May 19, 2016

CRAM FOR EPISODIC STREAMS NOW AVAILABLE

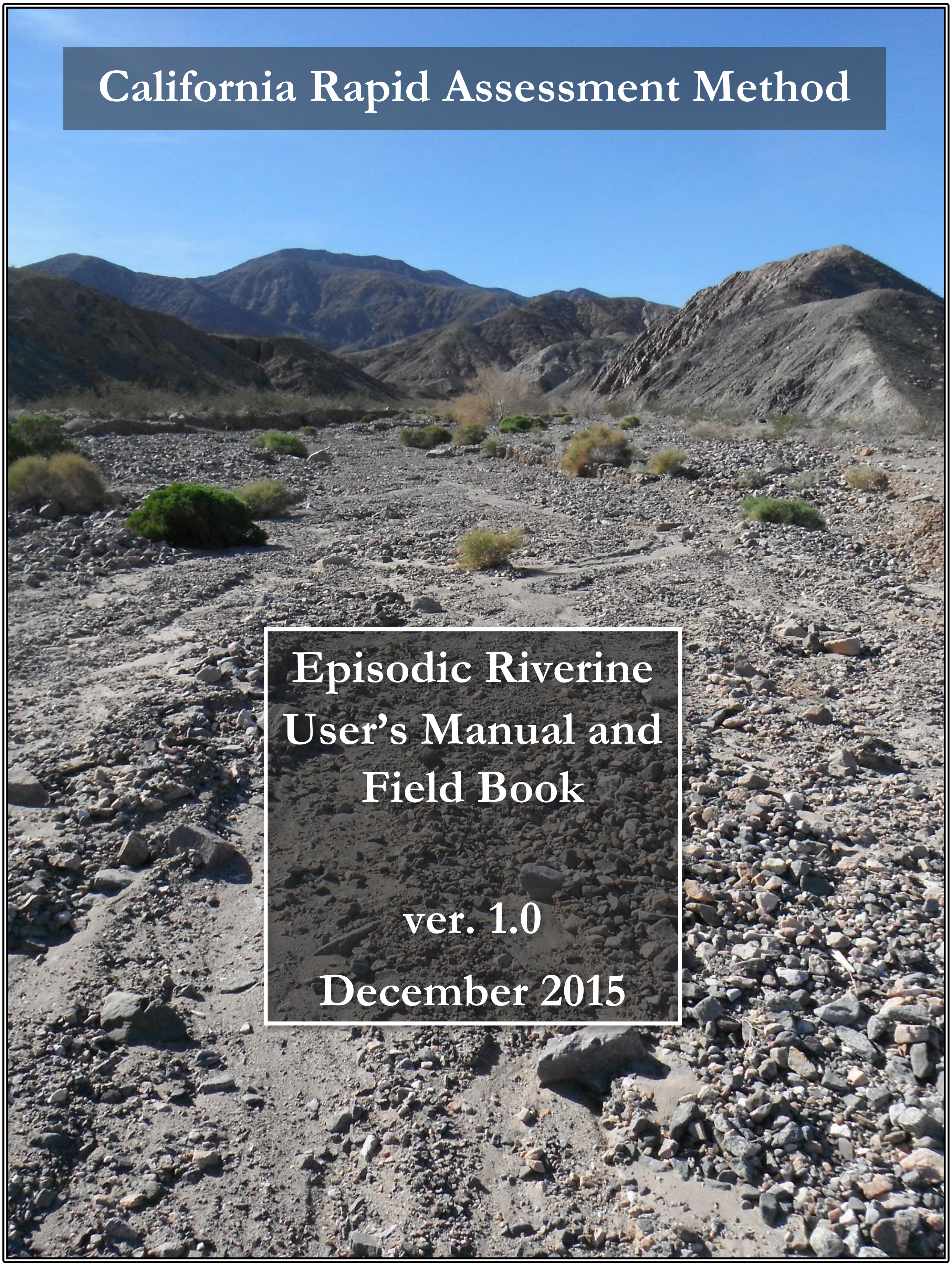
This module of the California Rapid Assessment Method for ***episodic streams*** has been produced for the California Wetland Monitoring Workgroup (CWMW) under leadership from the Southern California Coastal Water Research Project (SCCWRP). The CWMW recommends this module for assessing the condition of episodic streams in appropriate areas of California, primarily in areas with arid climates. It may now be downloaded at the CRAM website: www.cramwetlands.org

Like all CRAM modules, this method is being released after extensive field evaluations. These evaluations were conducted using the established procedures for producing new modules. It will be subject to ongoing modification and refinement based on additional field testing and subsequent validation.

We encourage CRAM practitioners who are familiar with episodic streams, desert ecosystems and arid-land hydrology to use the new module and report results or other feedback to the CWMW via the “Contact Us” section of the CRAM website, located at: http://www.cramwetlands.org/contact-us

Practitioners should note that eCRAM for the episodic module is under development, but not yet available.

California Rapid Assessment Method



Episodic Riverine User's Manual and Field Book

ver. 1.0

December 2015

FOREWORD

This module of the California Rapid Assessment Method (CRAM) has been developed to assess dryland episodic streams, herein termed the **episodic riverine CRAM module (ver 1.0).** Episodic streams are those that flow only in response to rainfall events and experience long periods of no measureable surface flow. This combined manual and field book are intended as a companion document to the User's Manual of CRAM (ver. 6.1; CWMW 2013) and its accompanying field book for riverine wetlands (ver. 6.1), herein termed the **standard riverine CRAM module**. The episodic module of CRAM is intended to build upon, not replace, the standard riverine module.

The episodic riverine CRAM module is based on the fundamental assumptions and relationships between condition and function shared between all CRAM modules. Four universal attributes of condition are recognized: (1) Buffer and landscape context; (2) Hydrology; (3) Physical structure; and (4) Biotic structure. However, the metrics comprising these attributes have been adapted to account for the unique characteristics of predominantly dryland episodic waterways.

This combined manual and field book provides the standard operating procedures for using CRAM to assess episodic waterways. The general procedure for applying the episodic module of CRAM consists of the same series of steps as described in the CRAM User's Manual. This document does not attempt to duplicate this information, but only addresses significant deviations from established methods or provide supplemental information germane to the assessment of episodic stream condition. Users should refer to the CRAM User's Manual for overarching key concepts, assumptions, and the developmental process of the CRAM method.

The data produced from appropriate application and use of this module results could be integrated into existing regulatory programs to provide improved evaluation of and compensation for impacts to episodic stream types, and underrepresented aquatic resource type in current state and federal monitoring programs. Appropriate application of this module by trained practitioners will help to facilitate a process for regulatory agencies and other entities to coordinate and share data, formulate best management practices, and agree upon mitigation and restoration priorities for episodic streams in California.

TABLE OF CONTENTS

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California Wetlands Monitoring Workgroup (CWMW). 2015. California Rapid Assessment Method (CRAM), Episodic Riverine User's Manual and Field Book, Version 1.0.

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TABLE OF FIGURES

TABLE OF TABLES

TABLE OF WORKSHEETS

CHAPTER 1: INTRODUCTION, STATEMENT OF NEED, GOALS, STRATEGIC CONTEXT, INTENDED USES

1.0 Introduction

Episodic waterways are streams and rivers that exhibit short-duration, highly localized, and extremely variable (flashy) flow in response to extreme rainfall events. When not underlain by bedrock or other impervious materials, episodic streams experience rapid infiltration of surface flow into the substrate which results in rapidly decreasing flow to downstream areas. The physical features and biological communities of these systems reflect the fact that surface water occurs at low frequency and typically does not persist, and that substrates are often dry (i.e., not saturated). In some cases, the substrate is renewed abruptly and at intervals shorter than what is typically needed for a climax riparian plant community to develop (Hecht 1993).

Chapter 1 of this manual presents the rationale for developing this module, including why it's needed, and its primary goal, strategic context, intended uses, and the geographic scope of its applicability. Chapter 2 covers key terms, the conceptual framework for assessment of episodic channels with CRAM, and its development process. Chapter 3 describes the timing to conduct assessments for episodic CRAM. Chapter 4 provides background information and rationale for each of the metrics and attributes. Chapter 5 describes the guidelines to completing the stressor checklist. This module has been developed with oversight and guidance provided by the statewide Level 2 Committee of the California Wetland Monitoring Workgroup (CWMW), which is charged with the oversight of Level 2 methodologies, including CRAM.

1.1 Statement of Need and Justification

CRAM was developed by the California Wetland Monitoring Workgroup (CWMW) as a field-based, diagnostic tool that can be used to cost-effectively assess and monitor the condition of most streams and wetlands throughout California (CWMW 2013). CRAM supports the State's Wetland and Riparian Area Monitoring Plan (WRAMP), as developed by the CWMW and endorsed by the California Water Quality Monitoring Council (Senate Bill 1070; Kehoe, 2006). CRAM "modules" are developed for differing wetland and stream classes in direct response to California's assessment and policy needs. Initial development of CRAM centered on wetlands and mesic watersheds (coastal and inland), but there has since been a need and desire to expand the applicability of the method to other resource types and inland regions of California (State) to account for the variability in type, form, and function that occurs with physiographic setting, latitude, altitude, and distance inland from the coast (CWMW 2013).

The standard riverine module of CRAM was developed to assess the condition of all stream types throughout the State. Although past validation efforts have shown that riverine CRAM is broadly applicable to a range of fluvial environments commonly encountered (Stein et al. 2009), the standard module draws heavily from conventional fluvial theories, such as concepts of equilibrium, dominant-channel forming discharge, and hydraulic geometry relationships that have less relevancy to fluvial systems characterized by long periods of no flow (Graf 1988a, 1988b). Furthermore, because the method emphasizes the functional benefits of structural complexity, it has been shown to be systematically biased against naturally simple fluvial systems, such as low order (i.e., headwater) streams in arid environments and desert streams that tend not to support species-rich plant communities with complex horizontal and vertical structure (Solek and Stein 2010; 2011). When applied to streams in these environments, the method can produce artificially low condition scores for some metrics, even for reference condition sites that are not subject to anthropogenic stress. Finally, the standard riverine module has limited application in river reaches with broad, depositional floodplains, such as those which occur where braided rivers and compound channel forms occupy low-gradient valleys, a characteristic common to many episodic streams in the State.

More than half the total stream miles in California, and more than two thirds in the drier Southern California region, are comprised of streams that do not flow continuously throughout the year. These streams have hydrologic regimes that are distinct from perennial watercourses and determine their resulting channel forms and vegetative characteristics. Although CRAM was originally developed to assess the condition of *wetland* areas that satisfy criteria according to the wetland definition as recommended for the California Wetland Area Protection Policy (SFEI-ASC 2012), most episodic streams would not qualify as wetlands under this definition. However, most would be regulated as *Waters of the State* and *Waters of the U.S*[1] by State and federal resource agencies.

The lack of appropriate assessment tools and a functional classification system has hindered the incorporation of episodic streams into State and regional stream monitoring programs. This has often resulted in these systems being overlooked, undervalued, and, consequently, inadequately monitored, mitigated or managed by regulatory and resource management agencies. The development of appropriate assessment tools for episodic channels is critical for mitigation and planning efforts that strive to improve the State's ability to address individual and cumulative impacts on all of its waterways.

1.2 When to Use this Manual

The episodic riverine CRAM module should only be applied in situations where a stream shows indicators of flow primarily for short durations during and immediately following rain events. In contrast, streams in which flowing water is present for almost the entire annual cycle are always assessed using the standard riverine module of CRAM. Intermittent streams should generally be assessed with the standard riverine module if they exhibit biological, hydrological, or physical characteristics commonly associated with conveyance of surface water or near-surface water for extended duration (i.e. several weeks to months).

Some episodic streams exhibit seasonally-predictable flows where surface flow ceases for a certain period each year, whereas others exhibit unpredictable and highly variable flow within and between years. The terms *intermittent* and *ephemeral* are hydrological classifications that have traditionally referred to this continuity of streamflow in time (Gebhardt *et al*. 2005). For intermittent episodic streams, flowing water is present in the channel for periods of weeks to months following the

[1] i.e., would be regulated as Waters of the U.S. if Clean Water Act legal jurisdictional criteria are met, such as connection to navigable waters. Some waters are not Waters of the U.S. even if ecological criteria are met. Note that those federal jurisdictional limits do not apply to Waters of the State.

cessation of precipitation[2]. In ephemeral episodic streams, flowing water is present in the channel only during or immediately after precipitation events. These streams can be dry or have very low flow over decadal time scales.

The episodic riverine module of CRAM was developed primarily for streams that exhibit unpredictable discharge patterns and flow only in response to extreme rainfall events. In these terms, most of the streams intended to be assessed with the episodic module of CRAM would be categorized as ephemeral. For most streams characterized by seasonal periodicity (i.e., intermittency) of flow, use of the standard riverine CRAM module may still be appropriate. Streams with intermittent flow share many of the characteristics of perennial streams in having well-defined channels and floodplain-like landforms that are built and reshaped between sizable and more consistent flow events. The relatively regular and predictable presence of water and sediment movement in intermittent streams produces readily recognizable channel forms, vegetation patterns, and stream processes to support the use of the standard riverine module of CRAM for assessing these systems.

Situations will undoubtedly arise where the decision of whether to apply the episodic riverine module CRAM will be in question. Stream origins usually occur as transition zones in which the location and length of the zone is subject to fluctuations in groundwater levels and precipitation. Frequently, streams change from ephemeral to intermittent, and intermittent to perennial, along a continuum, sometimes with no single distinct point demarcating these transitions. Furthermore, interannual weather conditions, as well as the physical and biological characteristics of landscapes, can vary over time. In transitional areas, at higher elevations, or in the more mesic areas of coastal California, use of the standard riverine module may be appropriate. In light of these variables, practitioners must rely on experience and good judgment in deciding when to apply the episodic riverine module CRAM.

The final decision on which riverine module to use should be evaluated on a site-by-site basis, based on examination of the physical and biological field indicators present at the site. If an otherwise perennial watercourse exhibits intermittency or interruptions due to hydrologic modifications, it should be considered perennial and be assessed with the standard riverine module of CRAM. If an otherwise intermittent waterway exhibits perennial indicators due to more frequent discharges from hydrologic modifications, then the water should be considered perennial based on the site evaluation and be assessed with the standard riverine module of CRAM. If an otherwise ephemeral waterway exhibits intermittent or perennial indicators due to more frequent discharges from hydrologic modifications, then it should be considered intermittent or perennial based on the site evaluation and be assessed with the standard riverine module of CRAM. If in doubt about which module to use, a general guiding principle is to apply both modules and compare the results (considering the presence or absence of stressors affecting the site). Best professional judgment should ultimately guide the practitioner as to the most appropriate module to use for a given circumstance.

[2] A distinction should be made between intermittent streams and *interrupted or discontinuous* streams, which are defined as having discontinuous flow in space.

1.3 Geographic Scope

Ephemeral, episodic streams are common throughout the dryland (arid and semi-arid) regions of California (USDA 2006) where annual evapotranspiration exceeds precipitation (Bailey 1995; Bull and Kirkby 2002). For these regions, annual average precipitation is typically less than 15 inches (380 mm). Drylands constitute over 60% of the State's landscape and broadly include the Mediterranean regions of the state, including the associated coastal zone of southern California, as well as the interior desert portions (Figure 1.1). Episodic streams are especially well-represented in the inland deserts of California (e.g., Mojave, Great Basin, Sonoran-Colorado), but are not exclusive to these regions.

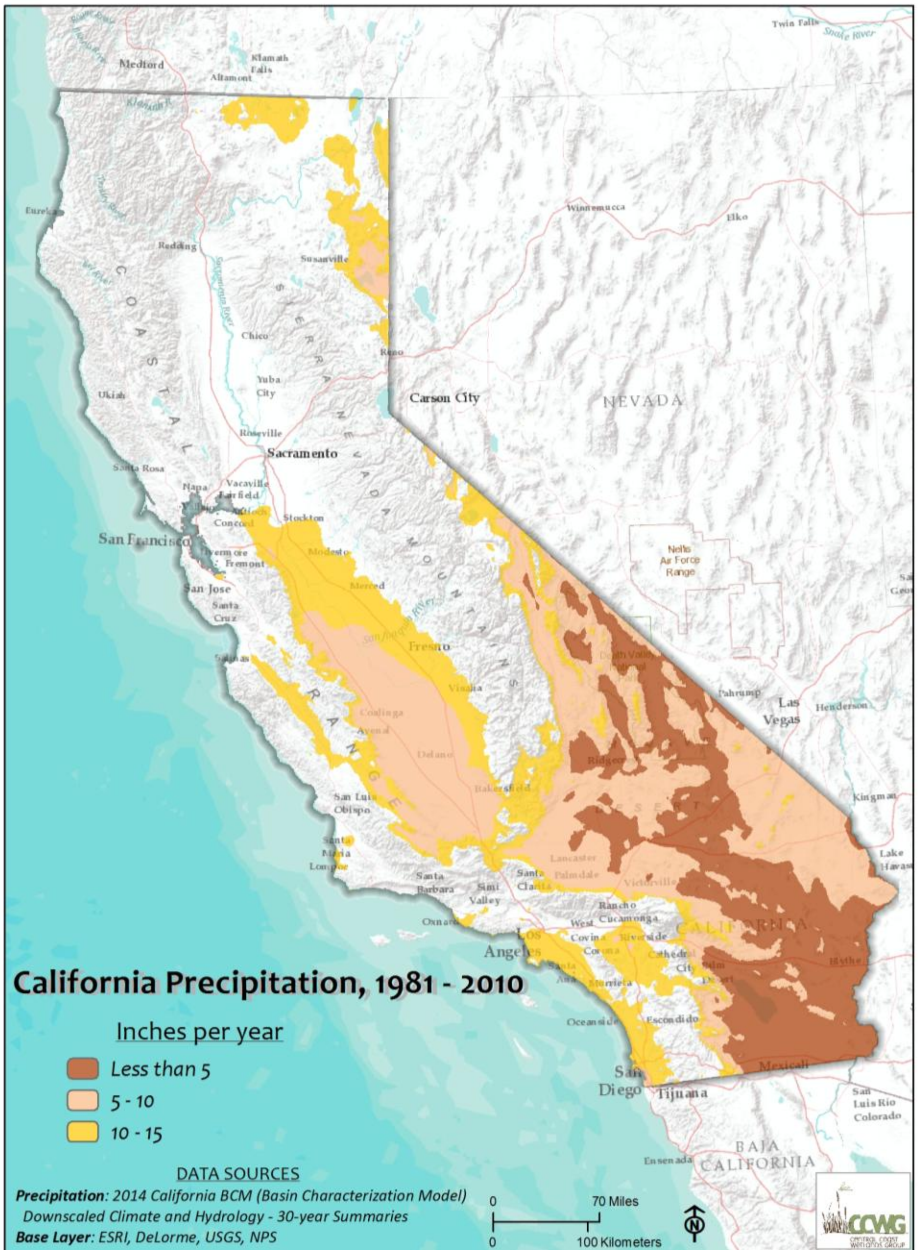

Figure 1.1: Rainfall in California showing areas with less than 15 inches (38 cm) of average annual precipitation

CHAPTER 2: PROCEDURES FOR USING CRAM FOR EPISODIC STREAMS

2.0 Summary

The general procedure for using the episodic module of CRAM consists of the same series of eight steps as described in Table 3.1 of the CRAM User's Manual. This field book does not duplicate this information, but only addresses significant differences from established methods and supplemental information germane to the assessment of episodic stream condition. Users should refer to the CRAM User's Manual for key concepts, assumptions, and the developmental process of the overall CRAM method.

2.1 Assemble Background Information

All CRAM assessments are aided by background information about the management objectives, history, known or expected stressors, and general ecological character of the area and location of the site to be assessed. Episodic streams, in particular, can be located within wide range of local climatic, geological, and vegetative environments, and the characteristics, flow regime (i.e., flow magnitude, frequency, duration, timing), and forms of these streams will vary accordingly. These variations are further influenced by a stream's position within its watershed.

Background materials may include a review of U.S. Geological Survey (USGS) topographic map quadrangles, the National Hydrography Dataset (NHD), Natural Resources Conservation Service (NRCS) soil survey maps, geology maps and/or high resolution topographic data (e.g., LiDAR-based) or aerial photography may help provide information when conducting the field investigation. Other important data may include land use/land cover maps, current construction activity in the area, and relevant reports on environmental impacts, cultural history, restoration and mitigation projects from water districts, flood control districts, open space districts, and state and federal agencies. All of this information can provide important context for interpreting conditions.

For episodic channels, the use of aerial imagery is particularly useful to develop a baseline understanding of the watershed in which the site is located, including its geologic setting, basin type, and valley context. This imagery can also be used to examine factors such as development extent, fire and flood history, vegetation coverage, sediment sources, and ecologically-sensitive areas, etc. A detailed examination of the site's setting within is valley will help to identify major tributary confluences, potential grade control (e.g., road crossings), and existing infrastructure (e.g., stormwater outfalls, drainage 'improvements', etc.) prior to conducting the field assessment. The use of publicly-available GIS data can further provide useful spatial and topographic information (e.g., contributing drainage area, valley slope at the site, degree of geomorphic confinement, and valley bottom width). To assist in evaluating whether flow in the stream is typical, current streamflow at nearby gauges, recent rainfall compared to normal, and drought status information can also be useful.

2.2 Episodic Stream Classification

Classification requires the application of standard definitions followed by the application of a standard typology or classification system. Classification can assist in informing upon the extent of the variability present within a given resource type and be useful for determining the most appropriate assessment application. The flowing information pertains to the classification of episodic waterways.

2.2.1 General Definitions

Episodic streams share the basic suite of hydrogeomorphic landforms common to all fluvial systems: a channel(s), an active floodplain, plus any portions of the adjacent areas that are likely to be strongly linked to the channel and immediate floodplain through hydrologic processes, bank stabilization and/or allochthonous organic material (productivity) inputs. Adjacent areas may or may not include vegetated areas, including riparian areas or stream-associated vegetation types. Together, these functionally-related hydrogeomorphic units make up the stream (or watercourse) and define its outermost bounds in cross section and length.

Because the terms "c*hannel*", "*stream*", and "*riparian*" are rooted in perceptions of waterways characterized by more consistent flow regimes, CRAM has adopted the following definitions as recommended by the Technical Advisory Team to the Policy Development Team for the California Wetland and Riparian Area Protection Policy (SFEI-ASC 2012) for use in the context of episodic streams:

> A *channel* is defined as:
>
> "*a landscape feature with well-defined beds and banks that have been formed by water and which under normal circumstances are maintained by the flow of water, or that are purposefully constructed and maintained to convey water. Channels can be subterranean for short lengths but are generally surface features. Channels can pass under bridges or through culverts and natural tunnels, but buried storm drains and water pipes are not channels* (SFEI-ASC 2012).

Channels have a defined course along which water flows continuously or periodically. Some channels may contain flowing water during every runoff event or receive water only during higher flow periods (Vyverberg and Brady 2014). The bed of a channel is its bottom and the physical confine of base flow or low water flow. Stream banks are vertical or sloped areas rising from the bed of the channel that form the lateral constraints (i.e., channel margins) of flow during all stages but flood stage. Usually the channel bed is clear of terrestrial vegetation, while the banks are subjected to water flow only during high stages, and therefore can support vegetation much of the time. Indicators of bed and bank may diminish as the stream transitions from intermittent to ephemeral episodic flow.

> A *stream* is defined as:
>
> "*a landscape feature consisting of one or more channels that convey flowing water plus adjoining riparian areas having conditions affected by interactions with the flowing water regardless of its origin, depth, extent, duration, or timing*" (SFEI-ASC 2012).

Flooding occurs when a stream overflows its banks and partly or completely fills its floodplain. The active floodplain is a relatively flat, depositional surface associated with a channel over which water and sediment from the channel flows when the capacity of the channel is exceeded. An active floodplain shows characteristics such as surface scour, drift lines, sediment deposited on the banks or surrounding plants, and plants flattened by flowing water. Floodplains typically parallel channels and can include features such as vegetated and non-vegetated bars, islands, and low benches among the distributaries of braided channel systems, as well as topographically higher channels (overflow or secondary channels) that carry water only during flood flows. Active floodplains and their surfaces are defined by the lateral extent of water that overflows secondary channels but is still contained within the larger watercourse.

In streams with near continuous flow, a floodplain is typically evident and becomes more continuous and developed as the flow volume and sediment transport capacity increase downstream. Occasionally, small, shallow ephemeral and intermittent channels in relatively broad, flat valley bottoms may form floodplains that are "reworked" during each storm event that results in overbank flow. Such floodplains usually are not accumulating alluvium like floodplains farther downstream. Not every stream is associated with a floodplain. Geomorphic floodplains may be absent from many episodic channels because the extreme variability of discharges prevents the repetitive over-bank flows needed for the vertical accretion of this landform (Graf 1988a), or due to confinement of the channel in high-gradient streams (see Section 2.2.2.2 below). However, where floodplains occur, they are considered integral to overall stream function through the accumulation of organic matter and mineral alluvium deposited during receding flood waters.

CRAM recognizes that streams are tightly coupled with their adjacent riparian area and CRAM employs the definition for riparian areas as defined by the U.S. National Research Council (NRC):

> *"Riparian areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes and biota. They are areas through which surface and subsurface hydrology connect water bodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems. Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes and estuarine-marine shorelines" (National Research Council 2001).*

It should be noted that the NRC definition does not require the presence of iconic riparian plant species to define a *riparian area* or *riparian zone*, but is inclusive of the strip of vegetation along a channel which may be (but is not necessarily) of distinct composition and density from the surrounding uplands. In some cases, the vegetation associated with an episodic channel may be comprised of predominantly upland species. Thus, while the presence of typical riparian vegetation may be an appropriate indicator in perennial and intermittent stream ecosystems, it is less relevant for more xeric environments where stream-associated riparian vegetation tends to be dominated by upland plant species.

