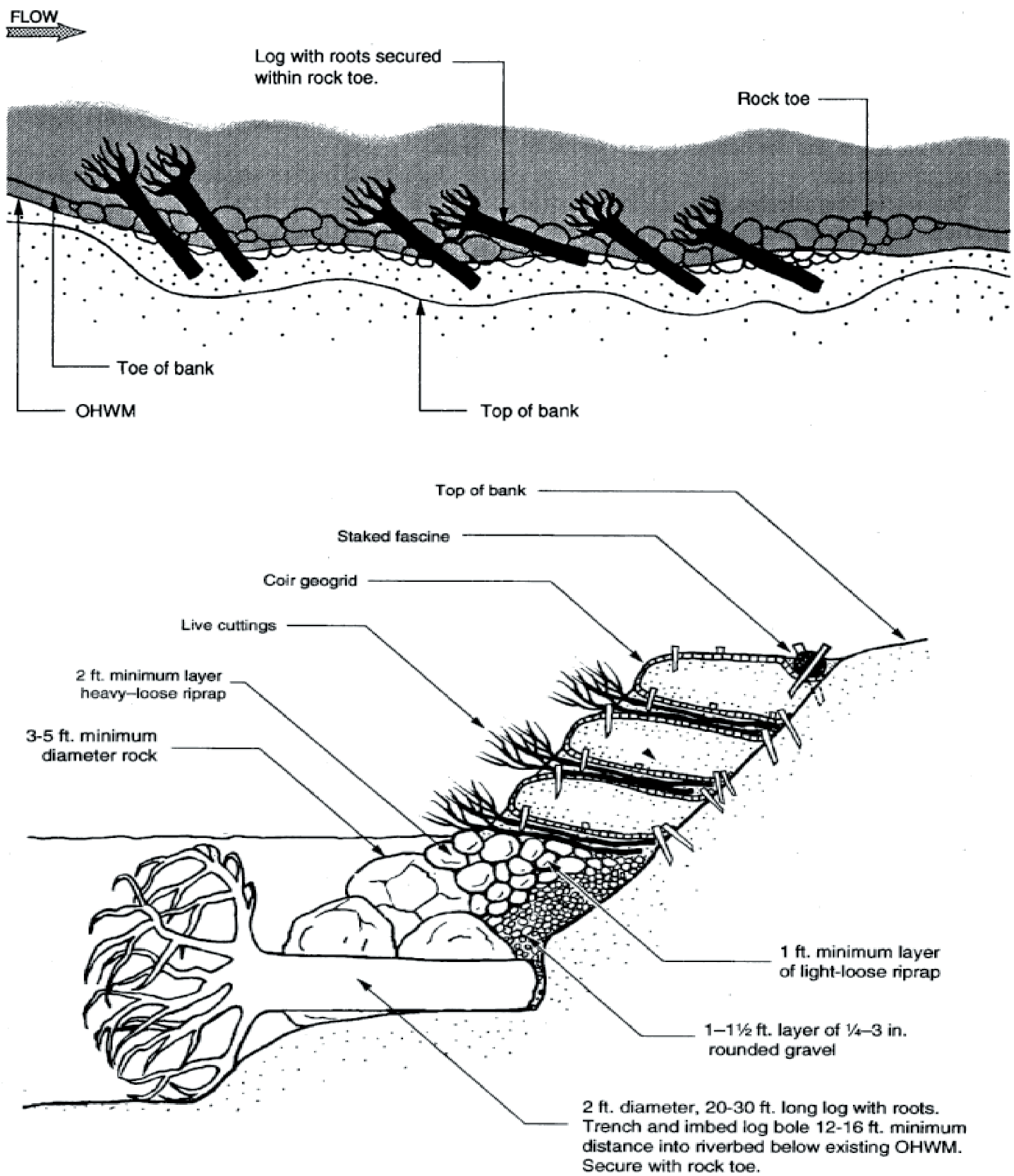
DESIGN CONSIDERATIONS:

- This method may cause channel scour and erosion of downstream and opposite banks if a modified floodplain is not constructed along the opposite bank. It may also cause upstream scour. [2].

[1] Source: California Department of Fish and Game, California Salmonid Stream Habitat Restoration Manual

[2] Source: Natural Resources Conservation Service, Stream Corridor Restoration Principles, Processes and Practices

FIGURE 15: ROOT WATDS AND BOULDERS



#9: BOULDER/ROCK REVETMENT

Rock rip-rap is a method for armoring stream banks with boulders that prevent bank erosion. Rock riprap can be used at the toe of the slope in combination with other vegetative methods on the upper portions of the bank. Rock can also be used for drainage outfall structures. Rip-rap footing is laid in a toe trench dug along the base of the bank. The size of the rock is determined according to the expected velocity in the channel, and can vary from 6″ to 18″ for velocities up to 10 feet per second up to 24″ minimum for higher velocities. Large angular boulders are best suited for this purpose because they tend to interlock. The rock's specifications must meet certain standards in order to assure that it is structurally sound.

