Bank Protection/Erosion Repair Design Guide

INTRODUCTION AND PURPOSE OF DESIGN GUIDE

This Design Guide is intended to clarify the Chapter 1 of the Water Resources 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.

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BANK PROTECTION/EROSION REPAIR DESIGN GUIDE
PART ONE:
TECHNICAL PRIMER ON STREAM FUNCTION AND FORM

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.

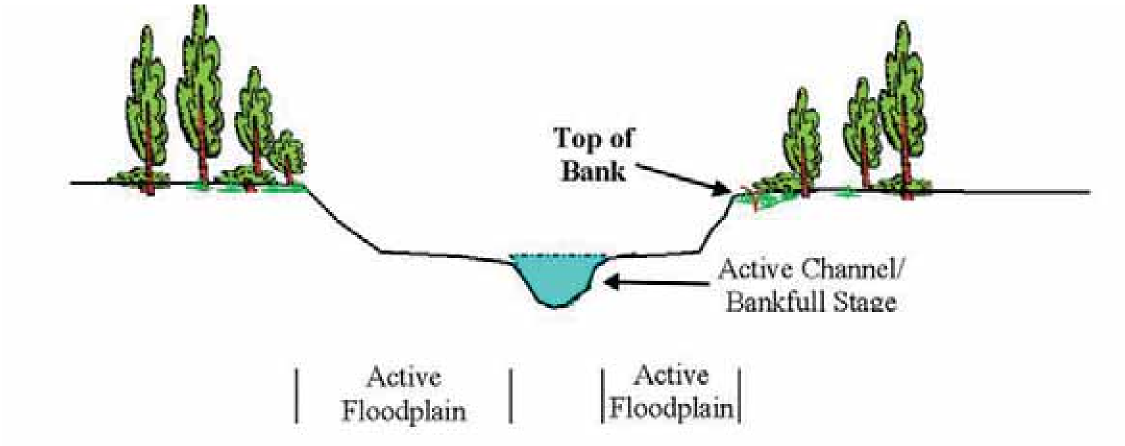
Experience has also shown, however, that significant problems arise when streams in the lower watershed are confined. By lining streams with levees or floodwalls, water that would otherwise slowly spread out over a large area of land in a beneficial way accumulates in the channel until it breaches its 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.

Figure 1: Cross-Sectional View of a Natural Stream



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.

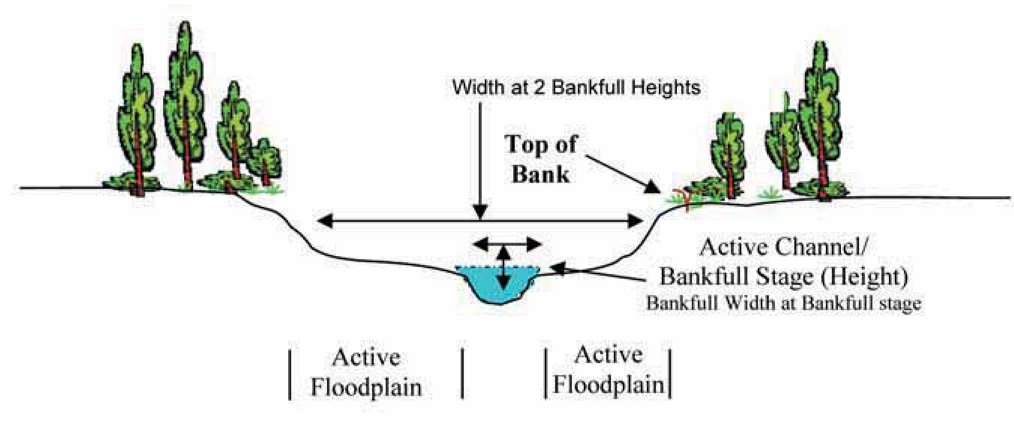
The active channel is an important feature because it transports the majority of the water and sediment in the stream system, and thus it influences the channel formation over time. As seen in Figure 1, the active channel is usually distinguished from the active floodplain by an abrupt change in the 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.

