Energy Research and Development Division
FINAL PROJECT REPORT

METHODS TO DESCRIBE AND DELINEATE EPISODIC STREAM PROCESSES ON ARID LANDSCAPES FOR PERMITTING UTILITY-SCALE SOLAR POWER PLANTS

With the MESA Field Guide

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ABSTRACT

Utility-scale, renewable energy projects are being planned and developed in dryland regions of California, mostly on public lands where episodic streams – streams having only periodic flow – are dominant. Developing these facilities can radically and detrimentally alter the landscape, drainage patterns, and natural habitat dependent on these streams.

Even though episodic streams can be dry throughout most of the year, they have high biodiversity. Habitat values are protected by existing environmental laws, and must be managed and protected whenever possible. To comply with the California Fish and Game Code, the California Department of Fish and Wildlife must be notified and consulted with when there is a potential for project-related impacts to streams. The notification requires an accurate description of the natural streams at the site, which implicitly includes an assessment of the type and recency of stream-related processes. However, such analysis and reporting has been problematic because no consistent protocol or guidance exists for project developers to use in place of methods and tools developed for other purposes. Consequently, many projects under-report the numbers of streams present. This has caused long and expensive delays in the permitting process; infrastructure has been damaged by flooding; and habitat that could have been conserved has been detrimentally impacted or destroyed.

To rectify this, the California Energy Commission contracted the authors to produce a scientifically based, geomorphic and ecological stream delineation method that project developers can use to inform the design and development of sustainable, low-impact projects in dryland environments. The *Mapping Episodic Stream Activity* (MESA) protocols described herein facilitate project permitting by providing a uniform delineation protocol; helps oversight agencies evaluate a project's potential impacts; and provides a formal method with broad application for developing land use and resource management plans, and evaluating land use and resource management practices.

Keywords: California Energy Commission, permitting application, fluvial processes, episodic streams, desert ecosystems, desert habitat, mapping protocols, jurisdictional watercourse

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ATTACHMENT

MESA Field Guide

EXECUTIVE SUMMARY

Introduction

To meet California's growing energy needs, public partners and private industries are planning and developing utility-scale, renewable energy generation facilities in arid and semi-arid regions of California. Individual facilities would cover hundreds to thousands of acres in arid and semi-arid ("dryland") regions of the state, mostly on public lands where episodic streams – streams having only periodic flow – are dominant. Developing these facilities can detrimentally alter the landscape, drainage patterns, and natural habitat.

The people of California have enacted environmental laws to protect natural environments, including those of dryland riparian systems. Although they are dry throughout most of the year, dryland stream corridors have higher biodiversity and habitat values than in the adjacent uplands. Episodic stream systems transport and deliver water, provide linear habitat connectivity and refuge, and concentrate seeds, organic matter and sediment. Because the desert riparian habitats depend on the persistence of episodic streams, the physical/hydrological processes that form and maintain these streams must be managed and protected whenever possible.

Purpose

The California Fish and Game Code (F&GC), requires that the California Department of Fish and Wildlife (CDFW) be consulted if a proposed development project has the potential to detrimentally effect a stream and thereby wildlife resources that depend on a stream for continued viability (F&GC Division 2, Chapter 5, section 1600-1616). The process of environmental permitting for utility-scale, renewable energy generation facilities requires an assessment of the natural drainage conditions including which channels and other fluvial (stream-related) landforms are active. However, because influx of water in episodic streams is unreliable in its timing and quantity, it can be difficult to recognize an "active" stream. As well, there is no existent, comprehensive, scientifically based protocol for mapping these streams, so practitioners have been using obsolete and (or) inappropriate methods to identify streams subject to F&GC jurisdiction.

The results have been unsatisfactory overall, because many permit applications have significantly under-represented the extent of episodic streams, and the operative fluvial processes on their sites. This has caused long and expensive delays in the permitting process; inappropriate infrastructure siting and stormwater drainage plans, and needless damage to the desert ecological habitat.

Objectives

To rectify this issue, the California Energy Commission contracted the research team to:

1) Produce a scientifically based, geomorphic and ecological stream delineation method that project developers or their representatives can use to inform the design and development of sustainable, low-impact projects in dryland environments;
2) Facilitate renewable energy project permitting by providing agencies and project developers a rigorous and uniform delineation protocol;

3) Develop a consistent method with which oversight agencies can evaluate the type and extent of off-site mitigation for dryland streams, and
4) Provide a formalized method with broad application for use in siting and permitting development projects, developing land use and resource management plans, and evaluating land use and resource management practices.

Conclusions and Recommendations

The protocols herein referred to as "Mapping Episodic Stream Activity" (MESA) involves three main steps:

1) Using high-resolution aerial imagery to recognize the stream forms and processes – gather information on the physical characteristics;
2) Documenting on-the-ground indicators of fluvial activity and inactivity, and;
3) Mapping the watercourse.

To do this, MESA is included as a stand-alone volume that can be removed from this report and taken into the field. The *MESA Field Guide* includes:

- A review of physical and ecological characteristics of dryland episodic streams;
- Clarification of terminology and definitions;
- Notes on how to map episodic streams including a review of channel forms and geomorphic units within the watercourse, including uplands, terraces and interfluves, floodplains and secondary channels, and islands;
- Guidance on how to identify and define watercourse boundaries;
- A *Photographic Atlas of Indicators of Episodic Stream Activity*, divided into upland/terrestrial, watercourse, and watercourse/playa margin environments, with accompanying explanation of the origin, physical setting, and hydrologic interpretation of each feature;
- An *Episodic Stream Indicator Data Sheet* integrated with the *Atlas* as an example approach to identifying landscape forms, their surficial geology, and organizing and documenting the observations made to determine the boundaries between active streams and fluvially inactive uplands;
- Graphical estimators of sediment grain size and percent cover;
- *Glossary* of terms used in the document, and
- References.

In addition, MESA:

- Recommends the **minimum** scale for field mapping and data presentation be 1:6000 (1 inch = 500 feet or 2.54 cm = 152.4 m).
- Recommends that delineation reports and maps be overseen by an appropriately experienced licensed Professional Geologist (PG) or geomorphologist;

- Standardizes terminology to describe the geomorphic units in an episodic fluvial system (uplands, terraces and interfluves, islands, floodplains and secondary channels), and the recency of fluvial activity in channels (active, dormant, abandoned, relict);
- Clarifies appropriate standards and regulations to be used in delineation reports, and
- Discusses how MESA delineations are integrated with other state and federal permitting processes.

To test its effectiveness, in Chapter 5, the researchers applied the MESA protocols to six reference sites, three that have been previously delineated in renewable energy project permit applications, and three that have not been previously delineated. In all cases, they found the MESA protocols produced accurate and comprehensive portrayals of the sites' streams.

CHAPTER 1: Introduction

1.1 Overview

Meeting California's energy needs in the 21st century requires the careful development and application of new and existing ecologically sustainable technologies. This is particularly true given the clear mandate to increase the use of solar and other renewable sources to meet the growing energy demand. In response, public partners and private industries are developing and planning to implement numerous, large-scale, renewable energy facilities.

Proposed, utility-scale facilities would cover hundreds to thousands of acres, mostly in arid and semi-arid ("dryland") regions of California. Most are planned to be sited on public lands where episodic streams – streams having only periodic flow – are dominant. Grading and drainage reconfigurations for utility-scale renewable energy facilities can greatly modify a site's watershed morphology and can adversely affect desert habitat.

Although mostly dry, recent studies have shown that the biodiversity and habitat values of dryland streams are considerably higher than in the adjacent uplands, transporting and delivering water, and providing linear habitat connectivity and refuge, and concentrating seeds, organic matter and sediment. Moreover, the ecological viability of the dryland environment depends on the sustainability of the physical/hydrological processes that form and maintain episodic streams and the habitat they support.

Historically, single-purpose flood management infrastructure for hazard protection was the predominant approach to accommodating development on alluvial fans. This approach depended upon a flood management system comprised of levees, debris basins, and hardened channels that captured water and sediment and conveyed it away from areas of risk to prevent property damage. While this approach to flood management has been effective at managing flood risk, extensive systems of concrete flood channels throughout Southern California have destroyed riparian and wetland habitats, reduced groundwater recharge, and created extensive maintenance obligations. The current best management practice however, is to integrate flood management with land use that conserves the beneficial values provided by alluvial fans through locally cost-effective sustainable development methods.

1.2 Natural Resource Conservation

The people of California place great value on streams, wildlife, and habitats associated with them, and have put various measures in place to protect and conserve these natural resources. The Fish and Game Code (F&GC), requires that the Department of Fish and Wildlife (CDFW) be consulted if a proposed development project has the potential to detrimentally effect a stream and thereby wildlife resources that depend on a stream for continued viability (FGC Division 2, Chapter 5, section 1600-1616).

The purpose of the consultation is to characterize the extent and nature of all stream resources on landscapes being considered for modification. A map of these resources is made and used to inform development project design so that the streams can preferably be avoided and

conserved, or where this is not reasonably possible, to identify the extent of the stream resources that may require conservation of similar resources elsewhere.

1.3 Statement of Need

Although fluvial processes are extensive in dryland landscapes, their extent is commonly overlooked during project planning, resulting in incomplete F&GC section 1600 et sequence Lake and Streambed Alteration applications. As well, recent events such as the July 2012 flood at the Genesis Solar Energy Project site show when development designs and siting decisions do not adequately consider the fluvial processes active on the landscape, not only is the ecosystem damaged, but also subsequent and often costly measures are required to protect a project's performance and initial capital investment.

Of the utility-scale renewable energy projects permitted or under consideration in the Mojave and Colorado Deserts of California, many are on public lands and are in part constructed with public monies. Thus, it is in the public interest to ensure that projects are designed and implemented using the most sustainable methods and with the least ecological impact. But to do this, the types and extent of stream processes active on the landscape must be adequately recognized and delineated, yet there is no consistent and scientifically based protocol to do this.

Both industry and public partners recognize the need to minimize or offset the negative impacts from these projects. Although the relationship between habitat and physical/hydrological processes in perennial streams in humid environments is well documented, it is less understood in episodic streams which are the predominant fluvial geomorphic features in dryland environments. The inappropriate transfer of perennial stream concepts, theories, and practices to arid regions has resulted in environmentally detrimental site designs, unnecessary delays to the permitting process, and unnecessary destruction of habitat. What is needed is a new method to effectively and economically identify the types, extent, and recency of stream processes active on the landscape so that information can be used to develop effective project designs and protect critical desert riparian habitat.

1.4 Goal and Objectives of the Agreement

The goal of the Agreement was to develop a consistent and comprehensive method to characterize and delineate the active watercourse processes and boundaries of episodic stream forms in the dryland environment.

The objectives of the Agreement were to:

- Produce a scientifically based, geomorphic and ecological stream delineation method that project developers or their representatives can use to inform the design and development of sustainable, low-impact projects in dryland environments;
- Facilitate renewable energy project permitting by providing agencies and project developers a rigorous and uniform delineation protocol;
- Develop a consistent method for by which oversight agencies can evaluate the type and extent of off-site mitigation for dryland streams, and

- Provide a formalized method with broad application for use in siting and permitting development projects, developing land use and resource management plans, and evaluating land use and resource management practices.

The goal and objectives were met through the accompanying Mapping Episodic Streams Activity (MESA) method.

1.5 Final Report

This final report describes the purpose, approach, results and conclusions of the work done under this Agreement, and includes the *MESA-Mapping Episodic Streams Activity Field Guide,* which is attached as a standalone volume.

CHAPTER 2:
Current Mapping Practices and Jurisdictional Considerations

2.1 Overview of Permitting Issues

The people of California have enacted environmental regulations to protect and conserve natural stream resources deemed to be valuable including ephemeral watersheds in desert areas. Unfortunately, due to misunderstandings of the F&GC jurisdictional criteria, a general lack of guidance, or improper conventions used to map the challenging physical and biological characteristics of episodic stream systems, many project developments fail to accurately describe the hydrologic conditions on the project site.

As noted in Chapter 1, there is currently no single or consistent, science-based method for mapping episodic streams. In the absence of such a tool, stream presence and extent is most often determined by the use of methods developed for other purposes, but that are ineffective in episodic systems that have widely fluctuating flows, lack iconic riparian vegetation, and have channel forms unlike those of perennial streams. Considering all these factors, it is understandable why so many episodic streams are excluded or overlooked in stream delineation reports, causing: (1) delays in the permit process; (2) inaccurate descriptions of on-site, hydrologic processes needed to make sustainable drainage designs; (3) vulnerability to infrastructure damage due to flooding or debris flow; and (4) or threats or damage to habitat caused by lack of avoidance or lower-than-appropriate mitigation for project impacts.

Inadequate delineation reports are often re-done in order for permits to be issued. As the case studies in Chapter 5 illustrate, stream delineation reports were re-done at least three times for the Ridgecrest Solar Power (El Paso Mountains), twice for the Rio Mesa Solar Electric Generating Facility (Palo Verde Mesa), and are being revisited for the second time at the Lucerne Solar Project (Lucerne Valley). Such re-mapping of the sites and re-submitting permit applications is costly to the project developer and reviewing agencies, results in delays in approval and construction, and can increase design costs if project footprints need to be adjusted to avoid or manage stream resources not originally considered.

2.2 Clarifying CDFW Jurisdiction and its Purpose

The F&GC requires that the CDFW be consulted if a proposed development project has the potential to detrimentally effect a stream and thereby wildlife resources that depend on a stream for its continued viability (FGC Division 2, Chapter 5, Section 1600-1616).

F&GC Section 1602 designates that **all** streams are subject to this code section. Although there are several mechanisms by which jurisdiction is acted on or resolved – each requires that all (or any) streams present on a site be identified in order to characterize the potential for adverse project-related impacts to them. F&GC Section 1600 et sequence jurisdiction extends to those streams subject to: (1) any potential detrimental impacts associated with the substantial diversion or the obstruction of the natural flow of a stream; (2) substantial changes to a stream's bed, channel, or banks, or the use of any material from the bed, channel, or banks; and (3) the disposal of debris or waste materials that may pass into a stream. A determination of F&GC

jurisdiction can only be applied once stream presence has been identified and a project design developed to a level of detail adequate for potential impact analysis.

2.3 Existing Stream Delineation Practices

Much of the work that has been done on fluvial systems has been in temperate regions on perennial streams that have a relatively regular and predictable presence of water and sediment, and readily recognizable channel forms and processes. However, dryland episodic streams have long recurrence intervals between their highly localized and difficult-to-predict surface-flow events, and often subtle channel features. Consequently, no single or consistent, science-based method exists for mapping and delineating dryland streams.

To compensate, stream delineation practitioners have often identified stream presence and extent by using survey methods and guidance developed for other purposes, and incorrect definitions and terminology. The following reviews problematic issues, conventions, and practices that commonly occur in site permit applications.

2.3.1 Obsolete Guidance for Jurisdiction

Title 14 CCR Section 1.72 Definition of a Stream

Many project applications incorrectly consider the definition of "stream" in Title 14, California Code of Regulations, Section 1.72 (14 CCR 1.72) as that used by the CDFW for jurisdictional purposes. The 14 CCR 1.72 definition of a "stream" was developed to address a specific sports fishing issue that came before the Fish & Game Commission, is not used by CDFW in general, and does not apply to F&GC Section 1600 et sequence.

By long practice, CDFW defines a stream as "a body of water that flows perennially or episodically and that is defined by the area in which water currently flows, or has flowed, over a given course during the historic hydrologic course regime, and where the width of its course can reasonably be identified by physical or biological indicators." The "*historic hydrologic regime*" is defined in practice by CDFW as circa 1800 to the present (Vyverberg and Brady 2013).

A Field Guide to Lake and Streambed Alteration Agreements

A number of projects have cited *A Field Guide to Lake and Streambed Alteration Agreements* as the guidance document for their stream mapping (CDFW 1994). A review of online environmental documents for projects throughout the state as recently as early 2013 used this document to determine F&GC jurisdiction or as guidance for the CDFW streambed alteration permitting process. However, due to its inaccuracies and unclear concepts, and to recent advances in fluvial geomorphology and ecohydrology, CDFW considers this document and its subsequent version of May 2000, to be obsolete: it has not been available from CDFW for more than a decade, and it is not to be used for jurisdictional determinations.

Ordinary High Water (OHW) as a Limiting Factor

Although methods to determine ordinary high water (OHW) levels are appropriate for defining the existence or extent of streams subject to federal jurisdiction, OHW protocols should not be used to define streams subject to state jurisdiction (Lichvar and others 2004, 2008; CDFW 2010). The concept of OHW was originally employed to delineate the extent of tidal and navigable Waters of the US. It is defined in the Code of Federal Regulations, Title 33, Part 328.3 as *"…that*

line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas."

While a number of western states have adopted the federal government's approach to delineating jurisdictional waters within their boundaries, the State of California does not. Rather, the California Water Code Section 13050(e) defines the Waters of the State separately and uniquely from the federal definition as *"…any surface water or groundwater, including saline waters, within the boundaries of the state."* The state definition places no limitation on the size of stream flow as is implicitly the case for the Waters of the United States (US).

Beneficial Uses as a Limiting Factor

Since the US Army Corps of Engineers (USACE) does not generally consider episodic streams to be Waters of the US for the purposes of enforcing section 404 of the Federal Clean Water Act, project developers often incorrectly assume that streams not recognized by the USACE are similarly unrecognized by the State Water Resources Control Boards (Water Boards). The lack of clear policy, pertinent definitions, and consistent use of terminology from the state agencies lends to the confusion. The State Water Boards have jurisdiction over **all** Waters of the State regardless of other designations, and all streams regardless of their beneficial use status are subject to F&GC jurisdiction.

Habitat Value as a Limiting Factor

Habitat value is an attribute that can certainly be used to inform resource management decisions, but it is not a consideration of F&GC section 1600 et seq. jurisdiction. CDFW assumes that where there is water there will be life, and the habitat used to sustain this life is to be protected.

Use of Descriptive Tools Developed for Other Purposes

Stream condition assessment protocols such as the California Rapid Assessment Method (CRAM--Collins and others 2008), or stream type classification systems like *Applied River Morphology* (Rosgen 1996) were not developed for use as stream mapping or delineation in the desert landscape (or anywhere else) and should not be used as such.

2.3.2 Existing Stream Mapping Practices and Conventions

Many project delineation maps and reports have incorrectly excluded streams based on criteria such as: (1) size, (2) duration or size of its flow, (3) weakly developed channel or bank form, (4) absence of riparian or wash-dependent vegetation, (5) absence of aquatic flora and fauna, (6) lack of hydrologic connectivity to other channels, or (7) quality of the habitat present. Similarly, the type of playa the stream flows into (such as dry and hard or wet and soft) has been cited as reason to exclude it from delineation. While these attributes certainly could influence project design or how to mitigate for project-related impacts, they are not a consideration in F&GC jurisdiction. The F&GC states that all streams and lakes are subject to Section 1600 et seq.

F&GC jurisdiction is exerted and (or) resolved by several mechanisms, but each begins with identifying all of the streams present on a site and a characterization of the potential for adverse, project-related impacts to the natural resources. F&GC Section 1600 et seq. was

enacted to conserve the fish and wildlife associated with stream ecosystems, places no limitations on the size of a watershed, the size of a stream, its duration of flow, or the absence of hydrologic connectivity to other waterbodies.

Stream Size as a Limiting Factor

It is common for site delineation maps to exclude small streams, even though they possess abundant indicators of recent flow, apparently because it is assumed that small streams contribute little to the ecosystem value. Smaller, more frequent, and highly localized flow events dominate the fluvial landscape of the dryland regions. These flows produce detectable vegetation patterns (for example, greater volume and height, or larger stem diameter) compared to upland areas. They also distribute sediment, seeds, and organic material as well as water, thus oftentimes supporting offsite habitats and biological populations beyond the boundaries of a project. Research suggests that the ecological importance of the more frequent flows in small, ephemeral streams may equal or exceed that in larger streams where surface flow is less frequent (CDFW 2010).

In summary, F&GC Section 1600 et seq. was enacted to conserve wildlife associated with stream ecosystems. The size of a watershed, the size of its streams, the duration of flows, and the absence of hydrologic connectivity to other waterbodies is immaterial. All streams are subject to F&GC section 1600 et sequence jurisdiction.

Exclusion of Upland Landscapes from Jurisdiction

Although most upland landscapes are dominated by terrestrial processes, they may also include swales, and first- and sometimes higher-order streams that are essential components of the larger streams and are therefore jurisdictional (CDFW 2010). We have included a location to describe their presence and the extent of their fluvial activity in the Upland section of the *Episodic Stream Indicators Data Sheet*.

Stream terraces and interfluves are upland landforms formed by fluvial processes no longer active , so are not jurisdictional. Terrestrial geomorphic indicators are characteristic and should be recorded on the *Upland Indicators* section of the *Episodic Stream Indicators Data Sheet*. Oftentimes however, features originally identified as terraces or interfluves upon closer inspection, are seen to contain indicators of active flow, so are actually floodplains. As such, they lie within the watercourse boundaries and subject to F&GC jurisdiction. Geomorphic and vegetation indicators of floodplains are identified in the *Watercourse Indicators* section of the *Episodic Stream Indicators Data Sheet*.

Misunderstanding of Channels and Watercourses

Most project delineation maps include streams in their most narrow confines. However, all functionally related channels and floodplains are part of the watercourse, and subject to F&GC jurisdiction. Certain fluvially inactive features, however, are not. Misunderstanding the functions of the channels and watercourses complexes leads to confusion and improper delineation.

<u>Floodplains</u> are the relatively flat areas of land associated with a stream, and over which water and sediment flows when the channel's capacity is exceeded. Floodplains usually parallel the stream channel, but may also occur at the terminal end of a stream where the channel joins an axial valley stream, transitions into a playa, or the channel ends and its stream flow spreads out

and seeps into the ground. Not every stream has a floodplain, but where floodplains do occur, they are integral to the stream's function and define the outermost limits of a stream's cross section and length. Indicators of flow on floodplains may be subtle (see *Photographic Atlas*), but should be documented on the Watercourse Indicators section of the *Episodic Stream Indicators Data Sheet*.

Transient channel forms are commonly overlooked as streams in project delineation studies because their features are often temporal and subtle. Compound, discontinuous and single-thread channel forms and combinations of these occur on alluvial fans where erosional channel segments alternate with depositional reaches that may lack a defined channel form (Thornwaite and others 1942; Schumm and Hadley 1957; Bull 1997; Field 2001). Across the fan, the stream channels tend to separate into distributary flows that 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. Regardless of variation in form along the way, these channels are still "streams" and therefore, subject to F&GC jurisdiction.

Islands are ecologically important bodies of land that generally lie within the watercourse. The unique habitat they provide are defined and generally formed by the water that surrounds, shapes, and interacts with them. The *Episodic Stream Indicators Data Sheet* includes spaces to record their details.

Well-defined Banks as a Limiting Factor

Many delineation maps include only those channels having well defined banks. The source of this *"well-defined banks"* criterion as applied to the Waters of the State is unknown. It is not used in the California Water Code, the F&GC, nor in practice relative to CDFW's administration of F&GC Section 1600 et sequence.

Streams and watercourses usually have banks that rise above and slope away from the bed. However, the degree of confinement along dryland ephemeral channels can vary, so the stream's banks can be slight or nearly imperceptible. Regardless of how subtle the channel topography is, if the physical and biological evidence for the location of a stream's waters at the highest level of confinement can reasonably be identified, then this line of flow defines the jurisdictional watercourse channel even though flow may be intermittent or ephemeral (CDFW 2010).

Top of Bank as a Limiting Factor

The source for the "top of the bank" as a criterion limiting jurisdiction is unknown, but it has been widely used to exclude small, first- and second-order streams that lack riparian vegetation on upland landscapes. In these areas, the stream ecosystem is maintained not solely by processes that occur below the top edge of a stream bank, but also by runoff from the adjacent upland surfaces above the stream bank. Although not structurally part of the main stream channel, these surfaces are hydrologically critical to maintaining the functional integrity of the stream ecosystem (McDonald and others 2004; Schwinning and others 2010). Project designs that maintain streams to the top of their bank but alter the runoff from the adjacent upslope landscape by grading and removing all the vegetation there can cause a complete loss of the functional integrity of the streams and hence, their ecosystems.

Absence of Aquatic Flora or Fauna as a Limiting Factor

Delineation reports have excluded streams that lack "*distinctive aquatic flora or fauna*". The Title 14, California Code of Regulations, section 1.72 (14 CCR 1.72) definition referring to streams as those that "…*support fish or other aquatic life"* may be the source of this criterion. However, F&GC Chapter 6, Fish and Wildlife Protection and Conservation states that Section 1600 et seq. was enacted to conserve the *fish and wildlife* associated with stream ecosystems, and it defines fish and wildlife as *"…all wild animals, birds, plants, fish, amphibians, invertebrates, reptiles, and related ecological communities, including the habitat upon which they depend for continued viability* (FGC Division 5, Chapter 1, section 45, and Division 2, Chapter 1, section 711.2(a), respectively). Whether or not a stream supports aquatic species is immaterial: F&GC Section 1600 et seq. jurisdiction applies to **all** streams.

Delineation by Vegetation

Although streams are defined by their geomorphic characteristics such as banks and channels, stream delineation mapping is often based primarily on their botanical expressions on aerial imagery and in the field. Regulation 14 CCR 1.72 refers to the current or past presence of riparian vegetation, and although it does not apply to the F&GC, it is often mistakenly cited as the stream definition used by the CDFW, which may explain why the presence of riparian vegetation is sometimes misused as a requirement of F&GC jurisdiction.

In practice, the LSA Program defines riparian areas as: "*areas adjacent to….intermittent, and ephemeral streams or lakes…..that are transitional between terrestrial and aquatic ecosystems and that are distinguished by gradients in biophysical conditions, ecological processes, and biota; an area through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. Riparian areas include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence*)" (NRC 2002). This definition does not rely on the presence of riparian plant species to define a riparian area.

Although vegetation signatures on aerial imagery are a good way to define areas for detailed field examination, vegetation is not a substitute for documenting the physical evidence of a stream's presence when determining jurisdictional watercourse boundaries.

CHAPTER 3:
Developing the MESA Protocol

3.1 Existing Resources for Identifying and Characterizing Episodic Streams

The need to understand the distinctive physical, hydrologic and ecological processes of episodic streams is increasingly acknowledged as critical to the development of fast-tracked construction of environmentally appropriate, sustainable, and cost-effective, renewable energy projects. The following resources provide tools and information useful for developing and ecologically managing episodic stream landscapes. Included are methods to identify fluvial processes active on alluvial fans, the potential distribution of floods and debris flows, and areas where anthropogenic activities may detrimentally impact stream flow patterns.

3.1.1 Guide to Episodic Stream Forms & Process

A Review of Stream Processes and Forms in Dryland Watersheds was developed by CDFW as a science-based approach to identifying dryland streams for the non-scientist (CDFW 2010) and therefore, as a starting point for interpreting landform relations and stream activity. The document synthesizes the scientific literature of stream processes and forms in dryland watersheds, and describes the most common stream forms and the associated processes and functions that must be identified to correctly map them.

3.1.2 Alluvial Fan Task Force

Alluvial fans are common landforms at the base of mountains in the arid landscape of southern California, and tend to be popular places to locate private residences as well as commercial enterprises – such as utility-scale renewable energy projects. Flooding is a normal process on alluvial fans, but tends to be triggered by intense, short-duration rainfall and thus flashy and unpredictable.

Compared to river floods, predicting the flow path of alluvial fan floods with their highly erosive soils mixed with water, rocks, boulders, trees and structural debris, is much less certain. River flood paths are usually quantified in linear distance, but alluvial fan flood paths are quantified in area. Because their flow characteristics are so different, flood hazards on alluvial fans cannot be managed by river flood standards.

In order to better protect life, property, and natural resources on alluvial fans, in 2007, the Department of Water Resources (DWR) in a partnership with the California State University, San Bernardino Water Resources Institute established the Alluvial Fan Task Force (AFTF). The AFTF has developed assessment tools that are useful for identifying the fluvial processes active on alluvial fans, the potential distribution of alluvial fan floods and debris flows, and should to be consulted early in the stream delineation process. The AFTF reports are available online at http://csusb.edu. This is valuable information

3.1.3 Geologic Compilation of Quaternary Surficial Deposits in Southern California, Special Report 217

In 2012, the Department of Conservation's California Geological Survey (CGS) released Special Report 217 – a compilation of maps of surficial deposits, including active stream deposits, in

southern California. CGS identified geologic hazards and natural resources, including streams, that could affect or be affected by development on alluvial fans in San Bernardino, Riverside, Los Angeles, Ventura, Santa Barbara, San Luis Obispo, Kern, Orange, Imperial, and San Diego Counties.

Older geologic maps of California group young alluvial deposits into a single unit identified as "Qal"- Quaternary alluvium (less than about 1.8 million years old). Because these deposits are often related to various geologic hazards such as seismic amplification, liquefaction, and expansion, many modern geologic maps focus on urbanizing areas and show details of Quaternary-age deposits such as their depositional origins, relative and absolute (radiometrically dated) age, grain size, and engineering properties. But, these maps also indicate where streams have deposited sediment on alluvial fans in the geologically recent past because areas of most recent deposition during Late Holocene time (within the last 500 years) are the most prone to damaging flooding and debris flows. Conversely, areas underlain by older alluvial deposits are less likely to be damaged. Therefore, mapping these deposits is a high priority (CGS 2012). The entire database of this work including GIS and PDF maps, and report are located at: http://www.consrv.ca.gov/cgs/fwgp/Pages/sr217.aspx.

3.2 Developing the MESA Protocols

To develop the MESA protocol, we:

- Identified the most salient issues preventing or inhibiting effective delineation of episodic streams in dryland watersheds;
- Reviewed and compiled existing literature;
- Selected a technical advisory committee (TAC) to guide the process and critically review the products;
- Selected a pool of reference sites that exemplify the most salient watershed morphologies, processes, conditions, and issues pertinent to permitting renewable energy projects;
- Conducted preliminary field reconnaissance mapping and documentation at the sites;
- Compiled a trial set of protocols for field documenting watershed conditions and features at reference sites; and
- Field tested and reviewed the protocols, selecting those most effective.

3.2.1 Identifying the issues preventing or inhibiting effective delineation of ephemeral watersheds

Our examination of numerous stream delineation reports revealed several persistent shortcomings or inadequacies that prevented effective description of the watersheds on the project sites, and accurate calculations of jurisdictional watercourse subject to mitigation.

- Maps and diagrams indicate what are and what are not active and thus not subject to F&GC jurisdiction, yet the field data and criteria used to make this determination are typically not included.

- The criteria for identifying "jurisdictional watercourses" are often obsolete, erroneous, or missing.
- Geomorphic features, especially those indicating presence or recency and spatial distribution of flow, are overlooked in the stream delineations. This is significant because it underestimates potential project impacts on stream resources, as well as under-reports the potential of fluvial processes to affect a project's overall sustainability.
- Terminology relating to fluvial geomorphic features, particularly those indicating activity and type of stream flow is inconsistent with current scientific use, and among siting permit documents.
- The scale of mapping is too small to allow sufficient evaluation of the site conditions.
- Much of the watershed mapping is being done by staff with apparently no or minimal formal training in arid landscapes or fluvial geomorphology.

Rectifying these issues would improve the overall veracity of the fluvial hydrology, ecologic, and hydraulic elements of the site reports and stream delineations, and facilitate evaluation of these reports.

3.2.2 Reviewing and Compiling Literature

We read and compiled a bibliography of references regarding stream delineation methods, dryland hydrologic processes, alluvial fan features, biological relationships, and renewable energy project siting applications. These works, included in Appendix F, provide essential background to practitioners working in the field.

