# A PRIMER ON

# STREAM AND RIVER PROTECTION

# FOR THE

# REGULATOR AND PROGRAM MANAGER

Technical Reference Circular
W. D. 02 - #1
San Francisco Bay Region
California Regional Water Quality Control Board
April 2003

**COVER PHOTOS**
Upper photo: Suisun Creek, Solano County. Photo credit: Matt Cover.
Lower Photo: Arroyo Las Positas, Alameda County. Photo credit: Pat Evans.

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# STREAM AND RIVER PROTECTION FOR THE REGULATOR

## FORWARD

This technical reference circular (Circular) has been prepared for the San Francisco Bay Regional Water Quality Control Board (Regional Board) to provide technical assistance on the administration of its regulatory and grant programs. Other regional boards will find the Circular useful, and a longer-term goal is to adapt this Circular to address different conditions around the State. The purpose of the Circular is to help government personnel recognize the linkages between water quality and the good physical conditions of stream channels. This Circular is a primer prepared for immediate use by the staffs of regional boards that have provided essential additions to its content, utility and clarity. Because it is a primer, the object is to translate a complicated field of river science into some generalizations that the relative novice to river science can apply to regulatory and program management issues. This effort to generalize in order to make important concepts reachable to a wide population of government personnel, property owners, and private consultants has the advantage of having immediate, positive effects on protecting the environment. The vulnerability of this approach is to offend the professionally trained who have as their task to illuminate the complexity of interacting variables in river systems and warn against over-simplification. Despite the inherent drawbacks to generalizing about natural systems and how they can be managed, this Circular represents the day-to-day realities that some good basic information capable of wide application has a place in the range of information made available by and for government agencies and the public. The Circular is intended to provide immediate internal agency technical assistance while soliciting outside review and comments. It is appropriate to apply this Circular now to water quality and grant programs at all levels of government in the San Francisco Bay Area, and it is also our intention for it to be modified over time based on input from its users.

The origins of this Circular were in an urban stream restoration and flood control channel design workshop held at the Santa Clara Valley Water District in July 2001. Part of the workshop involved the evaluation and redesign of a flood control channel on Calabazas Creek located in San Jose, California. The workshop design engineers reconfigured the Calabazas Creek channel cross-section and profile in order to retain, and in some of the workshop design alternatives, increase the flood capacity of the channel. Our other workshop design objectives were to significantly increase the long-term stability of the channel as well as improve and restore ecological habitat. This "have your cake and eat it too" design experience managed to grapple with difficult urban land use constraints. The engineers identified some previously unconsidered opportunities for increasing some project area rights-of-way and changed the treatment of the Creek within this allotted space. Although this design did not produce a natural creek in the historic sense of what was there before urban development arrived at its banks, the redesigned project did result in a creek with a more sustainable channel slope and a channel capable of supporting diverse aquatic and riparian habitat, including fisheries habitat, which also retained, if not increased, channel capacity.

While the channel design parameters and project features were necessarily unique to the reach of Calabazas Creek being considered, the process used to evaluate different alternatives for managing the channel can be applied widely to any landscape and project site. The evaluation process recognizes that different stream reaches under consideration for modification have a widely varying range of constraints and opportunities for protecting and/or restoring natural ecological functions. Therefore, the same thought process, once filtered through very different site conditions, will produce projects that may look very different from each other, but nonetheless, share the common feature that the projects display an improvement in the natural features and functions associated with more natural and healthy streams.

The Regional Board is interested in promoting any stream management evaluation process that can result in the protection or restoration of natural stream functions. This Circular applies concepts based on two decades of scientific and engineering advancements on the conditions needed both for lower maintenance, and for more sustainable and stable river channels. It applies in part new guidance that has been issued by federal agencies on watershed stream corridor management, floodplain management and stream channel engineering. The Circular is a response to the water quality engineers and biologists who have recognized the necessity to address the physical conditions of a stream channel, its floodplain and riparian corridor if we are to protect or improve the quality of the nation's waters.

The development of this Circular was assisted by Paul Amato, Dale Hopkins, and Bruce Wolfe of the Regional Board. Valuable review and comments were provided by the engineers and planners of the Santa Clara Valley Water District. Staff from the Regional Board who provided review and editing assistance included Greg Bartow, Thomas Mumley, Jill Marshall, Elizabeth Morrison, Richard McMurtry, Alexa LaPlante, and Nelia White. Review comments provided by federal , state and local agency personnel who have participated in our stream protection workshops using this circular were particularly valuable and appreciated. Drew Goetting and Zuyu Huang of Drew Goetting Consultants and Waterways Restoration Institute donated the production of figures # 4 and # 5. Particularly valuable assistance was provided by Matt Cover and Debbi Nichols on editing and report graphics and photography. Readers and users of this Circular are encouraged to relay their comments and suggestions for this Circular to Ann Riley at the Regional Board: (510) 622-2420 or **alr@rb2.swrcb.ca.gov**.

## CHAPTER ONE: USE OF THIS CIRCULAR

This Circular presents a step-by-step system to evaluate both the probable negative and positive changes to water quality from proposed development projects, land use changes, restoration projects or programs, stormwater and flood damage reduction projects, maintenance activities, and other activities that directly or indirectly impact streams. The system is assisted by tables that guide the user to consider what impacts a proposed project or change of land use may have on a stream channel. A decision tree then provides a process to plan for a project that can avoid these impacts. This Circular presents a process for evaluating or planning activities; it is not presenting prescriptive project design alternatives. The process can be followed without regard to the different design methods or techniques such as hydraulic modeling, application of watershed evolution models, etc., or different construction, restoration or revegetation strategies. This is guidance for design process and design results. A large variety of methods can be used to achieve the results.

This Circular assumes that we need to be using a stream protection system which can gain wide acceptance, is easy to understand, and is flexible. The guiding principle of this Circular is that a new pollution control strategy is required to follow the generation of wastewater treatment plants constructed at great public cost in the 1970s and 1980s. These plants were "brick and mortar" pollution control facilities designed to control "point" sources of pollution from industrial and commercial operations and to treat sewage. These facilities have done an admirable job controlling "point" source pollution, but little to control "non-point" source pollutants that still flow untreated as "urban runoff" into storm drains, streams, wetlands, and estuaries. The next generation of pollution control "facilities" must follow a different strategy while using similar biological treatment principles to address the pollutants in urban runoff. Such a different strategy uses a biological treatment "plant" in the form of natural wetland and riparian systems. These systems, when in adequate physical condition, rely on their natural functions to treat polluted water and provide other valued beneficial uses of our State's waters.

The content of this Circular is summarized by the two photographs on its cover. The Regional Board's water quality monitoring program reveals that a physically degraded waterway such as the Arroyo Las Positas, shown in the lower photo, has high pollutant levels, exceeding the water quality standards that support a clean and healthy environment. In contrast, water quality measurements on Suisun Creek in the upper photo indicate that a physically healthy creek corridor has the ability to protect and treat waters subjected to degrading pollutants. This phenomenon is not restricted to the two creeks on the cover, of course, with the preponderance of scientific research unambiguously making the connection between the quality of water draining our watersheds and the physical condition of these watersheds and their stream corridors.

**Short Term Applications**

Federal Clean Water Act Sections 404 and 401, Protecting Waterways From Fill

Existing regional board programs and regulatory activities which may apply the principles contained in this Circular include the review of applications for state water quality certification under Section 401 of the Federal Clean Water Act (CWA). CWA Section 401 is tied to CWA Section 404 that requires federally-issued permits for all proposed fill and dredge activities in the waters of the United States. Section 401 gives states broad authority to approve, conditionally approve or deny a Section 404 permit. Section 404 (b) (1) provides guidance for evaluating project alternatives and calls first for avoiding impacts, then minimizing impacts to assure that there is no net loss of fully functional streams, wetlands and/or other waterbodies. The analysis process described in this Circular helps the user practice an easily understood, step-by-step approach that is scientifically defensible and consistent to implement the impact avoidance and minimization called for by the Clean Water Act.

Stormwater Management and Non-point Source Control

Stormwater and non-point source pollution is the leading cause of water quality impairment in California. Furthermore, the Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan) includes a summary of adverse impacts from stormwater and non-point source pollution on the Bay's waterbodies, and states that non-point sources of pollution are now generally considered to be greater sources of pollution than from all other sources discharging into the Bay's watersheds.

The Regional Board's Watershed Management Initiative identifies major non-point source problems in the San Francisco Bay Region as:

1. Elimination of natural channels, including loss of wetlands, wildlife, fisheries and riparian habitat;
2. Increased sedimentation due to construction activities and land clearing;
3. Unmitigated changes in hydrology that upset the geomorphic equilibrium of streams, causing destabilization and erosion of channels, and more frequent flooding;
4. Increased pollutant loads associated with urban activities;
5. Impairment of fish habitat from water diversions and fish passage barriers due to the construction of in-channel reservoirs and diversion structures, the sedimentation of channels, and the removal of vegetation; and,
6. Increased pollutant loads associated with agricultural activity.

The planning process described in this Circular recognizes the critical role that implementation of local stormwater management plans, developed in response to U.S. Environmental Protection Agency (USEPA) regulations, have in the avoidance and minimization of the degradation of watersheds' and their streams' physical environments. Likewise, California's non-point source pollution control program administered under CWA Section 319 emphasizes broadly construed and integrated approaches for not only protecting the physical integrity of streams and rivers but restoring them as well.

CWA Section 319 requires that states develop polluted run-off or "non-point source" control programs. The Coastal Zone Act Reauthorization Amendments of 1990 (Section 6217) requires states to develop and implement management measures for non-point source pollution to restore and protect coastal waters. In January 2000, both the State Water Resources Control Board (State Board) and the California Coastal Commission adopted the "Plan for California's Non-Point Source Pollution Control Program," which was subsequently approved by the USEPA and the National Oceanic and Atmospheric Administration. This non-point pollution control program is organized into tiers. The first tier continues self-determined partnerships among local, state and federal entities using the CWA Section 319h and 205j state administered grants as an incentive mechanism to start pilot programs and projects. This "self-determined" stage will evolve into Tier II activities in which Waste Discharge Requirements administered under California's Porter Cologne Act will be applied as "regulatory encouragement" to negotiate agreements with agencies to address non-point pollution. Tier II can also cover regional board waiver of individual Waste Discharge Requirements as well as use of various other enforcement tools to ensure compliance.

The strategy behind USEPA's point source regulations has been to apply "the best available technology" to reduce or eliminate polluting discharges and, in the case of non-point or polluted run-off discharges, to apply "best management practices" to protect the environment from erosion, flashy hydrographs, and loss of pollutant-treating riparian and wetland buffers. The basic conceptual framework of this Circular and the principles of stormwater management share the same objectives: to avoid excessive streambank erosion, excessive sedimentation, and destabilizing enlargement or narrowing of stream channels. The range of activities which comprise stormwater management plans can include: land use planning and zoning, site design provisions, floodplain and stream channel restoration, community education and outreach, and landscape, streetscape and parking lot design. It is this category of activities that composes the first step in the Circular's design tree planning process described in Chapter Seven.

An example of provisions to implement stormwater runoff management in the San Francisco Bay Region that is protective of streams is the Regional Board's October 2001 amendment of the Santa Clara Valley's municipal stormwater permit. This permit amendment requires minimizing changes to stream channel hydrographs (avoiding large, flashy storm and flood flows) from new and redevelopment projects, monitoring the condition of the watershed to identify sources of pollutants and significant habitat and channel alterations, and practicing measures which reduce impacts to creeks, recognizing the relationships between flow, sediment and pollutants.

Another regulatory program being applied to the problem of reducing non-point source pollution is the setting and enforcement of ambient water quality standards as required under CWA Section 303(d). Under this approach, a regional board designates uses for its waters and then establishes acceptable water quality standards to protect those uses. Regional boards are conducting watershed surveys to determine which streams, rivers, wetlands and other water bodies are "impaired" or polluted and unable to support their designated uses. The boards then identify problem pollutants and establish a "total maximum daily load" (TMDL) of each pollutant the body of water can absorb and still meet its designated use. Once a TMDL is established, the regional board is charged with requiring implementation of plans that reduce the pollutants below TMDL levels.

Threatened and Endangered Species

Regional boards works cooperatively with the California Department of Fish and Game and the federal U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) to assist in the protection of threatened and endangered species. In June 2000, NMFS adopted regulations affecting fourteen groups of salmon and steelhead listed as threatened under the Endangered Species Act (ESA). The ESA provides a variety of tools for saving species threatened with extinction. Under Section 7 of the ESA, no federal agency may fund, permit or carry out any activity that could jeopardize the species. When activities of state and local governments and private citizens may harm listed species, Section 4(d) of the ESA requires that harm be controlled so that it does not lead to extinction. Under the ESA, a species may be listed as either "endangered" or in danger of extinction throughout all or a significant portion of its range, or "threatened" or likely to become endangered within the foreseeable future throughout all or a significant portion of its range. For species listed as threatened, Section 4(d) of the ESA provides that NMFS or USFWS issue protective regulations deemed necessary for the conservation of the species. NMFS has identified 52 distinct salmon populations known as Evolutionarily Significant Units (ESUs) of Pacific Salmon along the coasts of Washington, Oregon and California. Of these, 26 have been listed as threatened or endangered. The San Francisco Bay Area and the coast to the south are contained in the threatened steelhead ESUs in the NMFS-designated Central California and South-Central California areas. Local, state and tribal governments have assumed leadership roles in saving these species, with a notable example being the Fishnet 4C collaboration of Mendocino, Sonoma, Marin, San Mateo and Santa Cruz Counties to affect local land use planning, management and construction practices. It is intended that this Circular can assist efforts such as these to help avoid impacts to threatened or endangered species and complement existing local efforts to develop and implement ESA Recovery Plans for listed species. The Recovery Plans necessarily emphasize the protection of riparian corridors, reduction of stream pollutants, erosion and sediment control, and restoration of habitat.

Prevention of Degradation and Restoration of Aquatic Systems

Federal standards also direct the states to protect water bodies with anti-degradation provisions so that these waters can continue to support their designated uses. The Basin Plan specifies a policy of no net loss of wetlands, and specifies the prevention of degradation of main stem and tributary stream channels in the San Francisco Bay Region.

Grant programs administered under CWA Sections 319h and 205j are being used to return the structure, functions and diversity of aquatic ecosystems as a means of reversing or avoiding non-point source pollutant impacts. These grant programs have supported projects ranging from the control of dairy wastes, floodplain acquisition and restoration, replanting of riparian environments, restoration of stream channels and meanderbelts, formation of watershed councils and school education programs.

The State Board and regional boards have a substantial expansion of their mission to administer watershed improvement grant programs to address the causes of watershed degradation. This is a logical and positive complement to their traditional regulatory missions in that the grant programs give the regional boards the ability to offer substantial incentives, rather than solely regulations, to address water quality needs. This places the regional boards in a better position to establish positive working relationships with the public it typically regulates and other stakeholders, and to participate in the development of solutions to water quality problems. A recent expansion of the federally-based grant programs has occurred under the California Watershed Protection Grants Program. This Program is administered by the State Board and regional boards (originating with California's Proposition 13 in 1999) to improve the quality of the waters of the State through watershed planning and management, and river protection and restoration activities. Proposition 40, passed in 2002, includes grants for urban stormwater and non-point source pollution control and for the development of integrated watershed management plans. Proposition 50, also passed in 2002, contains additional watershed restoration and planning grant funds. The grant managers of these various restoration management and education programs can use this Circular to help them assess the environmental integrity of the management and restoration proposals coming before them for evaluation and priority ranking.

California's Porter-Cologne Water Quality Control Act

California's Porter-Cologne Act provides both immediate and long-term authority for the protection of the physical integrity of river and stream environments. The Act directs regional boards to regulate by the issuance of Waste Discharge Requirements (WDRs), any activity that results in a waste discharge that directly or indirectly impacts waters of the State. WDRs, when used to condition discharges into a waterbody, including fill, can and are being used to include the objective of protecting stable waterways by encouraging a balance between erosion, sediment transport and deposition as a means of avoiding the degradation of water quality. In the past, WDRs were primarily used to regulate point source discharges of liquid or solid waste to land (e.g., septic tank discharges, landfill operations, etc.). However, WDRs are the most appropriate means to regulate discharges of waste including fill material, sediment and changes in flows to waterways.

Each of California's regional boards is directed by a publicly developed and approved basin plan. The basin plans identify the actual and potential beneficial uses of the waters of the State as directed by the Porter-Cologne Act, set water quality objectives to protect those uses and present an implementation plan to meet those objectives.

In the San Francisco Bay Region, the Basin Plan's beneficial uses are directly related to the concern of the physical integrity of stream and river channels. These beneficial uses include cold freshwater habitat for trout and anadramous salmon and steelhead; fisheries migration including unimpeded river flows, protection of tidal areas and prevention of water quality barriers; preservation of rare and endangered species; and protection of wildlife habitat including riparian habitat. The Plan notes, "(t)hese habitats can be threatened by development, erosion, sedimentation as well as poor water quality." The Basin Plan defines wetlands broadly using the USFWS Guidance that recognizes seasonal wetlands as well as "riparian woodlands."

Because of the relationships among watershed conditions, erosion rates, sediment transport and deposition, vegetative cover and stream channel conditions needed to support the aforementioned beneficial uses, water quality objectives related to sediment, turbidity, temperature and nutrients are directly related to the physical condition of a watershed and its streams.

The water quality objectives section of the Basin Plan notes, "(t)wo decades of regulatory experience and extensive research in environmental science have demonstrated that beneficial uses are not fully protected unless pollutant levels in <u>all</u> parts of the aquatic system are also monitored and controlled" (emphasis added). The Basin Plan-specific objectives call for control of temperatures, turbidity, nutrients, depositional settleable materials and sediments. The Basin Plan states, "(t)he suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses."

The Basin Plan's Implementation Plan includes WDRs and stormwater pollution control measures, including runoff controls on erosion and sediment. The control of damage to stream channels from erosion and sedimentation is listed as a specific implementation measure. The Implementation Plan goes on to also describe use of the previously mentioned non-point source program and CWA Sections 404 and 401 to protect wetlands and waterways from fill. Also, the Implementation Plan includes a

Wetlands Protection and Management Program. This water quality implementation strategy recognizes that “wetlands also enhance water quality through such natural functions as flood and erosion control, stream bank stabilization, and filtration and purification of naturally occurring contaminants.” The Implementation Plan includes the Governor’s executive order (W-59-93), the California Wetlands Conservation Policy, and State Senate Concurrent Resolution No. 28, among other State of California waterbody protection policies. These policies set goals to ensure no net loss of wetlands, achieve a “long term net gain in the quantity, quality and permanence of wetlands acreage and values,” and make it a state priority to protect and restore wetlands. In response to state directives to develop regional strategies for wetland planning, the Regional Board has participated in development and publication of the Baylands Ecosystem Habitat Goals Report.

**Future and Longer Term Applications**

This Circular has been prepared to assist those who are intending to meet the existing laws and regulations described earlier. The Circular also recognizes that the conditions of the physical components of our watersheds, including their drainage network, vegetative cover, riparian corridors, stream channels and floodplains are likely to come under more federal, state and local control because of their direct relationship to water quality objectives.

Current water quality programs are evolving toward more specific on-the-ground standards and results-oriented criteria. Examples of this include the CWA Section 319 non-point source program, which is moving from encouraging local stewardships and demonstration projects, to adoption of local best management practices sufficient in specificity to enable state waiver of regulation of certain classes of discharges. A combination of this “third tier” of the non-point source program, in concert with the Porter-Cologne Act’s emphasis on control of direct, indirect and potential water quality impacts, will converge to realize substantial reductions in water quality problems. This advancement will necessarily need to entail the physical protection of wetlands and streams.

As outlined in the State Board's 2001 Strategic Plan, non-point source pollution reduction is being addressed through the stormwater program, the Watershed Management Initiative, and the adoption of TMDLs for those pollutants causing waterbody impairments. Because most of our waterbody impairments are due to non-point sources, there are two evolving regulatory approaches to correct this source of pollution. One is to solve the impairment through optimum use of the tiered approach just described, which can include the protection and restoration of streams and better site design and land use practices. This Circular is directly applicable to such protection and restoration.

The other approach is to establish a TMDL and its associated implementation plan. Such an implementation plan will likely include increased regulatory requirements. In the TMDL approach, numerous streams are classified as impaired and will need TMDLs to address turbidity, nutrients, temperature and other parameters directly related to the erosion and sedimentation of watersheds, stream channels and floodplains. Potentially, any further loss of riparian areas and drainage network in a specific watershed may result in an unimpaired watershed becoming impaired, with the subsequent requirement of TMDL adoption. Applying the principles in this Circular may increase fully functioning riparian corridors, and, because of their capability to filter non-point source pollution, result in less restrictive TMDLs in impaired watersheds or even prevent a watershed from being listed as impaired.

One of the lesser-known strengths of the TMDL approach is its flexibility and adaptability to broad watershed management initiatives. For example, we need not exclusively set "load" limits, but we can also have "commitments to action" tied to measurable factors such as extents of riparian buffer zones, riparian canopy coverage, and stable, vegetated stream banks. TMDLs provide an opportunity to identify and apply locally based remedies to improve watershed conditions. This leads to the significant role that both the State Board's Strategic Plan and the Regional Board's Basin Plan assign watershed management councils or partnerships in addressing water quality issues. The watershed approach not only intends to improve water quality by engaging a broad involvement of stakeholders, but it also intends to better integrate the relationships between the physical conditions of watershed and its water quality. Already, 44 watershed management areas have been identified statewide as priority targets for funding and technical assistance. Notable examples of these watershed management areas in the San Francisco Bay Region include the Santa Clara Basin Watershed Management Initiative, supported by the Santa Clara Valley Water District, Santa Clara County, local municipalities and a long list of stakeholders including industry, homebuilders, transportation agencies and environmental organizations, and the Tomales Bay watershed, where local agencies and stakeholders including residents, shellfish harvesters, and agricultural interests are working to address watershed impairments.

Municipal stormwater permits issued under USEPA's stormwater program are being updated to include revised new and redevelopment project sediment and runoff treatment controls, improved site design, and management of runoff volume and duration. Municipal stormwater permittees are being required to develop and implement Hydro-modification Management Plans (HMPs) for the watersheds in their jurisdictions. This will help ensure that the condition of stream channels and the urbanization of the associated watersheds will become even more strongly linked. This Circular can be applied in addressing the impacts of urbanization and implementing these HMPs.

Finally, there is increasing emphasis on the avoidance and minimization of impacts to waterbodies under both the State's Porter-Cologne Act and the CWA Section 404 permit program. This emphasis is because of research such as the National Research Council's 2001 report.[1] This report indicates that the preponderance of Section 404 mitigation projects, which were intended to ensure no net loss of wetlands, have failed to meet this important objective. In the face of such unacceptable wetland losses, in which only 20% of wetland impacts were offset by mitigation projects, resulting in an actual 80% loss of wetlands, both the nation and State are under pressure to better address this problem, namely the avoidance of impacts. This Circular can help project designers avoid and minimize impacts and improve the success of mitigation projects.

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[1] National Research Council N.A.S. Compensating for Wetland Losses under the Clean Water Act, National Academy of Sciences Press, Washington DC 2001.

## Common Questions About This Circular And Regulations Affecting Streams

Is This Circular Formally Adopted Regulatory Guidance?

No. It is meant to be used as assistance to agency staff, regulated public, and stakeholders in reviewing and developing projects that are protective of water quality, while being permitted more quickly. Regional Board staff will apply the concepts and processes for the avoidance and minimization of impacts to aquatic ecosystems described in this Circular, among other criteria and considerations, during their review of permit applications and structuring of regulatory programs. Applicants who follow the planning processes described in this Circular will therefore have the advantage of a more straightforward and timely review process by the Regional Board for permit applications.

Is This Circular Relevant To Small Scale As Well As Large Scale Projects?

Yes. The forward to this Circular cites the case of Calabazas Creek in San Jose in which a Santa Clara Valley Water District workshop used the planning process described in this Circular to redesign an urban flood control channel. This project involved a greater than 1,500 foot channel site where a large regional water agency was attempting to address a complex mix of objectives and conditions, including channel capacity for a design flood discharge, grade control structures, structural channel side slopes, and restricted rights of ways in an urban setting. This is considered a moderate to large-scale project by virtue of its multi-million dollar cost, sponsorship by a large agency, and its linear length of over a quarter mile.

How then would this planning process apply to a much simpler site, which might, for example, involve a private property owner of a small parcel in which only a few hundred feet of stream channel might be involved in the proposed action? The Stream Impacts Avoidance Decision Tree described and depicted in the Circular's Table 6 can easily be applied to small projects as well. The basic thought approach remains the same without regard to the scale of the project. What changes with scale is the amount of information collected on current watershed conditions, sediment loads and sizes, historic conditions and topography, geology and soils of the stream valley and channels, as it applies to the planning and design process.

Small streamside property owners should be concerned with the conditions up- and downstream of their property as well as with the activities of their neighbors across the stream. However, addressing current and historic watershed conditions affecting their property is something that is largely outside their control. Watershed councils or local or regional public works agencies will have better financial and technical means available to them, and should view individual site problems as connected to a broader watershed system. This speaks to the value of organizing to solve stream problems through a local watershed council so that costs can be shared among more property owners and levels of government and the remedies selected are more effective and long term because they are logically integrated with watershed conditions.

Regional boards, nonetheless, need to recognize that small projects typically go uncoordinated with other efforts and that these small projects need to be treated efficiently and effectively without the assistance of costly consultants. To assist the small parcel owner, this Circular provides simple and easy to understand figures and guidance in Chapters Four and Five (prepared at the request of regional board staffs) for use in lieu of the more complex decision tree provided in Chapter Seven. Direction on how to avoid counterproductive measures is a major emphasis of this process.

<u>Is The Stream Protection Planning Process Described in This Circular Relevant to Already Very Degraded Channels Constrained By Urban Development?</u>

Yes. Appendix B describes a case located on Codornices Creek in a commercial and residential area of the City of Berkeley in which the Creek is located in a very constrained corridor between buildings. The case was selected for description in this Circular to illustrate that even very degraded streams in areas in which adding more right-of-way to the creek corridor is not an immediate option, can none-the-less be partially restored. This case illustrates how a partial restoration can reduce property damage from flooding, increase channel stability, reduce erosion, and improve environmental values. In this case, a very degraded, unstable channel with failing concrete, rubble, and debris-filled banks now provides coastal steelhead habitat. The level of existing land use constraints will affect the range of options practical to implement, but even the most degraded concrete flood control channel can benefit from modifications described in this planning process in a cost efficient manner.

<u>What Are the Aerial Boundaries of Regional Boards' Authority Along Stream Channels and Corridors?</u>

Under the State's Porter-Cologne Act, regional boards are responsible for all activities that may result in a discharge to *waters of the State* and may impact the water quality in those waters. These waters include all stream channels and their corridors, be they perennial, ephemeral, and/or intermittent stream channels or mainstem, tributary and/or headwater channels. Regional boards follow the Army Corps' guidelines in determining the jurisdiction of *waters of the United States* subject to regulation under CWA Section 404 when they issue a Section 401 water quality certification. However, the Porter-Cologne Act expands the aerial extent of boards' authority as *waters of the State*. The Porter-Cologne Act requires boards to address both indirect and direct impacts of activities (including downstream impacts), as well as possible future impacts that can result in the degradation of water quality.

These regulatory authorities, when joined by the regional boards' responsibilities under the CWA Section 319 non-point source program, the municipal stormwater program that is partly concerned with avoiding concentrated runoff and erosion, and the pro-active cleanup of those waterways identified as impaired under Section 303(d), cumulatively require the regional board to consider the whole cross-section of a stream channel and its corridor when evaluating the potential water quality impacts of a proposed activity.