Although a State or federal agency Jurisdictional Delineation (JD) is helpful in identifying the boundaries of an episodic stream where a CRAM assessment is to be conducted, it is NOT a pre-requisite for conducting CRAM. CRAM can still be conducted on episodic streams that do not have an associated JD.

The area included in a CRAM assessment may or may not conform to the boundaries of an agency JD. If a relatively recent JD exists, it can be used to inform the limits of a CRAM Assessment Area; however, the CRAM Assessment Area guidelines should supersede the JD boundaries to ensure that the entire functional width of the stream course is evaluated. In the absence of a readily available JD assessment, boundaries should be sketched on the base imagery for the CRAM assessment, using the general guidelines in Table 2.1 and Figure 2.1 below.

Table 2.1: Guidelines to delineate an episodic stream for the purpose of CRAM

Delineating Feature	Description of Features
Low-flow Channel	The topographically lowest stream channel, or the dominant sub-channel within a compound channel watercourse, occupied by recurring flow events.
Active Floodplain Area	An area encompassing all contemporary stream channels and the interfluvial areas[3]. The active floodplain area may be defined by the hyporheic zone, the zone between the surface stream and alluvial ground water, and the parafluvial zone, the part of the active channel without surface water (Levick et al. 2008).
Upland	Any well-drained areas of higher ground that are dominated by terrestrial processes including all non-wetland areas that lack any field-based indicators of wetlands or other aquatic conditions

Episodic streams may have undergone a type conversion due to anthropogenic events or land use practices. *Perennialization* refers to the conversion of an episodic stream to one with a more consistent flow regime through the addition of surface water flow (usually at low levels) to the channel from artificial supplies of surface water. This process can result from dams impounding flood flows and releasing steady base flows, from discharge of treated wastewater effluent or irrigation return flow, or from cultural activities such as overwatering of landscapes (Smith 2000). *Perennialization* of formerly intermittent and ephemeral waterways can facilitate a shift in plant and animal community composition and has the potential to affect physical and chemical processes, all of which can contribute to the replacement of a diverse community of dryland species with exotics or invasive species. However, regardless of whether a conversion has occurred, the system should be evaluated according to its current type and metric scores should be assigned using the ratings for the current state of the system, without regard for what type it might have been in the past, or what it might become in the future.

For episodic streams known to be type-converted, the historical type should be noted in the Basic Information and on the Worksheet A.1 for Wetland Disturbances and Conversions completed as

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[3] If a vegetated wetland is present along the channel bottom or floodplain of an episodic system during the dry season <u>and the wetland</u> is fundamentally different in form and function from the surrounding stream environment such that a transition between the stream and another wetland type exists, that wetland should be assessed as such using the appropriate module of CRAM (e.g., depressional).

part of the Stressor Checklist Worksheet A.2, especially if the *perennialization* is known to have occurred recently (within the last 5 years). The stressor checklist enables the user to document whether the stream is currently being stressed by the conversion (i.e., if the process of conversion is continuing and a significant source of stress) and to better understand the degree to which changes in the flow or sediment regime have affected the structure and composition of the stream-associated plant community.

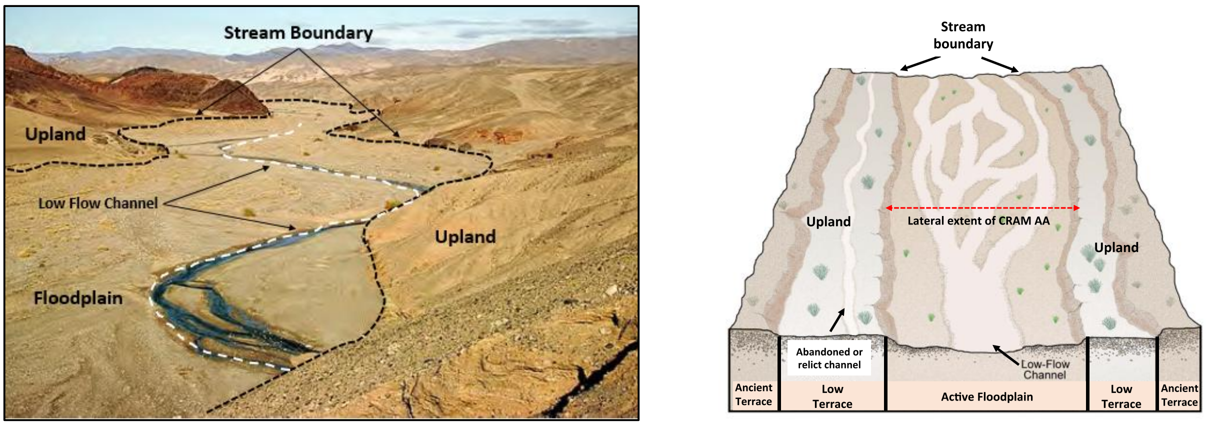

Figure 2.1: Identifying channels, floodplain, and upland terraces to delineate the boundaries of an episodic stream for CRAM. This example is for a compound channel form (photo courtesy of Marli Bryant Miller, diagram courtesy of Kris Vyverberg).

2.2.2 Episodic Stream Typology

CRAM typology is based on a functional classification approach similar to HGM (Hydrogeomorphic Method) that uses geomorphic setting, water source, and hydrology to infer function and ecology (Brinson 1993). CRAM defines a river or stream as a non-tidally-influenced (< 1 month), flow-through system with channelized flow between a distinct inlet and outlet (CWMW 2013). Although intermittent and ephemeral streams are formed and shaped by the action of water, they have hydrologic regimes that are distinct from perennial watercourses primarily in the infrequent nature of their flows, which in part determine their distinctive, resulting channel forms. Local geology, position within a watershed, regional climatic patterns, and vegetation can all influence a stream's resulting channel form, but morphology is driven largely by the discharge patterns associated with the local hydrologic regime (Lichvar and McColley 2008). This has inherent implications for mapping, delineation and condition assessment of these systems.

2.2.2.1 Episodic Channel Forms

Three primary channel forms characterize the majority of episodic streams of California: single-thread channels, compound or braided channels, and discontinuous channels (Lichvar and McColley 2008; Vyverberg 2010). While none of these forms are unique to dryland regions, episodic flow and sediment delivery processes make some forms more prevalent in these regions. Channelized flow, sheet flow, and debris flow dominate dryland episodic stream processes (Field and Lichvar 2007). Sheet flows and debris flows exert a strong influence on the morphology of some episodic fluvial landforms, such as alluvial fans (Field 2001, Blair and McPherson 2009), while channelized flow (the most frequently occurring process) produces less morphological variation in channel form.

2.2.2.2 Single-thread Channels

Single-thread channels consist of a single, meandering channel with lateral adjacent floodplains that, when present, are either contiguous or non-contiguous along the course of the channel. In general, the morphologies of dryland and temperate-region single-thread channels with adjacent floodplains are similar. However, transmission losses (Reid and Frostick 1997) and debris inputs from tributaries (Graf 1979, Webb *et al.* 1988), which may alter the form of the channel, tend to dryland stream processes. In drylands, these channel types tend to be shorter, more numerous, have a lower sinuosity than in temperate regions. They are generally first- or second-order tributaries that flow directly to larger, main stem channels (Schumm 1961).

2.2.2.3 Discontinuous Channels

Discontinuous channels are characterized by alternating erosional and depositional reaches. They are constantly in flux, as headcuts or knickpoints originating at the downstream end of the sheetflood zone migrate upstream, causing dramatic changes in channel morphology for any given location. Discontinuous channels develop primarily in dryland climates because the sediment yield is high (Tooth and Nanson 2000), sufficient vegetation is present to trap sediment on the sheetflood zones (Packard 1974), and transmission losses reduce the stream's ability to transport the sediment through the system (Bull 1997, Reid and Frostick 1997, Tooth 2000). Consequently, sediment has a tendency to move through discontinuous channels episodically (Schumm and Hadley 1957).

2.2.2.4 Compound and Braided Channels

Compound channels consist of a single, low-flow channel nested within a wider floodplain comprised of a network of frequently shifting, braided channels (Graf 1988a; Tooth 2000). They are generally the most common channel form for larger episodic streams in dryland regions. Dramatic channel widening and activation of braided channels accompany periodic flow events and a meandering form develops after a long (i.e., decades) sequence of low to moderate discharges (Kondolf and Curry 1986, Pearthree and Baker 1987, Kresan 1988, Graf 1988b, Friedman and Lee 2002). Compound channels are more common, and their development is enhanced, in arid climates for three primary reasons: the lower density of erosion-resistant vegetation (Graf 1978, Kondolf and Curry 1986), the greater prevalence of non-cohesive sandy soils (Cooke at al. 1993), and a higher ratio between record peak discharges and average annual discharge (Graf 1988b). These factors promote rapid channel widening during extreme events. Compound channels are mostly associated with low-gradient, sand-bed channels.

2.2.2.5 Alluvial Fans

Single-thread, discontinuous, and compound channels (or combinations thereof) can all occur on alluvial fan surfaces where erosional channelized segments alternate with depositional reaches that may lack a well-defined channel form (Thornwaite and others 1942; Schumm and Hadley 1957; Bull 1997; Field 2001). For example, a compound stream channel can emerge from the mountains at the fan apex then split into a network of distributary, single-thread watercourses. These channels can be separated by drainage divides or interfluves formed by dissection of older fan deposits, evidenced by their darkened varnish and the presence of desert pavement (areas of tightly packed cobbles where the wind has removed most interstitial sand). The degree of desert-pavement development affects surface hydrology and characteristics of adjacent channels, which may be reflected in channel geometry. Areas with very well developed desert varnish and desert pavement appear to have more deeply incised channels, whereas channels in areas with less developed varnish and desert pavement are much less incised (Sutfin 2013).

As confinement of a channel decreases and valley width increases, transitional states may create conditions where channel characteristics become undefined or indistinct, referred to as "floodout zones" (Tooth 1999, 2000; Grenfell 2012). As a process, floodout zones may dominate on the lower fan apron on alluvial plains where braided channels exist as short segments and develop distributary channels that disappear into unconsolidated alluvium. As a stream flows down an alluvial fan surface, its channels decrease in width and depth and lose definition. The reduced channel width, depth, and gradient can force water to overtop the banks of individual channels and combine with out-of-channel flows from adjacent channels to coalesce into a thin, relatively uniform expanse of unconfined water. This shallow flooding is superficially similar to overland flow and sheet flooding, but is here recognized as a distinct flood phase that occurs when the capacity of small, individual channels is exceeded and flood flows coalesce. This shallow, out-of-channel flooding is analogous to floods that overtop stream banks and inundate temperate region floodplains (Vyverberg and Brady 2014).

Thresholds may exist for the formation of floodout zones with regard to width-to-depth ratio and unit stream power, such that accommodation space becomes infinitely large and shallow sheet flow infiltrates readily into unconsolidated alluvium, leaving minimal to no trace of channelized flow (Dust and Wohl 2010). However, because of the lack of surface channel geometry, floodout zones are difficult to classify as a distinct channel type. Rather, these features are best considered as a unit or feature of the larger alluvial landscape, and may be characterized as a "terminal floodplain".

2.2.3 Operationalizing the Classification of Episodic Channel Forms for the Purposes of CRAM

Channel reach morphology tends to exist on a continuum, where form varies along the length of any given stream system and transitions from one form to another through space and time (e.g., a narrow, single-thread channel form in bedrock-dominated reaches transitions to a wide and braided channel form where the same stream flows through sands and gravels). This approach to classification of channel forms follows concepts of Schumm's (1977) basin model of erosive to depositional zones, where a continuum exists from primarily erosive bedrock channels in headwater reaches of a watershed to primarily depositional braided washes in the lowlands. Headwaters are characterized as predominantly *erosional zones*, whereas *zones of deposition* characterize relatively large rivers occurring in lowland environments. Transitional processes occur in intermediate *transfer zones* along the progressive spectrum from erosive headwaters to depositional lowland environments. In dryland regions of California, bedrock channels are present primarily in mountainous portions of a watershed, and drainage areas tend to be small compared to other channel types found in more lowland settings. Alluvial-bed channels confined and partially confined by bedrock, however, are relatively common in piedmont (valley) regions and exhibit stream gradients and channel geometry more similar to channels incised through unconsolidated alluvium (Sutfin 2013).

In this context, a downstream progression in channel form and channel bed confining material can be expected to occur in relation to distance from erosional headwaters (Montgomery and Buffington 1997). With increasing distance from high elevation mountainous portions of watershed the following progression of channel form and bed material can be expected:

- single-thread bedrock channels
- single-thread bedrock channels with alluvium
- discontinuous channels with incised alluvium
- piedmont headwater (alluvial bed) channels confined or partially confined by bedrock
- unconfined compound channels with braided channels, often dominated by sandy substrates.

In most cases the episodic CRAM module will apply to all five of these channel types, provided they are characterized by ephemeral, episodic flow. Standard riverine CRAM should be used if streams are supported by seeps, springs or other sources, and/or are underlain by bedrock that allow flow to persist for extended durations. However, the reference expectations for particular stream types may vary to reflect the distinct environments in which each of the five stream types occurs. These environments are expected to produce differences in hydraulic characteristics and channel geometry, which, in turn, will influence the stream's biological communities in terms of vegetation (i.e., canopy cover, life form, and growth form) and other indicators.

CRAM further sub-classifies rivers and streams as confined or non-confined. (CWMW 2013). Confined or non-confined channels can also be entrenched (Figure 2.3 below). Entrenchment is separate from channel confinement and strongly affects the hydrologic connectivity between streams with more continuous flow regimes and their surrounding landscapes

The degree of confinement for episodic streams is most accurately assessed based on the ratio of valley width to active floodplain width. Likewise, entrenchment is more accurately assessed based on the ratio of flood-prone width to active floodplain width.

A channel can be considered confined by artificial levees and urban development if the average distance across the active floodplain is more than half the distance between the levees or more than half the width of the non-urbanized lands that border the stream course. This assumes that the channel would not be allowed to migrate past the levees or into the urban development, or that levee breaches would be promptly repaired.

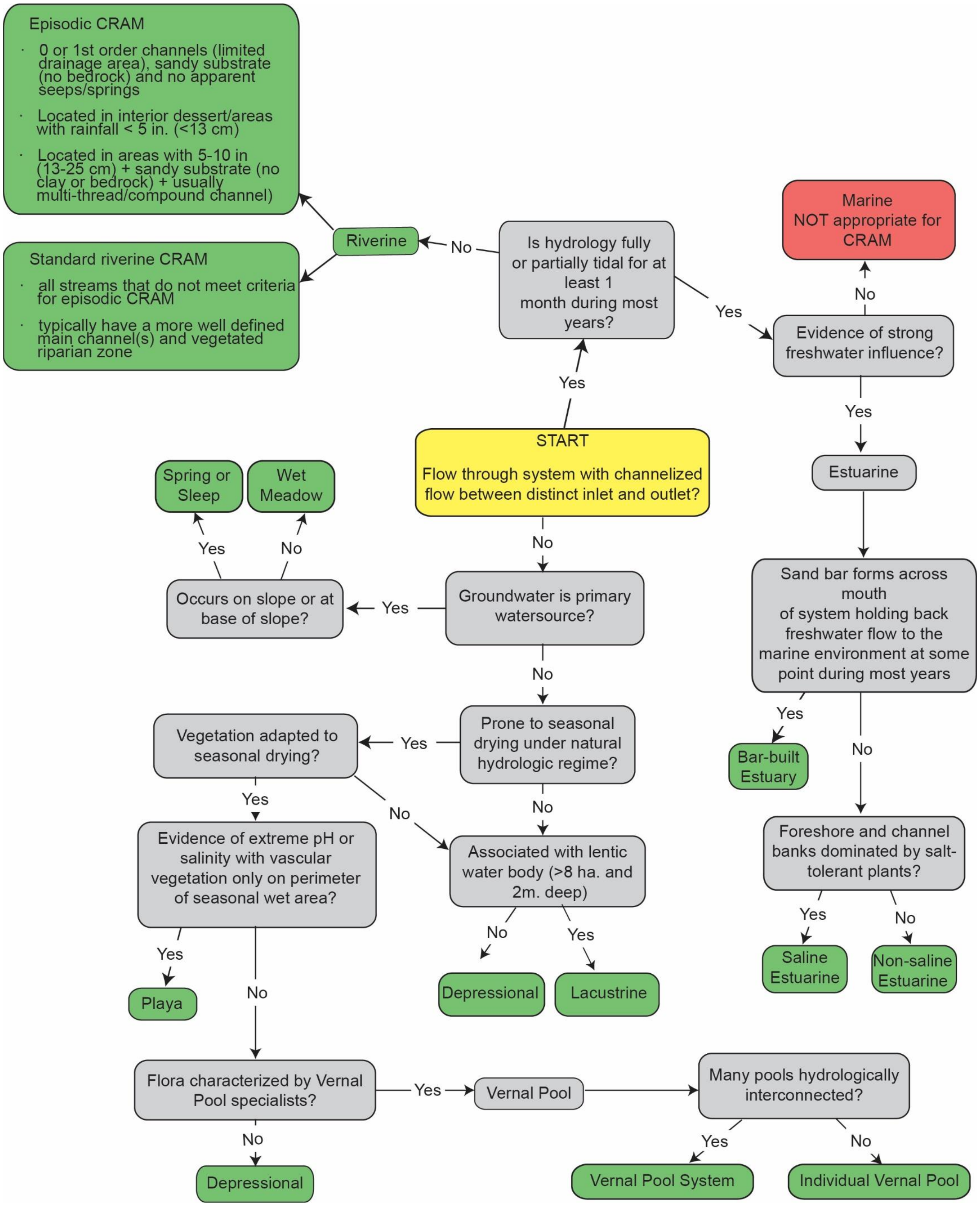

Figure 2.2: Flowchart to determine wetland type once a riverine wetland has been established.

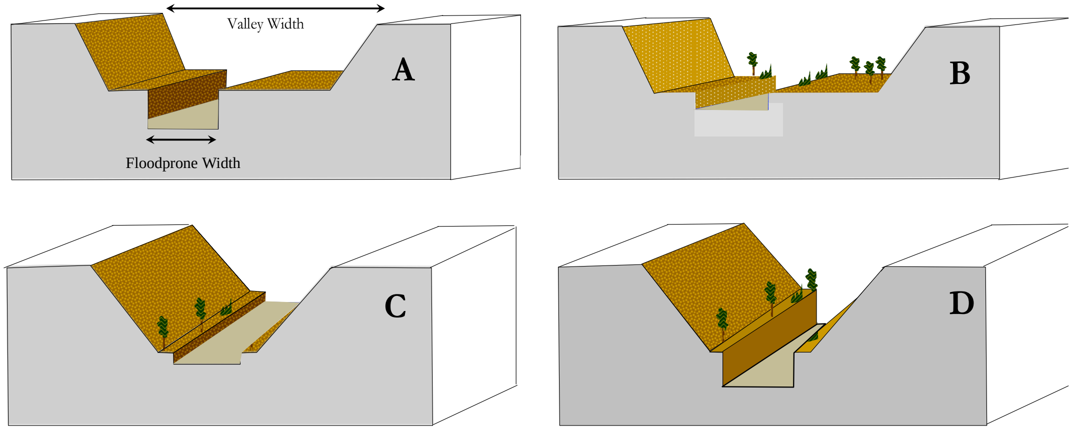

Figure 2.3: Illustrations of riverine confinement and entrenchment for episodic channels. (A) non-confined entrenched, (B) non-confined not entrenched, (C) confined not entrenched, and (D) confined. entrenched riverine sub-types.

2.2.3.1 Non-confined Episodic Riverine Sub-type

In non-confined episodic riverine systems, the width of the valley across which the system can migrate without encountering a hillside, terrace, or other feature that is likely to prevent further migration is at least twice the average floodplain width of the channel. Non-confined episodic riverine systems typically occur on alluvial fans and plains, and along broad valleys.

2.2.3.2 Confined Episodic Riverine Sub-type

In confined episodic riverine systems, the width of the valley across which the system can migrate without encountering a hillside, terrace, man-made levee, or urban development is less than twice the average floodplain width. A channel can also be considered confined if the average distance across the floodplain is more than half the distance between the levees or more than half the width of the non-urbanized lands that border the stream course. This assumes that the channel would not be allowed to migrate past the levees or into the urban area.

2.3 Verify the Appropriate Assessment Window

The Assessment Window is the period of time each year when assessments of condition based on CRAM should be conducted. In general, the CRAM Assessment Window falls within the growing season for the characteristic plant community of the system to be assessed.

Drylands in California span vast and topographically diverse regions; thus temporal variations in growing season will be related to seasonal changes in precipitation and evapotranspiration, as well as recent precipitation, snowmelt events, altitude, and latitude. The Assessment Window might vary within and between regions, and local or regional cues may be needed to determine when the window opens and closes each year. The best cues will be the early evidence of new growth of plants, and the subsequent senescence of the plants, for any particular system. For example, the assessment of a low-elevation, desert wash might begin early in the growing season (the window is opening), but well before complete summertime desiccation of stream-associated soils (the window is closing). Some experts can reconstruct conditions for the Assessment Window after it closes based on forensic botany and other field techniques. It should be clearly noted on the CRAM data sheets if an assessment is being done outside the designated Assessment Window.

However, drylands do incorporate two distinct subregions that differ sufficiently from each other in climate to warrant separate consideration for appropriate assessment windows. For episodic streams located in the Mediterranean California subregion and not subject to snowfall, the main growing season usually extends from March through September, although it may begin earlier at lower latitudes and altitudes. For sites subject to snowfall, the start of the growing season is retarded by the spring thaw, which at very high elevations may not happen until late May or June, depending on the depth of the snow pack. For interior desert regions, the assessment window will generally extend from mid-February to mid-June with an optimal window from mid-March to late April depending on rainfall and temperatures. In the warmest areas of the Colorado Desert, this window can be even earlier, sometimes as early as November. Typically, the months of July and August are the least optimal assessment windows in low elevation desert regions as temperatures can be extreme and plant cover will be minimal and species difficult to identify for the purposes of conducting CRAM.

Regardless of the optimal assessment window, rivers and streams should not be assessed during high water and flood periods, not only because some important indicators of channel condition might be concealed, but also because of the dangers presented by high flows. Because recent precipitation can have an effect on stream flow, and therefore can influence scoring, it is strongly recommended that field evaluations be conducted at least 48 hours after hydrology-altering events, when conditions would be considered “normal” or representative for the season. Generally, it takes about 48 hours for increased streamflow resulting from precipitation to attenuate.

2.4 Establish the Assessment Area

The assessment area (AA) is the portion of the stream that is assessed using CRAM. Examples of features that should be used to **establish riverine AA boundaries,** and other features that should not be used, are listed in Tables 2.2 and 2.3 below. Although the maximum extent of the Assessment Area (AA) can be estimated in the office with the aid of aerial imagery, this must be verified in the field. Printed aerials or Google Earth screen shots with scale bars should be assembled prior to field work and carried into the field.

The CRAM User’s Manual (CWMW 2013) describes the importance of maintaining hydrogeomorphic integrity and bounding an AA by obvious physical changes in topography, hydrology, or infrastructure that significantly control the sources, volumes, rates, or general composition of sediment supplies or water supplies within the AA at the time of the field assessment. The details underlying these concepts will not be reiterated here; only deviations from standard riverine module as they pertain to ephemeral, episodic channels will be discussed. As stated in the previous section, AA boundaries can be informed by jurisdictional delineations; however, they do not need to necessarily conform to jurisdictional boundaries – the functional AA boundaries should take precedence.

Table 2.2: Guidelines for identifying features that should be used to establish riverine AA boundaries

Refer to the CRAM Photo Dictionary at* **www.cramwetlands.org *for photos of each of the following examples.*

Examples of features that <u>should</u> be used to establish riverine AA boundaries	**Examples of features that should <u>not</u> be used to establish riverine AA boundaries**
• major changes in channel entrenchment, confinement, degradation, aggradation, slope, or bed form • major tributary or channel confluences • abrupt vertical drops in channel course (where waterfalls would be present if water was present) • transitions between stream or wetland types • diversion ditches • end-of-pipe large discharges • weirs, culverts, dams, drop- structures, levees, and other flow control, grade control, or water height control structures	• **at-grade**, unpaved, single-lane, infrequently-used roadways or crossings • **at-grade** bike paths and jogging trails • equestrian trails • bare ground within what would otherwise be the AA boundary • fences (unless designed to obstruct the movement of wildlife) • property boundaries, unless access is not allowed • transitions in channel bed substrate (e.g., sand bed to gravel bed) • spatial changes in land cover or land use along the stream border • state and federal jurisdictional boundaries

2.4.1 Detailed Procedure to Establish the AA for Episodic Stream Types

Prior to establishing the boundaries of the AA in the field, walk the area of interest to develop a general understanding of the overall site characteristics. It is helpful to first determine whether the system is confined or unconfined according to the CRAM guidelines and determine the site's position relative to its watershed setting (e.g., is it an eroding headwater reach vs. a low gradient, depositional reach). This will assist in determining the channel type, specific AA rules, and expectations for field indicators. Make note of the vegetation at the site and observe any differences across the hydrogeomorphic units present (lowflow channel, floodplain, upper terrace boundary, etc.). A sketch of the cross section (or mark up of an aerial) and labeling of these units can assist in delineating the AA boundaries of more complex channel forms. Lastly, note any observable anthropogenic influences on the AA and record a brief description of the site. Record all of this information in the appropriate box on the Basic Information form.

For episodic streams, the assessment of the AA should generally include both sides of the channels. If only one side of the channel can be assessed, this must be noted on the Basic Information form. To assist in standardizing the assessment of episodic streams (and for safety reasons), assessments should be restricted to the dry season. Dry season assessment in these systems, therefore, will always include the channel beds.

One major difference in the assessment area for episodic vs. standard riverine CRAM pertains to the concept of bankfull and how it affects the width of the assessment area. Under equilibrium conditions in mesic climates, bankfull corresponds to the usual high water contour that marks the inboard margin of the floodplain (i.e., the margin nearest the thalweg of the channel), which has an average recurrence interval of about 1.5 to 2.0 years (Leopold et al., 1964; Dunne and Leopold, 1978; Knighton, 1998; Simon et al. 2004).

