California Wetland and Riparian Area Protection Policy

Technical Advisory Team
Josh Collins, Chair

# Technical Memorandum No. 5: Stream Definition

Version 2
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**Technical Advisory Team**
**California Wetland and Riparian Area Protection Policy**
**Technical Memorandum No. 5: Stream and Riparian Definitions**
**Version 3: April 20, 2016**

## 1.0 Disclaimer

With this memorandum, the Technical Advisory Team (TAT) recommends a definition of California streams to the Policy Development Team (PDT) of the State Water Quality Control Board (State Water Board) for its Wetland and Riparian Area Protection Policy (WRAPP). This memorandum does not recommend any process or procedure for identifying, delineating, or classifying streams, nor are such recommendations being planned by the TAT at this time. However, the TAT recommends that such processes and procedures should be developed in the future to support the WRAPP. The California Wetland Monitoring Workgroup (CWMW) is preparing recommendations for stream mapping as part of the recommending methodology of the California Aquatic Resource Inventory (CARI).

The TAT reserves the opportunity to revise this memorandum and its other memoranda as necessary to make sure they are consistent with each other, consistent with the current status of relevant science, and that they meet the needs of the PDT for technical information and advice.

## 2.0 Purpose

The purpose of this memorandum is to recommend a scientific definition of California streams to the PDT with enough explanation to support an analysis of its applicability to WRAPP, and to support independent scientific peer review.

A variety of agencies responsible for stream management and protection in California have adopted different stream definitions for their particular programs. The lack of a standard stream definition leads to uncertainty about how to consistently identify and map them, which in turn leads to uncertainty about their locations, distribution, and abundance. The ability of state agencies to collaboratively and consistently protect streams is hampered by the lack of a clear, standard stream definition.

Other TAT memoranda recommend wetland definition (TAT 2012a), a landscape framework for wetlands (TAT 2012b), and an approach to wetland identification and delineation (TAT 2012c). The landscape framework memorandum recommends a definition of riparian areas that is incorporated into the recommended stream definition presented by this Memorandum Number 5. A future memorandum is bring planned to recommend a framework for monitoring and assessing aquatic and riparian areas in the watershed context. A description of the TAT, including why and how it was formed, and its general work plan is available in a separate memorandum titled “Technical Memorandum No. 1: Technical Advisory Team.”

The TAT has combined the stream and riparian definitions into a single memorandum because riparian areas are integral components of streams, based on the recommended stream definition. The TAT also recognizes that riparian areas are integral components of other kinds of surface waters, based on the wetland and riparian area definitions.

## 3.0 Methodology

### 3.1 Criteria of the Definitions

Criteria for successful definitions of California streams and riparian areas were developed through a consensus process with detailed editing of the language of each criterion (Table 1). These criteria are based on stream science and the intended applications of the WRAPP.

Note: The definitions do not need to explicitly list or reference indicative features (such as channels, beds, banks, etc.) that can be defined in the supporting technical memorandum. The definition should be concise.

A. Is scientifically sound and reflects current scientific knowledge.

B. Identifies streams as distinct features of landscapes.

C. References recurrent flooding or other lateral and longitudinal processes of hydrologic connectivity that are geomorphically and ecologically significant.

D. Does not limit streams in terms of their size or location in the landscape.

E. Does not limit streams in terms of the timing or duration of their surface or subsurface hydrology.

F. Does not limit the functions or ecosystem services of streams.

G. Does not exclude any stream due to its landscape origin or terminus.

H. Does not exclude any stream because of anthropogenic influences.

I. Applies to all regions of California.

J. References formative processes for which field indicators can be selected or developed to support field-based identification and delineation.

K. Is concise and restricted to definitional concepts and factors.

Much attention was given to efforts by California Department of Fish and Wildlife (DFW) to define streams for its Lake and Streambed Alteration Program (LSA), and by the North Coast and San Francisco Bay Area Regional Water Boards for their joint Stream and Wetland Systems Protection Policy (SWSPP). The PDT recognizes that consistency between the LSA definition, the SWSPP definition, and State Water Board definition is patently desirable. To the extent reasonable, the TAT has integrated scientific concepts, terms, and text from the LSA definition and the SWSPP definition into the recommended State Water Board definition. To help facilitate and guide this integration, the TAT has included scientists who are working on either the LSA or SWSPP definitions.

**3.2 Evaluation of Candidate Definitions.**

Many different definitions of streams have been developed by government agencies and scientific NGOs operating in California. The TAT assembled a set of candidate definitions based on the SWSPP and LSA efforts, plus other comparable efforts within the state. The list is not exhaustive, but it fairly represents the range of readily available stream definitions.

The TAT evaluated the representative definitions by scoring each of them relative to the criteria listed in Table 1. Each definition was scored as having high, medium, or low consistency with each criterion (Appendix A).

Many of the candidate definitions scored high for most of the criteria. However, most of them scored medium or low for the criterion relating to lateral hydrological connectivity (i.e., criterion "C": see Table 1 and Appendix A). This reflects the focus of most stream protection programs on in-stream resources. In essence, for most of the candidate definitions, "stream" is synonymous with "channel" plus "flow."

The TAT is not recommending either the LSA definition or the SWSPP definition to the State Water Board. Neither definition is sufficiently consistent with all the criteria. The TAT appreciates that the DFW and the Regional Water Boards developing SWSPP are fully aware of the integral relationships among channels, their floodplains, and all other components of stream ecosystems. The TAT expects that these Regional Water Boards and the LSA Program, as well as other California agencies will find that the recommended definition supports their efforts to manage and protect streams.

**4.0 Recommended Definition**

As of the date of this memorandum, the TAT recommends the following definition of California streams to the State Water Board in support of the WRAPP. The recommended definition will be considered draft and subject to revision until the State Water Board determines that the definition is final. Until then, the TAT reserves the opportunity to revise this definition to make sure it remains consistent with other definitions recommended by the TAT, and in response to reviews of it that might be provided to the TAT by the State Water Board.