3.2.3 Selecting the Technical Advisory Committee (TAC)

We wanted a TAC representing the breadth of potential users of the protocol. Our Technical Advisory Committee, which provided guidance and oversight, consisted of the following physical and biological specialists:

- Kit Custis, Consulting Engineering Geologist and Hydrogeologist
- Carolyn Chainey-Davis, Consulting Botanist
- Serge Glushkoff, Environmental Specialist, Renewable Energy Program, Department of Fish and Wildlife
- Todd Keeler-Wolf, Ecologist, Biogeographic Data Branch, Department of Fish and Wildlife
- Jeremy Lancaster, Engineering Geologist, California Geological Survey

In consultation with our TAC, over two meetings, we: (1) reviewed the tentative Project approach based on the proposal; (2) evaluated existing watershed regulations and policies, and protocols (state, federal, and the California Rapid Assessment Method-CRAM) for assessing watersheds and their applicability to episodic watercourse; (3) developed a list of 15 candidate reference sites for field examination and specific field methods to be used to evaluate landscape morphologies, processes, and conditions; (4) discussed related ongoing research and habitat considerations; (5) discussed overall project progress; (6) reviewed and critically evaluated a draft of the protocols including the *Episodic Stream Indicators Data Sheet*, the *Photographic Atlas of*

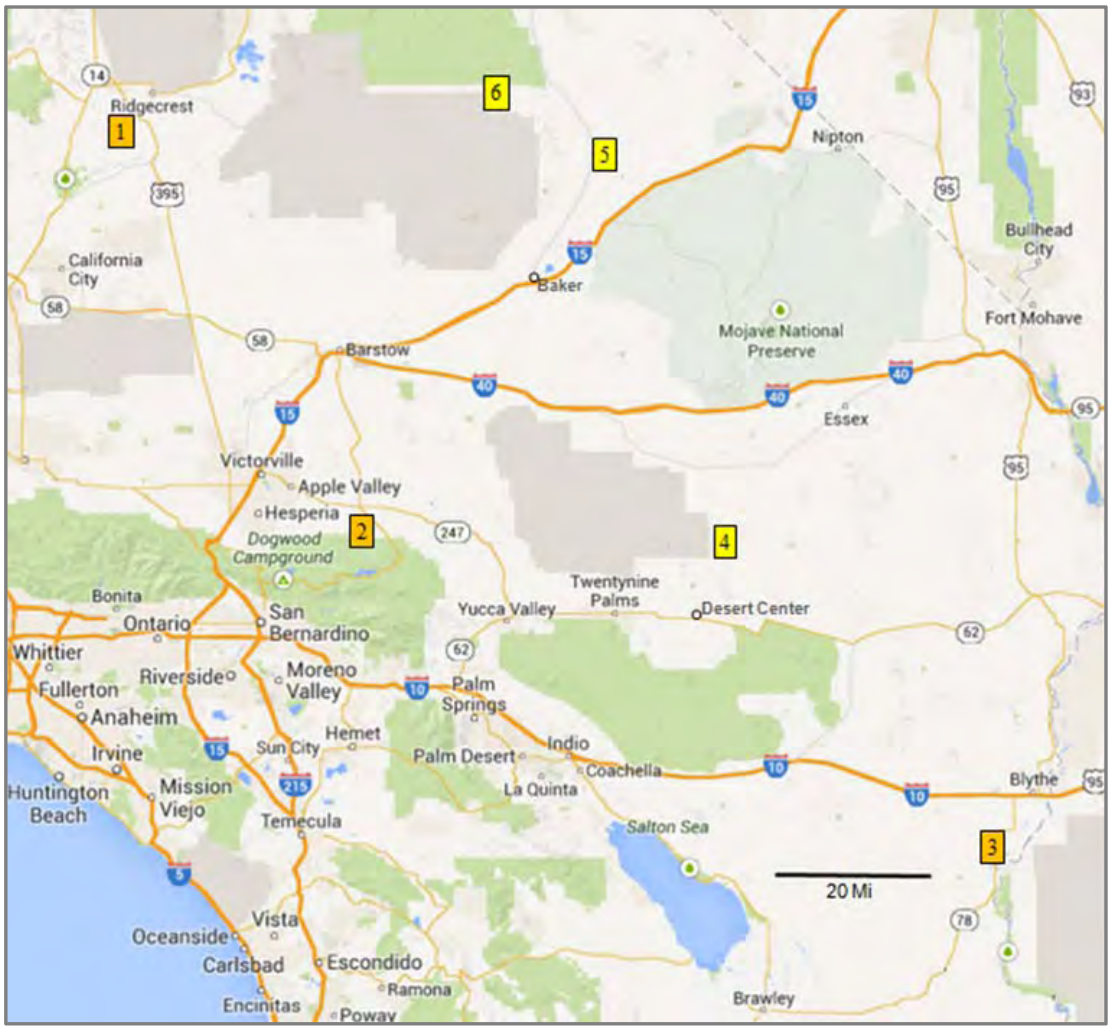
Indicators of Episodic Stream Activity; (7) evaluated stream delineation reports from three of the sites, and (8) mapped the streams in three of the reference areas not previously delineated (See #4 below).

3.2.4 Identifying Reference Sites Exemplifying Watershed Morphologies, Processes, Conditions, and Issues

In collaboration with our TAC, we developed a list of landscape morphologies, processes, and conditions, typifying those encountered in proposed, utility-scale solar energy projects in California, and identified 15 locations in the Mojave and Colorado deserts that had these characteristics. After a field reconnaissance, we selected six reference sites for our project: three having been previously delineated for solar project permits (El Paso fan, Lucerne Valley fan, and Palo Verde Mesa), and three that have not been studied in this context (Coxcomb Mountains, Silurian Hills, and the Avawatz Mountains) (Fig. 1). Each is briefly described below and their stream delineations using the MESA protocols are described in Chapter 5.

Figure 1: Location of reference sites in southern California delineated in this report (those under development review in orange).

1. El Paso Fan
2. Lucerne Valley fan
3. Palo Verde Mesa
4. Coxcomb Mts fan
5. Silurian Hills fan
6. Avawatz Mts



Previously Delineated:

We examined previously delineated sites to evaluate the methods and conclusions reached, and to discuss discrepancies where our MESA delineation differed from that in the project consultants' reports.

El Paso Fan

El Paso fan is located south of the town of Ridgecrest in northeastern Kern County, on the north flank of the El Paso Mountains (Fig. 1). The site is a moderately-inclined and deeply eroded fan complex that supports several active, major channels, and numerous minor ones that dissect an older fan surface (Fig. 2). It includes excellent exposures of old and recent fan and fluvial features, channels and flow sequencing, and distinct drainage-vegetation relationships.

The solar project planned at this site is under development review, however, we noted persistent and significant inconsistencies between the project developer's original reports and maps and the results of our site mapping reconnaissance.

Figure 2: El Paso fan and view across El Paso Wash west of Ridgecrest, Kern County. El Paso Mountains in background.

Lucerne Valley Fan

Lucerne Valley fan is located on the northeast side of the San Bernardino Mountains (Fig. 1). The site is undergoing a non-CEC permit review for a photo-voltaic energy project (Fig. 3). In the stream delineation report, the project consultant determined that few streams were subject to F&GC jurisdiction based on the absence of well-defined banks. Where banks became less defined the stream ceased to exist from a jurisdictional perspective. During our reconnaissance there, we identified numerous streams on the basis of their abundant bedforms indicating recent flows. The consultants' inability to recognize indicators of stream flow and thus stream presence suggests the need to educate field practitioners about the transitional nature of the fluvial processes and variability in dryland episodic stream form.

Palo Verde Mesa

Palo Verde Mesa is located in the Colorado Desert along the border of Riverside and Imperial Counties, south of Blythe in Riverside County (Fig. 1). Palo Verde Mesa is a complex of nearly planar alluvial fans of low relief crossed by numerous shallow channels, and deeply incised by a few, major through-going channels (Fig. 4) where most of the plants and animals concentrate. The vegetation is typical of the Colorado Desert subregion of the Sonoran Desert and is distinctive from that of the other reference sites in the Mojave Desert. Consultants' reports illustrate numerous channels and tributaries in detail. We examined a part of this site and overall, concurred with the consultants' delineation.

Figure 3: Lucerne Valley fan, San Bernardino County. View downstream toward Cougar Buttes.

Figure 4: Palo Verde Mesa. View across relatively planar surface of a relict alluvial fan on the right and a deeply incised channel on the left. View upstream toward Mule Mountains in background, Riverside County.

Sites Not Previously Delineated

To test the MESA protocols for effectiveness and practicality, we mapped three areas not previously delineated, but representing a range of conditions that could be encountered in potential, utility-scale renewable energy facility sites.

Coxcomb Mountains Fan

The Coxcomb Mountains fan is north of Desert Center on the east side of Coxcomb Mountains of Riverside County where the Mojave and Colorado Deserts ecosystems meet (Fig. 1). The fan has low relief and drains eastward toward Palen (dry) Lake and a belt of sand dunes to the north (Fig. 5). The woody plants in the region are dominated by creosote. The Coxcomb range is composed almost entirely of granite, illustrating the important role that source material plays in the formation of desert drainage systems: because granite so readily weathers to granules and sand, nearly all of the sediment along the entire length of the fan is much smaller than what normally occurs on alluvial fans. The channels are shallow and ill defined, out-of-channel flow is common, and uplands are weakly expressed.

Figure 5: Coxcomb Mountains fan; view downstream toward Palen Lake, Riverside County.

Silurian Hills Fan

The Silurian Hills are located north of Baker in San Bernardino County (Fig. 1). The fan complex drains the Silurian Hills westward into Silurian Lake. The main fan is a composite of two, lower fan segments, the larger of which receives significant water from Wingate Wash to the north. Old, relict fan surfaces contain abundant eolian sand. The distal fringe is interbedded with playa deposits (Fig. 6). The presence and distribution of vegetation is strongly controlled by drainage. This site was selected because its streams merge with a playa, it has numerous

distributary channels at the playa fringe, and eolian sand strongly influences both the channel form and vegetation patterns.

Avawatz Mountains- Sheep Creek Fan and Pipeline Wash

Sheep Creek fan and Pipeline Wash lie on the northern flank of the Avawatz Mountains in San Bernardino County (Fig. 1). Both fans have high relief and drain into the Amargosa River, which flows westward then northward into Death Valley.

Sheep Creek fan drains solely diorite bedrock. It includes three prominent segments of differing ages, a variety of age indicators, well exposed cross sections, active and relict channels, and simple but well defined relations between stream channel location and the presence of vegetation (Fig.7).

Figure 6: **Silurian Hills fan, view west toward Silurian Lake and Avawatz Mountains, San Bernardino County.**

Figure 7: Sheep Creek fan looking upstream toward the Avawatz Mountains, southern Death Valley, San Bernardino County.

Pipeline Wash is active across most its width, and drains an area of soft, sedimentary strata, so the fan, although proximal to Sheep Creek fan, is much finer grained (frequent mudflows), and channels are poorly developed. It includes three prominent segments of differing ages, a variety of age indicators, well exposed cross sections, active and relict channels, and simple but well defined relations between stream channel location and the presence of vegetation.

These sites were selected because although they both drain into an a axial valley stream (Amargosa River) and are adjacent to one another, the fans' morphologies and flow mechanisms are very dissimilar owing to the different sizes of their watersheds and to the different rock types there.

3.2.5 Conducting Geomorphic and Botanical Field Studies at Reference Sites

To develop the field methods that eventually became the MESA protocols, we completed detailed surveys of channel processes, forms, and functional biological relationships at each of the six sites using the following methods.

Analysis of Aerial Images

We examined high-resolution aerial imagery from Google Earth Pro for all six reference sites, and proprietary imagery available through CDFW. We then documented large- and small-scale geomorphic features pertinent to the "issues" identified in Chapter 2, and laid out potential traverses (transverse or longitudinal) on aerial images to be documented in the field.

Field Mapping and Documentation

Over the course of three, separate, field campaigns, at each site, we used a tape measure or electronic distance measuring device (EDM) to lay out the three to five traverses we had previously identified on the aerial imagery. The traverses ranged from a few hundreds of meters to over a kilometer. Along each traverse, we quantitatively described, interpreted, and photographed pertinent geomorphic features and made notes regarding the vegetation. Photographs were taken using a 35 mm digital camera, usually from the top of a 2.4 m step ladder which provided a much better perspective than ground-level photos would.

Electronic Field Mapping with GPS

We initially conducted our field mapping on high-resolution, paper, aerial imagery. However, after researching various types of field computers and tablet software, including the $5,000 Trimble GIS, we concluded that a 64GB Apple iPad running Garafa GIS software provided superior capability. The program allowed us to download and cache Google Earth Pro and Bing digital aerial images and base maps on the iPad and access them in the field.

In the field, we located and stored photos and field data such as vegetation transects, cross-sectional profiles, soil pits, and infiltrometer tests (Figs. 8 and 9). We also tested the accuracy of the iPad's built-in GPS capability using a pro-model, hand-held Garmin GPS; the iPad and GPS consistently located within 2 meters or so of one another, which was satisfactory for our purposes.

Back in the lab, field data was transferred from the iPad to ArcGIS for "clean up" and processing, and compiling the final delineation maps of each reference site (Chapter 5; Appx. A).

Botanical Mapping/Documentation

Carolyn Chainey-Davis, a member of the Project's TAC, generously completed numerous longitudinal and cross sectional botanical surveys further allowing us to discriminate between "active", "inactive", and "relict" channels based on plant composition, abundance, and vigor. As well, she contributed essential guidance in developing botanical aspects of the MESA *Episodic Stream Indicators Data Sheets*.

Figure 8: Example direct output of field survey data from El Paso Wash produced in the field using an Apple iPad with internal GPS on Google Earth base aerial image and Carafa GIS software

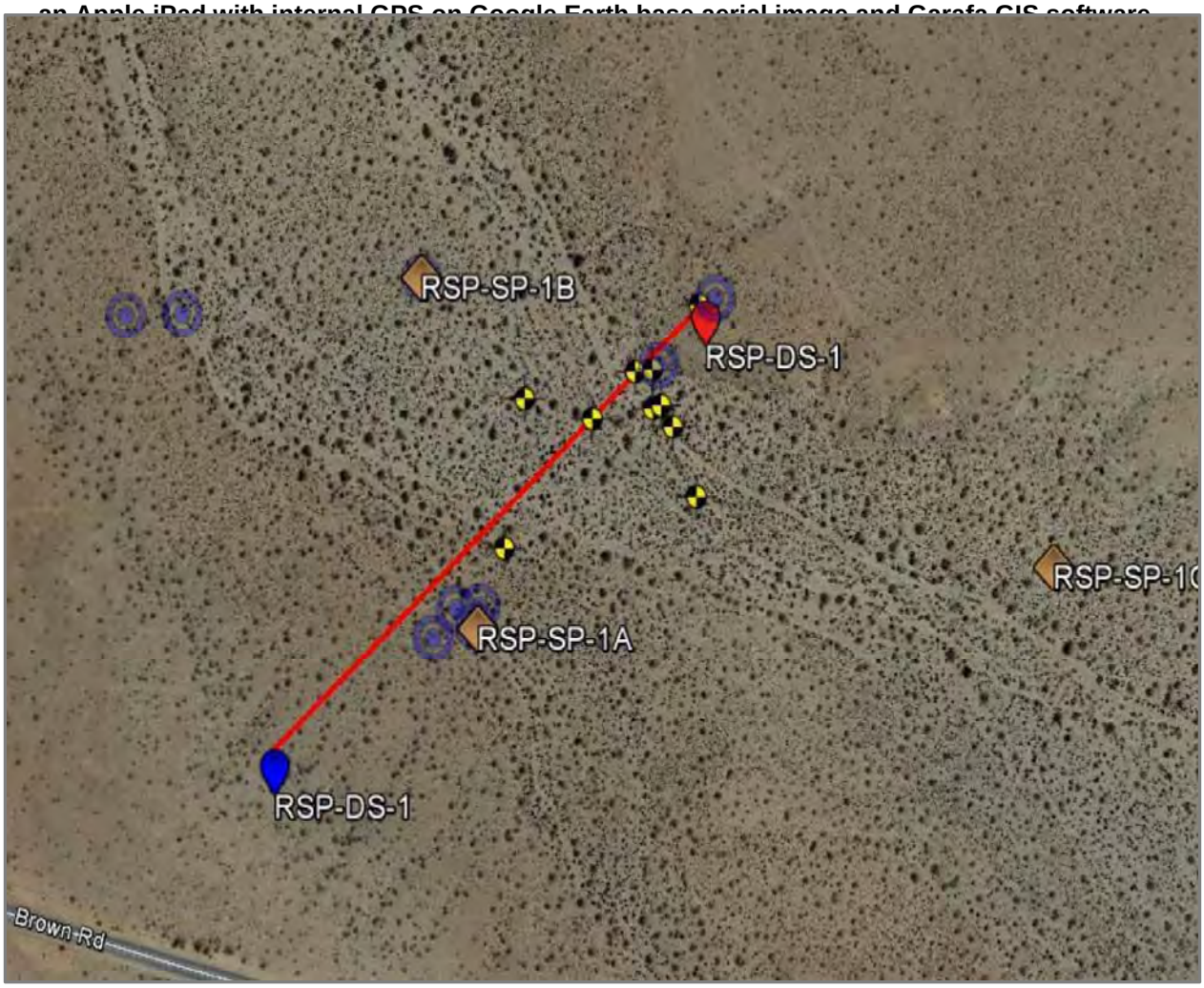
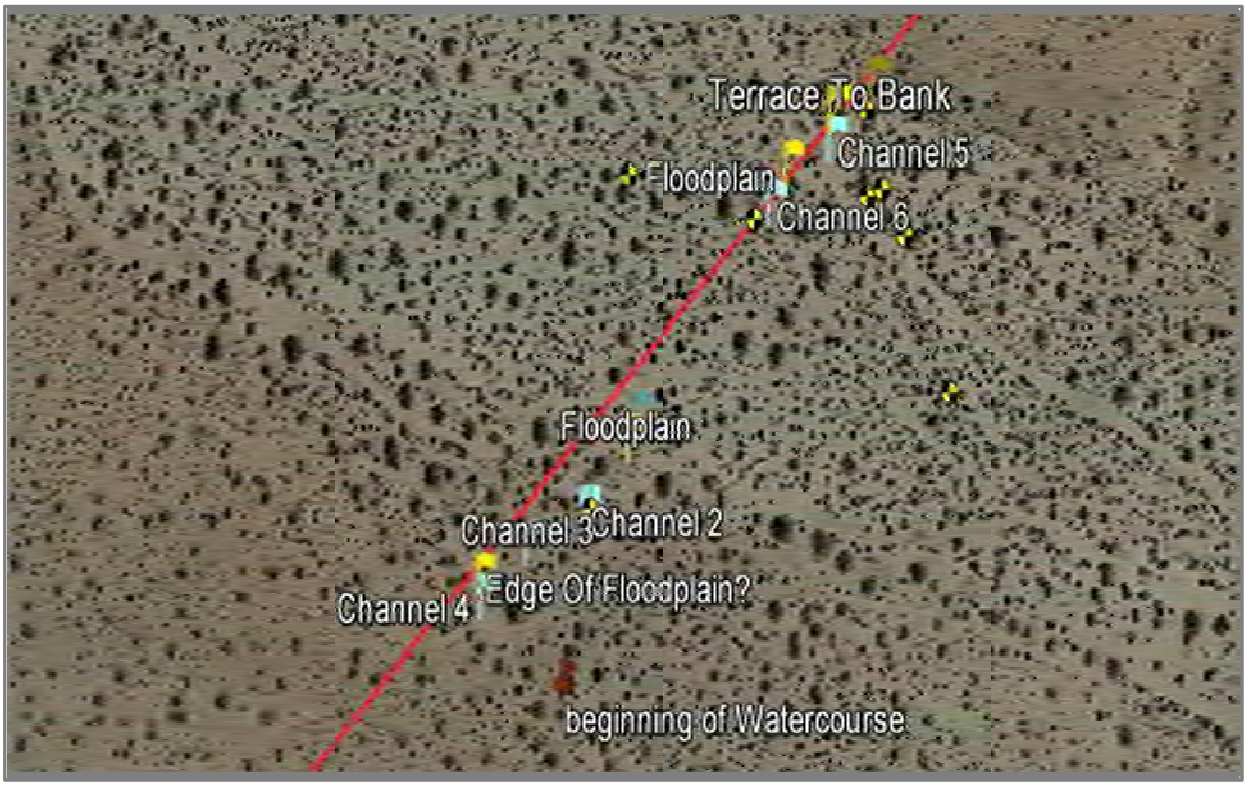


Figure 9: Detail of Figure 8 at El Paso Wash (EPW) showing the location of cross-section 1 (XS-1), geomorphic units and photo locations. Output directly from Apple iPad with internal GPS using Garafa GIS software.



Infiltration Testing

Important to identifying which parts of the potential development sites constitute "streams" and thus state jurisdictional watercourses is understanding the role of the fan surfaces in the overall drainage, and whether the uppermost part of the ephemeral watershed (typically referred to as swale) is actually part of the stream. Because the extent of these areas often cannot be defined based on geomorphologic observations alone, we conducted double-ring infiltration tests at the study sites as an indicator of their initial rainfall runoff conditions (Appx. C).

The double-ring infiltrometer test is used to measure the infiltration rate of soils, which is the amount of water per surface area and time unit that penetrates the soils. This infiltrometer consists of two, concentric metal rings 15.2 cm tall; the outer ring is 45.7 cm in diameter (Fig. 10). Both rings are welded to a metal cross bar fixing them as a single unit which is driven into the ground to an approximate depth of 5 cm using a wooden striking plate and 2-pound hammer. The infiltrometer is leveled with a spirit bubble and water is quickly poured into both rings using a deflector to prevent scour of the substrate.

Figure 10: Double-ring infiltrometer.

Immediately upon filling, an operator records the decline in water level in the inner ring (measured as "depth" from the top of the infiltrometer) over established time periods (such as 15 seconds, or 30 seconds) as measured with a stopwatch (Fig. 11). The water is allowed to seep into the soil without replenishment (a "falling head" condition) unless the infiltration is so rapid, refilling is required. Water seeping from the outer ring exerts an "hydraulic wall" so seepage from the inner ring is one-dimensional (downward rather than lateral) thus creating a more realistic simulation of early-stage, natural rainfall-induced infiltration (pre saturation), and to simplify the analysis of data (Bouwer 1961, 1986; Johnson 1966).

The downward infiltration rate depends on the soil's texture, structure and stratification (heterogeneity), the initial moisture content, the depth to an impervious layer, and the groundwater level. Since most of the soils we tested are heterogeneous, and many have subsurface layers of low permeability, we expressed our data as time-averaged infiltration for comparative purposes only, and do not consider them to represent absolute values.

Figure 11: Conducting infiltration test, Pipeline Wash, Avawatz Mountains.

Our tests throughout the six reference areas produced consistent and distinctive values for the fan surface, swales, tributaries, and main channels (Chapter 5) and most significantly demonstrated that there can be over an order of magnitude difference in the infiltration rate between the fan surfaces and the channels upon them. This supports the contention that the fan surfaces play an important role in directing runoff into the channels. As well, the swale areas tend toward greater infiltration as they merge with tributaries and thus appear to be an integral part of the stream.

Although infiltrometer testing proved useful in our determinations, we decided not to include it in the MESA protocols, but recommend it in cases where greater resolution is needed in site permitting to determine stream presence.

Soil Pits

We excavated soil pits at each reference site, conducting an infiltrometer test at each. We dug pits, approximately 1 m long, 0.6 m wide and up to 1 m deep, using a pick and shovel (Fig. 12) (Appx. B). The pits were shallow because we were most interested in the most recent history. Where soil was highly cemented, excavation could take 45 minutes to an hour. Once the pit was dug, we smoothed the sides using a hand trowel, and blew away the dust using canned compressed air. We then logged (described in sequence) the sediment and soil layers based on the US Department of Agriculture system, but modified for our specific needs details about the sedimentary strata and interpretations regarding their depositional environment.

We paid particular attention to surface and sub-surface features indicating age, including presence of Av, Bt-Bw, and petrocalcic horizons. These were important to determine the level of fluvial activity in channels and on surfaces.

Although we found the soil pits to be very useful, we did not include them in the MESA protocols because they are often time consuming to dig, log, and refill (one pit can take two hours); and logging of this type requires special expertise in soils and geology beyond that of most field personnel, and even many geologists. In many cases, soils in stream banks are sufficiently well exposed that pits do not need to be dug, but where topography is subtle,

excavating a soil pit may be the only way a determination can be made, such as whether a feature is a terrace or floodplain. In these cases, soil pits should be dug.

Figure 12: Logging a soil pit, El Paso Wash. Photo by Singleton Thibodeaux-Yost.

3.2.6 Compiling the MESA Field Guide and Protocols

To address the specific issues noted in Section 1 above; to improve the overall veracity of the fluvial hydrology, ecologic, and hydraulic elements of the site reports and stream delineations; and to assist in the evaluation of these reports, we selected specific methods to be included in the Mapping Episodic Stream Activity (MESA) protocol. The criteria for selection were: (1) Practicality: can the method be reasonably completed during the course of a field survey? (2) Significance: will the data obtained faithfully represent the overall conditions at the site?, and (3) Applicability: will the data inform decisions regarding how to address drainage issues at the site, and to accurately determine what is not an active stream and thus a jurisdictional watercourse.

The MESA protocol involves three steps to effectively delineate episodic streams:

1) Recognizing the stream forms and processes—gathering information on a site's physical characteristics in collaboration with a licensed Professional Geologist or geomorphologist with appropriate experience in desert systems;

2) Documenting the extent of on-the-ground indicators of fluvial activity and inactivity, and;

3) Mapping the watercourse.

On the basis of needs described here and in Chapter 1, and on the above criteria, we developed the MESA Field Guide (Attachment) which is intended to be a complete, stand-alone guide to be used in the field by personnel undertaking delineation and assessment of dryland episodic streams and watercourses. The MESA field guide includes:

A) A narrative section;

B) Practitioners' qualifications;

C) Recommended map scale;

D) Notes to the delineator and project reviewer;

E) A field data sheet for recording geomorphic indicators;

F) A photographic atlas of indicators of episodic stream activity;

G) A glossary of technical terminology; and

H) References.

A) The Narrative Section

The narrative section contains essential information needed to properly delineate episodic streams. It (1) reviews the physical characteristics and ecological significance of ephemeral streams in the California desert; (2) describes methods used to map ephemeral streams including existing mapping protocols, their applications (and misapplications) and limitations; (3) describes regulations relating to jurisdiction; (4) reviews episodic channel forms and geomorphic elements significant to the delineation process, and; (5) and offers guidance on defining the jurisdictional watercourse boundary. The technical foundation for the Field Guide and protocols is based on the CDFW (2010) *Review of Stream Processes and Forms in Dryland Watersheds*.

B) Practitioners' Qualifications

Although the applicants' stream delineation maps represent the elements of the site geomorphology, we have noted that little of the mapping is being done by geologists or geomorphologists, or by personnel having geologic/geomorphic training appropriate to do this type of arid lands fieldwork – for example geographers with specialized training in hydrology and geomorphology.

In addition to the permitting delays that inevitably result from stream delineation maps developed by what the evidence reviewed suggests are not appropriately trained and experienced earth scientists, work that includes geologic interpretations of the landscape or the relationship of a landform to underlying geologic structures must be done by a licensed geologist. The California Department of Consumer Affairs Board for Professional Engineers, Land Surveyors, and Geologists requires that, with few exceptions, geological work done in the state be conducted by a licensed geologist.

> CCR Title 16, Division 29, Section 3003: (d) *Professional geological work…[is] the application of scientific knowledge, principles and methods to geological problems…in investigating, measuring, interpreting and reporting on the physical phenomena of the earth.*
>
> and
>
> *(f)(2) The practice of geology…[includes] when geological reports, documents or exhibits constituting the practice of geology are disseminated or made available to the public or any individual…*

The MESA protocol recommends that the geomorphic aspects of the stream delineation element of a permit application be reviewed and approved by a geomorphologist or a licensed professional geologist with experience in arid region watersheds. This will increase the

likelihood that the geomorphic field work being conducted and used to inform project siting and design decisions is consistent with current professional standards of practice, abides by current state law, and will certainly reduce the chance that the delineation report will be rejected due to preventable errors or the absence of oversight from personnel with appropriate expertise.

C) Map Scale

The most fundamental mapping protocol is scale. In many of the permit applications we reviewed, the final delineation was conveyed on a scale too small to show many streams that upon field examination proved to be active and ecologically important. Recognizing the need to balance cost (= time) with an appropriate level of detail needed to make permitting decisions, we recommend that 1:6,000 (in = 500 ft or 2.54 cm = 152.40 m) is the **minimum** scale that sites should be mapped for permit applications since smaller scales do not allow the features needed to identify stream or botanical features to be noted. Completed delineation maps should be presented at a scale no smaller than this. However, we commonly mapped the reference sites at scales much greater than that (up to 1: 2,000) due to their complexity and density of features.

D) Notes to the Stream Delineator and Project Reviewer

Among other details, MESA recommends that vegetation mapping be separate from the stream mapping, and be conducted only by biological specialists with the appropriate expertise. It should be based on the classification system described in the California Native Plant Society and Department of Fish and Wildlife *Manual of California Vegetation*; it is the state standard for classification and mapping, and it is consistent with the national vegetation mapping classification system (Sawyer et al 2009). Plant communities should be documented in the field using the Protocol for Combined Vegetation Rapid Assessment.

E) Episodic Stream Indicators Data Sheet

After reviewing hundreds of our photographs and field descriptions, we compiled what we believed to be the essential data that should be collected into a field data sheet. The data sheet is intended to guide field assessment in a comprehensive and consistent manner. The guide underwent 13 iterations during the course of our field studies, and was extensively reviewed by our TAC, and tested in the field by the TAC member most experienced in dryland stream delineations.

The *Episodic Stream Indicators Data Sheet* includes a preface to be filled out during the preliminary phase of aerial image interpretation, and subsequent quantitative field sections to describe uplands, watercourses and channels, and areas of ponding/evaporation.

F) Photographic Atlas of Indicators of Episodic Stream Activity

One of the most notable aspects of delineation reports on sites we reviewed was the tendency to overlook entire stream channels, or not recognize indicators of fluvial activity in mapped channels then assigning terms like “abandoned”, “inactive”, or “relict”, thus excluding these streams from F&GC jurisdiction.

In episodic streams where flow may only occur every few years, evidence of that flow (activity) may be hard to recognize. However, it is incumbent on the field investigator to recognize the difference between a truly abandoned channel (one that has become hydrologically disconnected from its source), and one that has simply not experienced recent flow. To that end, we developed a photographic atlas (MESA, Chapter 6) using our own imagery and a

description of origin and occurrence, of geomorphic features indicating processes pertinent to this line of investigation. We divided the Atlas into: (1) Upland, terrestrial features indicating antiquity, or lack of fluvial activity; (2) Watercourse, fluvial features formed by transport, deposition, or out-of-channel flow; (3) Watercourse features formed by fluvial erosion; and (4) Watercourse and playa features formed by ponding or springs. It is our intention that field practitioners use this guide as they fill out the accompanying *Episodic Stream Indicators Data Sheet*, described below.

G) Glossary of Technical Terms

The goal of effective site reports is not only to be understood, but to not be misunderstood. The use of current, consistent, and scientifically defensible terminology will go a long way towards rectifying much of the confusion and will help to produce more accurate and technically sound delineation reports. The terms included here were compiled after concerted review of current, peer-reviewed publications and other documents.

H) References

Citations for sources of information and definitions used in the Glossary.

3.2.7 Testing the MESA Protocols

After selecting the MESA protocols and developing the *Episodic Stream Indicators Data Sheet*, we tested their applicability by completing stream delineation maps and reports of each of the six reference sites representative of those appropriate for permit applications (Chapter 5). By so doing, we were able to compare our results using MESA with three, previous permit applications (El Paso, Lucerne, and Palo Verde Mesa), and apply the protocols to three others sites having very differing geomorphic settings (Coxcomb Mountains fan, Silurian Hills fan, and Sheep Creek and Pipeline Wash in the Avawatz Mountains. Field testing by ourselves and three individuals who are not geologists but with varying levels of experience with desert fluvial systems resulted in and included the following:

a. Indicators: identified and documented dozens of the most common indicators for the Photo Atlas;

b. Data Sheet: repeatedly revised to improve discrimination of primary versus secondary indicators;

c. Notes to the Delineator and Project Reviewer: developed in the field with scientists and non-scientists in order to facilitate stream delineation reports and their review;

d. MESA Protocol and Field Guide: used the MESA Field Guide prototype in the field, to demonstrate the ability of specialists and non-specialist to use the data sheet, illustrations, definitions, and photographs to document and describe the indicators present, and to accurately discriminate between fluvially active and inactive areas.

e. Comparison of MESA results with topographic and hydrologic modeling results: where this information was available, the results developed using the MESA protocol compared favorably with the hydrologic results developed to characterize pre-project drainage conditions for the purposes of managing stream flow through the project area.

CHAPTER 4:
Introducing MESA - Mapping, Documenting, and Delineating Episodic Stream Systems

4.1 Overview

The MESA protocol and accompanying elements *(MESA Field Guide)* are collectively intended to help earth scientists, and desert ecologists identify and rigorously map episodic streams where water is absent, and perhaps has been so for several years. When aerial photo interpretation of the landscape is combined with correctly identified and documented surficial geologic indicators of fluvial activity (or inactivity), accurate determinations can be made regarding stream presence and the relative recency of fluvial activity. Landforms can then be linked with their formative and surficial processes; and the active watercourse differentiated from fluvially inactive uplands, terraces, and abandoned or relict channels. MESA and accompanying materials can assist in effecting more sustainable project developments and more focused ecosystem conservation plans.