A gravel blanket that is at least one foot thick should be placed under the rock rip-rap on slopes of 1:1 or greater. This prevents underlying soil from being washed out, which leads to slope slump and failure during periods of high flow. Geotextile fabrics should be avoided, since they prevent the natural establishment of vegetation[1].

This method should, where appropriate, be used with soil-bioengineering systems, or live vegetation, to stabilize the upper bank and ensure a regenerative source of streambank vegetation. A major benefit of this method is that the components are flexible and their function is not impaired by slight movement from settlement or other adjustments[2].

DESIGN CRITERIA AND CONSIDERATIONS:

- Rock should be keyed in approximately three feet below the bed elevation.
- Rock can be graded from larger at the toe to smaller at the upper banks.
- This method may cause channel scour and erosion, especially downstream and along opposite banks, if a modified floodplain is not constructed along the opposite bank. It may also cause upstream scour.

#9A: BOULDER REVETMENT WITH SOIL AND REVEGETATION

This method consists of placing soil over the boulders and installing vegetation by staking and/or direct seeding. Biodegradable erosion control mats are placed over the soil to help control erosion until vegetation establishes itself. Special care must be taken while driving live stakes between boulders to avoid damage to the cambium layer of the woody material and to ensure good soil/water/stake contact. Thick rip-rap layers may require special tools for establishing staking pilot holes.[2]

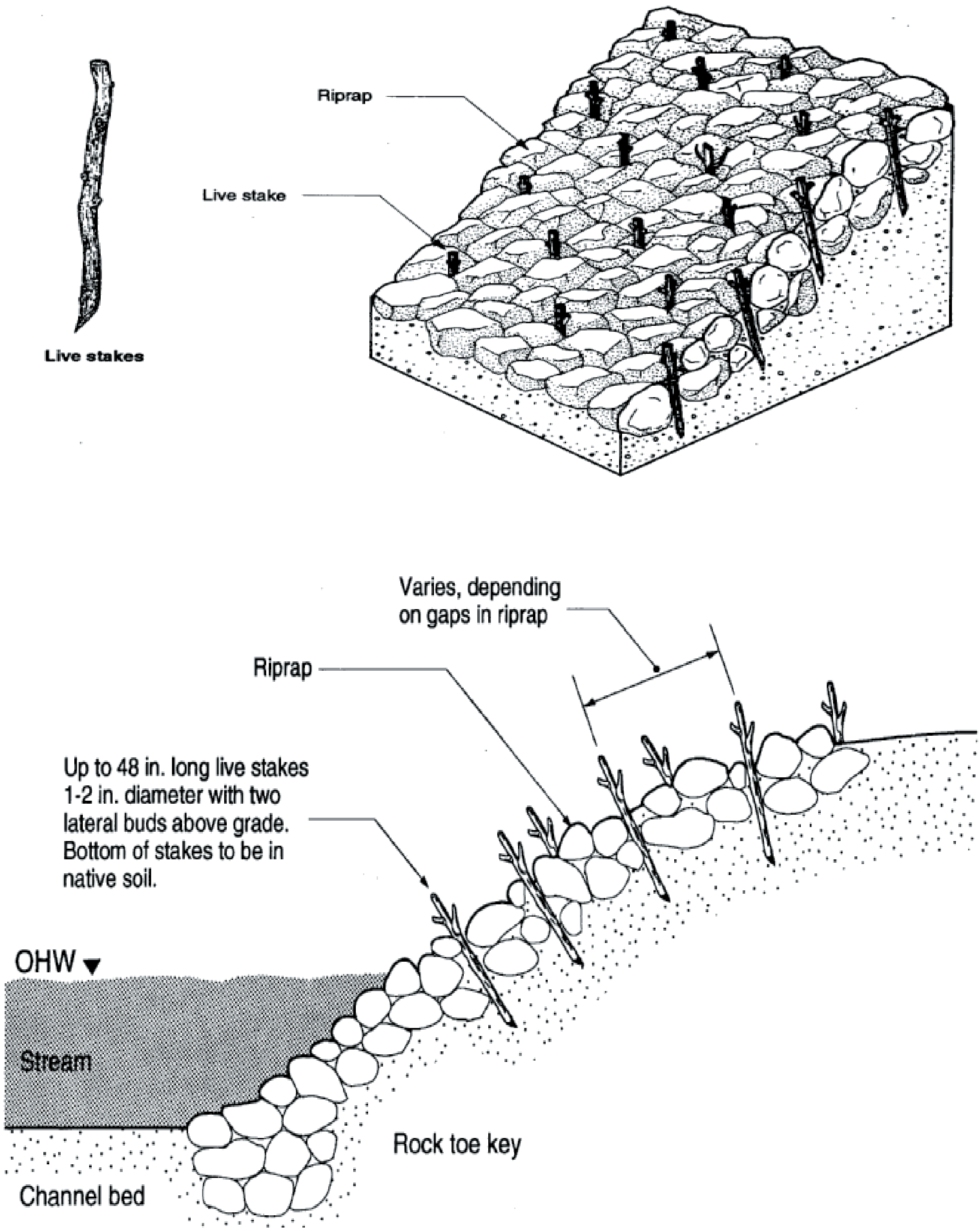
DESIGN CONSIDERATIONS:

- Woody material can be placed using a backhoe with an auger attachment, or by driving a steel bar between boulders, or by placing rock around durable planting tubes.
- This method may cause channel scour and erosion of downstream and opposite banks if a modified floodplain is not constructed along the opposite bank. It may also cause upstream scour.

[1] Source: California Department of Fish and Game, California Salmonid Stream Habitat Restoration Manual

[2] Source: Natural Resources Conservation Service, Stream Corridor Restoration Principles, Processes and Practices

FIGURE 16: BOULDER REVETMENT WITH SOIL AND REVEGETATION



#10: CELLULAR CONFINEMENT SYSTEM

Soil cellular confinement system (geocell) is a polyethylene plastic cellular system where structural strength is developed by the composite design of soil, plant roots, and the plastic's cellular configuration. This system is available in eight-inch deep honeycomb mats that can be installed in offset vertical layers to create terraced planting areas. The honeycomb cells are filled with soil, moderately compacted, and planted with woody vegetation and grasses. The structure functions similarly to a crib wall structure. This method can also be used in combination with slope grading and vegetation on the upper slopes.

This method can foster the development of vegetation.

#11: LIVE LOG CRIB WALLS

Live log crib walls are used to reduce sediment input and protect banks in areas where logs are available and boulders are not practical[1]. These temporary structures are designed to rot and degrade after live plant material has established itself. Cribbing provides protection in areas with near-vertical banks where bank sloping options are constrained by adjacent land uses.

In this method, two rows of base logs are placed parallel to the bank, in trenches below stream grade, to minimize undercutting of the structure. Tie-back logs are notched into the base logs and placed at regular intervals (typically 6 to 8 feet) along the base logs. Tie-back logs are attached to the base logs using re-bar pins or cables. There should be at least two tie-back logs connecting each pair of base logs. Once the first row of tie-back logs has been connected, a second set of face logs is placed on top of the tie-backs. This procedure is repeated until the desired level of bank protection is achieved. As each lift is constructed, the face logs and tie-backs are filled with a mix of gravel and cobbles to the top of the face log. It is not necessary to use topsoil in the fill material; but there should be sufficient fine-grain material to insure vegetation growth. Live cuttings are then laid in to form a complete cover layer. These live branches should be long enough to have their butt ends in the soil behind the crib wall. The tips should stick out of the crib wall no more than a quarter of the cutting total length. The branches are then covered with the gravel/ cobble mix to the top of the tie-backs, and the next layer is continued.

This method is effective on the outside of bends where high velocities are present, and in situations where a low wall may be required to stabilize the toe and reduce slope steepness[2]. The use of crib walls in a specific location must be considered carefully in the context of the stream's function. If placed incorrectly relative to the active channel, the bends in a meandering stream can induce considerable damage downstream or on the opposite bank. This method does not adjust to toe scour and should be used in combination with soil bioengineering systems and live plantings to stabilize the upper slopes2.

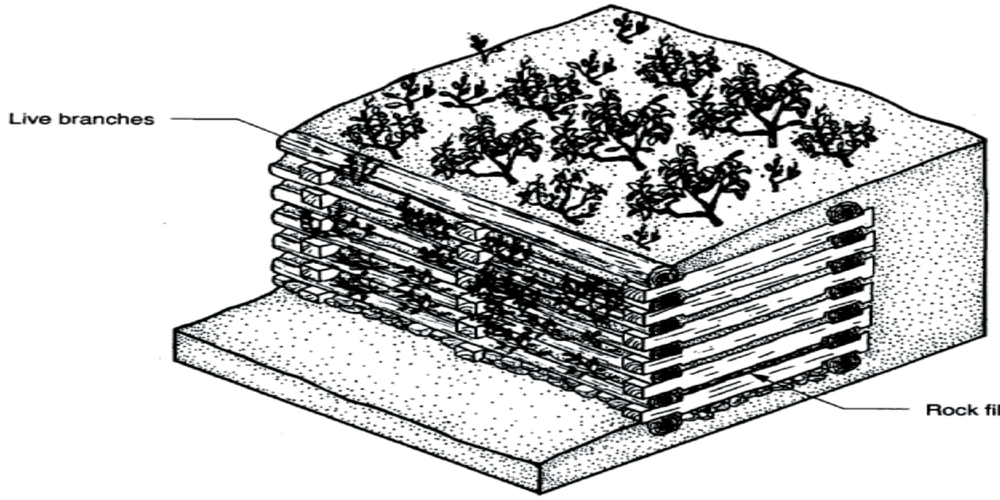
DESIGN CRITERIA AND CONSIDERATIONS:

- This method may cause channel scour and erosion of downstream and opposite banks if a modified floodplain is not constructed along the opposite bank. It may also cause upstream scour.
- As the logs rot, the crib wall can be undercut and eventually fail. If the structure fails, hazardous rebar and steel cable can be deposited in the river along with the logs and other debris of the structure.

[1]Source: California Department of Fish and Game, California Salmonid Stream Habitat Restoration Manual

[2] Source: Natural Resources Conservation Service, Stream Corridor Restoration Principles, Processes and Practices

FIGURE 17: LIVE LOG CRIB WALLS



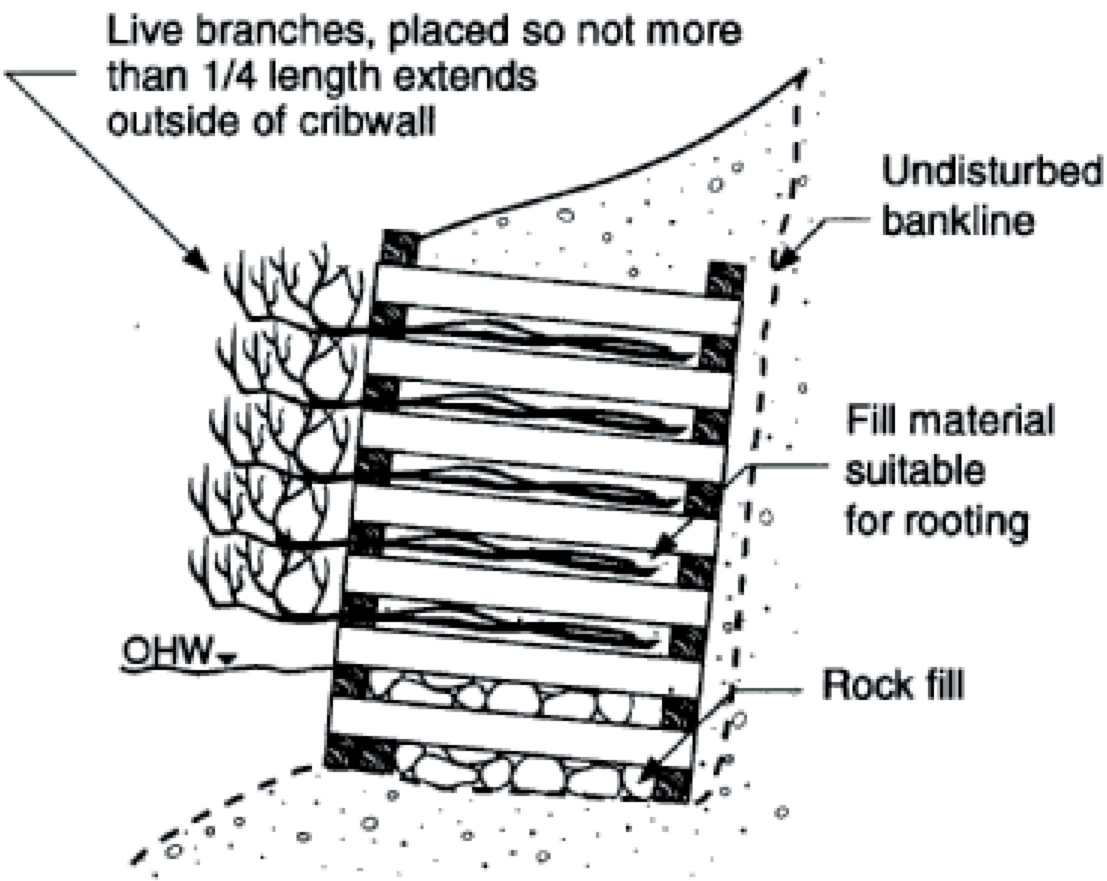


TABLE 2: EROSION REPAIR METHODS THAT ARE NOT RECOMMENDED:

Repair Method	Appropriate Slope	Appropriate Water Velocity	Environ Value	Cost
12 Concrete Crib Walls	Up to 0.25:1	High: up to 15 ft/sec; depending on size of crib wall openings.	Negative	High
13: Articulated Concrete Blocks	Up to 1:1	High: up to 15 ft/sec; for closed cell ACBs, low to medium for open cell ACBs.	Negative	High
14: Gabions	From 0.75:1 up to 3:1	High: up to 15 ft/sec; lower velocity if planted, depending on size and number of planting pockets.	Negative	High
15: Sacked Concrete	Up to 0.5:1	High: up to 15 ft/sec;	Negative	High
16: Gunite Slope Protection	Up to 1:1.	High: up to 15 ft/sec	Negative	Medium

#12: CONCRETE CRIB WALLS

Concrete crib walls consist of stacked interlocking concrete frames that form a retaining wall. Its structural strength is due in part to the composite design of a concrete frame with compacted backfill. Crib walls are constructed with open face panels that are planted by live staking. This method restricts plant growth to the size of the panel opening. As the crib wall slope is flattened and the lattice becomes more open, the vegetation potential increases, and the allowable velocity decreases because of the exposed soil and vegetation. Concrete crib walls perform similarly to live log crib walls. Because the crib wall is a rigid structure, it is more prone to massive failure in the event of undercutting or settlement.

All crib walls tend to cause channel bed and bank erosion both in the immediate area and other areas downstream, and may also cause erosion upstream. Most crib walls eventually fail because they attempt to resolve a symptom of erosion, not its cause. The use of concrete crib walls is discouraged. *This method is mentioned only for reference.*

13: ARTICULATED CONCRETE BLOCKS

Articulated concrete blocks (ACB) consists of concrete interlocking blocks that are cabled together to form mats that can be laid on the channel slope and/or channel bottom.

There are two styles of ACBs: open cell and closed cell. The open cell style allows for vegetation to be recruited into the soil filling each cell. Vegetation growth is restricted by the sizes of the cell openings and by the disconnection caused by the cell walls. In our arid climate, the long-term viability of vegetation within the restricted cell openings is problematic. However, open planting areas can also be constructed into the ACB mats by creating an opening in the mat by removing some of the blocks. The open areas can be revegetated with shrubs and trees. Irrigation is necessary to aid plant establishment.

This method will create channel and bank erosion both down and upstream of protected areas. It is environmentally unfriendly and prone to failure. When it fails, steel cables and stakes hazardously protrude from the mats into the channel. *This method is not appropriate for small erosion repair sites, and is discouraged because of the limited potential for biotic resources.*

#14: GABIONS

This method consists of placing large wire baskets filled with rocks on channel banks, either as mattresses or stacked in layers that resemble steps. Gabions can sometimes naturally revegetate if adequate water and soil are available. Gabions can also be revegetated using planting boxes. (Planting boxes are gabion cells that are left open to bare soil and revegetated with shrubs and trees.) Temporary irrigation may be provided to the planted vegetation in order to aid its establishment. But, wire baskets can deteriorate over time and may be harmful to fish.

Gabions are very hazardous and unfriendly to native fish, especially salmonids, which often try to spawn in gabions below the water line. The basket wire deteriorates quickly, and the fish are injured on the baskets' sharp wire barbs.

Furthermore, the baskets used to line or armor the banks of streams cause bed and bank erosion. They often undercut or fail due to slumping of the soil on which they are constructed. *The use of gabions is discouraged and are rarely permitted by the Department of Fish and Game except in extreme situations. The material is included here for information.*

#15: SACKED CONCRETE

Sacked concrete slope protection consists of burlap bags filled with concrete and placed against channel banks. Sacked concrete does not provide any revegetation potential. However, it offers the opportunity to contour walls around existing vegetation such as tree wells.

Sacked concrete should not be used because it causes erosion, degrades water quality, and destroys other beneficial uses. It is included here for reference. There may, however, be extreme circumstances where site constraints, vertical slopes, and high velocities preclude all other options.

#16: GUNITE SLOPE PROTECTION

Gunite slope protection consists of a pressurized concrete mixture sprayed over an eroded bank. The gunite can be textured, colored, and formed for aesthetics to mimic natural rock. Reinforcing steel may be placed against the bank prior to spraying. This is not an acceptable method of erosion repair, but is included here because it has been successfully used with soil nails to stabilize vertical slopes on upper banks where land use constraints preclude regrading of the slope. Sheet pile retaining walls have been used in a similar manner. Vegetation can be placed on the lower portions of the bank to enhance biotic resources.

Gunite slope protection causes erosion problems, degrades water quality and destroys other beneficial uses. *Therefore, the use of gunite slope protection is discouraged and is included here only for reference*.

SECTION 6 - OBTAINING PERMITS FOR STREAM-BANK REPAIR

(Taken from the Stream-Bank Repair Guidance Manual for the Private Landowner: Guadalupe and Alamitos Creeks)

PRACTICAL POINTS TO HELP YOU OBTAIN PERMITS FOR YOUR PROJECT

As noted earlier, if you are working in or around a creek or stream, you will likely need permits from a local, state, and/or federal agency. Below are some practical points to help you obtain permits for your project as quickly and efficiently as possible. Following this list is a matrix of activities and the agencies, which may require permits for those activities.