> *A stream is a physically defined course of perennial, seasonal, or episodic surface water flow inclusive of visibly evident physical, chemical, and biological processes and conditions resulting from recurrent interactions among the surface flow, subsurface water if it exists, and the adjacent landscape. Simply stated, stream is a channel plus its riparian area.*

It is important to note that the recommended definition is written in the present tense. This is necessary to denote that the definition pertains to extant streams. The TAT intends that the recommended definition pertains to landscape features that currently function as streams and that are expected to function as streams into the foreseeable future. Extinct streams, such as those evidenced by abandoned or paleo channels, that individually or in aggregate do not meet the steam definition criteria, are not considered to be streams.

As used here, the term, stream, is synonymous with many other common terms for natural features that can meet the criteria for the recommended stream definition, depending on their usage. Other names for natural features that can be synonyms with stream include: waterway, watercourse, tributary, swale, streamlet, spring run, runnel, rivulet, river, rindle, rill, gulley, crick, creek, burn, brooklet, brook, branch, beck, and arroyo. The names of artificial features that can, in many cases, meet the criteria of the stream definition include: trough, trench, moat, furrow, flume, drain, ditch, cut, chase, canal, and aqueduct. The long list of synonyms reflects the rich cultural history of California streams as well as their broad natural diversity.

**4.1 Key Assumptions of the Recommended Definition.**

The following assumptions underlie the recommended stream definition.

1. A stream is more than its channel. Channels are central features of streams, but a stream and its channel are not necessarily equivalent. Some portion of the landscape adjoining the channel is also part of the stream. The lateral limits of a stream at any point along its length can be estimated based on the lateral extent of measurable ecological and hydrological processes that directly connect the channel to its adjoining landscape. These processes can include, but are not necessarily limited to, surface flooding by water coming out of the channel, allochthonous input into the channel, shading of the channel, the filtration of surface runoff entering the channel, and the subsurface movements of water and dissolved materials to or from the channel though its bed or banks. Because these processes connect the channel to its landscape, there are, by definition, riparian.

2. *In a general sense, a stream can be defined as its channel plus its riparian area.* The area of a stream that is lateral to the channel is called its riparian area, or riparian zone. Some amount of riparian area adjoins every stream channel. The dimensions of the riparian area vary with riparian function. In other words, different riparian functions can extend different distances away from or along a stream channel. The riparian area definition is presented in the TAT Memorandum Number 3 (TAT 2012b), and is elaborated in this Memorandum Number 5.

3. Streams can contain wetlands, but streams and wetlands are not equivalent. Wetlands can exist within riparian areas and in channels. Wetlands are defined according to a particular set of hydrologic, edaphic, and vegetation criteria that distinguish wetlands from other landscape features, including streams. The recommended wetland definition is presented in the TAT Memorandum Number 2 (TAT 2012a).

4. Landscape features that are natural, constructed, or modified can be streams. Each government agency that adopts the recommended stream definition can determine, based on in its own criteria, whether or not it will, through the applications of its policies and programs, declare a particular landscape feature or a category of features exempt from the recommended stream definition.

## 5.0 Stream Form and Function

There is a great wealth of scientific information about streams. The purpose of this section is to provide operational definitions of the basic forms and features of streams, and to summarize the most salient facts about stream functions.

## 5.1 Stream Channel

Stream channels are landscape features that have been formed by water and that are maintained by the flow of water, or that are purposefully constructed and maintained to convey water. Channels can be subterranean for short distances but are generally surface features. For example, channels can pass under bridges or through culverts and short tunnels, but buried storm drains and water pipes are not channels.

Stream channels can be very broadly classified as meandering, straight, or braided (Twidale 2004). Natural meandering streams can be highly convoluted or simply sinuous in planform, but they maintain a single flow path with channel curves that have definite and repeated shape. They tend to be remarkably regular in planform, exhibiting strong positive relationships between meander length and channel length, and between meander length and the radius of curvature of the meanders (Leopold 1994). Straight channels bend randomly. Braided channels have multiple flow paths separated by bars and islands. A complete range of planform channel patterns exists in California, due to its great variability in climate and geology. The meandering form is most common, however.

### 5.1.1 Cross-section Form

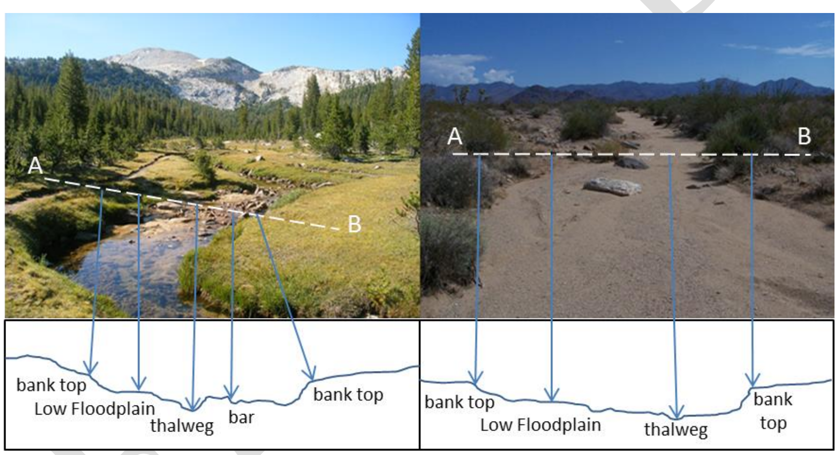


Figure 1. Cross-sections for a temperate montane stream (left) and an arid desert stream (right) showing differences in the number and character of typical features.

A stream cross-section is the vertical profile of a stream along a line extending across the stream perpendicular to the direction of the stream flow. Most descriptions of stream cross-sections include a universal set of topographic features, namely the channel bed, channels banks, and one or more floodplains. Each of these elements tends to have its own set of component features, not all of which are present in every stream channel (Figure 1).