Technically, episodic channel forms have no bankfull as commonly understood, because the concept is associated with a regular recurrence interval (typically characterized as a 2-year recurrence interval). A 2-year recurrence interval would often relate to the frequency of the migratory low-flow channel characteristic of these systems (Lichvar et al. 2009), but not necessarily to channel forming flows. The low-flow channel is unstable due to flashy (episodic) discharge events, poorly consolidated soils, and lack of stabilizing vegetation cover. It frequently fills with sediments and erodes a new portion of the floodplain (Bull 1997). This suggests that episodic streams in arid and semi-arid regions do not have separate bankfull channels and active floodplains; instead the bankfull and active floodplain combine to create a single active floodplain where the majority of fluvial activity occurs (Lichvar and McColley 2008).

The bankfull zone among low-gradient, compound channels is an extremely transient and less discernable feature. The dominant channel-forming discharge, although similar conceptually to the bankfull event of a perennial stream, is conveyed by a low-flow channel within the active floodplain zone (Lichvar and McColley 2008). The low-flow channel lacks an established position within the active floodplain and will form and relocate during low to moderate discharge events (5–10 years) instead of being maintained by continuous flows (Lichvar et al. 2009).

For compound or braided channel forms, the lateral extent of the watercourse equates to the flood-prone width, measured as the width of the entire active floodplain projected above all channel bars and fluvial surfaces to cover the width of the incised valley. This width represents the maximum channel width for a probable maximum flood in terms of hydrologic disturbance of braided washes and potential for subsurface hydrologic interactions within unconsolidated alluvial fill (Sutfin 2013).

Consequently, for episodic streams, the AA should be delineated based on the entire active floodplain area, inclusive of the primary and secondary channels, islands and parafluvial areas. The general procedures described below can be used to delineate the AA for most episodic stream types regardless of geomorphic setting (e.g., high- gradient headwater reaches or low gradient depositional reaches).

2.4.1.1 Establish the Longitudinal Extent of the AA

The AA should begin at a hydrologic or geomorphic break in form or structure of the channel that corresponds to a significant change in flow regime or sediment regime, as guided by Table 2.2. From this beginning, the AA should extend upstream or downstream for a distance ten times (10x) the average width of the AA, but at least 100 m, and for a distance no longer than 200 m. The AA should not extend beyond any confluence that obviously changes the sediment supply or flow, or that changes the width of the stream channel. In more urban settings, the AA may be logically divided by road crossings which may offer grade control, cause discontinuities in the conveyance of water or sediment, etc. (Chin and Gregory 2005). In more rural settings, changes in valley (confined or unconfined) or channel type, natural hard points, and tributary confluences may be more appropriate for delineating the longitudinal extent of the AA.

To the degree possible, the delineation of an AA should first be based on the features summarized in Table 2.2, but if these considerations are not applicable, then the AA can begin at any point along the channel reach of interest. For ambient surveys, the AA should begin at the point drawn at random from the sample frame, then delineated based on the presence of hydrogeomorphic breaks. If multiple reaches of a stream will be assessed with CRAM, these must be assessed independently based on either length or changes in physical characteristics as described.

2.4.1.2 Establish the Lateral Extent of the AA

To determine the lateral extent of the AA, first identify the low-flow channel. The low-flow channel has the lowest elevation in the active floodplain, contains flowing water the most frequently, often has recent indicators of flow or ponding (such linear bands of concentrated gravel and cobble, debris mounds entrapped in instream vegetation, zones of well sorted sands, mud cracks a general lower density of vegetation that surrounding uplands). In general, the AA should extend from the center of the low-flow channel to the outer extent (upland terrace edge) of the active floodplain to include adjacent areas that probably account for bank stabilization and any direct allochthonous inputs of organic matter into the active floodplain. Any vegetation that directly contributes organic material to the active floodplain, if present, should be included in the AA in their entirety. The AA can include topographic floodplain benches, bars, islands, secondary channels, meander cutoffs, and other features that are at least **semi-regularly** influenced by fluvial processes and are associated with the AA. Upland vegetated areas along adjacent sloping terrace margins may be included as part of the AA if they directly affect the active floodplain through some form of bank stabilization, contribution of organic material, or provision of shading.

The AA should not extend beyond the limits of the active floodplain, as indicated by transitions to fluvially inactive uplands, terraces with abandoned or relict (paleo) channels, or other surfaces that are geomorphically disconnected from the floodplain and channel-forming processes or are only inundated by infrequent extreme events under current flow conditions. Terraces and interfluves are considered upland landforms that were historically formed by fluvial processes but are no longer active and are generally <u>not</u> included in the AA (but see section on alluvial fans).

Riparian areas or any stream-associated vegetation growing along or on upper terrace margins may be included as part of the AA if they contribute plant material to the active floodplain or provide some form of bank stabilization, shading, etc. In some regions, changes in the density of certain plant species, such as cacti (*Opuntia* sp.), Joshua trees (*Yucca brevifolia*), and creosote bush (*Larrea tridentata*) are useful indicators of the limits of the active floodplain and transitions to upland areas. These species may occur with the active flow areas, but typically at substantially lower densities than in the adjacent upland areas.

2.4.1.3 Special Considerations for Episodic Channel Forms

Various channel forms characterize dryland episodic streams in California (Vyverberg and Brady 2014). In cross section, these channel forms are associated with an array of related geomorphic units including islands, bars, low-flow and secondary channels, and floodplains. Because of the diversity of channel forms and features, the process for establishing the lateral extent of the AA will differ by channel type.

Single-thread Channels: In general, the morphologies of episodic single thread and discontinuous channels are similar to those of perennial streams (Figure 2.4). Among single-thread forms, streamflow is restricted to a discrete, meandering channel form, and the lateral extent is fairly straightforward to delineate based on observable field indicators. Adjacent floodplains, if present[4], can be contiguous or non-contiguous along the course of the channel. Increased transmission losses (Reid and Frostick 1997), debris inputs from tributaries (Graf 1979, Webb *et al.* 1988), and the effectiveness of large floods in arid climates may slightly alter the form of these channels, and morphological features may be less distinctive or subtle when compared to typical non-episodic streams, but these features are generally observable in the field clearly enough to accurately define the lateral extent of the AA.

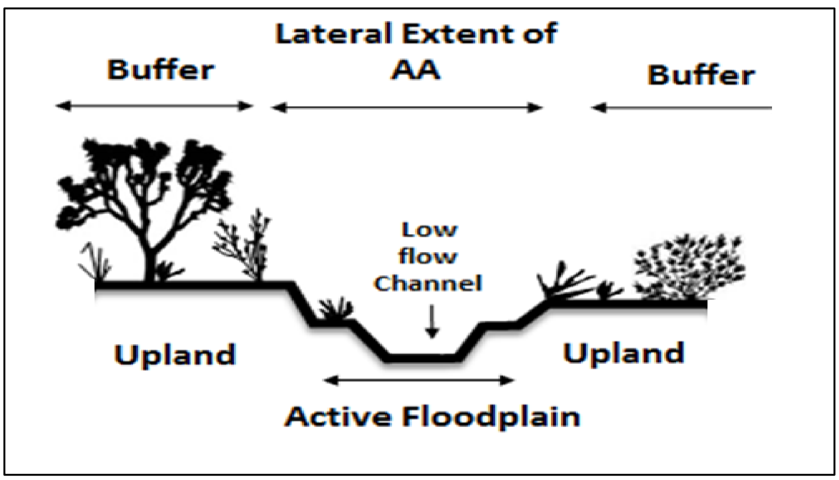

Figure 2.4: Cross-section diagram of a typical single-thread channel form showing the lateral extent of the AA in relation to its hydrogeomorphic units. The AA includes all portions and features of the active floodplain, but does not include upper terraces that are beyond the active floodplain and inundated only by extreme events under current conditions.

Discontinuous Channels: Discontinuous channels form a distinctive pattern of well-defined erosional channel segments that alternate with depositional reaches having poorly defined channel form and unconfined or subsurface flow. For these channel forms, the limits of erosional and

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[4] Adjacent floodplains may be absent in steep and/or constrained landscapes (e.g. narrow canyons)

depositional reaches are important considerations in defining AA longitudinal extent as these can constitute major changes in channel entrenchment, confinement, degradation, aggradation, or bed form. In defining the lateral extent for these channel forms, erosional channel segments will tend to be better defined and easier to delineate for the purposes of CRAM based on the procedures for single-thread forms. For depositional reaches with poorly defined channel form, refer to the procedures for **establishing AAs in compound and braided channels (below).**

Compound and Braided Channels: Compound channel forms consist of a single, low-flow channel nested within a wider watercourse defined by a frequently-shifting, braided network of secondary channels within the active floodplain. Within the braided watercourse, multiple active shallow channels divide and rejoin to form a pattern of gently-curved channel segments separated by exposed islands or channel bars. For these channel forms, the outer extent of the active floodplain is the most stable and reliable landform that can be used to determine the lateral extent of the AA (Figure 2.5). Flooded by low-to-moderate events, features of the active floodplain depend on the amount of time since the last major flow event (Riggs 1985, Lichvar et al. 2006). After such an event, few flow indicators will be present in the channel and vegetation may not be established (Lichvar et al. 2006). A few years after an event, vegetation on the active floodplain is frequently dominated by young plant growth, and the sediment texture is often coarser than in the low-flow channel.

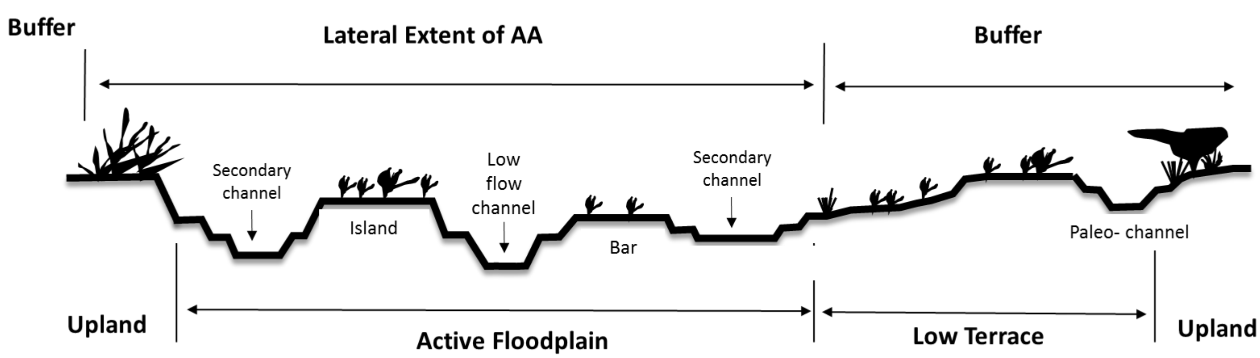


Figure 2.5: Cross-section diagram of a typical compound channel form showing the lateral extent of the AA in relation to its hydrogeomorphic units. The AA includes all portions and features of the active floodplain, but does not include upper terraces that are beyond the active floodplain and inundated only by extreme events under current conditions (diagram adapted from Lichvar and McColley 2008).

Upper terraces are hydrogeomorphic flood units most commonly associated with an abandoned or ancient floodplain and they possess minimal signs of recent flooding. This portion of the channel beyond the active floodplain is only inundated by extreme events under current conditions (Curtis et al. 2013). Consequently, the terrace is typically dominated by upland land forms and characterized by well-established vegetation. At the boundary between the active floodplain and the terrace, there is often a defining break in slope and a sharp change in vegetation species, percent cover, and successional stage. Note that the AA extends to the outside edge of any vegetation overhanging the active floodplain. Areas outside of the AA are assessed as part of the buffer.

Ancient terraces are abandoned floodplain surfaces that are not flooded under current climatic or geomorphic conditions. They are distinguished from the channel hydrogeomorphic floodplain units by upland landforms and terrestrial processes, such as soil development and surface rounding. The lack of flow indicators (e.g., drifts, fine sediment deposits) can be used to help distinguish abandoned from currently active flow surfaces. Islands or interfluves (upland ridges) may be present between adjacent stream channels flowing in the same direction. These are fluvially-inactive upland areas where terrestrial indicators dominate.

2.4.1.4 Establishing AAs in Channels on Alluvial Fans

Alluvial fans can extend for many kilometers across the landscape and form vast, complex networks of shallow and more defined incised channel and swales, bounded laterally by adjacent fans, bedrock outcrops, and relict fan surfaces. Across a fan surface, stream channels tend to diverge and diminish in width, depth, and discharge due to the diversion of water by sediment and debris blockages, seepage losses, and declining sediment transport capabilities. These landforms offer unique challenges for delineating the AA for the purposes of conducting a CRAM assessment. AAs will be more straightforward to establish on fan apices or on steeper fan surfaces with well-defined single-thread, or deeply incised, erosional channels, than for those located on fans of low relief crossed by numerous, poorly defined shallow channels that may be only a few centimeters deep.

For more challenging scenarios, it is important to distinguish indicators of fluvial activity and inactivity, as areas of activity are most likely to be included as part of the active floodplain within the watercourse boundary. Look for the presence of upland surfaces to delineate distinct AAs. In general, the AA should not extend across any well-defined upland area) If indicators of fluvial activity are present on what have been identified as "terraces" or "interfluves" they are more likely part of the active floodplain and as such, should be included within the AA. For floodout zones where channels can no longer be defined and overland flow is the dominant process occurring, CRAM is no longer appropriate as an assessment method and should not be used.

Table 2.3: Steps to establish riverine AAs on low relief alluvial fan surfaces

Step	Delineation Task
1	On the site imagery, identify the system of channels that are probably interconnected by surface flow and fluvial activity. To the extent possible, the boundary should follow the drainage divide or rim of the basin encompassing the selected channel system, without extending across an interfluve or desert pavement and without extending into non-buffer land cover.
2	Identify and number all well-defined channels within the system delineated from Step 1. These channels comprise the AA sample universe for the fan surface.
3	If there are fewer than three channels in your AA, assess all of them using the episodic riverine module. Additionally, if any channel looks substantially different than the others in the system (in terms of its vegetation, entrenchment, etc.), then it should be assessed independently as a separate AA.

	If there are more than three channels within the AA universe, randomly select three of these. Channels to be assessed within the system can be of different sizes but similar in terms of vegetation, depth, etc. These channels will be assessed individually using the episodic riverine module and their scores will be averaged.

Special Notes:
**The opposing banks of an AA can have different lateral extents (widths), due to differences in topography and plant structure.*

* *For systems without obvious or discernable floodplains (such as some confined, single thread channel in steep valleys), set the lateral extent of the AA on each side of the channel at a distance of no more than two times the width of the primary (e.g., low-flow) channel. This includes the adjacent areas that probably accounts for bank stabilization and most of the direct organic inputs (leaves, limbs, insects etc.) into the channel.* The *minimum width of the AA should extend* ***no less than*** *two meters (2 m) from the edge of the channel margin.*

**For AAs located on alluvial fans where lateral extent cannot be easily determined using standard hydrogeomorphic indicators, use the method described in Table 4 to delineate the AA(s).*

2.5 General Size Considerations for Episodic Riverine AAs

Experience has shown that most of the AAs that are delineated according to indicators of hydro-geomorphic integrity fall within a narrow range of size, although their shapes are more variable. This suggests that size guidelines can be applied to the process of establishing an AA without necessarily violating the criterion for the hydrogeomorphic integrity of the AA.

The standard riverine module of CRAM (ver. 6.1) is especially sensitive to structural complexity, thus larger AAs might tend to yield higher CRAM scores and having AAs of very different sizes can introduce variability into CRAM scores. However, because episodic streams in general tend to support less biotic structural complexity compared to their perennial stream counterparts, there is less opportunity to encounter such variability in structure, and size considerations for AAs can be relaxed to some extent.

In the case of large episodic riverine systems, overall size may be the dominant criterion for delineating the AA. The preferred AA size is generally greater for streams that tend to have broad, level planes than for those located on steep terrain. The size-frequency distribution via a Level 1 analysis was also considered when the recommendations for AA sizes were being developed. Examples of features that should be used to delineate an AA, and other features that should not be used, are listed in Tables 3.5 and 3.6 below. The preferred and minimum AA sizes for each wetland type are presented below in Table 3.7.

To the degree possible, the delineation of an AA should first be based on the hydrogeomorphic considerations presented in Table 2.2. Table 2.4 provides additional general guidance for determining the size limits of the AA.

Table 2.4: General size guidelines for delineating AAs in episodic streams.

Parameter	Size Guidelines
AA length	**Recommended**: Two times the average floodplain width **Maximum**: 200 m **Minimum**: 100 m
AA width in a steep valley lacking an obvious active floodplain	**Minimum extent**: No less than 2 m from the lateral extent boundary of the AA **Maximum extent**: No more than two times the active channel width on each side of the channel, including adjacent areas that probably account for bank stabilization and most of the direct allochthonous inputs of organic debris into the channel and active floodplain
AA width for wide, compound and braided channel forms	**Minimum extent**: No less than 2 m from the lateral extent boundary of the AA **Maximum extent**: 200 m

CHAPTER 3: DEFINITIONS AND RATIONALES FOR CRAM ATTRIBUTES AND METRICS

3.0 Summary

This chapter contains background information for each metric of CRAM as it relates to episodic streams. Each metric is supported by a definition, rationale, and an indication of the metric's sensitivity to seasonal variability in stream condition. Datasheets for episodic streams assessment are provided on the CRAM website (www.cramwetlands.org).

Attribute 1: Buffer and Landscape Context

CRAM includes two metrics to assess the Buffer and Landscape Context attribute for episodic channels: the Stream Corridor Continuity metric and the Buffer metric. An understanding of the larger landscape in which a particular watershed is located, the position of the AA in context of its watershed (i.e., high gradient headwater vs. low gradient depositional), and the qualities of the buffer surrounding the AA provide important insight on how geologic setting, basin type, valley context, and tributaries potentially influence the condition of an AA. Both of these metrics are best assessed with the aid of GIS, satellite imagery, or aerial photography, but must be verified in the field during the assessment.

Metric 1: Stream Corridor Continuity

Definition: Stream Corridor Continuity refers to the physical, ecological and hydrological continuity of the stream corridor in terms of its integrity and the habitat it provides to wildlife, either in the form of vegetation or intact soils. In general, good corridor continuity exists when a stream does not contain intervening land use types or obstructions that could inhibit the movements of wildlife along the stream corridor or discourage its use by wildlife. Any permanent physical alteration of the landscape surrounding the stream that would discourage wildlife activity or preclude the movements of wildlife between habitat types or patches are considered to be breaks in continuity.

This metric explicitly addresses the continuity of the AA with its stream corridor upstream and downstream in terms of the expected vegetation cover and "naturalness" of the channel. The "non-buffer land cover" types in Table 3.3 are considered as indications of land use conditions that break this continuity. While the condition of stream corridor upstream and downstream generally reflects the overall health of the riverine system, of special concern for this metric is the ability of wildlife to enter the stream corridor from outside of it at any place within 500 m of the AA, to move easily through adequate cover along the stream corridor through the AA from upstream and downstream, or to utilize the corridor as habitat. This metric does *not* consider the buffer condition of the AA, which is addressed in the Buffer Condition submetric.

Rationale. Ephemeral and intermittent episodic channels provide important wildlife movement corridors because they tend to contain continuous chains of vegetation that wildlife can utilize for cover and food (Levick et al. 2008). Most species of snakes and lizards preferentially utilize xeroriparian habitat because of the dense cover provided by the shrub, vine and groundcover layers of annual and perennial plants (Jones 1988; Rosen and Lowe 1996). Stream alluvium is often looser than the soils or colluvium of surrounding uplands, which enhances the potential for exploitation by specialized sand-burrowing species of wildlife. Channel bank material provides shelter for numerous species of wildlife, including reptiles, amphibians, birds, mammals and terrestrial invertebrates. Undercut banks are created through the action of water, wind, and gravity, independent of whether the stream contains water year-round. Crevices and bank slumps can be especially prevalent along ephemeral stream banks and provide desert wildlife refuge from predators as well as critical protection from extreme heat and aridity.

Identifying the location and presence of unnatural land uses and features along the channel corridor can also provide a means for detecting channel responses to human activities. The type, distribution, and distinctiveness of channel features and the magnitude of changes through time and space are potentially altered by channel adjustments resulting from human activities in the watershed. Grade control (e.g., road crossings), existing infrastructure (e.g., drainage 'improvements'), and other human influences can potentially induce unnatural channel adjustments. The spatial and temporal extent of the changes depends on both the sensitivity of the stream to change and the magnitude of the human-induced perturbation (Field and Lichvar 2007). Indications of change in expected channel form occurring in a particular location not only provide an understanding of how the stream system will evolve through time, but generally reflect a measure of the overall health of the system, with a loss of stream functions expected to accompany the anticipated channel adjustments.

Seasonality. This metric is not sensitive to seasonality.

Office and Field Indicators. The Stream Corridor Continuity metric is assessed as the total length of unfavorable land use (defined by the "non-buffer land cover" types in Table 3.3) and other anthropogenic features that break or disrupt the physical, ecological and/or hydrological continuity of the stream corridor over a distance of 500 m upstream and 500 m downstream of the AA (Table 3.1). "Non-buffer land covers" occupying less than 10 m of stream length are disregarded in this metric. Although the term "non-buffer land cover" is used in the context of this metric to indicate the presence of unnatural breaks in corridor continuity 500 m upstream and downstream of the AA, it is important to remember that the Stream Corridor Continuity metric does not assess the extent, size, or condition of the buffer surrounding the AA.

Scoring Instructions. Using satellite imagery or aerial photography, identify the presence of unfavorable land uses, anthropogenic features (e.g. road crossings), and existing infrastructure over a distance of 500 m upstream and 500 m downstream of the AA (Table 3.3), and then verify the results in the field while conducting the assessment. Use the steps outlined in Table 3.1 and Worksheet 3.1 to calculate the metric score. Printed screen shots of aerials, specifically near the AA, should be brought to the field. In addition, the results from any GIS-based landscape assessment (if completed) should be reviewed prior to scoring this metric (See Figure 3.1).

Table 3.1: Steps to assess Corridor Continuity

Step 1	Extend the average width of the AA 500 m upstream and downstream, regardless of the land cover types that are encountered (see Figure 3.1).
Step 2	Using aerial imagery, identify all the places where "non-buffer land covers" (see Table 3.3) at least 10 m long (measured parallel to the stream channel) interrupt the stream corridor within the average width of your AA on **either side of the channel** in the extended AA. Disregard interruptions of the stream corridor that are less than 10 m wide. Do not consider any open water areas as an interruption. It is possible for a non-buffer segment to cross one or both sides of a two-sided AA (see Figure 3.1). If a non-buffer segment crosses both sides it must be counted twice (one time for each side of the stream corridor).
Step 3	Estimate the length of each "non-buffer" segment identified in Step 2, and enter the estimates in the worksheet for this metric.

Special Notes:
** For compound, braided channel forms, use the established lateral extent boundary of the AA (where the transition from active floodplain to upland occurs) to define the limits of the stream corridor for the purposes of assessing this metric with aerial imagery.*

**Assume the stream corridor width is the same upstream and downstream as it is for the AA, unless a substantial change in width is obvious for a distance of at least 100 m. Width will relate to the expected dominant overstory vegetation present at the site.*

**To be a concern, a "non-buffer land cover" segment must break or sever the continuity of the channel corridor for a length of at least 10 meters on at least one side of the channel upstream or downstream from the AA.*

**If an obstruction such as a bridge crossing interrupts the stream corridor on both sides of the channel (and each interruption is at least 10 m wide), the width of the interruption is doubled to account for the width of the obstruction on both the right and left bank.*

Worksheet 3.1: Stream Corridor Continuity Metric for Riverine Systems

Lengths of Non-buffer Segments For Distance of 500 m Upstream of AA		Lengths of Non-buffer Segments For Distance of 500 m Downstream of AA	
Segment No.	Length (m)	Segment No.	Length (m)
1		1	
2		2	
3		3	
4		4	
5		5	
Upstream Total Length		Downstream Total Length	

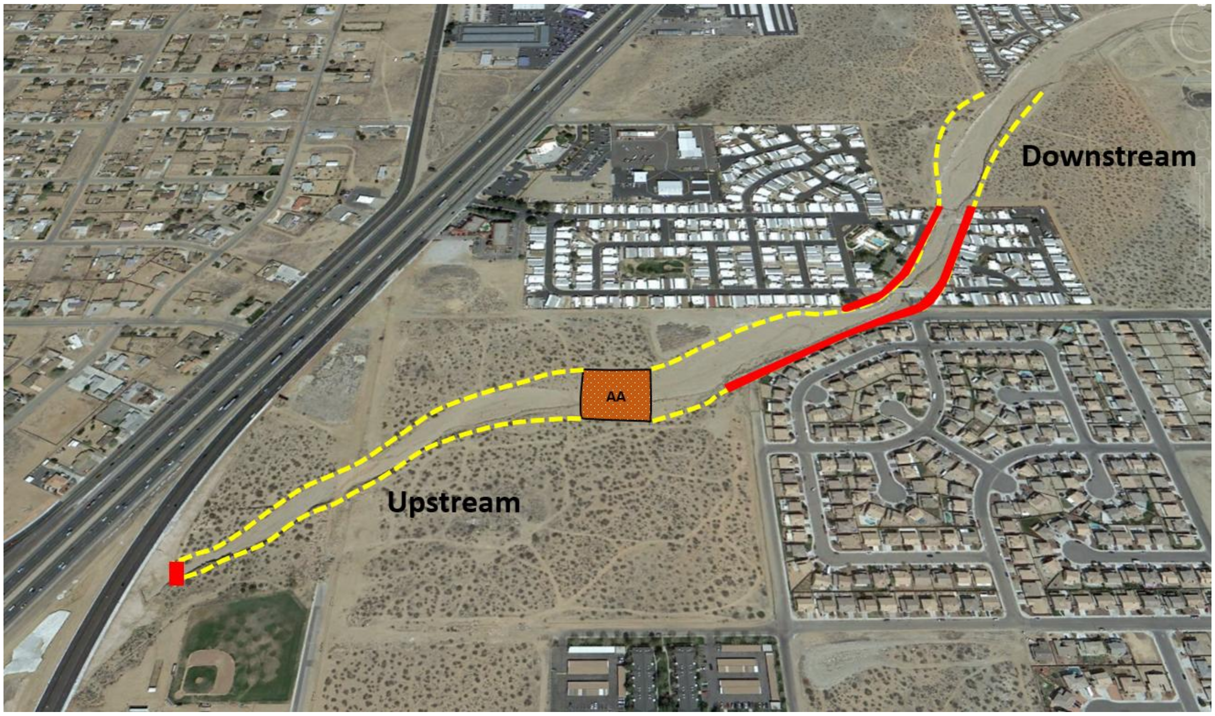


Figure 3.1: Diagram of method to assess the Stream Corridor Continuity metric. Using aerial imagery, the stream corridor is extended 500 m upstream and 500 m downstream of the AA (dashed yellow line extending from brown polygon). The red lines indicate the location of "non-buffer land covers" along the extended AA that break the stream corridor within this distance.