4.2 The MESA Field Guide

We developed an accompanying *Field Guide* as a "stand alone" volume (Attachment) intended to be taken into the field to help practitioners effectively implement the protocols. In addition to the protocol, the *Field Guide* includes:

1) A review of physical and ecological characteristics of dryland episodic streams;
2) Clarification of terminology, important definitions, and a glossary of terms used in the *Field Guide*;
3) Notes on how to map dryland episodic streams including a review of channel forms and geomorphic units within the watercourse, including uplands, terraces and interfluves, floodplains and secondary channels, and islands;
4) Guidance on how to identify and define watercourse (jurisdictional) boundaries;
5) A *Photographic Atlas of Indicators of Episodic Stream Activity*, divided into upland/terrestrial, watercourse, and watercourse/playa margin environments, with accompanying explanation of the origin, physical setting, and hydrologic interpretation of each feature;
6) An *Episodic Stream Indicator Data Sheet* integrated with the *Atlas* to provide an example approach to identifying landscape forms, their surficial geology, and organizing and documenting the observations made to determine the boundaries between active streams and fluvially inactive uplands;
7) *Glossary* of terms used in the document;
8) Graphical estimators of sediment grain size and percent cover, and;
9) References.

4.3 The MESA Protocol

The MESA protocol for mapping episodic stream activity has three steps:

1) Recognize the stream forms and processes – gather information on the physical characteristics;
2) Document on-the-ground indicators of fluvial activity and inactivity, and;
3) Map the watercourse.

4.3.1 Step 1: Recognize the Dryland Episodic Stream Forms and Processes

- Review and select current aerial imagery of the project area that shows stream behavior across water years. Select high-resolution base map imagery displaying landscape signatures and that can be mapped at a **minimum** scale of 1:6000 (1 inch = 500 feet; 2.54 centimeters = 152.40 meters). This is consistent with existing CEC guidelines (CEC 2007).
- Review the sections on Channel Forms and Geomorphic Units in the Field Guide.
- Select and outline the watercourses and related landscape forms based on their aerial signatures, such as changes in landscape color, vegetation density, and drainage pattern. Identify any disturbances in the project area that could be caused by humans.
- In consultation with the licensed Professional Geologist (PG) or geomorphologist overseeing the project, identify the basic geological and geomorphic units.
- Select transects for detailed field examination (Step #2) across representative watercourses. Examples are shown in the *Field Guide.*

4.3.2 Step 2: Document Indicators of Fluvial Activity and Inactivity

- In the office, prepare the prefatory section of an *Episodic Stream Indicator Data Sheet* (included in Appendix D) or other data sheet that will document indicators of fluvial activity and inactivity.
- Review the *Photographic Atlas of Indicators of Episodic Stream Activity*.
- Once in the field, walk the selected transects, documenting the presence and absence of all indicators of fluvial activity and inactivity on the *Episodic Stream Indicator Data Sheet*.
- Photograph points of transition between geomorphic units and watercourse boundaries.
- Use the information above to draw a representative watercourse cross-section that identifies the fluvially active and inactive geomorphic units, and note vegetation relationships present. An example cross-section is shown in the *Field Guide.*

4.3.3 Step 3: Map the Active Watercourse

- Use the *Definitions of Stream and Upland Landforms* in the *Field Guide* for suggestions on mapping dormant, abandoned, or relict channels or terraces that are no longer functionally part of the watercourse (and therefore, not jurisdictional).
- Use the *Guidance for Determining the Watercourse Boundaries* to determine areas of fluvial activity and inactivity and map the watercourse boundaries.

- Use other pertinent references such as FEMA flood maps (Federal Emergency Management Agency), state and local highway department stormwater management plans, and project-related hydraulic analyses and stormwater management plans to refine the watercourse boundaries.

4.3.4 Other MESA conventions

Length of Stream Mapped

For streams that enter and exit a project footprint, map the entire length within the project boundary, and at least 76 m of stream upstream and downstream of the project area (CEC 2007). Include any stream segments that exit and re-enter the project area. If development designs will eliminate stream segments by diverting their flow around the project area, the minimum length of stream to be mapped upstream and downstream of project boundaries will be determined by: (1) the site-specific diversion design including how far upstream potentially detrimental impacts to a stream are likely to occur, and (2) the site-specific design for returning flows to downstream stream segments that lie outside the project boundaries. If diversions would redirect or consolidate streams within the project area into natural stream channels outside of the project area, the receiving stream or streams should also be mapped regardless of their location relative to project boundaries.

Definitions of Channel Activity and Non-Activity for Purposes of Defining Jurisdiction

Jurisdictional streams are active channels and watercourses. Because of the episodic nature of flow in dryland streams, they might receive water only once in several years so therefore, features indicating recency of flow may be subtle and difficult to identify in the field. Current CDFW practice is that in order for a channel or watercourse to be deemed "inactive" (and therefore, not jurisdictional), it must be demonstrated not to have received flow since circa 1800 (Vyverberg and Brady 2013). This is done by documenting evidence of antiquity, such as development of an Av horizon which takes 500 to 4,000 years to form (Young and others 2004; Miller and others 2009) or demonstrating hydrologic disconnection from source waters. Other examples can be found in the Uplands section of the *Photographic Atlas of Indicators of Episodic Stream Activity* in the *Field Guide*.

The following definitions are used in the MESA protocols:

Jurisdictional:

<u>Active channel</u>: A channel receiving sufficiently frequent flow to have physical or biological evidence of fluvial activity on the landscape during the current hydrological regime (circa 1800).

May or may not be jurisdictional:

<u>Dormant channel</u>: 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.

Non-jurisdictional.

<u>Abandoned channel</u>: A channel along which stream flow demonstrably no longer occurs; for example a channel isolated from its water source through faulting or stream capture, or by

human constructs such as levees. The presence of physical indicators of antiquity (fluvial inactivity) is necessary to demonstrate abandonment, and the cause of the abandonment (such as a levee or road berm) should be identified. With time and the absence of flow, an abandoned channel will become a relict landform.

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. Usually has clear geomorphic indicators of antiquity in the thousands of years.

Definitions of Geomorphic Units for Purposes of Defining Jurisdiction

Jurisdictional:

Watercourse: includes all functionally related and fluvially active swales, single-thread channels, compound channels, braided channels, discontinuous and distributary channel networks, islands, and floodplains.

Floodplains and secondary channels: lie within the bounds of an active watercourse. They receive water during high flow, and are essential to stream and ecosystem function.

May or may not be jurisdictional:

Islands: are bodies of land within the watercourse (jurisdictional) unless their landscapes and ecosystem characteristics can be documented to differ from those of the watercourse, and there is minimal physical or biological exchange between them and the stream, in which case, they would not be jurisdictional.

Non-Jurisdictional:

Uplands: Landforms formed by non-active fluvial or by terrestrial processes. Document features of antiquity or inactivity. However, uplands may include active drainage swales and first- and sometimes higher-order streams that **are** jurisdictional.

Terraces and interfluves: are upland landforms and as such, no longer experience fluvial activity. Document features of antiquity or inactivity. However, if surfaces of features interpreted as terraces or interfluves have indicators of fluvial activity, they are most likely floodplains within the watercourse boundaries, and as such, would be jurisdictional.

4.4 Steps to Integrating MESA with the Project Permitting Process

4.4.1 CDFW Lake and Streambed Alteration Agreements

The jurisdictional criteria specified in F&GC Section 1600 et sequence can only be applied once stream presence has been identified and a project design has been developed to a level of detail adequate for a potential impact analysis. Project applicants should be encouraged to acknowledge this two-step process by (1) accounting for all streams present in a project area as part of an initial site characterization used to inform project design for the purpose of avoiding streams present and then; (2) when unavoidable, to serve as a base map for characterizing the extent of stream loss. To affect this:

- Adopt a science-based stream delineation protocol like MESA that is based on the geologic and geomorphic processes responsible for the form and function of the streams being mapped.

- Update guidance on CEC and CDFW/Lake and Streambed Alteration Agreement Program websites, and include this guidance in permitting packages.
- Integrate stream delineations with the project planning and site characterization process, creating a base map of all streams present by desk-top and field mapping informed by review of project reports, including geologic and hydrologic analyses of stream activity at relevant recurrence intervals as a precursor action to determining potential project impacts and adverse environmental effects.

Considering the infrequent occurrences of surface flows – oftentimes years – questions regarding the presence, form, and extent of activity of episodic streams are best answered by examining the evidence left on the landscape by the processes that created them, particularly: (1) the geology of fluvial deposits, (2) the landforms modified by stream activity, and (3) the features formed from terrestrial processes that operate on fluvially inactive landscapes. This evidence is collectively defined as the "surficial geology of an area", and its study and documentation allows the most subtle features of the physical landscape to be understood.

Given that the streams being mapped are first and foremost the result of geologic and geomorphic processes, project consultants should provide an appropriately experienced and licensed geologist or geomorphologist to supervise stream delineation mapping field surveys, geomorphic interpretations, and report development. The assessment of the environmental impacts of a project's proposed stream modifications should then be determined in consultation with a regionally experienced ecologist.

4.4.2 Nexus with Federal Waters of the US

F&GC Section 1600 et sequence is more expansive than that used by the USACE and the Regional Water Quality Control Boards to determine federal jurisdiction for the purposes of enforcing section 404 of the Clean Water Act. F&GC jurisdiction commonly extends beyond the top of stream banks to include floodplain areas and associated vegetation, and is not linked to a specific recurrence interval of stream flow, as the federal OHWM concept explicitly is. As such, federal jurisdiction is generally a subset of the more expansive Waters of the State jurisdiction.

CHAPTER 5:
Application of MESA to Reference Sites

To test the applicability of the MESA protocols, we applied them to six field areas typifying the geomorphic settings and processes most likely to be encountered in siting utility-scale renewable energy projects (Fig. 13). Each presents unique challenges to the delineation of its streams. We selected three sites that had pre-existing delineation studies, and three sites that have not been delineated.

5.1 Sites previously delineated

Our delineations compare the results using the MESA protocols with the delineations done previously, and examine the source of any differences.

- **El Paso fan:** West of Ridgecrest.
  High relief source. All drainage exits site. One, prominent, main through-going channel incised into old alluvial fan deposits, and numerous smaller channels and drainage swales on the older fan. At issue is the extent of jurisdiction in the largest wash, and whether smaller channels and swales are jurisdictional.
- **Lucerne Valley fan:** Southeast of Victorville.
  Very high relief source. All drainage exits site. One prominent, main through-going complex of channels, and numerous smaller channels incised into older fan deposits. At issue is which channels constitute "active streams".
- **Palo Verde Mesa**: South of Blythe.
  Low relief and externally drained. Several, large and well vegetated channels deeply incised into older fan deposits (the mesa); and numerous moderate and small channels on top of the mesa. At issue is how to recognize which channels are active and how to map the small channels when so many small streams are present.

5.2 Sites not previously delineated

Sites presenting difficult mapping and delineation decisions were chosen to test and refine the MESA protocols.

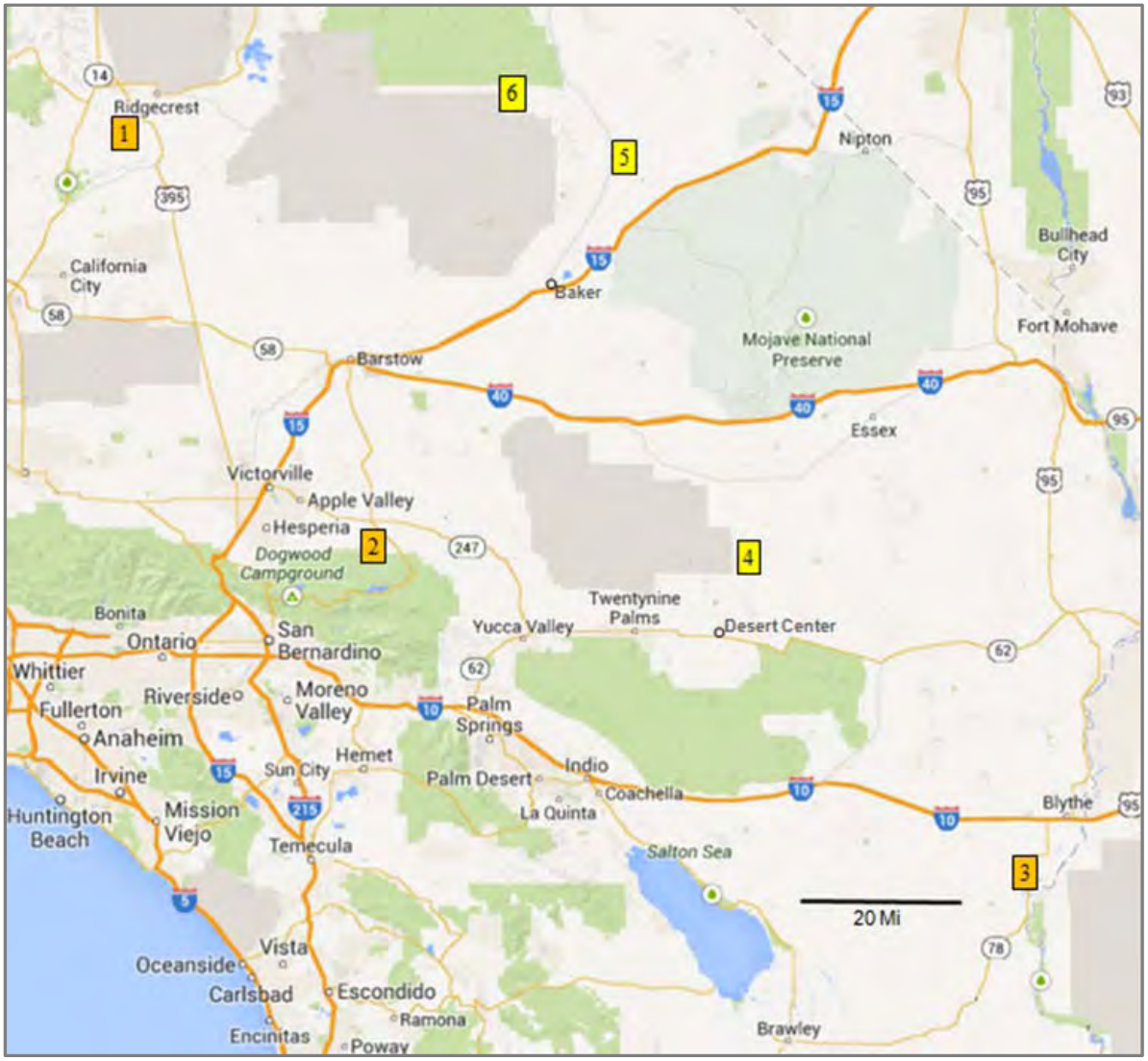
- **Coxcomb fan:** North of Desert Center.
  Low relief, granite source produces abundant and anomalously fine-grained but granular sediment (sand and granules). All drainage exits site. Few, through-going channels; drainage is mainly along broad complexes of shallow, braided channels that readily migrate laterally during high flows.
- **Silurian Hills fan:** North of Baker.
  Low relief but includes drainage and sediment from large source areas off site. Highly variable geomorphology on site including playa fringe and dune field. Numerous small, shallow channels and major complexes of braided channels on old fan surface are laterally stable. Moderate to low sediment supply. Includes both relict and newly formed channels.

- **Avawatz Mountains fans:** Southern Death Valley.
  Sheep Creek fan has large, high relief (tectonically uplifting) source and very large and coarse sediment supply. Drains into a major, axial valley stream (Amargosa River) on site. Mid-fan segment has few channels deeply entrenched in old fan deposits (stable laterally), but lower fan has numerous active, dormant, and abandoned channels and channel complexes. Major flood events and mudflows.

Pipeline Wash fan has moderate relief and receives abundant and unusually fine-grained sediment (silt and clay). The mid-fan channels are inset into older fan deposits, but the lower fan is a broad plain of enumerable, very shallow, laterally migrating and discontinuous channels and complexes carrying mudflows and flood water across a coppice dune field into a major, axial valley stream (Amargosa River). The Amargosa River course has recently migrated across the fan toe.

Figure 13: Location of reference sites delineated in this report (previously delineated in orange).

1. El Paso Fan
2. Lucerne Valley fan
3. Palo Verde Mesa
4. Coxcomb Mts fan
5. Silurian Hills fan
6. Avawatz Mts (Sheep Creek and Pipeline Wash)



MESA protocols are applied to each of the six sites described below. In addition, in order to clarify the origin and level of activity of certain fluvial features, we excavated soil pits and conducted infiltrometer tests. Although these methods yielded information that provided additional confidence to our delineations, they are not part of the MESA protocols. However, they are recommended whenever they can provide needed clarification.

5.3 Sites Previously Delineated

5.4 El Paso Fan

5.4.1 Location

The area delineated herein coincides with the proposed, utility-scale, Ridgecrest Solar Power Project. The delineation area and solar project site covers 3,920 acres of undeveloped public land administered by BLM in the El Paso Mountains in southeast Indian Wells Valley, about 5 miles southwest of Ridgecrest in northeastern Kern County, California (Fig. 14).

The delineation area (hereafter referred to as the "site" or "the area") is located in T. 27 S., R. 39 E., Sec. 14, 23, 24, 25, 26, 27, 34, and 35 on the Ridgecrest South and Inyokern SE, USGS 7.5-minute topographic quadrangles (1972, 1973). Elevations range from 860 m in the southeast to 786 m at its southwestern boundary. The site is accessed southwest from U.S. Highway 395 along Brown Road, a paved two-lane road.

5.4.2 Setting

The delineation area is situated on an alluvial fan on the north slope of the El Paso Mountains – hereafter referred to as the "El Paso fan" – in the southwest portion of the Basin and Range Geomorphic Province (CGS 2002). El Paso fan is bisected by several, large washes and numerous smaller, single-thread streams. All flow north across a relatively gentle slope of about two percent, eventually converging with El Paso Wash, the largest of the washes, which crosses Brown Road finally draining into China Lake to the north. Historic use of the site includes mining, stock grazing, and trash dumping; and a former railroad line skirts the area on the west and south. Currently, the land is used for recreational hiking and off-road vehicle use along the numerous BLM-designated dirt roads, and lesser undesignated tracks that cross the site.

El Paso Wash is the main geomorphic feature of the delineation area, but there are several smaller washes in the southwest corner of the site and numerous channels cross the fan and drain into El Paso Wash.

The local rainfall is bimodal with a winter rainy season in December through March and a wetter season summer season in July through September.

All streams on the site are ephemeral, but surface evidence and local experience indicates that surface flow has occurred in many of the smaller streams every year between 2009 and 2013. Although dry most of the time, El Paso Wash has a history of major flooding, most recently in 1984, and is a FEMA-designated, 100-year floodway.

Figure 14: Location map of the El Paso fan delineation area and site of Ridgecrest Solar Power Project (on hold as of August 2013), Kern County, California.

The project site is entirely underlain by Pleistocene fan deposits including stream and debris flow units of matrix-supported, angular-to-rounded, pebble-to-cobble-sized clasts in a sand matrix in places cemented to a Stage IV to V petrocalcic horizon (Fig. 15). In places, Pleistocene strata are overlain by unconsolidated Holocene alluvium, largely reworked from the Pleistocene deposits. The fan has the surface rounding of an older landform; streams crossing the fan have fairly well-defined, generally single-thread channels that incise slightly into the underlying Pleistocene fan deposits. Active streams and washes contain unconsolidated, moderately well sorted gravel, cobble, sand, and silt (Fig. 16). On the fan surface, which has the surface rounding of an older landform, the streams have fairly well-defined, generally single-thread channels that flow across and are incised slightly into the older underlying Pleistocene fan deposits.

Figure 15: A: Pleistocene stream deposit with cross bedded sand and gravel channels. B: Detail of Pleistocene debris flow deposits with matrix-supported angular-to-rounded pebbles and cobbles in sand matrix cemented to a Stage IV to V petrocalcic horizon. Both images of a road cut in the delineation area on the north side of Brown Road.

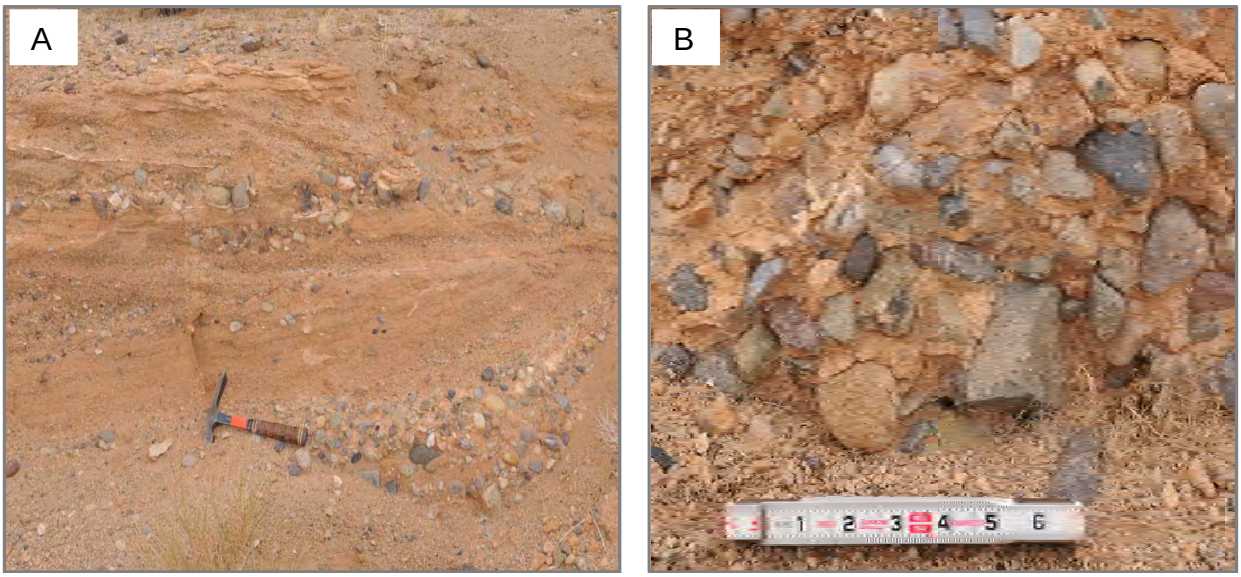
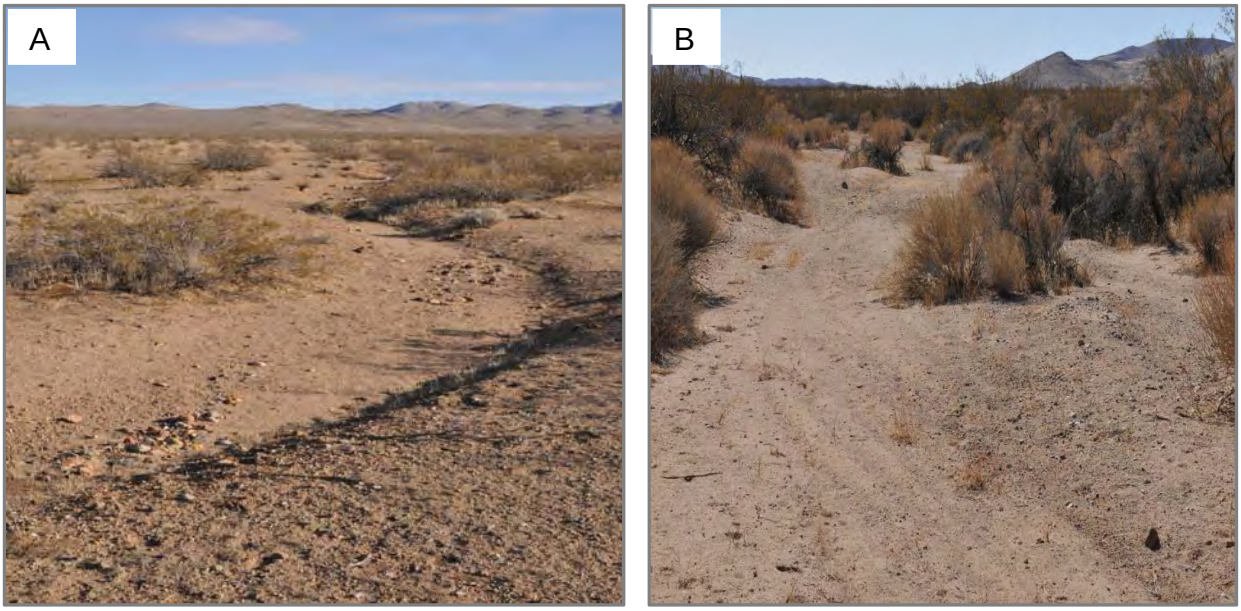


Figure 16: A: View across the surface of El Paso fan from within the southern solar field along a typical, single-thread channel slightly incised into the older fan. B: View upstream along El Paso Wash, a multi-thread compound channel incised 9 + m into its alluvial fan. Has well-establish vegetation on islands bars separating individual low- flow and secondary channels. El Paso Mountains in background.



The fan's surface is covered by sparse to moderately dense Mojave creosote bush scrub with local areas of Mojave Desert wash scrub in El Paso Wash north of Brown Road (Fig. 17). The greatest density and most vigorous vegetation is strongly associated with the single-thread streams on the fan surface and in the larger, deeply incised, multi-channeled washes.

Figure 17: View across the surface of El Paso fan from within the southern solar field looking to the southwest; Sierra Nevada in the background.

5.4.3 Description of the Solar Project

The original design of the solar project was for a utility-scale, solar thermal, electric generating facility on the stable, upper surface of El Paso fan (Fig. 18). The site would have used approximately 1944 acres of parabolic mirrors to collect heat energy from the sun to generate high-pressure steam fed to a turbine generator. The solar fields – one north and one south of Brown Road – would have been completely cleared of vegetation and graded into multiple, relatively flat terraces generally sloping east-to-west from nearly level to two percent. Mirrors would be mounted on piers approximately 4 meters above the native ground and roads. El Paso Wash, which flows diagonally through the center of the project, would have been avoided, although all of the tributary streams on the fan above would have been eliminated. On-site stormwater was to be collected by a system of interior canals parallel to the mirrors directing runoff into existing streams and washes (AECOM 2009). The project is currently on hold as a change from solar thermal to photovoltaic technology is considered.

5.4.4 Consultants' Jurisdictional Stream Delineation

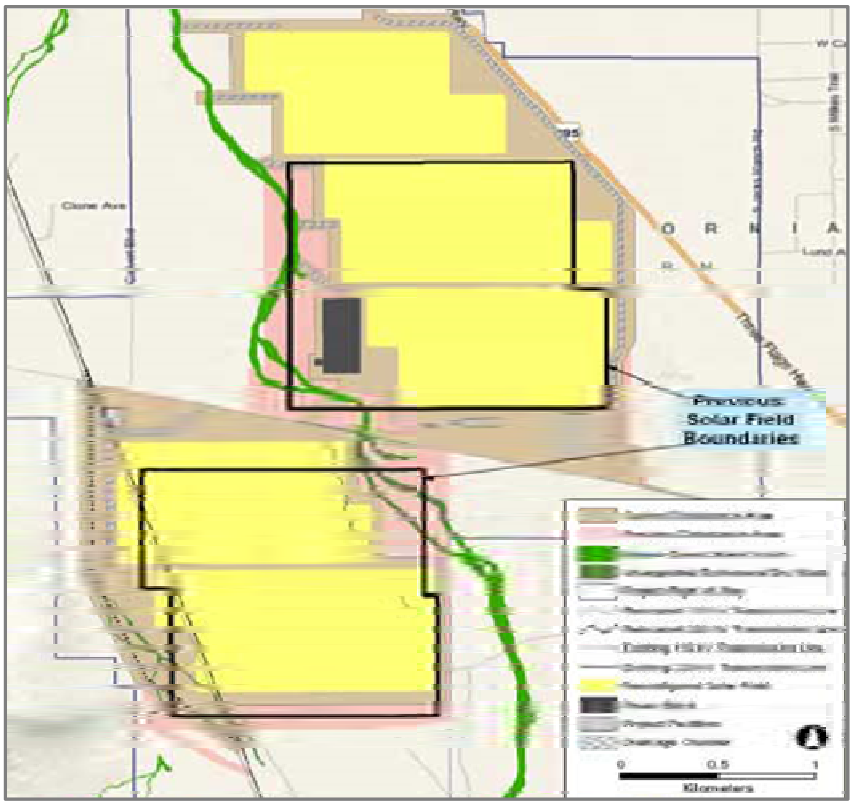
Method

In spring 2009, the consultant's preliminary investigations included review of high-resolution aerial photographs, USGS topographic maps, high resolution aerial photos, NRCS Soil Survey reports and maps, and a variety of state and federal hydrological databases and inventories (EDAW 2009).

In addition, the following criteria were used to interpret the jurisdictional limits of streams subject to F&GC Section 1600 et sequence:

- Title 14 CCR 1.72 defining a stream as a "*body of water that flows at least periodically or intermittently through a bed or channel having banks and [that] supports fish or other aquatic life;*"
- The Holland Code Classification System was used to identify and define the lateral extent of xeric riparian vegetation communities (where applicable) per the Title 14 CCR 1.72 stream definition; and
- Where riparian vegetation was absent, ephemeral washes or streams were located by the presence of shelving and/or evidence of scour that resulted in a well-defined bank, bed, and channel.

Figure 18: Plan view of the two solar fields (bright yellow rectangles) configured to avoid El Paso Wash (bright green thread through the middle of the image. Graphic: AECOM 2009.



Field delineation at the site was done by a team of four ecologists, at least three of whom have experience in state and federal delineation of arid region streams (EDAW 2009). The presence, extent, and type of jurisdictional streams were recorded with sub-foot accuracy GPS units. Post-field analysis, editing, and refinement of the field data was done by a GIS specialist and the ecologists who performed the fieldwork.

The project consultant used the Holland Code Classification System for vegetation communities to identify xeric riparian vegetation associated with all washes within the disturbance area. In areas where upland and wash-dependent indicator species from two or more Holland vegetation communities were present, the indicator species that occurred with the greatest

vegetation coverage (absolute dominance based on percent cover) identified the vegetation community.

The project consultant used diagnostic field features (such as well-defined bank, bed, and channel) with the vegetation communities present to determine the lateral extent and acreage of two types of streams were determined subject to F&GC jurisdiction: (1) vegetated ephemeral dry washes, and (2) unvegetated ephemeral dry washes.

Vegetated, ephemeral dry washes were characterized as being desert washes that present an established bed, bank, and channel and that support wash-dependent vegetation, in this case Mojave Desert Wash Scrub. Unvegetated ephemeral dry washes were defined by the presence of shelving and (or) scour that created a well-defined bed, bank, and channel (EDAW 2009).