- **Learn the rules.** Familiarize yourself with applicable state, local, and federal agency permitting requirements. Determine which agencies may be involved in your project. Take time to study the protocols and regulations of these agencies. Refer to their web sites. Read staff reports, permit conditions, and studies relating to your project or similar projects.
- **Contact the agencies in charge of granting permits for your project.** You may need to obtain different permits for your project from a number of agencies. Contact the agencies that may need to issue a permit for your project to determine who will be involved. Ask about the agency's permitting process, obtain relevant forms, and discuss potential timelines for obtaining your permits. Do not expect to get schedule commitments at this stage, but at least get an idea of the how the process works and a feel for how long it may take.
- **Write a complete project description.** A complete project description is crucial. Include drawings, photographs and other supporting materials to assist the regulatory agencies in understanding what your project entails. Photographs and descriptions enable them to provide guidance and direction before a site visit can be scheduled.
- **Consult early and become familiar with agency staff.** Consultation with permitting and regulatory agencies should begin as early as possible. An in-person meeting is the best way to discuss your project. Try to have plans, maps, photographs of the project location, and other information available at the meeting. You can also request that a staff person meet you at the site.
- Reduce adverse environmental impacts. Design your project to eliminate or reduce as many potential health concerns and environmental impacts as possible. Consider environmentally superior alternatives described in the previous section. These methods are also generally easier and much faster to permit. Incorporate the suggestions you receive during early consultation. Employ a qualified design consultant with specialized expertise in stream analysis and design.
- **Pay attention to details.** Follow all the rules and listen to agency staff guidance. Respond promptly to requests for information. Be on time for meetings with representatives of the regulating agencies. Do not cut corners. Get in writing all dates, procedures, fees, etc..
- **Be willing to negotiate.** Recognize that government regulators may have a great deal of authority over your project, but that they are willing to negotiate. You should be, too.

- **When in doubt, ask.** If you are not sure whether your project needs a permit or whether it is regulated at all, ask. Going ahead without following the proper guidelines will ultimately cost you time, money, and goodwill.
- **Keep good records.** Keep notes of conversations and meetings. Ask for interpretations of rules to be written by the agency representatives. An easy way to do this is to confirm conversations by E-mail. Remember, agency staff time is limited; it is easier for them to review or comment on your understanding than for them to compose the correspondence.

PROHIBITED ACTIVITIES

Before you decide to do work near a creek or river, you should consider that it is illegal to place, store, or dispose of materials of any kind on the banks of, or into, a watercourse. Prohibited materials include dirt, soil, and concrete; pool and spa water; paints, solvents, and soaps; yard and animal waste; automobile and machinery fluids; and firewood and building materials. Remember to comply with best management practices that prevent pollution from entering the waterway and damaging the ecosystem.

AGENCIES THAT MAY REQUIRE PERMITS

Use this chart to help you determine which agency may be involved in your project. A checked box indicates that an agency may be involved and should be contacted, but does not mean they definitely will be involved.

	Santa Clara Valley Water District	Your City's Planning or Public Works Dept	NOAA	CalEPA DTSC	SWRCB Water Rights	Regional Water Quality Control Board	California Fish and Game	Army Corps of Engineers	U.S. Fish & Wildlife Service
Involve work on the bank of a river, stream, or lake?	X	X				X	X	X	X
Involve excavation of the bank?	X	X				X	X		
Involve placement of piers?	X		X	X		X	X	X	
stabilization or erosion control?	X	X				X	X	X	X
Require the removal of riparian or other wetland vegetation?	X	X	X			X	X	X	X
Involve planting riparian or wetland vegetation?	X		X			X	X	X	X
Affect native plants, wildlife, or fisheries?	X		X			X	X		X
Result in stormwater discharge into a creek or wetland?	X	X				X	X	X	X
Divert or obstruct the natural flow or change the natural bed or bank of a creek or wetland?	X	X				X	X	X	X
Involve repair, rehabilitation, or replacement of any structure or fill adjacent to a creek or wetland?	X	X				X	X	X	X
Involve placement of bank protection or stabilization structures or materials (e.g., gabions, riprap, concrete slurry/sacks)?	X	X				X	X		X
Involve building any structure adjacent to a creek or wetland?	X	X				X	X	X	X
Involve fish and wildlife enhancement, attraction, or harvesting devices and activities?	X					X	X	X	X