In Figure 3.1, a combination of housing developments and rip-rap walls lining the channel on the south and north side of the stream break the corridor continuity downstream, while a road crossing breaks the continuity upstream. The remainder of the yellow dashed line does not have any breaks. Note that for the purposes of scoring this metric for compound, braided systems, the stream corridor is assessed at the lateral boundary of the AA (where a transition from floodplain to upland occurs).

Table 3.2: Rating for Stream Corridor Continuity.

<table>
<tr><td>Rating</td><td>For Distance of 500 m Upstream of AA:</td><td>For Distance of 500 m Downstream of AA:</td></tr>
<tr><td>A</td><td>The combined total length of all non-buffer segments is less than 100 m.</td><td>The combined total length of all non-buffer segments is less than 100 m.</td></tr>
<tr><td rowspan="3">B</td><td>The combined total length of all non-buffer segments is less than 100 m.</td><td>The combined total length of all non-buffer segments is between 100 m and 200 m.</td></tr>
<tr><td colspan="2">OR</td></tr>
<tr><td>The combined total length of all non-buffer segments is between 100 m and 200 m.</td><td>The combined total length of all non-buffer segments is less than 100 m.</td></tr>
<tr><td>C</td><td>The combined total length of all non-buffer segments is between 100 m and 200 m.</td><td>The combined total length of all non-buffer segments is between 100 m and 200 m.</td></tr>
<tr><td rowspan="3">D</td><td>The combined total length of non-buffer segments is greater than 200 m.</td><td>any condition</td></tr>
<tr><td colspan="2">OR</td></tr>
<tr><td>any condition</td><td>The combined total length of non-buffer segments is greater than 200 m.</td></tr>
</table>

Metric 2: Buffer

Definition: For the purposes of CRAM, a buffer is a zone of transition between the immediate margins of the AA and its surrounding environment that is likely to help protect it from anthropogenic stress (see Figure 3.2). The buffer is the area adjoining the AA that is in a natural or semi-natural state and is currently not dedicated to anthropogenic uses that would severely detract from its ability to entrap contaminants, discourage forays into the AA by people and non-native predators, or otherwise protect the AA from stress and disturbance. Areas adjoining the AA that probably do not provide protection are not considered buffers.

To be considered as buffer, a suitable land cover type (refer to Table 3.3) must be at least 5 m wide starting at the edge of the AA extending perpendicular from the channel and extend along the perimeter of the AA (measured parallel to the channel) for at least 5 m. The maximum width of the buffer is 250 m. At distances beyond 250 m from the AA, the buffer becomes part of the landscape context of the AA. Three submetrics comprise the Buffer metric: A) percent AA with buffer, B) average buffer width, and C) buffer condition. These three submetrics are intended to address the multiple characteristics of the buffer that work in concert to influence the degree to which it performs its buffer functions.

Rationale. Buffers provide important benefits and services, including water quality improvement, stream bank stabilization, flood control, wildlife habitat, and groundwater recharge (USDA, 2006; Castelle et al., 1994; Wenger, 1999; Correll, 1996). Buffers can protect streams and wetlands by filtering pollutants, providing refuge for wildlife during times of high water levels, acting as barriers to disruptive incursions by people and pets, and moderating predation by ground-dwelling terrestrial predators. Buffers can also reduce the risk of invasion by non-native plants and animals, by either obstructing terrestrial corridors of invasion or by helping to maintain the integrity and the resistance of stream wetland communities to invasions. Because regulation and protection of streams historically did not extend to adjacent uplands, these areas, in some cases, have been converted to recreational, agricultural, or other human land uses and might no longer provide their critical buffering functions.

The extent, width, and condition of buffer areas are key features that enhance many functions essential to establishing and maintaining healthy streams and wetlands. Buffers vary in size based on factors such as adjacent land use, land ownership, topography, wetland/stream area, and ecological functions. Generally speaking, buffers that are wider, longer, and more densely vegetated with native herbaceous, shrub, and tree layers provide more benefits than buffers that are narrower, shorter, and sparsely vegetated. Buffers can be located along the edges of streams, as well as on adjacent hill slopes, and may include portions of both the riparian and upland zones. In vegetated areas adjacent to active channels and floodplains, buffers provide important hydrological and ecological functions, such as maintenance of lateral connectivity between the stream channel, adjacent floodplains and uplands, as well as up/down stream longitudinal connectivity

Submetric A: Percent of AA with Buffer

Definition: This submetric is based on the positive relationship between the extent of buffer present and the functions provided by aquatic areas. Areas with a higher percentage of buffer typically provide more habitat values, better water quality and other valuable functions.

B. Rationale. The ability of buffers to protect a stream increases with buffer extent along its perimeter. For some kinds of stress, such as predation by feral pets or disruption of plant communities by cattle, small breaks in buffers may be adequate to nullify the benefits of an existing buffer. However, for most stressors, small breaks in buffers caused by such features as trails and small, unpaved roadways probably do not significantly disrupt the buffer functions.

C. Seasonality. This metric is not sensitive to seasonality.

D. Office and Field Indicators. The assessment of the buffer perimeter of the AA should be conducted first in the office, using aerial imagery and land-use maps, as available. The office work should then be verified in the field. This submetric is scored by visually estimating from aerial imagery (with field verification) the percent of the AA that is surrounded by at least 5 meters of buffer land cover (Figure 3.2). The upstream and downstream edges of the AA are not included in this metric, only the edges parallel to the stream.

Figure 3.2: Percent of AA with Buffer for Episodic Riverine AAs. The blue line is the edge of the AA, the red line indicates where there is no buffer or less than 5 meters of buffer adjacent to the AA, while the green line indicates where buffer is present. The north side of the AA directly adjoins a non-buffer development, and on the southeast side of the AA there is a fence less than 5 meters from the AA. In this example 45% of the AA has buffer.

Table 3.3: Guidelines for identifying buffers and breaks in buffers.

*Please refer to the CRAM Photo Dictionary at www.cramwetlands.org for photos of each of the following examples.

Examples of Land Covers Included in Buffers* Buffers can cross these land covers	**Examples of Land Covers Excluded from Buffers** Buffers do not cross these land covers
• at-grade bike and foot trails with light traffic • horse trails • natural upland habitats • nature or wildland parks • range land and pastures • railroads (with infrequent use: 2 trains per day or less) • roads not hazardous to wildlife, such as seldom used rural roads, forestry roads or private roads • swales and ditches • vegetated levees	• commercial developments • fences that interfere with the movements of wildlife (i.e. food safety fences that prevent the movement of deer, rabbits frogs, etc.) • intensive agriculture (row crops, orchards and vineyards) • golf courses • paved roads (two lanes or larger) • active railroads (more than 2 trains per day) • lawns • parking lots • horse paddocks, feedlots, turkey ranches, etc. • residential areas • sound walls • sports fields • urbanized parks with active recreation • pedestrian/bike trails (with heavy traffic)

Worksheet 3.2: Percent of AA with Buffer

In the space provided below, make a quick sketch of the AA, or perform the assessment directly on the aerial imagery; indicate where buffer is present, estimate the percentage of the AA perimeter providing buffer functions, and record the estimate amount in the space provided.

Percent of AA with Buffer: ______________%

Table 3.4: Rating for Percent of AA with Buffer.

Rating	Alternative States
A	Buffer is 75 - 100% of AA perimeter.
B	Buffer is 50 – 74% of AA perimeter.
C	Buffer is 25 – 49% of AA perimeter.
D	Buffer is 0 – 24% of AA perimeter.

Submetric B: Average Buffer Width

Definition: CRAM uses a fixed buffer maximum width of 250 m and fixed minimum width of 5 m. Average buffer width is assessed as the average length of eight straight lines that are drawn at regular intervals perpendicular to the AA from its perimeter outward to the nearest non-buffer land cover (see Figure 3.3), or 250 m (the maximum buffer width), whichever is first encountered. CRAM assumes that the functions of the buffer do not increase significantly beyond 250 mm, thus the maximum buffer width is set at 250 m. The minimum length of buffer along the perimeter of the AA is also set at 5 m. Any area that is less than 5 m wide and 5 m long is considered too small to be a buffer. See Table 6 above for more guidance regarding the identification of buffers for CRAM AAs.

Rationale. A substantial body of research exists that correlates wetland buffer widths with stream function. Although there is technically not a single optimal width for a buffer, a wider buffer has a greater capacity to serve as habitat for wetland edge-dependent species, to reduce the inputs of non-point source contaminants, to control erosion, and to generally protect the wetland from human activities. Recommended widths for different stream functions range from as small as 3 m for bank stabilization and stream shading to 100 m or more for protection of certain types of wildlife habitat (Hawes and Smith 2005). CRAM errs on the conservative side by prescribing a maximum buffer width of 250 m to provide ample leeway for the buffer to accommodate multiple buffer functions.

Seasonality. This metric is not sensitive to seasonality.

Office and Field Indicators. This procedure can be performed initially in the office using the site imagery, and then revised based on the field visit. See Table 3.3 for more guidance regarding the identification of buffer and non-buffer land cover types for CRAM AAs. The procedure has five steps as presented in Table 3.5 below.

Table 3.5: Steps to estimate Buffer Width for riverine systems

Step 1	Identify areas in which open water is directly adjacent to the AA, with <5 m between the edge of the AA and the open water. **These areas are excluded from buffer calculations.**
Step 2	From the previous sub-metric, identify the areas that have buffer adjacent to the AA.
Step 3	For the area that has been identified as having buffer, draw straight lines 250 m in length perpendicular to the axis of the stream channel at regularly spaced intervals starting at the AA boundary. For one-sided riverine AAs, draw **four** lines; for AAs that include both sides of the stream draw **eight** lines (see Figure 6 below).
Step 4	Estimate the length of each of the lines as they extend away from the AA. Record these lengths on the Worksheet 3.2 in the accompanying document.
Step 5	Calculate the average buffer width. Record this width on the Worksheet 3.2.

Figure 3.3: Diagram of approach to estimate Average Buffer Width for Episodic Riverine AAs. Continuing with the example from above, draw 8 lines evenly distributed within the buffer (red lines indicate where no buffer is present). The lines end in this example when they encounter the road to the south.

Table 3.6: Rating for average buffer width.

Rating	Alternative States
A	Average buffer width is 190 – 250 m.
B	Average buffer width 130 – 189 m.
C	Average buffer width is 65 – 129 m.
D	Average buffer width is 0 – 64 m.

Submetric C: Buffer Condition

Definition: CRAM assesses the condition of a buffer using two parameters: 1) the overall condition of its substrate, and 2) the amount of human visitation[5]. Buffer conditions are assessed only for the portion of the channel border that has **already been identified as having at least 5 m of buffer** (i.e., as in Figure 3.4). Thus, evidence of direct impacts (parking lots, buildings, etc.) by people are excluded from this metric, because these features are not included as buffer land covers; instead these impacts are included in the Stressor Checklist.

Rationale. The condition or composition of the buffer, in addition to its width and extent, determines the overall capacity of the buffer to perform its critical functions. Maintenance of buffers in their natural condition has been identified as one of the most effective means of protecting multiple outstanding resource values, including water quality, hydrology, unique species and natural communities, and watershed ecosystem function (Hawes and Smith 2005). For episodic systems, and intact buffer also provides continuity of hillslope derived sediment sources and the active floodplain. This promotes maintenance of geomorphic functions along the stream reach.

Seasonality. This metric is not sensitive to seasonality.

Office and Field Indicators. Buffer condition must be assessed in the field. Absence of recent substrate disturbance and absence of trash or debris are assumed to indicate good buffer conditions. For the purpose of assessing substrate condition in the buffer, no evidence of problems more than 3 years old should be considered. Narratives for Buffer Condition ratings are provided in Table 3.7. If there is no buffer, assign a score of D.

[5] Given the naturally low cover of vegetation in many dryland landscapes, it is not included as one of the parameters of buffer quality for the episodic module. This is different than for the standard riverine module, which does consider vegetation.

Figure 3.4: Diagram of method to assess Buffer Condition for Riverine AAs. Continuing with the example from above, this submetric assesses the condition of the buffer only where it was found to be present in the two previous steps (the shaded areas shown).

Table 3.7: Rating for Buffer Condition

Rating	Alternative States
A	Buffer for AA has > 75% undisturbed substrate, and is apparently subject to little or no human visitation.
B	Buffer for AA is characterized by between 25% and 75% cover of mostly undisturbed substrate and is apparently subject to little or low impact human visitation.
C	Buffer for AA is characterized by substantial (>75%) cover of soil disturbance/compaction, and/or there is evidence of at least moderate intensity of human visitation.
D	Buffer for AA is characterized by barren ground and/or highly compacted or otherwise disturbed soils, and/or there is evidence of very intense human visitation, or there is no buffer present.

Attribute 2: Hydrology

Hydrology is the most important direct determinant of stream and wetland function (Mitch and Gosselink 1993). It includes the sources, quantities, and movements of water, plus the quantities, transport, and fates of water-borne materials, particularly sediment as bed load and suspended load. The physical structure of a stream is largely determined by the magnitude, duration, and intensity of water movement. Hydrology affects many other physical processes, including nutrient cycling, sediment entrapment, and pollution filtration, and constitutes a dynamic habitat template for associated plants and animals.

Metric 1: Water Source

Definition: Water sources directly affect the extent, duration, and frequency of the hydrological dynamics within an Assessment Area, and include direct inputs of water into the AA as well as any diversions of water from the AA. Diversions are considered as part of water source because they affect the ability of the AA to function as a source of water for other habitats while also directly affecting the hydrologic regime of the AA. Inputs of water affecting conditions during episodic high flow events are especially important because they strongly influence the structure and composition of stream and wetland plant and animal communities. The water source metric looks beyond the scale of the AA to the upstream watershed within about 2 km.

Rationale: Periodic inflows of water and sediment to streams are important to their ability to perform and maintain most of their intrinsic ecological, hydrological, and societal functions and services. The flow of water to a stream channel also affects its sedimentary processes, geo-chemistry, and basic physical structure. Although episodic streams do not flow continuously, they perform the same critical hydrologic functions as perennial streams: they move water, sediment, nutrients, and debris through the stream network and provide connectivity within the watershed (Levick et al. 2008).

Seasonality: Water source should be evaluated during the dry season.

Office and Field Indicators: The Water Source metric is concerned with *direct* sources of water and sediment to the AA and emphasizes the identification of the unnatural inputs or diversions of water and sediment that directly affect conditions of the AA. Direct, natural sources of water include precipitation, snow melt, groundwater, and seasonal stream flows. Examples of direct, unnatural inputs include storm drains that empty into the AA or into the watershed upstream, or irrigation runoff from agriculture. Landscape indicators of unnatural water inputs include adjacent intensive development, irrigated agriculture, and wastewater treatment discharge. Evidence of unnatural inputs can include the unexpected presence of base flow during dry periods, occurrence of emergent hydrophilic aquatic species (e.g., *Typha* sp., *Carex* sp.) in areas where they would not be expected, and nutrient enrichment based on the presence of blue-green algae.

Scoring Instructions: The assessment of this metric can be assessed initially in the office using site imagery, and then revised based on the field visit. To score this metric, use the aerial site imagery and any other information collected about the watershed to assess the water source to the AA within a 2 km area upstream (Figure 3.5). Topo maps or detailed watershed maps can be useful to determine the watershed area for a specific AA. The office work should initially focus on the immediate margin of the AA, and then expand to include the smallest watershed or storm drain system that directly contributes to the AA or its immediate environment, such as adjacent reach of the same riverine system.

Engineered hydrological controls such as weirs, flashboards, grade control structures, check dams, etc., can serve to demarcate the boundary of an AA, but they don't affect the sources of water supplied to the AA. These features may temporarily impound water, but they are not the source of the water. These features should <u>not</u> be considered in the assessment of this metric. In addition, large dams greater than 2 km upstream from the AA are not considered in this metric as these will have ubiquitous effects on broad geographic areas of the watershed of which the AA is a small part. However, the effects of land use, such as urbanization, on hydrologic dynamics in the immediate watershed containing the AA are considered in this metric because these can both increase the volume and intensity of runoff during and immediately after rainy season storm events and reduce infiltration that supports base flow discharges during the drier seasons later in the year. Although flows that are influenced by land use are most pronounced during the wet season, they can also affect conditions in the stream during the dry season.

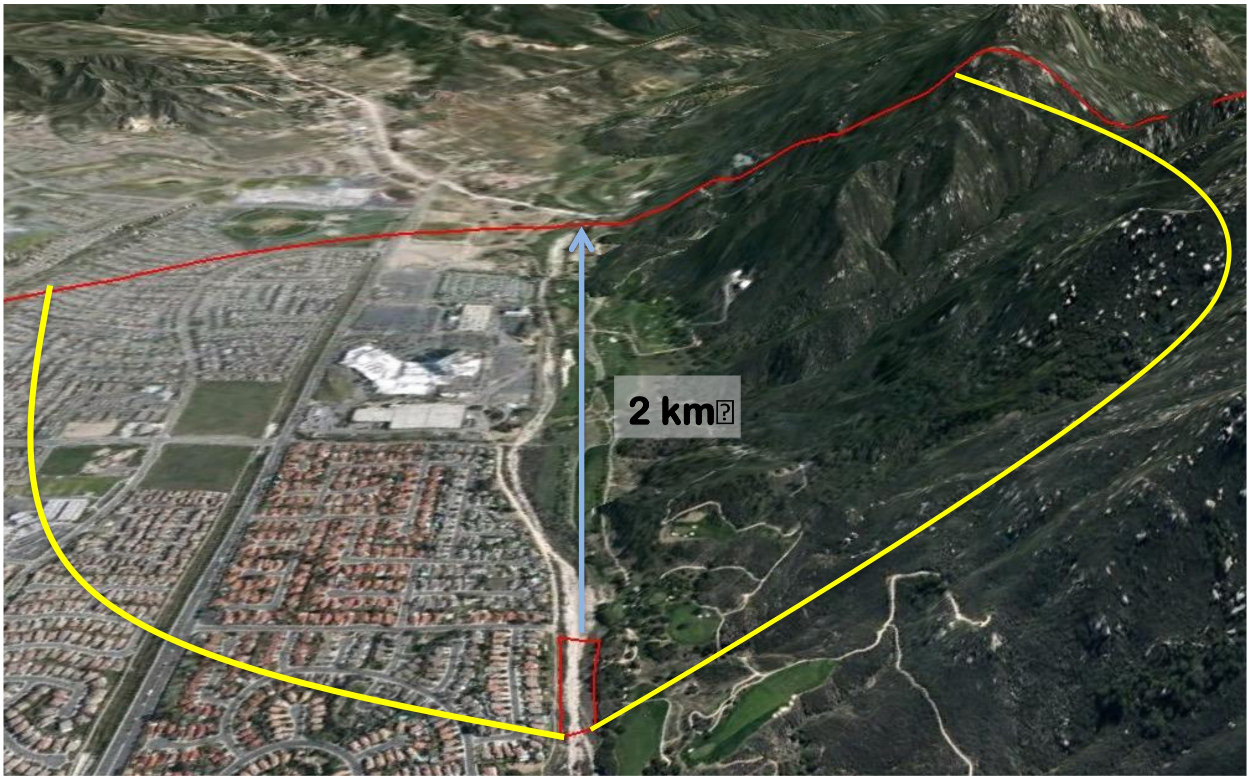


Figure 3.5: Diagram of approach to assess water sources affecting a CRAM AA showing an oblique view of the watershed. After identifying the portion of the aerial imagery that constitutes the contributing watershed region for the AA, assess the condition of the water source in a 2 km region (represented by yellow lines) upstream of the AA (represented with green box).

Special Considerations for Episodic Streams: Baseflow (or normal low flow) in a stream between rainfall events is provided either by groundwater discharge into the channel or unsaturated drainage from the soil moisture zone above the water table to the groundwater zone. The seasonal or continual presence of baseflow defines a stream as intermittent or perennial, respectively. Ephemeral episodic streams are unique in that they are located above the water table year-round and runoff from rainfall, not groundwater, is the primary source of water for stream flow (i.e., there is no baseflow component). Therefore, these streams flow for very short periods of time and are typically dry for most of the year.

Table 3.8: Rating for Water Source.

Rating	Alternative States
A	Freshwater and sediment sources **that affect the condition of the AA, by influencing flow characteristics or hydroperiod in the AA,** are precipitation, snow melt, groundwater, and/or natural runoff, or natural flow from an adjacent freshwater body, or the AA naturally lacks water in the dry season. There is **no indication** that conditions are substantially controlled by artificial water sources.
B	Freshwater and sediment sources that affect the condition of the AA are mostly natural, but also obviously include occasional or small effects of modified hydrology. Indications of such anthropogenic inputs include developed land or irrigated agricultural land that comprises **less than 20%** of the immediate drainage basin within about 2 km upstream of the AA, or that is characterized by the presence of a few small stormdrains or scattered homes with septic systems. No large point sources or dams control the overall hydrology of the AA.
C	Freshwater and sediment sources that affect the condition of the AA are primarily urban runoff, direct irrigation, pumped water, artificially-impounded water, water remaining after diversions, regulated releases of water through a dam, or other artificial hydrology. Indications of substantial artificial hydrology include developed or irrigated agricultural land that comprises **more than 20%** of the immediate drainage basin within about 2 km upstream of the AA, or the presence of major point source discharges that obviously control the hydrology of the AA. OR Freshwater sources that affect the condition of the AA are **substantially controlled** by known diversions of water or other withdrawals directly from the AA or from its drainage basin.
D	Natural, freshwater and sediment sources that affect the condition of the AA have **been eliminated** based on the impoundment of all possible wet season inflows and diversion of all dry-season inflows.

Special Notes:

*To assist in determining a 2 km watershed area upstream from the AA, StreamStats (available at http://water.usgs.gov/osw/streamstats or www.ecoatlas.org) can be used to delineate an upstream catchment from a user-defined pour point.

Metric 2: Sediment Transport

Definition: Sediment transport is the dominant process in episodic systems. Sediment behavior in response to water flow determines the channel form of an episodic stream and affects the potential for that channel to provide other ecosystem services.

Rationale: The pattern and balance of inflows and outflows of water and sediment is a major determinant of stream and wetland functions. The patterns of import, storage, and export of sediment and other water-borne materials can be altered by human actions or other perturbations to the system. In most systems, plant recruitment and maintenance are dependent on water and sediment flow. The interactions of sediment, geology, and topography are major determinants of the distribution and abundance of native plants and animals found within a system. **Special Considerations for Episodic Channels**

The *effectiveness* (i.e., the relative capacity of flows to alter or "rework" a channel) of large, episodic floods in dryland climates for change is substantial. Channel features are frequently reworked. Episodic systems exhibit a rapid response to rainfall and tend to be shaped by high-magnitude flow events. The transitory nature of morphological features in these climates is further enhanced by generally less cohesive soils and poorly vegetated banks. These processes create a fabric of highly-varied, transient channel forms.

Certain types or reaches of stream systems in arid regions are particularly sensitive to human land use and are, therefore, where the most dramatic changes of channel form and function are likely to occur. Compound channels can experience rapid widening during large floods. Activities such as land clearing that remove bank-stabilizing vegetation are likely to increase the sensitivity of the channel to dramatic widening. Additionally, urbanization is likely to produce a widening response during much smaller, more-frequent rainfall events, because of the increased peak discharge produced in such watersheds. Subtle changes in sediment to water ratios of floodwaters resulting from human activities will yield responses that will first manifest at headcuts. Headcuts

represent the point on discontinuous ephemeral streams where the most abrupt slope break is found and a threshold between erosion and deposition is present (Pelletier and DeLong 2004). Alluvial fans are prone to avulsions, reflecting the inherent instabilities in channel position for streams at the junction of steep, confined bedrock mountains and flat, open alluvial valleys. Increases in sediment supply caused by human activities will tend to increase the frequency of avulsions and the likelihood of changing the form and function of the existing channel. Hydrological modifications to episodic channels can concentrate flows, increase flood intensities, and increase sediment transport and erosion, although the effects of such modifications may not manifest for years or even decades until the next flash flood (Stein et al. 2011).

Natural sediment dynamics at high-quality reference sites vary depending on their position in the watershed. This metric measures the deviation from natural conditions and therefore must take into account the unique nature of episodic streams in different sections of their watersheds. In general, streams in the upper watershed are often first order channels with steep gradients and extremely flashy flows. These streams are characterized by erosional processes and, under natural conditions, will perform much of the work of extracting sediment and moving it downstream. Anthropogenic alterations can disrupt these processes and cause aggradation in reaches that would otherwise be erosional. In other cases, streams in the upper watershed can respond to stress with incision, often leading to accelerated erosion and disconnecting streams from their past floodplains. Streams in the lower watershed are characterized by depositional processes. These streams are lower gradient, often braided, compound channels where continual aggradation and dynamic sediment processes are the norm. These systems can respond to impacts by widening and deepening the primary low-flow channel, up to the point where all secondary channels are subsumed into one wide main channel. This process is often termed *planform simplification*.