The stream corridor cross–section that can come under the boards' jurisdiction can include a buffer zone and streamside vegetation on top of a terrace above a stream channel, floodplain, and active or bankfull channel. These terraces, which are former floodplains, may be perched many feet above the channel and may, in a few instances, form the tops of a stream canyon.  Nonetheless, they are an integral part of a functioning channel system  subject to board authority.

The best way to determine the aerial extent of a regional board's authority for any given activity is to consult with staff from that board in the early stages of project planning.  This sets up good communications and working relationships between the permitting agencies and the permit applicant and shortens permitting times.

<u>Are there other technical documents, books or materials with additional information that can complement this Circular?</u>

Appendix A of this Circular provides a list of books, government documents and other sources which describe the principles, concepts and methods of stream corridor protection management and restoration.  Consultants who specialize in watershed management and restoration should be (or become) familiar with these reference documents.

# CHAPTER TWO: THE CONCEPTUAL FRAMEWORK: NATURALLY STABLE STREAMS ADDRESS MULTIPLE NEEDS

## Avoiding Excessive Erosion and Deposition

The purpose of this Circular is to provide a consistent, logical and easily understood system for agency staff and project sponsors/consultants to evaluate proposed projects that may affect stream corridors. The conceptual framework, which provides this consistency, is the recognition that we attain the goal of healthy, non-degraded stream systems by protecting and restoring a balance amongst the naturally occurring variables that affect the stability of stream corridors. The variables we are most concerned with here involve the proper width of the channel, the proper depth, a functioning corridor of plants, and a channel slope in balance with the stream valley's slope and channel sinuosity (channel length). These variables are all affected by the sediment supply to the streams. An easily discernible condition of "destabilization" is a stream corridor that is already or is about to be subject to excessive erosion and/or excessive deposition and has or will have a degraded vegetative corridor along its banks, floodplain and terrace slopes.

Potential watershed and or stream channel disturbance activities can be linked to specific reactions that watersheds and streams make in response to them, thereby causing a predictably undesirable environmental degradation. A simple and common example of an activity that destabilizes a stream channel is the narrowing of a channel by adding riprap, retaining walls or some other "hardscape" to stream banks. The channel, which is now too narrow, will compensate by eroding deeper, with the frequent consequence of eroding the streambed out from under "hardscapes"intricately placed on stream banks to protect them. The hard materials, such as rock and concrete, then collapse into the channel, causing further impacts and requiring additional expense. This commonly occurring situation would, of course, represent excessive erosion. The condition of excessive deposition can be caused by a number of watershed and channel conditions, but a common example is represented with the situation where a culvert has been placed too high in a stream channel crossing, such that it acts as a partial dam, slowing and trapping the sediment being transported by the stream and filling the culvert and stream channel.

Regulatory, restoration, stream protection and grant programs have the common objectives of preventing impacts to stream stability and/or restoring stream stability. This Circular, then, directs its user to avoidance and corrective measures, which can be applied, in order to prevent or reverse degradations. It is important to repeat that this Circular does not intend to provide specific design solutions to replace or modify project proposals. Rather, the Circular is intended to provide both a step-by-step project evaluation process and a step-by-step planning process to avoid unnecessary impacts to stream corridors and prevent implementation of well-intentioned but counter-productive stream modifications.

**Integrating River Science and Engineering**

Many engineers and environmental planners are familiar with what is being referred to as the "geomorphic approach" to stream and river management. The term "geomorphic" is derived from the discipline of fluvial geomorphology, which is the study of how water forms and changes the physical features of the earth. An easy to use shorthand for "geomorphic approach" is the "river science approach", which recognizes how the behavior of streams is related to watershed, streamside and in-stream channel conditions. In the past two decades, river engineering, or the modification of streams and rivers for flood, erosion control, and stormwater management, has undergone a substantial advancement. This advancement has involved improving the conventional tools used by hydraulic engineers who specialized in converting natural river systems into engineered canals, by combining the analytical concepts contained in hydraulic models with natural river science.

River scientists understand how the natural components of river systems, including watershed conditions, valley and channel slopes, low water discharges, as well as flood discharges, channel meanders, riparian vegetation, sediment loads and transport, affect the outcomes of human interventions on rivers, their floodplains and watersheds.

Federal water project planning and design documents have provided a new set of design criteria for river management projects on the basis of the integration of the two fields of hydraulic engineering and fluvial geomorphology. This represents a major engineering design paradigm shift in which the old assumption was that environmental features of rivers, such as streamside vegetation, meanders and floodplains, conflicted with hydraulic engineering practices and objectives. The newer river project design context is that natural stream dynamics and features are not in conflict with the hydraulic engineer's objectives of flood and erosion control, but that these environmental components must be integrated with hydraulic engineering to produce the best multi-objective design solutions.

Hydraulic engineers and river scientists have arrived at a mutually supporting definition of channel stability which is the overall principle supporting this Circular. A channel is considered to be in balance - or in "equilibrium" - when the sediment supply entering a stream channel is approximately equal to the sediment supply exiting the stream system. This is another way of expressing the concept that there is not excessive erosion or excessive deposition. At the same time, different "schools" of river planning and management have developed to help guide management and design practices to meet this equilibrium objective. Some practitioners emphasize or are more comfortable with one or more schools, but they can all be successfully combined and work in a complementary manner.

These schools or approaches to river protection, management and restoration include those who apply regional information on the "hydraulic geometry of river channels" to arrive at stable channel designs. This is often referred to as the "empirical school" because it is based on field observations and measurements of river channels, their discharges and shapes. This school recognizes, for example, the physical relationships, which frequently exist between the stable dimensions of river channels and their discharges, and the sizes of drainage areas of the rivers. It recognizes other physical relationships such as the widths of stream channels with the lengths of channel meanders, the spacing of pools and riffles and shapes of meanders.

Another school of river study and management focuses on watershed processes and relies on an understanding of how the changing relationships between stream discharges, sediment quantities and sizes interact to affect the degradation or aggregation of channels and stream slopes. This school can develop simple or complex models of how watershed conditions such as precipitation, discharge, sediment, geology, soils, slopes, vegetation, land use changes and channel modifications can affect river channel reactions over time.

A third school applies quantitative analytical models to estimate flood discharge and stage relationships, the sediment budgets affecting river channels, and sediment transport conditions. This is the domain of hydraulic engineers who apply continuity, flow resistance and sediment transport equations to describe the forces operating on river dynamics. This discipline is creating a new generation of more complex models that help support the paradigm of restoring the natural functions and features of rivers. For example, new modeling tools such as two-dimensional models are helping us understand more about the interactions of flows between river channels and floodplains.

Finally, a fourth evolving school entails the classification of watershed or river types to help organize information on river channels and better apply it to the design of healthy, in-balance river systems. Classification schemes apply information from the empirical and watershed process schools to address river restoration and management problems. A concept derived from this school is the use of information from stable channels to correct instabilities in the same kinds of channels that are in degraded condition. This is referred to as the use of "reference" channels.

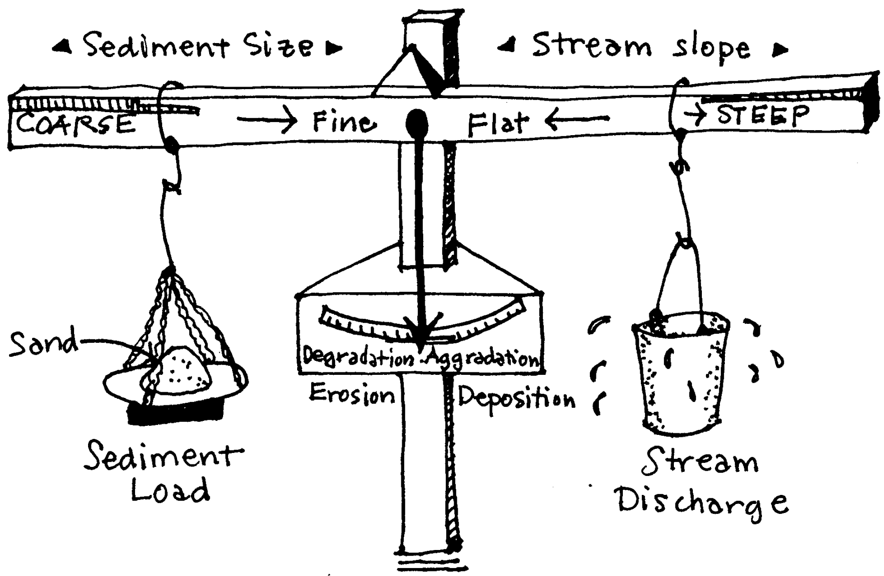
This Circular is intended to support without prejudice recognition of the positive contributions of all these schools of river management. The planning processes described by this Circular can employ one or all of these schools in any combination.

**The Concept of Stable Channels**

The stability of stream channels is directly linked to the water quality of our waterbodies. The first task, therefore, is to describe what is meant by the concept of "stability." The term "stability" as this Circular uses it describes a condition in which the sediment sizes and loads, water discharges, and channel shapes and slopes are in balance.

This balance is often referred to as an "equilibrium" condition among the variables, which interact to determine the stream system. These variables include the stream valley slope, stream channel slope, sediment loads, sediment sizes, discharges, roughness of the stream channel, and bankfull channel widths and depths. Figure 1 shows an illustration frequently used to describe this concept of equilibrium, called Lane's Scale.

**Figure 1. Lane's Scale**




Lane's Scale
A.W. Lane, "The Importance of Fluvial Morphology in Hydraulic Engineering," Proceedings of The American Society of Civil Engineers, Vol. 81, No.745, 1955

A widely accepted way to apply the concept of equilibrium to a stream channel is to establish that the sediment loads entering a channel are equal to those leaving it. The term “graded stream” is often used interchangeably with the phrase “a stream in equilibrium”, and refers to a stream where, over a period of time, its slope and channel characteristics have adjusted so that the available water discharges have just the energy and velocity required for the transportation of the sediment load from the drainage basin. The condition of this equilibrium or stability can be viewed over a long-term scale in which channels take years to make adjustments to ever changing watershed conditions.

Equilibrium can also be viewed as a short-term objective, in which the goal is to avoid excessive erosional and depositional instabilities. In this short-term context, it is easy to identify the channel that is unstable and not in equilibrium. An unstable channel is one in which deposition requires regular removal and dredging maintenance programs to protect channel capacities and habitat or fish passage. An unstable channel is also one in which its banks are collapsing, or the bed is eroding down at a rapid rate.

In the past, conventional engineering practices have attempted to attain “stable” channels by applying channelization, levees, floodwalls, concrete or gabion retaining walls, riprap, rock, sheet piling, rubble, weirs and grade control structures to channels. The logic of “locking” the channels into an immobile condition to avoid the influence of the natural forces and variables acting on the behavior of streams has been reevaluated as a result of observing several decades of stream responses to this concept of stream channel control. The natural response of channels in reaction to these controls has been to undermine the very structures meant to accomplish the stabilizing. Concrete has cracked and failed, grade control structures have induced erosion and collapsed, and streams have eroded around bank protections. The stream responses have been consistent enough over time to demonstrate how conventional engineering techniques, such as channel straightening, culverting, grade control structures, vegetation removal, floodplain encroachment, riprap, etc., can in fact lead to unintended and undesirable stream instabilities. The system described here therefore recognizes a more sophisticated and effective path to “stream stability” that works with the inclination of the natural variables to create stability as opposed to employing the counter-productive strategy of trying to overcome the natural processes of streams.

The conceptual framework for the criteria contained in this Circular follows the guidance provided by a coordinated effort of fifteen federal agencies, which produced a stream restoration manual in 1998 ("Stream Corridor Restoration, Principles, Processes and Practices," by the Federal Interagency Stream Restoration Working Group, coordinated by the Natural Resources Conservation Service). It is also consistent with guidance from recent U.S. Army Corps of Engineers' memoranda and reports. Among these reports is, "Stream Management," by J. Craig Fischenich and Allen Hollis, March 2000, Army Corps of Engineers. Appendix A includes a more complete list of supporting publications.

## CHAPTER THREE: THE LINKS BETWEEN CHANNEL STABILITY AND WATER QUALITY

The protection of water quality and aquatic ecosystems is not possible without protecting the equilibrium among the components and various processes making up a stream system. To restore water quality to a stream, not only do we need to control pollutants, such as stormwater runoff and industrial and sewage treatment plant discharges, at their source, but we also need to assure the existence of the natural structural components of a stream. Such natural structural components include stream bed and banks, streamside vegetation, in-channel pools and riffles, channel flows or discharges, the transport of sediment, and the adjustment of channel slopes. These features and activities are required to create the in-channel habitats and conditions necessary for aquatic life to survive. These stream channel components, or "stream-structures" and stream "processes", make the beneficial "functions" of streams possible. These functions include conveying low and high flood discharges, moving sediment eroded from the watershed, providing reliable water supplies for human and wildlife needs as well as in stream aquatic organisms, moderating water temperature, turbidity and nutrient loading (especially nitrogen and phosphorous), protecting dissolved oxygen levels, moderating pH and biochemical oxygen demand, and providing food and habitat for aquatic and terrestrial wildlife.

Research[2] has indicated that prevention of water quality problems is very difficult without these natural systems and processes influencing the streams. Water quality in pipes, concrete channels and unstable eroding channels is consistently measured at lower levels then naturally stable channels. The water quality is low because the natural "treatment" functions of the healthy stream are lost: control of excessive soil loss and temperature, control over excessive sedimentation, uptake and recycling of nutrients, control of excessive aquatic plant and algae growth, and aeration of water with oxygen. Therefore, when a regional board protects these functions, it is protecting not only the beneficial uses of creeks, streams, rivers and associated wetlands, it is also preventing the

[2] An excellent summary of this research is contained in The Practice of Watershed Protection, Center for Watershed Protection, Ellicott City, Maryland.

degradation of the physical and chemical water parameters used to quantitatively determine the quality of water.

The stability of stream channel corridors cannot be separated from the overall condition of the watershed in which they are located. While localized conditions are often responsible for channel stability or instability, it is common that upper watershed conditions contribute to destabilizing hydraulic conditions and sediment loads. A common example is that upstream watershed erosion transports excessive sediment supplies to lower reaches. Frequently, downstream channel or watershed conditions also influence the stability of upstream channel reaches. A common example of this kind of impact occurs when the elevation of the stream bed is lowered to install a culvert, which then causes an up-channel slope adjustment through headcutting erosion as the stream adjusts to a new lowered "base" elevation at this downstream location.

It is of course desirable for the regulator and program manager to try to address up and downstream watershed influences. Optimally, there will be increasing opportunities to conduct coordinated and cumulative watershed assessments in lieu of project-by-project assessments. For most small and moderately sized projects, it is difficult to extend the influence of project applicants far beyond the up- and downstream boundaries of their properties. However, by following these guidelines to channel stability, the projects that are implemented will often have greater ability to successfully respond and adapt to problems of increased watershed discharges and/or sediment loads and will exhibit greater resiliency to existing or future land use impacts on the watershed.

## CHAPTER FOUR: AVOIDING THE COMMON CAUSES OF INSTABILITY

River and stream managers practicing in both urban and rural environments report their frustrations in applying the just described “geomorphic “ principles to channels already impacted by land uses such as logging, mining or the ubiquitous over-urbanized stream corridors in which structures have encroached too closely to floodplains and channels. How does this Circular address these difficult realities?

Because land use changes often make irreparable long-term changes to watersheds, our stream management objectives cannot usually include the return of an environment to its historic conditions. In Chapter Two, “ The Conceptual Framework,” this Circular described our stream management objectives to protect water quality as the protection or restoration of natural stream “structure” (e.g., channel shapes, meanders, pools, riffles, streamside vegetation, etc.), stream processes and functions (e.g., transport of sediment, conveyance and storage of flood flows) and stream dynamics (e.g., relationships among discharges and sediment deposition and transport, and relationships of vegetation to in-stream habitat and temperatures). Experience in different settings has indicated that even though the restoration of historic environmental conditions may be difficult or impossible, we can nonetheless improve the natural structure, functions, and dynamics of streams. This in turn helps protect and restore water quality.

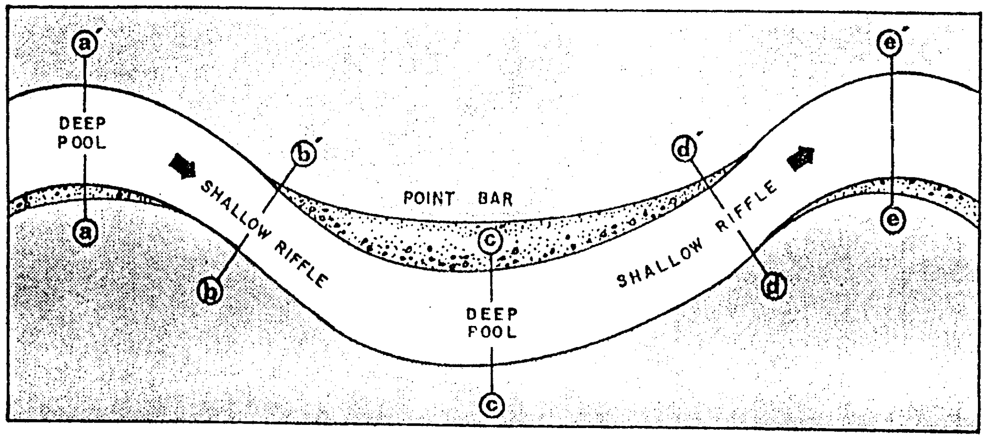
Avoiding stream degradation and improving the quality of streams therefore becomes an achievable, practical objective, even in the center of densely developed cities! Stream shapes can be modified so that they efficiently move their sediment loads without resulting in excessive erosion or deposition. The stream lengths and slopes can be corrected to be better matched with the slopes of the stream valleys. The “boundary” conditions of stream channels can be improved by revegetating them. These three measures, providing stable active channel widths and depths, providing for channel slopes and lengths in balance with their valleys, and providing a vegetated channel boundary along stream channels, will significantly improve the stability and quality of the stream environment while giving more resiliency for the environment to absorb and react to future watershed changes and disturbances.

Chapter Seven of this Circular includes various stream impact avoidance tables. These tables are designed to help organize your thinking about how to identify potential impacts to the stability of stream channels and how to avoid these impacts. This section intends to prepare you for the use of these tables. A table developed by the Federal Interagency Stream Restoration Working Group (Table 2) is reproduced in this Circular because it nicely summarizes the potential effects different land uses and projects may have on the stability and environmental quality of stream channels. Table 3, "Channel Modifications and Responses," lists how these land use activities are frequently translated into physical changes in streams. These physical changes commonly are stream channel filling, widening and straightening, stream bank hardening, stream slope grade control structures, culverting, diversion of flows, and loss of floodplains, vegetation and woody debris. Table 4, "Degraded Channel Conditions," groups these reactions of streams to land use changes and channel modifications into three channel instability categories we are trying to avoid: excessive erosion, excessive deposition, and degraded channel boundary conditions. Table 5, "Avoidance and Corrections of Impacts" indicates what measures can be taken to avoid these three undesirable conditions. The following discussion describes what field observations of excessive erosion, excessive sedimentation and degraded boundary conditions look like.

**Excessive Erosion**

What It Looks Like

Erosion is a natural and healthy on-going process in stream channels. Without some erosion of the beds and banks of stream channels, there would not be the natural features of streams that support aquatic life. The healthy transport of sediment from streambeds or banks or "healthy erosion" is responsible for the formation of stream channel length and meanders, pools and riffles, and hiding places for fish and other aquatic species under banks. Refer to Figure 2.



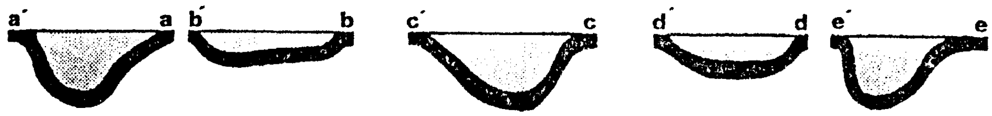


**Figure 2. Features Formed by Erosion and Deposition**

Erosion that destabilizes stream channels produces accelerated erosion in which the stream widens or deepens by several or many feet in only a few storm flows. In these situations, you may see large numbers of trees falling over into the channel. Many of the remaining trees have a significant amount of soil eroded out from under their roots. Stormwater pipe outfalls that used to be positioned near the bottom of the channel are now perched high above the channel bottom. Culvert headwalls or other retaining walls are collapsing with the stream channel cutting around them. Sections of stream banks break off and fall into the channel (leading to an excessive sediment contribution to the stream). Stream banks undergoing excessive erosion are too unstable to allow for the recolonization of plant life and so remain devoid of vegetative cover.

There are many cases, of course, in which there is not excessive erosion of a stream bank if we are viewing the process of erosion as a natural one. However, since this natural, "healthy erosion" may be in conflict with a structure too close to a channel, it is considered problem erosion. In these situations it is appropriate to evaluate the advantages of relocating the problem structure against the disadvantages of creating long term channel instability problems by bank hardening for the property as well as for streamside property owners located on the opposite bank and up and down stream.

Common Causes of Excessive Erosion

One of the most common causes of excessive erosion in streams is the introduction of greater discharges in relation to the sediment loads (refer to Figure 1, Lane's Scale). These increased flows often occur as the result of adding new stormwater pipe outfalls, which drain new development sites to a creek channel. The removal of small headwater channels by fill or culverting to accommodate development concentrates stormwater runoff into fewer channels or small smooth pipes, thereby eroding downstream channels into larger ones.

The other most common cause of excessive erosion of stream channels is the placement of hard structures and materials such as concrete, retaining walls, gabions, rock, sheet-metal, etc., to "save" stream banks from erosion. These well-intended "remedies" are actually counterproductive, because hardening and smoothing the banks creates erosional eddies at the up and downstream ends of the structures and often deflect erosive flows into the opposite bank. Frequently, these structures narrow the active (bankfull) channel and force the channel to make up for the lost cross-sectional area by eroding deeper and or wider. The channel typically responses to this hardening by undercutting the very structures intended to stabilize the stream. Without distinction between rural and urban river channels, the observer can view the remnants of riprap, concrete retaining walls and pieces of gabions strewn along riverbeds which came in conflict with the stable widths, depths and slopes of the river.

The other most common causes of excessive stream channel erosion are the straightening of channels by the removal of meanders. This shortening of channels means the channels travel to a downstream elevation in a shorter distance creating a steeper channel. This steepened channel has more erosive power and uses this power to compensate and reflatten its slope. This process can entail the development of in-channel head-cuts in which the channel erodes down its bottom, and this channel lowering or incision works its way up the stream channel. The channel may also attack its banks in an effort to recreate its meanders. Refer to Figure 3.

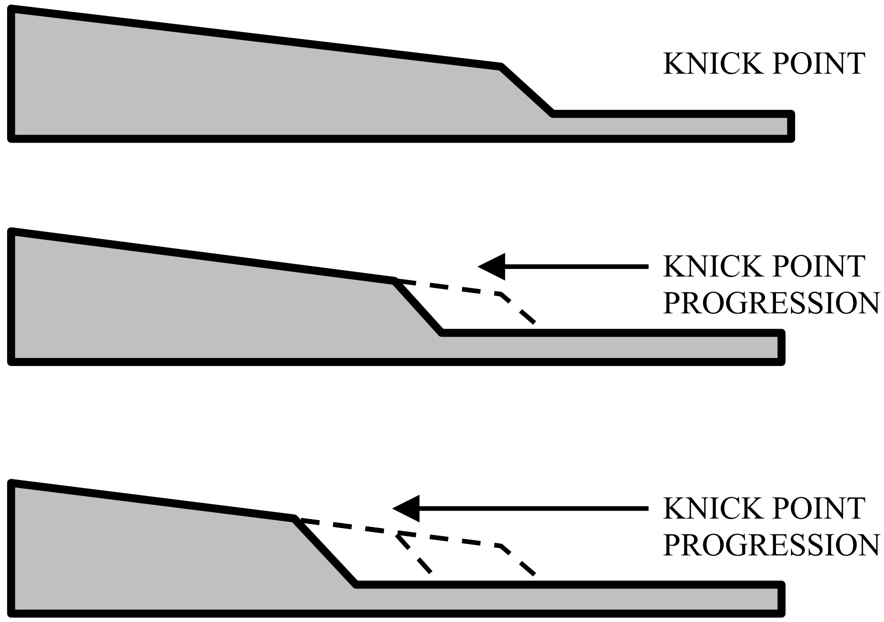



**Figure 3. Channel Headcutting**

**Figure 3.  Photo A**

**Figure 3. Photo B**

**Figure 3. Photo C**

Photos A, B, and C - **Examples of Headcuts**

The California landscape commonly contains what is referred to as incised or entrenched stream systems. Historic photos of streams in the Bay Area from the later 1800's to the early 1900's show that the bottoms of stream channels are much higher in the landscape, with the ground adjacent to the streams receiving frequent over bank flows. Natural phenomena including climate changes and tectonic–seismic movements of the earth have resulted in the channels eroding down through the soil mantle; this lowering of the channels relative to their old flood plains continues in many Bay Area watersheds. This process can be induced or accelerated by land use changes as well. This landscape type, in which the old abandoned floodplains can now be as much as 20-40 feet above the channel, confines a channel within narrow terrace banks so that the flood flows which once spread out are now concentrated in a smaller cross-section. Because this is a widely occurring process, the presence of incised or entrenched streams should not automatically set off alarms to do something about them. In situations where the incision is lowering the channel at a rate of several feet a year and system wide bank collapse is occurring, intervention can be merited.

Related to this issue, is the confinement of flood flows by artificial levees, berms or floodwalls. Because of the unnaturally intense erosive powers of these confined and concentrated stream flows, it is typically difficult or impossible to retain a stable vegetated corridor along the stream channel.

Finally, in the category of well-intended, but frequently counterproductive, channel stabilization measures are the use of grade control structures and or sediment basins to catch sediment and or "control" the elevations of stream bottoms. Unless designed with adequate information and forethought, grade control structures such as weirs, check-dams, groins, etc. can flatten channel slopes and stimulate unanticipated channel meandering that cuts around these structures, often damaging the structures in the process.

If sediment basins are not designed with a good understanding of what the stable balance is between sediment load and size and stream discharges, it is not unusual for these basins to be responsible for very damaging downstream erosion. This is because a stream discharge which has just had a significant portion of its sediment removed produces a condition commonly referred to as a “sediment starved” stream, and the stream will pick up sediment from its banks and beds until its sediment load, discharge and channel slope are in balance again. In-channel aggregate mining can produce the same starved channel effect downstream of the mining areas.

**Excessive Sedimentation**

What it Looks Like

The deposition of sediment into stream channels is as natural and healthy a process as the transport and erosion of sediment just described. Natural depositional features in streams include point bars, riffles, floodplains and even natural levees (refer to Figure 2).

In flatter gradient, low energy stream systems, unstable stream banks may collapse into a stream channel, and much of the sediment remains in place for a long enough time to fill in a section of the channel bottom. Sometimes this contributes towards the channel forming a new shape. Often the channel needs to readjust to a larger shape and it widens, contributing to even more bank erosion and failure. In some circumstances, such as when the active channel is over-widened by a channelization project, the channel may reform a smaller active channel within the over-widened area. In steeper coastal streams typical of the San Francisco Bay Area, however, the sediment from failing stream banks usually does not remain in place but is transported downstream over a relatively short time to the Bay or the Pacific Ocean. Sediment transported to the mouths of rivers can help nourish marshes and beaches and coastal estuaries. However, this accelerated sediment transport to the mouths of streams can build depositional deltas that can fill or degrade these coastline environments.