	Santa Clara Valley Water District	Your City's Planning or Public Works Dept	NOAA	CalEPA DTSC	SWRCB Water Rights	Regional Water Quality Control Board	California Fish and Game	Army Corps of Engineers	U.S. Fish & Wildlife Service
Use materials from a streambed (including but not limited to boulders, rocks, gravel, sand, and wood debris)?	X	X		X		X	X	X	X
Require the disposal or deposition of debris, waste, or any material containing crumbled, flaked, or ground pavement with a possibility that such material could pass into a creek or wetland?	X	X		X		X	X	X	X
Involve the removal of any materials from, or add fill to, a creek or wetland?	X	X	X	X		X	X	X	X
Involve grading or fill near a creek or wetland?	X	X	X			X	X		X
Involve a bridge or culvert?	X	X				X	X	X	X
Involve utility pipe lines?	X	X				X		X	
Involve a septic leach field near a creek or wetland?	X	X				X	X		
Require a water well near a creek or wetland?	X	X	X				X		
Involve work within historic or existing coastal wetlands?	X					X	X	X	X
Remove water from a creek for storage or direct use on non-riparian land?	X	X	X		X	X	X	X	X
Require that hazardous materials be generated and/or stored on site?	X	X		X		X			
Take place in, adjacent to, in a building adjacent to or near a river that has been designated as "wild and scenic" under state or federal law?	X					X	X	X	X

	Santa Clara Valley Water District	Your City's Planning or Public Works Dept	NOAA	CalEPA DTSC	SWRCB Water Rights	Regional Water Quality Control Board	California Fish and Game	Army Corps of Engineers	U.S. Fish & Wildlife Service
Require water to be diverted from a river, stream, or lake for the project or activity?	X	X			X	X	X	X	X
Affect water quality by the deposition of silt, an increase in water temperature, a change in the pH level, or in some other way?	X		X			X	X	X	X
Occur in an area where endangered or rare plant species are thought or known to occur?	X	X				X	X		X
Occur in an area where endangered or threatened fish, bird, or animal species are thought or known to occur?	X	X	X			X	X		X

SAN FRANCISCO BAY AREA JOINT AQUATIC RESOURCE PERMIT APPLICATION

As discussed earlier, projects in or near creeks and even intermittent streams can be regulated by many agencies, the local city government, local agencies, such as the Santa Clara Valley Water District, state agencies, such as the San Francisco Bay Regional Water Quality Control Board, and California Department of Fish and Game, and federal agencies, such as the Army Corps of Engineers and U.S. Fish and Wildlife Service, to name a few. For projects with an aquatic component, such as work near a creek or stream, a single application called the San Francisco Bay Area Joint Aquatic Resource Permit Application (JARPA) has been designed to replace individual applications for state, regional, and federal agencies. As suggested earlier, consider taking advantage of this consolidated application to streamline the project permit application process.

If a project requires local approval, such as that of the local city government or Santa Clara Valley Water District, be sure to check with these agencies about what to include in the application, since the JARPA document does not consider local agency requirements.

CALIFORNIA ENVIRONMENTAL QUALITY ACT

Prior to obtaining permits for a project, a California Environmental Quality Act (CEQA) review will be required if the project is undertaken by a public agency or if a public agency needs to issue a permit for a project. CEQA is found in Section 21000 et seq. of the Government Code, and the CEQA guidelines are found in Section 1500 et seq. of the California Code of Regulations.

The Guidelines have the force of law, and lay out the way CEQA is administered.

(See http://ceres.ca.gov/topic/env_law/ceqa/)

The purpose of the CEQA review is to inform project decision-makers of the issues associated with the project, to identify significant environmental impacts and reduce them, and to disclose to the public the rationale for the decision to approve a project. The agency responsible for the CEQA review is called the lead agency, and it is usually the agency with the most involvement in the project. The local municipality's planning department usually handles the CEQA review, however, CDFG is also a lead agency for purposes of issuing a Streambed Alteration Agreement.

Once the lead agency is identified, all other agencies that require a permit to be issued for the project, whether state or local, become responsible. Responsible and trustee agencies must consider the environmental document prepared by the lead agency and do not, except in rare instances, prepare their own environmental documents.

THERE ARE FOUR POSSIBLE SCENARIOS REGARDING CEQA REQUIREMENTS:

1. The project is exempt from CEQA. Exemptions are listed in the CEQA Guidelines. Specific rules should be consulted, but essentially, a categorical exemption cannot be used if the project has the potential for an individual or cumulative significant effect on the environment. Documentation of exemptions should be obtained from the lead agency. Unless a public hearing is required by the local agency for the project, a categorical exemption does not require a public hearing. The document is simply filed at the county for a specified period.

2. A Negative Declaration is issued by the lead agency for the project. A Negative Declaration can be issued if the project will have no significant impact on the environment without the need for mitigation measures to reduce a project impact to a less than significant level. A public hearing to adopt the findings and the Negative Declaration is required.