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, <u>it is important that armoring the channel be avoided on individual properties whenever possible</u>, 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. <u>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.</u> 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. <u>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.</u>

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. <u>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.</u>

Geotechnical Failures

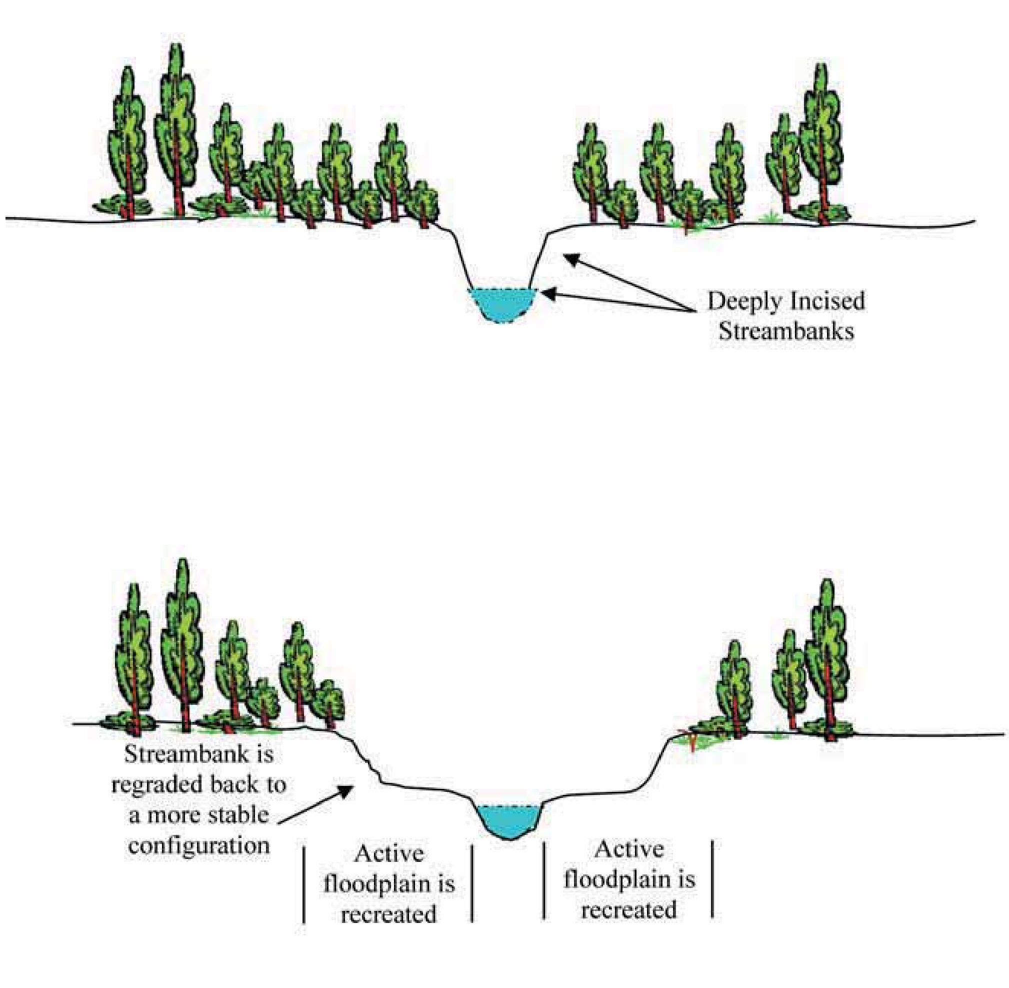
Geotechnical failures occur when gravitational forces are greater than the strength of the soil. These failures are usually caused by over steepened banks and/or excess moisture in the soil. This results in the movement of earth, better known as a landslide. Near a stream, the likely causes of this type 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). <u>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.</u>

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



BANK PROTECTION/EROSION REPAIR GUIDE 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. <u>A qualified professional may be needed to help determine whether, and to what extent, erosion is in need of repair.</u>

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.