Sedimentation may occur in floodplains as well as in active channels. Floodplains are depositional features and well suited for sediment and woody debris storage. The river project planner should design with the objective of keeping sediment transported through active channels and rely on floodplains to trap, store and move sediment loads along the river corridor. Excessive sedimentation of floodplains can result in active channels loosing their frequent over bank cycles of flooding and degrade the health of riparian habitats. This occurs because the over bank stream flows become less regular and groundwater tables are much lower in elevation from the now higher surface of the floodplain. Concentration of larger flows in the active channel caused by the higher floodplains can also result in undesirable channel erosion and incision. In extreme cases, floodplains can acquire so much sediment the elevations of the floodplains are higher than the surrounding landscape, and river flooding can become very destructive to floodplain inhabitants.

The Common Causes of Excessive Sediment

Excessive sediment loads are not caused only by failing stream banks. The worst sedimentation problems can be caused by the introduction of sediment from logging, mining, agricultural and construction practices, or activities of man. In the context of Lane's Scale, the balance between increased sediment load and discharges is changed. Note that the shift in sediment sizes from smaller to larger also affects the aggradation and local flattening of a stream channel slope. Both the increase in sizes of sediments and increase in amounts can affect what is referred to as the "competency" of a stream to move larger sediments and its "capacity" to move greater amounts of these sediments. If the ability of the stream to move sediment has been overwhelmed by the increases in sizes and or amounts, the stream will typically drop the sediment in the channel, causing in-channel sediment bars, and the formation of multiple, migrating channels. These unstable, migrating channels can lead to extensive bank erosion.

A classic example of a land use which has overwhelmed California rivers with sediment has been mining done in a manner to cause large-scale erosion of watershed lands. Mining-caused sediment has filled stream and river channels and floodplains in much of California, so that the shapes and slopes of river channels and elevations of floodplains have been significantly changed for a long period of time. San Francisco Bay residents still live with the legacy of mid-1800's mining activities in the form of toxic mercury and heavy metal-laden sediments deposited on the bottoms of rivers, streams and the Bay. Contaminated Bay and creek sediments have impacted our ability to safely eat seafood and have made it difficult to restore some of the Bay's creek environments.

Excessive sediment has a long list of undesirable impacts. They include the smothering of stream benthic organisms and fish-spawning areas, increases in turbidity, and accelerated filling of marshes and other wetlands. If stream widening and meandering is increased as a result of an introduction of excessive sediment, the subsequent collapse of riparian vegetation causes habitat degradation and water temperature increases and other subsequent impacts to water quality.

**Degraded Boundary Conditions**

What it Looks Like

Degraded stream boundary conditions are obvious to any observer. Sometimes at its worst there is not a living plant to be seen along a stream channel. Often these situations are accompanied by the ruins of failed bank stabilization attempts with the pieces of concrete, gabions, sheet metal and or rock strewn about the channel bottom. Concrete along stream channels is often broken and failing near the stream bottom because the "hardscape" on the stream banks has caused all the sediment transport to shift to the streambed thereby lowering the bottom of the creek out from underneath the concrete. Sometimes the observer sees the stream in the earlier stages of vegetation losses, in which trees and shrubs are falling over and becoming uprooted.

Stream channels without vegetative cover and shade often support excessive algae growth. The odors and visual effects are easy to note, but the ultimate damage can be the robbing of dissolved oxygen and cool stream temperatures needed to support aquatic fauna.

Degraded stream boundaries can also include too much vegetation of the wrong kind. A ubiquitous example of this in coastal California is the invasion of stream channels by non-native exotic plants such as the giant reed (arundo donax). This invasive plant can take hold in the bottoms of some channels and catch sediment, filling the stream channels. They can crowd out the native species, which contribute to the natural dynamics of assisting sediment transport including the formation of pools and instream habitat niches. Streamside terrestrial habitats can be degraded as well with the loss of the diversity of ecological niches provided by a diverse native riparian woodland.

Common Causes of Degraded Boundary Conditions

Channel disturbances can be so dramatic that they lead to the inability of native plant species to establish permanent residency on the channel banks. These disturbances can include the introduction of extremely flashy flood flows because of watershed development, clearing, grazing, farming or logging operations. These disturbed conditions can create the environments that favor invasive exotic species to move in or the channel may remain with very little permanent vegetative cover.

Frequently the loss of streamside vegetation can simply be explained by its removal by streamside property owners. Usually the removal is done in ignorance as to the consequences this will have on their properties. A common belief is that the substitution of vegetation with a "hardscape" such as concrete, gabions or rock will make the stream banks more stable. Hardscapes can trap water draining to the streams behind them and pore pressure can break through or heave these hard impervious structures. (Note that the addition of engineered "weep holes" to walls does not necessarily address this issue.) Because of the influence of these structures on channel dynamics, they are prone to creating those very erosional conditions that then lead to their failure.

Stream scientists have determined that streamside vegetation has a profound influence on the stability of stream channels. Stream channels undergoing some erosion and depositional changes in which sediment loads and sizes are in balance with the stream discharges and channel slopes may show some localized disturbance of streamside vegetation. However, one of the wonderful qualities of native riparian species is their ability to thrive in the dynamic, ever adjusting stream environments. Willows and cottonwoods live in this front line of disturbance, colonizing and recolonizing stream banks and in the process, protecting their stability against the high velocities of flood discharges. They create enough stability in this challenging environment to allow other plant species to take hold among them such as alders, sycamores, bay and dogwood. Even in situations where new meanders maybe forming, vegetation quickly recovers these erosional sites. However, one of the indicators of an out –of –balance system, as previously discussed, is a channel which cannot support a vegetative cover.

Bare stream banks will tend to erode and widen creating conflicts with streamside land uses. If stream banks are planted, there is a greater tendency for the stream to make any additional adjustments to its size by deepening.  Unlike solid retaining walls, rocks or gabions, plants have the ability to expand their protective structural components, i.e. roots, to deeper levels in the streambed and profile.  Riprap and concrete are easily undercut by unstable, adjusting stream channels but its much harder for a stream to under cut roots because the roots expand to new locations and reproduce themselves in vertical and horizontal directions to fill the voids caused by soil loss.  Unfortunately, structural walls do not have this expansive and flexible capability.  The literature in the evolving field of "soil bioengineering" which is concerned with the stabilization of hill slopes, streams and other difficult environments with plant materials uses quantifiable measurements to conclude that the tensile strength of plants roots can exceed that of concrete.  Research is now being published which indicates the level of resistance of planted stream systems to different values of shear stresses (pressure on stream channel boundaries in pounds per square foot)  (see References and Reading list in Appendix A).

## CHAPTER FIVE: SIMPLE PRACTICES FOR STABILIZING CHANNELS

This chapter has been prepared to provide an easy to understand summary of recommended practices for addressing stream management for the layperson. The owner or manager of small property parcels who is applying for permits because of activities which may affect water quality can use Figures 4 and 5 to avoid counterproductive activities which can destabilize stream channels and to practice helpful stabilizing measures for their streamside property. The following Chapter Seven is designed for use by water agencies, public works departments, consultants and other professionals with watershed management training. Figures 4 and 5 are a useful introduction to Chapter Seven. The regulator may want to encourage the small property manager as well as watershed professionals to venture further into the material contained in this last chapter, once the reader has an understanding of the information presented.

**Common Channel Destabilizing Practices - as illustrated in Figures 4 A - H**

- Over-widening a stream channel can spread out flows so that they have less energy to carry sediment. These channels tend to become sediment traps and because they are filling may "blow-out" wider to accommodate its discharges. Over-narrowing a channel with bank stabilization works often causes bed and bank erosion problems.
- Taking a meander out to make for more usable room on property may backfire because the creek will start meandering more in other sections and or develop a very unstable, steepening bottom.
- Grade control structures have been prescribed to hold the bottoms of stream channels at a desired elevation but these structures often result in unintended channel erosion. Grade control structures are any structures intended to hold or modify the elevation of the bottom of a stream. Frequently, bridge footings and culverts affect the grades of streams. If, for example, a culvert is dropped into a channel so its bottom is below the natural creek slope, the culvert will tend to catch sediment and fill. In the meantime, this lowering of the creek bed can create channel erosion that moves in an upstream direction as shown in Figure 3. If grade control structures such as dams, check dams, weirs, etc. are

put too high in the channel, they will collect sediment and tend to flatten the stream slopes. This flattening of the stream slopes can induce unwanted meandering and destructive bank erosion. Some property owners like to place small rock dams or weirs in their creeks to make pleasant water falls or ponds for waterfowl or swimming. These features can in fact cause a great deal of property damage by creating erosion from unanticipated meander development on the flattened slopes behind the dams. They can cause serious downstream erosion because sediment has dropped behind these dams and the stream is now sending "hungry" water downstream to pick up its missing sediment by eroding the streambed and banks.

- Vegetation removal invites stream bank erosion, as does the placement of hard structures on stream banks. Replacing native species with non-native species often results in failure because the non-natives do not have the unique qualities needed to survive in the very dynamic environments of creeks. The worst-case scenario is introducing plants such as bamboo, English ivy, pampass grass, hypericum, Scotch and French broom and other invasive species that become too aggressive and kill the usefully functioning native vegetation.
- We usually cannot avoid destabilizing a stream if we change the relationship between the sediment loads and discharges. Pumping water from the stream reduces the ability of the remaining stream flows to transport sediment and retain a functioning ecosystem. If sediment is allowed to run off in substantial quantities from agriculture, construction, logging or mining areas into stream channels, the sediment may quickly overwhelm the transport capacity of the stream. This in turn can result in long term excessive channel widening and erosion as well as contribute to nutrient loading, high water temperatures, and destruction of fisheries habitat and migration passage.
- Filling the smaller headwater channels at the tops of watersheds concentrates the storm runoff into culverts of fewer, but larger channels. This concentrates storm discharges into more turbid, erosive flows, and downstream property damages are predictable.

**Figure 4 A**

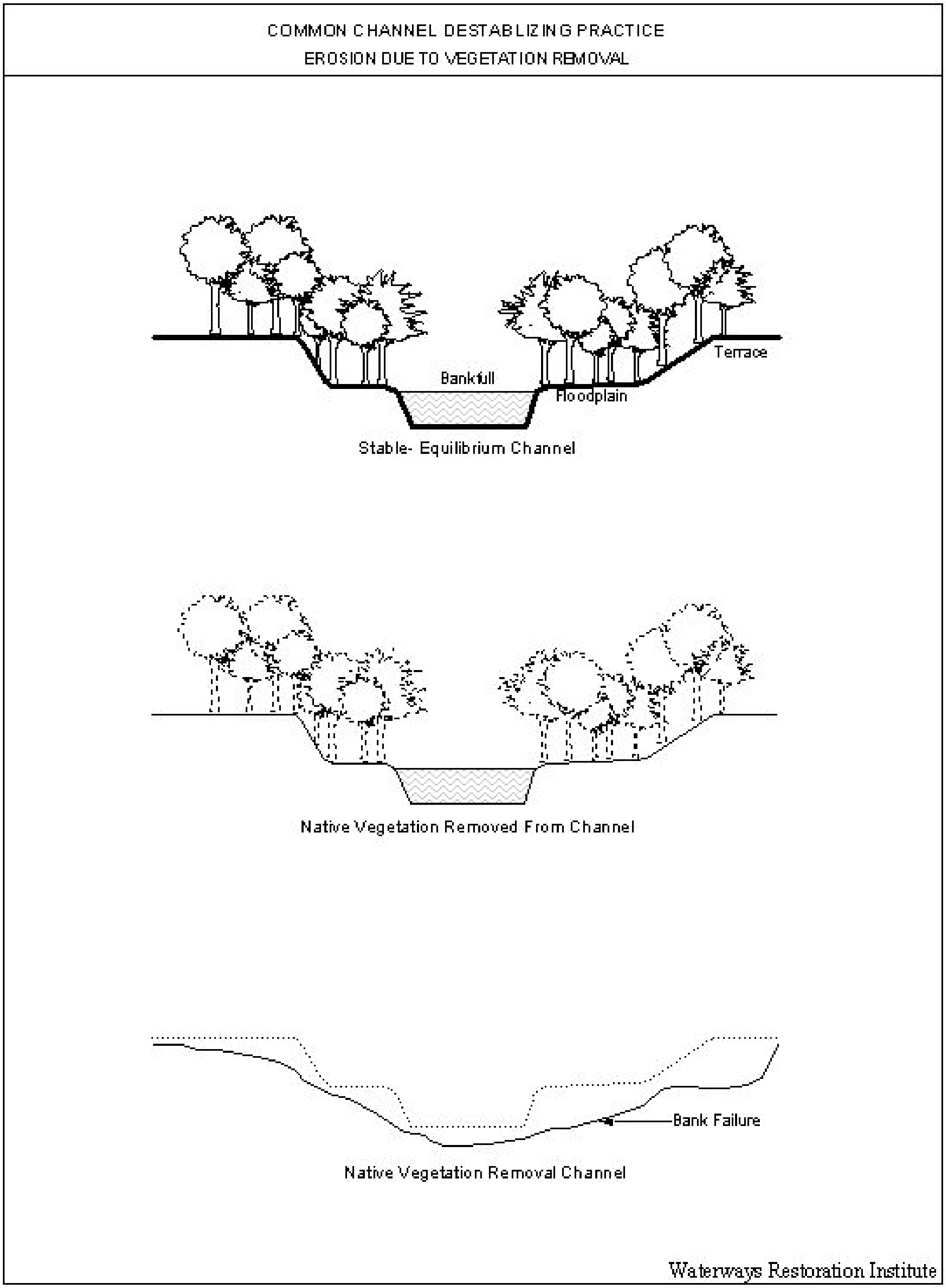

COMMON CHANNEL DESTABLIZING PRACTICE
EROSION DUE TO VEGETATION REMOVAL
Terrace
Bankfull
Floodplain
Stable- Equilibrium Channel
Native Vegetation Removed From Channel
Bank Failure
Native Vegetation Removal Channel
Waterways Restoration Institute

**Figure 4 B**

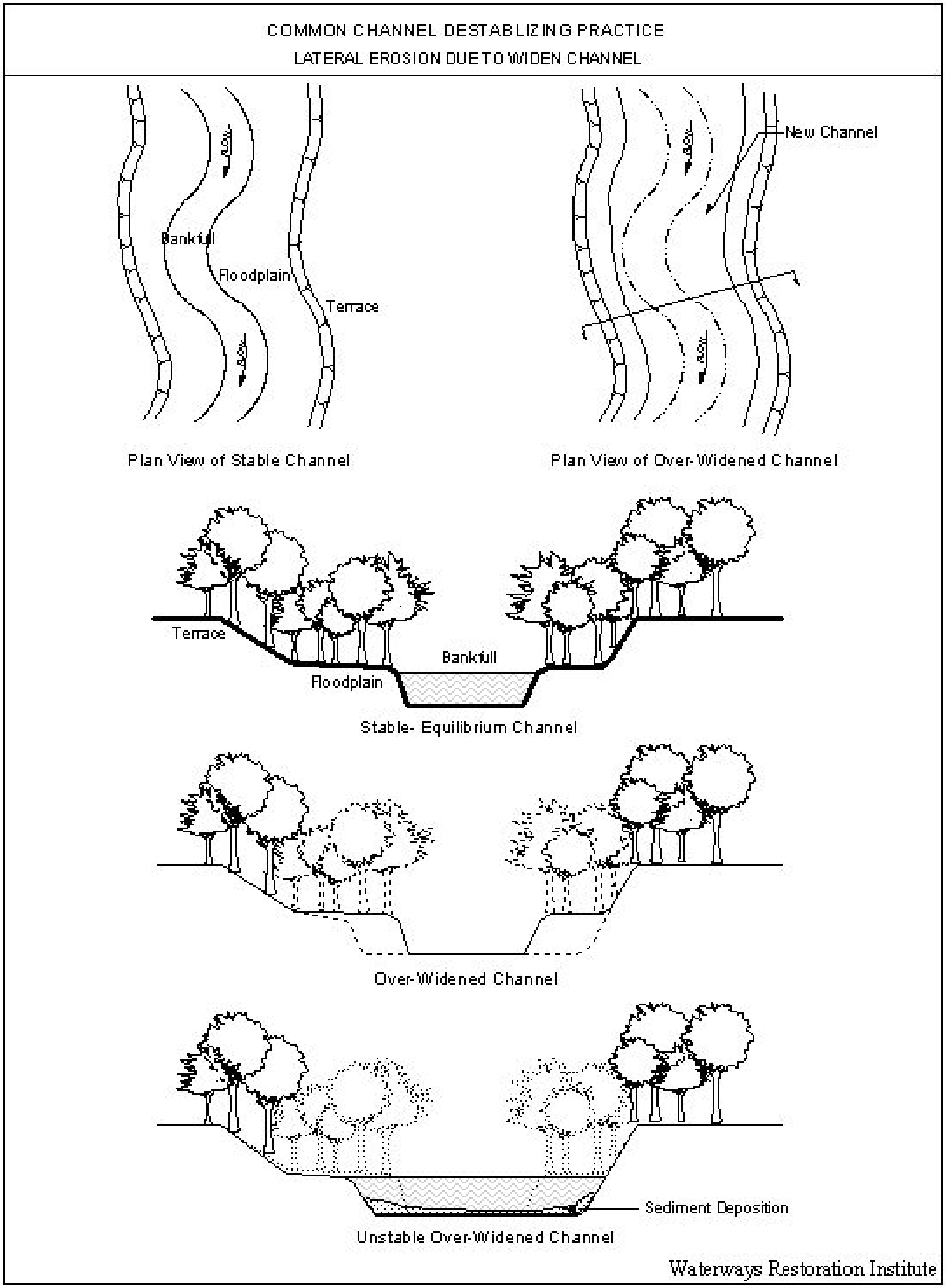

COMMON CHANNEL DESTABLIZING PRACTICE
LATERAL EROSION DUE TO WIDEN CHANNEL
Bankfull
Floodplain
Terrace
New Channel
Plan View of Stable Channel
Plan View of Over-Widened Channel
Terrace
Bankfull
Floodplain
Stable- Equilibrium Channel
Over-Widened Channel
Sediment Deposition
Unstable Over-Widened Channel
Waterways Restoration Institute

**Figure 4 C**

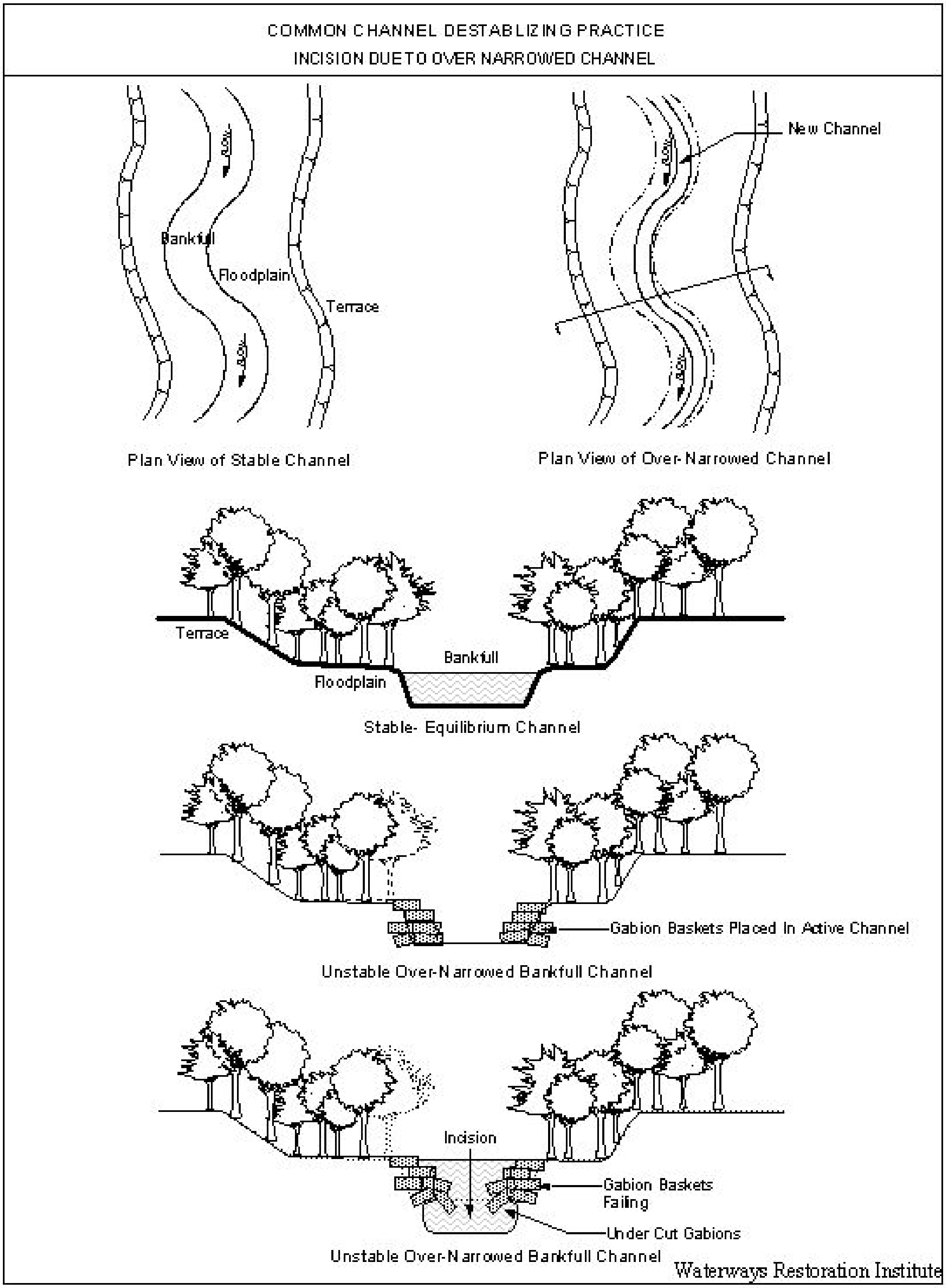

COMMON CHANNEL DESTABLIZING PRACTICE
INCISION DUE TO OVER NARROWED CHANNEL
New Channel
Bankfull
Floodplain
Terrace
Plan View of Stable Channel
Plan View of Over-Narrowed Channel
Terrace
Bankfull
Floodplain
Stable- Equilibrium Channel
Gabion Baskets Placed In Active Channel
Unstable Over-Narrowed Bankfull Channel
Incision
Gabion Baskets Failing
Under Cut Gabions
Unstable Over-Narrowed Bankfull Channel
Waterways Restoration Institute

**Figure 4 D**

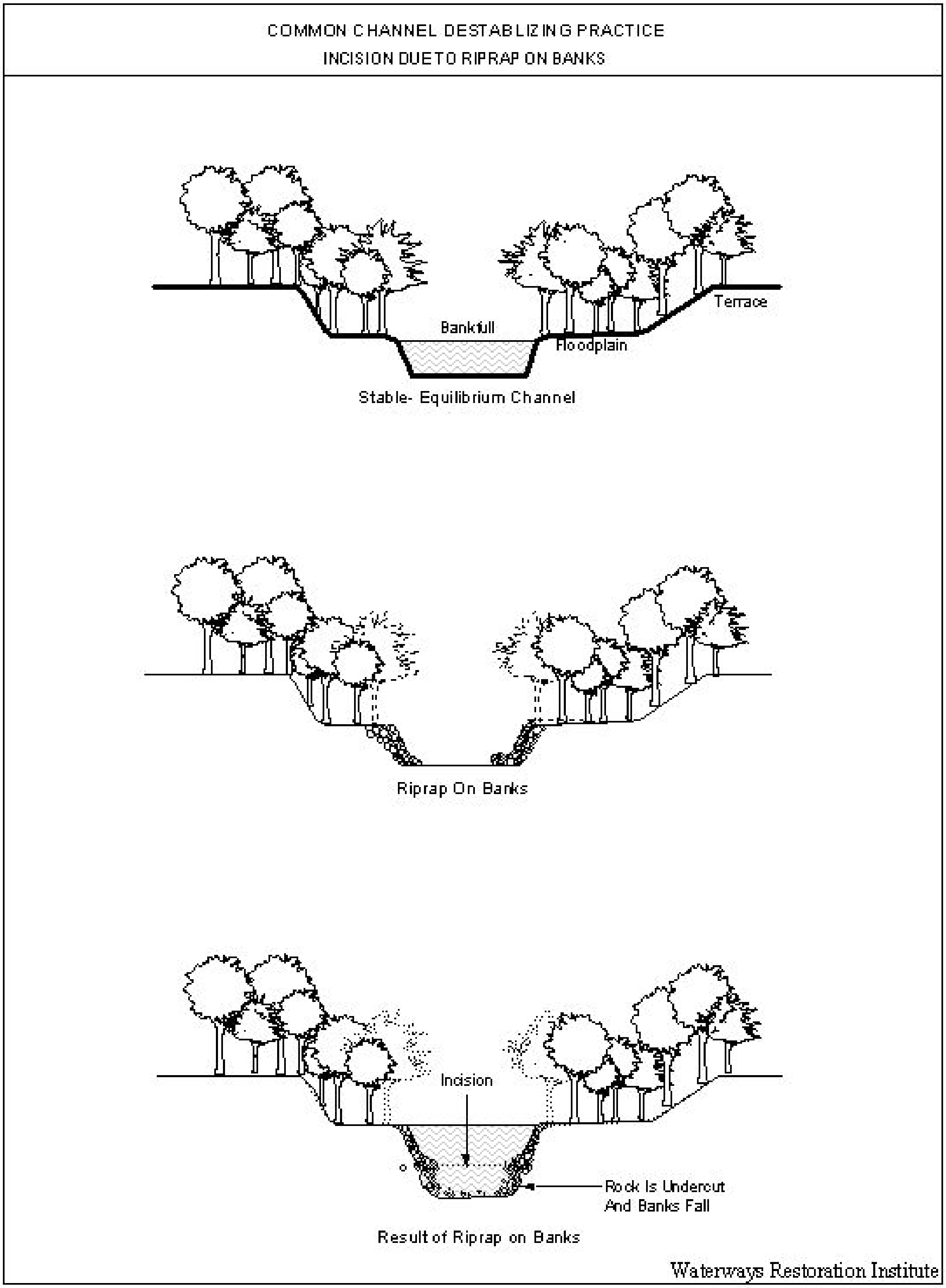

COMMON CHANNEL DESTABLIZING PRACTICE
INCISION DUE TO RIPRAP ON BANKS
Terrace
Bankfull
Floodplain
Stable- Equilibrium Channel
Riprap On Banks
Incision
Rock Is Undercut
And Banks Fall
Result of Riprap on Banks
Waterways Restoration Institute