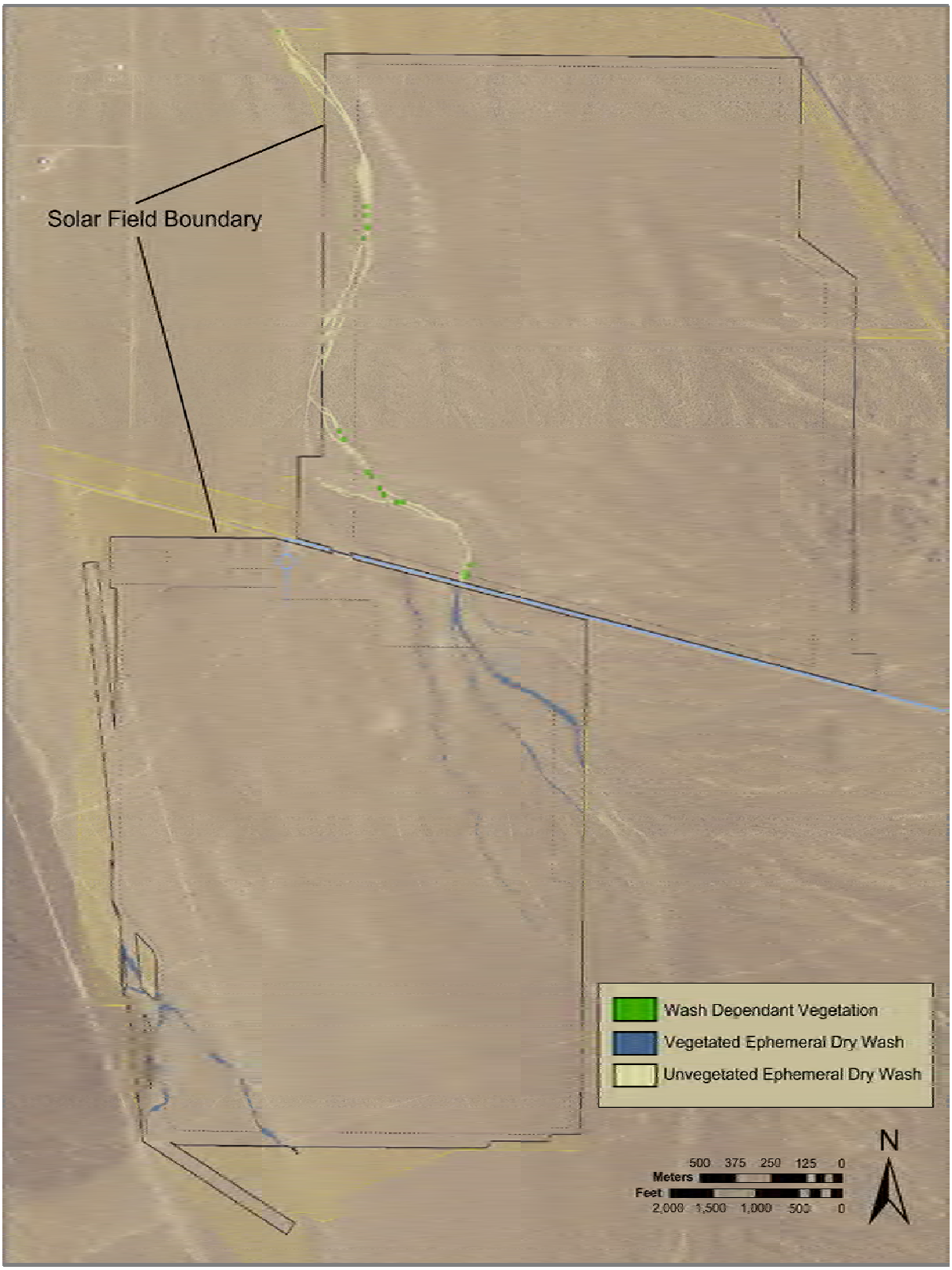
Where evidence of past surface water flow was observed but distinct shelving and (or) scour was absent, the linear or lateral extent of the jurisdictional boundaries was determined to have ended. The features present that exhibited these characteristics were identified as:

- Swales supporting low volume and duration surface flow;
- Low-lying, undefined, relatively linear features in the landscape that are unvegetated or primarily associated with Mojave creosote bush scrub;
- Eroded, relict washes that received only "sheetflow" during precipitation events;
- Channels visible on 2005 aerial photography but otherwise not delineated during the original field surveys were subsequently revisited in early 2009 to confirm that all evidence of bed, banks, scour, and shelving was gone from the delineation area and (or) that the vegetation associated with these features was Mojave creosote bush scrub.
- Landforms separating the multi-thread low flow channels in the compound channel of El Paso Wash were identified as "islands or terraces" and designated as jurisdictional "riparian interfluves" if they were populated by wash-dependent vegetation or an intermix of wash-dependent vegetation and Mojave creosote bush scrub. If they were populated by Mojave creosote bush scrub habitat these "interfluves" were determined to be upland features and considered non- jurisdictional.
- Jurisdictional linear extent was determined to have ceased where a channel having well-defined bed and banks loses its distinctive features and becomes one that only supports sheet flow, and (or) its features began to blend into the landscape and (or) become a swale or relict channel (EDAW 2009).

Consultant's Results

The consultants' delineation study identified and mapped six streams for a total of 16.6 acres of potentially jurisdictional streams in the project area: 8.2 acres of Mojave Desert wash scrub vegetated ephemeral wash and 8.4 acres of unvegetated ephemeral dry wash (EDAW 2009) (Fig. 19).

Figure 19: Streams within the delineation area determined by the project consultants as potentially subject to F&GC Section 1600 et sequence jurisdiction. Light yellow streams in the north solar field (north of Brown Road) are mapped as vegetated ephemeral dry wash; blue streams in the south of Brown Road are mapped as unvegetated ephemeral dry wash. Map adapted from EDAW, Ridgecrest Solar Project Jurisdictional Delineation Report for Regulated waters of the US and state. Prepared for Solar Millennium (2009).

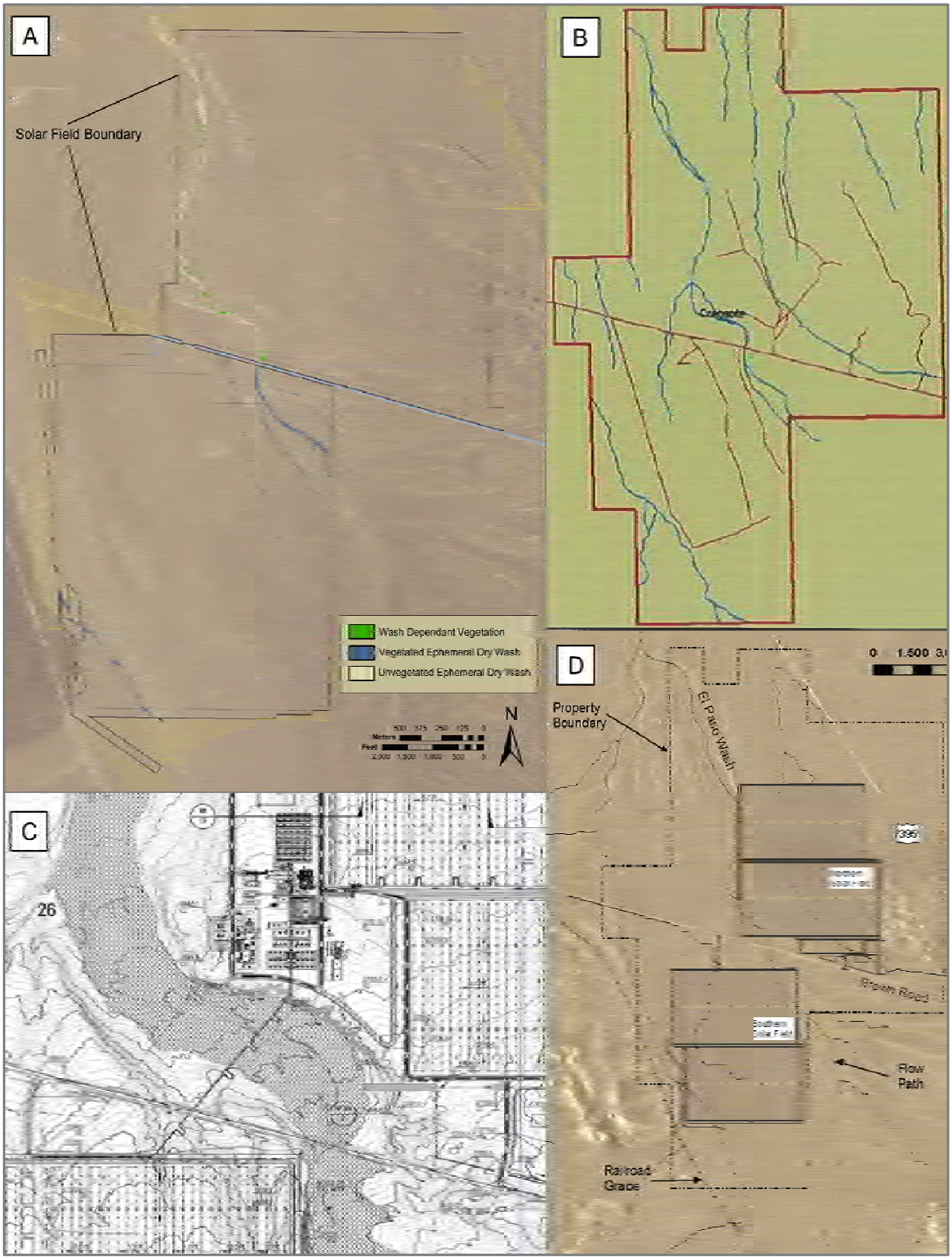


Our comparison of the stream delineation map with project area maps completed for other purposes revealed inconsistencies in the number and size (or area) of streams identified (Fig. 20 A). For example:

- The Wind and Water Erosion Modeling element of the geotechnical report provided an overview on vegetation community and stream relations and identified the presence of many more streams (16) than the stream delineation report (Fig. 20 B).
- The FEMA floodplain map updated for the project indicates that in contrast to the modest width of the low flow channels as mapped for the stream delineation, nearly the entire width of El Paso Wash is active during a 100-year recurrence interval flow event , influencing the project design for the placement of the solar fields (Fig. 20 C).
- The Drainage Report identifies the same streams as the jurisdictional mapping, but also maps streams present in the north east and southern solar fields that were not mapped or sampled for vegetation by the stream delineation report (Fig. 20 D).

No explanation is provided for the discrepancies between the streams accounted for by the stream delineation report versus those identified by other project elements, nor why the consultant's jurisdictional report would not apply their sampling and mapping techniques to these areas and report on the results.

Figure 20: Variance in mapped stream presence between project reports. A: Project consultant's stream delineation map. B: Geotechnical report; blue lines represent stream presence. C: From the FEMA flood map; gray represents the 100-year floodplain. D: From the Drainage Plan; black lines represent existing stream paths across project site. Graphics: AECOM 2009.



5.4.5 MESA Protocol-based Stream Delineation

Methods

Our pre-field survey methods were similar to those used by the project consultant with the following additions. We:

- Acquired and reviewed geologic maps and reports of the area;
- Reviewed aerial imagery to identify distinct aerial signatures, and
- Selected areas for on-the-ground field review and verified the preliminary mapping based on analysis of aerial photographs and use of the guidance embodied in A Review of Stream Processes and Forms in Dryland Watersheds (CDFW 2010).

Our in-field survey methods were also similar to those used by the project consultant with the following exceptions, variations and additions:

- The use of surficial geology and surface indicators of stream presence and absence more extensive than the indicators used for the project delineation study.
- Adjusted the transect location in the field according to observations.
- Surveyed transects and completed MESA Data Sheets using surficial geology and surface indicators of stream presence and absence more extensive than the indicators used for the project delineation study.
- Surveyed upstream and downstream of the cross sectional transects to develop a broader understanding of the features and transitions of geomorphic units.
- In areas of question, conducted more detailed investigations using soil pits and infiltrometer tests to discriminate between fluvially active and inactive areas where the surficial evidence of stream flow was subtle – such as in swale areas – or obscured by long time between surface flow or the influence of other processes.
- Conducted vegetation and vegetation surveys as a secondary rather than a primary or diagnostic indicator of landform type.
- We navigated to, photo-documented, and mapped our stream delineations, sampling locations, and stream and botanical survey transects in the field using an iPad, Google Earth imagery, and GIS-based Garafa mapping software.

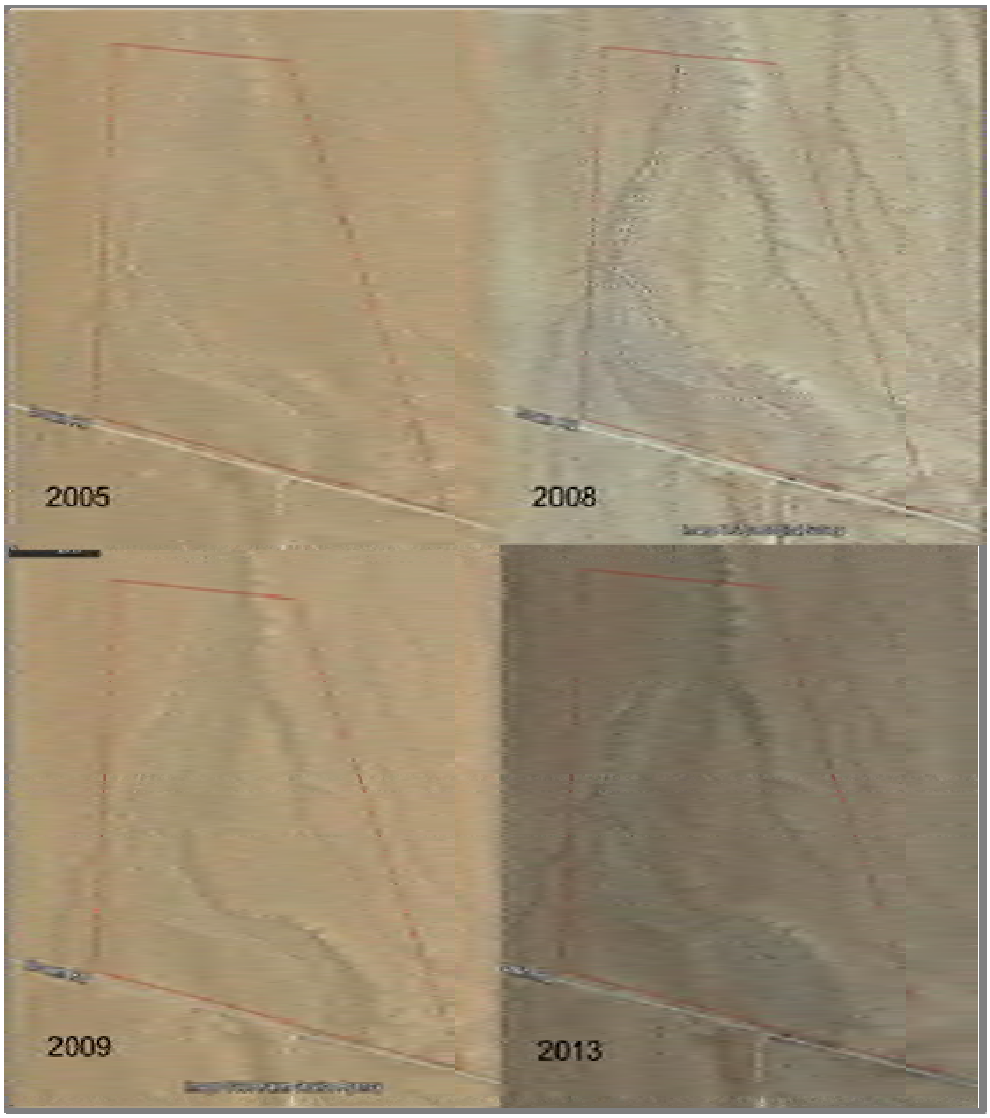
Step 1: Recognizing Dryland Episodic Stream Forms and Processes

We used Google Earth software and aerial photography to review and create our preliminary map of the study area. The historical imagery tool in Google Earth allows the review of available aerial photography from different time periods. This allowed a comparison of anthropologic influences and vegetation response over different seasons and years (Fig. 21).

We then drew unlabeled polygons around the different aerial signatures and presumed geomorphic units to locate transects that would cross as many different geomorphic units as possible to identify the landform types. Once in the field, some lines were slightly adjusted so

that the data collected would better represent the variety and extent of the geomorphic units (Fig. 22).

Figure 21: Historic imagery. Google Earth aerial imagery spanning an 8 year time period. The variety of historical imagery allows a review of vegetation response to variations in precipitation between wetter or dryer years.



Step 2: Documenting Indicators of Fluvial Activity and Inactivity

We then walked the transect line and identified the geomorphic units using the *MESA Field Guide* and *Episodic Stream Indicator Data Sheet*. Once the geomorphic units were identified, we returned to the start of each line and began collecting indictors of fluvial activity for each geomorphic unit (Fig. 23). We walked approximately 30 m upstream and downstream of each transect, mapped where each geomorphic boundary occurred, and took photos. As data collection and mapping progressed, the geomorphic unit boundaries and cross section profile were adjusted as appropriate. The data sheet and an example of a completed data sheet is included in Appendix D. Areas not covered by transects were walked and evidence of activity or antiquity were noted and mapped.

Figure 22: Preliminary site map using MESA protocol. A: Study area with unlabeled polygons drawn around the aerial signatures and presumed geomorphic units and the initial transects based on preliminary mapping. B: How the transects were refined in the field.

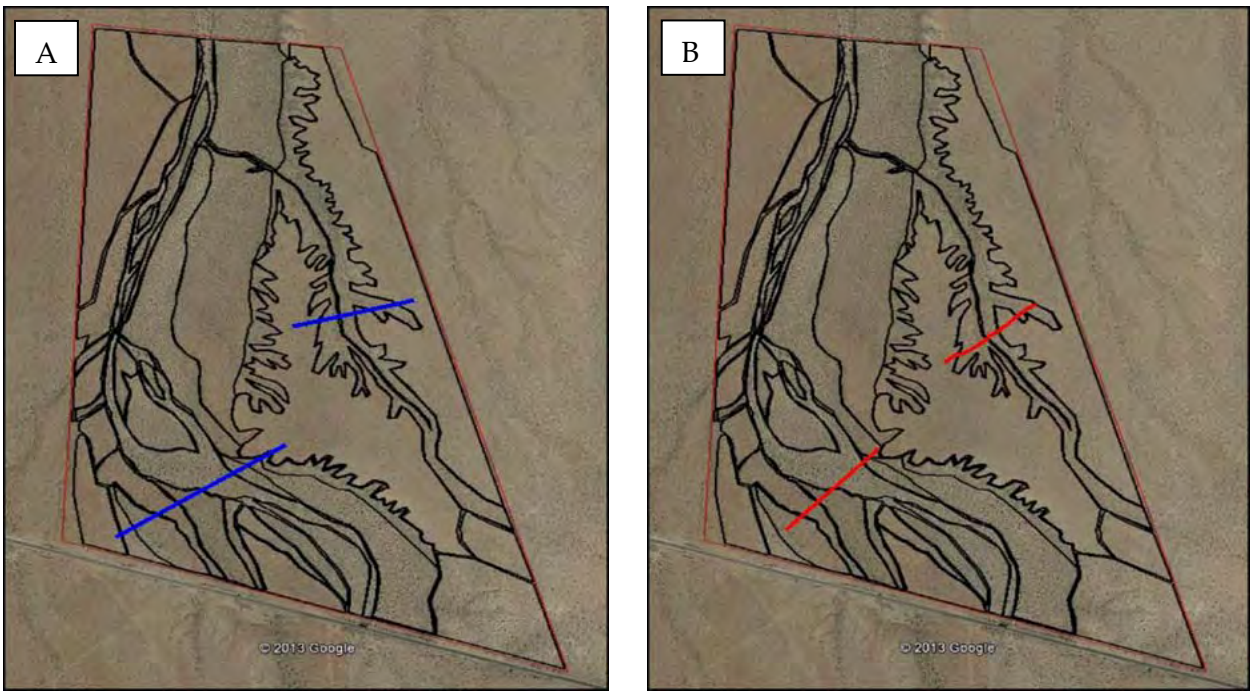
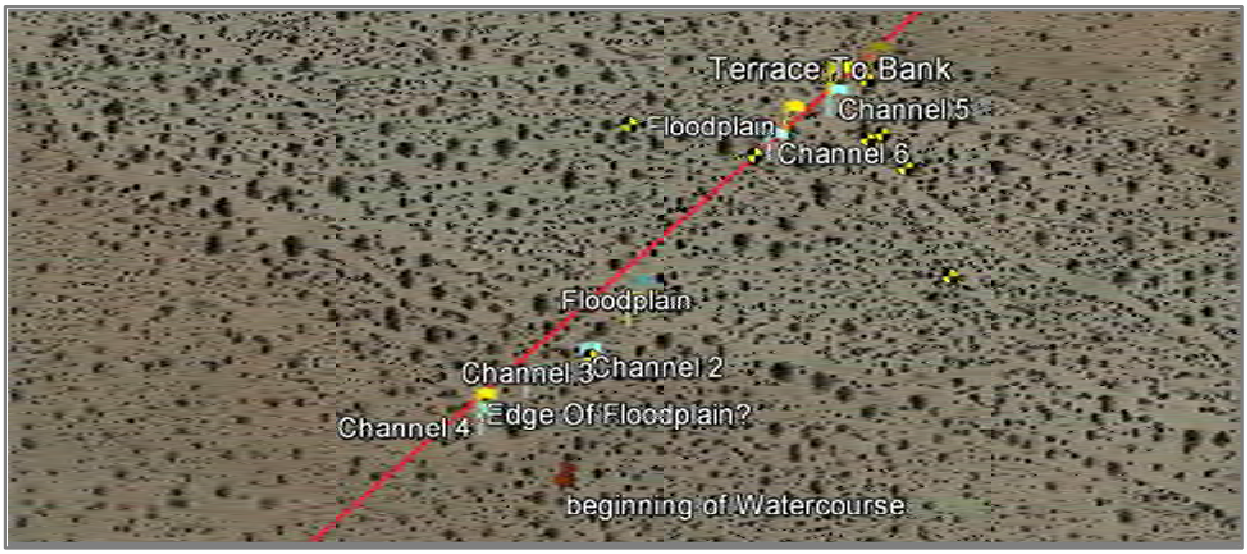


Figure 23: Example of mapping the geomorphic units using the MESA Protocol, Episodic Stream Indicators Data Sheet, the iPad, and Garafa software.



Step 3: Mapping the Active Watercourse

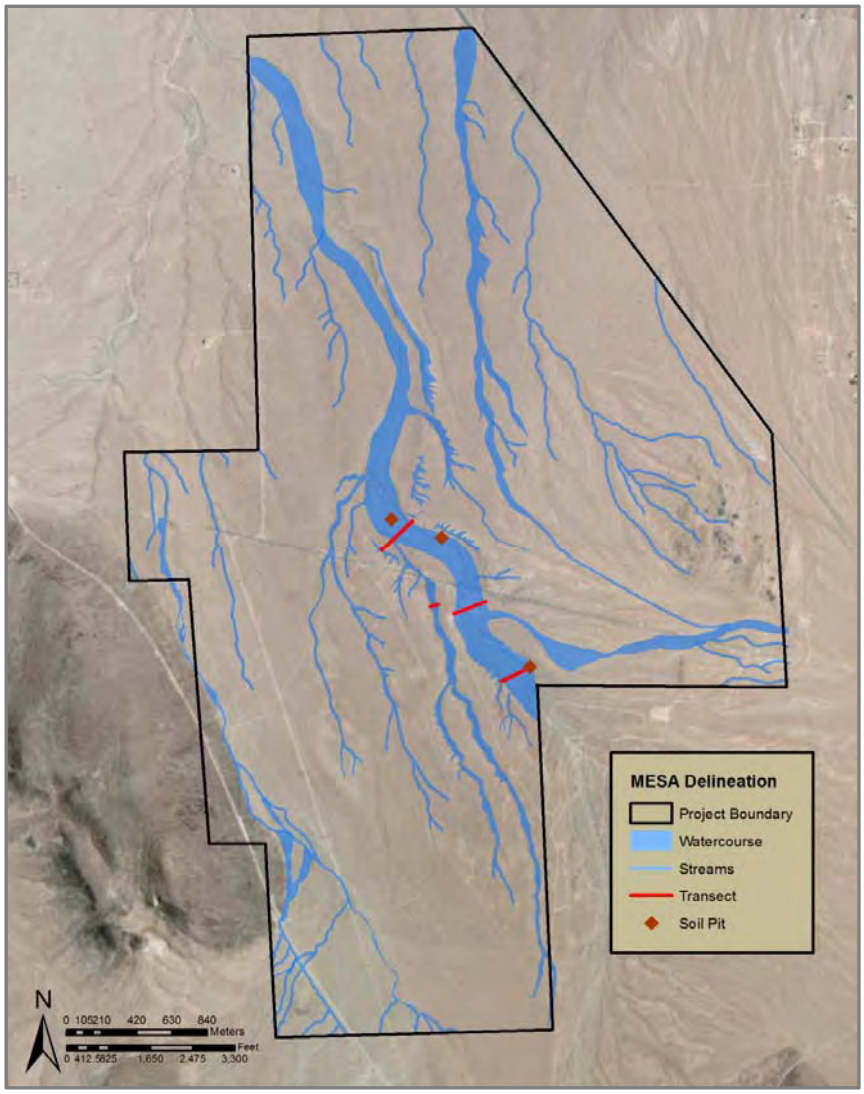
After the geomorphic units were identified using the MESA Protocol and *Episodic Stream Indicators Data Sheet*, the identifications were applied to the rest of the mapping area based on similar aerial signatures of fluvial features, soil color and vegetation patterns. These results were compared with the consultant's delineation maps, hydrology reports and FEMA 100-year floodplain maps. Polygons were drawn around the active watercourse using Google Earth Pro and Esri ArcGIS software.

MESA Protocol-based Stream Delineation Results

We re-evaluated the entire area mapped by the original project consultant for the Ridgecrest Solar Power Project stream delineation. In a complex fluvial system, differences in the accounting of the number of streams and their acreages are expected. However, in a landscape of few streams and of those present having a fairly simple form, accounting inconsistencies are most likely due to differences between the mapping methods used.

We determined there are 76 streams in the delineation area, including one dormant stream and several short, first-order streams that because of their small size and proximity to each other we mapped collectively as an area rather than as individual streams. The dormant stream was included because it retains its potential for hydrologic reactivation and stream function, and thus presents an opportunity for rehabilitation and onsite mitigation of other project-related stream impacts. Collectively there are 357 acres of potentially jurisdictional streams in the delineation area (Fig. 24).

Figure 24: Stream delineation of El Paso fan using the MESA protocol. Sampling locations, and stream and botanical survey transects were photo-documented and mapped in the field using an iPad, Google Earth imagery, and GIS-based Garafa mapping software.



Although the morphology of the stream channels on the fan can be subtle, the differences in color and surface texture between the channels and the fluvially inactive upland fan, and the changes in vegetation density, vigor and alignment between channels and upland surfaces are distinctive (Fig. 25).

The larger watercourses – El Paso Wash through the center of the site and an unnamed wash on the southwest edge of the delineation area – are broad, well-defined, multi-thread compound channels of varying width and definition.

The unnamed wash on the southwest is comprised of a less defined network of channels that are concentrated, impounded, redirected, and then dispersed again where the watercourse passes beneath an abandoned railroad grade through pipes, concrete culverts, and timber trestles.

El Paso Wash is deeply incised ± 9 m into the older alluvial fan deposits. In the delineation area, its width varies from approximately 91 m to greater than 213 m. Inset within the banks of the wash are two, well-defined, low-flow channels that join and separate and rejoin. Between these channels are topographically higher bars and islands having networks of secondary channels; where the low-flow channel form is intermittently lost, short reaches of braided channel form occur. There is also a discontinuous landform interpreted to be a floodplain at an elevation of ± 1 m above the low-flow channels and at or slightly above the elevation of the bars and (or) islands.

In the absence of surficial indicators of fluvial activity we excavated a soil pit to a depth of 0.73 m to determine the sediment type; the relative age of the deposit; and to confirm the nature of the landform as preliminarily mapped based on form, location, and aerial signature (Fig. 26) (Appx. B, soil pit EPW-SP-1C). Rounded stream gravels and cobbles occur at the bottom of the pit; overlain by slightly silty, medium- to coarse-grained sand that includes a trace of floating pebbles and granules, massive to weakly bedded sand layers, pinched out cross-bedding, a scour channel with finer sand infilling overlain by few millimeters thick surface crust and deflation surface with a coarse pebble and granule lag. The surface silt and sands had been removed by deflation and redeposited around creosote bushes as coppice dunes which are now being eroded away. No other indicators of surface antiquity were found. Based on the occurrence of young fluvial deposits, we interpreted the body to be the remnant of a floodplain. Whether the deposits forming the body were laid down during the 1963-64 winter flood events or from a larger event in 1984, this landform lies within the bounds of the jurisdictional wash and within the FEMA 100-year floodplain currently designated for the site (AECOM 2009).

Figure 25: Stream morphology and vegetation relationships. A: Active, single-thread stream (within the dashed white line) on the surface of El Paso fan. Note small floodplain. B: Detail of unconsolidated sand and gravel deposit in the active stream channel (the larger dark brown cobbles and boulders are basalt and exhumed elements of older (relict) debris flow deposits). C: View across fan surface showing the sparse vegetation versus the density and robustness of the vegetation aligned with the stream channel in A. D: Detail of upland fan surface with a weakly developed pavement that consists primarily of pebbly sand, and sandy pebble-gravel, with fine-grained sand and silt between pebbles and gravels, rubification on undersides of many of the clasts, and no rock varnish.

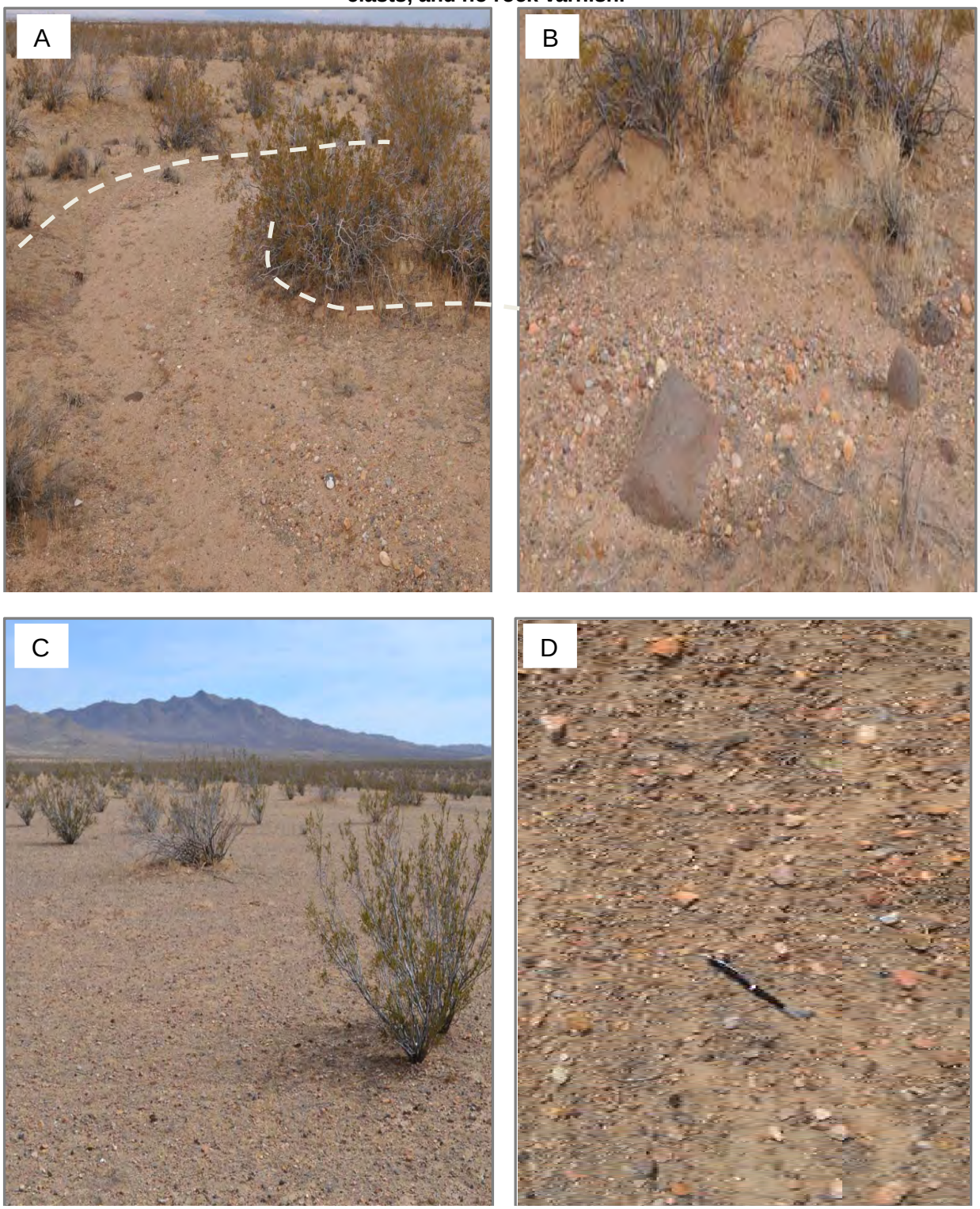


Figure 26: Soil pit excavated to determine shallow subsurface sediment type, and to confirm the nature of the landform, which was interpreted to be a floodplain. The annotated photograph of soil pit EPW-SP-1C and its interpretive narrative are included in Appendix B.

Islands, Bars, or Interfluves

As noted above, the low-flow channels are separated by large bars or low islands. Described as "interfluves" by the project consultant, this interpretation is not consistent with our findings, or our understanding of the consultants' term to describe them. Regardless, the consultants determined that the "interfluves" were jurisdictional where wash-dependent vegetation was present, and non-jurisdictional "upland elements" where wash-dependent vegetation was absent.