The overall form of a cross-section can be classified based on the likely frequency of out-of-channel flooding. For a variety of reasons relating to changes in sediment loads and flow regimes (see section below on stream dynamics), streams can down-cut, or incise, and thus abandon their floodplains. Entrenched channels are so deeply incised that out-of-channel flooding is very uncommon. Channel beds can also aggrade, or gain elevation due to a net accumulation of sediment. Aggradation can arrest incision, such that the stream flow can establish new floodplains below the elevation of previous floodplains. In some rare cases, severe aggradation has caused stream flows to reoccupy previously abandoned floodplains.

Unnatural changes in channel form that result from human activities are termed hydromodification, which is a major source of impacts to many California streams.

### 5.1.2 Channel Bed

The bed of a stream channel is the area between the channel banks that is mainly composed of materials deposited by water flowing between the banks or that have been chemically or structurally conditioned or altered by such flow. The thalweg is a line drawn between the lowest points of a channel along its flow direction, indicating the bottom of the channel bed. A channel bar is an elevated area of the bed consisting of materials that have been deposited by the stream flow (Strahler and Strahler 1996, Ritter et al. 1995). Types of bars include mid-channel bars (also called braid bars of braided channels), point bars (common on the insides of meander bends in meandering channels, see Figure 1), and mouth bars (common in stream deltas).

### 5.1.3 Active Channel.

A channel is an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water (Langbein and Iseri 1960). An active channel receives sufficient and frequent enough flows to maintain or reform physical evidence of the flow, such as a cleanly scoured or recently deposited substrate, ware marks on channel bank, changes in soil characteristics, or changes in vegetation. For non-arid regions of California (see Figure 1 above), the active channel is generally considered to be the portion of the channel that is wetted or would be wetted by bankfull flow (Leopold 1994, Cinotto. PJ. 2003) (see the section on flow below), which corresponds to the height of flow above the bed that is just below the threshold of inundation of the lowest floodplain. In very arid regions (see Figure 1 above), where the recurrence interval of bankfull or effective flow may be relatively long, the active channel can be defined as the portion of channel below the ordinary high water marks on either channel bank (Lichvar et al. 2009).

### 5.1.4 Channel Bank

The banks of a stream channel confine the dominant or effective stream flows (see section below on flow). They slope upward from channel beds and generally perpendicular to the flow direction. The steepness of the bank is largely the result of interactions among the erosive actions of the flow (e.g., undercutting, abrasion, or chemical conditioning), and the resistance of the bank materials to such actions. Bank stability varies relative to the materials forming the banks, bank condition, bank height, and bank angle.

The banks of entrenched channels can extend far above the active channel. The portion of the bank above the active channel is sometimes referred to as the upper bank. The tops of such tall banks generally correspond to an abandoned floodplain (i.e., a terrace) or natural levee, and may approximate the elevation of the adjacent valley floor.

Very high channel banks (i.e., extreme entrenchment) can effectively eliminate riparian areas subject to out-of-channel flooding. The width of such streams generally depends on the lateral extent of riparian functions that are not directly related to surface hydrology, such as input of allochthonous debris, shading, bank stability, and drawdown of adjacent groundwater.

**5.1.5 Bank Top**

The tops of the banks of a channel correspond to transitions between the channel and its adjacent riparian area. They are therefore transitions between two different sets of geomorphic processes. Channel width is a manifestation of interactions between the erosive actions of effective flow and the resistance of the bank material to such actions, whereas the adjacent riparian area is mainly delimited by interactions between flood flows, biogenics (e.g., plant growth, animal burrowing, etc.), wind erosion and deposition, runoff, and some hillslopes processes (e.g., landsliding and other terrestrial mass-wasting events that deliver materials to the channel). Natural levees can form adjacent to channel banks. The crest of a natural levee is usually slightly landward of the bank top.

The identification of bank tops can be important. It may be necessary for delineating federal, state, and local agency jurisdictions. Many local stream set-back ordinances that are designed to protect stream resources require identification of bank tops, as do methods for mapping channels and riparian areas (see section below on riparian areas).

Bank tops can be very subtle features, however. This is especially true for very low gradient, small streams that are not entrenched and have easily eroded banks. Bank tops can be very difficult to identify for small, low-gradient channels in sandy environments, low-gradient grassy swales, distributaries of braided channels, and for rapidly aggrading or avulsing channels with very active, broad floodplains.

In many cases, the correct identification of bank tops requires special expertise and abundant field experience. The TAT recommends that the State Water Board consider supporting research to develop field indicators of bank tops that can be used to delineate them throughout the state.

**5.1.6 Floodplain**

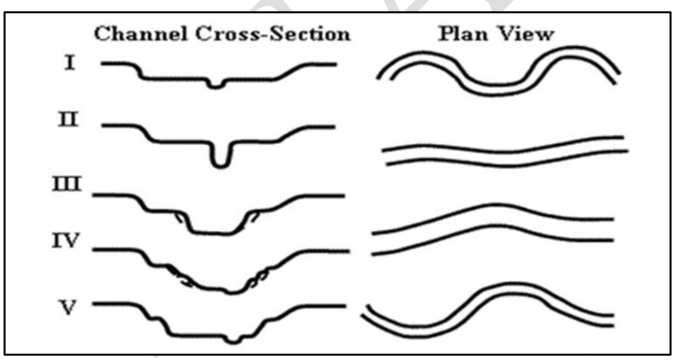


Figure 2. Channel evolution model showing a stable channel with a broad floodplain in Stage I, incision in Stage II, widening in Stages III and IV, and new floodplain formation at a lower elevation in Stage V.

Floodplains are generally horizontal surfaces at or above the height of the active channel that are inundated by stream flows at regular periodicities, depending on their height relative to the channel bed (Leopold et al. 1964). Higher floodplains are inundated less frequently.