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 June 15th and October 15th, to minimize a 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, <u>but do not use rodenticides</u>. 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 <u>NOT</u> 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

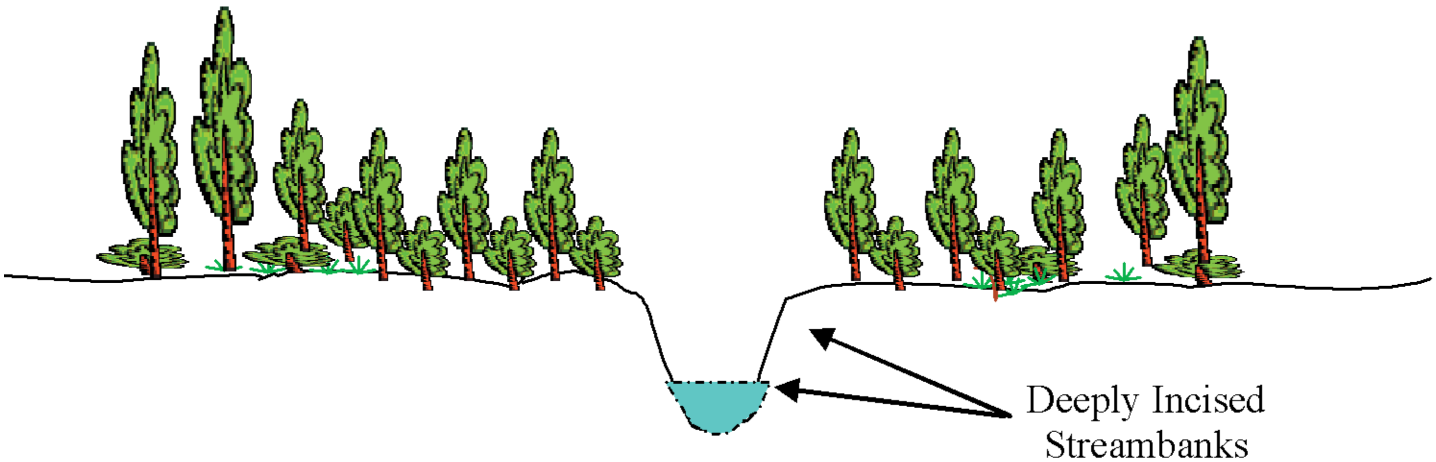
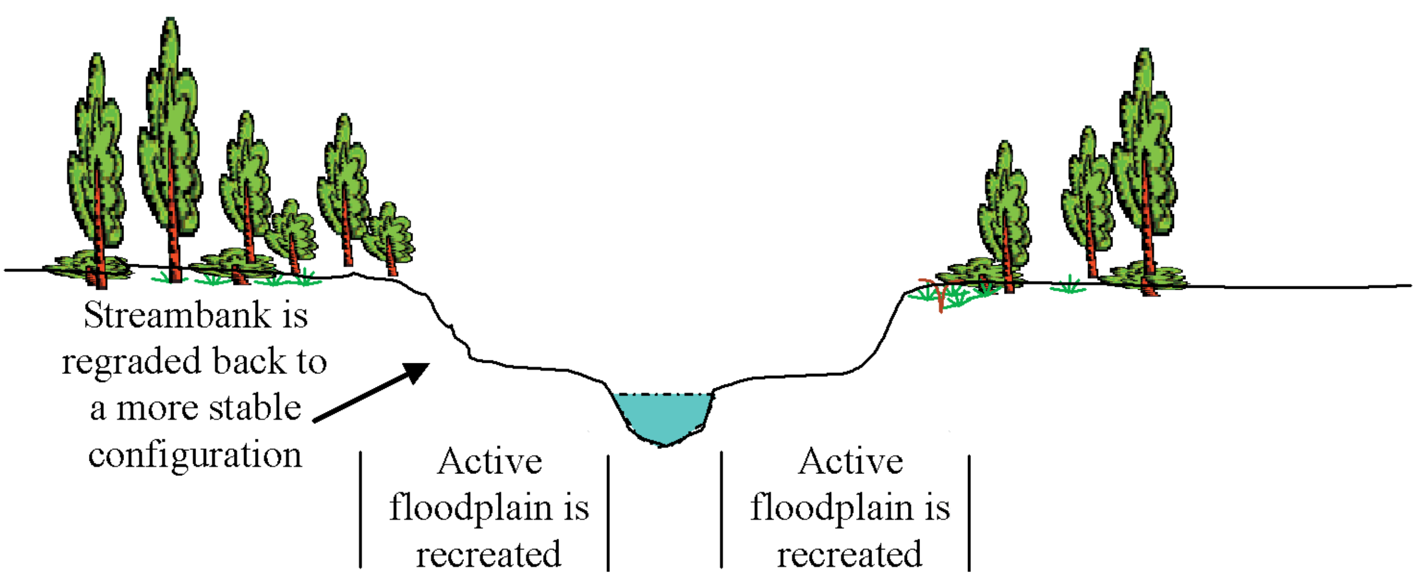