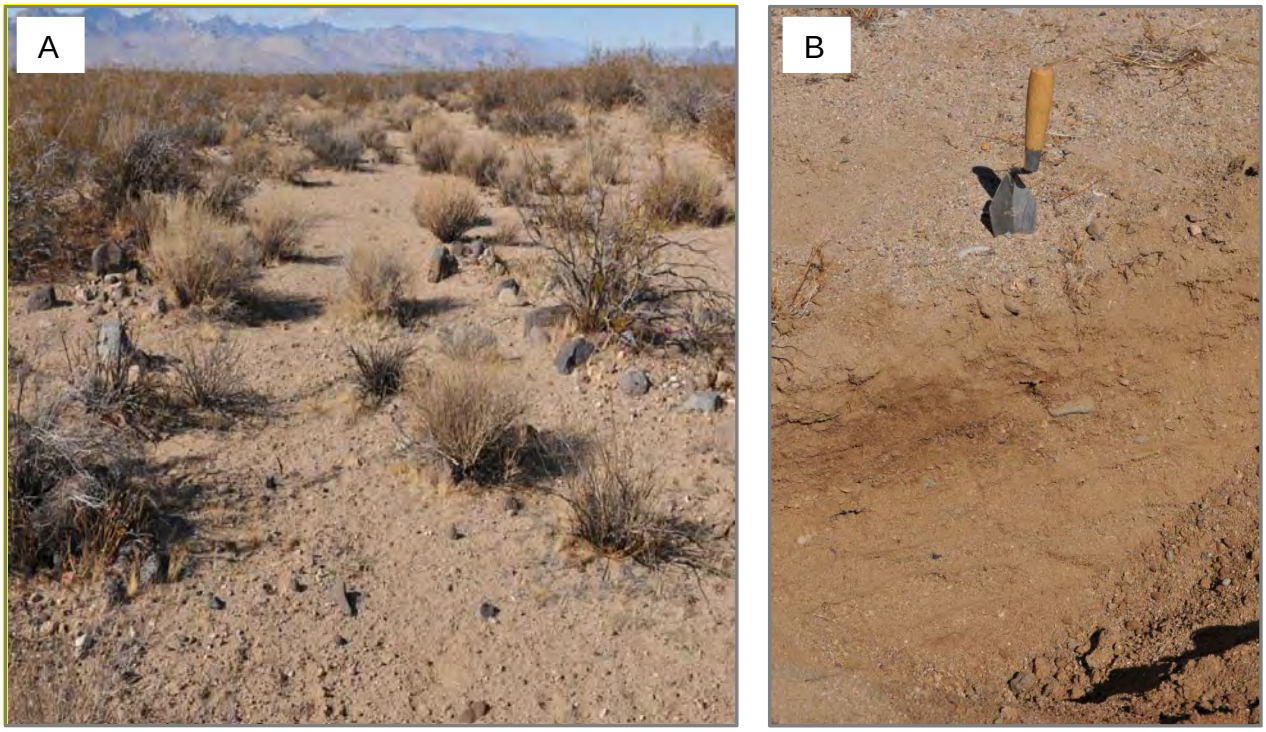
An interfluve is a relatively undissected upland or ridge between adjacent stream channels flowing in the same direction. An interfluve is **not** a bar constructed of active stream deposits periodically eroded and redeposited during higher flow events, or an island around which channels split before rejoining downstream. Therefore, the landforms identified by the consultant as interfluves are either large bars or low islands with the only question being the degree of fluvial exchange between these features and the stream channels that surround them.

Although the indicators of fluvial activity are subtle on the large bars and islands, we identified topographically higher secondary channels crossing them in association with gravel ramps on the upstream side of woody plants. Furthermore, the elevations of floodplain remnants are at or slightly above the elevations of the "interfluves." Collectively, this evidence indicates that fluvial activity has occurred well beyond the streamside edge of these landforms and indicates that rather than being "interfluves", the landforms are actually large bars or low islands formed by deposition of unconsolidated stream deposits during high flows. They are overtopped by

flows slightly lower than those that inundate the floodplain, and are being actively reworked and eroded by the more frequent low-flows.

Given the different interpretations of the landforms (non-jurisdictional interfluve vs. jurisdictional bar or island), we excavated a soil pit to a depth of 0.30 m (Fig. 27) (Appx. B, Soil Pit EPW-SP-2). Beneath the surface of loose, silty sand and pebbles with a few cobbles lacking indicators of antiquity, is weakly bedded, loose, silty sand with floating pebbles and a scoured lower boundary. This overlies interbedded, coarse, silty sand; bedded, sandy-cobbly pebble gravel; lenses of sub-rounded pebble gravel; and well, parallel bedded, fine sand. The stratigraphy indicates that the entire body is of fluvial origin, and the absence of weathering or an Av horizon indicates relatively recent disturbance. The presence of secondary channels and the topographic relationship with the floodplain remnant in combination with the soil pit evidence demonstrates that the landform still experiences flows over its surface; therefore, it lies within an active watercourse.

Figure 27: A: Secondary channel on large bar or low island separating the two low flow channels of El Paso Wash. B: Soil pit excavated in the secondary channel to determine the sediment type and its relative age. The annotated photograph and soil pit EPW-SP-2 and its interpretative narrative are included in Appendix B.



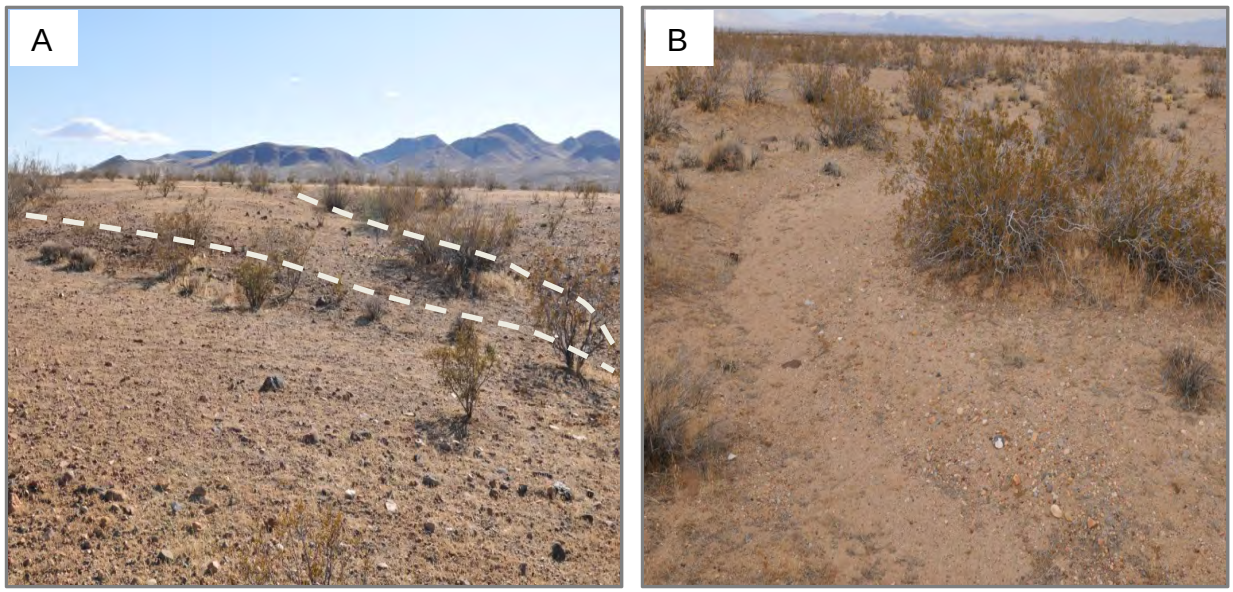
Swales

The project consultants deemed a channel not to be jurisdictional if there was evidence of past surface water flow but distinct stream banks or evidence of scour were absent (Fig. 28). The features that typified these conditions were identified as: (1) relict washes that receive "sheetflow" during precipitation events, (2) swales supporting low volume and duration surface flow, and (3) relatively undefined linear features in the landscape that are unvegetated or mainly associated with Mojave creosote bush scrub.

The term "swale" was not defined by the project consultants but apparently they used it to refer to a steam's headwater or source area. This is consistent with our understanding of the term, which we define here as "a depression or hollow where runoff from the surrounding uplands accumulates" (Appx. E, Glossary). Swales that yield channel flow are important sources of water, sediment, nutrients, and other materials during runoff, and are integral parts of a stream.

However, the consultants provided no evidence as to how either swales or relict channels were identified, or where they are located. Nor did we find any relict channels using the surficial indicators of antiquity in the *MESA Field Guide*.

Figure 28: A: Two swales that converge and then drain into El Paso Wash. These features were excluded from the consultants' stream delineation even though swales that yield channel flow are important sources of water, sediment, nutrients, and other materials during runoff, and are integral parts of a stream. B: View downstream along an "undefined linear feature" that is unvegetated but "associated with Mojave creosote bush scrub" according to the consultants. It was excluded from their delineation even though we found abundant surficial indicators of active fluvial processes including sediment transport, sorting, and deposition. Based on the MESA protocols, both of these features are active streams.



Anthropogenic Influences

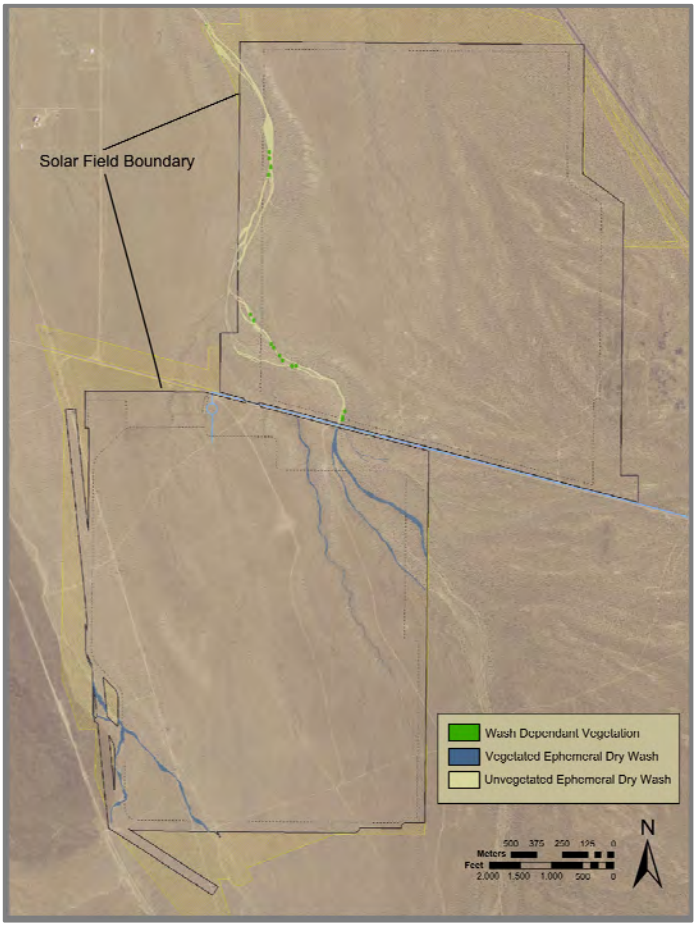
The Ridgecrest Solar Power Project solar fields are divided north from south by Brown Road. El Paso Wash and an unnamed tributary flow over the road at two unculverted low points.

The project consultant identified only the current low-flow channel of El Paso Wash as jurisdictional (Fig. 29, in blue) excluding or failing to recognize the broader channel form and its floodplain. They also identified the upstream reach of the unnamed tributary east of El Paso Wash, but excluded or failed to recognize that the tributary crosses the road and continues downstream to where it joins El Paso Wash (Fig. 29, also in blue). No rationale for the exclusion was provided.

During our review of the aerial imagery, we noted a history of road repairs and the presence of a well-defined channel form downstream of the road, which indicates that even though the road

beheads the channel and appears to effectively retain runoff from lesser flows (ponding outlined in brown Fig. 30) the downstream reach of the tributary is active.

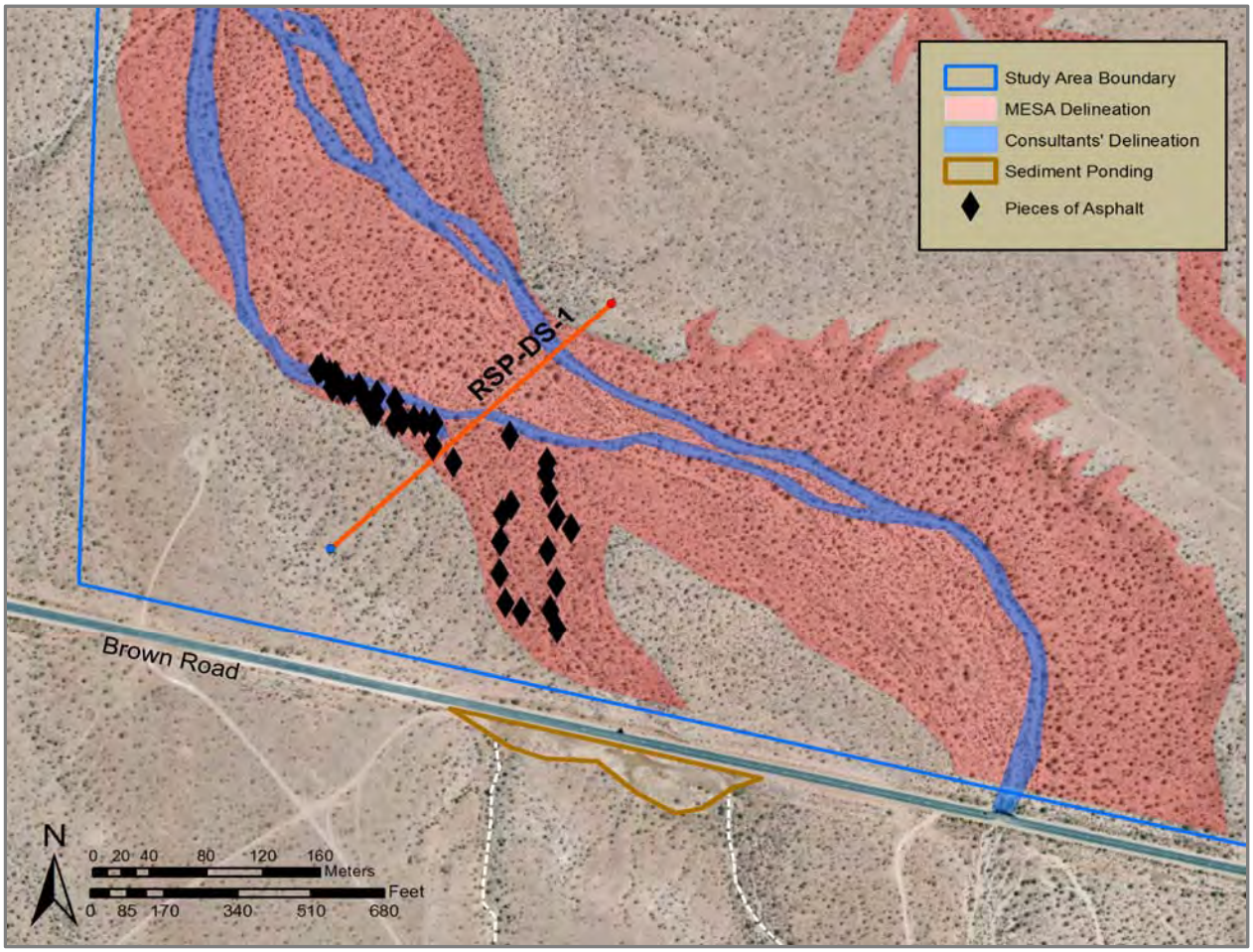
Figure 29: Project consultant's stream delineation. Light yellow streams in the north solar field (north of Brown Road) are mapped as vegetated ephemeral dry wash; blue streams in the south of Brown Road are mapped as unvegetated ephemeral dry wash. Map adapted from EDAW, Ridgecrest Solar Project Jurisdictional Delineation Report for Regulated waters of the US and state. Prepared for Solar Millennium (2009).



There, a sandy substrate, recent light rains, and heavy OHV use obscured the subtle fluvial indicators on the tributary reach downstream of Brown Road, but there are active gravel bars within the largest channel as well as the edges of its floodplain (Fig. 31 A). Mixed in with the gravel are numerous pieces of broken asphalt. The asphalt pieces vary in composition and in stage of weathering and decomposition (Fig. 32 B). The presumed, multiple generations of asphalt present indicates that the road was overtopped multiple times and bedload transporting flows washed the asphalt from the road downstream into El Paso Wash. We surveyed the watercourse for pieces of asphalt and mapped its location using the iPad Garafa GIS software (Fig. 30, black diamonds). One gravel bar contained pieces of asphalt overlying a decaying tire (Fig. 32). The presence of historic human debris allows an age to be established for activity within this wash. Within the time period of the tire being deposited (regardless of method of deposition), a flood event sufficiently large to transport large pieces of asphalt deposited the

material on top of the tire. The age of the tire and asphalt from Brown Road places the flooding event within the life span of the solar project and the F&GC jurisdictional time period of activity (0 to ~200 years).

Figure 30: MESA delineation of El Paso Wash and dormant channel at Brown Road. Red line is MESA transect for data collection and cross section. Black diamonds indicate pieces of asphalt. The thick blue lines represent the consultants' jurisdictional delineation of the low flow channels of El Paso Wash, and pink indicates the extent of the delineation using the MESA protocol. The upstream reach of the tributary with the asphalt (to the left of El Paso Wash) continues upstream (south) of Brown Road and is shown by dashed white lines; the area outlined in brown south of the road is where stream flow from the beheaded upstream reach of the tributary is captured and impounded by the road embankment.



We concluded that the wash segment downstream of Brown Road was functional only at flows large enough to overtop the road (dormant), but that it retains its potential to function if reconnected to the full range of stream flows occurring upstream. Re-establishing hydrologic connectivity by installing culverts or other engineered structures and allowing the wash flow beneath the road would:

- Prevent the destruction of the road from overtopping flows and therefore decrease the amount of maintenance;

- Eliminate the distribution of asphalt into the water course which can be deleterious to wildlife and is in violation of the F&GC, and
- Reestablish connectivity for desert tortoises and other species that tend to use dry washes as seasonal migration corridors but that must now cross the road and thread their way between vehicles in order to get to the other side.

Although installing engineered structures to allow hydrologic and biologic connectivity would be initially expensive, they become cost effective over time by decreasing maintenance and eliminating the potential for environmental mitigation with respect to wildlife and habitat.

Figure 31: Dormant stream gravel bars with asphalt. A: Gravel ramps on floodplain including pieces of asphalt mixed in. B: Pieces of asphalt from bar in A; note different material and stages of decomposition.

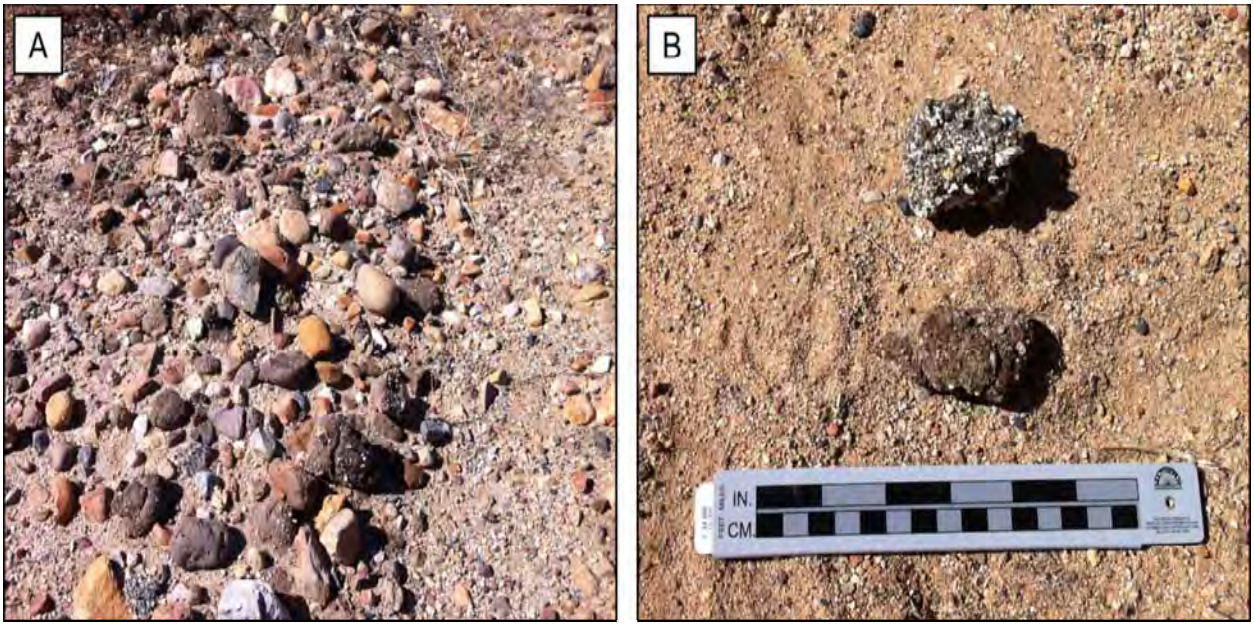
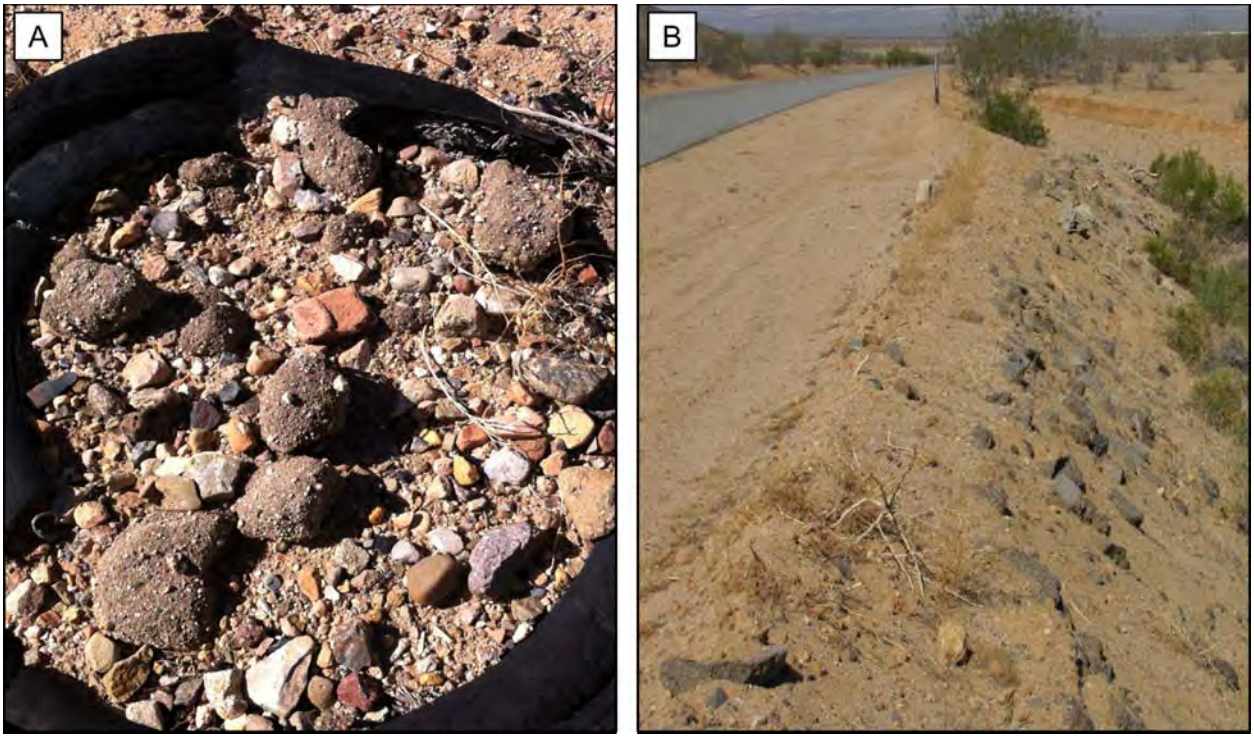


Figure 32: Evidence of anthropogenic influence. A: Decaying tire overtopped with gravel and asphalt. B: Waste asphalt along Brown Road upstream of dormant channel, March 2013.



Reasons for the Discrepancies between Stream Delineations

Our delineation identified 76 streams in the area for a total of 357 jurisdictional acres, while the consultants' stream delineation reported 16.6 acres of potentially jurisdictional streams. Reasons and contributing factors that appear to account for the discrepancy include:

1. **Stream delineation mapping as a precursor action to determining F&GC jurisdiction.** F&GC Section 1602 designates that **all** streams are subject to this code section. There are several mechanisms by which jurisdiction is acted on, or resolved – but each begins with identifying **all** (or any) streams present on a site in order to characterize the potential for adverse project-related impacts to them. The only jurisdictional criteria specified in F&GC Section 1600 et sequence are: (1) detrimental impacts associated with the substantial diversion; or (2) obstructing the natural flow of a stream, or substantially changing or using any material from its bed, channel, or banks; or (3) disposing of debris or waste materials where it may pass into a steam. These criteria can only be applied once stream presence has been identified and a project design developed to a level of detail adequate for potential impact analysis.

2. **Misapplying jurisdictional criteria.** The consultants' project stream delineation report cites incorrect criteria to characterize and identify "jurisdictional streams" and thus to determine the acreage of streams potentially subject to project-related impacts. These include:

   - Incorrect definition of a "stream" in Title 14, California Code of Regulations, Section 1.72 to characterize streams subject to CDFW jurisdiction;

   - Delineated only those watercourses that support or have previously supported riparian vegetation, and

- Delineated only unvegetated channels having well-defined bed, banks and channels.

3. **Stream Form and Process.** Using an incorrect stream definition and over relying on vegetation to define a geomorphic feature notwithstanding, the following interpretations in the consultants' report suggests a lack of familiarity and understanding of dryland stream processes and forms in general, and of the role of small, first order streams in desert ecosystem function in particular:

   - Where an otherwise recognized stream failed to conform to some of the misapplied criteria outlined in (2), or the channel form became less distinct or intermittently lost, the entire stream was considered not to be jurisdictional.
   - Where some evidence of past surface water flow was observed but distinct shelving and/or scour was absent, the linear or lateral extent of the jurisdictional boundaries was determined to have ended.
   - Where the channel form was subtle to begin with and the associated vegetation was not wash-dependent, the feature was not recognized as a stream.

4. **Over reliance on vegetation mapping using Holland 1986 Classification system:**

   - The consultant used the Holland 1986 vegetation classification system and the presence and absence of different types of vegetation to determine which streams were subject to F&GC jurisdiction. However, presence or absence of vegetation using any classification scheme is not a determining factor for stream presence and thus, for jurisdiction. The CDFW Lake and Streambed Alteration Program (LSAA) website notes under the topic of Jurisdictional Determination that "Vegetation maps produced under the state standards do not imply regulatory jurisdictional determinations under… Section 1600 of the F&GC … Similarly, terms such as "riparian" and "wetland" in the vegetation keys and type descriptions may inform but do not imply or assert regulatory jurisdiction or the lack thereof." http://www.dfg.ca.gov/biogeodata/vegcamp/natural_comm_background.asp

   - Holland 1986 provides "preliminary descriptions of the terrestrial natural communities of California," and is described by the author as a "coarse filter" of vegetation classifications. Moreover CDFW has since replaced the Holland scheme with more recent tools to classify vegetation. The CDFW website states that "Holland types originally tracked by the California Natural Diversity Data Base are provided as 'legacy information' with the understanding that the CDFW no longer supports Holland codes and community. Instead, all new information on terrestrial natural communities is to use the state's standard nomenclature as provided in the current Natural Communities List." An example of recent vegetation mapping which meets state and federal standards is the "California Desert Vegetation Map in Support of the Desert Renewable Energy Conservation Plan." Available on the CDFW state website as of April 2013.

5.4.6 Conclusions-El Paso Fan

- The project consultants determined there are 6 streams present for a total of 16.6 acres of potentially jurisdictional streams, while we determined that many more streams are present for a total of 357 acres of potentially jurisdictional streams.
- Discrepancies between the consultants' calculated area of jurisdictional streams, and ours using MESA protocols is largely the result of their applying incorrect stream delineation criteria, and the over-reliance on vegetation to define geomorphic features.
- The project consultant used high resolution aerial images of the project, and field surveys conducted by a team of ecologists with expertise in arid region ecosystems and experience in state and federal stream delineations. But they then incorrectly used vegetation community characteristics combined with bank characteristics to diagnostically determine streams subject to F&GC jurisdiction. None of the staff was a geologist or geomorphologist.
- Their use of an incorrect stream definition and over reliance on vegetation to define a geomorphic feature notwithstanding, the project consultant's interpretations suggest a lack of knowledge about dryland fluvial geomorphology (processes and forms) and of the importance of small, first order streams in desert ecosystem function in particular.

5.4.7 Recommendations

- Adopt a science-based stream delineation protocol like MESA, update guidance on CEC and CDFW/LSA websites, and include this guidance in permitting packages.
- Integrate stream delineations with the project planning and site characterization process, creating a base map of all streams present by desk-top mapping informed by review of geologic and hydrologic analysis of stream activity at relevant recurrence intervals.
- A licensed Professional Geologist or geomorphologist with arid region experience should supervise stream delineation mapping, field surveys, and reporting.

5.5 Lucerne Valley Fan

5.5.1 Location

The Lucerne Valley fan delineation area coincides with a proposed solar project located in the Lucerne Valley in the southwestern part of San Bernardino County in the Mojave Desert geomorphic province on the north side of the San Bernardino Mountains and at the foot of Blackhawk Mountain (Fig. 33).

The delineation area and project site occupies 516 acres at an elevation of approximately 914 to 975 m above mean sea level, approximately nine miles east of the community of Lucerne Valley and south of California State Highway 247 at the intersection of Santa Fe Fire Road, in T. 4 N., R. 2 E, Sec. 19, 20, 29, and 30, and in Section 24 of T. 4 N, R. 1 E. on the Cougar Buttes, San Bernardino County 7.5-minute USGS topographic quadrangle (1994). The site is located south of Foothills Road and is bordered by Donaldson Road on the west and by an unnamed drainage approximately 396 m east of Santa Fe Fire Road. The site is bisected by two named roads – the aforementioned Santa Fe Fire Road and Zircon Road – and several unnamed dirt tracks

Historically the site was used for low-level mineral exploration but is otherwise vacant and undeveloped. The Blackhawk Landslide, a large and geologically renowned slide that occurred approximately 20,000 years ago, is less than 518 m from the project's eastern boundary. The site is completely within public lands administered by the United States Department of Interior's Bureau of Land Management (BLM).

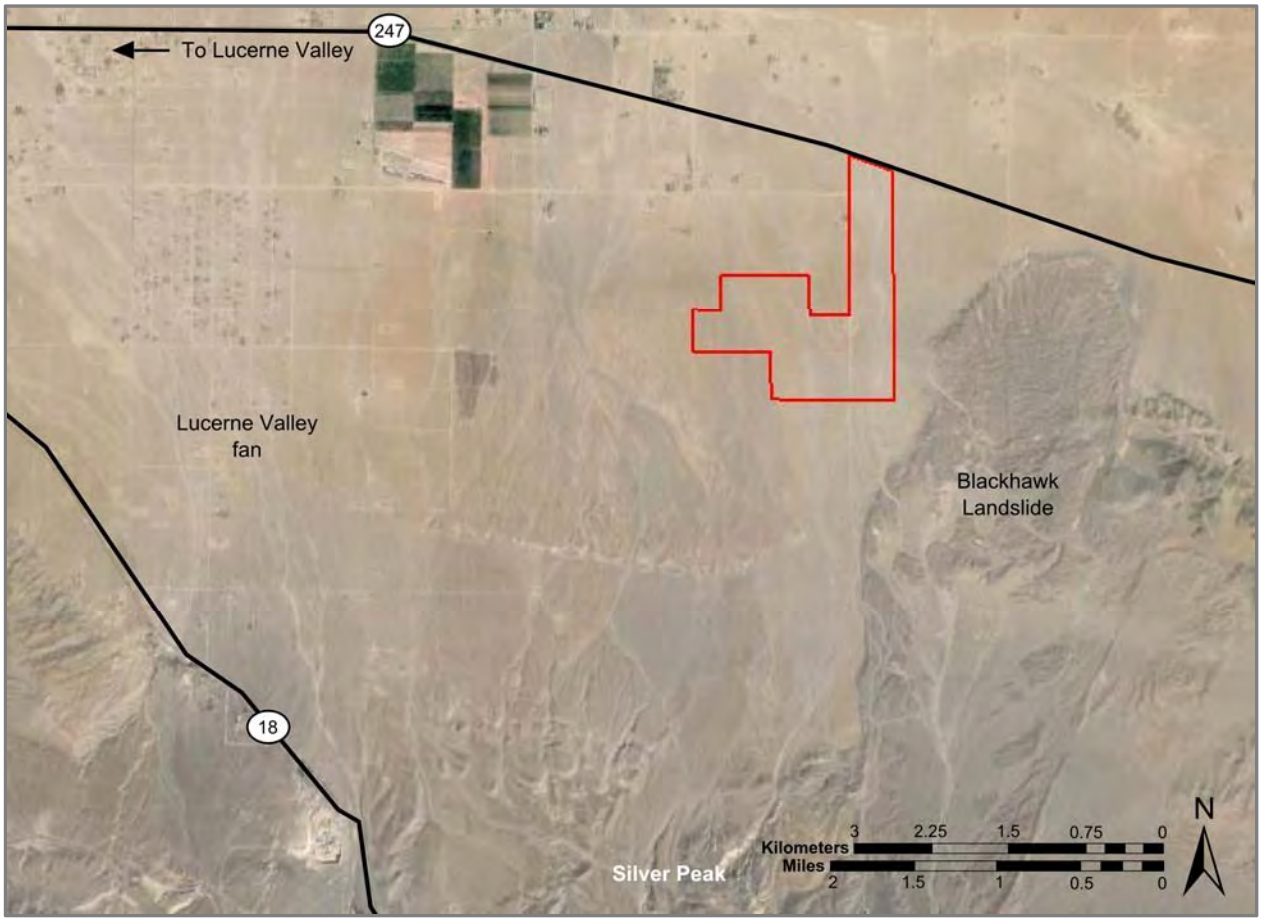
5.5.2 Setting

The delineation area is located on the distal portion, or toe, of an alluvial fan. The fan is youngest and most active on the east side of the site and becomes progressively less so as the site transitions to older fan deposits to the west. The surface and shallow subsurface geology is composed of Quaternary alluvium deposits to a depth of 60 m or so. The unconsolidated surface sediments consist of Holocene-age coarse material and younger alluvium deposits that overlie deeper, older formations. The coarse materials are exposed along the northern foot of the San Bernardino Mountains as fragments derived from the uplands of Blackhawk Mountain that grade into a series of younger active and inactive alluvial fan deposits that cover the delineation area. The alluvium is composed of gravel, sand, silt and clay also derived from adjacent hills. Younger deposits range in thickness from a few centimeters to approximately 30 m (USGS 2000).