Floodplains can exist between channel banks, as part of channel banks, or lateral to them. In entrenched channels that are still incising, the lowermost floodplain can be an almost imperceptible feature of the channel banks. Channels that have stopped incising after becoming entrenched can establish inset floodplains as the channel banks erode and "lay back," meaning that they become less steep (see Figure 2 above). Floodplains can slope toward, away from, or parallel to the channel.

**5.1.7 Inner Gorge.**

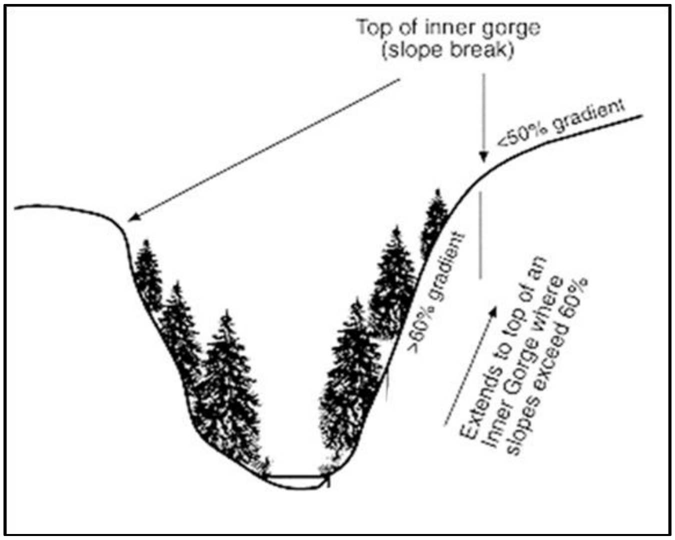


Figure 3: Diagram of an inner gorge.

Streams in gorges have a particularly strong functional relationship to hillslope processes. The channel bank tends to be contiguous with a section of the adjoining hillslopes called the inner gorge (Figure 3). Inner gorges are steeper than about 50% slope (Kelsey 1988, WA DNR 2016) and extend at least 10 feet above the channel banks. They are created by combinations of channel incision and mass wasting of the hillslopes. Inner gorges can extend to great heights along highly confined channels in mountainous terrain. The top of the inner gorge is typically a distinct break in slope. Inner gorges can deliver large amounts of sediment and other materials to streams.

**5.2 Flow**.

Streams can be usually identified by the presence of flowing surface water in a channel with a distinguishable bed and bank. However, it is not always possible to identify streams based on the presence of flow. This is because surface flow might only be present during certain seasons or times of the year (i.e., intermittent or ephemeral streams); or only in direct response to precipitation (i.e., episodic streams). Many small streams, particularly in the headwater regions of watersheds, have episodic flow regimes. Although streams are by definition landscape features that convey flowing water, the flows do not need to be perennial for the streams to affect local and downstream beneficial uses (e.g., Izbicki 2007; Winter 2007, Alexander et al. 2007).

Stream flow regimes are naturally dynamic, especially in arid regions, and may transition over time or along their lengths between episodic, intermittent, and perennial condition. These transitions can result from a variety of natural and unnatural factors, such as flow diversions or impoundments, transfers of water from other streams, changes in vegetation or soils, and seasonal or inter-annual variations in precipitation and runoff (Dunne and Leopold 1978). The magnitude of flow is important for the formation and maintenance of a channel, transport of sediment, and the flux of solutes (Doyle et al. 2005). Flow duration is critical to biological processes and communities, while the timing of high and low flows strongly influences the structures of stream biological communities (Poff and Ward 1989). Gaining reaches of streams receive significant amounts of groundwater. They tend to have relatively consistent base flows. Losing reaches help recharge groundwater supplies. Although stream flow can be used as an indicator of streams, no particular timing, duration, recurrence interval, or magnitude of flows is required for stream identification. The full range of flow regimes is evident among California streams.

The hyporheic zone is the area beneath and alongside a stream bed where shallow groundwater and surface flows mix. Hyporheic flow can be very important for the health of in-stream biota. It can be the only flow evident in intermittent streams during the dry season.

The relationships among drainage area, stream flow, sediment loads and transport, and channel form have been abundantly studied for stable temperate streams with perennial flow regimes. For these streams, the flow that moves the most sediment over the long term, rejuvenates bars, and maintains the channel form in profile, plan view, and cross-section is termed the effective flow. It is closely approximated by bankfull flow, the height of which corresponds to the lowest floodplain, and other well-known field indicators (Wolman and Miller 1960, Leopold et al. 1964, Dunne and Leopold 1978). Many methods of perennial stream assessment and design rely upon the relationships between bankfull flow and stable channel form.

However, the concept of bankfull flow and its relationship to stable channel form are not applicable to large numbers of California streams. In these cases, the channels are unstable, due to past or ongoing changes in sediment loads and flow. Some of these channels will conform to the predictive relationships between bankfull flow and channel form if they stabilize. But, for most episodic streams, the effective flow is not known, because the timing and magnitude of the stream flows are highly irregular. The TAT recommends that the State Water Board support research to determine effective flow for such episodic streams so that they can be effectively designed and restored.

### 5.3 Riparian Area

The TAT recommends the following riparian definition provided by the National Research Council (NRC 2002), with one essential clarification: the TAT specifies that all aquatic areas, including wetlands, have riparian areas (TAT 2012b). While this is implied by the NRC definition, it is explicitly stated by the TAT.

> *Riparian Areas are zones along aquatic areas, including streams, lakes, and wetlands, through which surface and subsurface hydrology and other physical and biological processes interconnect these aquatic areas and their adjacent landscapes. They are distinguished by gradients in biophysical conditions, ecological processes, and biota. They can include aquatic areas, wetlands, and portions of uplands that significantly influence the conditions or processes of aquatic areas.*

The TAT does not assume that riparian areas are defined by plant species specifically adapted to riparian conditions. Instead, in keeping with the NRC definition, the TAT assumes that riparian areas are defined by spatial gradients in biophysical and ecological processes that do not necessarily depend on any particular plant species or assemblage of species.