Seasonality: Hydroperiod should be evaluated during the dry season.

Office and Field Indicators: This metric evaluates deviation from "least-disturbed" or reference condition. To evaluate departure from the reference condition, the practitioner looks at indicators of alterations to sediment processes. These indicators are different for different parts of the watershed. To score this metric, visually survey the AA for field indicators of an altered sediment transport, then assign a rating score using the alternative state descriptions in Table 3.10.

Table 3.9a: Field Indicators of Altered Sediment Transport for upper watershed (typically single thread) streams.

Condition	Field Indicators (check all existing conditions)
Indicators of Natural Processes in Upper Watershed Reaches	☐ Soil texture and grain size differences between the low-flow channel and floodplain ☐ The channel contains embedded woody debris of the size and amount consistent with what is naturally available in the riparian area. ☐ Channel bars consist of well-sorted bed material (smaller grain size on the top and downstream end of the bar, larger grain size along the margins and upstream end of the bar).
Indicators of Altered Sediment Transport in Upper Watershed Reaches	☐ The channel is characterized by steep or deeply undercut banks ☐ An obvious historical floodplain has recently been abandoned. ☐ The channel bed appears scoured to bedrock or dense clay. ☐ Recently active flow pathways appear to have coalesced into one channel ☐ The channel has one or more knickpoints indicating headward erosion of the bed. ☐ Soil texture and grain size differences between the low-flow channel and floodplain are not evident or distinctive.

Table 3.9b: Field Indicators of Altered Sediment Transport for Lower watershed (typically multi-thread) streams.

Condition	Field Indicators (check all existing conditions)
Indicators of Natural Processes in Lower Watershed Reaches	☐ Soil texture and grain size differences between the low-flow channel, floodplain, and upper terrace surfaces are distinct. ☐ Braided compound channels ☐ High density of channels (3 or more primary flow channels within AA) ☐ The channel contains embedded woody debris of the size and amount consistent with what is naturally available in the riparian area. ☐ Channel bars consist of well-sorted bed material (smaller grain size on the top and downstream end of the bar, larger grain size along the margins and upstream end of the bar).
Indicators of Altered Sediment Transport in Lower Watershed Reaches	☐ Planform simplification (previously braided channels appear to have coalesced into fewer channels or into one single channel) ☐ Low channel density (2 or less primary flow channels per AA) ☐ Soil texture and grain size differences between the low-flow channel and floodplain are not evident or distinctive. ☐ An obvious historical floodplain has recently been abandoned, as indicated by the age structure of its riparian vegetation. ☐ The channel bed appears scoured to bedrock or dense clay. ☐ Recently-active flow pathways appear to have coalesced into one channel (i.e. a previously braided system is no longer braided). ☐ The channel has one or more knickpoints indicating headward erosion of the bed.

Table 3.10: Rating table for Sediment Transport

Rating	Alternative State (based on the field indicators listed in the worksheet above)
A	Most of the channel through the AA is characterized by natural sediment processes, with little evidence of altered sediment transport. Based on the indicators of condition, typical sediment transport processes are occurring.
B	Most of the channel through the AA is characterized by some evidence of altered sediment transport, none of which is severe. Based on the indicators of condition, typical sediment transport processes are occurring, but the reach is shows a trend toward excess transport or deposition due to moderate disequilibrium conditions.
C	There is evidence of severely altered sediment transport of most of the channel through the AA or the channel bed (and/or banks?) is artificially hardened through less than half of the AA. Based on the indicators of condition, typical sediment transport processes are severely altered.
D	The channel bed and banks are concrete or otherwise artificially hardened through most of AA.

Metric 3: Hydrologic Connectivity

Definition: Hydrologic connectivity refers to the maintenance of natural hydraulic connections and sediment transfer routes. Nadeau and Rains (2007) defined it as "the hydrologically mediated transfer of mass, momentum, energy, or organisms within or between compartments of the hydrologic cycle." In dryland streams, this hydrologic connection may only occur episodically during flood pulses, yet it still provides a substantial amount of the mass, momentum, energy and organisms delivered to the watercourse.

This metric essentially describes the maintenance of natural hydraulic connections of surface (and subsurface) flows and sediment movement between the hydrogeomorphic units (i.e., channels, floodplain, and upland terraces) of a stream system. This includes the ability of flows in channels to exceed the channel banks and flood adjacent areas. In addition, sediment transfer routes from adjacent hill slopes to the stream are not interrupted. Generally, the degree of hillslope coupling determines the short-term response of the stream to events that occur on the hillslope, and the importance of the valley flat as a buffer to sediment transfer.

Rationale: Hydrologic connectivity between a channel and its adjacent areas promotes the exchange of water, sediment, nutrients, and organic carbon. Inputs of organic carbon are of great importance to ecosystem function. Litter and allochthonous input from adjacent uplands provides energy that subsidizes the aquatic food web (Roth et al. 1966). Connection between the channel and its floodplain promotes the import and export of water-borne materials, including nutrients. Hydrologic connections with shallow aquifers and hyporheic zones influence most stream and wetland functions. Plant diversity tends to be positively correlated with connectivity between wetlands and natural uplands, and negatively correlated with increasing inter-wetland distances. Amphibian diversity is directly correlated with connectivity between streams and their floodplains (Amoros and Bornette 2002). Linkages between aquatic and terrestrial habitats allow wetland-dependent species to move between habitats to complete life cycle requirements.

Hydrologic connectivity also implies coupling of the streams with adjacent hillslope areas. This coupling provides important sediment supply to the channel and floodplain, supporting natural sediment transport processes. Church (1983) developed a classification of landscape units (decoupled, partially coupled, and coupled) for hillslopes and channels. Decoupled hillslopes are identified when sediment or debris, mobilized by a landslide, is interrupted by a valley flat. Partially coupled hillslopes are identified when only a portion of a landslide deposit can be stored on a valley flat. Coupled hillslopes are identified when sediment or debris directly enters the stream channel.

Seasonality: This metric is not sensitive to seasonality.

Field Indicators: This metric essentially measures the degree to which the lateral movement of floodwaters or sediment delivery to the floodplain is artificially obstructed or restricted by anthropogenic features, such as engineered (armored) levees, unnaturally steep banks, or other human-induced perturbations. This metric is assessed based on the potential for anthropogenic features to restrict or impede water, sediment, and debris mobilized on the hillslope from entering the stream. This metric is scored as the percent of the AA's lateral boundary (as determined at the time the AA was established) that is artificially obstructed or restricted by unnatural features such as levees, road grades, or other human-induced perturbations. Use Table 3.11 to rate the hydrologic connectivity. Fully coupled hillslopes will tend to be associated with high gradient, confined, single-thread channels located in erosional (headwaters) areas of a watershed.

For channels that are determined to be naturally decoupled with their hillslopes (i.e., sediment or debris mobilized by a landslide is interrupted by a valley flat), this metric is assessed based on the potential for anthropogenic features to restrict or impede water in a channels from exceeding the banks and flooding adjacent areas. In these cases, this metric is scored as the percent of the AA's lateral boundary (i.e., the limit of the active floodplain as determined at the time the AA was established) that is artificially obstructed or restricted by unnatural features such as levees, road grades, or other human-induced perturbations. Decoupled hillslopes will tend to be low-gradient, unconfined, compound channels located in depositional areas of a watershed.

Table 3.11 Rating of Hydrologic Connectivity for Episodic Channels

Rating	Alternative States
A	Floodwaters from the low-flow channel have mostly unrestricted access to the floodplain and adjacent transition zones. Less than 10% of the boundary of the stream reach that contains the AA is artificially hardened or obstructed by features such as rip-rap, concrete banks, levees, or other anthropogenic structures.
B	The lateral movement of floodwaters from the low-flow channel to the floodplain and adjacent transition zones is restricted (e.g., artificially hardened or obstructed by features such as rip-rap, concrete banks or levees) for 10-50% of the AA. These restrictions also impede sediment delivery from hillslope areas to the floodplain. Restrictions may be intermittent along margins of the stream that contains the AA, or they may occur only along one bank.
C	The lateral movement of floodwaters from the low-flow channel to the floodplain and adjacent transition zones is restricted (as described above) for 50-90% of the AA. Restrictions may be intermittent as described above.
D	The lateral movement of floodwaters from the low-flow channel to the floodplain and adjacent transition zones (and sediment movement from hillslopes to the floodplain) is severely restricted, as evidenced by the presence of artificially hardened structures for more than 90% of the AA.

Attribute 3: Physical Structure

Physical structure is defined as the spatial organization of living and non-living surfaces that provide habitat for biota (Maddock 1999). For example, the distribution and abundance of organisms in riverine systems are largely controlled by physical processes and the resulting physical characteristics of habitats (e.g., Frissell *et al.* 1986). Metrics of the Physical Structure attribute in CRAM therefore focus on physical conditions that are indicative of the capacity of a stream or wetland to support characteristic flora and fauna.

Metric 1: Structural Patch Richness

Definition: Patch richness is the number of different obvious types of physical surfaces or features that may provide habitat for aquatic, wetland, riparian, or terrestrial species. This metric is different from topographic complexity in that it addresses the number of different patch types, whereas topographic complexity evaluates the spatial arrangement and interspersion of the types.

Rationale: The richness of physical, structural surfaces and features in a stream reflects the diversity of physical processes, such as energy dissipation, water storage, and groundwater exchange, which strongly affect the potential ecological complexity of the system. The basic assumption is that natural, physical complexity promotes natural, ecological complexity, which in turn generally increases ecological functions, beneficial uses, and the overall condition.

Seasonality: This metric should be assessed in the dry season so that the stream bed is accessible, conditions are safe, and physical features are readily observable.

Field Indicators: From an ecosystem perspective, episodic flow and sediment movement produce transient channel forms that expand/contract laterally/longitudinally. This creates diverse and spatially variable physical habitats (Vyverberg 2010). Visible patches of physical structure typically occur at multiple points along the hydrologic and moisture gradient, but these features may be more diffuse and tend to be distributed randomly within the various floodplain units of dryland episodic streams (Curtis and Lichvar 2010). Examples of these specialized, physical habitats include the local retention of residual water on smaller secondary channels, the concentration of stream bed sediment that is often looser than the soils of surrounding uplands that can be exploited by specialized sand-burrowing species of wildlife, or the small caves and crevices in eroded dry wash banks that provide refuge from predators and from extreme heat and dryness (Levick et al. 2008). Water-cuts can form along the inside margins of channels in a stair-step configuration to indicate fluctuating water levels, stream energy, and differential erodibility in the substrate (Vyverberg and Brady 2014). Ripple-dune sequences are often found in low-gradient, hydraulically-smooth streams where the bed consists of fine sand or silt (Gordon et al. 2004). When present, these bed form characteristics can be observed in a dry stream bed by closely examining the local profile of the channel. Depositional features are often absent or subtle in very small, low-order channels due to low sediment supply and/or steeper stream gradients.

Scoring Instructions: This metric is scored using the Structural Patch Type Worksheet 3.4 for episodic channels, with the rating based on the percent of total expected patch types for these systems. Prior to fieldwork, the imagery of the AA should be reviewed to survey the major physical features or patch types potentially present. The office work must be field-checked using the Structural Patch Worksheet 3.4, by noting the presence of each of the patch types expected, and calculating the percentage of expected patch types actually found in the AA. Table 3.12 contains narratives for rating the Structural Patch Richness Metric for episodic channels.

Patch Type Definitions for Episodic Channels:

Abundant wrack or organic debris in channel or on floodplain. Wrack is an accumulation of natural floating debris along the high water line. Organic debris includes loose fallen leaves, twigs, and seeds not yet transported by stream processes. This patch type does not include standing dead vegetation. The organic debris must be free of its original growth position. Senesced plant material that is still attached to the parent plant does not count as a patch type (for example, an annual grass thatch from the previous growing season)

Animal mounds and burrows. Burrows are holes excavated in banks and surfaces, and can be common in undisturbed surfaces, especially in soft substrate. Many vertebrates make mounds or holes as a consequence of their foraging, denning, predation, or other behaviors. The resulting soil disturbance (bioturbation) helps to redistribute soil nutrients and influence plant species composition and abundance. To be considered a patch type there should be evidence that a population of burrowing animals has occupied the Assessment Area. A single burrow or mound does not constitute a patch. Animal mounds can include those made by invertebrates (ants, termites, etc.)

Bank slumps or undercut banks in channels. A bank slump is a portion of a bank that has broken free from the rest of the bank but has not eroded away. Undercuts are areas along the bank that have been excavated by flowing water. These areas can provide habitat for invertebrates and vertebrates. For the bank slump to be counted as a patch type the slump (i.e. fallen material) must still be present *in situ*.

Biotic or algal soil crusts. Biological crusts are soil communities of mosses, lichens, alga, fungi or cyanobacteria. They are typically found on fluvially-undisturbed surfaces and appear as soft, puffy, dark-colored growths (resembling popcorn). Biological soil crusts play a significant role in the process of formation, stability and fertility of soil, prevention of soil erosion caused by water or wind, augmentation of vascular plant colonization, and stabilization of sand dunes, especially in desert ecosystems.

Cobbles and boulders. Cobbles and boulders are rocks of different size categories. The intermediate axis of cobble ranges from about 6 cm to about 25 cm. A boulder is any rock having an intermediate axis greater than 25 cm. Exposed cobbles and boulders provide roosting habitat for birds and shelter for amphibians. They contribute to patterns of shade and light and air movement near the ground surface that affect local soil moisture gradients, deposition of seeds and debris, and overall substrate complexity.

Debris jams. A debris jam is an accumulation of driftwood and other flotage across a channel that partially or completely obstructs surface water flow and sediment transport, causing a change in the course of flow.

Coarse woody debris. A single piece of woody material, greater than 10cm in diameter and greater than 1 m long.

Pannes or pools on floodplain. A panne is a shallow topographic basin lacking vegetation. Pannes fill with water at least seasonally due to overland flow to form pools. In episodic systems these can be highly transient, but still provide temporary habitat

Plant hummocks/sediment mounds/coppice dunes. Hummocks are mounds along the banks and floodplains of fluvial systems created by the collection of sediment and biotic material around plants. Sediment mounds are depositional features that lack plant cover and are formed from repeated flood flows depositing sediment on the floodplain. Coppice dunes are formed by the accumulation of wind-blown sand around and beneath vegetation. Hummocks, sediment mounds, and coppice dunes are typically less than 1m high.

Point bars and in-channel bars. Bars are sedimentary features within fluvial channels. They are patches of transient bedload sediment that can form along the inside of meander bends or in the middle of straight channel reaches. They sometimes support vegetation. They are convex in profile and their surface material varies in size from finer on top to larger along their lower margins. They can consist of any mixture of silt, sand, gravel, cobble, and boulders.

Pools or depressions in channels. Pools are areas along fluvial channels that are much deeper than the average depths of their channels and that tend to retain water longer than other areas of the channel during periods of low or no surface flow.

Sand ripples. Ripples are sedimentary features formed in fine-grained sediments from the interaction a moving fluid (air or water) with a mobile substrate (mostly sand-size sediment). As current velocity (or wind) increases over the fine-grained substrata, the streambed is molded into a predictable succession of ripple like bed forms (often associated with dunes). Ripples are relatively small sedimentary features and are generally associated with low gradient (<1%), meandering, higher order channels within unconfined valley segments. A well-developed floodplain typically is present.

Secondary channels on floodplain. Channels confine riverine flow and consist of a bed and its opposing banks. The systems of diverging and converging channels that characterize braided and anastomosing fluvial systems usually consist of a primary (low-flow) channel that contains flowing water the most frequently and one or more secondary channels of varying sizes. Secondary channels (also known as overflow or high-flow channels) are topographically higher channels that carry water only during higher flows. Tributary channels that are part of the same drainage network and only convey flow between the floodplain and the primary channel are also regarded as secondary channels

Swales on floodplain. Swales are broad, elongated, sometimes vegetated, shallow depressions that can sometimes help to convey flood flows to and from floodplains to channels. However, they lack obvious banks, regularly spaced deeps and shallows, or other characteristics of channels. Swales can entrap water after flood flows recede. They can act as localized recharge zones and they can sometimes receive emergent groundwater. Swales that yield channel flow are important sources of water, sediment, nutrients, and other materials during runoff events.

Variegated, convoluted, or crenulated channel margins. As viewed from above, a stream channel can be mostly straight, broadly curving (i.e., arcuate), or variegated (e.g., meandering). In plain view, a variegated channel margin resembles a meandering pathway. Variegated channel margins provide greater contact between water and land. This can be viewed on a scale smaller than the whole AA (2-3 m). Large boulders, exposed tree roots, and fallen vegetation along the margins can contribute to variegation.

Vegetated islands (exposed at high-water stage). An island is an elevated body of land that is periodically surrounded by and isolated from the upland landscape by water. The unique habitats they provide are defined and generally formed by the water that surrounds shapes, and interacts with them. Islands differ from hummocks and other mounds by being large enough to support trees and large shrubs.

Water-cuts along channels. Water cuts are fluvial features that form along the inside margins of channels in a stair-step configuration to indicate fluctuating water levels, stream energy, and differential erodibility in substrates.

Table 3.12: Rating of Structural Patch Richness

Based on Worksheet 3.4.

Rating	Non-confined Episodic Riverine	Confined Episodic Riverine
A	≥ 12	≥ 8
B	9 – 11	6 – 7
C	6 – 8	4 – 5
D	≤ 5	≤ 3

Metric 2: Topographic Complexity

Definition: Topographic complexity refers to the micro- and macro-topographic relief and variety of elevations within a stream due to physical and abiotic features and elevation gradients that affect moisture gradients or that influence the path of flowing water.

Rationale: Topographic complexity promotes variable hydroperiods and concomitant moisture gradients that, in turn, promote ecological complexity by increasing the spatial and temporal variability in energy dissipation, surface water storage, groundwater recharge, particulate matter detention, cycling of elements and compounds, and habitat dynamics. In dryland ephemeral channels, topographic gradients can afford habitats that can be occupied by both ephemeral and perennial vegetation, although this vegetation can be sparse on surfaces that are rarely inundated by flood waters (Batanouny 1973). Areas that are aerated due to flow across complex surfaces may promote volatilization of compounds or re-suspension and export of water-borne material.

Compared to perennial streams, streamflow-driven changes in sediment storage in dryland channel reaches do not generate significant long-term topography in channel bed forms (Singer and

Michaelides 2014). Streamflow in dryland ephemeral channels is short lived, episodic, and spatially discontinuous because it is generated by brief rainstorms that are typically much smaller in area than the drainage basin; reach-wide floods are infrequent (Wolman and Gerson 1978). This spatially and temporally discontinuous channel flow transports and sorts sediment along the bed intermittently and irregularly. The spatially-heterogeneous streamflow interacts with fluctuating width and hillslope-supplied sediment grain-size distributions to sort sediment along the channel into relatively coarse and fine sections that persist between floods (Yuill et al. 2010). Sediment may accumulate into incipient bar forms during some flows, but this topography may be subsequently eroded during different spatial distributions of flow. The cumulative effect of these processes produces a relatively simple topography, manifested in straight longitudinal profiles (Powell et al., 2012; Vogel, 1989), symmetrical cross sections (Leopold et al. 1966), and poorly-developed bar forms (Hassan, 2005).

Seasonality: This metric is not sensitive to seasonality.

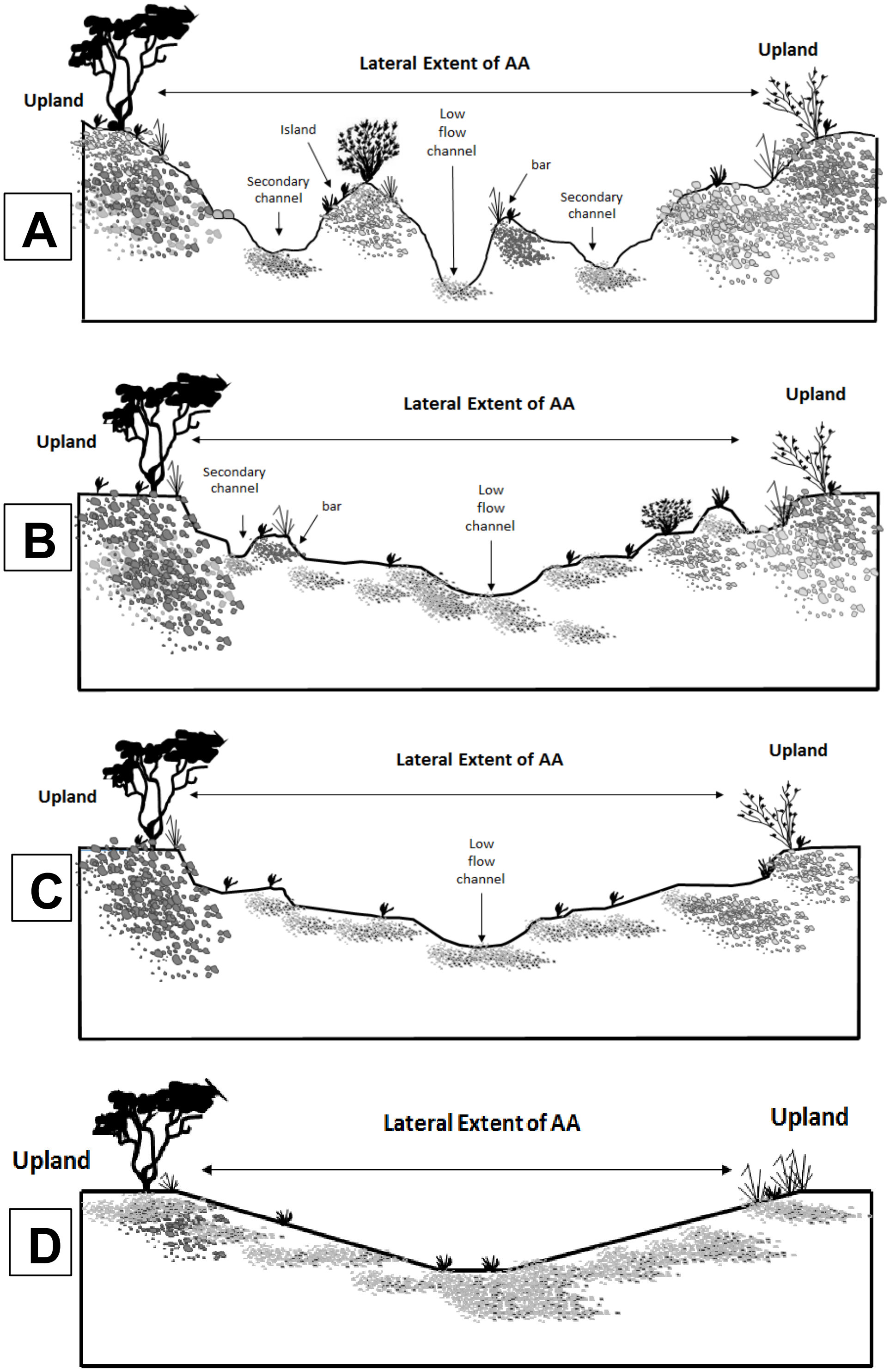
Field Indicators: Macro-topographic relief refers to the presence of major breaks in slope along stream margins while micro-topography is the surface relief created by the presence of physical patch types such as boulders or cobbles, partially buried woody debris, undercut banks, etc. Examples of topographic features used to score this metric include in-channel depressions, soil pits, sediment mounds, bars, debris jams, cobbles, boulders, slump blocks, tree-fall holes, plant hummocks, and sediment mounds. In dryland ephemeral channels, topographic features may be more diffuse, tend to distributed randomly within the various floodplain units, and are not associated with any specific flow-event levels as in perennial streams (Curtis and Lichvar 2010). Major breaks in slope may be accompanied by distinct shifts in late-stage vegetation and dominant sediment size above the break in slope.

Scoring Instructions: This metric is scored for episodic streams using the alternative states described in Table 3.13. At three locations along the AA, sketch the cross-section profile of the AA lateral extent (by convention, the cross-section is depicted looking downstream). Draw the cross-section from the AA boundary down to its deepest area then back out to the other AA boundary. Try to capture the macro-topography (e.g., breaks in slope) and intervening micro-topographic relief. Label the location of the low-flow channel and flood plain units. Based on these sketches and the profiles in Figure 3.6, choose a description in Table 3.16 that best describes the overall topographic complexity of the AA.

Worksheet 3.5: AA Topographic Complexity

Profile 1
Profile 2
Profile 3

Figure 3.6: Scale-independent schematic profiles of Topographic Complexity. Each profile A-D represents a characteristic cross-section through an AA. Use in conjunction with Table 3.16 to score this metric.



Special Notes:
CRAM defines a bench as a "relatively level topographic surface that exists at or above the channel-forming discharge of the channel (e.g. a floodplain or terrace). It is connected and parallel to the bank. It does not include surfaces within the active channel composed of the same size material being transported as bedload (e.g. bars). The surface should be wide enough to provide measurable hydraulic effects for the stream in which it exists (generally at least 0.5 m for very small streams, but the "effective" size of the bench will be wider in larger systems) and should be present for a significant distance along the AA reach. As stream water level rises and each surface is inundated, the bench allows for increased wetted perimeter length without a major increase in water depth. Water flowing over these surfaces will have different hydraulic dynamics compared to water flowing in the active channel, typically having reduced velocity and shear stress. The effect of each bench is an increase in the range of complex velocity dynamics in the stream cross-section and an increase in the range of moisture gradients and thus habitat complexity".

While the presence of bankfull benches is usually associated with perennial and seasonally intermittent streams that experiences periodic flows and subsequent transport and deposition of sediment during moderate, i.e. bankfull events (Erskine and Livingstone 1999), benching can form at the boundary of the low-flow channel and at the edge of the AA in dryland ephemeral channels. However, in dryland ephemeral channels, these features tend to be created by the removal of previously aggraded sediment, during eventswhich may have recurred over decadal time scales (Lichvar and McColley 2008).