West of the young alluvial fan deposits (on the east) the surficial geology is dominated for the next mile or so by geologically young slope wash and alluvial deposits. These areas consist of oxidized slope wash and alluvium deposited on a substrate of moderately old fan and/or very old fan deposits on the north side of the San Bernardino Mountains (USGS 2000).

Stream flow is north out of the mountains crosses the site over relatively flat slopes of about 2 to 2.5 percent, eventually converging with the Lucerne Valley Wash approximately 2.5 km downstream. The Lucerne Valley Wash receives all runoff from the site and flows to the northwest for a distance of approximately eight miles to Lucerne Lake. Lucerne Lake receives runoff from the delineation area only in the wettest of years due to the high rates of evaporation, and the loss of surface flow into highly permeable wash sands.

Figure 33: Location map of the Lucerne Valley delineation area and site of the proposed Lucerne Valley Solar Project. Map adapted from that prepared for BLM: Ecology and Environment, Inc. Final Environmental Impact Statement for the Proposed Chevron Energy Solutions, Lucerne Valley Solar Project, 2010.



The delineation area is dominated by seven larger streams and numerous lesser channels. The largest streams are mapped as active washes with deposits consisting of unconsolidated medium to coarse grained sand and sandy gravel with subordinate fine sand and silt. The stream channels are not vegetated and are characterized by active and recently active sediment accumulation with little or no soil-profile development (USGS 2000).

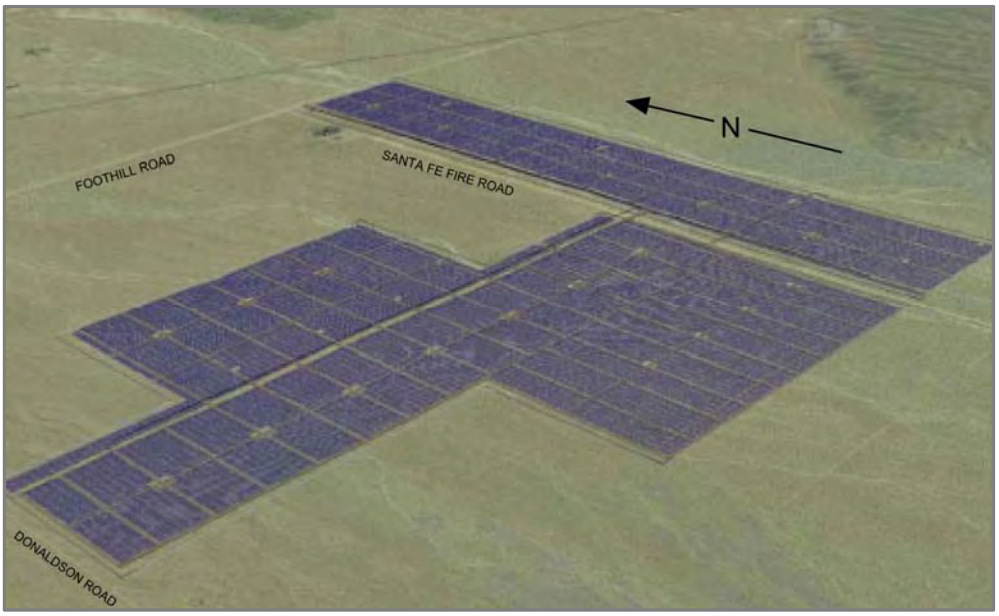
From east to west across the area the streams vary in the following way: (1) the east edge of the site is bounded by the largest of the streams – a watercourse of varying width and definition and comprised of a braided network of channels that are laterally mobile and reflective of rapidly changing flow patterns; (2) west of Santa Fe Fire Road and through the central part of the site the streams are broader with less defined boundaries at the southern boundary of the site and develop a well-defined, meandering single-thread form as the streams flow north and across the site, (3) west of Santa Fe Fire Road and interspersed throughout the central part of the site there are numerous, small, shallow channels whose capacity is likely quickly exceeded during runoff-generating precipitation events, and (4) on the west side of delineation area the streams have fairly well-defined, generally single-thread channels that flow across and are incised slightly into underlying very old debris flow fan deposits. These deposits are matrix-supported angular, to subrounded pebble to cobble-sized clasts of light and dark gray metamorphosed limestone in a well-cemented sand matrix (stage IV to V petrocalcic horizon).

Approximately 95 percent of the site is sparsely to moderately vegetated, with the remaining areas made up of unvegetated desert washes (~ 4 percent), and roads and disturbed areas associated with mineral exploration (~1 percent). The vegetation is dominated by shrubs and herbaceous understory and most closely corresponds with the creosote bush-white burr sage scrub (*Larrea tridentata-Ambrosia dumosa)* shrubland alliance (Sawyer et al. 2009). The most-densely vegetated portions of the site are located east of Santa Fe Fire Road and within 1/4 mi to the west of Santa Fe Fire Road.

5.5.3 Description of the Proposed Solar Project

The project proposes to construct a solar generating facility of approximately 45 megawatts. The facility will use solar photovoltaic (PV) panels mounted on a framing system supported by driven steel piers (Fig. 34). In addition to the arrays of solar panels, a grid of roads will be constructed to provide access to the facility and the solar panel arrays, and a small operations and maintenance building will be constructed to provide office space for maintenance staff and to house maintenance equipment. A final Environmental Impact Statement (FEIS) has been prepared for the project (Ecology and Environment 2010).

Figure 34: Simulated aerial view of proposed solar project build-out of the 516 acre site, of which 100 percent of the area will be utilized. Map adapted from that prepared for BLM: Ecology and Environment, Inc. Final Environmental Impact Statement for the Proposed Chevron Energy Solutions, Lucerne Valley Solar Project, 2010.



The proposed plan is to leave the site topography and the natural paths of the streams in their current form and orientation; however, the ground will be cleared of all vegetation and the surface of the ungraded earth scarified. Grading will be limited to constructing a grid of access roads engineered from compacted native soils. The access roads will be constructed so the finished grade is flush with the existing ground on either side so as to maintain stormwater runoff into and through the site to the north (Ecology and Environment 2010).

To maintain the existing drainage through the site solar panels will be mounted on piers driven into the ground and designed to maintain a minimum clearance of 7 cm above the 100-year flood elevation (Westwood Professional Services, Inc. 2010).

Project-related flood impacts were analyzed with a composite method using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) model in combination with sheetflow analysis to model water depths and extents. HEC-RAS is industry-standard software that allows modeling of water flow and sediment transport in natural streams, and the development of water surface profiles.

The composite modeling approach is intended to better describe the likely stream flow conditions by allowing for the variations in flow that occur between stream channels of differing size and form characteristic of this site.

The hydraulic analysis used the six largest washes and their contributing watersheds to determine flow volumes for the site. The project hydrologists, hydrologists from BLM, and independent peer reviewers of the project hydrology study have all concluded that even though the peak 100-year flow is likely greater than that presented, the project will have little impact on water flow down gradient of the site as a result of project development. Should the increase in peak flow prove true as the hydraulic model is updated the technical consensus is that the relative differences between pre-development and post-development hydrology should remain; however, the pier scour and the depth of pier placement, height of the PV panels above the ground surface, and the placement of solar PV blocks may need to be reconsidered (Ecology and Environment 2010).

5.5.4 Consultants' Jurisdictional Stream Delineation

Methods

Before beginning their field work for the stream delineation, the project consultant examined high-resolution aerial photographs, USGS topographic maps, and Google Earth images to identify streams potentially subject to CDFW jurisdiction. They followed these preliminary investigations with field surveys conducted by two biologists, both having expertise in arid region ecosystem flora and fauna, and one having expertise conducting state and federal stream delineations (Chambers 2009).

In the field, they recorded boundaries and dimensions of jurisdictional features on a GPS unit, topographic maps, aerial photographs, and (or) field notes. Potential jurisdictional areas were field-checked for the presence of definable channels and (or) wetland vegetation, riparian habitat, soils and hydrology.

The consultants noted surficial indicators of stream presence according to the US Army Corps of Engineers (USACE) wetland Manual and Arid West Supplement guidelines including inundation, saturation, high water table, watermarks, drift lines, sediment deposits, surface soil cracks, water stained leaves, biotic crusts, and aquatic invertebrates. Shallow subsurface indicators of wetland and (or) saturated soil conditions included the presence of hydrogen sulfide odor and oxidation/reduction features in the soil (Chambers 2009, USACE 1987, 2006 respectively). The stream survey results were subsequently digitized to determine the jurisdictional acreage, and all data were reproduced using geographic information system (GIS) software for display on aerial photo-based maps.

The consultants identified streams potentially subject to CDFW jurisdiction using the guidance described in *A Field Guide to Lake and Stream Bed Alteration Agreements* (CDFW 1994), and Section 1.72 of Title 14 of the California Code of Regulations (14 CCR 1.72) which defines a stream

(including creeks and rivers) as a *"body of water that flows at least periodically or intermittently through a bed or channel having banks and supports fish or other aquatic life. This includes watercourses having surface or subsurface flow that supports or has supported riparian vegetation."* (Chambers 2009).

Consultants' Results

The consultants' study noted that of the many streams observed within the project footprint, only the seven largest were considered or delineated. No explanation for the exclusion of the smaller streams was provided (Chambers 2009).

These same seven streams are considered in the project's hydrology study, although the hydrologists added one of the streams excluded by the stream delineators and excluded one the delineators did not. The added stream was one of those otherwise excluded by the project delineators as a non-jurisdictional linear erosion feature, and the excluded stream was one on the east side of the project area that may have been viewed by the hydrologic study as a subordinate feature relative to the much larger watercourse it parallels, and thus not of consequence from a flood management perspective.

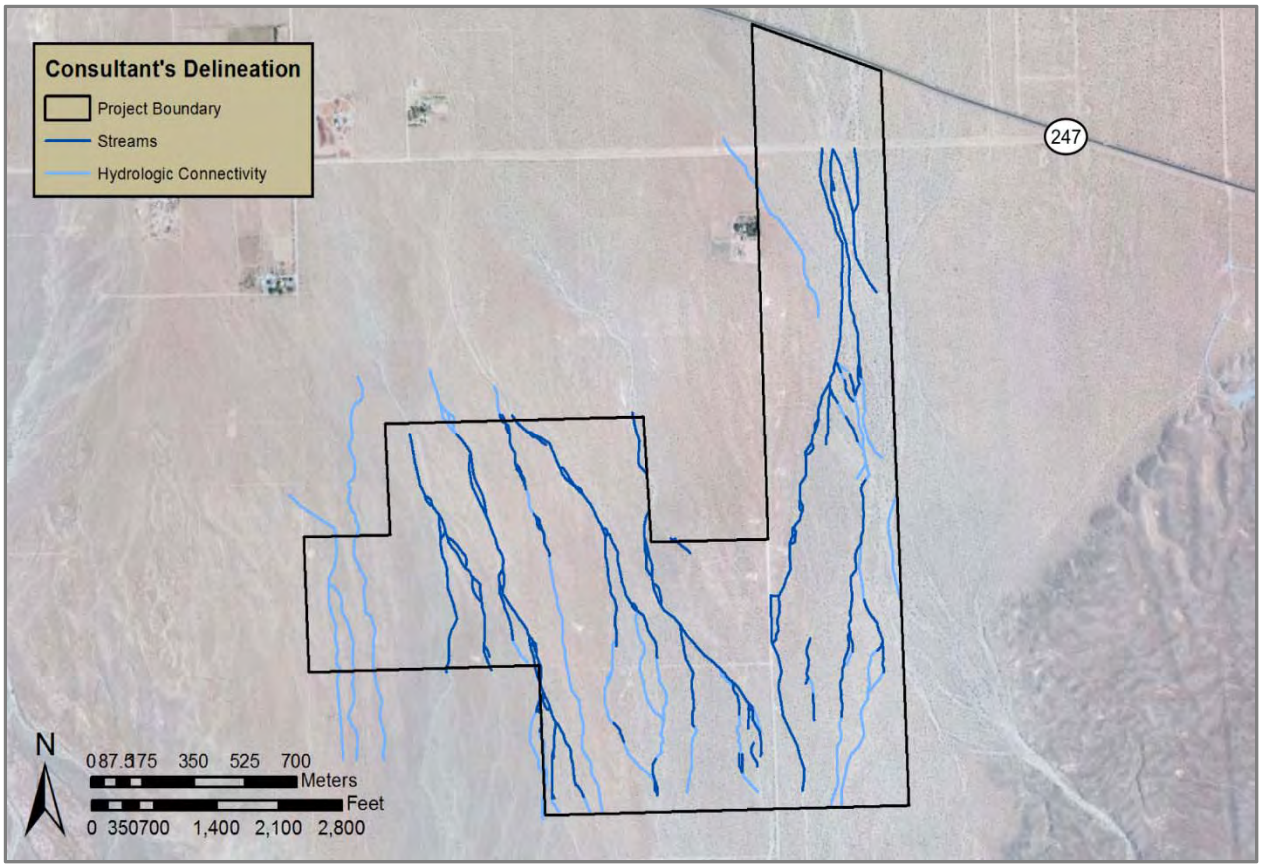
The project consultants dug soil pits looking for hydric soil layers and oxidation/reduction features associated with the streams selected for delineation, but found none, so determined that no jurisdictional wetlands are present within the project delineation area (in this setting, none would be expected).

The consultants' delineation study noted that that CDFW jurisdiction tends to be more expansive than other regulatory agencies because, rather than from the Ordinary High Water Mark (OHWM) used by the USACE and the Regional Water Quality Control Boards (Water Boards), F&GC jurisdiction commonly includes the top of stream banks, and can extend beyond the top of a bank to include riparian vegetation. The consultants' delineation study does not define the terms "riparian" or "riparian vegetation" in general or relative to dryland environs, or acknowledge the CDFW view of floodplain areas as integral parts of stream function and thus in practice within the bounds of F&GC jurisdiction.

The consultants' delineation study identified two problem areas in determining acreages of jurisdictional waters: (1) channel forms with surface flows that tend to subside into the sandy soils of the channels or along or outside of identified wash boundaries without leaving definable banks, and (2) "hydrologic connectivity features" present in the southwest corner and near the western boundary of the site that do not have well-defined bank-to-bank features (Fig. 35). Because bank-to-bank width measurements were not possible in these two problem areas, they were excluded in the determinations of jurisdictional waters (Chambers 2009).

The term "hydrologic connectivity" is not defined in the consultants' reports, but based on the context of use it appears to refer to long, linear erosional features that contain fluvial sand and gravel deposits suggesting the feature is a stream but that the absence of well-defined banks indicates is not.

Figure 35: Project consultant's stream delineation map. Dark blue color designates streams and stream segments identified as subject to CDFW jurisdiction. Lightest blue color designates streams and stream segments determined to be non-jurisdictional based on the absence of well-defined banks. Map adapted from that prepared by Chambers Group, Inc. for BLM: Environmental Impact Statement, Appendix D, Comprehensive Biological Resources Assessment for the Chevron Solar Project Site Community of Lucerne Valley, California, 2009.



The consultants' report concluded that, based on bank-to-bank measurements of the seven streams, there are 12.32 acres of potentially jurisdictional streams within the project area. All seven streams mapped were deemed to be of "poor" or "low quality" for wildlife due to off-highway vehicle usage, pedestrian traffic, and the absence of aquatic wildlife and/or aquatic plant species (Chambers 2009). But all of one stream and parts and pieces of the other six exhibited defined bank characteristics, including OHWMs, and thus the stream and the well-defined parts of the others were determined subject to F&GC jurisdiction.

5.5.5 MESA Protocol-based Stream Delineation

Methods

Our pre-field survey methods used for the MESA delineation were similar to those used by the project consultants with the following additions:

- We acquired and reviewed geologic maps and reports of the area;

- We preliminarily mapped all apparent watercourse boundaries and landform locations based on interpretation of aerial signatures such as changes in landscape color, vegetation density, and drainage pattern;

- We selected areas for on-the-ground field review and verification of the preliminary mapping based on analyzing aerial photographs and using the guidance in *A Review of Stream Processes and Forms in Dryland Watersheds* (CDFW 2010).

Our in-field survey methods were also similar to those used by the project consultant with the following variations and additions: We

- Used surficial geology and surface indicators of stream presence and absence similar to but more extensive than the USACE indicators used for the project delineation study;

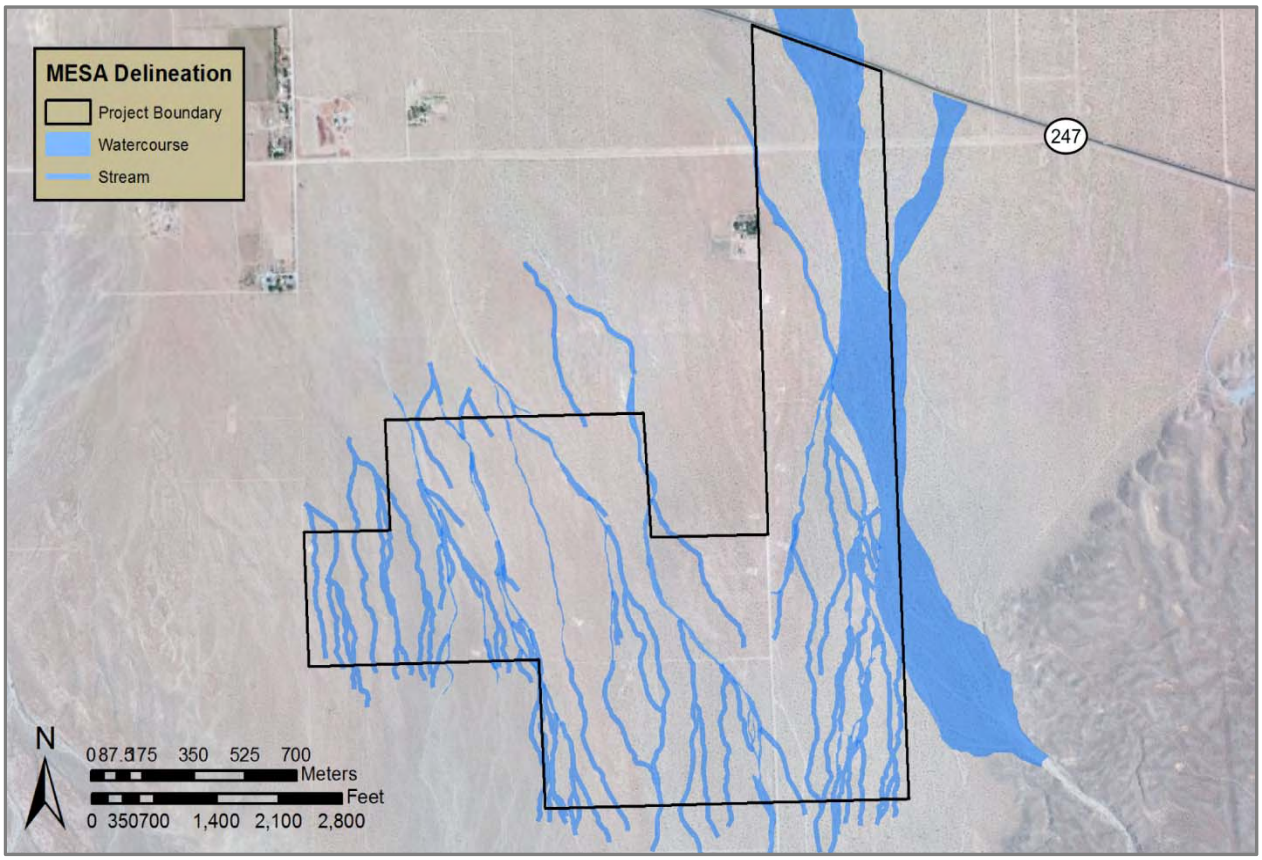
- Excavated soil pits not in search of hydric soils but to discriminate between fluvially active and inactive areas where the surficial evidence of stream flow was obscured by long time between surface flow events or by other processes – such as windblown sand deposits or anthropogenic impacts (e.g., OHV use).

- Conducted pre- and in-field investigations to refine our initial stream delineations. We photo-documented and mapped our stream delineations, sampling locations, and stream and botanical survey transects in the field using an iPad, Google Earth imagery, and GIS-based Garafa mapping software. We further refined pre-field stream delineations and jurisdictional acreages determined in the office by drawing upon detailed topographic and hydraulic data part of the hydrology study developed for proposed solar project.

MESA Protocol-based Stream Delineation Results

The consultants' delineation report for the site noted that while many streams were observed within the proposed project footprint only the seven largest streams were considered or accounted for, and no explanation for the exclusion of the smaller streams was provided. We verified the seven dominant streams identified by the consultants' delineation and hydrologic studies, but determined that their "hydrologically connected" linear erosional features are actually streams, along with dozens of other large and small tributaries that they had not identified (Fig. 36).

Figure 36: MESA stream delineation map, Lucerne Valley. See enlarged version (Appx. A).



As described above, the streams vary in form and complexity, and as they enter and leave the site. Because of this there are a number of different ways to account for individual streams, and no comparative total is provided here. The point is not to equivocate over numbers of streams or acreages calculated, but rather to evaluate the effectiveness of the skills and methods applied to the task of identifying streams present and to be conserved through avoidance or to characterize the scale of loss if they are not. To this end, various aspects of three streams characterized by the project delineation study were comparatively re-considered using the MESA protocol (Fig. 37).

We selected the following three features for comparison:

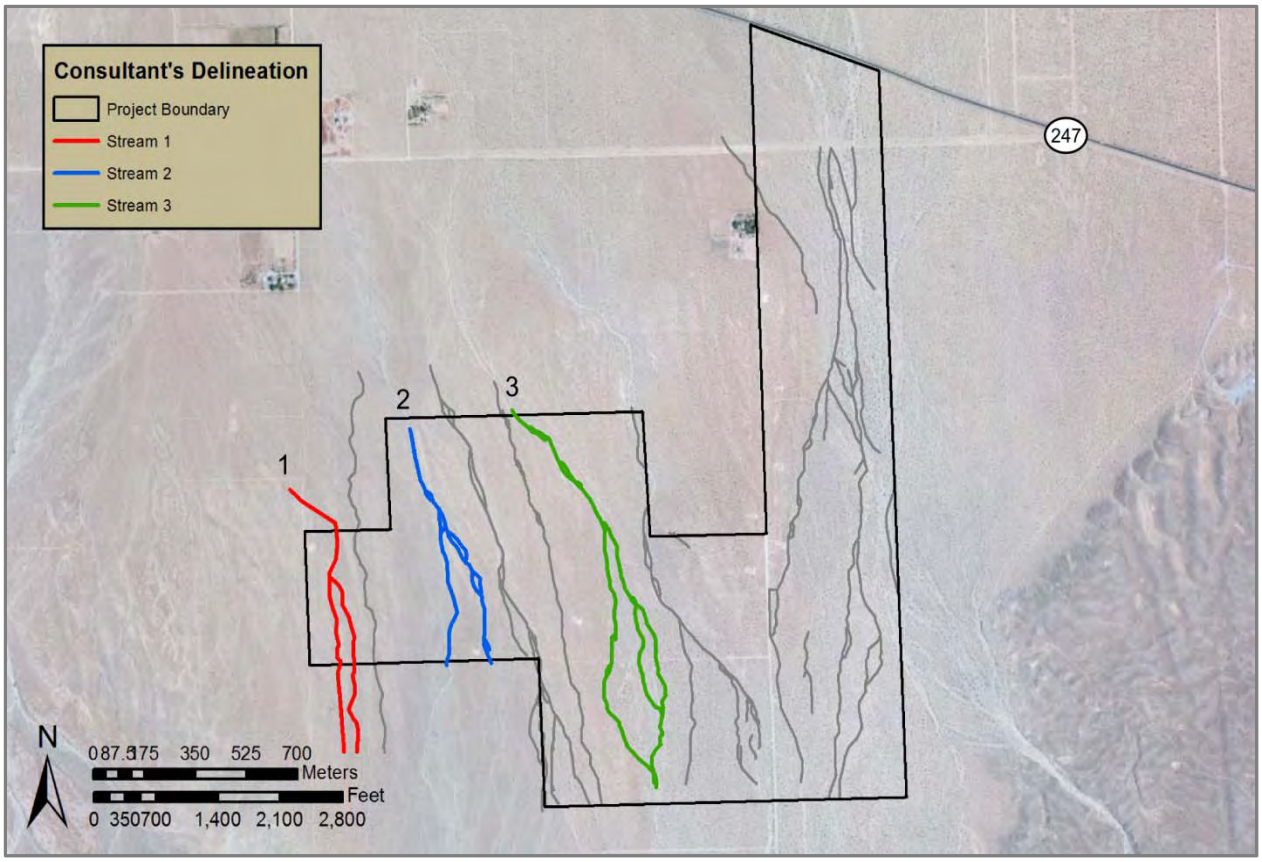
1) A "non-jurisdictional, hydrologically connected linear erosional feature" as determined by the consultants' study, but identified as a stream by the project hydrology study and our MESA delineation;

2) A stream mapped by the consultants' and project hydrology studies, and our MESA delineation;

3) A stream mapped by the consultants' study, the project hydrology study, and our MESA delineation study, but that the project delineation study excluded large sections as non-jurisdictional.

Each of these is discussed below.

Figure 37: Project stream delineation study map and features comparatively re-considered using the MESA protocol. [1] In red, Non-jurisdictional hydrologically connected linear erosional features; [2] In blue, stream similarly mapped by this investigation and the project delineation and hydrology studies; [3] In green, stream mapped similarly by this investigation and the project delineation and hydrology studies, but that the project stream delineation determined large sections of which to be non-jurisdictional. Map adapted from Chambers (2009).



1) Hydrologically connected linear erosional feature. This feature is on the far west side of the area (Fig. 37, feature in red). The project delineation study determined that because this landform did not exhibit well-defined, bank-to-bank features it was not a stream and thus was not included in the calculation of jurisdictional stream lengths and acreages. Both the hydrology study and our investigation identified this landform as a stream (Fig. 38). As well, the USGS (2000) also mapped this feature as an active stream or wash with deposits consisting of unconsolidated medium to coarse grained sand and gravel with subordinate fine sand and silt and little to no soil development.

Given the subtle topography of the project area in general and in this portion of the project area in particular, we excavated several soil pits to depths of 0.45 m to 0.61 m to assess the shallow subsurface sediment types and soil development, the relative age of the deposits, and to assess the efficacy of the surficial indicators of fluvial activity and inactivity to confirm and refine the landform boundaries mapped in the preliminary effort.

Soil pit LRN-SP-1 (Appx. B) confirmed that landforms identified as upland fan surfaces based on aerial photographic signatures, and surface indicators in the field such as caliche fragments, rock varnish, and a rocky pavement underlain by a well-developed vesicular A horizon (Av), were indeed fluvially inactive fan deposits many thousands of years old.

Soil pit LRN-SP-2 (Appx. B) in an area identified as being within a watercourse from aerial photographic signatures, and from surface indicators in the field such as coarse sediment sorting, sand and gravel bars, and cut banks, contained young stream deposits indicative of recent fluvial activity, thus substantiating our initial interpretation.

Figure 38: Hydrologically connected linear erosion feature. Feature identified by the project delineation study as a "hydrologically connected linear erosional feature" but mapped as a stream in our investigation, the project hydrology study, and the USGS (2000). The watercourse, including the floodplain, is within the bounds of the dashed white lines; uplands at arrows. Note the substrate color is lighter in the channel and darker on the uplands, and the vegetation is larger but more widely spaced in the channel than on the uplands.

In addition to our soil pits, we used topographic data and modeling results from the project hydrologic study as a check on stream presence and dimensions determined using MESA. Although the hydrology study and associated hydraulic modeling was focused on project-related impacts to flooding and vice versa, the methods combined with detailed site topography allow modeling of water flow in natural stream channels, and the development of water surface profiles in those streams over a range of calculated flows.

As a check on consistency, we then compared the water surface profiles from eight channel cross sections for a 10-year recurrence interval flow as calculated for the consultants' HEC-RAS modeling to the MESA protocol mapping (Fig. 39 and 40). Stream channel dimensions developed using the MESA protocol were compared with the 10-year flow data were selected because we presumed that the smaller runoff events would be wholly or largely contained within the channel and thus a better indicator of channel dimensions than 100-year recurrence flows which seemed more likely to overflow the banks of individual channels and combine with flows from adjacent channels to confound channel dimension determinations.

Figure 39: Comparison of hydrologically connected linear erosional feature channel dimensions using project hydrological data and MESA. Comparison of eight channel cross section widths on the hydrologically connected linear erosion feature identified by the project delineation as a non-jurisdictional feature and as mapped as a stream by the project hydrology study and this investigation. Hydrology Study, Lucerne Solar Project, Westwood Professional Services for Chevron Energy Solutions, 2010. Image: Google Earth Pro.