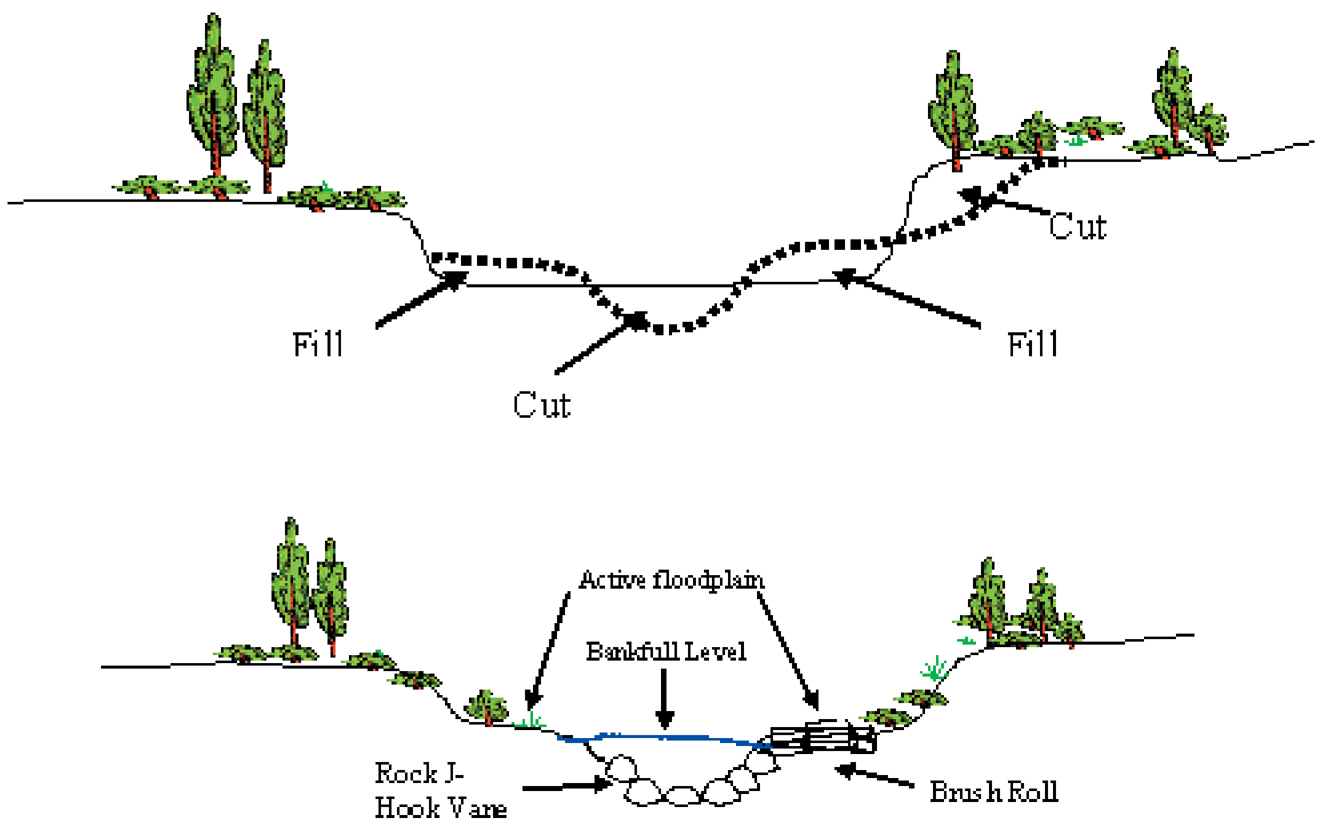
Figure 5: The same stream channel as Figure 4, but stream banks have been regrades to create terraces where vegetation can be planted



How to Create a Modified Floodplain In Broad Flat Stretches with Sediment Deposition

In some cases, a stream may have experienced heavy sediment deposition overthe 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.