Table 3.13: Rating of Topographic Complexity for Episodic Channels

Rating	**Alternative States** (based on Worksheet 3.5 and diagrams in Figure 3.6 above)
A	AA, as viewed along a typical cross-section, has a distinct low-flow channel, and if located in the lower watershed, is nested within a braided network of numerous secondary channels. Surficial features such as islands, bars, boulders or cobbles, partially buried woody debris, undercut banks, secondary channels, debris jams, etc. contribute to abundant micro-topographic relief as illustrated in profile A.
B	AA, as viewed along a typical cross-section, has a distinct low-flow channel. The low-flow channel is still the dominant channel feature and, if located in the lower watershed, secondary channels are present, but less numerous than as described for profile A. Surficial features are less distinct and varieties of surficial features are less numerous. The AA resembles profile B.
C	AA, as viewed along a typical cross-section, has a very poorly defined low-flow channel and, if located in the lower watershed, secondary channels are poorly developed or completely absent. Surficial features are generally absent (i.e., the channel surface is homogenous) and micro-topographic relief is limited. The AA resembles profile C.
D	AA, as viewed along a typical cross-section, is best characterized by a uniform planar bed channel of homogenous soil texture with no micro-topographic complexity (includes concrete channels). The low-flow channel (if present) is the only flow feature in evidence. The AA resembles profile D.

Attribute 4: Biotic Structure

Biotic Structure assesses plant communities that contributes to a stream's material structure and architecture. Living vegetation and coarse detritus are examples of biotic structure. CRAM assesses Biotic Structure based on three metrics: 1) Plant Community, 2) Horizontal Interspersion, and) Vertical Biotic Structure.

Metric 1: Plant Community Metric

Definition: The Plant Community Metric is composed of three submetrics: Number of Plant Layers, Number of Co-dominant Plant Species, and Percent Invasion. For the purposes of CRAM, a "plant" is defined as an individual of any vascular macrophyte species of tree, shrub, herb, forb, or fern, whether emergent, prostrate, decumbent, or erect, including non-native (exotic) plant species. Mosses and algae are <u>not</u> considered in the plant community metric.

Rationale: Vegetation strongly influences the quantity, quality, and spatial distribution of water and sediment within streams. Vascular plants associated with streams entrap suspended sediment, decrease the velocity of water flowing through the channel, and function as habitat for stream associated wildlife. Plant detritus is a main source of essential nutrients.

Considerations for Dryland Episodic Streams

Although species-rich riparian plant communities and classic wetland zones may be absent, the vegetation associated with ephemeral episodic streams still provides important structural elements of food, cover, nesting and breeding habitat, and movement-migration corridors for wildlife that are not as available in adjacent uplands (Levick et al. 2008). Functional services of these communities include moderating soil and air temperatures, stabilizing channel banks and interfluves, seed banking and trapping of silt and fine sediment favorable to the establishment of diverse floral and faunal species, and dissipating stream energy which aids in flood control (Howe *et al.* 2008). In arid environments, stream-associated vegetation tends to contribute a disproportionately high biological diversity to the environment relative to their total area (when compared with more mesic streams and watersheds), with most of this diversity comprised of herbaceous species (Bagstad et al. 2005; Warren and Anderson 1985).

Limited water availability and disturbance by floods are the key drivers that structure the plant communities of streams characterized by episodic flow regimes. In arid regions, these communities have naturally adapted to low moisture, high temperatures, and high evaporation rates (Nilsen et al., 1984; Friedman and Lee, 2002). In general, episodic systems tend to have lower plant species cover overall because of frequent disturbances as a response to storm discharge events, lack of developed soils, and well-drained, coarse soil textures that lack soil moisture. These factors markedly affect plant germination rates and vegetative responses. At a regional scale, elevation, followed closely by local moisture availability, are the most important factors that tend to distinguish the plant communities among dryland episodic streams (Szaro 1990, Bendix 1994, Minckley and Brown 1994), (Johnson et al. 1984). At the local scale, stream gradient, valley width or cross-sectional area, geomorphic setting (e.g., canyon, arroyo, shallow wash), soil characteristics, and fire history can all influence plant community patterns (Szaro 1990; Bendix 1994; Minckley and Brown 1994; Evans 2001).

The structure and composition of the vegetation of dryland streams is also related to patterns of flow and the size of the stream. Intermittent (seasonal) episodic stream channels may have a water table close to the surface that allows for a greater diversity of vegetation, while ephemeral episodic streams do not have a water table as close to the surface, therefore limiting the abundance of vegetation (Katz 2001). Because of the general inaccessibility of water to plants in ephemeral channels, these systems tend to be characterized by the predominance of xeroriparian vegetation. Larger streams tend to have more scattered trees and shrubs, such as willows (*Salix* spp.), cottonwoods (*Populus* spp.), and mesquites (*Prosopis* spp.). Phreatophytic species are able to survive because their root systems have the ability to make contact with deeper groundwater that is lacking immediately outside the slopes of the channel (Rundel and Gibson 1996). However, not all dry wash species are phreatophytes; many other species, such as grasses and shallow rooted shrubs, rely solely on groundwater discharge or precipitation (Scott et al. 2000).

Seasonality: Generally, this suite of metrics is best assessed during the latter third of the growing season, when all plant layers have developed to their full extent. However, in more xeric regions, annual herbaceous vegetation will be present in the early part of the growing season.

Field Indicators: The Plant Community Metric is assessed in terms of the similarity between the dominant species composition of the plant community and what is expected based on CRAM verification and validation studies, regional botanical surveys, and historical resources. This metric requires the ability to recognize the most common and abundant plants species present at a site. When a CRAM field team lacks the necessary botanical expertise, voucher specimens will need to be collected using standard plant presses and site documentation. This can greatly increase the time required to complete a CRAM assessment.

A thorough reconnaissance of an AA is required to assess its condition using the plant community submetrics. The assessment for each submetric is guided by a set of Plant Community Worksheets (Worksheet 3.6). The Plant Community metric is calculated based on these worksheets. (A dominant species represents ≥10% relative cover.)

Plant Community Submetric A: Number of Plant Layers Present

The first submetric of the Plant Community Metric is the Number of Plant Layers Present in the AA. Plant layers play a significant role in the assessment of the biotic structure attribute of CRAM. For the purposes of CRAM, a plant "layer" is a stratum of vegetation indicated by a discreet canopy at a specified height class. Layers are distinguished from one another by the differences in average maximum heights of their associated co-dominant plant species. To be counted in CRAM, a layer must cover at least 5% of *the portion of the AA that is suitable for the layer*. Although the "short," "medium," and "tall" layers might be found throughout all portions of the AA, they are not expected to occur in areas of exposed bedrock, active point bars, low-flow channels, etc. The "very tall" layer is usually expected to occur along the upper terrace margin of episodic streams. Species may occupy different layers in different regions of California, and the identification of dominant species must be based on an identification of the actual species present in the AA.

It is essential that the layers be identified by the actual heights of plant species in the AA (i.e., the approximate maximum heights at the time of the assessment), regardless of the growth potential of the species. For example, a young desert willow sapling between 0.5 m and 1.5 m tall would belong to the "medium" layer, even though in the future the same individual tree might belong to the "Very Tall" layer. Some species might belong to multiple plant layers. For example, thickets of mulefat (*Baccharis salicifolia*) of different age classes might collectively have representation in all four height layers. The height of any individual vining plant, such as desert wild grape *(Vitis girdiana),* is determined by its current maximum growth, but these species may have individuals present in more than one plant layer. In the case of parasitic plants, such as desert mistletoe (*Phoradendron californicum*), its associated layer is determined by the height at which they are growing in their host tree or shrub, not the true height of the plant itself.

Layer definitions:

Very Short Vegetation. This layer includes all vegetation that is less than 20 cm. in height. It includes small emergent vegetation and plants. It can include young forms of species that grow taller. Vegetation that is naturally short in its mature stage includes very short annual grasses and species such as *Cryptantha sp., Astrida,* Chamaesyce *sp.* (sandmat).

Short Vegetation. This layer ranges from 20 cm to 50 cm in height. It includes small plants that are naturally short in their mature stage. It can also include young forms of species that grow taller.

Medium Vegetation. This layer ranges from 50 cm to 1.5 m in height. Examples of plants in this layer include ephedras (*Ephedra sp.).*

Tall Vegetation. This layer ranges from 1.5 m to 2.5 m in height. It includes the tallest emergent vegetation, larger shrubs, and small trees. Examples include *Baccharis salicifolia* (mulefat), *Salix exigua* (narrow-leaf willow).

Very Tall Vegetation. This layer includes trees and shrubs (or any plants) that are greater than 2.5 m in height. Examples include *Alnus* spp. (Alder), *Salix gooddingii* (black willow), *Chilopsis linearis* (desert willow), *Populus balsamifera* (Cottonwood), and *Platanus racemosa* (Sycamore). Prosopis sp. (mesquite), and (Acacia sp. (acacia). Non-woody species that may occur in this layer may include *Arundo* and *Typha* spp.

Scoring Instructions: Using the established plant layer heights for episodic CRAM, determine the layers that comprise at least 5% absolute cover of the portion of the AA that is suitable for supporting that plant layer. Assign scores as listed in Table 3.15.

Figure 3.7: Flow Chart to Determine Plant Community Submetrics

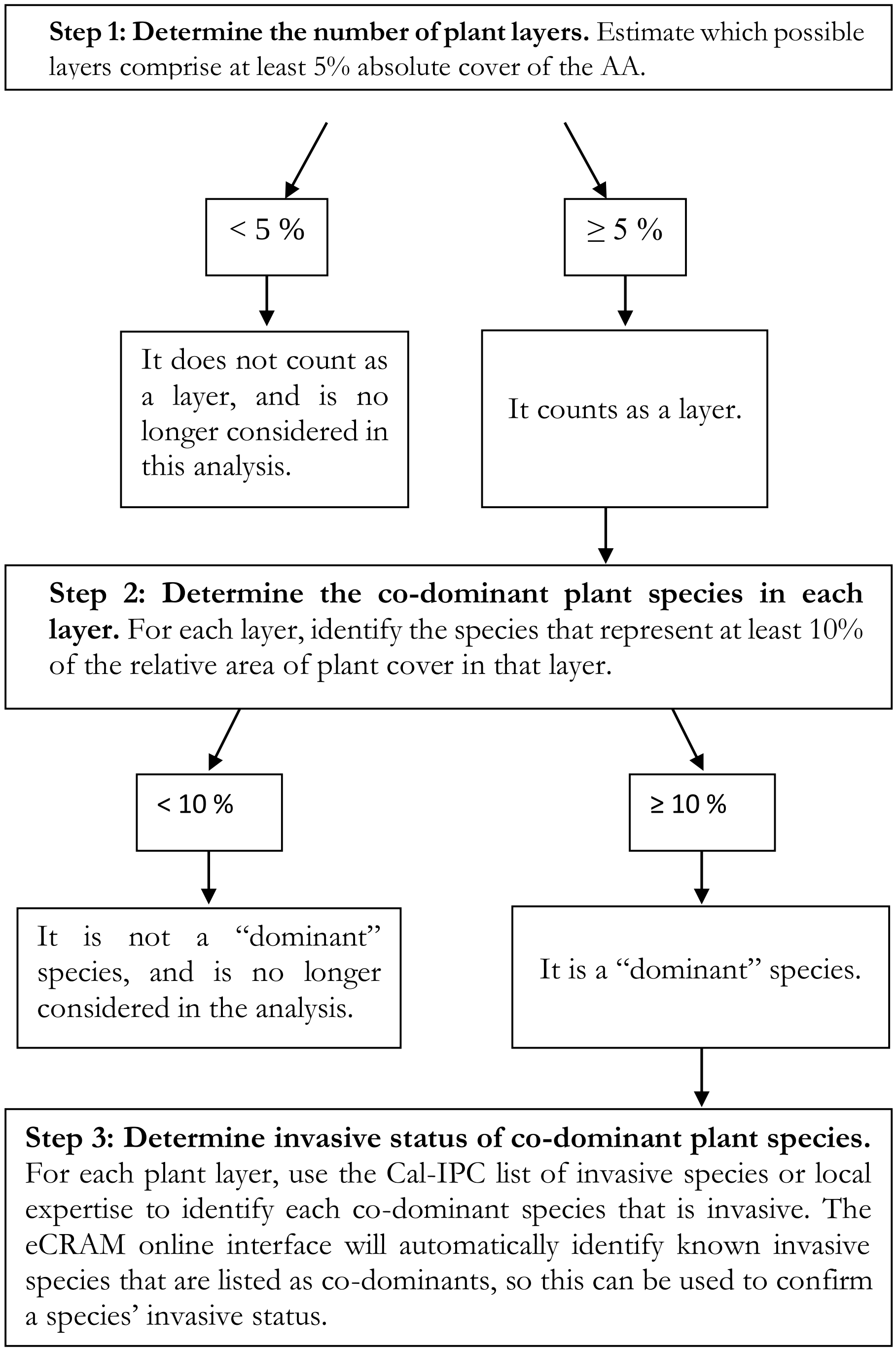


Table 3.14: Plant layer heights for all episodic riverine systems.

Channel Type	Plant Layers				
	Very Short	**Short**	**Medium**	**Tall**	**Very Tall**
Confined and Non-confined Episodic Riverine	<0.2 m	0.2-0.5 m	0.5 – 1.5 m	1.5 – 2.5 m	> 2.5 m

Important Scoring Notes*:*

** Standing (upright) dead or senescent vegetation from the previous growing season can be used in addition to live vegetation to assess the number of plant layers present. However, the lengths of prostrate stems or shoots are disregarded. In other words, fallen vegetation should not be artificially "held up" in growth position to determine the plant layer to which it belongs. The number of plant layers must be based on the character of the vegetation as it manifests itself in the field at the time of the assessment.*

**If the AA supports less than 5% plant cover and/or no plant layers are present (e.g. some concrete channels), automatically assign a score of "D" to the plant community metric.*

Plant Community Submetric B: Number of Co-dominant Species

For each plant layer identified in the AA, every species represented by living or dead vegetation that comprises at least 10% relative cover within the layer is considered to be dominant in that layer, and should be recorded in the appropriate part of the Plant Community Metric Worksheet.

Scoring Instructions: List the names of all co-dominant plant species in each layer. Use this list to determine the total number of co-dominant species for all the layers that are represented in the AA. When identifying the total number of dominant species in an AA, count each species only once; do not count a species multiple times if it is found in more than one layer. Dead or senescent vegetation is disregarded in the scoring of this metric; only count living vegetation as a co-dominant. When identifying the total number of dominant species in an AA, count each species only once; do not count a species multiple times if it is found in more than one layer. Assign scores as listed in Table 3.15.

Special Notes:

** Refer to the CRAM Photo Dictionary at www.cramwetlands.org for a list of plant identification resources.*
** If there are unknown plant species that are considered dominant in the AA, take a representative photograph and a voucher specimen sample for later identification. Make sure to photograph and collect any flowers, fruit, or seeds that are present to help in the identification process.*

**It is important to secure permission from the landowner or managing agency prior to collecting any plant samples.*

Plant Community Submetric C: Percent Invasion

For the purposes of this sub-metric, “invasive” plants are defined as species that are non-native to the wildland ecosystems of California and have the potential to spread into these ecosystems. Invasive, non-native species can displace native species, hybridize with native species, alter biological communities, and alter ecosystem processes”. They are considered to collectively constitute one of the gravest threats to the biodiversity of California’s native ecosystems (Warner et al. 2003).

Non-native plant species are those that have been introduced to native wildland ecosystems after European contact as a direct or indirect result of human activity (Warner et al. 2003). Many of these non-native species are now “naturalized” in California, and may be widespread in occurrence. Naturalized plant species (if not considered invasive) can provide valuable buffering services for stream and wetland areas. However, the presence of invasive species can contribute to a loss of stream or wetland functions or services, such as by excluding all other plant species from an area.

CRAM uses the California Invasive Plant Council (Cal-IPC, a non-regulatory advisory group) inventory to determine the invasive status of plants. This inventory categorizes non-native invasive plants based on an assessment of the ecological impacts of each plant and represents the best available knowledge of invasive plant experts in California.. The inventory cannot address, and is not intended to address, the range of geographic variation in California, nor the inherently regional nature of invasive species impacts. While it notes where each plant is invasive, only the cumulative statewide impacts of the species have been considered in the evaluation. The impact of these plants in specific geographic regions or habitats within California may be greater or lesser than their statewide rating indicates. Therefore, while CRAM recommends use of the Cal-IPC inventory, it permits its *augmentation by regional experts.* In other words, is a plant species in the buffer is recognized to regionally or locally pose an invasive threat, but is not included in the Cal-IPC list, it can still be considered invasive for the purposes of scoring this metric. If this is done, it should be noted in the Comments section of the Basic Information sheet.

Scoring Instructions. The number of invasive co-dominant species for all plant layers combined is assessed as a percentage of the total number of co-dominants;i.e., the number of co-dominant invasive species in the AA divided by the number of all co-dominant species in the AA. Scoring is as shown in Table 3.15.

Worksheet 3.6: Plant Community Metric: Co-dominant species richness for riverine wetlands

A dominant species represents ≥10% relative cover.

Very Short (<0.2 m)	**Invasive?**	**Short (0.2-0.5 m)**	**Invasive?**
Medium (0.5-1.5 m)	**Invasive?**	**Tall (1.5 -3.0 m)**	**Invasive?**
Very Tall (>3.0 m)		**Total number of co-dominant species for all layers combined (enter here and use in Table 3.15)**	
		Percent Invasion *Round to the nearest integer* (enter here and use in Table 3.15)	

Special Notes:

* *Combine the counts of co-dominant species from all layers to identify the total co-dominant species count. Each plant species is only counted once when calculating the Number of Co-dominant Species and Percent Invasion submetric scores, regardless of the numbers of layers in which it occurs.*

Table 3.15: Ratings for submetrics of Plant Community Metric.

Rating	Number of Plant Layers Present	Number of Co-dominant Species	Percent Invasion
Non-confined Episodic Riverine Wetlands			
A	> or = to 4	≥ 7	0 – 15%
B	3	5 – 6	16 – 30%
C	2	3 – 4	31 – 45%
D	0-1	0 – 2	46 – 100%
Confined Episodic Riverine Wetlands			
A	> or = to 4	≥ 6	0 – 15%
B	3	4 – 5	16 – 30%
C	2	2 – 3	31 – 45%
D	0-1	0 – 1	46 – 100%

Metric 2: Horizontal Interspersion

Definition: Horizontal interspersion is essentially a measure the plant community organization of the AA in a two-dimensional plan view. Plant zones can be comprised of a single species or obvious multi-species associations that remain relatively constant in makeup throughout the AA and are arrayed along gradients of elevation, moisture, or other environmental factors.

Rationale: The existence of multiple plant zones indicates a well-developed plant community that is reflective of fluvial, sedimentary and bio-chemical processes. The amount of interspersion among these plant zones is indicative of the spatial heterogeneity of these processes. Richer native communities of plants and animals tend to be associated with greater zonation and more interspersion of the plant zones. Among episodic streams, the structure and composition of the vegetation is related to both the size of the stream and patterns of flow, although most of the diversity is comprised of herbaceous species (Bagstad et al. 2005).

Considerations for Dryland Episodic Streams

The vegetation associated with streams in semi-arid and arid regions is typically spatially heterogeneous. Often, distinct vegetation patch types can be readily distinguished on the basis of species composition, species dominance, or vegetation structure (Stromberg et al. 1996; Shafroth et al. 2002). Zonation typically occurs between fluvial surfaces with spatial distributions generally reflecting an adaptation to flooding. Vegetation may also establish on sand bars, and subsequently initiate the formation of various depositional features such as small current shadows, bars, benches, ridges, or islands (Tooth and Nanson, 2000). Zones of hydromesic rhizomatous or stoloniferous ruderals (e.g., *Paspalum distichum*, *Cynodon dacytlon*) on the floodplain can indicate areas of regular flooding, since clonally reproducing plants may readily recolonize floodplain sites following flood disturbance (Stromberg 1993) and may be better adapted to persist in the shade of young, dense cottonwood stands (Friedman et al. 1996). A shift to zones of more xeric ruderals (e.g., *Bouteloua aristidoides, Sisymbrium irio*) can indicate limits of the regularly flooded zone. Xeroriparian vegetation patterns likely reflect surface flow patterns quite strongly because of the inaccessibility of the water table at most xeroriparian sites (Lichvar and Wakeley 2004). However, even a slight increase in stream soil moisture can increase vegetation biomass, height, and stem density, making it distinct from adjacent uplands areas (Lichvar and Wakeley 2004).

Many plant species, including some community dominants, can occur in both the stream and adjacent upland habitats (Bloss and Brotherson 1979, Warren and Anderson 1985, Leitner 1987, McArthur and Sanderson 1992). For example, upland plants such as *Ambrosia* spp. *(*bursage*)* and *Larrea tridentata* (creosote bush) can occur on lower, middle, and upper parts of banks, but less-xeric species, such as *Chilopsis linearis* (desert willow) and *Acacia greggii* (catclaw acacia) are only found on the lower parts of banks of larger, wetter washes, with upland species on the upper banks. (Hupp and Osterkamp 1996). As a response to channel disturbance from episodic events, it is common to find upland species that have been washed down into the stream channel during storm events.

Vegetation structure also shifts as watershed size and flood intensity increase, leading to zonation in recruitment patterns and age classes between fluvial surfaces. Along braided or sand-bed ephemeral streams with intense flood scour, species composition tends to shift towards pioneer species, such as *Populus* and *Salix* spp. Initial seedling establishment of pioneer riparian trees typically occurs on "fluvial disturbance patches," which are moist and free of competing vegetation and plant litter (Auble et al. 1994). Pioneer species can be more abundant in the active channel bed than on the stream banks or floodplain (Bloss and Brotherson, 1979). Where rivers are constrained in narrow valleys, flood deposition and scouring are the most important processes creating recruitment sites for pioneer species (Scott et al. 1996). Woody plants may also become established on low-elevation gravel bars, islands, and debris fans in canyons during multiyear droughts (Cooper et al. 2003).

Scoring: This metric is scored by assessing the number of distinct plant "zones" and the amount of edge (interspersion) between these zones. It is important to base the assessment of this metric on a combination of aerial image interpretation and field reconnaissance. An "A" condition means BOTH more zones AND a greater degree of interspersion, and the departure from the "A" condition is proportional to BOTH the reduction in the numbers of zones AND their interspersion. A zone may include groups of species of multiple height categories; however, this metric is not solely based on the layers established in the Plant Community Submetric A.

Plant zones may be discontinuous and they can vary in number within a stream. Dryland examples may include a non-contiguous fringe of *Chilopsis linearis* (desert willow) and *Acacia greggii* (catclaw acacia) with a sparse understory of grasses and herbaceous vegetation along the lower banks of larger desert washes, patchy zones of upland plants such as *Ambrosia* dumosa *(*bursage*)* and *Larrea tridentata* (creosote bush) on elevated land within the floodplain a zone, or a zone of low growing vegetation, such as Chamaesyce spp. (sandmat), that is mostly associated with a sandy, low-flow channel. In all cases, the plant zones are defined by a relatively unvarying combination of growth form and species composition. Think of each plant zone as a vegetation complex of relatively non-varying composition extending from the top of the tallest vegetation present at the site down to ground level.

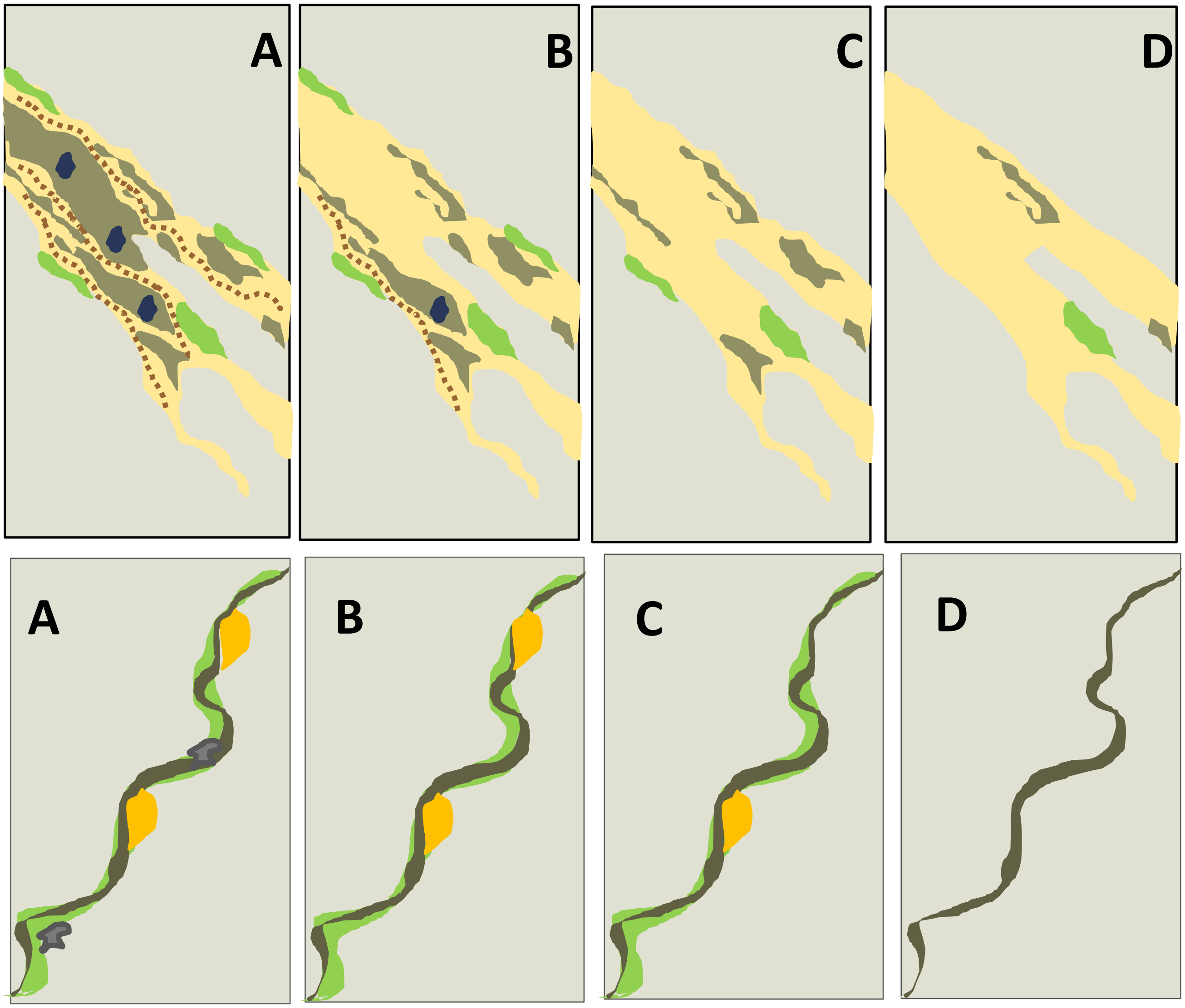
Seasonality: This metric is not sensitive to seasonality, however assessment of the site in the early part of the growing season will increase the likelihood that herbaceous annuals are present and identifiable.