Riparian areas can be envisioned as sets of functions extending away from stream channels (see Figure 4 below). Different riparian functions can extend different distances (Keller and Swanson 1979, Benda and Sias 1998, Naiman et al. 2000, Ildhart et al. 2000, NCASI 2006, Collins et al. 2006). Riparian areas can include those portions of terrestrial landscapes that significantly influence exchanges of energy and matter with aquatic areas (NRC 2002).

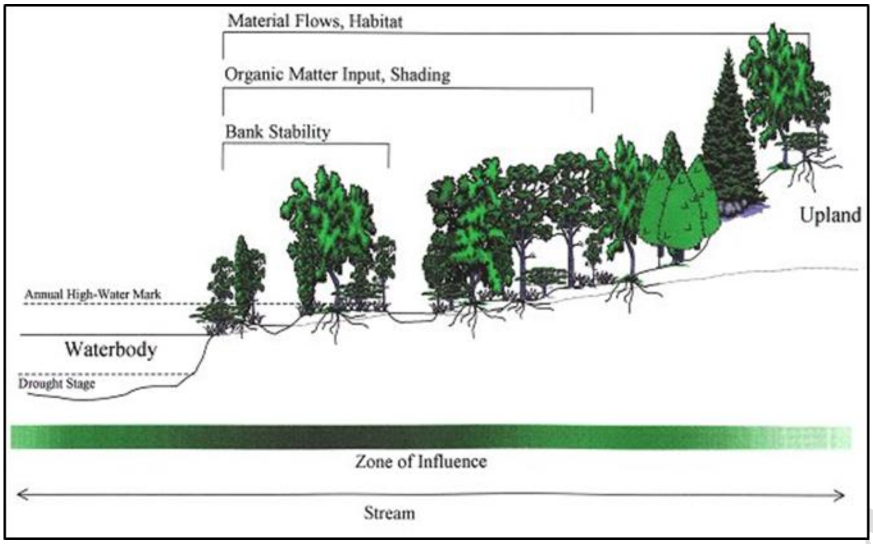


Figure 4. Schematic of generic riparian influences on a stream. The darker portion of the shaded horizontal bar corresponds to the greater intensity of influence (NRC 2002).

Numerous studies have defined the widths of riparian areas based on the occurrence of particular water quality functions. There is no "one-size-fits-all" riparian area to provide the necessary water quality functions to protect all the ecological services or beneficial uses of streams. The scientific literature indicates that the total number of water quality functions provided by riparian areas tends to increase with their overall width and length.

Although they account for only a small proportion of the total area of many watersheds, riparian areas are contribute significantly to the biodiversity of a watershed or landscape. This is particularly dramatic in arid regions of California, as evidenced by the high number of plant and animal species found along arid streams.

The lateral limits of a stream can be delimited based on the lateral limits of riparian processes that have measurable influences on the condition of the stream channel or stream flow. For example, the lateral limits of selected vegetation or other structures that shade the channel, direct inputs of allochthonous material into the channel, groundwater drawdown and recharge through the channel banks, and the measurable effects of recurrent out-of-channel flooding can be used define different functional stream widths.

This approach to determining the functional lateral limits of a stream landward of its channel has a number of scientific advantages. First, it requires identification of the functional relationships between the beneficial uses of a stream and its riparian area. Second, it supports consideration of site-specific opportunities and constraints for stream restoration and protection. Third, it provides a basis for identifying the functions that connect the stream to its landscape setting. Fourth, it serves as a framework for deciding stream width based on the lateral extent of riparian functions that are needed to support selected stream beneficial uses. Fifth, it is repeatable and not arbitrary.

This approach also has some drawbacks. Since many streams and especially their riparian zones have been severely altered beginning long ago, reference stream conditions are not well known. As a result, the natural relationships between riparian processes and stream condition are also not well known. It may be that the riparian functions most needed to protect the beneficial uses of streams naturally extended farther from the stream channels than existing conditions indicate. Furthermore, while this approach to delimiting streams focuses on the riparian processes that directly affect the condition of the channel and/or the stream flow, there may be other riparian functions that do not have such effects, and therefore do not get adequately considered by stream protection efforts. For example, wildlife that use the riparian zone but not the channel might not be well supported by this approach to defining and delimiting streams. However, if warranted, such riparian functions could be added to the approach on a case-by-case basis.

The TAT recommends that the State Water Board develop a method of approximating the functional widths of streams by mapping their channels and the lateral extent of selected riparian functions that are expected to have measurable positive effects on the beneficial uses of the streams. The TAT also recommends that the State Water Board support research to develop field indicators of the presence of these riparian functions that can be used to calibrate the stream mapping method and to delineate the stream in the field.



## 5.4 Planform

The form of a stream as viewed from above, or in plan-view, is called its planform. The major planform characteristics of a stream are the width, length, and sinuosity of its channel (Figure 1), and width of its riparian area.

### 5.4.1 Valleys, Meander Belts, and Stream Corridors

Valleys are landscape features that formed as lake beds or as floodplains. Under natural conditions, streams tend to migrate back and forth across their valleys, variously eroding sediments on the outside of their meanders, and depositing sediment on the inside of the meanders. Where sediment supplies are adequate to support net deposition, valley form and gain elevation over time.