**Figure 4 E**

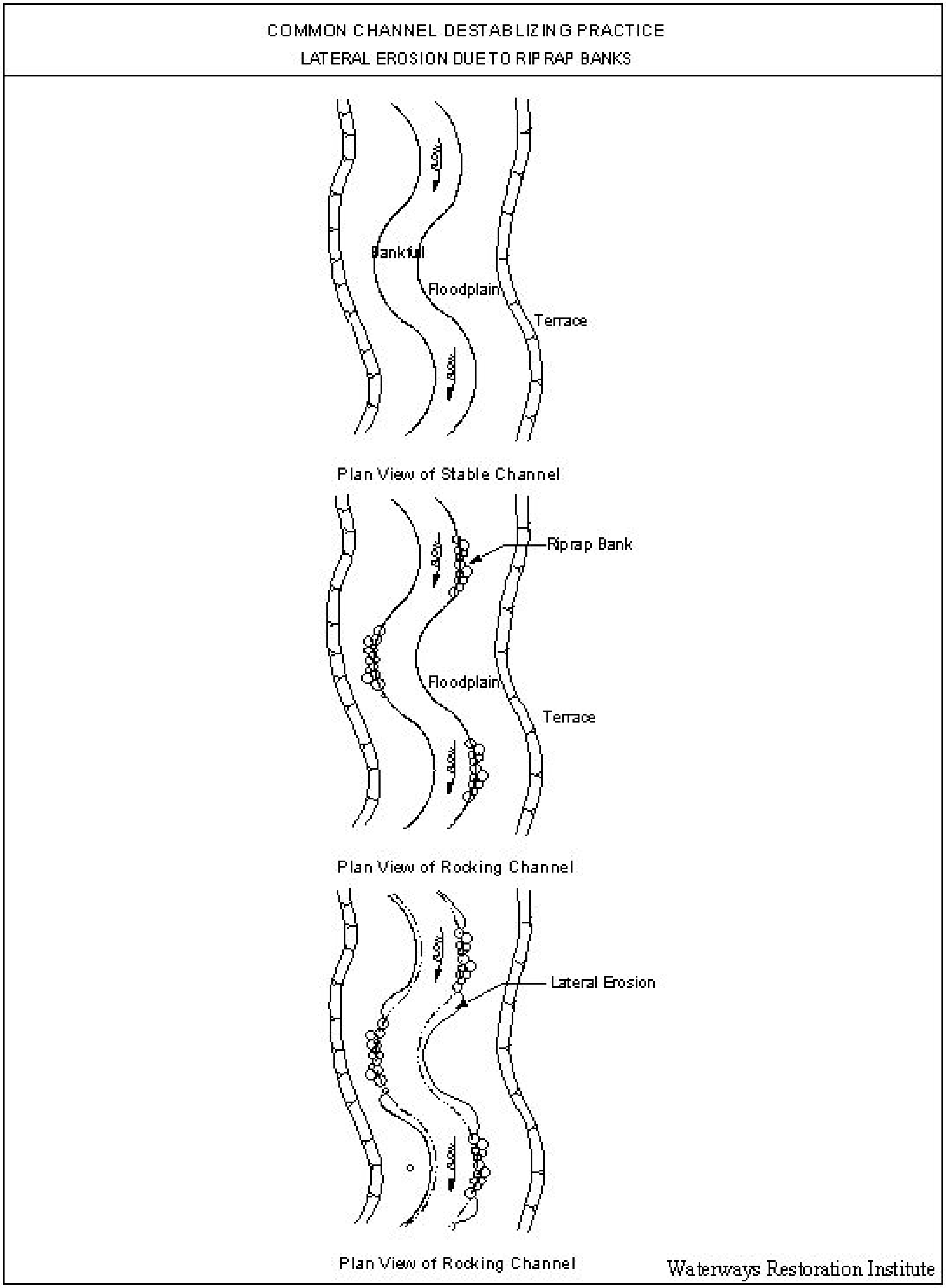

COMMON CHANNEL DESTABLIZING PRACTICE
LATERAL EROSION DUE TO RIPRAP BANKS
Bankful
Floodplain
Terrace
Plan View of Stable Channel
Riprap Bank
Floodplain
Terrace
Plan View of Rocking Channel
Lateral Erosion
Plan View of Rocking Channel
Waterways Restoration Institute

**Figure 4 F**

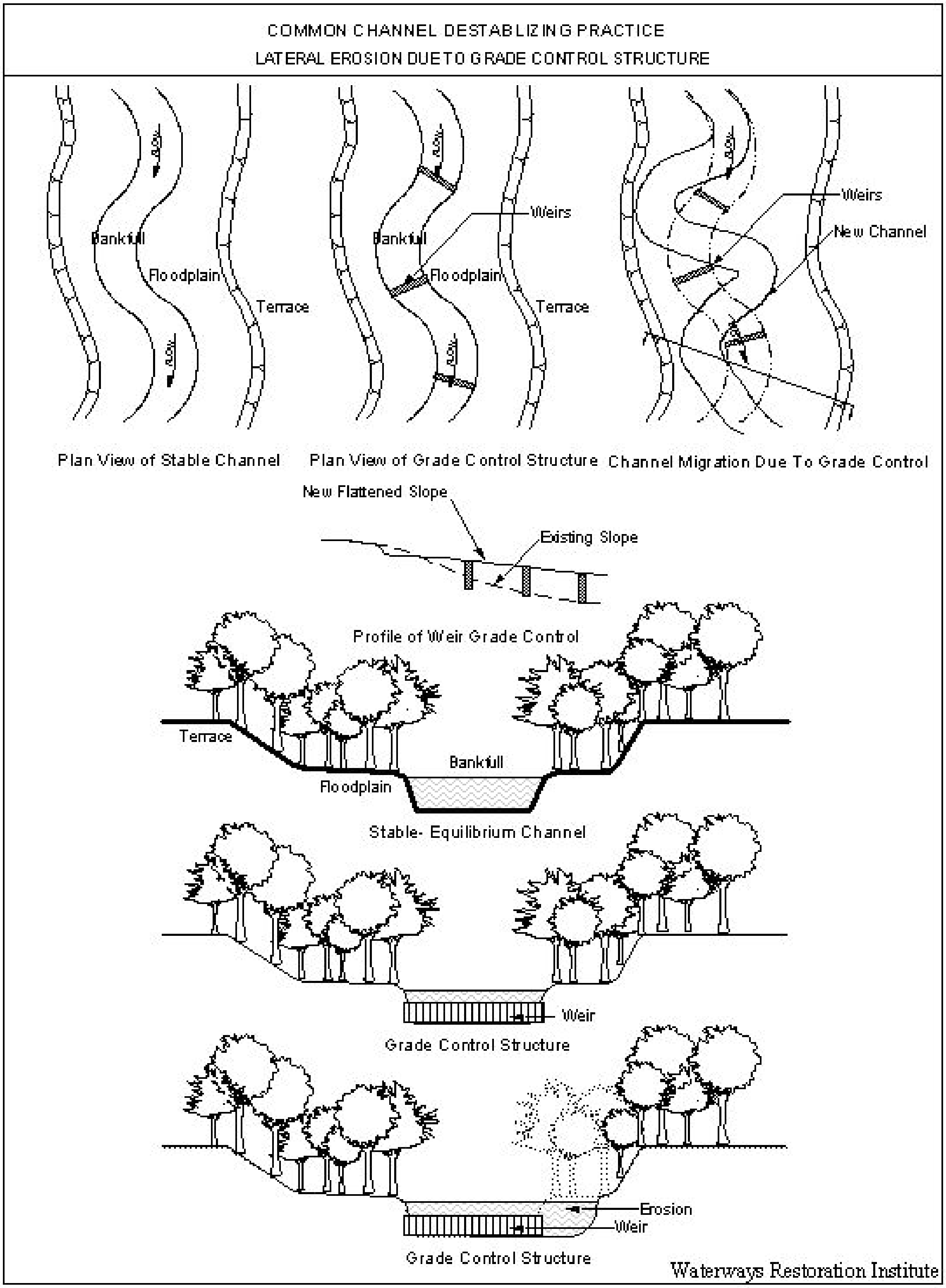
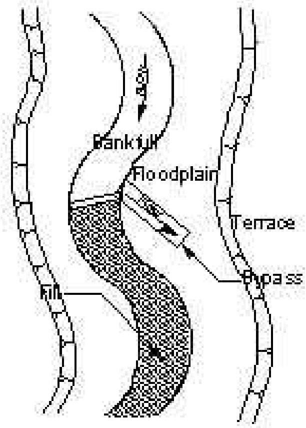
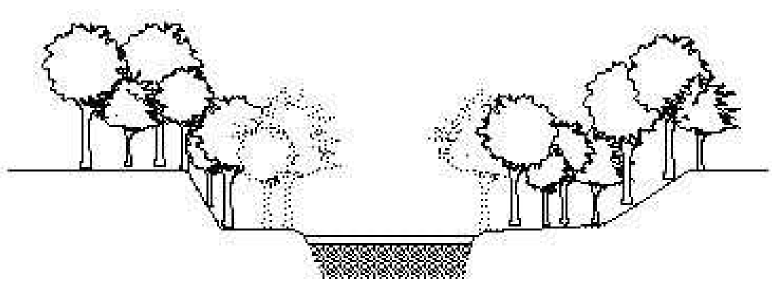

COMMON CHANNEL DESTABLIZING PRACTICE
LATERAL EROSION DUE TO GRADE CONTROL STRUCTURE
Bankfull
Floodplain
Terrace
Weirs
New Channel
Plan View of Stable Channel
Plan View of Grade Control Structure
Channel Migration Due To Grade Control
New Flattened Slope
Existing Slope
Profile of Weir Grade Control
Terrace
Bankfull
Floodplain
Stable- Equilibrium Channel
Weir
Grade Control Structure
Erosion
Weir
Grade Control Structure
Waterways Restoration Institute

**Figure 4 G**

COMMON CHANNEL DESTABLIZING PRACTICE
DIVERSION OF FLOWS



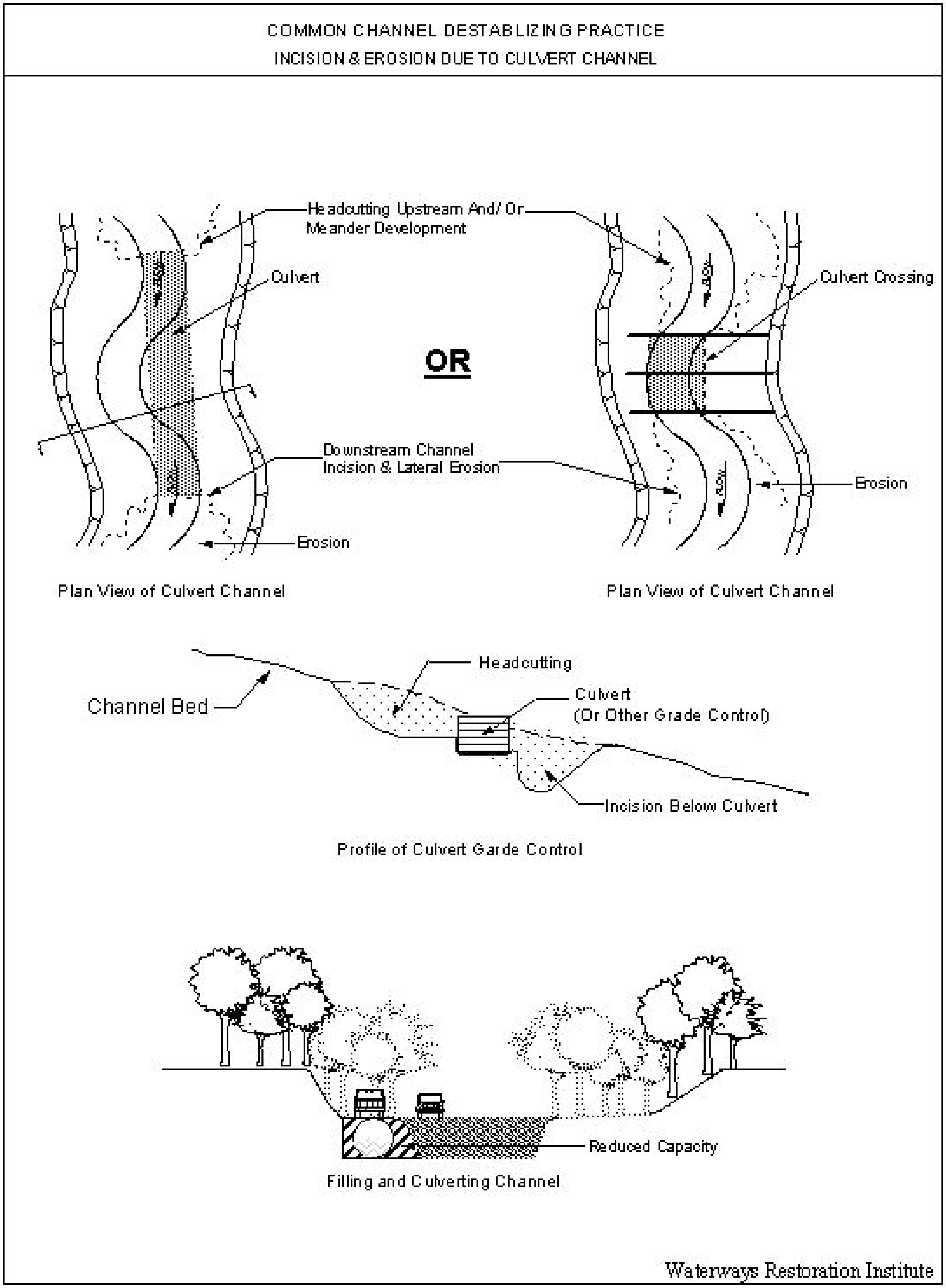

Plan View of
Diverting Flow Channel



Diverting Flows

Waterways Restoration Institute

**Figure 4 H**


COMMON CHANNEL DESTABLIZING PRACTICE
INCISION & EROSION DUE TO CULVERT CHANNEL
Headcutting Upstream And/ Or Meander Development
Culvert
OR
Culvert Crossing
Downstream Channel Incision & Lateral Erosion
Erosion
Erosion
Plan View of Culvert Channel
Plan View of Culvert Channel
Headcutting
Channel Bed
Culvert
(Or Other Grade Control)
Incision Below Culvert
Profile of Culvert Garde Control
Reduced Capacity
Filling and Culverting Channel
Waterways Restoration Institute

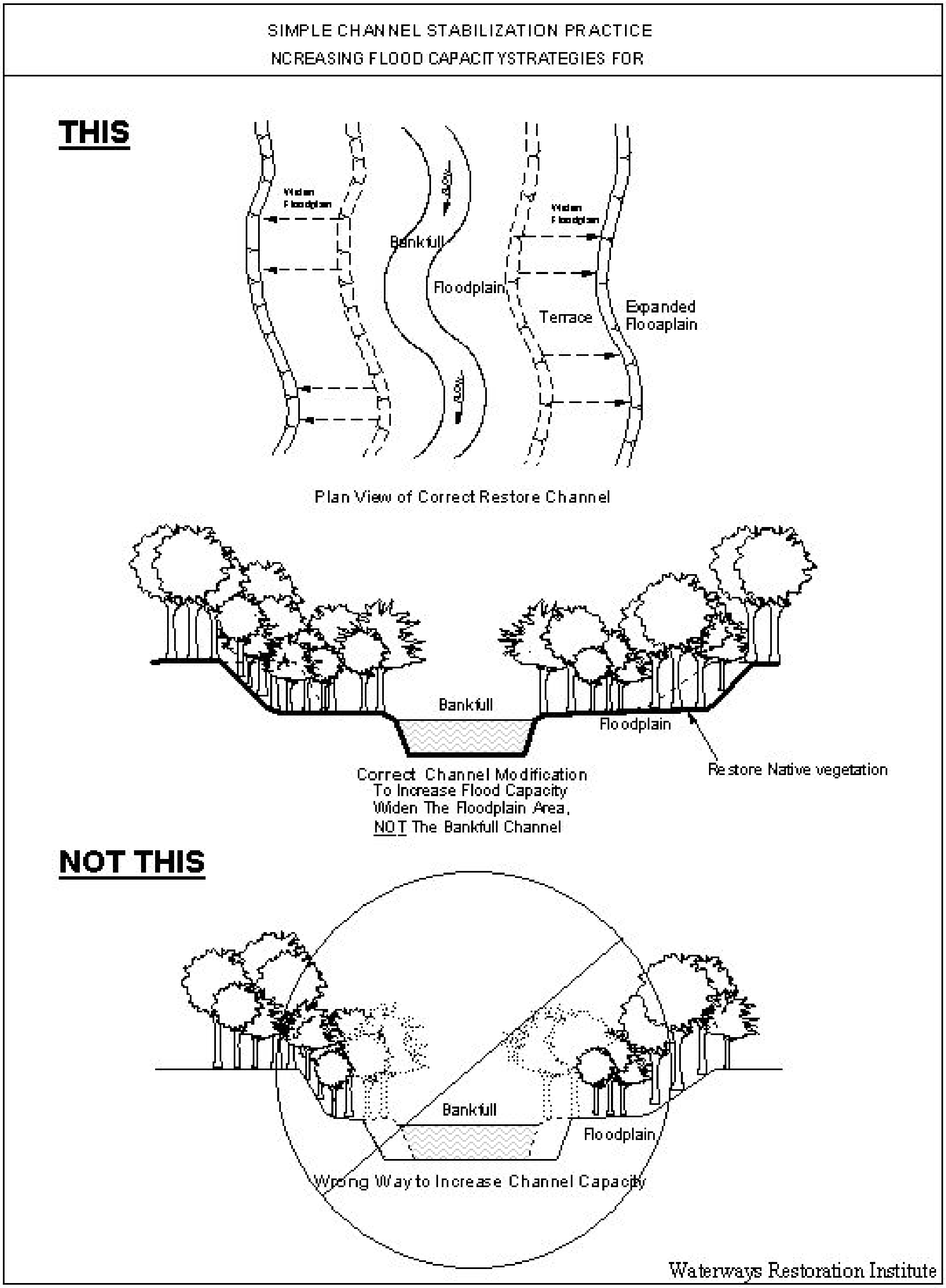
**Simple Channel Stabilizing Practices - as illustrated in Figure 5**

- Use reference reaches of channel to size the channels and determine sinuosity. Helping the stream channel return to a stable width and depth will contribute significantly to solving erosion or sedimentation problems. The simplest approach for determining what this stable width and depth is to help the property owner find nearby stream reaches in what appears to be a stable, healthy channel condition with a similar slope and soils. The shape of this stable reach, or "reference reach" can be copied in the area that is unstable. For most streams in the San Francisco Bay Area, a healthy, stable reach will have well vegetated banks (vertical banks are natural), a single, unbraided channel (without center channel sediment bars), point bar formations, or steps and pools in steeper reaches, and no signs of headcutting as illustrated in Figure 3. If the channel is straight on relatively gentle or flat valley slopes (5% or less slope) for a distance of more than eight times the channel width then suspect a degraded straightened channel. If the meanders appear unmodified this is another good indication that the reach observed provides a good reference reach. Even if the channels appear degraded in very urban settings, you can usually find reaches where stable active channels have formed despite the compromised conditions. A reference channel does not have to be located in a pristine environment. Restoring a new stable channel cross -sectional area may entail the removal of existing bank control works.
- Restoring the floodplain area is the best way for the property manager to increase the flood capacity of the stream corridor. This spares the active channel from becoming over-widened (Figure 6 defines the terms used in this chapter).
- Attempt to recreate where old removed meanders used to flow. Re-attach them to the channel if this is still possible. If this is not an option increase the length of the channel as much as feasible by excavating more length where it can be fit in and around the site constraints. Meanders can also be re-established by assisting their development through adding woody debris, rootwads, wood or rock deflectors to the stream channel. It is best to use experienced help with

these kinds of modifications so that they do not destabilize the channel slope or width and result in unintended channel reactions.

- The most effective and risk free channel improvement is to revegetate stream banks with willows, cottonwoods, dogwood and ninebark. These species are widespread in the Bay Area and usually easy to collect in adequate numbers as cuttings from plants along stable portions of stream channels. Even if some of them get washed out or die, little is lost and much is gained by the vegetation that survives. Extend the planting projects from the top of the active channel all the way to the top of the terrace. Make sure there is a protected buffer area on top of the terrace, or the ground level where the structures or land uses begin, to avoid impacts to the channel from the adjacent storm drainage and activities.
- Remove fill from those channels that have been filled. Significant benefits can be achieved even by recovering some of the small headwater ephemeral channels. Remove culverts when feasible. If culverts must remain, but are installed either too high and create dams in the channel, or too low so that they fill with sediment or create up-slope erosion, it will be necessary to realign the culverts at a more appropriate elevation and slope. Sometimes culverts are perched high above the downstream reach because the force of the flows concentrated and excelerated by the culvert erode the stream bottom. In these cases, the channel slope can be recreated using boulder steps and pools.The state and federal fisheries agencies have guidelines on the re-establishment of channel slopes for fisheries passage which should be followed.
- In steeper, headwater streams which typically have very low sinuosities, or meandering, the energy of the stream is expended in a series of drops referred to as boulder steps and pools. If the channel slopes need to be restored to a more stable condition in these steep reaches, it is necessary for the drops or steps to not be too high and or spaced too far apart. Generally, steps over a foot and a half can be the most unstable. Refer to figure 11 on page 90

**Figure 5**


SIMPLE CHANNEL STABILIZATION PRACTICE
NCREASING FLOOD CAPACITYSTRATEGIES FOR
THIS
Bankfull
Floodplain
Terrace
Expanded
Flooaplain
Plan View of Correct Restore Channel
Bankfull
Floodplain
Restore Native vegetation
Correct Channel Modification
To Increase Flood Capacity
Widen The Floodplain Area,
NOT The Bankfull Channel
NOT THIS
Bankfull
Floodplain
Wrong Way to Increase Channel Capacity
Waterways Restoration Institute

## CHAPTER SIX: ADDRESSING THE ISSUE OF OFF-SITE INFLUENCES

An inherent weakness in the common approach of permitting individual projects as they occur randomly through time at scattered locations is that the management plan prescribed for any one site occurs in isolation from other watershed sites and activities. The source of a property owner's stream or river problem may be on their own property, a nearby neighbor's, or miles away in the watershed. The measures taken to address the stream problem could make things better or worse for nearby neighbors.

The isolated, uncoordinated project could use the principles described here but the new stability could be over-powered by something such as a new stormwater culvert installed up stream. The first consideration is that if the stream stabilization project has stable width and depth dimensions, and carefully matches the stream sinuosity, channel slope and valley slope, the stream will be more resilient to future impacts on the site. The stream should have a better defense against serious damage from any erosional headcuts moving upstream which may enter the restored section. Likewise if stream meandering is traveling in a down stream direction towards the restored section which already has a stream length in balance with the valley, and a stream shape conducive to efficient sediment transport, the channel has a better chance of maintaining a stable condition. In other words, the resiliency of the site to defend against and recover from current, future or distant watershed disturbances is increased.

The small property owner commonly suffers the consequences of the actions of its neighbors in the up, down or across channel locations. Such watershed disturbances out of the control of the property owner are not uncommon. It is this situation, which has popularized the organization of watershed councils on small creeks to large rivers. The regulator should encourage property owners to take advantage of gathering neighbors, and fellow watershed inhabitants and seeking coordinated help from local, state and federal agencies in order to attract the cooperation and resources of others in addressing problems that necessarily cross property lines. These coordinated efforts include the advantages of being able to attract government assistance with technical expertise, materials, equipment and grants of funds. A list of stream partnership organizations and watershed councils in the San Francisco Bay Area is provided in Appendix C.

## CHAPTER SEVEN: TOOLS FOR REGULATORS AND PROJECT ANALYSTS

### The Avoidance and Correction of Impacts to Streams

The following section provides three tools to help apply the principles of good stream management described in this Circular. The first tool is a series of tables that can be taken on field visits when negotiating a permit action. The tables can be used to help explain relevant state and federal regulations that affect the applicant. The tables help lead the regulator and applicant through an analysis of whether modifications to water courses may make positive or negative impacts to water quality and help the applicant meet the necessary regulations in a logical, flexible and consistent manner.

The second tool is an Impact Avoidance Decision Tree, which has been prepared for use by regulators, project applicants or consultants. The decision tree provides a thought process for considering how to best avoid environmental degradation by following a sequence of project design considerations. This Circular has been prepared in enough technical detail to provide guidance to experienced public works engineers and consultants involved in the larger or more expensive project proposals. It is also a relevant process, as well, for use by the small property owner. The third tool is really a toolbox containing a few commonly used stream restoration project design terms, restoration methods and information on San Francisco Bay Area streams useful for restoration planning.

### Table One: State and Federal Regulations Affecting Stream Protection

The first table takes the user through a list of regulatory authorities and guidelines that direct the protection of streams and rivers. This table has been provided in order to remind the regulator to clearly state to the public why a regulatory activity or program is taking place. The ultimate goal stated by the table is to encourage a balance among the physical processes of the stream so that desirable water quality is attained and the beneficial uses of the State's waters are protected or improved.

**TABLE 1. State and Federal Regulations Affecting Stream Protection Involved in Stream Protection**

**Goal #1: Attain a balance among the physical processes of the stream so that the "highest water quality, which is reasonable" is attained and the beneficial uses of the state's waters are protected and/or improved.**

**Step #1: Identify the provisions in the Federal Clean Water Act, Porter-Cologne Act and other Board programs (NPS, urban runoff, TMDLs, etc.) that address the protection of stream functions.**

**Regulatory Provisions**

Federal Clean Water Act:

a. Section 401 Water Quality Certification:

Requires the State or Regional Water Quality Control Board to provide "certification that there is reasonable assurance that an activity which may result in discharge to navigable waters of the US will not violate water quality standards". United States Code 1341(a) (Section 401). See also California Code of Regulations Title 23, Division 3, Chap. 28, Sections 3830-3869.

b. Section 404(b)(1) Army Corps of Engineers Guidance for Evaluating Alternatives:

1. Avoidance (least practicably damaging alternative)
2. Minimization of adverse effects
3. Mitigation to assure a no net loss of functional values.

The Regional Board's Basin Plan requires that alternatives analysis must be reviewed for all projects, including USACE Nationwide Permits.

Porter-Cologne Water Quality Control Act:

Gives broad authority for actual and potential impacts to Waters of the State. Any person proposing to discharge waste (including fill) into a waterbody that could affect its water quality is required to file a Report of Waste Discharge. Regional boards may issue Waste Discharge Requirements (WDR's), such as a permit regulating the conditions associated with the discharge. California Water Code, Division 7.

SF Bay Water Quality Control Plan (Basin Plan):

- No Net Loss of Wetland Policy (based on 404(b)(1) guidelines, Senate Resolution 28, and Governors Executive Order W-59-93)
- Protect Existing/Potential Beneficial Uses
- Tributary Rule: Prevent degradation of the Bay, mainstream and tributary waterways
- Identify impaired waterways and reduce pollutant discharges (TMDL)

California Environmental Quality Act (CEQA):

-Gives State and Regional Boards authority to require minimization for projects that will impact Waters of the State.
-Prohibits Regional Boards from approving a project if feasible alternatives or feasible mitigation measures exist that would result in less adverse impacts to Waters of the State.

Plan for California's Non-Point Source Pollution Control Program:

Hydromodification management measures 5.1-5.4 call for evaluating the potential effects of proposed channelization and channel modification on the physical and chemical characteristics of surface waters and on instream and riparian habitat, planning and design undesirable impacts, and education measures to provide greater understanding of watersheds and promote projects that retain or re-establish natural hydrologic functions. Management measures 6A-6D call for protection and restoration of wetlands and riparian areas and education measures as under 5.4 above.

National Pollutant Discharge Elimination System (NPDES):

NPDES Permits require the evaluation of impacts of changes in frequency, magnitude, and duration of flow for the watershed.

Stormwater Runoff Program:

1. Municipal Program

-New and redevelopment provisions in municipal permits require stormwater programs to minimize impacts to creeks through controlling changes in hydrograph, requiring stormwater retention, preparation of management plans, and mitigation measures.

2. Industrial Program
3. Construction Program

Coordination with Additional Federal and State Regulations: 1. U.S. Environmental Protection Agency - Federal Clean Water Act, commenting agency to the Corps; 2. U.S. Army Corps of Engineers - Federal Clean Water Act Section 404 Permit; 3. U.S. Fish & Wildlife Service - Endangered Species Act, Fish and Wildlife Coordination Act, consultation with Corps; 4. National Marine Fisheries Service - Anadromous Fish Conservation Act, Endangered Species Act, consultation with Corps; 5. California Department of Fish & Game - Streambed Alteration Agreement, California Environmental Quality Act (CEQA); 6. California Coastal Commission - Coastal Zone Management Act, CEQA; 7. Bay Conservation and Development Commission - MacAteer Petris Act, CEQA

**Table 2: Potential Effects of Major Land Use Activities**

This table is reprinted from the Federal Interagency Stream Restoration Working Group's publication, Stream Corridor Restoration, Principles, Processes and Practices. The table identifies the potential environmental degradations from such land use and disturbance activities as dams, levees, roads, bridges, vegetation clearing and channelization, etc. Table 3 references this federal table and adds another layer of detail by further linking these disturbance activities to stream channel responses that can impact the functions and stability of streams.