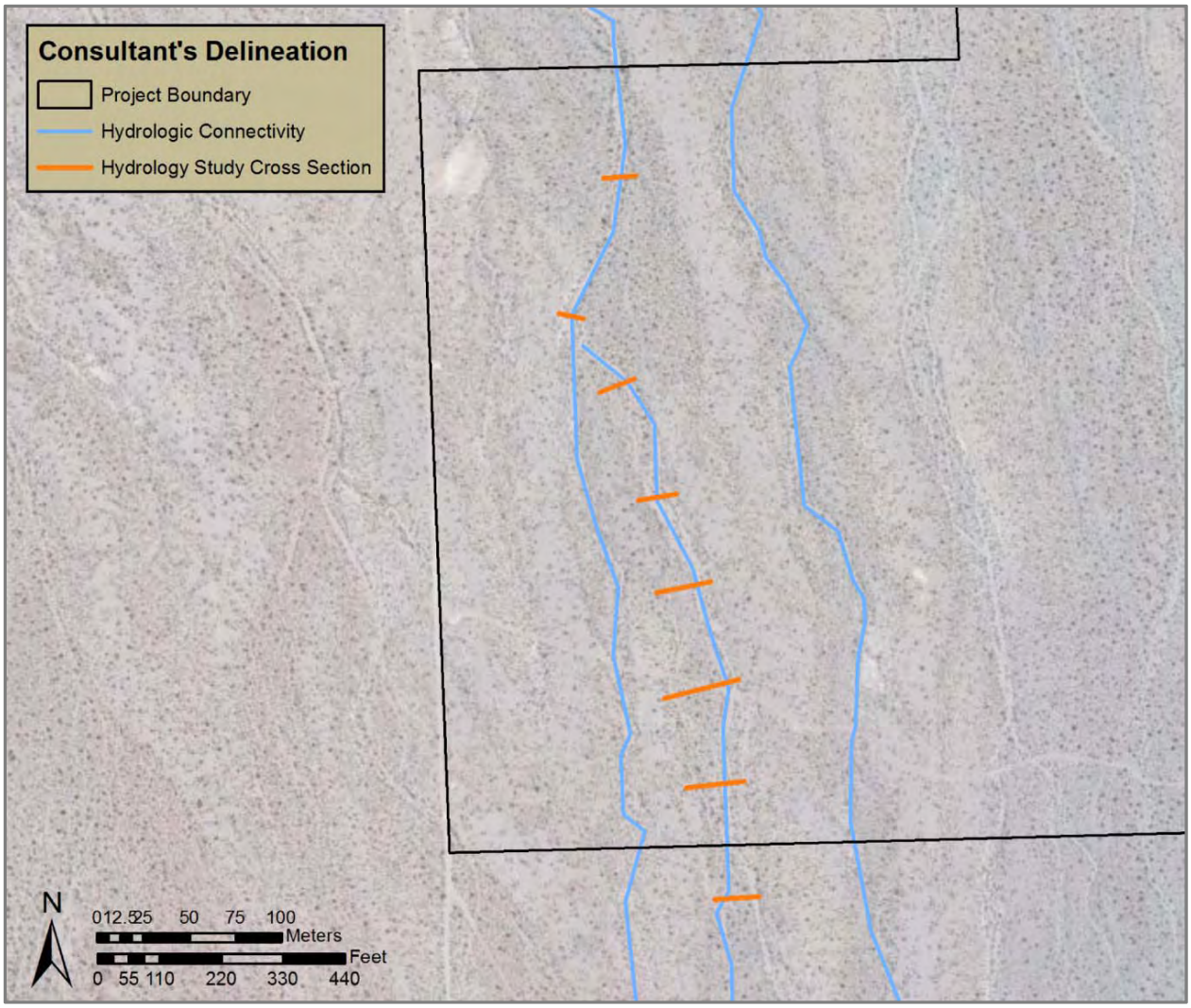
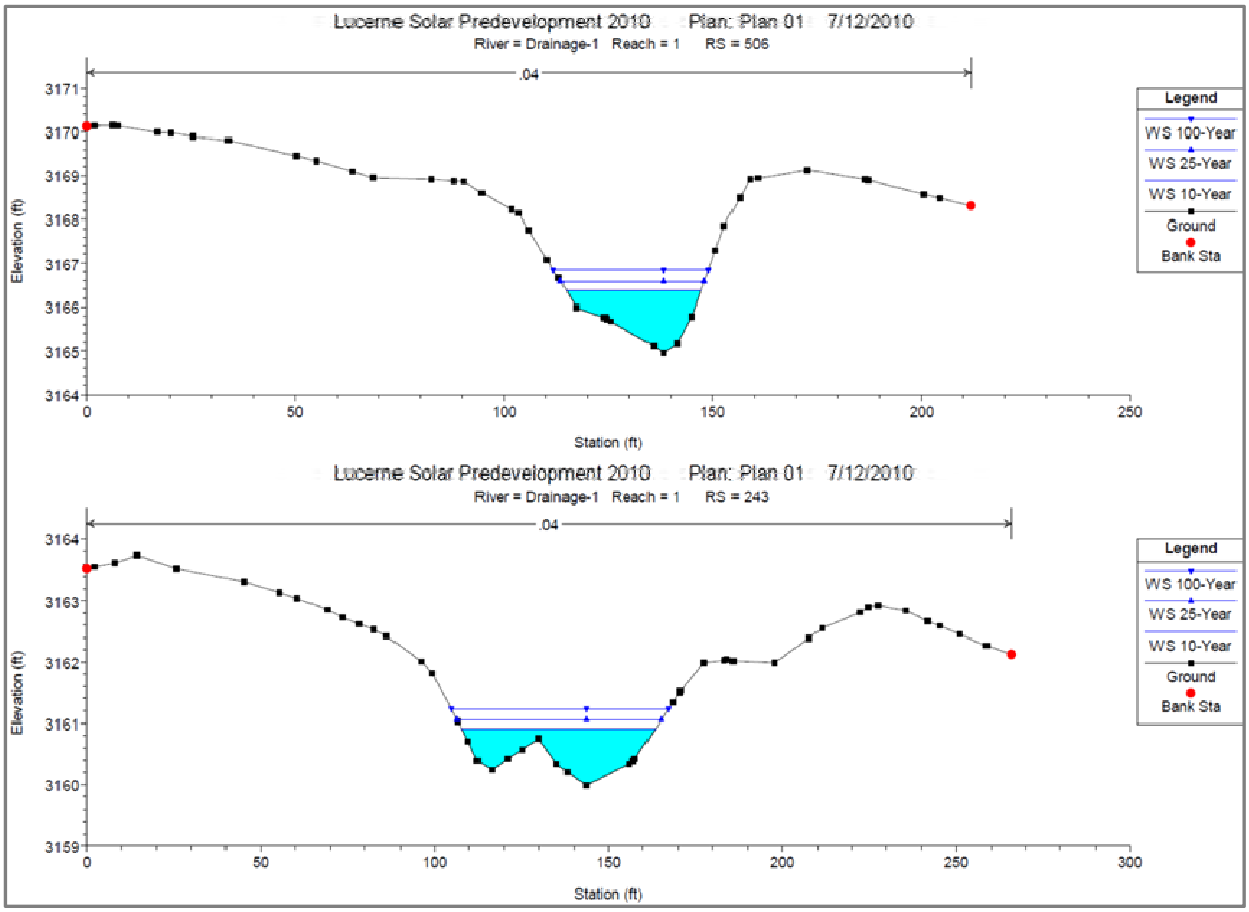


Figure 40: Stream cross sections and water surface profiles developed for the project site. Hydrology Study, Lucerne Solar Project, Westwood Professional Services (2010) for Chevron Energy Solutions.



The project stream delineation, project hydrology studies, and our work calculated the stream length through the project site as 575 m. The hydrology study calculated the average cross-sectional width as varying from 14 m to 42 m for an average width of 28 m, and 3.9 jurisdictional acres, while our work calculates an average width of 26 m for 3.6 acres. No cross section widths or acreages were developed by the consultants' delineation study since the feature was deemed to be non-jurisdictional and thus was excluded from further consideration.

2) Stream mapped by the consultant, the project hydrology study, and our MESA delineation (Fig. 41). All three studies calculated the stream's length as 2418 m. The consultants' delineation determined the average bank-to-bank width to be 2.7 m and a total jurisdictional area to be 1.1 acres, while the project hydrology study determined an average channel width to be 33 m for a total of 20 acres. Our MESA delineation determined an average channel width of 26 m for a total of 17 acres.

3) Stream mapped by all three studies, but large sections of which were excluded as non-jurisdictional by the project delineation study (Fig. 42). The stream was similarly mapped by our MESA investigation and the project stream delineation and hydrology studies, but that the project stream delineation excluded large sections of as non-jurisdictional. All three studies calculated a total stream length of 1508 m. The project delineation study determined the average bank-to-bank width as 2.7 m and the total jurisdictional area as 1 acre. The project hydrology

study determined the average channel width at 54 m for a total of 20 acres. Our delineation determined an average channel width as 52 m for a total of 19 acres.

Figure 41: Comparison of stream channel dimensions using the project delineation data, the project hydrological data, and MESA. Comparison between twenty channel cross sections on a stream similarly mapped by our MESA investigation and the project stream delineation and hydrology studies. Hydrology Study, Lucerne Solar Project, Westwood Professional Services for Chevron Energy Solutions, 2010. Image: Google Earth Pro.

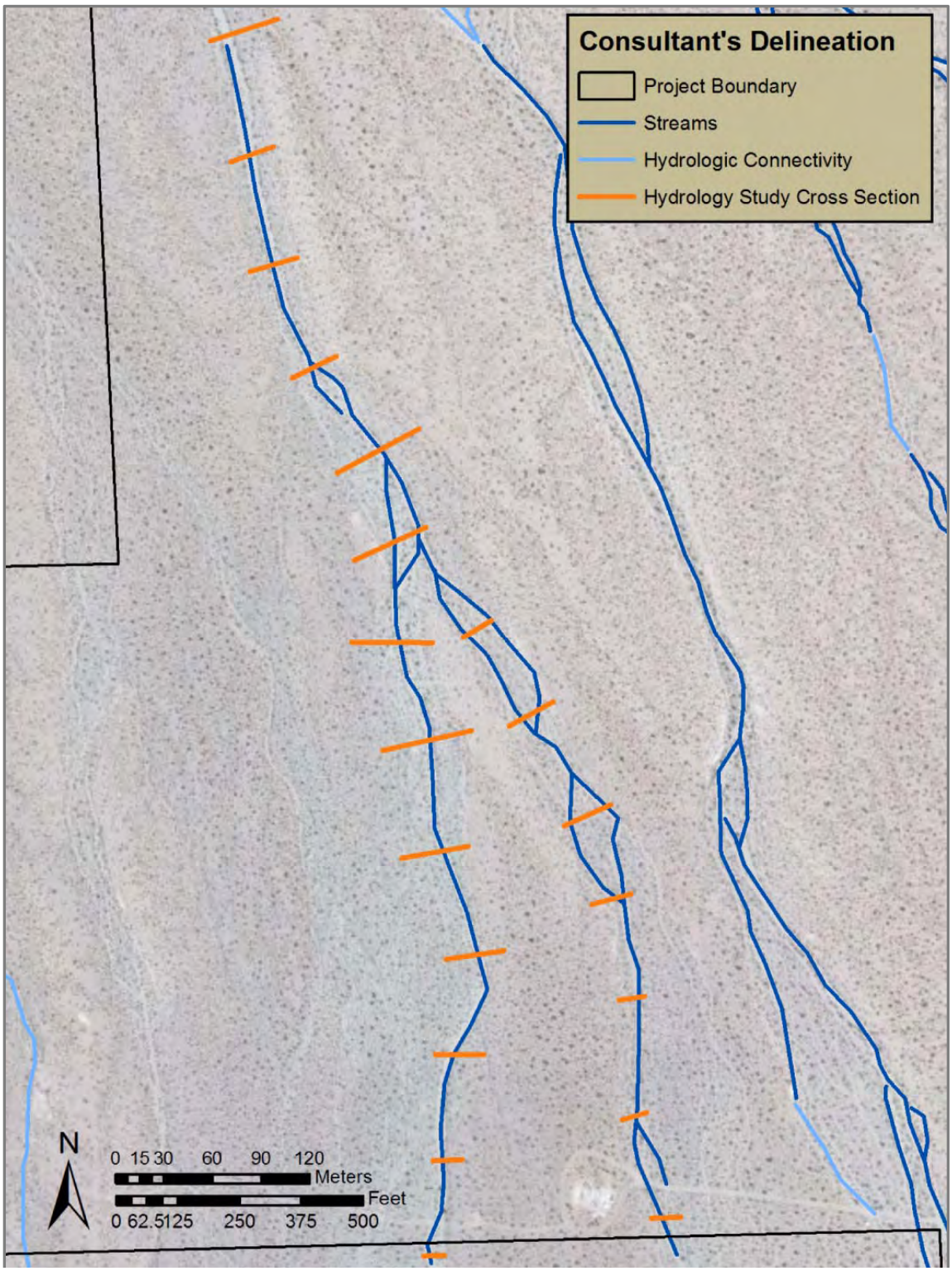
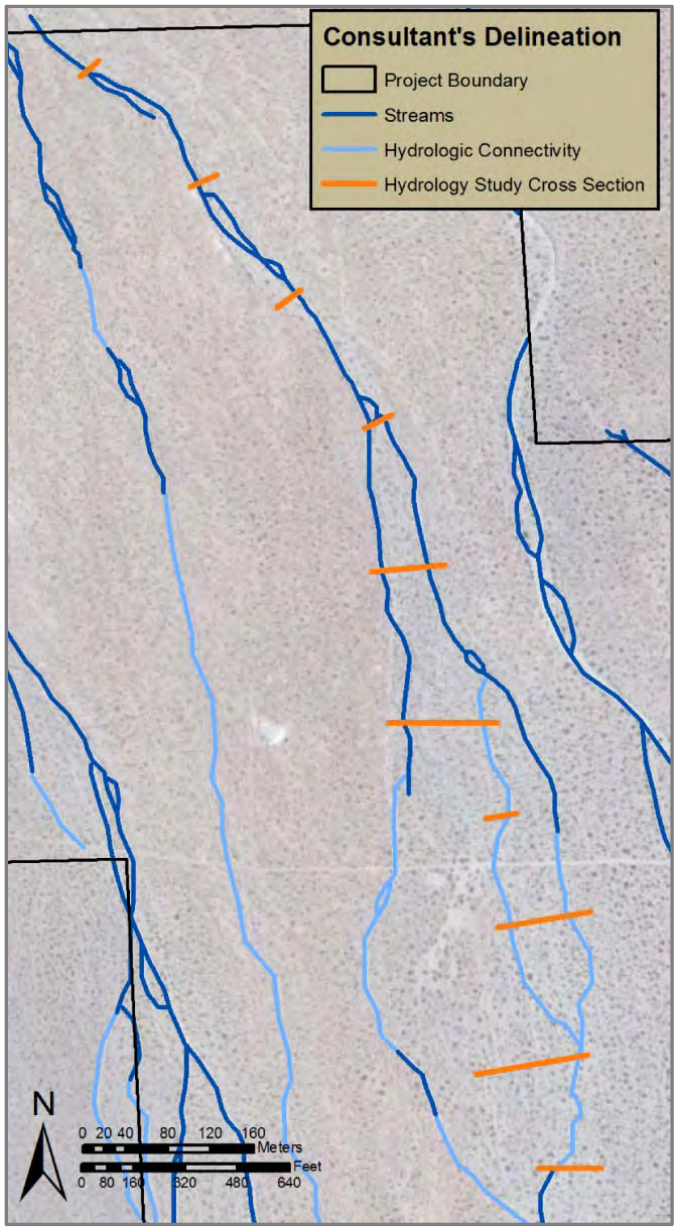


Figure 42: Comparison of channel dimensions on poorly defined stream segments using the project delineation and hydrological data, and MESA. Comparison of ten stream channel cross section dimensions on a stream similarly mapped by our investigation and the project stream delineation and hydrology studies, but large sections of which were excluded by delineation study as non-jurisdictional. . Hydrology Study, Lucerne Solar Project, Westwood Professional Services for Chevron Energy Solutions, 2010. Image: Google Earth Pro.



5.5.6 Reasons for Discrepancies in Recognizing Jurisdictional Streams

The consultants' stream delineation report determined that, based on bank-to-bank measurements of the seven streams mapped, the project area contains 12.32 acres of potentially jurisdictional streams. Of this, the three streams re-analyzed total 2.3 acres according to the consultants' study. Our delineation, which was also checked against the topographic data and modeling results from the project hydrologic study, determined that these three streams totaled ± 40 acres.

Three reasons and contributing factors that likely account for the discrepancies between the project and our delineation:

1) Selective Delineation

Although the project delineation study noted that many streams were observed within the project footprint, only the largest streams were accounted. No explanation was provided for why the smaller streams were excluded. F&GC Section 1602 designates all streams subject to this code section. There are several mechanisms by which jurisdiction is acted on, and (or) resolved, but each begins with identifying **all** the streams present on a site and characterizing the potential for adverse project-related impacts to these natural resources.

2) CDFW Lake and Streambed Alteration Agreement Guidance

The project delineation study used guidance from *A Field Guide to Lake and Streambed Alteration Agreements* (CDFW 1994). Due to its inaccuracies and unclear concepts, and more significantly advances in the sciences of fluvial geomorphology and stream ecology, neither this document, nor a subsequent version dated May 2000, have been in use or available from CDFW for at least a decade.

A) Definitions. The project delineation study incorrectly used the definition of a "stream" from Title 14, California Code of Regulations, Section 1.72 to characterize streams subject to CDFW jurisdiction. This definition of a stream is not used by the CDFW in general, nor specifically in the administration of F&GC Section 1600 et sequence.

B) Beneficial Uses. The project FEIS states that *"ephemeral streams and washes do not have beneficial use designations assigned by the State of California"* (Ecology and Environment 2010). The point of the statement is unclear and the information provided is misleading. It suggests that: (1) no ephemeral streams or washes in the state have beneficial use designations, and (2) may be confusing or conflating beneficial use designations for an aquatic resource type or class with jurisdictional interest.

Because the USACE does not typically find such streams to be waters of the US for the purposes of enforcing federal Clean Water Act section 404, people tend to assume that such is the case as well for the State Water Boards. The lack of clear policy, pertinent definitions, and consistent use of terminology from the Water Boards lends to the confusion. All Waters of the State regardless of other designations are subject to the jurisdiction of the Water Boards.

Moreover, beneficial uses are generally designated for streams and their watersheds – not just a stream or some part of the stream system as stated here. Additionally, it is the uses of the water that are designated, not the stream itself, and these uses – including environmental considerations – are designated regardless of stream order or stream type unless specifically noted otherwise in the regional Basin Plan. For example, the Regional Water Quality Control Plan (or Basin Plan) for the Colorado River Basin designates ground water recharge and certain habitat uses as beneficial uses for many large dry wash systems in that region.

C) Habitat Value. The project delineation report states that the drainages mapped "…were considered to be of poor or low quality to wildlife, primarily due to OHV usage and pedestrian traffic…" suggesting that locally impaired ephemeral streams are of low ecological value. This

rather parochial view of stream function and value is not reflected in the F&GC section 1600 et seq., nor in the eco-hydrological sciences that are the foundation of this area of natural resource management and conservation.

Because stream channels move sediment, seeds, and organic material, as well as water, they support habitats and biological populations beyond the watercourse itself – for example, by moving sand between headwater sources down the channel to wind corridors that carry it to offsite dune habitats of fringe-toed lizards, or by concentrating and germinating seeds in the saturated sediment at a stream terminus to provide summer food for desert tortoises. These off-site values may equal or exceed those present locally, and that these values may be detrimentally impacted by on-site activities is an appropriate project consideration.

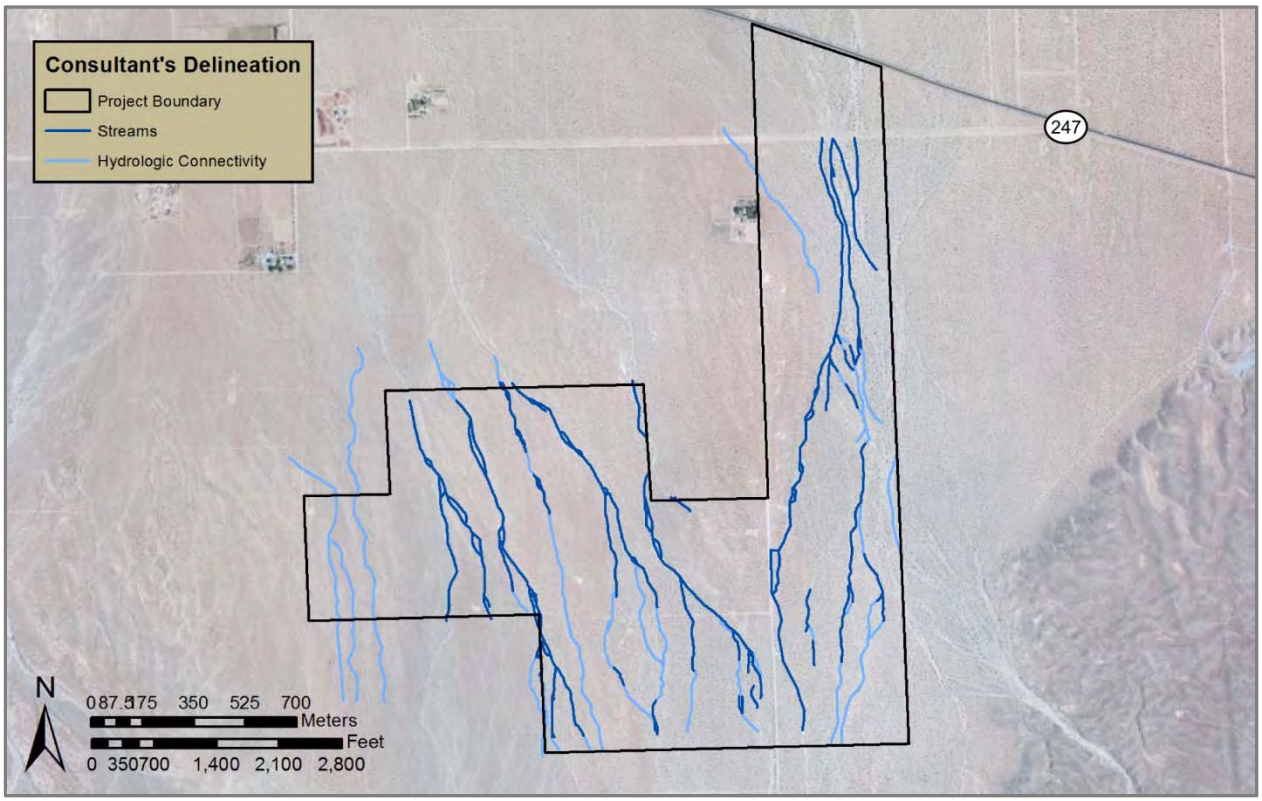
D) Stream Form and Process. The delineation report identified two problem areas in the determination of jurisdictional water acreages in the project area: (1) channel forms with surface flows that tend to subside into the sandy soils of the channels or along or outside of identified wash boundaries without leaving definable banks, and (2) "hydrologic connectivity features" present in the southwest corner and near the western boundary of the site that did not exhibit well-defined bank-to-bank features. Because bank-to-bank width measurements were not possible in either of these areas, they were not included in the determinations of jurisdictional waters (Chambers 2009).

Where channel form became subtle, intermittently lost, or failed to conform to some of the misapplied criteria outlined in the Jurisdictional Criteria section below, that segment of the stream ceased to exist from a jurisdictional perspective – this even though the project delineation study otherwise recognized and mapped the linear continuity of the stream channels. The dark blue lines within the boundary of the delineation area are streams and stream segments determined to be subject to F&GC jurisdiction (Fig. 43). The lightest blue lines designate streams and stream segments of the problematic areas identified by the project delineation study and excluded from the calculus of jurisdictional stream acreage. In several areas, streams within the project boundaries meander out and then in again, gaining and losing and regaining jurisdictional status as they do – as if what happens to the stream segment within project bounds has no connection to or implication for that out-of-bounds segment.

These difficulties identifying active stream channels and approach to interpreting stream continuity are not reflected in the hydrologic study conducted for the project, nor encountered in our mapping and may represent: (1) a lack of knowledge about or experience with the sometimes subtle and transient nature of arid region stream channel forms and processes on alluvial fan landforms; (2) the inability to recognize floodplain features (such as those areas where surface flows "…subside into the sandy soils along or outside of identified wash boundaries…"; and (or) (3) if recognized were unknowingly excluded floodplain areas from the watercourse boundary.

Not every stream or stream reach is associated with a floodplain, but where floodplains do occur CDFW considers them to be integral to stream function, and to define the outermost jurisdictional bounds of a watercourse in cross-section and length.

Figure 43: Project consultant's stream delineation map. Dark blue color designates streams and stream segments identified by the project consultant as subject to CDFW jurisdiction. Lightest blue color designates streams and stream segments the project consultant determined to be non-jurisdictional based on the absence of well-defined banks. Map adapted from that prepared by Chambers Group, Inc. for BLM: Environmental Impact Statement, Appendix D, Comprehensive Biological Resources Assessment for the Chevron Solar Project Site Community of Lucerne Valley, California, 2009.



3) Misapplication of Jurisdictional Criteria:

The project delineation study cites incorrect or obsolete criteria to characterize and identify streams and to determine the stream acreage potentially subject to project-related impacts. These include:

A) The presence of well-defined banks,

B) The top of bank as the lateral extent of CDFW jurisdiction on smaller streams with little or no riparian vegetation,

C) The absence of riparian vegetation,

D) Stream size,

E) The presence of aquatic flora or fauna, and

F) The extent of lateral jurisdiction as defined by Ordinary High Water Marks (OHWM).

A) Well-defined Banks. To the mistakenly applied definition of a stream, the project delineation study added the caveat that jurisdictional streams have *"well-defined banks."* The source of the *"well-defined banks"* criterion as applied to the Waters of the State is unknown. It is not used in the California Water Code, the F&GC, nor in practice relative to CDFW's administration of F&GC Section 1600 et seq.

The project delineation study recognized the subordinate nature of the banks associated with the multi-thread channel braids of the largest stream on the east side of the delineation area and used the outermost banks of that stream to define its jurisdictional bound. However, it is not clear that they recognized subordinate features on the other streams, or if they did, how the consultants dealt with them. The wide discrepancy between channel widths as determined for the project delineation study, the project hydrology, and our stream mapping suggest that the project delineation study may have mapped solely the most apparent low-flow channel banks, and then only to the tops of their banks, excluding floodplain areas altogether.

B) Top of Bank as a Jurisdictional Boundary on Streams Lacking Riparian Vegetation. The source of this criterion is unknown but its great limitation as a stand-alone delineation criterion is nicely illustrated by its application to the small, first- and second-order streams that dominate arid region environs. In these areas where the uplands most strongly influence a stream, the stream ecosystem is maintained by conserving not only the top edge of a stream bank, but also the adjacent upland surfaces that are structurally part of a stream bank but also are a major source area of the runoff-supplied water critical to maintaining the functional integrity of these streams and their associated ecosystems (McDonald and others 2004; Schwinning and others 2010).

Project designs such as that proposed here to maintain the natural form of the streams to the *top of the bank* but then propose to fundamentally alter the adjacent landscape by removing all vegetation and scarifying the earth would result in the complete loss of the functional integrity of the streams and the stream ecosystem – as will certainly be the case with this 516 acre site.

C) Stream Size. F&GC Section 1600 et seq. was enacted to conserve the fish and wildlife associated with stream ecosystems, with no limitations based on the size of a watershed, the size of a stream, its duration of flow, or the absence of hydrologic connectivity to other waterbodies.

D) Presence or Absence of Riparian Vegetation. The misapplied definition of a "stream "that refers to the current or past presence of riparian vegetation may explain why vegetation is sometimes misused as an indicator of F&GC jurisdiction. While the presence of riparian vegetation may be an appropriate indicator in temperate perennial and intermittent stream ecosystems, it is not a meaningful indicator of dryland episodic stream environments where stream-associated upland species are dominant.

E) Presence or Absence of Aquatic Flora or Fauna. The stream definition referring to streams as those that "*…support fish or other aquatic life"* is misapplied to ephemeral streams. F&GC Section 1600 et seq. was enacted to conserve *fish and wildlife* associated with stream ecosystems and defines fish and wildlife as *"…all wild animals, birds, plants, fish, amphibians, invertebrates, reptiles, and related ecological communities, including the habitat upon which they depend for continued viability* (FGC Division 5, Chapter 1, section 45, and Division 2, Chapter 1, section 711.2(a), respectively). A stream is still jurisdictional relative to F&GC Section 1600 et seq. whether or not it supports aquatic species.

F) Ordinary High Water Mark (OHWM). The project delineation study first notes that CDFW jurisdiction tends to be more expansive than other regulatory agencies because F&GC jurisdiction commonly extends beyond the OHWM used by the USACE and the Water Boards. Later in their summary conclusion the rationale provided for CDFW jurisdiction is the presence

of defined bank-to-bank characteristics having erosional shelves 0.3 to 1 m high, and indicators of OHWM. It is not clear whether the reference to the OHWM indicators was used to identify CDFW jurisdictional boundaries, or is simply intended as corroborating evidence of those boundaries. In either case, the reference to OHWMs suggests that there may be some confusion about the application of the Ordinary High Water (OHW) concept to Waters of the State.

The OHW concept is not used by the State of California to determine Waters of the State, nor by the CDFW to delineate stream boundaries for the purpose of determining F&GC jurisdiction pursuant to Section 1600 et seq.

5.5.7 Conclusions-Lucerne Valley Fan

The project delineation report determined as non-jurisdictional (1) channels where surface flows subsided into the sandy soils of the channels or along or outside of the channel without leaving definable banks, and (2) *"hydrologic connectivity features"* lacking well-defined banks, and of the seven streams evaluated there are 12.32 acres of potentially jurisdictional streams within the project area. However, the MESA delineation determined these features to be streams along with the addition of many dozens of previously unidentified large and small tributaries. Re-evaluation of three streams and their dimensions resulted in a greater than an order of magnitude increase from 2.4 acres of jurisdictional stream area to approximately 40 acres—a value consistent with the project's hydrological data for the same streams.

5.5.8 Recommendations

Considering the lack of appropriate guidance and protocols to map desert streams, their episodic flows, often complete absence of iconic riparian vegetation, and channel forms that challenge conventional notions of what a "real" stream should look like, it is perhaps understandable why many episodic streams are inappropriately excluded or never identified in stream delineation reports.

To improve the delineation of this area, we recommend that the CEC:

- Adopt a science-based stream delineation protocol like MESA, update guidance on CEC and CDFW/LSA websites, and include this guidance in permitting packages.
- Require the project applicant to map all streams present as determined by field surveys.
- Integrate stream delineations with the project planning and site characterization process, creating a base map of all streams present by desk-top mapping informed by review of geologic and hydrologic analysis of stream activity at relevant recurrence intervals.

5.6 Palo Verde Mesa

5.6.1 Location

The area delineated herein is coincident with a portion of the proposed but since withdrawn, Rio Mesa Solar Electric Generating Facility located on 5,750 acres of the Palo Verde Mesa in southeastern Riverside County. Located along the western side of the Colorado River floodplain approximately 13 miles southwest of the community of Blythe, California, the land is

in a combination of private ownership (Metropolitan Water District) and public lands administered by United States (U.S.) Bureau of Land Management (BLM) (Fig. 44)

The delineation site lies at an elevation of approximately 100 to 150 m above mean sea level in T. 8 S., R. 2 E., Sec. 9, 10, 11, 14, 15, and 16 of the Thumb Peak, 7.5-minute USGS topographic quadrangle (1983). The site is located west of State Road 78 and is bisected east to west by the Bradshaw Trail, north to south by the Transmission Line Road, two lesser dirt roads – the Opal Mine and Hodge Mine roads – and other, unnamed dirt tracks.

Historically the site has seen use for mineral exploration and for military training during World War II, trash disposal and, currently, recreational off-road vehicle use and camping. It is now vacant and undeveloped.

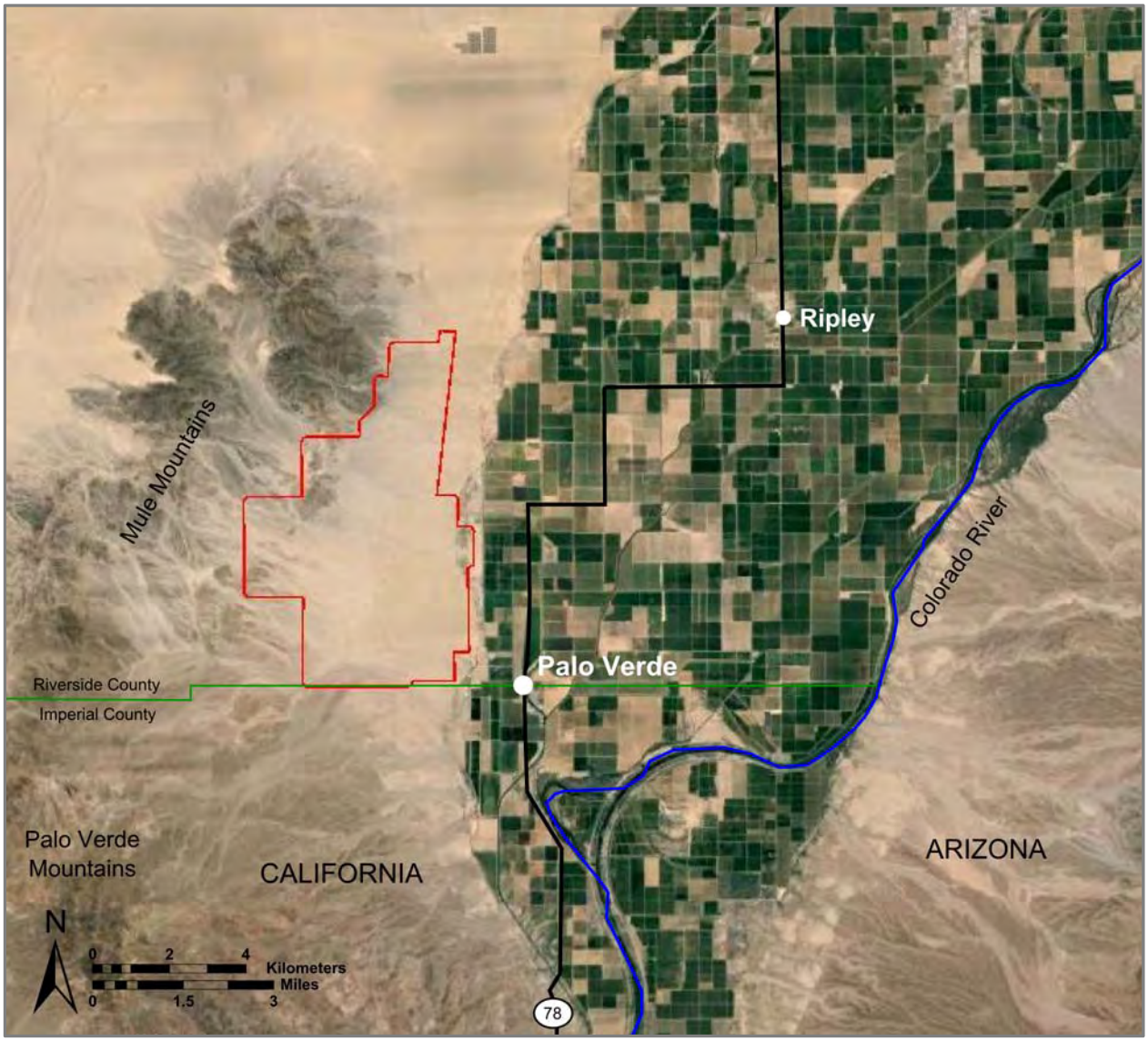
5.6.2 Setting

The Palo Verde Mesa area lies at the border between the southern Mojave Desert and westernmost Colorado Desert geomorphic provinces so it shares geological and vegetation aspect of both (CGS 2002). The Mesa forms a 21 m-high bluff along the western edge of the Colorado River Floodplain, and is bounded on the south and west by the Mule Mountains, to the north by the Chuckwalla Valley, and to the east by the broad floodplain (Palo Verde Valley) of the Colorado River. The alluvial terraces of the mesa are formed of Pleistocene Colorado River floodplain deposits on the east that transition westward to Quaternary-age, coalescing, alluvial fan deposits derived from the Mule Mountains (USGS 2006; CGS 2011; URS 2011). Unconsolidated Holocene sand and gravels fill the active washes. Locally mantling the alluvial fan deposits are small areas of unconsolidated sheet sand and dunes that may have blown east and south from the Chuckwalla Valley and Ford Dry Lake.