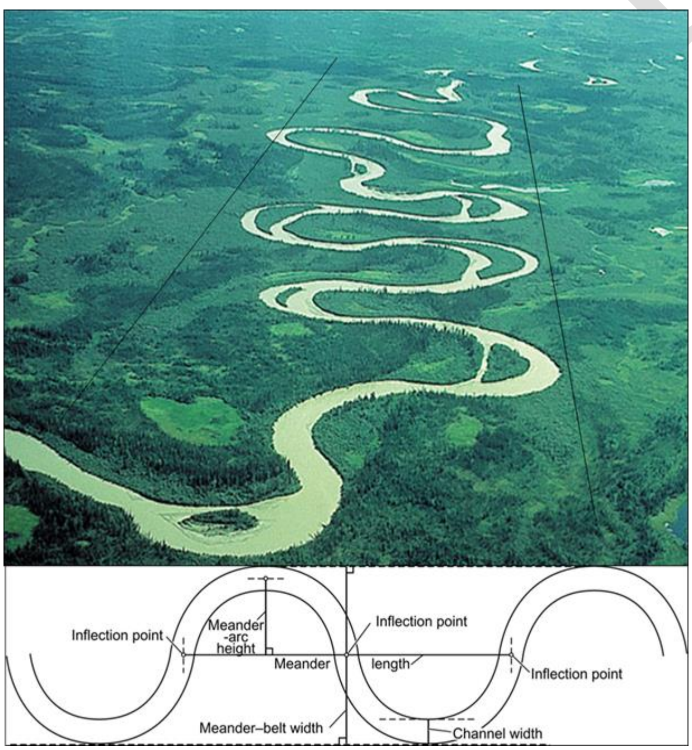


Figure 5: Diagram of a meander belt and the basic metrics of channel plan form.

The portion of a valley that is delimited by the meanders of its stream channel is commonly referred to as the meander belt or stream corridor (Figure 5). It can also be defined as the area of the landscape that a channel uses to maintain its planform (Riley 2003). The meander belt tends to include the riparian areas along the inside of the meanders but not along their outside. Meander belts therefore do not typically include the entire stream as defined here.

Channels that are less than half as wide as their valleys are considered to be confined. This generally means the valley is not much wider than the meander belt of its stream.

### 5.4.2. Stream Networks.

A stream network consists of the streams that together drain a landscape to a common point. The network may be continuous or interrupted by wetlands, lakes, subterranean flows, etc. The streams of a network can be systematically categorized by the number of their tributaries. That is, streams have no tributaries are termed first-order; the confluence of two or more first-order streams forms a second-order, channel, the confluence of two or more second-order channels  forms a third-order channel; etc. Networks are conventionally categorized by their largest channel order. Basic parameters of channel form, including cross-sectional area, effective flow, gradient (i.e., slope of the thalweg slope), and drainage area tend to be correlated to stream order (Horton 1945, Strahler 1957).

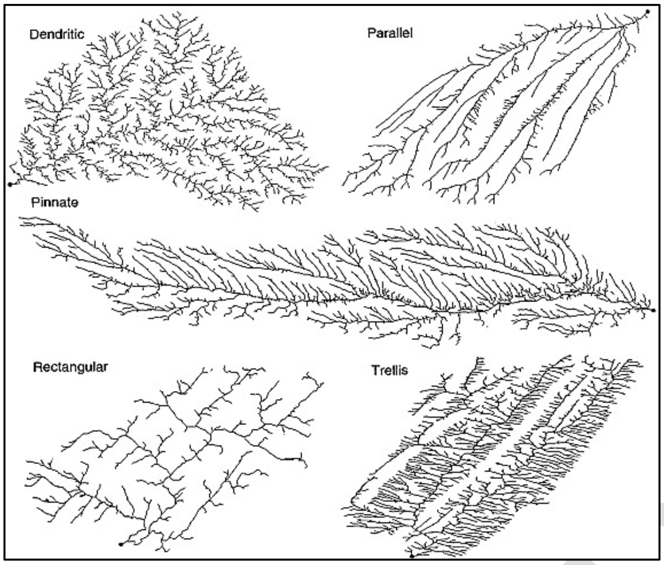


Figure 6. Common types of stream networks. (Zernitz 1932).

Networks can also be categorized by their overall planform, which relates to the steepness and geology of the landscapes they drain (Mejía, and Niemann 2008). The common form of networks are called dendritic, parallel, pinnate, rectangular, and trellis (Figure 6). The first three types are common in California. Rectangular and trellis networks are common among the parallel ridges formed by up-tilting of the Great Valley Series along the west side of the Sacramento Valley.

### 5.4.3 Alluvial Fan

Alluvial fans disserve special attention as unique stream features (Bull 1977).  They are depositional features created by streams, where the stream gradient abruptly flattens and the ability of the stream to transport sediment therefore substantially decreases (NRC 1996). Fans owe their name to their fan-like shape in plan-view. They spread outward and downward from their apices (see Figure 7 below). Fans commonly occur where streams with large sediment loads intersect lakes and valleys, and where steep streams intersect less steep streams. A fan intersecting a lake or other body of water that is larger than the fan is commonly called a delta.

Active fans are characterized by episodic, high-velocity flows of water that cause much erosion, sediment transport, and deposition along rapidly changing distributary channels (NRC 1996, FEMA 2003). Inactive fans are characterized by one or more entrenched channels that dissect the fan and disconnect the stream flows from the surfaces of the fan adjacent to the channels.

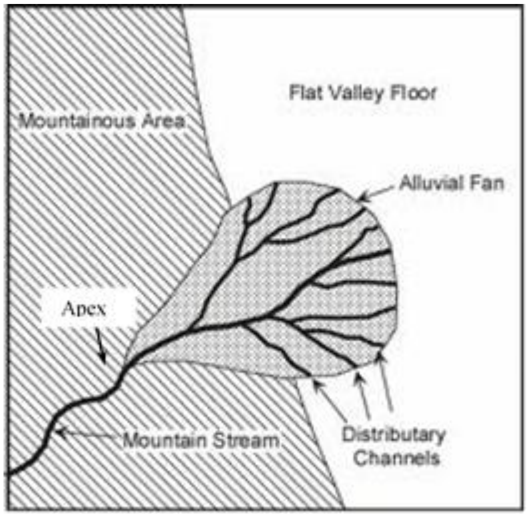


Figure 7. Common types of stream networks. (Zernitz 1932).