Worksheet 3.7: Horizontal Interspersion

Use the spaces below to make a quick sketch of the AA in plain view. It is helpful to first label the major hydrogeomorphic units present, and then identify and major plant zones (this should take no longer than 10 minutes). Label the zones and record them on the right. Based on the sketch, choose a single profile from Figure 12 that best represents the AA overall.

	Assigned zones: ***1)*** ***2)*** ***3)*** ***4)***

Figure 3.8: Schematic diagrams illustrating varying degrees of interspersion of plant zones for compound episodic channels. Each plant zone must comprise at least 5% of the AA. The pink area represents the boundary of an AA, other colors represents a unique plant zone or feature, the light green background represents upland areas that are part of the buffer and not included in the AA. Dotted lines represent the locations of distinct low-flow and secondary channels within the AA.



Special Note:

**When assessing this metric, it is helpful to first map the hydrogeomorphic units (low-flow channel, active floodplain with secondary channels, and upper terrace and then assign names of plant species or associations of species associated with these zones. Include the presence of terrace islands and other major geomorphic features as well as open water and bare ground to the colored patches in the figure above.*

Table 3.16: Rating of Horizontal Interspersion for Riverine AAs.

Rating	**Alternative States** (based on Worksheet 3.7 drawings and Figure 3.8)
A	AA has a high degree of plan-view interspersion.
B	AA has a moderate degree of plan-view interspersion.
C	AA has a low degree of plan-view interspersion.
D	AA has minimal plan-view interspersion.

Metric 3: Vertical Biotic Structure

Definition: The vertical component of biotic structure assesses the degree of overlap among plant layers. The same plant layers used to assess the Plant Community Composition Metrics are used to assess Vertical Biotic Structure. To be counted in CRAM, a layer must cover at least 5% of the portion of the AA that is suitable for the layer.

Rationale: The overall ecological diversity of a stream tends to correlate with the vertical complexity of the wetland's vegetation. For many types of streams and wetlands in California, overlapping layers of vegetation contribute to vertical gradients in light and temperature that result in greater species diversity of macroinvertebrates, amphibians, and birds. In riparian areas, the species richness of birds and small mammals tends to increase with the density and number of well-developed, overlapping plant layers. Many species of birds that nest near the ground or water surface in wetlands commonly require a cover of vegetation at their nest sites. Multiple layers of vegetation also enhance hydrological functions, including rainfall interception, reduced evaporation from soils, and enhanced filtration of floodwaters. Although structurally complex riparian canopies with intricately interdigitated plant layers are mostly lacking in dryland ephemeral streams, the vegetation associated with these systems still provides important structural elements of cover, nesting and breeding habitat, and movement-migration corridors for wildlife that are not as available in the adjacent uplands (Levick et al. 2008).

Seasonality: This metric should be assessed late in the growing season.

Field Indicators: Vertical structure must be assessed in the field. The vertical component of biotic structure is the spatial extent and vertical overlap of the overall number of plant layers.

Plant layers for this metric are determined in the same way as defined in the Plant Community Metric. Only the maximum height of any vegetation should be used to determine the plant layer to which it belongs. For example, although a tall tree might span the entire range of all the layers, it can only represent one layer, based on its overall height. Standing (upright) dead or senescent vegetation from the previous growing season can be used in addition to live vegetation to assess the number of plant layers present. However, the lengths of prostrate stems or shoots are disregarded. In other words, fallen plants are not lifted into a vertical position as evidence of plant height.

Scoring Instructions: Using the same plant layers identified from the Plant Community Composition metric, use the following worksheet and figures to assess the Vertical Biotic Structure metric.

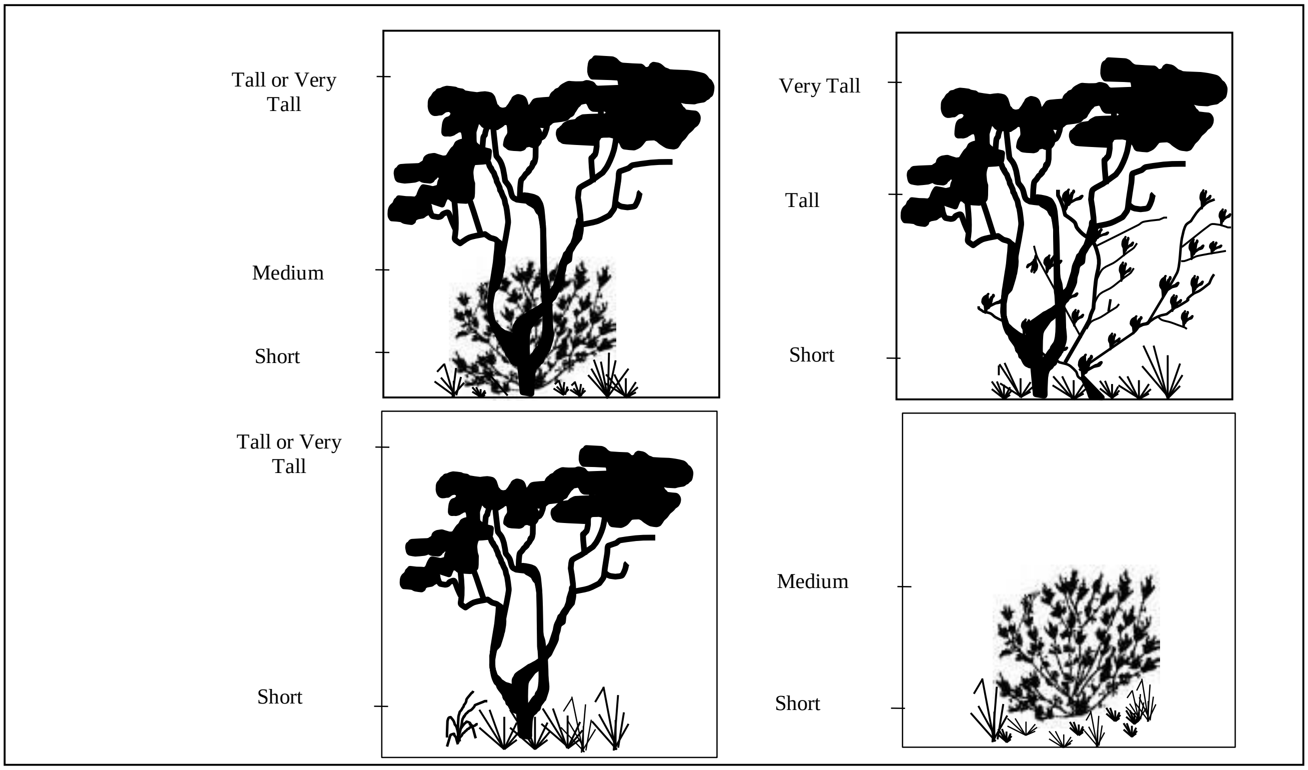


Figure 3.9: Stylized diagrams of example scenarios that illustrate the concept of vertical overlap of plant layers for Episodic CRAM Riverine AAs. Many additional combinations of layer overlap exist.

Special Notes:

**The "A" condition can be obtained only when >25% of the vegetated area of the AA has two layers that overlap*

**It is important to accurately estimate the extent of overlap, particularly when the AA contains only two layers. The aerial imagery can help in determining the extent of overlap between layers.*

**This metric assesses the vegetated area of the AA, and disregards areas that are unvegetated*

Table 3.17: Rating of Vertical Biotic Structure for Episodic Riverine AAs

Rating	Alternative States
A	More than 25% of the vegetated area of the AA supports overlap of 2 or more plant layers.
B	10-25% of the vegetated AA supports overlap of 2 or more plant layers.
C	Less than 10% of the vegetated AA supports overlap of 2 or more plant layers.
D	AA is sparsely vegetated overall.

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APPENDIX A: GUIDELINES TO COMPLETE THE STRESSOR CHECKLISTS

Definition: A stressor, as defined for the purposes of the CRAM, is an anthropogenic perturbation within a stream, wetland or their environmental setting that is likely to negatively impact the condition and function of the CRAM Assessment Area (AA). A disturbance is a natural phenomenon that affects the AA.

There are four underlying assumptions of the Stressor Checklist: (1) deviation from the best achievable condition can be explained by a single stressor or multiple stressors acting on the wetland; (2) increasing the number of stressors acting on the wetland causes a decline in its condition (there is no assumption as to whether this decline is additive (linear), multiplicative, or is best represented by some other non-linear mode); (3) increasing either the intensity or the proximity of the stressor results in a greater decline in condition; and (4) continuous or chronic stress increases the decline in condition.

Major episodic disturbances, such as very large storms, landslides, earthquakes, or anthropogenic stressor events, such as sudden reservoir drawdown and toxic spills, can significantly alter the form, structure, and even the location of a riverine system. Over time, the system will adjust both physically and ecologically to such episodic perturbations. Repeated use of CRAM at perturbed sites will help document their responses. The completed stressor checklist will also provide insight into the source of lower scores following episodic events.

The process to identify stressors is the same for all stream types. For each CRAM attribute, a variety of possible stressors are listed. Their presence and likelihood of significantly affecting the AA are recorded in the Stressor Checklist Worksheet. For the Hydrology, Physical Structure, and Biotic Structure attributes, the focus is on stressors operating within the AA or within 50 m of the AA. For the Buffer and Landscape Context attribute, the focus is on stressors operating within 500 m of the AA. More distant stressors that have obvious, direct, controlling influences on the AA can also be noted.

Worksheet A.1: Wetland disturbances and conversions

<table>
<tr><td>Has a major disturbance or episodic event occurred at this site?</td><td>Yes</td><td colspan="2">No</td><td></td><td></td></tr>
<tr><td>If yes, was it a flood, fire, landslide, or other?</td><td>flood</td><td colspan="2">fire</td><td>landslide</td><td>other</td></tr>
<tr><td>If yes, then how severe is the disturbance?</td><td>likely to affect site next 5 or more years</td><td colspan="2">likely to affect site next 3-5 years</td><td colspan="2">likely to affect site next 1-2 years</td></tr>
<tr><td>Has this site been converted from another type? If yes, then what was the previous type?</td><td>Perennial non-confined riverine</td><td colspan="2">Perennial confined riverine</td><td colspan="2">Episodic ephemeral</td></tr>
</table>

Worksheet A.2: Stressor Checklist

HYDROLOGY ATTRIBUTE (WITHIN 50 M OF AA)	Present	Significant negative effect on AA
Point Source (PS) discharges (POTW, other non-stormwater discharge)		
Non-point Source (Non-PS) discharges (urban runoff, farm drainage)		
Flow diversions or unnatural inflows		
Dams (reservoirs, detention basins, recharge basins)		
Flow obstructions (culverts, paved stream crossings)		
Weir/drop structure, tide gates		
Dredged inlet/channel		
Engineered channel (riprap, armored channel bank, bed)		
Dike/levees		
Groundwater extraction		
Ditches (borrow, agricultural drainage, mosquito control, etc.)		
Actively managed hydrology		
Comments		

PHYSICAL STRUCTURE ATTRIBUTE (WITHIN 50 M OF AA)	Present	Significant negative effect on AA
Filling or dumping of sediment or soils **(N/A for restoration areas)**		
Grading/ compaction **(N/A for restoration areas)**		
Plowing/Discing **(N/A for restoration areas)**		
Resource extraction (sediment, gravel, oil and/or gas)		
Vegetation management		
Excessive sediment or organic debris from watershed		
Excessive runoff from watershed		
Nutrient impaired (PS or Non-PS pollution)		
Heavy metal impaired (PS or Non-PS pollution)		
Pesticides or trace organics impaired (PS or Non-PS pollution)		
Bacteria and pathogens impaired (PS or Non-PS pollution)		
Trash or refuse		
Comments		

BIOTIC STRUCTURE ATTRIBUTE (WITHIN 50 M OF AA)	Present	Significant negative effect on AA
Mowing, grazing, excessive herbivory (within AA)		
Excessive human visitation		
Predation and habitat destruction by non-native vertebrates (e.g., *Virginia opossum* and domestic predators, such as feral pets)		
Tree cutting/sapling removal		
Removal of woody debris		
Treatment of non-native and nuisance plant species		
Pesticide application or vector control		
Biological resource extraction or stocking (fisheries, aquaculture)		
Excessive organic debris in matrix (for vernal pools)		
Lack of vegetation management to conserve natural resources		
Lack of treatment of invasive plants adjacent to AA or buffer		
Comments		

BUFFER AND LANDSCAPE CONTEXT ATTRIBUTE (WITHIN 500 M OF AA)	Present	Significant negative effect on AA
Urban residential		
Industrial/commercial		
Military training/Air traffic		
Dams (or other major flow regulation or disruption)		
Dryland farming		
Intensive row-crop agriculture		
Orchards/nurseries		
Commercial feedlots		
Dairies		
Ranching (enclosed livestock grazing or horse paddock or feedlot)		
Transportation corridor		
Rangeland (livestock rangeland also managed for native vegetation)		
Sports fields and urban parklands (golf courses, soccer fields, etc.)		
Passive recreation (bird-watching, hiking, etc.)		
Active recreation (off-road vehicles, mountain biking, hunting, fishing)		
Physical resource extraction (rock, sediment, oil/gas)		
Biological resource extraction (aquaculture, commercial fisheries)		
Comments		

APPENDIX B: GLOSSARY

Abandoned fan and **abandoned fan surfaces:** Holocene Epoch fan deposits that contain incised tributary drainage networks, may or may not have varnished surface clasts, and do not convey water, sediment, and debris from the upland drainage basin; they may also be subject to deposition and erosion due to avulsive processes during extreme events. See *relict fan* and *relict fan surfaces*.

Abandoned channel a channel along which stream flow no longer occurs; e.g. a channel isolated from its water source through faulting or stream capture, or by human constructs such as levees. With time and the absence of the processes responsible for its formation an abandoned channel will become relict.

Active channel: The portion of a channel receiving sufficient and frequent enough flows to leave evidence of recent fluvial activity, such as a cleanly scoured substrate, a line impressed on the bank, changes in soil characteristics, or changes in vegetation.

Active floodplain: A fluvial zone that receives frequent overbank flood flow (Williams 1978, Rosgen 1996).

Aseasonal Intermittent flow: Exhibits unpredictable and highly variable intermittent flow within and between years. Usually occur in climatic transition zones and semiarid areas. Although major rainfall and discharge events may be broadly seasonal, flow follows no distinct pattern and drying may occur in any season. Duration of flow, no flow, and drying events is highly variable within and between years, depending on antecedent climatic conditions. See *intermittent* flow.

Aggradation: An increase in the channel bed or floodplain elevation by deposition of sediment in excess of that the stream is capable of transporting; the opposite of degradation

Allochthonous: external source of energy (carbon) for a stream or channel (e.g., dead leaves, branches, and dead trees that fall into a stream or channel)

Alluvial: Refers to natural, channelized runoff from terrestrial terrain and the material borne or deposited by such runoff.

Alluvial fan: Gently sloping fan-shaped landforms that form where steep, confined mountain streams flow out onto a plain or valley.

Alluvium: A general term for unconsolidated clay, silt, sand, and gravel deposited as sorted or semi-sorted sediment in the bed of a stream or its floodplain or delta, or as a fan at the base of a mountain slope.

Anastomosing river: Sinuous, low-gradient channels consisting of multiple interconnected branches transporting a suspended or mixed load.

Anthropogenic: Arising from human activity.

Aquatic area: A general term for any area in a landscape exhibiting physical, chemical, and/or biological conditions resulting from the presence of standing or flowing surface water and/or shallow groundwater. Aquatic areas include stream and river channels.

Aquatic support areas: Non-wetland areas exhibiting some but not all the characteristics of wetlands. They can be areas that are changing from wetlands to uplands, or from uplands to wetlands, or they might be areas situated between, and affected by, wetlands and uplands. See Technical Memorandum No. 3 (SFEI-ASC 2012).

Arroyo: Entrenched ephemeral streams or channels with vertical walls that form in dryland and desert environments.

Assemblage. A collection of individual plant or animal species.

Assessment Area: A general term used for the portion of a system that is the subject of an evaluation.

Assessment Window: The appropriate period of time when assessments of condition should be conducted.

Attribute: Obvious, universal aspects of a resource's condition. For example, CRAM recognizes four attributes of condition: (1) buffer and landscape context; (2) hydrology; (3) physical structure; and (4) biotic structure.

Avulsion: The rapid full or partial redirection of the course from one channel into another, less sinuous and steeper channel due to the blockage of the channel by sediment or debris. Avulsions are typically formed during large storm events when high discharge erodes a new channel in the floodplain. Avulsions are more common in braided or aggrading stream channels.

Bajada: A coalesced alluvial fan; a broad, continuous, gently inclined depositional surface that extends from the base of mountain ranges out into and around an inland basin, formed by the lateral coalescence of a series of separate but confluent alluvial fans.

Bank: The land on the outermost edge of a channel that confines or otherwise defines the stream's boundary when its waters rise to the highest level of the channel.

Bankfull : In typical fluvial systems, the discharge that fills the active channel to a stage above which any further increase in depth results in a rapid increase in width as flow spreads across the floodplain; sometimes alternatively considered the 1.5-year recurrence interval flow (Dunne and Leopold 1978, Rosgen 1996) even if not associated with incipient inundation of floodplain. This average recurrence interval is commonly associated with perennially flowing stream channels where precipitation is evenly distributed, but is typically irregularly recurrent at multi-year or decadal intervals for episodic streams. Bankfull as commonly defined may not apply to many episodic streams, due to the irregularity of flow events. Bankfull also may be regarded as the "channel forming flow;" i.e., the rate of discharge (Q) that performs most of the channel functions associated with sediment movement and formation of the channel itself. This portion of the definition is more germane to episodic watersheds and streams.]

Bank slump: A portion of a bank that has broken free from the rest of the bank but has not eroded away.

Bankfull stage: The water depth at which fluvial discharge completely fills the active channel and begins to spread out onto the floodplain.

Bar: A transient sedimentary feature within a fluvial channel that is often exposed during low-water periods. Bars direct flows and form along the inside of a meander bend (point-bar) or in the middle of straight channel reach (in-channel bar). They are convex in profile and are comprised of alluvial or tidal deposits of sand, gravel, cobble, or other material. Their surface material varies in size from small on top to larger along their lower margins and they sometimes support vegetation.

Base flow: That part of stream discharge sustained by groundwater discharge and not attributable to direct runoff or melting snow.

Bed forms: Bedding surface features that are individual elements of a mobile granular or cohesive bed.

Bedload: The part of the total sediment load that is moved on or immediately above the stream bed. Includes the larger or heavier particles (boulders, pebbles, gravel) transported by traction or saltation along the stream bed.

Benches: Relatively level topographic surface that exists at or above the channel-forming discharge of the channel (e.g. a floodplain or terrace). It is connected and parallel to the bank. It does not include surfaces within the active channel composed of the same size material being transported as bedload (e.g. bars).

Beneficial uses: Term used to define the resources, services, and qualities of wetland areas and other waters of the State of California that are the ultimate goals of protecting and achieving high water quality. Beneficial uses serve as a basis for establishing water quality objectives and discharge prohibitions to attain these goals.

Benthic: Pertaining to the river bed.

Berm: A flat strip of land, raised bank, or terrace bordering a wetland, aquatic area, or aquatic support area. Berms can be natural or artificial in origin.

Borrow ditch: A ditch dug along a roadway to furnish fill and provide drainage.

Boulder: A size category of rock having a long axis greater than 25 cm.

Braided channel: Interlacing or tangled network of several small, branching, and reuniting shallow channels separated from each other by floodplains, islands or channel bars. Braided channels commonly appear to be part of a single channel, and in plain view appear to be strands of a complex braid.

Buffer: An area extending from the immediate edge of the Assessment Area that is in a natural, or semi-natural, state and protects the Assessment Area from stressors

Calcrete: A conglomerate consisting of surficial sand and gravel cemented into a hard mass by calcium carbonate.

Caliche rubble: Fragments of a sedimentary rock formed by evaporation and precipitation of calcite ($CaCO3$) in soil, sediments, or preexisting rock.

Catchment: See *watershed.*

Channel: A landscape feature with well-defined beds and banks that have been formed by water and which under normal circumstances are maintained by the flow of water, or that are purposefully constructed and maintained to convey water. Channels can be subterranean for short lengths but are generally surface features. Channels can pass under bridges or through culverts and natural tunnels, but buried storm drains and water pipes are not channels (SFEI 2012). Channels may be found in wetlands, and they can contain wetlands, deep water aquatic areas, and aquatic support areas. The system of diverging and converging channels that characterize braided and anastomosing fluvial systems usually consist of one or more main (primary) channels plus secondary channels.

Channel fan: A thin, narrow accumulation of alluvium deposited in a fluvial channel that results from the downstream loss of stream flow and decline in sediment transport capacity.

Channel-forming flow: The dominant discharge, defined as a theoretical discharge that, if maintained, would produce the same channel geometry as the natural long-term *hydrograph*. Channel-forming discharge concepts are applicable to stable alluvial streams (i.e., streams that have the ability to change their shape and are neither *aggrading* nor *degrading*). In dryland environments, the channel forming discharge may occur over a broader range of flow conditions. In these environments, channels may adjust following each substantial flood event because runoff is typically generated by localized high-intensity storms, substrate is more easily erodible, and stabilizing bank vegetation is sparse or absent.

Channel morphology: The form and physical characteristics of a stream channel.

Channel stability: A measure of the degree of channel aggradation (i.e. net accumulation of sediment on the channel bed causing it to rise over time) or degradation (i.e. net loss of sediment from the bed causing it to be lower over time).

Coalesced or **coalescing alluvial fans:** The lateral growth of adjacent alluvial fans until they finally combine to form a continuous, inclined deposit along a mountain front. See *Piedmont and piedmont plain*.

Coarse woody debris: A single piece of woody material, greater than 30 cm in diameter and greater than 3 m long.

Cobble: A size category of rock having a long axis from about 6 cm to about 25 cm.

Cobble bar: Bars composed of cobbles that form behind obstructions in stream channels. Their formation depends on flow competence and cobble availability of the system.

Condition: The ability of an ecological system to maintain its complexity and capacity for self-organization with respect to species composition, physio-chemical characteristics, and functional processes, relative to healthy systems of the same type. There are three primary aspects of condition: location, form, and structure.

Compound channel: A channel form typical of many dryland intermittent and ephemeral fluvial systems characterized by a single, low-flow meandering channel nested within a larger watercourse defined by a frequently shifting, braided channel network. See *Braided channel*.

Composite fans: Alluvial fans built-up through both hyper-concentrated floods and debris flows and that contain features found on both streamflow fans and debris flow fans. Slopes on composite fans typically range from 4-8 degrees (AFTF 2010b).

Confinement: The physical restriction of lateral movement by a fluvial channel because of the presence of bedrock or other geologic features (e.g. terraces, hillsides).

Confluent drainage pattern or **network:** A network of individual stream or /channels that combine with one another to form a single stream/channel.

Continuous Inundation: Hydrological conditions on the land surface or in the upper substrate of a given area that are perennial or tend to persist for at least twelve months.

Crested ripples: Transient sedimentary features within a fluvial channel formed by lower-intensity fluid movement over particles smaller than 0.7 mm. May be localized within or extend laterally across low-flow channels.

Culvert: A covered drain or channel that crosses under a road, railway, etc.

Dormant channel: A channel isolated from its principal water source by natural causes or human constructs such as roads, but that retains its potential for hydrologic reactivation and stream function.

Debris flow: A mix of water and debris, which may include particles ranging in size from clay to boulders and may contain woody debris and other materials, that flows down a stream channel or steep slope, sometimes at great velocity, and contains more than 60 percent debris (less than 40 percent water) by volume.

Debris flow fan: Alluvial fans built-up through successive debris flow events. Slopes on debris flow fans may be as steep as 6 to 8 degrees, and may have terminal lobes, marginal levees and trapezoidal or U-shaped channels with relatively low width-to-depth ratios. Deposition is episodic, and rapid aggradation or plugging may occur in much deeper channels than is the case for stream flow fans. Even channels that appear to be stable during water flood events may be subject to avulsion during or after debris flow, and this contributes to the uncertainty in down-fan flow path typical for alluvial fans (AFTF 2010b).

Degradation: The long-term lowering of a fluvial channel due to such factors as changes in sediment supply or increased scouring that results in changes in channel cross-sectional area.

Delineation: The application of a technical and procedural methodology to identify the boundary of a wetland area or an aquatic support area within a specified study site by identifying the presence or absence of indicators of wetland criteria at multiple points at the site and by establishing boundaries that group together sets of points that share the same status as wetland versus non-wetland, or similarly for aquatic support areas.

Deposition: The settlement of materials out of moving water and onto the bed, banks, or floodplain of a riverine channel.

Desert pavement: Tightly interlocking gravel at the surface formed after years of surface exposure in the absence of active streamflow over the surface.