## Table 2: Potential Effects of Major Land Use Activities

| Potential Effects | Vegetative Clearing | Channelization | Streambank Armoring | Streambed Disturbance | Withdrawal of Water | Dams | Levees | Soil Exposure or Compaction | Irrigation and Drainage | Contaminants | Hard Surfacing | Overgrazing | Roads and Railroads | Trails | Exotic Species | Utility Crossings | Reduction of Floodplain | Dredging for Mineral Extract. | Land Grading | Bridges | Woody Debris Removal | Piped Discharge/Cont.Outlets |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Homogenization of landscape elements | ■ | ■ | □ | □ | □ | □ | □ | □ | ■ | □ | □ | ■ | □ | □ | ■ | □ | ■ | ■ | ■ | □ | □ | □ |
| Point source pollution | □ | □ | □ | □ | □ | ■ | □ | □ | □ | ■ | ■ | ■ | ■ | □ | □ | ■ | □ | ■ | □ | □ | □ | ■ |
| Nonpoint source pollution | ■ | ■ | □ | ■ | □ | □ | ■ | □ | ■ | ■ | ■ | ■ | ■ | ■ | □ | ■ | □ | ■ | ■ | □ | ■ | ■ |
| Dense compacted soil | ■ | □ | ■ | □ | □ | ■ | ■ | ■ | □ | □ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | ■ | □ | □ | □ |
| Increased upland surface runoff | ■ | □ | □ | □ | □ | □ | □ | ■ | ■ | □ | ■ | ■ | ■ | ■ | □ | □ | □ | □ | ■ | □ | □ | □ |
| Increased sheetflow w/surface erosion rill and gully flow | ■ | □ | □ | □ | □ | □ | □ | ■ | ■ | □ | ■ | ■ | ■ | ■ | □ | □ | □ | □ | ■ | □ | □ | □ |
| Increased levels of fine sediment and contaminants in stream corridor | ■ | ■ | □ | ■ | □ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Increased soil salinity | □ | □ | □ | □ | ■ | □ | □ | □ | ■ | ■ | ■ | □ | ■ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| Increased peak flood elevation | ■ | ■ | □ | □ | □ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | □ | □ | □ | □ | ■ |
| Increased flood energy | ■ | ■ | ■ | ■ | □ | □ | ■ | ■ | ■ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | □ | □ | □ | ■ | ■ |
| Decreased infiltration of surface runoff | ■ | □ | ■ | □ | □ | □ | □ | ■ | ■ | □ | ■ | ■ | ■ | ■ | □ | □ | □ | □ | ■ | □ | □ | ■ |
| Decreased interflow and subsurface flow | ■ | ■ | ■ | □ | □ | □ | □ | ■ | □ | ■ | □ | □ | □ | □ | □ | □ | □ | □ | ■ | □ | □ | ■ |
| Reduced ground water recharge and aquifer volumes | ■ | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | ■ | □ | □ | ■ |
| Increased depth to ground water | ■ | ■ | □ | □ | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | ■ | □ | □ | □ |
| Decreased ground water inflow to stream | ■ | ■ | ■ | □ | ■ | □ | ■ | ■ | ■ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | ■ | □ | □ | ■ |
| Increased flow velocities | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | ■ | □ | ■ | ■ |
| Reduced stream meander | □ | ■ | ■ | ■ | □ | ■ | ■ | □ | □ | □ | ■ | □ | □ | □ | □ | □ | ■ | □ | ■ | □ | ■ | ■ |
| Increased or decreased stream stability | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | ■ |
| Increased stream migration | ■ | □ | □ | ■ | □ | □ | □ | ■ | □ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | □ | □ | ■ | ■ |
| Channel widening and downcutting | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | □ | ■ | ■ | ■ |
| Increased stream gradient and reduced energy dissipation | □ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ | □ | □ | □ | □ | □ | □ | □ | ■ | ■ | □ | □ | ■ | ■ |
| Increased or decreased flow frequency | ■ | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | □ | ■ | □ | □ | ■ |
| Reduced flow duration | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | □ | □ | □ | ■ | ■ |
| Decreased capacity of floodplain and upland to accumulate, store and filter materials and energy | ■ | □ | □ | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ | ■ | ■ | ■ | □ | ■ | ■ |
| Increased levels of sediment and contaminants reaching stream | ■ | ■ | ■ | ■ | □ | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | □ | □ | ■ | □ | ■ | ■ | ■ | ■ | ■ |
| Decreased capacity of stream to accumulate and store or filter materials and energy | □ | ■ | ■ | ■ | □ | □ | ■ | □ | □ | ■ | □ | □ | □ | □ | □ | □ | □ | ■ | □ | □ | ■ | ■ |
| Reduced stream capacity to assimilate nutrients/pesticides | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ | □ | □ | ■ | ■ | □ | □ | ■ | ■ |
| Confined stream channel w/little opportunity for habitat development | □ | ■ | ■ | ■ | □ | □ | ■ | □ | □ | □ | □ | □ | □ | □ | □ | □ | ■ | □ | □ | □ | □ | □ |

■ Activity has potential for direct impact.    □ Activity has potential for indirect impact.

**In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).**
**By the Federal Interagency Stream Restoration Working Group (FISRWG) (15 Federal agencies of the U.S.)**

## Table 2: Potential Effects of Major Land Use Activities (cont'd)

| Potential Effects | Disturbance Activities: Vegetative Clearing | Channelization | Streambank Armoring | Streambed Disturbance | Withdrawal of Water | Dams | Levees | Soil Exposure or Compaction | Irrigation and Drainage | Contaminants | Hard Surfacing | Overgrazing | Roads and Railroads | Trails | Exotic Species | Utility Crossings | Reduction of Floodplain | Dredging for Mineral Extract. | Land Grading | Bridges | Woody Debris Removal | Piped Discharge/Cont.Outlets |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Increased streambank erosion and channel scour | ■ | ■ | □ | ■ | □ | ■ | ■ | ■ | □ | □ | □ | ■ | □ | □ | □ | □ | □ | ■ | □ | □ | ■ | ■ |
| Increased bank failure | ■ | ■ | □ | ■ | ■ | ■ | ■ | ■ | □ | □ | □ | ■ | □ | □ | □ | □ | □ | ■ | □ | □ | ■ | ■ |
| Loss of instream organic matter and related decomposition | ■ | ■ | ■ | ■ | □ | ■ | ■ | □ | □ | □ | □ | ■ | □ | □ | □ | □ | ■ | ■ | □ | □ | ■ | □ |
| Increased instream sediment, salinity, and turbidity | ■ | ■ | □ | ■ | □ | ■ | ■ | □ | ■ | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | ■ | □ | ■ | ■ |
| Increased instream nutrient enrichment, siltation, and contaminants leading to eutrophication | ■ | □ | □ | ■ | □ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ | ■ | ■ | ■ | □ | □ | ■ | ■ |
| Highly fragmented stream corridor with reduced linear distribution of habitat and edge effect | ■ | ■ | ■ | □ | ■ | ■ | □ | □ | □ | □ | ■ | ■ | □ | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | □ |
| Loss of edge and interior habitat | ■ | ■ | ■ | ■ | □ | □ | ■ | □ | □ | □ | ■ | ■ | ■ | □ | ■ | □ | ■ | ■ | ■ | □ | ■ | □ |
| Decreased connectivity and width within the corridor and to associated ecosystems | ■ | ■ | ■ | ■ | □ | ■ | ■ | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ |
| Decreased movement of flora and fauna species for seasonal migration, dispersal, and population | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ |
| Increase of opportunistic species, predators, and parasites | ■ | ■ | ■ | □ | □ | ■ | ■ | □ | □ | ■ | □ | ■ | □ | ■ | ■ | ■ | □ | □ | □ | □ | ■ | ■ |
| Increased exposure to solar radiation, weather, and temperature extremes | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | □ | □ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | ■ | □ | ■ | □ |
| Magnified temperature and moisture extremes throughout the corridor | ■ | □ | □ | □ | □ | □ | ■ | ■ | □ | □ | ■ | ■ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| Loss of riparian vegetation | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | □ |
| Decreased source of instream shade, detritus, food, and cover | ■ | ■ | ■ | ■ | ■ | □ | ■ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | ■ | □ | □ | ■ | □ |
| Loss of vegetative composition, structure, and height diversity | ■ | ■ | ■ | □ | ■ | □ | ■ | □ | ■ | □ | ■ | ■ | ■ | □ | ■ | □ | ■ | ■ | □ | □ | □ | □ |
| Increased water temperature | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | □ | □ | □ | □ | ■ | ■ | □ | □ | ■ | □ |
| Impaired aquatic habitat diversity | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | ■ | □ | □ | ■ | □ | ■ | ■ | □ | □ | ■ | ■ |
| Reduced invertebrate population in stream | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | ■ | □ | □ | ■ | □ | ■ | ■ | □ | □ | ■ | ■ |
| Loss of associated wetland function including water storage, sediment trapping, recharge, and habitat | □ | ■ | □ | ■ | ■ | ■ | ■ | □ | ■ | □ | ■ | ■ | ■ | □ | ■ | □ | ■ | ■ | ■ | □ | □ | □ |
| Reduced instream oxygen concentration | ■ | ■ | ■ | ■ | ■ | ■ | ■ | □ | □ | □ | ■ | ■ | □ | □ | □ | □ | ■ | ■ | □ | □ | ■ | ■ |
| Invasion of exotic species | ■ | ■ | ■ | ■ | ■ | □ | ■ | □ | □ | □ | □ | ■ | □ | □ | ■ | □ | ■ | □ | □ | □ | □ | ■ |
| Reduced gene pool of native species for dispersal and colonization | ■ | ■ | ■ | ■ | ■ | □ | ■ | □ | □ | □ | □ | ■ | □ | □ | ■ | □ | ■ | □ | □ | □ | ■ | □ |
| Reduced species diversity and biomass | ■ | ■ | ■ | ■ | ■ | □ | ■ | ■ | ■ | □ | ■ | ■ | □ | □ | ■ | □ | ■ | □ | □ | □ | ■ | □ |

■ Activity has potential for direct impact.

□ Activity has potential for indirect impact.

**In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).**
**By the Federal Interagency Stream Restoration Working Group (FISRWG) (15 Federal agencies of the U.S.)**

**Table 3: Potential Impacts to Beneficial Uses**

This table sets the stage for first linking watershed and or channel modifications to losses in stream structures and functions that provide water quality, aquatic habitat and water and sediment conveyance benefits. The ultimate goal is to protect the structure, function and diversity of the stream channel and its riparian corridor. These linkages have been nicely displayed in Table 3, from the Federal Interagency Stream Restoration Working Group Stream Corridor Restoration Manual. (Table 3 should be considered its own column within Table 2, but, due to space constraints, this is not possible.) Table 3 and should be read down vertically to acquire the next level of detail to associate the land use changes already identified in Table 2 with common channel modifications and responses to the modifications.

The first column in Table 3 lists the commonly used conventional engineering practices on stream channels, which can contribute to upsetting the stability among the variables affecting channel behavior. This column then relates horizontally to the second column. This column, "The Most Common Physical Consequences of Disturbance Activities," helps the user of Table 3 to forecast how the commonly proposed modifications to channels can cause channel responses including changes to shapes, slopes, erosion, deposition and sediment transport. The goal here, then, is to help the project proponent to protect stable channel shapes and slopes along with stream functions.

# TABLE 3. Channel Modifications and Responses

TABLE 3. Channel Modifications and Responses

| **Land Uses with Potential Impacts and Potential Disturbances Impacting Beneficial Uses [<u>See Federal Table on Function Losses</u>]** | **The Most Common Physical Consequences of Disturbance Activities to Streams** |
|---|---|
| **<u>Goal #2:</u> Protect the structure, function and diversity of the stream channel and its riparian corridor by taking the necessary watershed management, stream corridor protection, or restoration measures.** | **<u>Goal #3</u>: Protect stable channel shapes and slopes, along with stream functions.** |
| <u>Land Uses with Potential Impacts</u><br>Residential development, commercial, industrial, institutional, government, highways, roads, railways, airports, grazing, feedlots, rowcrops, mining, timber harvest, recreational water sports, irrigation, water supply, and flood control.<br><br>Identify the common channel modifications associated with changing land uses. Refer to the Table 2 provided by the Federal Stream Corridor Restoration Manual. | |
| **<u>Step #2:</u> Identify the links between disturbance activities and the loss of stream structure, functions and dynamics.** | **<u>Step #3:</u> Forecast how the channel may react to proposed changes.** |
| **<u>Potential Channel Modifications</u>**<br><br>**These modifications often result in** → | **<u>Potential Channel Responses</u>**<br><br>**these results.** |
| Stream straightening and meander removal | Channel slope steepens, elevation or grade lowers, bottom erodes, water table drops, base flows decrease, banks collapse, riparian vegetation degrades, water temperature increases.<br><br>Downstream sedimentation: upstream channel erosion by headcutting. |
| Watershed vegetation removal or change from forests to shrub or grasslands<br><br>Vegetation clearing or removal | Channels erode wider<br><br>Change in timing and concentration of runoff, channel erosion and bank failure<br><br>Increased sediment supply to the downstream channel |
| Stream bed or bank hardening with rocks, gabions, sheetwalls, concrete cribwalls riprap and other debris or products | Up and downstream bank failure, stream bottom incision. Discharges flowing downstream are sediment starved = erosion. Loss of point bar formation, pools, riffles. |

Table 3-cont.

| | |
|---|---|
| Streambed disturbances: animal, human use, and equipment | Increased fine sediments, bank erosion from access, riparian vegetation degrades, water quality decreases |
| Modification of channel shape | Active channel narrowed by bank hardening or encroachment by structures: erosion |
| Modification of channel widened for flood control. | Sedimentation and channel filling Riparian vegetation impacts, bank failures, water temperature increase |
| Grade controls placed in the stream bed: dams, checkdams, weirs | Flatten grade, initiate meander development, banks blow out, structures fail; Downstream erosion from sediment starved discharge; Channel slope, and sinuosity not in balance with valley slope |
| Off-channel sediment detention basins. | Can create an imbalance between sediment quantity and discharges leading to downstream channel erosion. |
| Off-channel discharge retention or detention basins. | Withdrawal of water, can lead to imbalance between discharges and sediment supplies causing sedimentation. |
| By-pass channels or projects that divide or split flows. Withdrawal of water for irrigation or water supplies | Sedimentation in one or both channels |
| Culverting-undersized, wrong grades, wrong slopes | Culvert lowers the channel grade: erosion upstream (headward);<br>Culvert raises the channel grade: deposition upstream, erosion downstream;<br>Deposition in culvert |
| Bridges with wrong alignments, grades, low clearances or narrow spans | Create hydraulic constrictions, backing water up and create flooding.<br>Concentrate runoff into channels: erosion |
| Dams for water storage | Sedimentation behind dams, sediment starved water downstream: erosion.<br>Upstream: base level of streambed raised.<br>Stream channel sedimentation and backwater flooding. |
| Levees, berms, floodwalls, reduction of floodplain | Increased stream power and erosion, downstream flooding, disruption of local drainage, loss of floodwater storage. |
| Soil exposure, compaction, road construction, watershed paving, overgrazing, stormwater concentration | Concentration of discharges, increase of discharges.<br>"Flashy" flows: erosion, widescale bank failures. |
| Contaminant pipe discharges and runoff | |

Table 3 - cont.

| | |
|---|---|
| Trails, utility crossings including water and sewer pipes, gas lines, (low clearances, grades, and spills), and railroad crossings | Create hydraulic constrictions, backing water up and create flooding.<br>Concentrate runoff into channels: erosion. |
| Dredging channels for sands, gravels and minerals, aggregate removal | a. On-site: channel widening, aggradation; upstream headward erosion; excessive downstream incision, lowering groundwater tables.b. Off-channel: large scale raising of downstream channel beds and floodplains, destabilizing river shapes, meanders and channel capacities if sediment transported to channels.  Borrow pits capture meanders, grades destabilized. |
| Land grading, construction activities | Increase sediment load in relation to discharge, channel sedimentation. |
| Woody debris removal from channel | Loss of channel roughness, reduction of pools, riffles, flashier flows,<br>channel incision and or widening, and backwater habitat. |
| Introduction of exotic species:  animal and plant. | Plants may be less capable of holding bank shapes and may out compete native plants, which more effectively provide bank structure and active channel shapes. This can cause bank collapse, channel erosion. Invasion of sun loving plants in the active channel creates channel filling. |
| Drainage, land reclamation | Dewatering wetlands |

**Table 4: Degraded Stream Channel Conditions**

The fourth table, "A Summary of Stream Channel Degradation," is designed to help the regulator to categorize the channel instabilities likely to occur from proposed channel modifications.  The major categories of instability are: excessive erosion, excessive deposition and degraded channel boundary conditions.  This categorization of the instabilities in Table 4 can be used to lead us to the next step in the thought process, which is to ask how can we avoid this kind of instability and encourage the desired type of long-term stability instead?

The stated goal of Table 4 is to: "Avoid the Destabilization of Streams Which Can Lead To Excessive Erosion and Deposition."  Table 4 uses the term <u>excessive</u> for a very definite reason.  This returns us to the conceptual framework discussed in Chapter

Two. Natural stream systems in equilibrium erode some soil from their channels and redeposit it to form point bars, channel backwaters, pools, meanders and other in-channel features. Overbank sediment deposition helps form floodplains. Streams should erode and deposit sediment, and meanders should form, otherwise the structure, function and processes of streams will be lost. We become concerned only when the natural balance of these processes is upset. These concepts can be hard to remember when a regulator is visiting a site with a property owner or manager who is anxious about his property but does not understand that there may not actually be a stream problem threatening his property. We need to carefully assess the context of the eroding stream and the seriousness of potential impacts from the stream. Whether the site is located in the middle of a park or next to a major road, for example, should affect the evaluation. We do want to avoid the pools of stream channels filling with sediment, the aggradation of channels which fill up culverts and bridge clearances, the suffocation of fish redds required for spawning fish, the collapse of stream banks, the accelerated entrenchment of channels, and the degradation of the stream side vegetation.

| **Table 4. Degraded Stream Channel Conditions** |
|---|
| **Goal #4: Avoid the destabilization of stream channels which can lead to excessive erosion, deposition, channel degradation, and ultimately endangered structures.** |
| **Step #4: Categorize the impacts which are likely to occur in the project reach:** |
| **Environmental Degradation** |
| 1. Excessive Erosion<br>a. Lateral channel movement<br>b. Widening<br>c. Deepening, accelerated incision, channel far below floodplain or entrenched<br>d. Slope steepening |
| 2. Excessive Deposition<br>a. Channel filling with sediment and or rushes, reeds, grass<br>b. Channel filling and adjusting wider<br>c. Channel braiding from a former single channel<br>d. Channel higher, slope flattening, meander and channel length increasing |
| 3. Degraded Channel Boundary Conditions<br>a. Little or no vegetation from edge of active channel to the floodplain to the top of terrace.<br>b. Little or no vegetation on top of the terrace.<br>c. Blank slumping.<br>d. Whole bank collapse<br>e. channel steps, pools, riffles replaced by homogenous runs. |

**Table 5: Avoidance and Correction of Impacts to Streams**

This table is a list of channel modification criteria which can be employed to meet the stated goal of "Avoiding Stream Instabilities" by correcting excessive erosion, deposition and degraded channel boundary conditions. The following section of this Circular provides the level of detail necessary to describe these corrective strategies as well as a process for professional project planners to employ in order to respond to different project site conditions. These design processes are too complicated to be set into a table and so they are explained using a decision tree, which integrates the influences of site constraints and opportunities into the planning criteria.

| **Table 5. Avoidance and Correction of Impacts to Streams** |
|---|
| **Goal #5: Apply the following stream corridor planning criteria to correct or avoid existing or future instabilities. Go to Avoidance Decision Tree as next step.** |
| **Step #5: After determining the causes of the existing/future impacts identified in column #4 by evaluating the land uses and disturbance activities using columns #2 and #3, remove or correct the causes of the instabilities. Refer to column #1 for implementation tools.** |
| **Apply Channel Stabilizing Criteria** |
| 1. To the extent practical, address watershed sources of increased discharges, flow rates, harmful concentration of runoff and sources of excessive sediment. Implement Stormwater Best Management Practices (BMP's) and Watershed Improvement Programs. |
| 2. Protect or recreate the proper bankfull channel widths and depths. |
| 3. Protect or recreate as much floodplain as possible.<br><br>Protect from:<br>a. Fill<br>b. Encroachment |
| 4. Prevent or remove grade control structures, which are creating up and downstream erosion. Instead, use instream structures, if necessary, to support a calculated equilibrium channel slope. |
| 5. Stabilize the channel slope by creating a channel length, which is properly matched to the valley slope and sinuosity. |
| 6. Remove or restrict hard structures on streambanks and plant banks with willow and cottonwood posts and other native plants. |
| 7. Remove culverts and replace with bridges or open channels when possible. Refer to NMFS culvert standards. |
| 8. The first steps to reduce flood damages should include: avoidance of new structures encroaching on floodplains, removing or relocating structures in hazardous places, and<br>correcting backwater flow floods behind hydraulic constrictions such as culverts, bridges and pipes. |
| **Go to the Decision tree for Detailed Guidance** |

**Steam Impacts Avoidance Decision Tree**

Introduction To The Decision Tree

The Decision Tree was developed to offer a level of detail sufficient for a project design engineer or consultant to understand the design criteria and process that can meet our stated goal to assist San Francisco Bay Area streams to a more sustainable stability. This design process can be substituted for the conventional engineering methods, as listed in Table 2 of the Impacts Avoidance Table, that are used to constrain channels, and which negatively impact the structure, functions and dynamics of the stream system. The objective is to avoid the disturbance activities and the stream responses to them, as listed in the Stream Impacts Avoidance Table. The Tree recognizes that some sites have more opportunities and or constraints than other sites and that this realistically shapes how we address the problem to create more stable channels.

The Decision Tree can be applied to small incremental project proposals as well as the large development proposals. The smaller projects such as the common stream bank stabilization projects, would presumably have fewer opportunities for the redesign of site plans or acquisition of additional space, however, sometimes some key site adjustments are possible even in limited spaces which contribute significantly to solving problems. The first feature of the Decision Tree is the recommendation that watershed management improvements and the use of "Best Management Practices" for stormwater management and erosion control for site specific development needs are considered at the beginning to be a part of the channel protection process.

Typically there are two major institutional arrangements affecting stream channels: those in public and those in private ownership. The Decision Tree is designed to be relevant to either scenario:

A. Channels without pre-existing government flood control or water supply projects:

- Usually have multiple private property owners
- Streams are frequently political boundaries for cities and counties: multiple political jurisdictions

- Conditions for accommodating channel stability improvements will vary significantly from reach to reach

B. Government Project Channels

- Cross-sectional stream channel area has to accommodate project design discharges.
- Some access by government maintenance or emergency vehicles is desirable or required (e.g., maintenance roads, access ramps).
- Well-defined project right-of-way boundaries are often designated by fencing, and lands, easements and rights-of-ways are in government ownership.

The Decision Tree is divided into two main columns with the one on the left reflecting more site opportunities and flexibility and the column on the right representing the more common scenario of difficult site constraints conflicting with the return of natural functions to streams. The arrows and numbered boxes designate the order of the problem solving measures.

The technical assumptions behind the Decision Tree are simple and widely accepted. The first assumption is that stream channels with the properly designed "active" or "bankfull" channel widths and depths will be more stable and best able to maintain water quality and provide habitat for stream corridor wildlife. Much has been written in river literature in regards to this active channel (see Appendix A). It is desirable to protect or restore the correct shape of this channel because over time it is this channel that transports the most sediment through the watershed and provides the natural functions and dynamics of the stream system. A part of this assumption is that it is desirable to have the stabilizing influence of the floodplains and streamside vegetation act in concert with this active channel.

The second assumption is that the streams, which are neither too long, nor too short and in which the valley slopes, channel slopes and sinuosity are in balance, will also have the desired stability and environmental quality. The Fourth Impacts Avoidance

Table introduces these assumptions. The Decision Tree helps us act on these assumptions.

The design of such features as specific channel widths, depths, slopes, and meanders, and revegetation systems that the Decision Tree calls for can be accomplished using a variety of restoration design methods or "schools." These schools of restoration previously described in Chapter Two may use analytical models, stream channel evolution models, stream process models, stream classification systems, and or hydraulic geometry concerned with the relationships of channel shapes and the watershed landscapes. Any or all of these methods may be appropriate depending on how extensive or complex a proposed project may be. It is not the intent of this Circular to prescribe which of these tools should be used in the design of any particular project, nor obviously can the Circular cover the substance of these methods which requires extensive training and is the subject of books. To assist project planners who want to apply the principles of hydraulic geometry, the last section of this chapter, "Applying Avoidance Concepts" provides some basic information from the San Francisco Bay Region which can be used to design stable channels.

Decision Tree Planning Process

**Box #1 - First Impact Avoidance Measure:** <u>Determine and Protect Stable Channel Width and Depth</u>

The first task is to determine a stable bankfull or active channel shape. Regional hydraulic geometry can be used as initial guidance and nearby similarly situated stable reference reaches on the same channel or channel of the same type to determine a width and depth in feet. Shear stress calculations, sediment transport data, estimates of effective discharges and other technical assessments can likewise be applied to designating active channel shapes. No modifications should be tolerated which widen or narrow an appropriately sized active channel.

**Box #2 - Second Impact Avoidance Measure:** Assure Vegetated Boundary Along Active Channel

Provide for a vegetated boundary on each bank of the active channel in order to assure that the channel will successfully form to the correct stable dimensions. Vegetation should be used to form this boundary to assure the natural structure required for the transport and deposition of sediment, formation of a thalweg, pools, riffles, floodplains and other physical components of a living stream.

**Box #3 - Third Impact Avoidance Measure:** Determine a stable channel length and sinuosity

The stable length for an active channel will include matching the channel slope and sinuosity (how much the channel meanders) with the valley slope. The channel slope will be influenced by both the slope of the overall stream valley and by grade controls imposed on the channel slope such as culverts and bridges.

The first step in determining the correct channel length is to use historic records as guidance to what the sinuosity of the stream used to be. An optimum situation for stabilizing the channel would be to return a straightened – or shortened channel to its historic course. Usually, however, land use changes over time make this infeasible. The real object of this step therefore is not to return the path of the creek to historic conditions but to recreate the channel length to the degree possible within the constraints of the stream corridor widths.

If there are inadequate historic maps, photos or records to estimate a historic sinuosity, then a sinuosity can be determined using regionally based data on the relationship between the length of a meander and the width of a stream. Using national data, scientists find that meander lengths, on the average, range from seven to ten times stream bankfull channel widths. No one has completed a comprehensive study on the average range of channel lengths and bankfull widths for the San Francisco Bay Region. Preliminary guidance developed for Bay Area streams, using Waterways Restoration Institute channel restoration records, indicates thus far that, for Rosgen "B" channel types[3], channel lengths tend to be about eleven times channel widths, for Rosgen "C" channel types, about ten times channel widths, and for channels entering the Bay or Ocean near or at tidal areas, or Rosgen "E" channels, about eight to nine times channel widths. A channel length (distance) consists of two concave banks where pools form and three riffle or meander "cross-over" points located between the pools. (Alternatively, a meander length - or distance - can also be measured as three pools and two crossover or riffle areas).