Entire active fans can satisfy the criteria for the recommended stream definition. Each distributary channel has an adjoining area of the fan surface that owes its form and structure to recurrent, out-of-channel flooding. In aggregate, all the areas subject to flooding from one or more distributary channels comprise the entire fan surface. The triangular planform of a fan indicates that any distributary channel may convey flow. When there is adequate flow, all the distributary channels can be activated. The fan plus its riparian area can therefore be regarded as a reach of stream.

Inactive fans usually have one entrenched channel. In such cases, the entrenched channel and its riparian area comprise the stream. It should be noted, however, that channel aggradation at the apex of an inactive fan can alter the downstream course of the stream flow, such that it abandons the entrenched channel(s) and re-activates the larger fan. Changes in runoff or sediment supply resulting from climate change, land use change, or extreme events (e.g., major rainstorms or upstream landslides) can initiate redirection of flow across a fan, from an entrenched channel to one or more other existing or new channels. These temporal dynamics of a fan support its identification as a stream reach.

### 5.5 Profile Form

The profile form of a stream is usually depicted as a plot of its thalweg height over distance, relative to a fixed vertical datum. The heights of bars, floodplains, and bank tops are often added to the profile. The locations of pools, riffles, rapids, glides, falls, etc., are usually also noted. There are a few commonly recognized categories or types of natural stream profiles, namely pool-riffle, step-pool, and flat. The pool-riffle form is typical of stable, gently sloping and moderately steep channels. The step-pool form is typical of steep channels. The flat form is typical of streams with aggrading channels or with beds materials that resist erosion, such as bedrock. Artificial channels tend to have flat profiles, meaning their slope is constant.

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## Appendix A

## Assessment of Existing Candidate Stream Definitions

**Table 1:** Criteria for selecting or developing a stream definition and a riparian definition for the California State Water Quality Control Board.

Note: The definitions do not need to explicitly list or reference indicative features (such as channels, beds, banks, etc.) that can be defined in the supporting technical memorandum. The definition should be concise.

L. Is scientifically sound and reflects current scientific knowledge.

M. Identifies streams as distinct features of landscapes.

N. References recurrent flooding or other lateral and longitudinal processes of hydrologic connectivity that are geomorphically and ecologically significant.

O. Does not limit streams in terms of their size or location in the landscape.

P. Does not limit streams in terms of the timing or duration of their surface or subsurface hydrology.

Q. Does not limit the functions or ecosystem services of streams.

R. Does not exclude any stream due to its landscape origin or terminus.

S. Does not exclude any stream because of anthropogenic influences.

T. Applies to all regions of California.

U. References formative processes for which field indicators can be selected or developed to support field-based identification and delineation.

V. Is concise and restricted to definitional concepts and factors.

**Table 2:** Existing Candidate Definitions

| Agency | Definition |
|---|---|
| No. 1<br><br>SF Bay and North Coast Regional Water Boards | A stream is a body of water that flows perennially, intermittently, or ephemerally through a bed or channel having banks. Streams can include, but are not limited to, areas commonly referred to as rivers, canals, channels, creeks, ditches, floodways, headwaters, swales, and washes. Streams may be found in natural, constructed, or modified channels. Degraded conditions do not change the regulatory status of a stream.<br><br>Streams are formed when water has sufficient energy to erode sediment and carry it downstream. Streams can be identified by the evidence of surface water in a channel with a distinguishable bed and bank; however, surface flow volume, duration, or recurrence are not required for stream identification. A stream must exhibit channel form and identification can be made solely on the presence of a channel with a distinguishable bed and bank.<br><br>Source: Draft Steam and Riparian Area Definition and Identification Procedures, RB2 and RB1 |
| No. 2<br><br>California Coastal Commission | Measure 100 feet landward from the top of the bank of any stream mapped by the USGS on the 7.5 minute quadrangle series, or identified in a local coastal program. The bank of a stream shall be defined as the watershed and relatively permanent elevation or acclivity at the outer line of the stream channel which separates the bed from the adjacent upland, whether valley or hill, and serves to confine the water within the bed and to preserve the course of the stream. In areas where a stream has no discernible bank, the boundary shall be measured from the line closest to the stream where riparian vegetation is permanently established. For purposes of this section, channelized streams not having significant habitat value should not be considered.<br><br>Source: 14 CCR 13577(a) |
| No. 3<br><br>California Department of Fish and Game (#1) | A stream is a body of water that flows at least periodically or intermittently through a bed or channel having banks and supports fish or other aquatic life. This includes watercourses having a surface or subsurface flow that supports or has supported riparian vegetation.<br><br>Source: 14 CCR 1.72 |

**Table 2:** (continued)

| Agency | Definition |
|---|---|
| No. 4<br><br>California Department of Forestry and Fire Protection | “Stream” means a natural watercourse as designated by a solid line or dash and three dots symbol shown on the largest scale United States Geological Survey map most recently published.<br><br>Source: PRC 4528(f) |
| | “Watercourse” means any well-defined channel with distinguishable bed and bank showing evidence of having contained flowing water indicated by deposit of rock, sand, gravel, or soil, including but not limited to, streams as defined in PRC 4528(f). Watercourse also includes manmade watercourses.<br><br>Source: PRC 4528(f). |
| | “Watercourse bank” means the portion of the channel cross-section that confines the normal high water flow.<br><br>Source: 14 CCR 895.1 |
| | “Stream” means a natural perennial or intermittent water course as designated by a solid line or dash and three dot symbol on the largest scale United States Geological Survey map most recently published or as corrected on the management plan map to reflect conditions as they actually exist on the ground. (Reference: Section 4799, Public Resources Code.)<br><br>Source: 14 CCR 1526.1 |
| No. 5<br><br>California Reclamation Board | “Stream” means natural or regulated water flowing in any natural or artificial channel. Streams may be perennial, flowing continuously; intermittent or seasonal, flowing only at certain times of the year; or ephemeral, flowing only in direct response to precipitation.<br><br>Source: 23 CCR 4 |
| No. 6<br><br>Lake and Streambed Alteration Program, California Department of Fish and Wildlife | A stream is a body of water that flows perennially, intermittently, or ephemerally. Streams include a channel, banks, bed, and floodplains where present.<br><br>Source: Lake and Streambed Alteration Program, Proposed Draft Definitions 2010. |