Desert varnish: A thin, dark, shiny film composed of iron oxide (with traces of manganese oxide and silica) that forms on the outer surface of pebbles, boulders, and rock outcrops in desert regions the becomes increasingly dark with long exposure.

Detritus: Newly dead or decaying organic matter

Discontinuity: The complete sequence of reaches between headcuts along a *discontinuous channel*.

Discontinuous channel: A channel form along which fluvial processes change from aggradation to degradation and a well-defined channel form is periodically lost along the stream length.

Distributary flow pattern, channel, or **network:** Channels flowing away from the main stream and not rejoining it. The number of channel forks commonly exceeds the number of channel confluences, creating a divergent distributary, rather than convergent tributary drainage pattern.

Disturbance: The consequence of natural changes in forcing functions, or controlling factors, through space and over time; disturbance is natural, regardless of its frequency, persistence, or magnitude.

Divergent flow, channel or **drainage network:** See *Distributary flow pattern*.

Drainage network or system: The spatial and geometric relationship between individual streams or channels in an area; may be dendritic, trellis, parallel, or distributary.

Drift: Organic debris oriented to flow direction(s) that is larger than small twigs. Often collects behind/in obstructions or is simply deposited by receding flow.

Drop structure: An artificial structure, typically small and built on streams with steep gradients, to pass water to a lower elevation while controlling the energy and velocity of the water as it passes over.

Dryland regions: A collective noun for the arid and semi-arid regions of California, equivalent to regions defined as the "Arid West" by the Natural Resources Conservation Service (U.S. Department of Agriculture 2006). This region broadly includes the Mediterranean regions of the state, including the associated coastal zone of southern California, as well as the interior desert portions. These are areas where annual potential evapotranspiration is greater than rainfall (Bull and Kirkby 2002).

Dryland farming: A system of growing crops in arid or semiarid regions without artificial irrigation, by reducing evaporation and by special methods of tillage.

Duff: A spongy layer of decaying leaves, branches, and other organic materials along a wetland shore or in a riverine riparian area.

Dunes: Transient sedimentary features formed by higher-intensity fluid movement over previously formed ripples. May be localized within or extend laterally across low-flow channels.

Duration: The length of time that an area is continuously saturated or covered (inundated) by water. It is the period available for the formation of anaerobic substrate conditions. It does not refer to the presence or lack of seasonal occurrences of inundation or saturation, but to the length of time an area is continuously saturated or covered (inundated) by water. Also see *Hydroperiod.*

Ecological Service: An ecological process or function for which a system can be managed that has value to people. Key ecological services for many types of streams include flood control, groundwater recharge, water filtration, and conservation of cultural values, aesthetics, and the support of special-status species.

Effective discharge: Discharge that is capable of carrying a large proportion of sediment over time.

Effective valley width: The portion of a valley within which its fluvial channel is able to migrate without cutting into hill slopes, terraces, man-made levees, etc.

Emergent vegetation: Plant species typically growing on saturated soils or on soils covered with water for most of the growing season; the leaves of emergent aquatic species are partly or entirely borne above the water surface.

Entrenchment: The inability of flows in a channel to exceed the channel banks (i.e. the vertical containment of stream); a measure of the degree to which fluvial flood flows are contained within channel banks without access to the effective valley. Entrenchment as a field measurement is calculated as the flood-prone width divided by the bankfull width.

Ephemeral flow: Flowing water is present only during or immediately after precipitation events in a typical year; typically occurs in small watershed areas as a direct response to precipitation. An ephemeral stream flows for less time than it is dry. Ephemeral stream beds are located above the water table year-round; runoff from rainfall, not groundwater, is the primary source of water for stream flow. Ephemeral streams may or may not have a well-defined channel and often includes episodic dryland region channels (e.g. desert washes).

Ephemeral stream: A stream that exhibits ephemeral flow.

Equilibrium: A basic principle of fluvial geomorphology which holds that stream channel form –its cross sectional shape, planform, and gradient – is adjusted to the prevailing watershed conditions that control the amount of sediment and water delivered to the channel (Leopold *et al*. 1964; Dunne and Leopold 1978).

Episodic: Occurring sporadically or incidentally, as in episodic flow and sediment transport.

Exposed root hairs: Roots of trees or shrubs that have been exposed by erosion of sediment. Tend to be located where benches have formed.

Facultative wetland (FACW): Wetland indicator category; species usually occurs in wetlands (estimated probability 67–99%) but occasionally found in non-wetlands.

First- or **second-order streams:** Relative to stream order. The smallest and second smallest headwater tributary to downstream watercourses. See *Stream order*,

Flashy flow or **discharge pattern:** Periods of no flow or low-magnitude flow, high- frequency events separated by short-duration, high-magnitude, low-frequency events.

Flood terrace: As defined here, a relatively ephemeral geomorphic surface formed by deposits where over bank flow has occurred and is oftentimes reworked and rebuilt by subsequent flood events. A similarly formed but less persistent landform superficially related to temperate region *floodplains* and *stream terraces*.

Floodplain: The surface or strip of relatively broad, flat area adjacent to a fluvial channel that is prone to flooding, and which has evolved through the deposition of alluvial materials, as evidenced by deposits of fine sediment, wrack lines, vertical zonation of plant communities, etc. Corresponds to the height of the bankfull flow in perennial streams.

Flood prone: Susceptible to inundation by extreme flood events. The height of the flood prone area approximately corresponds to twice bankfull height among perennial streams.

Flow path uncertainty: The perceived, historical channel or network of channels cannot be relied on to convey the base flood without the creation of new flow paths or the abandonment of existing flow paths (AFTF 2010a).

Fluvial: Of, relating to, or happening in, a river, stream, or channel.

Forb: A plant with a soft, rather than permanent, woody stem that is not a grass or grass-like.

Foreshore: The boundary between the vegetated wetland and any adjoining semi-aquatic, non-wetland area, such as a non-vegetated riverine channel bar,

Functions: What physical or ecological systems do e.g. store flood waters, recharge aquifers, protect shorelines from erosion, filter pollutants from water, and support of native biological diversity.

Gravel sheets: Sand ridges aligned in flow direction that are deposited due to reduced flow competence. May be localized within or extend laterally across low-flow channels. Also termed harrow marks

Headcut: An abrupt vertical drop in the bed of a stream channel that is actively eroding upstream (or in a headward direction). The process of head cutting involves the initiation of channel incision at a nick point as the stream channel bed elevation adjusts to a natural or human induced disturbance. In flowing streams, head cuts resemble a small waterfall. A small plunge pool may be present at the base of the head cut due to the high energy of falling water. When not flowing, the head cut will resemble a very short cliff or bluff in a fluvial channel.

Headwater channel or **stream:** Headwater channels are typically considered to be first- and second-order streams (Gomi *et al.* 2002), meaning streams that have no upstream tributaries (i.e., "branches") and those that have only first-order tributaries, respectively. See *Stream order*.

Herbaceous: A plant having stems with little or no woody tissue and that die down annually.

Hummock: A mound composed of organic materials (typically less than 1m high) along the banks and floodplains of fluvial systems created by the collection of sediment and biotic material.

Hydraulic analyses: Analytical methodologies for assessing the movement and behavior of stream flow and floodwaters and determining water surface elevations.

Hydraulic parameters. Slope, roughness, channel geometry, discharge, velocity, turbulence, fluid properties, sediment size, etc.

Hydraulic roughness. Channel boundary characteristic contributing to energy losses, commonly described by Manning's roughness coefficient (n).

Hydric soil. A soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part.

Hydrograph: A graph showing stage, flow, velocity, or other properties of water with respect to time.

Hydrographic apex: The highest point on an alluvial fan where the flow is last confined and at which flow-paths become *distributary*.

Hydrologic connectivity: A measure of the ability of water to flow into or out of a channel, or to accommodate rising flood waters without persistent changes in water level.

Hydrologic regime. Characteristic pattern of precipitation, runoff, infiltration, and evaporation affecting a water body.

Hydroperiod: The characteristic frequency and duration of inundation or saturation during a typical year.

Hyper-concentrated flood: A moving mixture of suspended sediment and water containing between 20 and 60 percent sediment by volume.

Hyporheic: The saturated zone under a river or stream channel, comprising substrate with the interstices filled with water.

In-channel bar: A transient sedimentary feature within a fluvial channel that forms in the middle of straight channel reach.

Indicators: Visible clues or evidence about field conditions. Indicators are identifiable in the field but are not necessarily quantitative characteristics.

Interfluve: A relatively un-dissected higher ground (or upland) between two adjacent stream channels that flow in the same general direction in the same drainage network.

Intermittent flow: A condition in which flowing water is present for periods of weeks to months following the cessation of precipitation, but not throughout the annual cycle; typically occurs because of a combination of precipitation and groundwater discharge. Runoff from rainfall is a supplemental source of water for stream flow. Water from springs, rainfall, or runoff from surface sources such as melting snow can also provide water for stream flow. These systems tend to be characterized by discernible channels which show evidence of annual deposition or scour (USDA and USDI 1994). During dry periods, intermittent streams may not have flowing water. Also see *seasonal* and *aseasonal* intermittent flows.

Intermittent stream: A stream characterized by intermittent flow.

Interspersion: A measure of the number of distinct patches (as in plant zones) and the amount of edge between them.

Inundation: A condition in which water from any source continuously or recurrently covers a land surface. Inundation may include flooding, a condition in which the substrate surface is temporarily covered with flowing water from any source, such as overflowing streams or rivers, surface runoff from adjacent slopes, groundwater discharge, or any combination of such sources. Inundation can be recurrent or continuous.

Invasive: Pertaining to a species that has been introduced from other regions by the actions of people and that exhibits a tendency to significantly displace native species, hybridize with native species, alter biological communities, or alter ecosystem processes.

Island: An area of land above the usual high water level in a fluvial system and, at least at times, surrounded by water. Islands differ from hummocks and other mounds by being large enough to support trees or large shrubs.

Island elevated body of land periodically surrounded by and isolated from the upland landscape by water. Islands are part of a watercourse unless their landscape and ecosystem characteristics differ from those of the watercourse, and there is minimal physical and biological exchange between the two.

Knickpoint: An abrupt change in channel slope formed by differential erosion above/below the change in slope. May extend partially or entirely across a low-flow feature(s). See definition for headcut.

Lag gravel pavement: A residual accumulation of coarse rock fragments remaining on a surface after the finer material has been removed by wind or water erosion.

Landscape: General term referring to a set of visible, physical geographic features, including landforms, aquatic areas, vegetation, land uses, and built structures that can be viewed together in a single scene. In the context of landscape ecology, landscape refers to a mosaic of patches that recurs over a broad region of the earth's surface (Forman 1995).

Litter: A layer of organic matter or debris (partly decomposed leaves, twigs, etc.) on the ground. Typically oriented to flow direction(s)

Littoral zone: The nearshore area of a water body, where it is sufficiently shallow to allow light to penetrate to the bottom and reach rooted vegetation; corresponds with the limit of submerged aquatic vegetation

Low-flow channel: The topographically lowest stream channel, or the dominant sub-channel within a compound channel watercourse. Among ephemeral streams, it is the channel within a larger watercourse occupied by frequent flow events; on intermittent and perennial streams, it is the channel within a larger watercourse that is occupied and sustained by the lowest groundwater discharge. In the Arid West, the low-flow channel of an ephemeral stream will form and relocate during low to moderate discharge events (5–10 years) instead of being maintained by continuous flows, as in perennial streams. See baseflow.

Main stem: Relative to stream order. The largest and downstream-most watercourse.

Meander: The curves of a stream or channel as viewed from above; a meander cutoff is a new, shorter channel across the narrow neck of a meander.

Meandering: The curving or winding of a stream or channel in its alluvial valley.

Metric: A measurable component of an attribute.

Mudcracks: Transient sedimentary features formed by the drying of fine-grained sediment. May be localized in depressions within low-flow feature(s).

Muddy point bars: Transient sedimentary features formed due to reduced flow velocity and located on the inside bend of low-flow feature(s).

Natural levee: A low ridge landward of the active floodplain of a channel that forms by deposition during flood events.

Nonpoint source discharge: Any discharge to a wetland resulting from diffuse sources (e.g. land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification). Includes any type of discharge that does not meet the legal definition of "*point source*".

Normal circumstances: The hydrologic, substrate, and vegetation conditions that are present in the absence of altered circumstances. Normal circumstances include natural seasonal and inter-annual variations in hydrology, substrate, and vegetation conditions.

Obligate wetland (OBL). Wetland indicator category; species occurs almost always (estimated probability 99%) under natural conditions in wetlands.

Ordinary high water mark (OHWM): 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 the soil, destruction of terrestrial vegetation, or the presence of litter and debris. For dryland channels, an alternative definition is "That part of the active channel where sediment transport is due to the most frequent or repeating hydrologic discharges, resulting in the development of bed and bank or other physical features, including vegetation, representing long-term trends in either storm or annual discharge events. This definition recognizes that, in some instances, extreme events may have developed the outermost physical features of the active channel and that the current "ordinary" limits may occur within these features" (Lichvar and Wakeley 2004).

Organic: Pertaining to, or derived from, living organisms, or to compounds containing carbon as an essential component.

Overland flow: The down slope movement of water taking the form of a thin, continuous layer over relatively smooth soil or rock surfaces and not concentrated into channels larger than rills (i.e., very small, steep-sided channels resulting from erosion and cut in unconsolidated materials by concentrated but intermittent flow of water). This flow typically is short lived with a limited travel distance; a relatively high-frequency, low-magnitude event.

Panne: A shallow topographic basin that forms on a fluvial floodplain. Pannes lack vegetation and fill with water at least seasonally due to overland flow.

Patch: A spatially distinct structural element of a wetland system large enough to serve as habitat for wildlife, or to serve as an indicator of spatial variations in hydrological or edaphic (soil) conditions within a wetland

Perennial flow: Flowing water is present for the entire annual cycle; typically occurs in larger geographical areas because of a combination of precipitation and groundwater discharge.

Perennial stream: A stream characterized by perennial flow.

Perturbation: A change in watershed conditions, such as percentage of forest cover, significant enough to engender a stream channel response.

Piedmont and **piedmont plain**: The descriptive term for a relatively broad, generally low relief area at the base of the mountain front that slopes down toward the center of the valley. Piedmonts are composed mostly of sediment (alluvium) shed from adjacent highlands by stream flows or debris flows, but they often include complex mixtures of eroded bedrock and various types of surficial geologic deposits and landforms (House 2005).

Pioneer species. A species that colonizes a previously un-colonized area.

Planar (plane) bed: A reach of a fluvial channel characterized by long, relatively straight portion of uniform depth. A flat, almost featureless bedding surface.

Planform simplification. Channel response to altered discharge of water and sediment by widening and deepening the primary low-flow channel, up to the point where all secondary channels are subsumed into one wide main channel.

Periphyton: Benthic algae that grow attached to surfaces such as rocks or larger plants.

Point-bar: A transient sedimentary feature within an fluvial channel that form along the inside of a meander bend.

Point-source discharge: Any discernible confined and discrete conveyance (e.g. a pipe, ditch, channel, or conduit) from which pollutants are or may be discharged into a waterway. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

Pool (on floodplain): A shallow topographic basin on a fluvial floodplain that has been inundated by water.

Pool (in channel): A depression within a fluvial channel that is much deeper than the average depth of the channel. Pools tend to retain water longer than other areas of the channel during periods of low or no surface flow.

POTW: Publicly-owned treatment work; a term used in the United States for a sewage treatment plant that is owned, and usually operated, by a local government agency. They are usually designed to treat domestic sewage and not industrial wastewater.

Primary channel: A channel in fluvial system that conveys the majority of the surface water flow.

Rating: A state relative to the full range of possible states, from worst possible state to best possible.

Reach: A segment of a river, stream, or channel that has generally consistent physical and biological characteristics.

Recurrent Inundation: Hydrological conditions on the land surface or in the upper substrate of a given area that persist for less than twelve months. A recurrent hydroperiod may be periodic and sustained, or episodic and intermittent, such as the inundation of a dryland region streambed by floodwaters.

Relict: A landform remnant that has survived after the processes responsible for its formation have ceased.

Relict channel: An "old" channel made by processes no longer locally operative; e.g. a stream that once drained a lake that is now permanently dry. Antiquity may be demonstrated by the presence of rock varnish, soil development, rock weathering, and the absence of recent fluvial activity.

Relict fans and **relict fan surfaces:** Alluvial fan deposits that occurred during the Pleistocene Epoch under a different climate regime, and contain deeply incised tributary drainage networks that do not convey water, sediment and debris from the upland drainage basin. See also *abandoned fans* and *abandoned fan surfaces*.

Riffle or rapid: A submerged, topographical high area in a fluvial channel created by the accumulation of relatively coarse-grained sediment (gravel, cobble, or boulders) causing turbulent surface flow and indicated by standing waves.

Riparian: Areas through which surface and subsurface hydrology interconnect aquatic areas and/or connect them with their adjacent uplands (based on Brinson et al. 1981). They are distinguished by gradients in biophysical conditions, ecological processes, and biota. They can include wetlands, aquatic support areas, and portions of uplands that significantly influence the conditions or processes of aquatic areas (SEFI-ASC 2012).

Riprap: Broken stones loosely deposited in water or on a soft bottom to provide a foundation and protect a riverbed or river banks from scour: used for revetments, embankments, breakwaters, etc.

Ruderals: Disturbance-adapted herbaceous plants.

Run: A reach of straight, smooth, fast-moving fluvial flow between riffles; also called a glide.

Runoff: That part of precipitation that appears in surface streams. Runoff in streams begin when depression storage in the watershed (*e.g.*, ponds, small depressions) is full and the rate of rainfall exceeds the rate of infiltration (Dunne and Leopold 1978).

Scour: Concentrated erosive action of flowing water in streams that removes and carries away soil and debris from the bed and banks.

Secondary channel: A topographically higher channel in a fluvial system that conveys flood flows, but not the majority of the flow. Also known as overflow or high flow channels.

Seasonal intermittent flow: Exhibits seasonally predictable intermittent flows where surface flow ceases for a period each year. When the water is not flowing, it may remain in isolated pools or surface water may be absent. Flow commences in the wet season and may be sustained by or intermittent over the wet season. See intermittent flow.

Sediment: Organic or inorganic material that has been transported and/or deposited by wind or water action. Sediment can be coarse (i.e., gravel or larger) or fine (i.e. clay, silt, sand). A fresh splay of sediment is one that has been deposited during the current or previous season's runoff event.

Sediment mound: A depositional feature (typically less than 1m high) along the banks and floodplains of fluvial systems formed from repeated flood flows depositing sediment on the floodplain. Sediment mounds lack plant cover.

Shallow flooding: Unconfined flows that exceed the channel capacity of distributary channels and spread out over broad, relatively low relief areas, such as alluvial plains.

Sheet flood or **sheet flood zones:** Shallow, unconfined flow that occurs in channel fan areas of discontinuous channels, and on low relief areas of alluvial fans where channels no longer exist; a relatively low-frequency, high-magnitude event.

Single-thread channel: A channel form where flow is restricted to a discrete channel.

Sinuosity: A measure of a stream's "crookedness" measured as the total stream length along the stream thalweg divided by the valley length. Sinuosity is the result of the stream dissipating its flow forces. Intermittent streams have a varying flow regime, and so tend to be less sinuous downstream than perennial streams.

Sorting: A measure of the spread of particle size in the substrate. Well-sorted particles are made up of similarly sized particles. Poorly sorted particles are made up of a wide variety of different particle sizes.

Stable: The relative state of the location, geometry and roughness of a channel, network of channels or landform where any changes of location, geometry and roughness can be ignored in assessing flood risk (AFTF 2010a).

Stream: A landscape feature consisting of one or more channels that convey flowing water plus adjoining riparian areas having conditions affected by interactions with the flowing water regardless of its origin, depth, extent, duration, or timing. (SFEI-ASC 2012). A stream may have more than one active channel or, as is often the case, secondary channels that receive water only during higher flow events. Low-flow channels, active channels, banks associated with these channels, floodplains, and stream-associated vegetation, may all occur within a single larger channel, designated the stream channel to discriminate between it and similar but smaller subordinate features that lie within its bounds. The boundaries of the stream channel define the maximal extent or expression of a stream on the landscape.

Streamflow fan: Alluvial fans built-up through successive hyper-concentrated floods. Slopes on stream flow fans are generally less than 3-4 degrees, which is considered to be the threshold between streamflow fan deposition and debris flow deposition. Channels on streamflow fans have large width-to-depth ratios and are typically braided. Erosion and deposition can alter channel flow during a single flood event where deposition occurs as bars along the margins or center of the channel (AFTF 2010b; NRC 1996).

Stream terrace: One of a series of level surfaces in a stream valley, flanking and more or less parallel to the stream channel, originally occurring at or below, but now above, the level of the stream, and representing the dissected remnants of an abandoned floodplain, stream bed, or valley floor produced during a former stage of erosion or deposition.

Stream order: A measure of the position of a stream (defined as the reach between successive tributaries) within the hierarchy of the *drainage network or system*. A commonly used approach allocates order '1' to unbranched tributaries, '2' to the stream after the junction of the first tributary, and so on. It is the basis for quantitative analysis of the network.

Stream power. The rate of doing work, or a measure of the energy available for moving rock, sediment, or woody or other debris in a stream channel, as determined by discharge, water surface slope, and the specific weight of water.

Stress: The consequence of unnatural, anthropogenic changes in forcing functions or controlling factors; key stressors are anthropogenic actions that tend to modify the quantity and/or quality of physical or biological habitat, sediment supplies, and/or water supplies upon which the desired functions of the wetland depend.

Stressor: An agent that inflicts stress.

Succession. Changes in the composition or structure of an ecological community.

Surface water: Freestanding or moving water above the ground surface.

Suspended sediment: The part of the total sediment load that is carried for a considerable period of time in suspension above the bed. It consists of mainly of clay, silt, and sand.

Swale: Depression or hollow where runoff from the surrounding uplands accumulates. Swales that yield channel flow are important sources of water, sediment, nutrients, and other materials during runoff, and are considered source areas to and integral parts of streams.

Terrace or terrace zone: A planar surface or zone representing infrequently or rarely flooded remnants of a former floodplain, from paleo surfaces that are completely abandoned to modern surfaces that infrequently receive flood waters.

Terrace floodplain: An abandoned alluvial feature formed during historic hydraulic conditions. This surface will occasionally flood as a result of the short-term heavy and long-term moderate rainfall patterns found in the Arid Southwest (Graf 1988; Osterkamp and Friedman 2000).

Thalweg: The line connecting the lowest or deepest points along a stream or channel.

Thatch: A matted layer of partly decayed leaves, stems, etc. between growing vegetation and the soil.

Topographic apex: The point at which an alluvial fan is last confined within the mountain front.

Transmission losses: Decrease in discharge in a downstream direction due to infiltration of water into the channel bed; especially pronounced in arid climates

Transportation corridor: A linear pathway for a particular mode of transportation (highway, road, rail, canal, etc.)

Transport capacity: The maximum amount of sediment that can be carried along by a stream.

Tributary: A type of secondary channel that conveys flow to a primary channel.

Trim line: A line along a stream bank below which erosion by flowing water is readily apparent; the feature is usually characterized by a small notch on the bank

Undercutting: The removal of material at the base of a stream or channel bank by the erosive action of flowing water.

Unnatural levee: An artificially raised embankment along a wetland that constrains water flows. Their primary purpose is to provide hurricane, storm, and flood protection relating to seasonal high water, storm surges, precipitation, and other weather events.

Unstable: The relative state of the location, geometry, and roughness of a channel, network of channels or landform that cannot be ignored in assessments of flood risk (AFTF 2010b).

Uplands: Well-drained areas of higher ground that are dominated by terrestrial processes. Include all non-wetland areas that lack any field-based indicators of wetlands or other aquatic conditions.

Vegetation: Rooted macrophytes, parts of which may be emergent, submerged, or floating, including monocots, dicots, and ferns. An area is vegetated if at least 5% of it is covered by vegetation. The area exhibits wetland vegetation if the dominant vegetation is hydrophytes.

Vegetation management: The practice of manipulating vegetation within a prescribed management area. Includes prescribed burning, grazing, chemical applications, timber harvesting, and any other economically feasible methods of enhancing, retarding, or removing the above-ground parts of plants.

Wash: A broad, shallow, sandy or gravelly, and normally dry bed of an intermittent or ephemeral stream.

Watercourse: The area within and along which water flows perennially or episodically through one or more channels. Where present, swales, single-thread channels, compound channels, braided channels, discontinuous and distributary channel networks, and floodplains all lie within the bounds of a single larger channel designated the "watercourse" to discriminate between it and functionally related but subordinate fluvial landforms that lie within its bounds. See definition of *stream*

Watershed: An area of land that drains water, sediment, and dissolved materials to a common outlet and is separated from other watersheds by a divide. Catchment, catchment area, catchment basin, drainage basin, and drainage area are watershed synonyms.

Water table: The top of the groundwater, below which is the zone of saturation in the substrate.

Wetland: An area that, under normal circumstances, meets the following criteria (1) has continuous or recurrent saturation of the upper substrate caused by groundwater or shallow surface water or both; (2) the duration of such saturation is sufficient to cause anaerobic conditions in the upper substrate and; (3) lacks vegetation or the vegetation is dominated by hydrophytes. The term, wetland, can be used as a noun or an adjective. An individual wetland (noun) consists of all the wetland areas of one kind that touch each other and that together are bounded by areas that either do not meet the wetland criteria or that are areas of other kinds of wetlands. A wetland area (adjective) meets the three criteria of the wetland definition. There are many kinds of wetland areas, based on their water sources, hydroperiod, substrate conditions, geomorphic setting, plant community composition, etc. (e.g., Cowardin et al 1979; Brinson 1993; Tiner 2003).

Wetland criteria: Aspects of wetland condition verified by the observation of indicators. The wetland criteria used to define, identify, and delineate wetland areas are hydrology, substrate, and vegetation. Sometimes alternatively identified as wetland factors. See also Indicators.