    Hint: If, at any time along the permitting or review process, you find that your proposed project can have a significant impact on the environment, and by redesigning your project, the impact can be eliminated or reduced to insignificant, you will save yourself time and money by redesigning your project.

3. A **Mitigated Negative Declaration** is issued for the project. This means that there are significant impacts from your project on the environment, but mitigation measures during implementation can be adopted to reduce these impacts to a less than significant level. A mitigation monitoring and reporting plan is required to identify, what, who, when and where for each mitigation measure, thus ensuring that all mitigation measures are implemented. A public hearing is required.

4. An **Environmental Impact Report** (EIR) is required to study the significant impacts of your project on the environment. Various alternatives to your project must be identified and evaluated and the environmentally preferred alternative must be selected unless there are overriding circumstances that make the project desirable, even though there are significant unmitigated impacts. This finding must be made by the approving body of the lead agency, along with the findings and MMRP. Because there are more alternatives to evaluate, there is a slightly longer review period and a requirement to specifically respond to comments. For this reason, an EIR can be the most time-consuming and complicated scenario.

SECTION 7 - REFERENCE MATERIALS

There is a wide body of literature that provides more detailed information on these bank protection repair techniques. We have identified several of the more comprehensive documents. A more complete list can be found at http://www.4sos.org/wssupport/ws_rest/rest_con.asp.

A CITIZEN'S STREAMBANK RESTORATION HANDBOOK

This 171 page handbook is a guide to restoring eroding streambanks using vegetation and flexible systems. It, features installation guidelines, sample budgets, case studies and tips on choosing the best restoration solution. $20 plus $5 shipping. To order call 800/284-4952 or E-mail sos@iwla.org.

HOW TO HOLD UP BANKS: USING ALL THE ASSETS

An informative, well-illustrated booklet on controlling stream erosion. Produced by the Boquet River Association (BRASS), a small nonprofit group with extensive experience in stream monitoring and restoration, the book helps citizen groups tap community resources and find success with low-cost techniques. Techniques covered include streambank shaping; grass, seedling, and live posts planting; log cribbing and stone riprap installation. To order send $8 to

BRASS, c/o Essex County Government Center, Box 217, Elizabethtown, NY 12932, or call 518/873-3688.

STREAM CORRIDOR RESTORATION: PRINCIPLES, PROCESSES, AND PRACTICES

Developed by an interdisciplinary team of stream and watershed management specialists, hydrologists, engineers and other EPA, federal agency, and private group representatives. A printed document is available for $71, a CD-ROM version sells for $60. Available through the Center for Watershed Protection. at http://www.cwp.org

THE PRACTICE OF WATERSHED PROTECTION: TECHNIQUES FOR PROTECTING AND RESTORING URBAN WATERSHEDS -- At $80, 150 articles are included on all aspects of watershed protection. Drawn from past issues of Watershed Protection Techniques as well as a wealth of other Center papers and reports, this 800-page book is organized around the eight tools of watershed protection, and indexed for easy reference. Available through the Center for Watershed Protection. at http://www.cwp.org.

URBAN STREAM RESTORATION PRACTICES: AN INITIAL ASSESSMENT This assesses the performance of 24 urban stream restoration practices from sites around the Mid-Atlantic and Mid-west, and provides recommendations for improving their application in a variety of urban stream environments. It costs $20. Available through the Center for Watershed Protection. at http://www.cwp.org.

STREAM-BANK REPAIR GUIDANCE MANUAL FOR THE PRIVATE LANDOWNER - - GUADALUPE AND ALAMITOS CREEK – This focuses on erosion repair in mercury-contaminated streams, but it is relevant to a broad range of erosion repair projects. Some of the most relevant information from this document is contained in this Design Guide. This publication can be obtained from the Santa Clara Valley Water District.

MAINTAINING CORTE MADERA CREEK: A CITIZENS' GUIDE TO CREEK-SIDE PROPERTY PROTECTION – Created for the Town of Portola Valley and its residents to help guide bank stabilization and revegetation efforts along Corte Madera Creek, a tributary to San Francisquito Creek. The report was created to facilitate communications between the Town and private property owners who wish to address erosion and property loss. The document can be found at http://www.cityofpaloalto.org/public-works/jpa-projects.html.

GUIDELINES FOR BANK STABILIZATION PROJECTS: IN RIVERINE ENVIRONMENTS OF KING COUNTY – Produced by the King County Department of Public Works Surface Water Management Division, Seattle, Washington in 1993. This report is an exceptional manual that clearly and comprehensively describes the planning, design, permitting, and construction aspects of bank erosion repair. From a technical perspective , it is very applicable to California streams. This resource, including some of its illustrations, was used to help prepare this Bank Protection Design Guide.