**Table 2:** (continued)

| Agency | Definition |
|---|---|
| No. 7<br><br>U.S. Army Corps of Engineers (Rivers and Harbors Act) | Federal regulatory jurisdiction, and powers of improvement for navigation, extend laterally to the entire water surface and bed of a navigable waterbody, which includes all the land and waters below the ordinary high water mark. Jurisdiction extends to the edge (as determined above) of all such waterbodies, even though portions of the waterbody may be extremely shallow, or obstructed by shoals, vegetation or other barriers. Marshlands and similar areas are considered navigable in law, but only so far as the area is subject to inundation by the ordinary high waters.<br><br>The "ordinary high water mark" on non-tidal rivers is the line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil; destruction of terrestrial vegetation; the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding areas.<br><br>Ownership of a river or lake bed or of the lands between high and low water marks will vary according to state law; however, private ownership of the underlying lands has not bearing on the existence or extent of the dominant Federal jurisdiction over a navigable waterbody.<br><br>Source: 33 CFR 329.11(a) |
| No. 8<br><br>TAT recommended definition | A stream is a physically defined course of perennial, seasonal, or episodic surface water flow inclusive of visibly evident physical, chemical, and biological processes and conditions resulting from recurrent interactions among the surface flow, subsurface water if it exists, and the adjacent landscape. Simply stated, stream is a channel plus its riparian area.<br><br>Source: This memorandum |

**Table 3A:** Scoring Candidate Stream Definitions. The TAT assigned a single whole integer score of 1 (low), 3 (medium), or 5 (high) to each candidate definition 1-12 (see Table 1 above in this Appendix A) for each criterion A-J (see Table 2 above in this Appendix A). Higher scores indicate greater consistency between the candidate definition and the criteria.

| **Definitions** | **Criteria** | | | | | | | | | | | **% Maximum Possible core** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | **K** | |
| No. 1 | 5 | 5 | 3 | 3 | 3 | 5 | 5 | 5 | 3 | 3 | 3 | 78 |
| No. 2 | 1 | 5 | 1 | 1 | 3 | 3 | 3 | 1 | 5 | 1 | 3 | 49 |
| No. 3 | 5 | 5 | 5 | 3 | 3 | 3 | 5 | 3 | 5 | 3 | 5 | 82 |
| No. 4 | 5 | 5 | 3 | 5 | 3 | 5 | 5 | 5 | 5 | 3 | 1 | 82 |
| No. 5 | 3 | 5 | 1 | 5 | 5 | 3 | 5 | 5 | 5 | 1 | 5 | 78 |
| No. 6 | 5 | 5 | 3 | 5 | 3 | 5 | 5 | 3 | 5 | 1 | 5 | 82 |
| No. 7 | 5 | 5 | 3 | 5 | 5 | 3 | 5 | 3 | 5 | 5 | 1 | 82 |
| No. 8 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 100 |

**Table 3B:** Comments supporting the scores presented in Table 3A immediately above.

| **Definition** | **Comments** |
|---|---|
| No. 1 | Criterion C: flooding or lateral riparian connectivity might be discounted; episodic flow might be excluded; non-fluvial systems without sediment transport might be excluded. Criterion E: arid systems without annual flow might be discounted; lateral riparian connectivity might be discounted. Criterion I: might not pertain to arid regions. Criterion J: might exclude non-fluvial and riparian processes. Criterion K: combines explanation and definition. . |
| No. 2 | Criterion A: fixed width discounts current riparian concepts; differences between bank and watershed concepts are blurred; reference to stream course preservation ignores stream temporal dynamics such as meandering. Criterion C: disregards flooding or lateral riparian connectivity. Criterion D: ignores systems not evident on USGS 7.5 min quadrangles. Criteria E-G: limiting systems to those evident on USGS 7.5 min quadrangles also limits applicability with respect to flow regime, ecosystem services, landscape position. Criterion J: does not reference any formative processes. Criterion K: combines identification and definition. |
| No. 3 | Criterion D: limiting systems to those supporting fish or other aquatic life might restrict applications from headwaters and arid systems. Criterion E: arid systems without annual flow might be discounted; lateral riparian connectivity might be discounted. Criterion E: emphasis on aquatic life might discount other ecosystem services. Criterion H: might not pertain to artificial systems. Criterion J: does not reference any formative processes. |

**Table 3B** (continued)

| Definition | Comments |
|---|---|
| No. 4 | Criterion C: flooding or lateral riparian connectivity is not referenced might be discounted. Criterion E: arid systems without annual flow might be discounted. Criterion J: might exclude non-fluvial and riparian processes. Criterion K: definition distributed across multiple sections of state codes and regulations. |
| No. 5 | Criterion A: does not reference banks or beds. Criterion C: disregards flooding or lateral riparian connectivity. Criterion F: might discount riparian services. Criterion J: does not reference any formative processes. |
| No. 6 | Criterion C: flooding or lateral riparian connectivity might be discounted. Criterion E: arid systems without annual flow might be discounted. Criterion H: discounts or might not apply to artificial systems. |
| No. 7 | Criterion C: flooding or lateral riparian connectivity might be discounted. Criterion F: might discount riparian services. Criterion H: discounts or might not apply to artificial systems. Criterion K: combines jurisdictional concerns and definition Criterion J: does not reference any formative processes. |
| No. 8 | Definition is designed to satisfy all criteria. |