At this point, it is less confusing if we rename what the literature refers to as a channel "length" and instead call it a channel "distance." The distance refers to a straight down valley instance – "as the crow flies." Our goal is to calculate a channel sinuosity (or length) over this given distance or the feet that "a fish swims" up the creek. The Waterways Restoration Institute also uses the following values for estimating a meander planform for Bay Area streams: the radius of curvature of the meanders average 2.3 times the stream channel widths, and the amplitudes of the meanders average about 2.7 times the stream channel widths.

In the absence of any historic or existing on-the-ground indications of channel planform, the planner can use these average values for meander shapes to draw out a meander on graph paper, using a compass and scale. This drawing should <u>not</u> be used to lay out a design meander on the ground, but you can use the drawing to measure an average channel length or sinuosity for the type of stream being managed.

Once a value for a stable channel length or sinuosity is selected from historic records and or regional averages, the planners can try to fit that length into the reach of stream proposed for stabilization. The shape of the meander can be fluid and random and determined largely by the land use constraints such as parking lots, utility posts, structures, roads, etc. However, the shape of the meander should not allow the values for the radius of curvature to deviate from a normal range of 1.5 to 4.5 times active channel

[3] The Rosgen channel classification system is in wide and increasing use as a method to describe easily recognizable types of channels. "B" channels tend to be located in moderately steep portions of watersheds. "C" channels are on flatter slopes.

width, nor should the shape not realistically match the type of landscape the stream flows through. Common sense dictates that a channel is not going to accommodate looking like the folds of an accordion on a steep, upper watershed valley with a 10% slope, for example.

The stable channel slope can be computed as the valley slope divided by the sinuosity. Refer to Figures 9, 10, and 11 in the Applying Avoidance Concepts section, which follows: "Geometry of Meanders", "Meander Shapes and Lengths," and "Meander and Channel Slope Restoration."

**Box #4 -Fourth Impact Avoidance Measure:** New Channel Length and Meanders Should Occur Without Abrupt Grade Differences

Integrate the new channel length into the reach of concern so that it transitions "seamlessly" with stable up and downstream elevations.

Typically there is a location both up and downstream from the reach of concern that places a control on the elevation of the bed of the channel. These controls on the channel elevation or grade, whether in a rural, suburban or urban setting are usually culverts or bridges. The project planners can prescribe that culverts be replaced at a different elevation and-or slope in order to match a more stable stream slope. Culverts are frequently placed below historic stream slopes at road crossings to provide more clearance from the creek bottom to the top of the roadbed. (Probably, most common is just the haphazard placement of culverts). Recall that culverts that are too low can create upstream headcutting and downstream deposition and filling. Culverts that are too high act as dams, trapping sediment upstream, and can erode downstream channels. Culverts that are too small cause discharges to back up behind them, also creating a depositional environment that can fill the culvert with sediment and debris. Small culverts can constrict flows and increase the erosive force of discharges flowing down stream.

If a grade control structure has been built into the channel bottom it will typically cause two forms of channel instability. The structures usually overflatten the channel slope upstream. This upstream channel flattening will typically cause meander development, which often results in bank erosion and instability of terrace slopes. Downstream channel erosion usually follows because: a) the sediment load the stream is transporting gets trapped behind the structure, which acts as a dam, and therefore the "sediment hungry" downstream discharges pick up sediment from the stream channel, and, b) the sudden drop in elevation below the grade control structure creates high energy "waterfalls" which can undermine the base of the structure. Because grade control structures (often intended to stabilize grades) frequently actually destabilize grades, they should be removed and replaced with the proper channel length.

The correct elevational drops between the up and downstream ends of the channel reach can be calculated by multiplying the correct channel slope times the calculated feet of restoration channel length. There should be a "seamless transition in the channel bottom from a logical downstream point and elevation to where the project reach begins to the correct upstream elevation for that end of the project reach. In steeper, upper watershed channels the channel may require that the slope drops with small "step-pool" structures. Experience monitoring stream projects in the San Francisco Bay Area indicate a tendency for step pool drops more than 18" high to redistribute the bed material into forming shorter drops. The distinction between these step-pools and conventional grade control structures is that the former are designed to support a calculated channel slope and do not shorten, over flatten or over steepen the channel, as grade control structures are designed to do. Rock weirs placed to support a calculated design slope can help restore channel lengths and slopes.

**Box #5 - Fifth Impact Avoidance Measure:** Protect a Meander Belt Width for a Stable Planform

Provide for a channel meander belt width that accommodates the proper active channel width and amplitude for the meander.

A channel meanderbelt is defined as the space an active channel uses to meander the width and length it requires for a stable planform on the landscape. The amplitude of a meander defines the minimum floodplain space required by the creek for physical stability. Without this space the creek will usually react by either creating head cutting

(Figure 3) and, or the creek will attack its banks, trying to re-establish its meander pattern. Both reactions create substantial erosion and harm to adjacent property.

A meanderbelt width can be simply calculated by adding the active channel width to the meander's amplitude. A reasonable estimate for a stream meander amplitude is 2.7 times the active channel width, without regard to changes in stream type, for the San Francisco Bay Region. (The changes in channel meander patterns between lower watershed channels and upper watershed channels can be represented by the different channel meander distances).

**Box #6 - Sixth Impact Avoidance Measure:** <u>Protect or Restore Adequate Side Slopes From the Tops of Banks to the Tops of Terraces</u>

Provide for stable terrace slopes joining the floodplain or channel bank to the top of the ground elevation at the project site.

This part of the stable channel equation is unfortunately the least conducive to generalizing for project planning. In many situations in the San Francisco Bay Region, terrace slopes with a 1.5 to 1 slopes (1.5 foot horizontal distance for every foot vertical distance), which are planted using soil bioengineering revegetation methods, are not too steep to be stable. Of course, any site with more gentle slopes such as 2:1 and 3:1 may be even more stable. Some areas have geology and soil mantles with inherently unstable properties, with landslide zones and seismic fault lines complicating the picture. Site-specific measures have to be applied to these difficult sites. Keep in mind unstable terrace slopes are frequently due to localized drainage problems.

Counter-intuitively, a headwater stream channel may require a greater right-of-way or protected corridor than downstream channels with wider meanderbelts. This it because headwater channels in the San Francisco Bay Region are characteristically deeply entrenched in the landscape. In small and large watersheds alike, the stream channels in the upper portions can be located 30 to 50 feet or more below the level ground of a site. For such a stream to have natural terrace slopes at 2:1, it requires 60 to 100 feet on <u>each</u> side of the channel in addition to the required meanderbelt width to create a stable channel corridor. In contrast, a lower watershed active channel which overflows onto a floodplain which has no terrace or in which the floodplain is located only a few feet below the top of the terrace (level ground elevation) requires little or no horizontal space to make the transition from the bottom of the channel to the ground level. A ten-square mile watershed stream, for example, may need an 80 foot corridor to support a stable meander plan form on its way into the Bay, but up in the coastal hills, that stream may need a corridor over 200 feet to protect its stability.

**Box # 7 - Seventh Impact Avoidance Measure:** Protect and Restore the Floodplain and Meanderbelt

Protect a stream corridor that has enough feet to accommodate the combined stability needs of the active channel width, meanderbelt and terrace slopes.

Where possible seek expansion of the width of the floodplain area beyond the minimum required for the calculated channel meanderbelt. This floodplain area will contribute to the cross-sectional area needed to convey a design discharge for flood control considerations, add to the ability of plants to stabilize the stream system and reduce terrace side slope erosion hazards. This increases the ability of the stream system to support a riparian corridor and water treatment functions of the riparian wetland.

Regulators, public works engineers, stream project designers, land planners, and property owners have a tendency to view the available stream corridor as the space that should be minimized in order to accommodate other streamside land uses. This perspective blinds the viewer to what are often opportunities to expand the stream corridor enough to assure a stable channel that will no longer create chronic maintenance problems. The lack of meander corridor problem can often be solved by removing a few parking spaces in parking lots, acquiring a vacant lot, or rearranging the location of "out" buildings/structures, such as tool shacks, play equipment, utility boxes or poles, sidewalks and trails, driveway accesses, etc. Put the correct meander on the plan first, and then view the spatial conflicts as an opportunity to improve the site plan.

Remember, do not go to a site assuming a wider right-of way is necessary. Make the suggested calculations first so that you are proceeding with the best information. Project designers can be pleasantly surprised that existing available right-of-ways actually accommodate a stable channel planform.

It is counterproductive for planners to propose new development or new structures, such as retaining walls, next to a destabilized channel, as this placement will be in a hazard area. Widely used products such as concrete walls, articulated concrete blocks, gabions and other "retaining" methods encroaching on the corridor required for a stable channel is a recipe for project failure. A sustainable site plan developed with the objective to avoid flood and erosion hazards enjoys a long-term economy in the context of a lowered local public works hazard and the reduction of maintenance costs while simultaneously protecting the beneficial uses of the waterway.

Common features of older, conventional flood control projects are two maintenance roads along each project boundary. The removal of one road (an essentially redundant feature given the capabilities of modern day equipment to accomplish maintenance work from one side) can provide new right-of-way use opportunities that can accommodate a new cross-section design containing a more stable, complex and functional project.

If there are no options to expand a project's right-of-way for a stable meander belt, it is best to compromise the design by steepening the terrace slopes and not narrow the meander belt.

**Box #8 - Eighth Impact Avoidance Measure:** Protect and Restore Terrace Side Slopes

After all opportunities to expand a stream corridor required for a calculated stable channel and stream corridor are realized and there still remains some undersized sections, the compromised stream sections should first steepen the terrace side slopes to reduce the required stream corridor width.

Terrace side slopes can be both steep and stable using a variety of bioengineering revegetation systems. Some of these systems can integrate permeable physical structures such as vegetated wood crib walls, which allow for unrestricted water movement though the banks. It is more important to assign scarce space in difficult urban situations to retain the integrity of the active channel and meander for both stability and protection of stream functions and water quality. Ecologists may present other habitat priorities based on the specific habitat needs of a listed endangered species, for example. In the absence of these kinds of specific environmental needs, however, this planning process advises the project managers to consider in-stream aquatic habitat needs as a priority over visual quality or landscaping schemes for terrace slopes in resolving conflicts over the use of tight spaces.

**Box #9 - Ninth Impact Avoidance Measure:** Employ Intensive Soil Bioengineering Revegetation Systems.

Impermeable retaining walls such as concrete, rock, sheet-metal, and wood can have high failure rates because of the build up of pore pressure behind the structures in a water saturated environment. Engineers have recognized the superior tensile strength of plant roots to hold stream banks and terrace slopes. Stability will be improved if these rigid structures are removed, particularly if they are compromising stable channel shapes. For those projects with terrace slopes compromised because of narrow project widths, the use of the most dense and deeply planted soil bioengineered revegetation systems will maximize stability of the slopes. If vertical walls are constructed, the cost of their maintenance and eventual replacement should be a factor in the planning.

**Box #10 - Tenth Impact Avoidance Measure:** Meander Lengths Should Be the Last Physical Feature Compromised Within the Meanderbelt

In the event of a severe restriction of right-of-way options, the meander length should be the next component after terrace side slopes to be compromised. Meander length compromises require rocked outside channel bends and acceptance of future stream bottom erosion and planform instabilities. The channel slope can sometimes be broken up into very small drops as a means of compensating for the lack of channel length. Channel headcutting and long term maintenance costs are commonly associated with this kind of compromise. (Correct bankfull channel widths and depths should always be a protected project feature with an exception made for alluvial fan braided channels.)

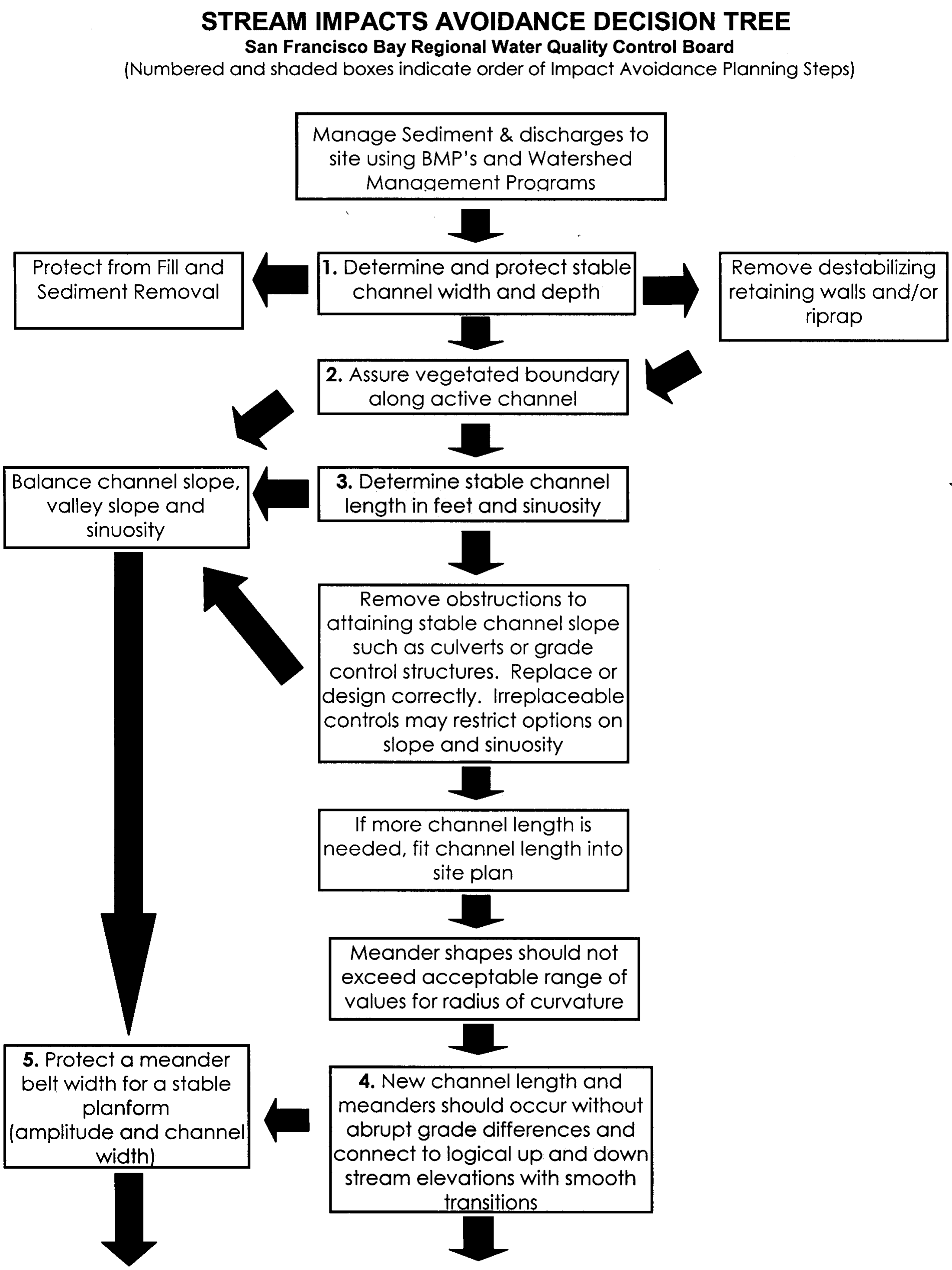
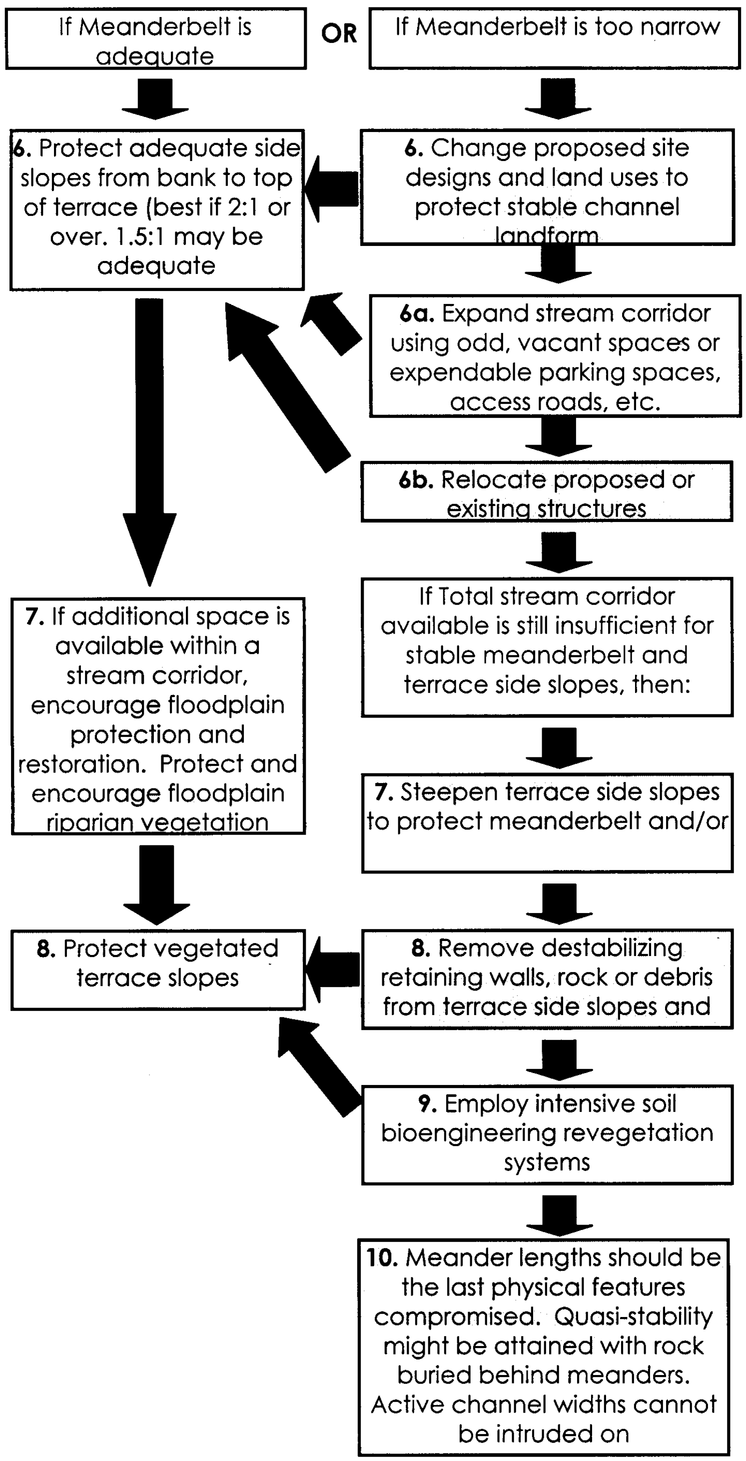



**Table 6**

**Table 6 – cont.**


If Meanderbelt is adequate
OR
If Meanderbelt is too narrow
6. Protect adequate side slopes from bank to top of terrace (best if 2:1 or over. 1.5:1 may be adequate
6. Change proposed site designs and land uses to protect stable channel landform
6a. Expand stream corridor using odd, vacant spaces or expendable parking spaces, access roads, etc.
6b. Relocate proposed or existing structures
7. If additional space is available within a stream corridor, encourage floodplain protection and restoration. Protect and encourage floodplain riparian vegetation
If Total stream corridor available is still insufficient for stable meanderbelt and terrace side slopes, then:
7. Steepen terrace side slopes to protect meanderbelt and/or
8. Protect vegetated terrace slopes
8. Remove destabilizing retaining walls, rock or debris from terrace side slopes and
9. Employ intensive soil bioengineering revegetation systems
10. Meander lengths should be the last physical features compromised. Quasi-stability might be attained with rock buried behind meanders. Active channel widths cannot be intruded on

## Applying Avoidance Concepts

This Circular is not intended to be a stream restoration manual, nor does it prescribe which restoration tools or methods should be applied to particular stream management cases. However during the course of explaining a design process to use to avoid environmental impacts, a number of terms are used with which the reader may not be familiar. References are made to available information on the shapes and sizes of stable stream channels and the Circular's figures contain much of this information. This final portion of the Circular provides illustrations to explain this technical terminology and provide the practicing consultant with some information particular to San Francisco Bay Region streams that can be applied to designing stable channels. It is hoped that other regional boards will prepare circulars such as this. Each region has landscapes not shared by the other regions, and, for this reason, each circular needs to be customized for these differences.

### The Shapes of San Francisco Bay Area Streams

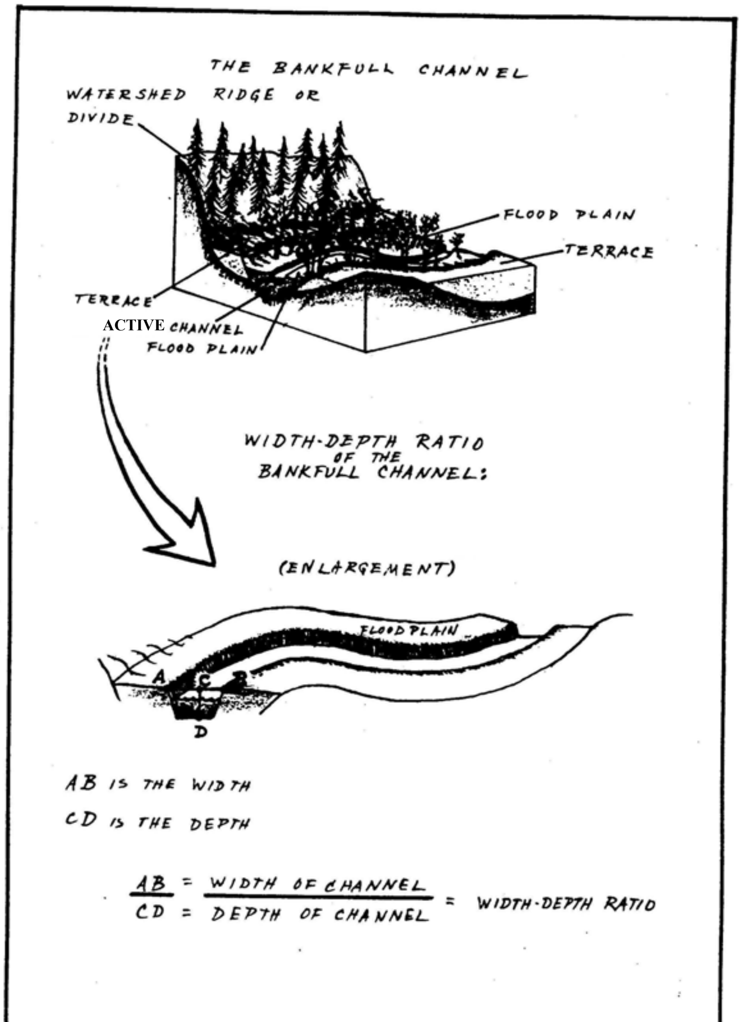
Bankfull Channels, Floodplains and Terraces

Figure 6 illustrates some terms used frequently in this Circular: bankfull channel, floodplain and terrace. The bankfull channel refers to the channel that carries most of the sediment of a stream over a long period of time and it is here that the most dynamic part of the stream system is located. This is the part of the stream system that contains the erosional and depositional features of a stream as illustrated in Figure 2. This is where the pool and rifle habitats form which are so important to aquatic organisms and this is where the sediment transport dynamics can create meandering. The terms "active channel", "bankfull channel" and "low flow channel" are often used interchangeably. This can create some confusion because sometimes engineers will construct what they call a "low flow" channel into a channelization flood control project in an effort to create some fish passage in an over-widened channel. Sometimes these channels are called "trickle" channels. The bankfull and active channels this Circular refers to are self-sustaining, natural channels as opposed to artificial constructions for fish passage.

The active or bankfull channel spills over on to the floodplain on the average of twice every three years, or is formed on the average, by what hydrologists refer to as the one in one and a half year discharges. Because the bankfull or active channel is the part of the stream system responsible for the transport of the most sediment over time, it can become destabilized quickly if it is too wide or too narrow, and therefore become a depositional or erosional problem.

The bankfull channels in the San Francisco Bay Area have been eroding down in their beds over the past hundred years or more due to both climatic and land use changes. Streams used to overflow frequently onto expansive wide floodplains. We can still see remnants of this landscape type on the very flat gradient reaches of stream channels where they enter the Bay or Ocean and the active channels are connected to their broad floodplains. Upstream in the steeper portions of watersheds, most of the active or bankfull channels are confined with very little floodplain because of how they have eroded down or become entrenched in the landscape. Figure 7 shows typical cross-sections of a stream channel in the Bay Area for the upper part of the watershed, the middle section, and the flatter lower elevations. The older floodplains now serve as the ground surface, and are now cut off from flooding by the entrenched stream channels.

These older abandoned floodplains are called terraces.




**A.L. Riley, <u>Restoring Streams in Cities, Island Press 1998</u>**

**FIGURE 6. The Components of a Stream Corridor**

The terms “active channel” and “bankfull channel” refer to the same part of the stream system. On the average, this channel is formed by discharges up to the 1.5-year flood, or the flood that occurs on the average of twice every three years. “A low flow” channel refers to a channel that is formed within an active channel by summer flows. If a stable active channel exits, these dry season low flow channels usually form quickly and easily without assistance within the active channel.

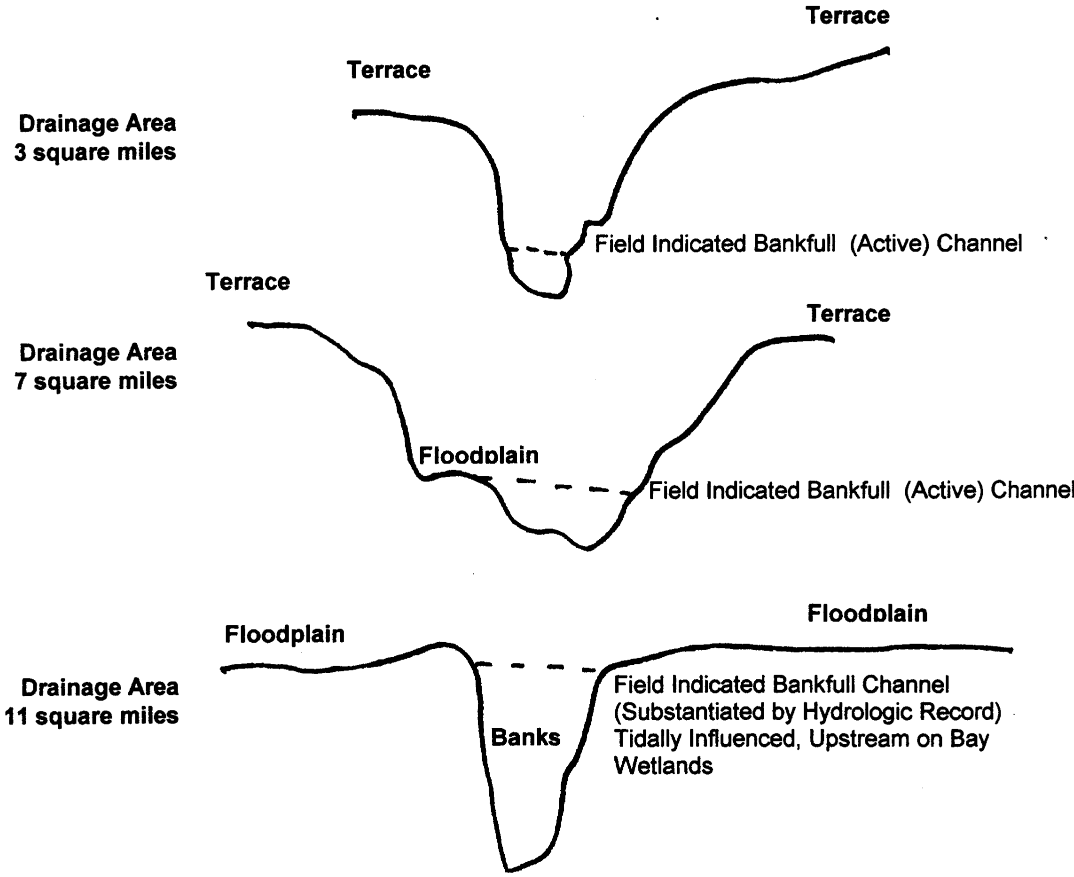



**FIGURE 7. Typical Bay Area Stream Channel Shapes**

A popular and widely disseminated depiction of the channel processes and adjustments to expect after a channelization project, developed by Schumm, Harvey and Watson [4] in 1984, is not a good model to apply to Bay Area streams. Their diagrams and descriptions address flat gradient Midwest environments such as the Midwest and do not represent what usually happens in our steeper, flashier, coastal streams. When these flatter gradient channels widen and deepen after channelization, the sediment falls into the bottoms of the newly formed larger channels and new smaller channels form within this depositional zone. In contrast, in the Bay Area, sediment from collapsing stream channel banks usually moves in "slugs" in a relatively short period of time out to the Bay or Ocean, and does not become a permanent feature of the newly adjusting channels. In

[4] S.A. Schumm, M.D. Harvey and C.C. Watson, "Incised Channels: Morphology Dynamics and Control," Water Resources Publications, Littleton, Colorado 1984

the Bay Area, channelization tends to produce over-steepened, headcutting channels that become both wider and deeper than their pre-disturbed conditions.

Planform Stability of Streams in the Bay Area

The return of sinuosity to a degraded stream channel as recommended by Box #5 in the Decision Tree raises the issue as to whether this represents a new stability in the sense that the longer stream channel will stay in a place and not migrate across the floodplain. Streams in equilibrium may migrate, changing the location of their active channels on the floodplain. Obviously this dynamic may raise long-term concerns for property owners. How should we view this issue in the Bay Area?

Years of monitoring and good record keeping will provide the only definitive information on this tendency for meander development in the bay area landscape. Comparisons of historic maps from the 1800's and early aerial photos starting in the 1930's indicate that many channels have been straightened, filled, culverted and or leveed, but where stream reaches remain unimpacted, the current day meander locations appear to closely match the location of these historic meanders. Where grades have been flattened behind dams, reservoirs and grade control structures, records and field investigations indicate active meander migrations. Streams just entering their flat bay marshes also indicate very dynamic, migrating channels.

An explanation for the relative planform stability for the remaining types of unimpaired channel reaches can be partially explained by the meanders being trapped within increasingly entrenched stream corridors. The relative planform stability of bay area streams can also be explained in part by the commonly occurring structural soils, which offer resistance to channel movement because they contain a high percentage of clays and other resistance materials. The climate also provides enough rainfall to support good vegetative cover and vegetative recovery in disturbed areas, also adding some resistance to channel migrations. Drier regions of the bay area with high sand content in the soil can be expected to exhibit more meander migration. The degree of vegetative cover may be a primary influence on planform stability in many situations. The significance of these observations is that the fortunate factors of structural soils and good growing conditions provide supportive environmental conditions for restoration approaches succeeding in the creation of relatively stable planforms under average conditions.

Multiple Channels and Wetland Environments

Water flowing down steep alluvial fans tends to collect in small, multiple and very dynamic, constantly meandering channels, referred to as braided channels. The alluvial fans usually represent environments where sediment is transported down steep mountainous or hilly areas where it is dropped in the shape of a fan as the sediment reaches a flatter valley gradient. While these massive landscape features are ubiquitous in the mountainous areas of California they are a comparatively uncommon feature in the Bay Area and when they occur, are present on a relatively small scale. Braided channels on alluvial fans can represent the equilibrium condition for these naturally very dynamic systems. Because of the incredible dynamic nature of these landscapes it is very risky to allow development of any kind near them, and it is ill-advised to attempt to transform them into what might be perceived as more stable single channels because the landscape is not conducive to supporting a single channel.

If braiding is occurring because of excessive sediment inputs, and physical damage to channels from mining, grazing or logging then it is appropriate to explore the option of returning the unstable braided system to a single channel type after or while addressing the cause of the excessive sediment loads.

In some regions of the Bay Area, stream channels were historically discontinuous in that they “disappeared” into subsurface groundwater or spread into wetlands. Management and restoration objectives need to be addressed on a case-by-case basis for these environments based on localized ecological needs and land use constraints.

Figure 8 is a graph developed by fluvial geomorphologist Luna Leopold, which represents the relationship between the average bankfull channel dimensions in the Bay Area with the drainage areas of the channels using data obtained from U.S. Geological Survey stream gaging stations. This can be a useful tool to determine if a stream channel is significantly under or over sized. The Regional Board is encouraging the development of this type of hydraulic geometry data for sub-regions in the Bay Area to make this data even more useful in representing the different climatic conditions found in the northern, southern and eastern portions of the Bay Area. Figures 8a and 8b represent relationships for the East Bay subregion on the west side of the East Bay hills.

FROM: "WATER IN ENVIRONMENTAL PLANNING"

Tom Dunne and Luna Leopold
W.H. Freeman Inc. 1978

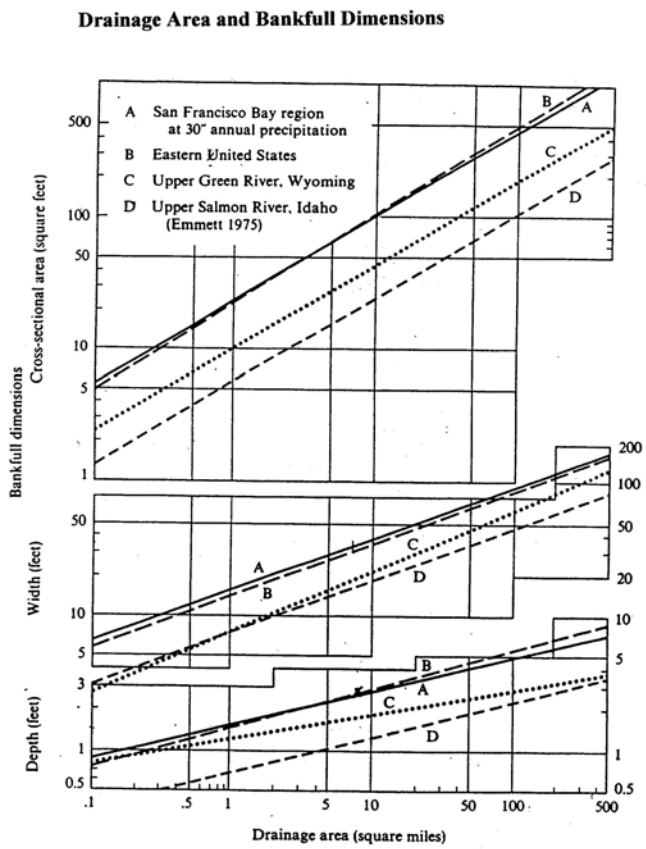
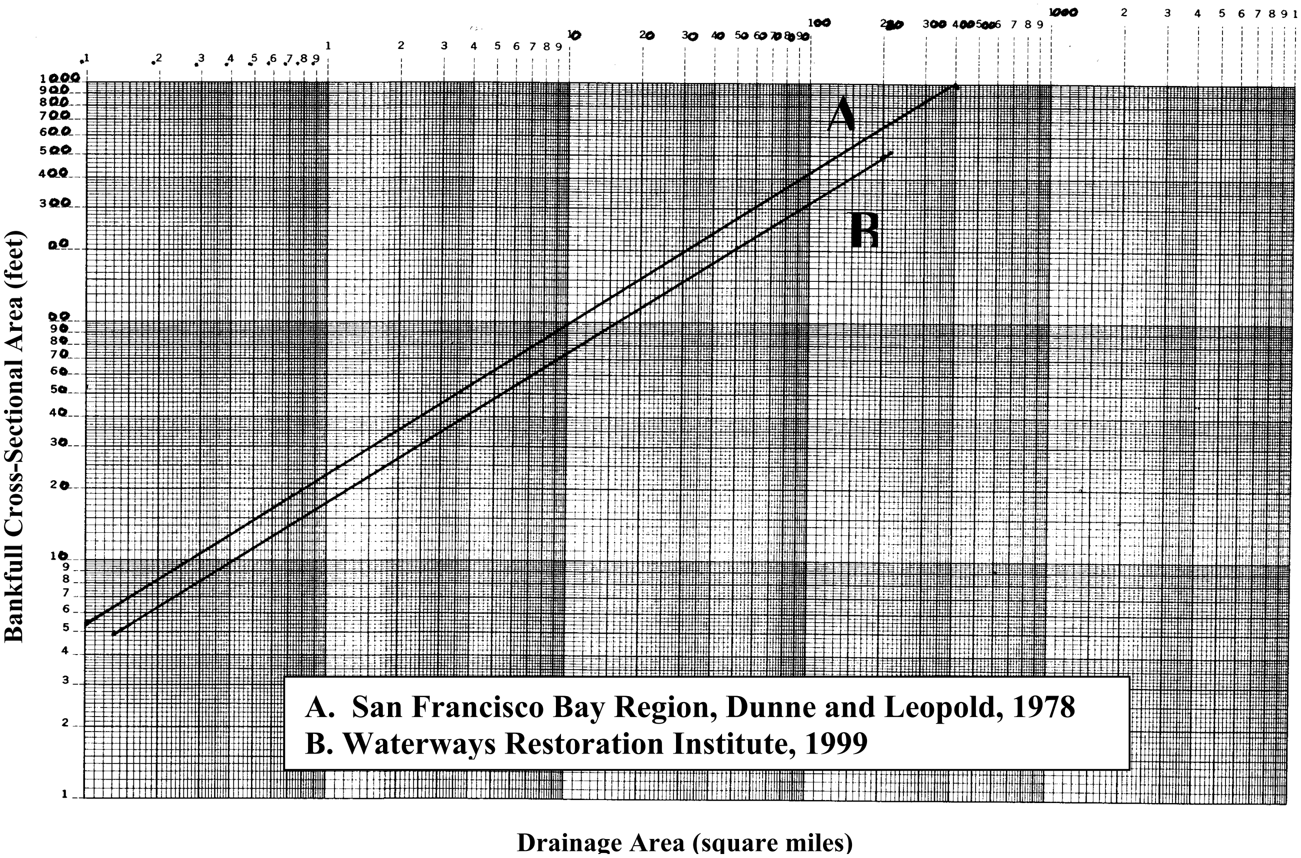



**FIGURE 8. San Francisco Bay Regional Data on Stream Dimensions**

**Figure 8a. Adjusted Regional Curve for the East San Francisco Bay Region**



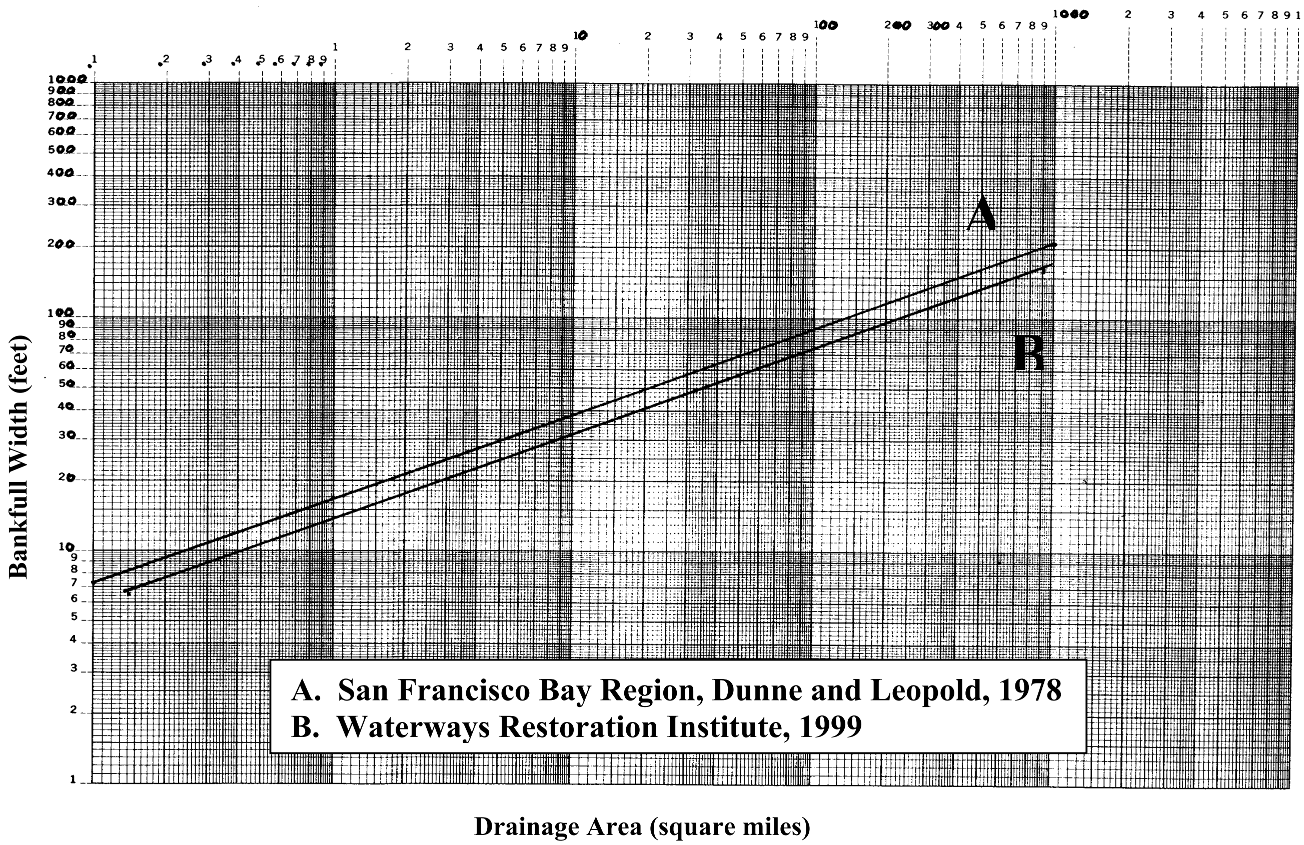
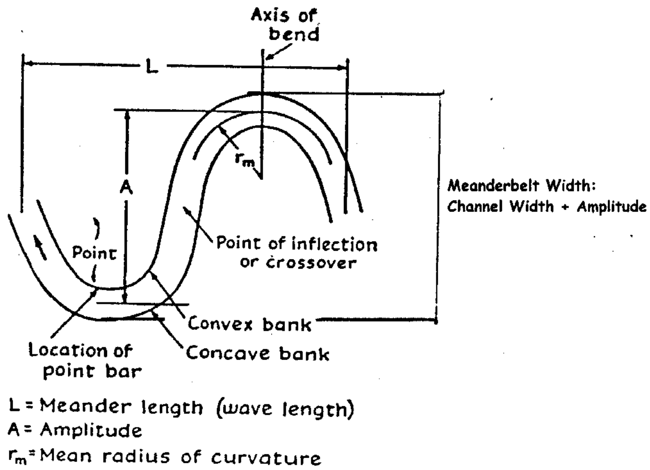



**Figure 8b. Adjusted Regional Curve for the East San Francisco Bay Region**

**Stream Channel Meanders and Slopes**

Figure 9 shows a diagram of a stream meander such as appears in Figure 2, but the diagram breaks a meander down into different quantifiable sections. The components of meanders can be quantified in this way and because there tends to be a relationship between the shapes of meanders and the width of a stream and the type of stream channel. The data in this diagram can be used to estimate the stable sinuosity of a stream in the San Francisco Bay Region. The diagram should not be used to design stream meanders because stream meanders are rarely found in the landscape with the perfect sinusoidal(s) curves shown in the diagram. Figure 10 uses nationally derived data to draw relationships between channel widths and their lengths. Again, this kind of information can be developed particular to the San Francisco Bay Region and its sub-regions. Figure11 shows a graph used to design steep channels. Steep, headwater streams expend energy in relatively straight drops and pools called step-pool channels. Drops over 12-18 inches may cause channel instability and or fish passage problems and therefore, a slope broken up by numerous, small drops may be more stable and desireable. Recent reasearch on high gradiant gravel bed rivers in the Pacific Northwest provides some guidance on the spacing of boulder-steps which may be useful for applying to our steep coastal California streams.




**Regression Equations**
**From L. B. Leopold and M. G. Wolman, "River Meanders"**
**Geological Society of America Bulletin**, V. 71, 1960

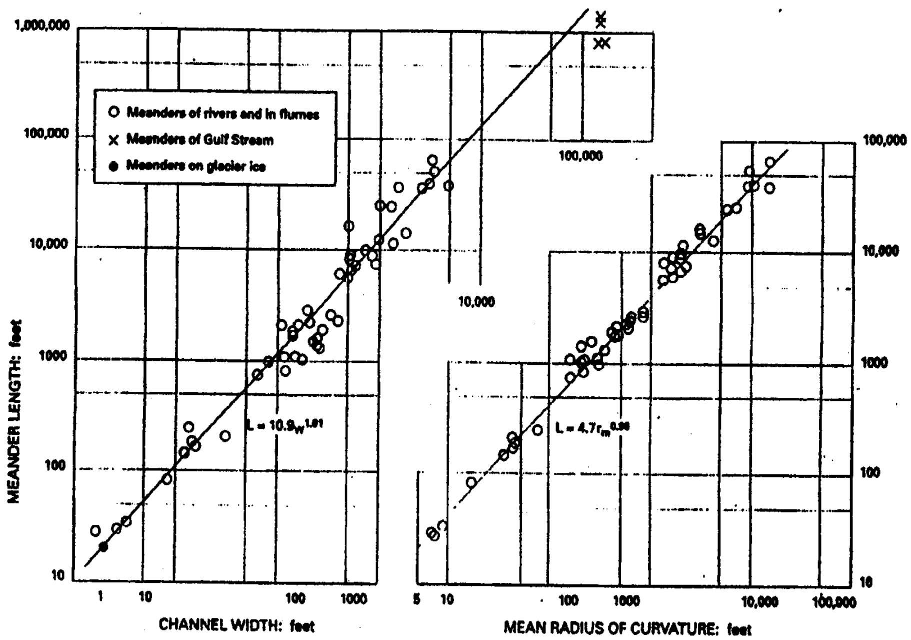
| Meander Length to Channel Width | Amplitude to Channel Width | Meander Length to Radius of Curvature |
|---|---|---|
| $L = 10.9w^{1.01}$ | $A = 2.7\ w^{1.1}$ | $L = 4.7r_m^{0.98}$ |
| Meander length ranges from 7-10 times the channel width | *$A = 2.7\ w$ | Approximately 1/5 Of Meander Length |

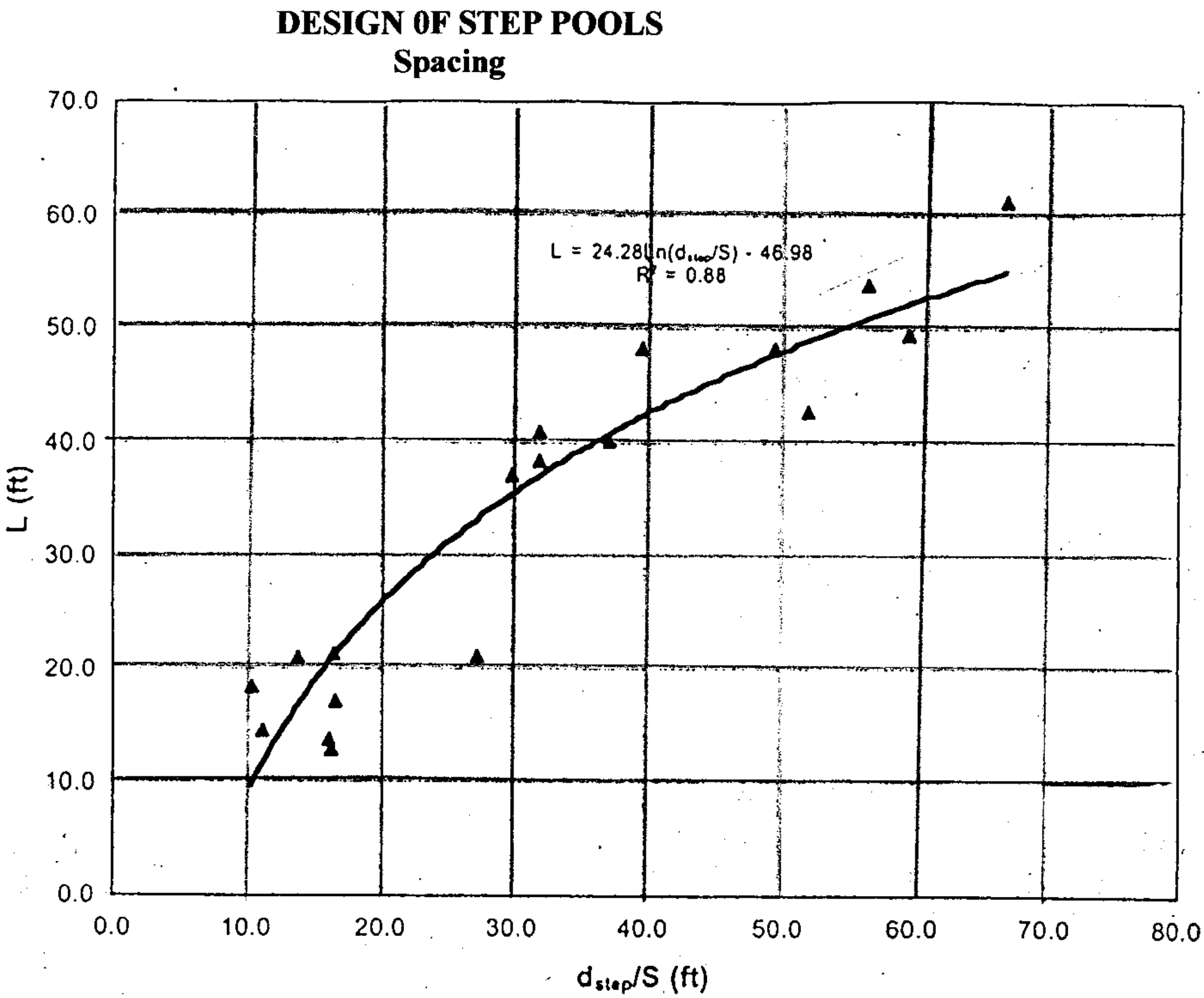
Radius of Curvature to Channel Width
$rm = 2.3w$
(ranges 1.5 - 4.5)**

*Waterways Restoration Institute-computed SF Bay Area Average
**Dave Rosgen

**FIGURE 9. Geometry of Meanders**

**FIGURE 10. Meander Shapes and Lengths**. National Data. "A View of the River", Luna B. Leopold, Harvard Press, 1994.






**From: A.R. Maxwell, A.N. Papanico, Washington State University, "Spacing of Step-Pool Systems in Gravel-Bed Rivers," Proceedings of the Seventh Federal Interagency Sedimentation Conference, March 25-29, 2000, Reno, Nevada**

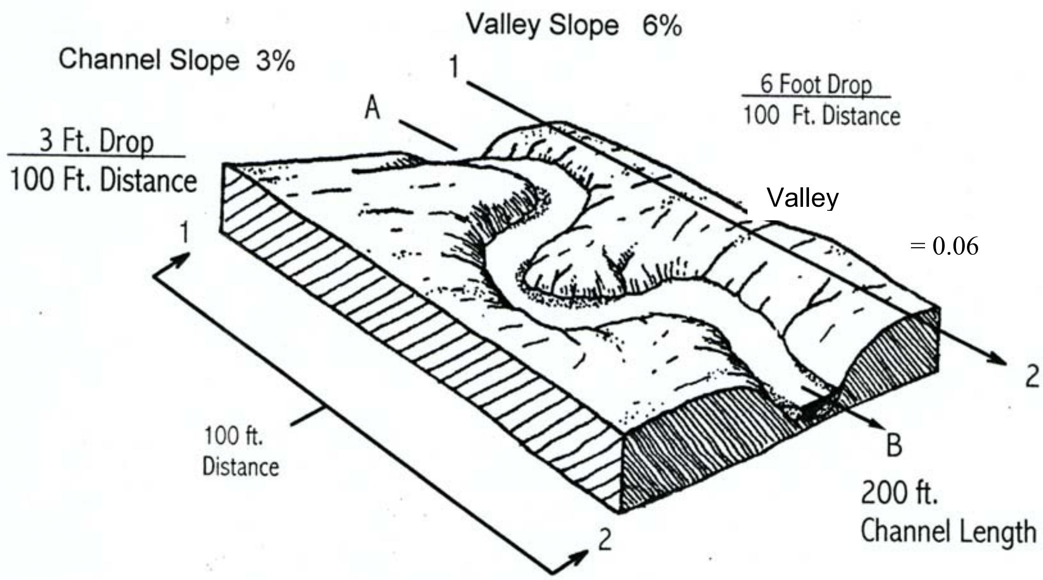
**For slopes in the range of 3 – 19%**

$$L = 24.28 \ln \left( \frac{d\ step}{s} \right) - 46.98$$

**Where:**

**L=step spacing in feet**
**d step = step height**
**S = channel slope**

**FIGURE 11. Step – Pool Channels**




$$\text{Sinuosity} = \frac{\text{Valley Slope}}{\text{Channel Slope}} \quad \frac{6\%}{3\%} = 2$$

6 foot drop / 200 feet = 0.03

$$\frac{\text{Channel Length (A,B)}}{\text{Distance}} \quad \frac{200}{100} \; (1,2) = \text{Sinuosity } 2$$

Elevation Drop for Valley Slope
Slope X Straight Valley Distance
0.06 X 100 = 6 foot drop

$$\text{Channel Slope} = \frac{\text{Valley Slope}}{\text{Sinuosity}} \quad \frac{.06}{2} = .03$$

Elevation Drop for Channel Slope
Slope X Design Channel Length
0.03 X 200 = 6 foot drop

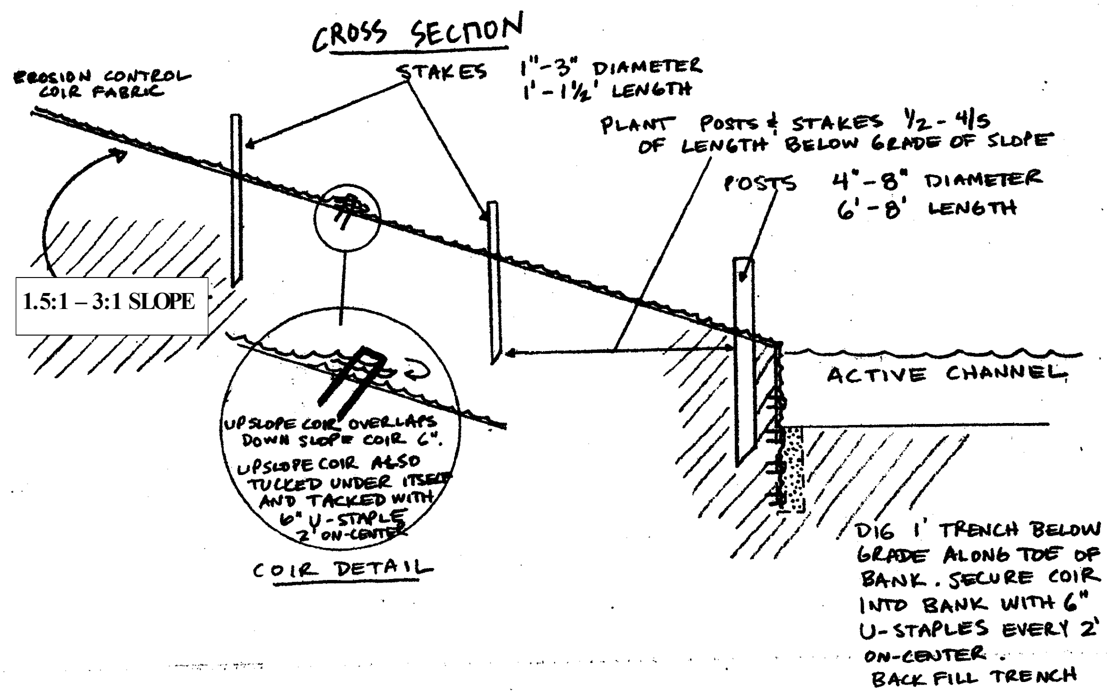
Channel Length = Valley Distance X Sinuosity
100 X 2 = 200

**FIGURE 12. Meander and Channel Slope Restoration** (Waterways Restoration Institute) Figure 11 illustrates the relationships between the sinuosity of a stream and its channel slope and valley slope. This Circular recommends that a good way to stabilize the plan form and slope of a stream is to make sure the three features of the stream landscape, sinuosity, channel and valley slopes are in balance with each other.

**Stream Channel Revegetation**

This Circular refers to the profound influence vegetation has on the shape and stability of a stream channel. Revegetating a stream channel alone, without regard to what the proper channel shapes are, may not solve the problems the property owner or manager is facing. However by combining revegetation in concert with the proper channel shapes and slopes the property manger has a very good chance of successfully addressing their problems. Figure 12 shows a very effective and increasingly popular method of revegetating stream channels using 4 to 8 foot long branches cut from willow or cottonwood trees. A hole is driven into the ground using a ram attachment on the end of an excavator, or by simply using a sledgehammer and a piece of construction stake or long crow bar. The long 2-5 inch thick willow or cottonwood "post" is then planted in the hole. These posts will quickly root and send out new leaves and become large size trees with masses of root growth to bind stream banks. Because the posts are driven so deeply into the channel and because of the area covered by the root growth, these posts can out perform the traditional riprap used to protect stream banks.

**Figure 13A. Willow and Cottonwood Posts Installation Diagram**



**Photos:**

13 B Photo: Willow Post. Note planting end has been pointed for easy installation.

13 C Photo: Installing a willow or cottonwood post by hand.

13 D Photo: Mechanical installation of willow or cottonwood posts. Illinois Water Survey

13 E Photo: Willow and cottonwood growth after one year of mechanical installation, Illinois Water Survey.

**Figure 13A.** Willow post installation with geotextile fabric. Photos: (B) A watershed management ranger is holding a post he has cut from a willow. This is a 5-foot long, 3-inch thick branch cut from a willow shrub with the lateral branches removed. The lower portion of the branch is pointed with a saw for easy planting.

(C) The post is driven into a stream bank with a mallet using a two-by-four board to protect the post from splitting.

(D) Large scale projects can install many posts quickly along long reaches of stream using a ram attachment on the end of an excavator.

(E) One year after mechanical installation when posts have grown to trees.

13 A credit: Urban Creeks Council of California. Photo credits: B and C - Waterways Restoration Institute; D and E - Illinois Water Survey

**Figure 14A. Installation Diagram for Brush Layering**

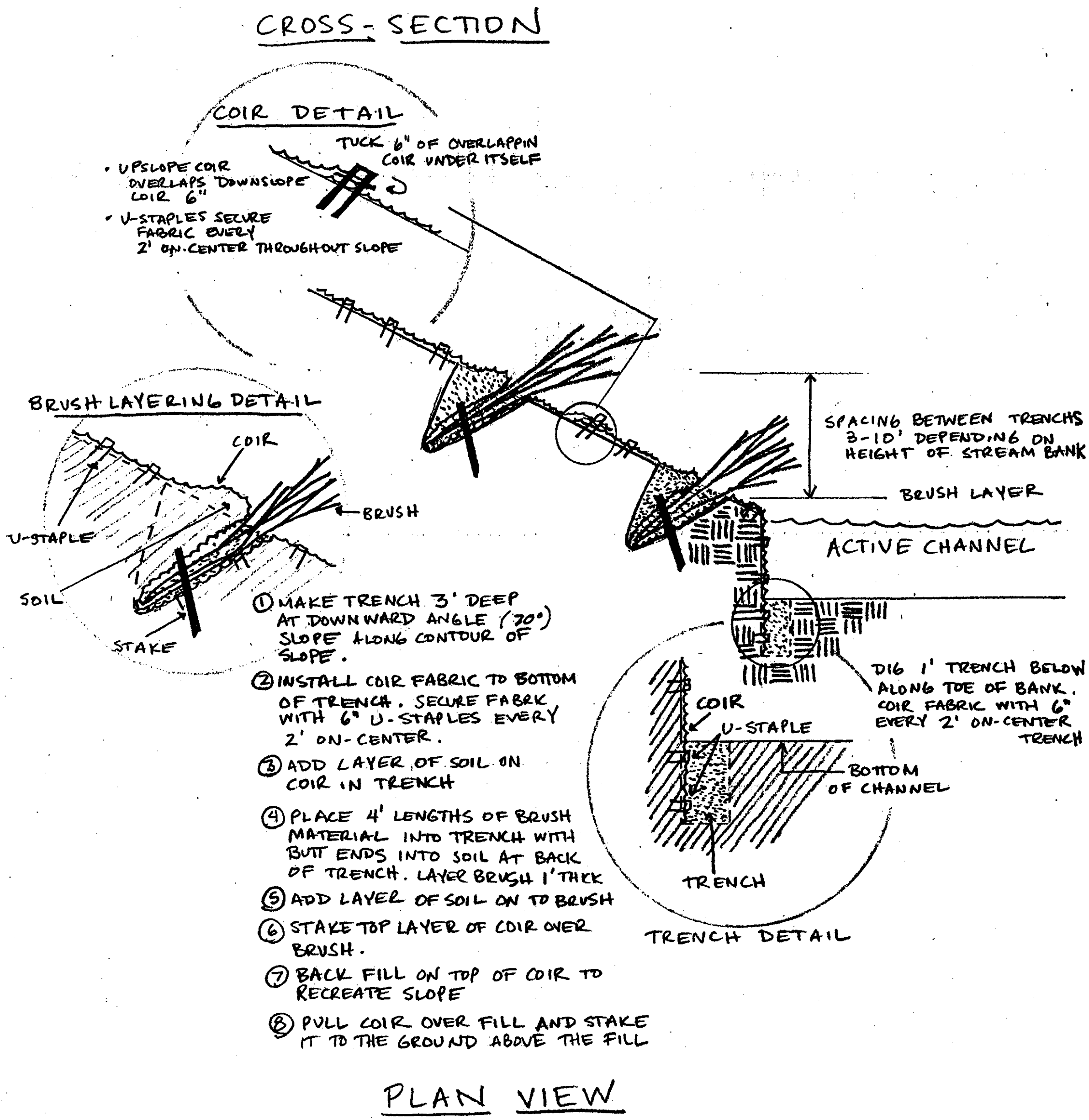



**Figure 14. Brush Layering Installation**

Figure 14 illustrates a "soil bioengineering" technique (a bundling of plant material and soil to control erosion on difficult sites) called "Brush Layering." This system of stream bank strengthening can be used to rebuild eroded or collapsed stream banks. The plant material cut from willows, cottonwoods or other riparian species is layered perpendicularly to the stream bank slopes. These layers of vegetation grow quickly, sending a mass of root growth into the banks and slowing the velocities of erosive stream flows on the banks.

**Figure 14 B**

**Figure 14C photo**

**FIGURE 14. Brush Layering Installation.**

Figure 14B. Brush layering installed with Coir© fabric and willow posts on Codornices Creek at Body Time Building, 8th-9th Streets, Berkeley, CA, in 1996.

Figure 14C. Same site in 2001, in stable condition despite proximity of urban development to top of bank.

Construction specifications: Urban Creeks Council of California

Photos: Waterways Restoration Institute

**Figure 15A.  Diagram Brush Matting Installation**

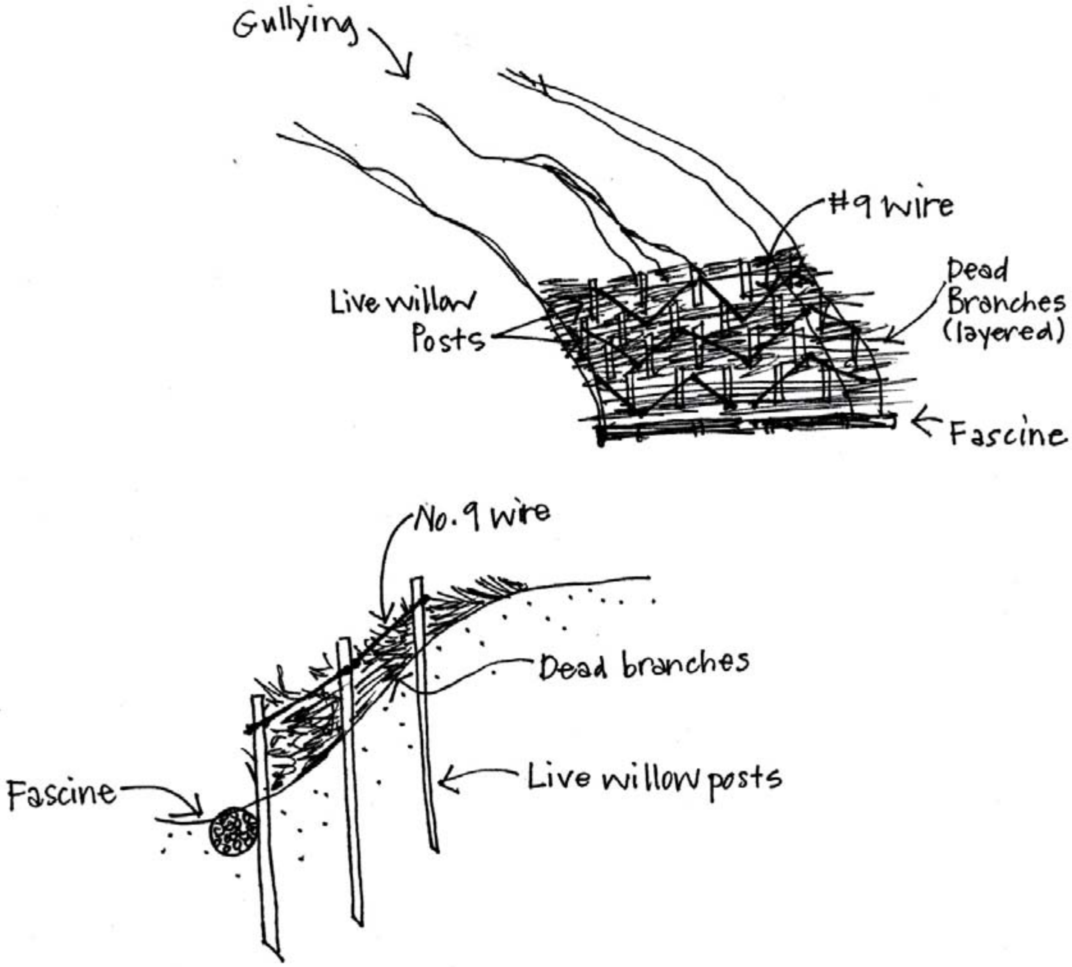



**Figure 15A.  Brush Matting Installation; Figure 15B. Brush Matting;  Figure 15C Brush and Post Installation:** Brush Matting is a system described in soil bioengineering literature in which the cut ends of willows are pushed into the ground where they then root. The stems are wired down onto the stream bank with wood stakes cut from lumber and wire. This system offers extensive plant coverage over the bank.  Figure 15C - this photo shows just installed brush layering near the foot of the stream bank.  The system shown up bank from that is brush- and-post, which is very similar to brush matting, but it is easier to install.  Live posts are driven into the bank and the space around the posts are filled in with dead plant material held down with wire or heavy twine between the posts.  This system is conducive to building the bank up by trapping sediment and the substantial structure protects banks from high sear stresses.

**Figure 15B. Brush Matting**

**Figure 15C.  Brush and Post Installation**
Construction Specifications:  Restoring Streams In Cities, Island Press, Wash. D.C. 1998
Photos: Waterways Restoration Institute

## APPENDICES



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Soil Conservation Service, Soil Bioengineering for Upland Slope Protection and Erosion Reduction, Engineering Field Handbook, U.S.D.A. 1992

## APPENDIX B - EXAMPLE OF A STREAM STABILIZATION PROJECT

The following case illustrates a very degrade stream in a commercial-industrial and residential setting. The case involves Codornices Creek forming the boundary of two cities, Albany and Berkeley, California. The Creek was straightened in the reach shown in the mid-1960's and presented a continual bank erosion, maintenance and flood hazard problems for the adjacent properties. A project was proposed to widen the active channel (not its flood plain) and add more rock or concrete to the channel.

Rather than using this conventional approach and repeating the management practices of the past, the Creek was restored using the approach described in this Circular. A more stable active channel width and depth were determined using the regional relationships shown in Figures 8A and 8B and measurements from a reference site at a nearby creek. The historic sinuosity was first estimated using the relationships of channel lengths to channel widths as shown in Figures 9 and 10. Later, a diagram of this section of Codornices Creek carefully drawn by a city engineer in the early 1960's before it was straightened was found, confirming this calculated estimate of the a more natural sinuosity. The space between the buildings did not allow for a fully restored channel length but it was possible to add significant channel length to the Creek. Brush layering, willow posts, and geotextile fabric were added to the restored channel shape and length. The project was immediately tested one month after installation by a one-in-twenty-five year flood, which caused no bank erosion or neighborhood flooding.

**Figure 16A. Channel Restoration Case - Photo A - Before project conditions, 1995**

**Figure 16B. Before Project Conditions: Concrete failure**

Photo A: Codornices Creek has been straightened from a historic sinuosity of 1.3 to approximately 1.0. Because of the instability this straightening caused, adjacent property owners tried to harden Creek banks with sacrete, concrete and other miscellaneous materials. These bank treatments further narrowed the active channel, destabilizing the channel even more.

Photo B: Historic bank stabilization projects had narrowed the active channel, resulting in more frequent flooding into adjacent residential and commercial buildings (1995 photo).

**Figure 16C. Creek Restoration Project**

The 1996 stream restoration project resulted in a properly sized active channel using the regional relationships of bankfull channel sizes and drainage areas. The Creek channel was lengthened significantly to provide a sinuosity of a little over 1.2, but the project could not meet the design objective of 1.3 because of adjacent land use conflicts. The banks were planted with willow stakes at the top of the active channel, and brush layering combined with geotextile fabric was installed above that. Photo C shows the flood of January 1996 occurring immediately after completion of the project. No flood damage or bank failures occurred.

**Figure 16D.**

Photo 15D shows the same site in 2001. The channel capacity of the Creek has been approximately doubled, and the neighborhood no longer floods every year or two. The proper width of the reconstructed active channel and the length added to the channel have solved most instability problems. A new headcut formed because the Creek is still too short, but growth of the willow stakes has prevented any bank failure to date. Coastal steelhead have been found at the site. Another phase of the restoration project will occur between 2003-5 when one of the adjacent residential buildings will be replaced, which provides the opportunity to restore the Creek's optimum sinuosity of 1.3. The path of the newly restored channel does not follow the historic alignment of the creek. In fact it diverts dramatically from the historic alignment. The fact that the stabilizing length of the creek is being returned over the same valley slope, however, is providing us with in a stable, equilibrium channel.

## APPENDIX C - San Francisco Bay Area Watershed Partnerships and Organizations

The Regional Board is indebted to the **Creek Speak Newsletter**, a project of the Aquatic Outreach Institute located in Richmond, for the following list of San Francisco Bay Area watershed organizations. This list was issued in Fall 2002. Contact the Aquatic Outreach Institute for updates of this list at www.aoinstitute.org

***East Bay Watersheds***

**Alameda Creek (includes Arroyo de la Laguna, Arroyo del Valle, Arroyo Mocho, Sinbad Creek, and Stonybrook Creek); Fremont, Livermore, Pleasanton, Sunol, Union City**

- Alameda Creek Alliance: Jeff Miller, 510-845-4675, alamedacreek@hotmail.com, http:/www.alamedacreek.org/

**Alhambra Creek (includes Franklin Creek); Martinez**

- Friends of Alhambra Creek: Shirley and Igor Skaredoff, 925-229-1371
- Contra Costa Resource Conservation District: Carla Koop, 925-672-6522 x109, www.ccrcd.org

**Arroyo Viejo Creek (includes 73rd Avenue Creek, Country Club Creek, Melrose Highlands Creek, and Rifle Range Creek); Oakland**

- Sandra Marburg, 510-635-4465

**Baxter Creek (aka Bishop Creek and Stege Creek, includes Canyon Trail Creek, Mira Vista Creek, and Poinsett Creek); El Cerrito, Richmond**

- Friends of Baxter Creek: Apple Szostak, 510-231-5778, http://www.creativedifferences.com/baxtercreek/

**Blackberry Creek (aka Marin Creek); Berkeley**

- Friends of Five Creeks: See Cerrito Creek

**Cerrito Creek; Albany, Berkeley, Richmond, Kensington**

- Friends of Five Creeks: Susan Schwartz, 510-848-9358 or 510-412-7257, F5creeks@aol.com, http://www.fivecreeks.org/

**Claremont Creek (aka Harwood Creek); Berkeley, Oakland**

- Also see Temescal Creek

**Codornices Creek; Albany, Berkeley**

- Friends of Five Creeks: See Cerrito Creek
- Neighborhood Association, Alan Gould, 510-848-4465

**Contra Costa Watershed Forum**

- John Kopchick, 925-335-1227, jkopc@cd.co.contra-costa.ca.us; Kae Ono, 925-335-1230, kono@cd.co.contra-costa.ca.us, www.cocowaterweb.org

**Garrity Creek; Richmond**

- Barbara Pendergrass, 510-223-6091, hilltopcreek@yahoo.com, www.geocities.com/hilltop.html

**Glen Echo Creek (includes Cemetary Creek and Rockridge Creek); Oakland**

- Valerie Winemiller, 510-653-4552

**Harwood Creek (aka Claremont Creek); Berkeley, Oakland** (also see Temescal Creek)

- Kids for the Bay: Mandi Billinge, 510-985-1602, www.kidsforthebay.org

**Kirker Creek**; **Pittsburg**

- Contra Costa County Resource Conservation District: Junko Bryant, 925-672-6522 x4, www.ccrcd.org

**Lafayette Area**

- Carl Piercy, 925-284-4251

**Leona Creek (aka Lion Creek); Lion Creek (aka Leona Creek), includes Chimes Creek (aka Hillsmont Creek) and Horseshoe Creek; Oakland**

- Gary Scott, 510-845-4842; or Robin Freeman, 510-848-5713

**Marsh Creek (San, Dry, and Deer); Contra Costa**

- Contra Costa County Resource Conservation District: Nancy Thomas, 925-672-6522, Nancy.Thomas@ca.usda.gov

**Marin Creek (includes Blackberry Creek); Albany, Berkeley**

- Friends of Five Creeks: See Cerrito Creek

**Middle Creek; Albany, Berkeley**

- Friends of Five Creeks: See Cerrito Creek

**Pinole Creek**; **Pinole**

- Dr. Joe Mariotti, 510-724-1235; Carol Arnold. 510-724-9265, c2arnold@aol.com.

**San Leandro Creek (includes Buckhorn Creek, Grass Valley Creek, Moraga Creek, and Stonehurst Creek); Oakland, San Leandro**

- Friends of San Leandro Creek: Susan Criswell, 510-577-6069, susanc@fslc.org, http://www.fslc.org/

**San Pablo Creek (includes Bear Creek, Lauterwasser Creek, Castro Ranch Creek, Appian Creek, Wilkie Creek); Orinda, El Sobrante, Richmond, San Pablo**

- El Sobrante, San Pablo, Richmond: San Pablo Watershed Neighbors Education and Restoration Society (SPAWNERS): Martha Berthelsen, 510-231-9566, martha@aoinstitute.org
- Richmond, San Pablo: Creek Keepers, (510) 622-2337
- Orinda: Friends of Orinda Creeks: Cinda MacKinnon, 925-253-9690

**Sausal Creek (aka Dimond Creek, includes Palo Seco Creek and Shephard Creek); Oakland**

- Friends of Sausal Creek: Charlotte Bell, 510-501-3672, coordinator@sausalcreek.org, www.sausalcreek.org

**Stege Creek (aka Baxter Creek); El Cerrito, Richmond**

- Friends of Five Creeks: See Cerrito Creek

**Strawberry Creek**; **Berkeley**

- Friends of Strawberry Creek, Janet Byron, 510-848-4008, bjanet@earthlink.net

**Sulphur Creek**; **Hayward**

- Sulphur Creek Nature Center: Mike Koslosky, 510-881-6747

**Temescal Creek (includes Harwood Creek (aka Claremont Creek), Tunnel Creek, and Vicente Creek (aka Grandview Creek)); Berkeley, Emeryville, Oakland**

- Friends of Temescal Creek: Bruce Douglas, 510-655-0341, FoTemescal@aol.com, http://www.aoinstitute.org/temescal/

**Village Creek; Albany, Berkeley**

- Friends of Five Creeks: See Cerrito Creek

**Walnut Creek (includes Bolinger Creek, Galindo Creek, Grayson Creek, Green Valley Creek, Grizzly Creek, Happy Valley Creek, Las Trampas Creek, Pine Creek, San Calanio Creek, San Ramon Creek, Sycamore Creek, and Tice Creek); Concord, Danville, Lafayette, Orinda, Pleasant Hill, Walnut Creek**

- Friends of the Creek: Pam Romo, 925-939-8979; or Terri Williamson, 925-944-1491

**Wildcat Creek (includes Laurel Creek); Richmond, San Pablo**

- Margaret Kelly, 510-525-2233 or Creek Keepers, (510) 622-2337
- Waterways Restoration Institute: Ann Riley, 510-848-2211

***North Bay Watersheds***

- North Bay Riparian Station: Andy Peri, 415-332-1941, andy@numenet.com, http://www.mywatershed.org/
- Point Reyes Bird Observatory: Geoffrey Geupel, http://www.prbo.org/

**Corte Madera Creek (includes Tamalpais Creek); Corte Madera**

- Friends of Corte Madera Creek Watershed: 415-457-6045, fcmcw@microweb.com, http://www.microweb.com/fcmcw/

**Lagunitas Creek**; **Lagunitas**

- Salmon Protection and Watershed Network (SPAWN): Reuven Walder, 415-488-0370 x102, spawn@igc.org, http://www.spawnusa.org/

**Mill Valley Creeks; Marin**

- Mill Valley Stream Keepers: Nancy Dempster, 415-455-5818

**Napa River; Napa**

- Napa County Resource Conservation District, 707-252-4188

**Novato Creek**; **Novato**

- Friends of Novato Creek: Sue Lattanzio, 415-883-8339

**Redwood Creek; Marin**

- National Park Service: Carolyn Shoulders, 415-331-0771

**Russian River**

- Friends of the Russian River: 707-865-1305, pirana@ev1.net

**San Geronimo Valley Creek**; **San Geronimo**

- SPAWN: See Lagunitas Creek

**Sonoma Creek**; **Sonoma Valley**

- Sonoma Ecology Center, 707-996-9744, sec@vom.com, www.sonomaecologycenter.org

**Stemple Creek and tributaries**

- The Bay Institute's and Center for Ecoliteracy's Students and Teachers Restoring a Watershed (STRAW) Project: Laurette Rogers, 415-506-0150, rogers@bay.org
- Trout Unlimited: John Milanovich, johnkostin@hotmail.com, 415-292-6589, www.northbay-tu.org

**Tolay Creek**; **Sonoma**

- Save the Bay, (510) 452-9261, Anya Peron-Burdk, anya@savesfbay.org, www.savesfbay.org

**Tomales Bay**; **Marin**

- Tomales Bay Watershed Council, (5415) 663-9092

## ***San Francisco Watersheds***

**Glen Canyon; San Francisco**

- San Francisco Natural Areas: Lisa Wayne, 415-753-7266

**Islais Creek; San Francisco**

- Julia Viera, 415-826-5669

**Lobos Creek; San Francisco**

- National Park Service: Marc Albert, 415-668-4392, marc_albert@nps.gov

**Mission Creek; San Francisco**

- Mission Creek Conservancy: Toby Levine, 415-552-4577

## ***South Bay Watersheds***

- Mike Vasey, 415-338-1957, mvasey@sfsu.edu
- Acterra, 650-326-0252
- CLEAN South Bay: Trish Mulvey, 650-326-0252
- Friends of Santa Clara County Creeks: Don Whetstone, 408-867-3877
- Salmon Steelhead Restoration Group: Roger Castillo, 408-238-2040, http://www.silichip.org/
- Santa Clara Basin Watershed Management Initiative: Alice Ringer, 408-945-3024, alice.ringer@ci.sj.ca.us, http://www.scbwmi.org/
- Santa Clara County Creeks Coalition: Linda Elkind, 650-529-0151
- Santa Clara Valley Open Space Authority, 408-224-7476
- Santa Clara Valley Audubon Society: Craig Breon, 408-252-3748, craig@scvas.org, http://www.scvas.org/
- San Francisco Bay Bird Observatory, 408-946-6548
- Streams for Tomorrow: Keith Anderson, 408-683-4330

**Barron and Matadero Creeks**; **Palo Alto**

- Barron Park Association: Douglas Moran, 650-856-3302, http://www.cyberstars.com/bpa/
- Friends of Matadero Creek: Linda Frost, 650-856-1456

**Calabazas Creek**; **Cupertino**

- Friends of Calabazas Creek: Tom Schaefer, 408-257-7734, tom.schaefer@acm.org

**Coyote Creek**; **San Jose**

- Coyote Creek Alliance: Dominic Kovacevic, 408-289-1681

**Guadalupe River**; **San Jose**

- Children's Discovery Museum BioSITE: Amity Sandage, 408-298-5437, http://www.cdm.org/biosite.html
- Guadalupe River Park and Gardens: 408-277-4744 ext. 355, http://www.grpg.org/

**Los Alamitos Creek**; **New Almaden**

- Friends of Los Alamitos Creek: Lila Freitas, 408-997-6383

**Los Gatos Creek; Campbell and San Jose**

- Los Gatos Creek Streamside Park Committee: Don Heberd, 408-379-3273
- Willow Glen Homeowners Association: Larry Ames, 408- 294-9462, http://www.wgna.net/

**San Francisquito Creek; Palo Alto**

- San Francisquito Creek CRMP: Pat Showalter, 650-962-9876, http://www.pccf.org/crmp/
- San Francisquito Creek Joint Powers Authority: Cynthia D'Agosta, 650-251-8830

**Saratoga Creek**; **Saratoga**

- Saratoga Creek Project: Garth Bacon, 408-867-4774, http://www.susd.k12.ca.us/creek/project/saratoga.html

**Stevens Creek; Cupertino**

- Friends of Stevens Creek Trail: McClellan Ranch Park, 408-255-5780, http://www.stevenscreek.com/friends/

***Bay Area Watershed Resources***

- Aquatic Outreach Institute: 510-231-5655, http://www.aoinstitute.org/
- Friends of the San Francisco Estuary: Steve Cochrane, 510-622-2337, http://www.abag.ca.gov/bayarea/sfep/about/friends.html
- Golden West Women Fly Fishers: Annette Thompson, 510-569-7763, annette@2468.com
- San Francisco Bay Joint Venture: Beth Huning, 415-883-3854, www.sfbayjv.org
- Urban Creeks Council: Josh Bradt, 510-540-6669, http://www.urbancreeks.org/
- Watershed Assessment Resource Center: Steve Cochrane, 510-622-2337 or Laurel Marcus, 510-832-3101