The area is bounded by agricultural lands on the east and currently undeveloped lands on the north, south, and west. Streams flow east from the Mule Mountains through numerous, small channels, coalescing with large, ephemeral washes that cross the site over flat slopes of about 1 percent. The washes eventually converge with Hodges Drain—a canal on the east border of the area that conveys runoff into the Colorado River (URS 2011).

The area is divided into 11 drainage systems comprised of seven large and numerous smaller washes and individual channels. Although all are ephemeral, surface flows occur in most years. The largest streams are mapped as active washes with deposits consisting of unconsolidated medium to coarse grained sand and gravel with subordinate fine sand and silt (CGS 2011, URS 2011). The stream channels are not vegetated and have accumulated sediment with little or no soil-profile development.

Figure 44: Location map of the Palo Verde Mesa delineation area and site of withdrawn Rio Mesa Solar Generation Facility (terminated July 2013). Map adapted from the Biological Resources Technical Report for the Rio Mesa Solar Power Generating Facility, Riverside County. Prepared for BrightSource Energy, Inc. by URS, 2011.



5.6.3 General Description of the Solar Project

The project, as originally proposed, included a 3,700-acre solar field covered with an array of 85,000 mirrors and three towers, but before the project was withdrawn, one of the towers and its solar field was eliminated from the design and is not shown in Fig. 45, an artist's rendering of project build-out. The facility proposed to use a proprietary solar thermal technology that uses mirrors guided by a tracking system mounted on piers to focus sunlight on a solar power boiler located near the center of each solar field. The heat generated would have then been used to produce steam to drive an electrical generator in the towers.

A grid of roads would have been constructed to access the mirrors, but across most of the site the topography and the present, natural stream paths were to be maintained, limiting grading and leveling to the banks of the steeper washes. The ground was to have been cleared of all vegetation but the roots retained to stabilize soil (WRA 2012). Grading was to have been

limited to constructing a grid of access roads engineered from compacted native soils, at the existing ground level to maintain stormwater runoff into and through the site (URS 1011, WRA 2012).

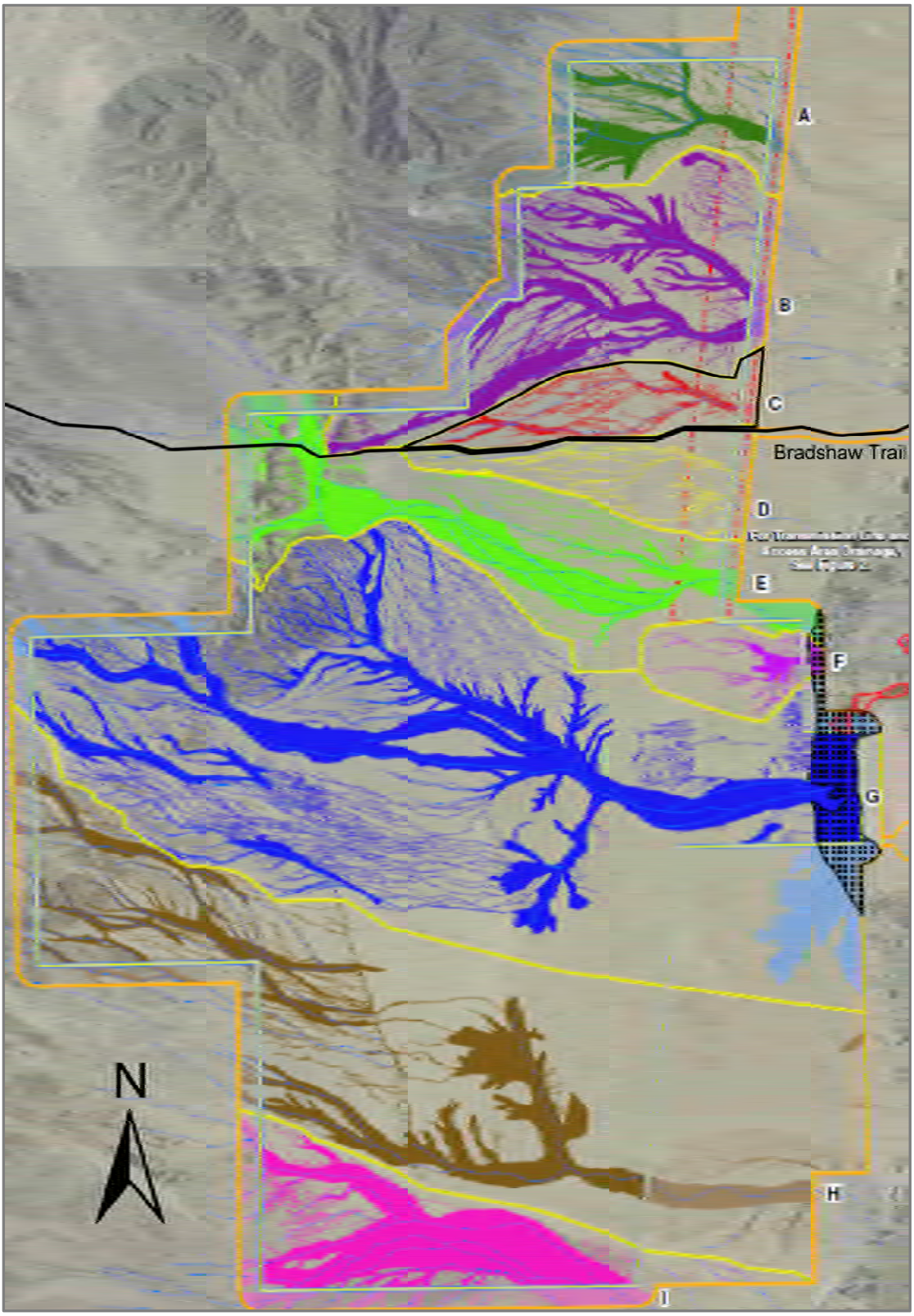
Figure 45: Simulated aerial view to the west of proposed Rio Mesa solar project build-out of the 5,750 acre site. The Mule Mountains are in the upper middle of the photo with the Chuckwalla Valley behind and to the right of the mountains. Image from the Biological Resources Technical Report for the Rio Mesa Solar Power Generating Facility, Riverside County, CA. Prepared for BrightSource Energy, Inc. by URS, 2011.

5.6.4 Consultants' Jurisdictional Stream Delineation

Methods

Because the study area is so large (3,700 acres) and there are many streams present, the consultants mapped the site largely using high-resolution aerial imagery supported by limited field surveys (URS 2011, WRA 2012). Eleven, east- and southeast-trending drainage systems mapped as blue lines on USGS topographic maps were identified as typifying the ephemeral washes that occur throughout the site based on their size, flow direction, connectivity, flow patterns, vegetation composition, and topography (URS 2011) (Fig. 46). Project personnel identified streams potentially subject to F&GC Section 1600 et sequence jurisdiction and verified them in the field according to physical parameters such as topographic demarcation, soil characteristics, vegetation cover, and connectivity of drainages to the Colorado River (URS 2011).

Figure 46: Palo Verde Mesa delineation area drainages. Nine of the eleven drainage areas identified in the project area with streams potentially subject to F&GC Section 1600 et sequence jurisdicition. Drainage C, the area outlined in black with streams designated in red, was selected for comparison using the MESA protocol. Map adapted from URS, Biological Resources Technical Report for the Rio Mesa Solar Power Generating Facility, Riverside County, California, Appendix K, Jurisdicitonal Delineation Information. Prepared for BrightSource Energy, Inc. 2011.



In addition to the preliminary desk-top analyses and field surveys, the consultants' report (URS 2011) stated the following criteria were used to interpret the jurisdictional limits of streams subject to F&GC Section 1600 et sequence:

- At minimum, intermittent and seasonal flow through a well-defined bed or channel with banks and that also supports fish or other aquatic life.
- A watercourse having a surface or subsurface flow regime that supports or has previously supported riparian vegetation.
- Hydrogeomorphically distinct top-of-embankment to top-of-embankment limits (well-defined bed and bank).
- Outer ground cover and canopy of typical riparian-associated vegetation extends beyond the top of the bank that would normally be sustained by surface and/or subsurface waters of the watercourse.
- The definition of a stream was based on that in Title 14 CCR 1.72.

Field data were incorporated into a GIS data base for subsequent analysis and mapping. Data collected along transect lines were plotted on recent aerial photographs having one to two foot resolution, and drainage features within the survey area were manually digitized into the GIS data file using the nearest reference location data to aid in the mapping. Features for each drainage system included single, large channels with well-defined bed and banks, and broad, but sometimes weakly expressed assemblages of shallow, braided, ephemeral channels. When determining drainage acreages, categories of 0.5-0.9 m wide, 0.9-1.8 m wide, 1.8-2.7 m wide, 2.7-3.7 m wide, 3.7-4.6 m wide, and greater than 4.6 m wide were used; the maximum width was used in each case so 0.5-0.9 m was 0.9 m and 0.9-1.8 m was 1.8 et cetera, giving a buffer zone that maximized the acreage of streams. In addition to the stream channels, all palo verde and (or) ironwood woodland was considered as wash-dependent vegetation, and was added to the stream delineation acreage.

Results

In the Drainage C project area of 295 acres, the consultants' stream delineation identified and mapped approximately 24 acres of potentially jurisdictional streams (URS 2011).

5.6.5 MESA Protocol-based Stream Delineation

Methods

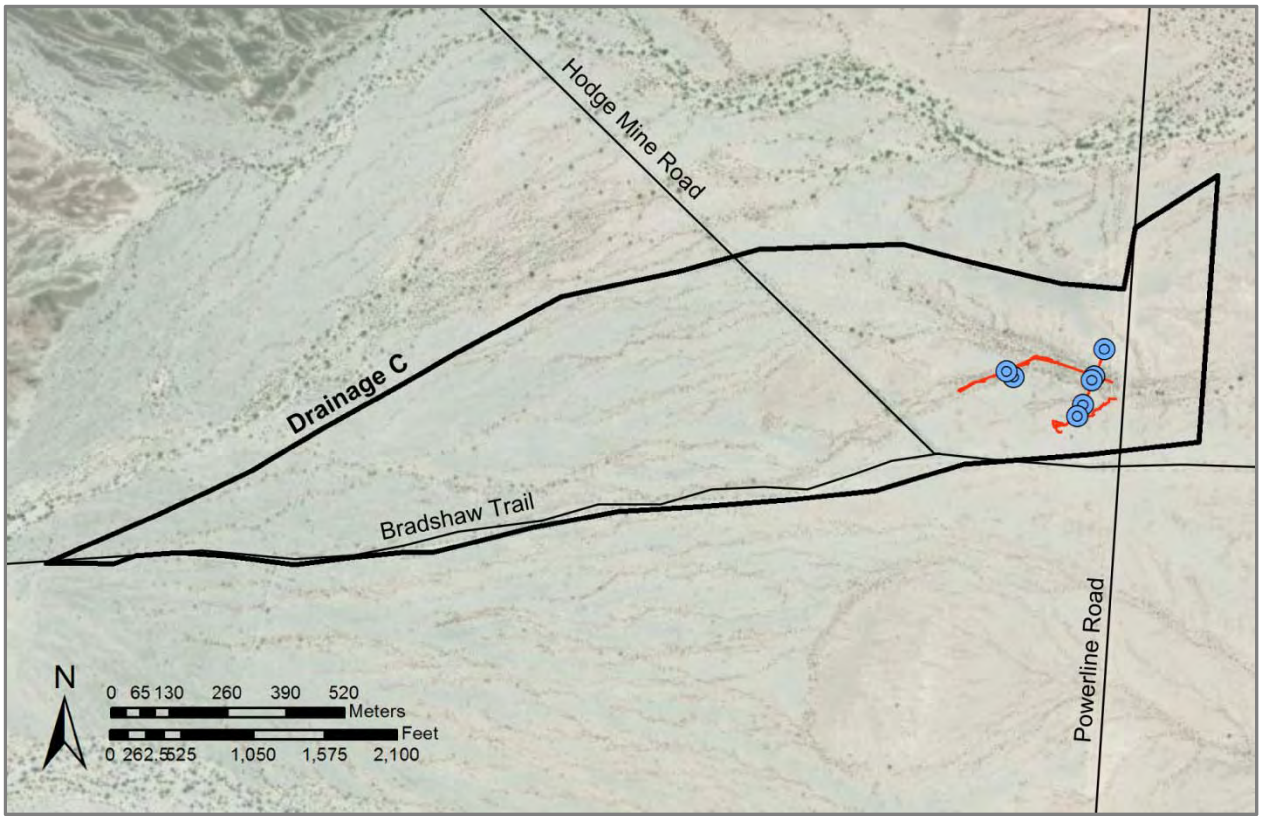
Our pre-field survey methods were similar to those used by the project consultant with the following additions:

- We acquired and reviewed geologic maps and reports of the area, and;
- We selected areas for on-the-ground field review and verification of the preliminary mapping based on analysis of aerial photographs and use of the guidance embodied in *A Review of Stream Processes and Forms in Dryland Watersheds* (CDFW 2010).

Our in-field survey methods were also similar to those used by the project consultants with the following variations and additions:

- We used surficial geology and surface indicators of stream presence and absence similar to but more extensive than those used for the consultant's study, and excavated one soil pit; and
- We photo-documented and mapped our stream delineations, sampling locations, and stream and botanical survey transects in the field using an iPad, Google Earth imagery, and GIS-based Garafa mapping software (Fig. 47).

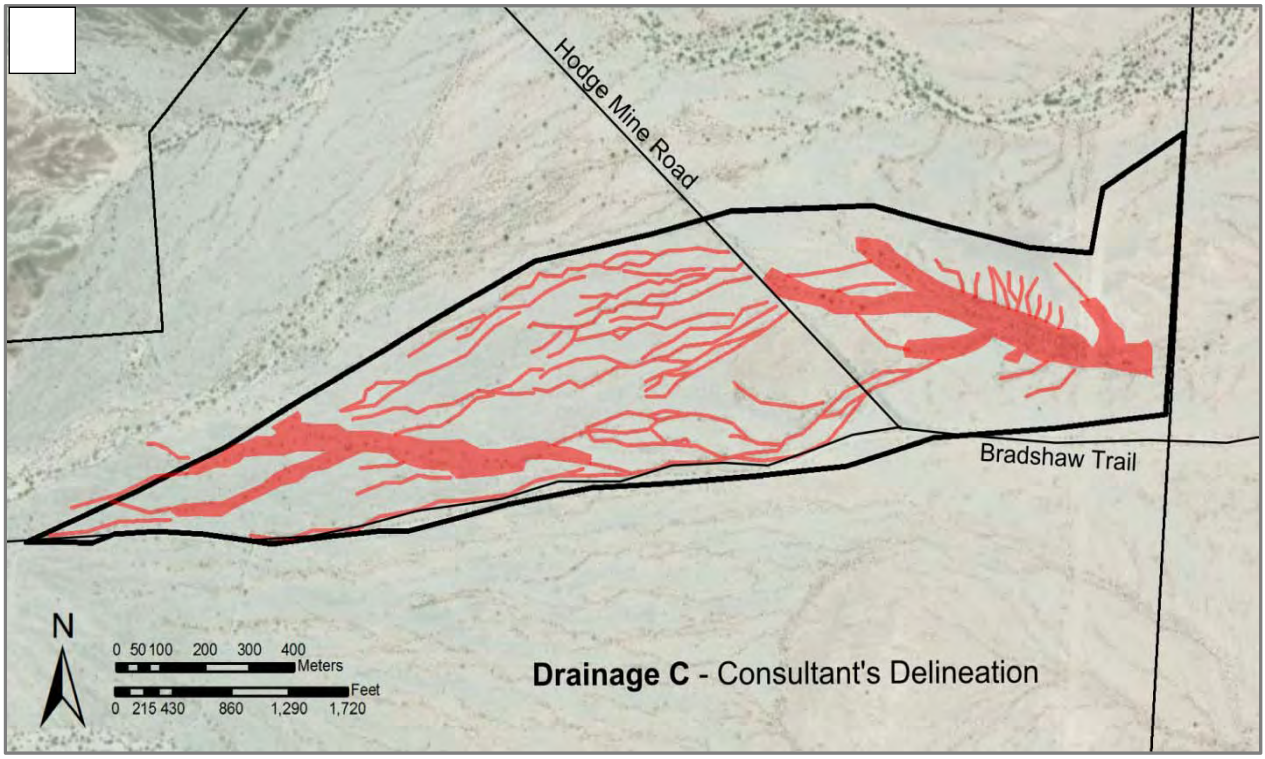
Figure 47: MESA stream delineations, sampling locations, and stream and botanical survey transects were photo-documented and mapped in the field using an iPad, Google Earth imagery, and GIS-based Garafa mapping software.

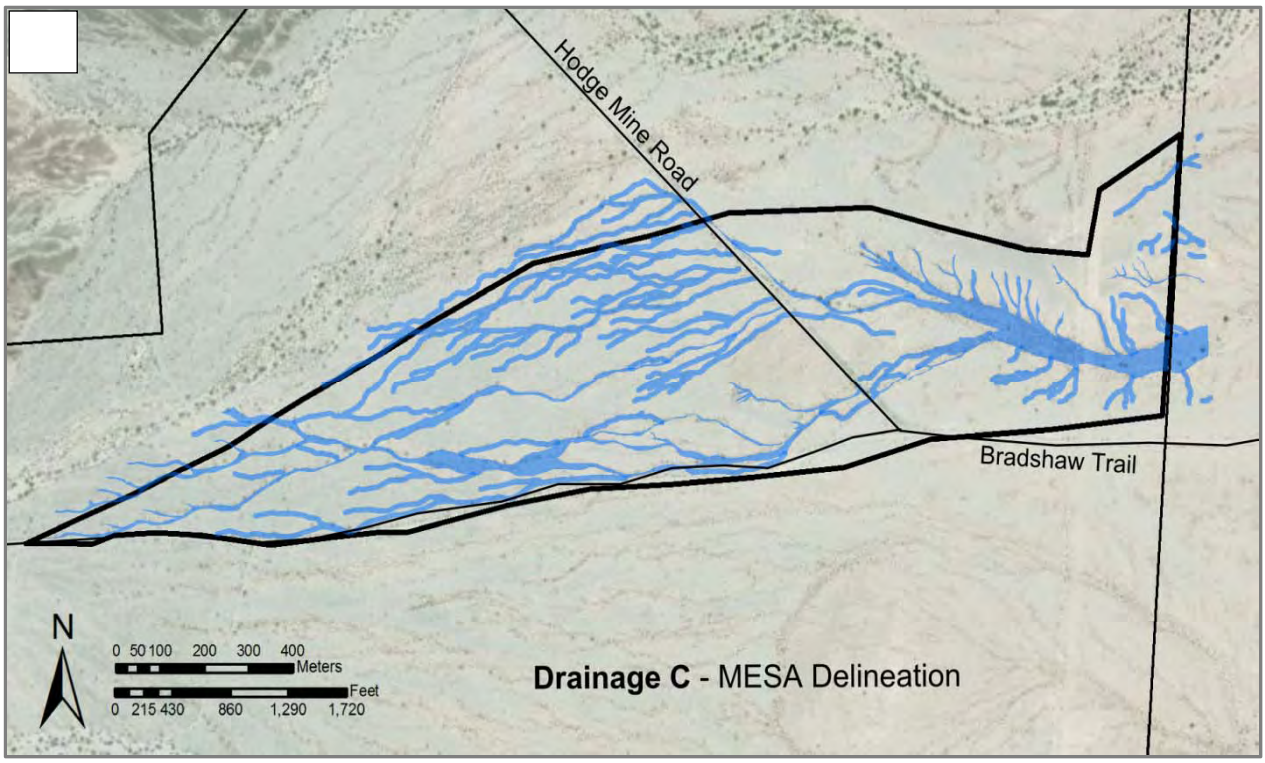


As part of our comparison, we would have liked to have been able to consider a report on existing flood hazards and channel stability conducted for the project using a combination of HEC-RAS and FLO-2D modeling (VTN 2011a, b) but we were not able to acquire it. The effect of incorporating this information on the total area of jurisdictional streams is unknown.

Given the large size of the delineation area (3,700 acres) and the large number of streams present, we focused our study on one of the eleven drainages identified by the consultants' delineation study (Drainage C) (Fig. 48).

Figure 48: Comparison of Drainage C project stream delineation results with MESA protocol, Rio Mesa Solar Project. A: Aerial map of Drainage C, one of the eleven drainage areas identified in the project area with streams potentially subject to F&GC Section 1600 et sequence jurisdiction. The streams were largely mapped using high-resolution aerial photography with minimal field verification. Map adapted from URS, Biological Resources Technical Report for the Rio Mesa Solar Power Generating Facility, Riverside County, California, Appendix K, Jurisdicitonal Delineation Information. Prepared for BrightSource Energy, Inc. 2011. B: Aerial map is Drainage C as mapped using the MESA protocol.





Flowing east out of the Mule Mountains, Drainage C incises into approximately 295 acres of a very nearly level alluvial surface north of and parallel to the Bradshaw Trail. From its origin at the base of the mountains, young, unvarnished coarse gravel and sand on the western fan surface fines to the east and grades into the Palo Verde Mesa river terrace deposits. The surficial differences between the two deposits can be subtle, and discriminating between the two is complicated by a local veneer of eolian sands across both deposits that appears similar in color and texture to unconsolidated, fine-grain parts of the river terrace (URS 2011).

Although the morphology of the stream channels can be subtle, changes in vegetation density, vigor and alignment; and the texture between the channels and the fluvially inactive upland fan surface are distinctive. Vegetation concentrates outside of the low-flow channels along topographically higher secondary channels, floodplains, and in swales. The dominant vegetation community in the mid- to eastern end of the drainage is mainly creosote bush, white bursage, and big galleta grass (*Pleuraphis rigida*) (the Creosote Bush-White Bursage Scrub with Big Galleta Grass Association of Sawyer and others (2009). This community makes up low cover with intermittent seasonal annuals and typically occurs on sandy fans or lower bajadas and occasionally at the edges of sand sheets and dunes from 75 to 1200 meters elevation.

The surface of the drainage area is covered by sparse to moderately dense vegetation with the greatest density and most vigorous vegetation strongly associated with the many shallow stream channels that cut the surface of the drainage area. The larger multi-channeled washes and many small individual channels are composed of active wash deposits of unconsolidated, angular to subangular gravels and sand with abundant evidence of recent stream flow and sediment transport. In many streams, coarser particles form small but distinctive bar deposits that are often obscured by eolian sand that fills the channels between runoff events (Fig. 49).

The upland fan surface has a weakly developed pavement that consists primarily of sand, pebbly sand, and sandy pebble-gravel, with fine-grained sand and silt between pebbles and gravels, no rock varnish or rubification, and abundant carbonate coatings on the undersides of many of the coarser particles.

Because the topography of the project area is particularly subtle in this part of the project area, we excavated a soil pit on the upland surface in order to assess the efficacy of using surficial indicators of fluvial activity to define landform boundaries. The soil pit was to a depth of 0.45 m deep. Beneath a weakly developed surface pavement is a thin, vesicular Av horizon overlying a poorly sorted sand with gravel lenses and floating pebbles indicating a fluvial rather than eolian origin (Fig. 50).The soil pit confirmed that the landform we identified as an upland fan surface based on its aerial photographic signatures, and surficial indicators in the field, consists of fluvially inactive fan deposits. The weakly developed Av horizon suggests a geologically young age, but still likely greater than several thousands of years old.

Figure 49: Stream (or watercourses) typical of Drainage C. The channels have been filled with eolian silt and fine-grained sand. A: Black dashed and dotted line marks edge of bank. The dashed white lines in both photos mark the outermost boundary of the watercourse as defined by the presence of the fluvially inactive (and darker) upland fan surface. Note the denser and larger vegetation in the channels as compared to that on the upland fan surface.

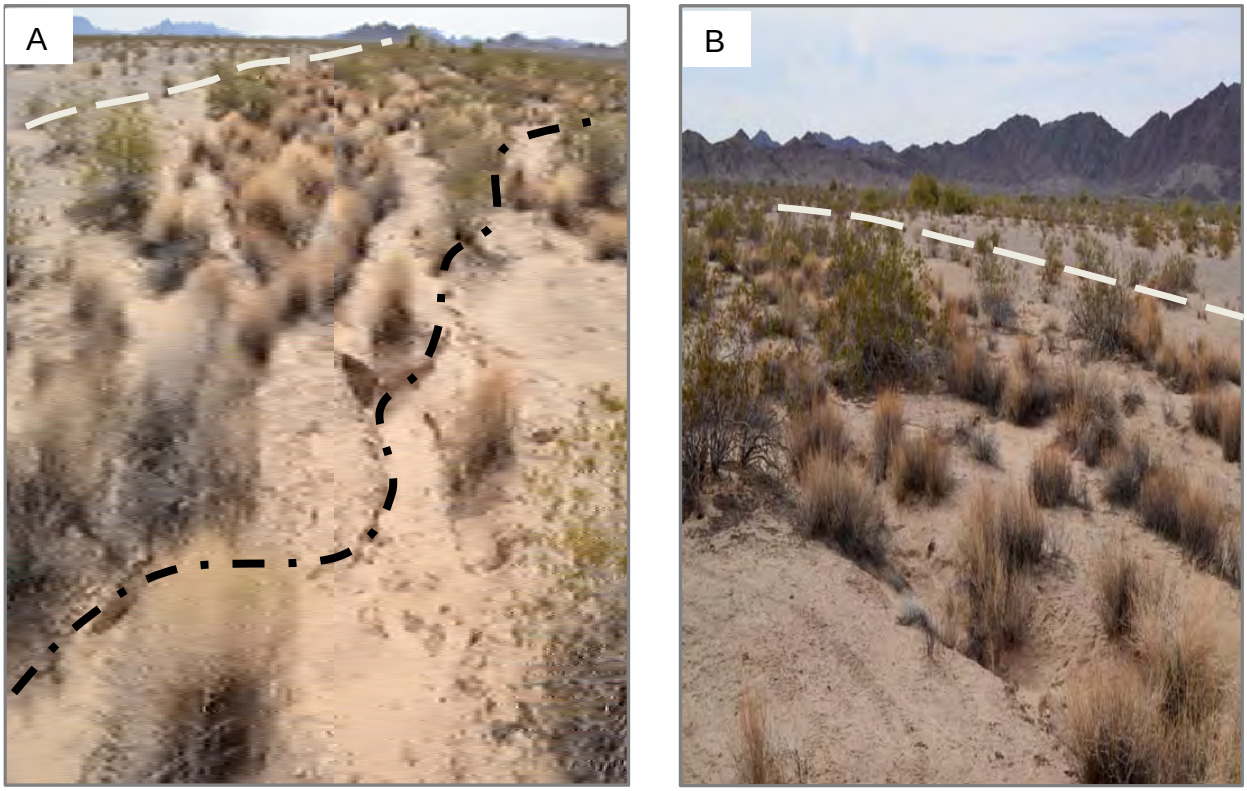
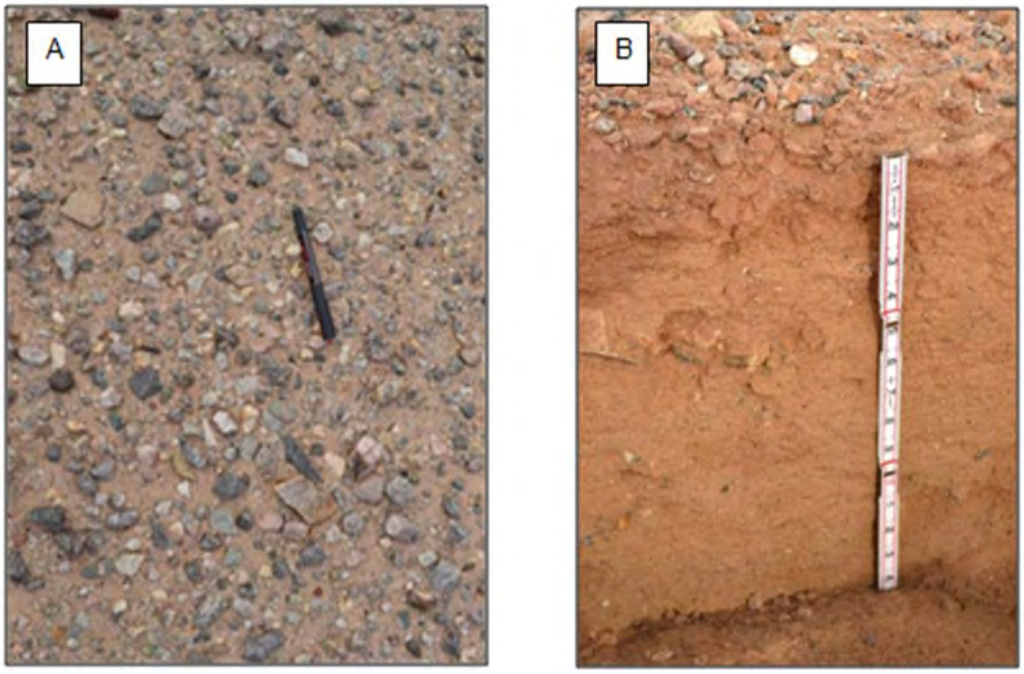


Figure 50: A: upland fan surface with weakly developed pavement of sand, pebbly sand, and sandy pebble-gravel, with interstitial fine-grained sand and silt. B: soil pit beneath the weakly-developed pavement. A thin Av horizon overlies poorly sorted sand with gravel lenses and floating pebbles indicating a fluvial rather than eolian origin.



Results – MESA Delineation

The consultants determined that there are approximately 24 acres of potentially jurisdictional streams in the approximately 295 acres of Drainage C (URS 2011) whereas our delineation identified approximately 31 acres of potentially jurisdictional streams.

5.6.6 Similarities and Differences Between Consultants' and MESA Stream Delineations

The 31 acres of jurisdictional streams in Drainage C determined using the MESA protocol is only 7 acres more than that calculated by the project consultants' approach (24 acres) over the total 295 acre drainage area – a relatively small difference given the subtleties of the streams and surrounding landscape. The greatest discrepancy is that the application of the jurisdictional criteria outlined in the consultant's report could not have produced their map or the acreages they determined.

Factors that could account for the similarity between the MESA and project stream delineation acreages and the discrepancies between the project map and the project narrative include:

1) **Stream delineation mapping as a precursor to determining F&GC jurisdiction.** F&GC Section 1602 designates that <u>all</u> streams are subject to this code section. Although there are several mechanisms by which jurisdiction is acted on or resolved – each requires that all (or any) streams present on a site be identified in order to characterize the potential for adverse project-related impacts to them. The only jurisdictional criteria specified in F&GC Section 1600 et sequence are: (1) the detrimental impacts associated with the substantial diversion or the obstruction of the natural flow of a stream, or (2) the substantial change, or the use of

any material from its bed, channel, or banks, or (3) the disposal of debris or waste materials where it may pass into a stream.

These criteria can only be applied once stream presence has been identified and a project design developed to a level of detail adequate for potential impact analysis. Perhaps unburdened from the notion of a "CDFW jurisdictional stream" having to be of particular size and shape, the delineators accounted for **all** the streams on the aerial photographs, verified their presence during field surveys, and reported the acreages accordingly.

2) **Using stream size classes to determine stream acreages**. The consultants calculated drainage acreages based on stream width categories (URS 2011). The reasons for this approach are unknown although it may have been intended to facilitate area calculations after stream locations were mapped. Whatever the consultants' rationale, their acreage calculations assumed a maximum width, that is, a stream in the 0.5-0.9 m wide category was 0.9 m wide, and a stream in the 0.9-1.8 m wide was 1.8 m wide, and so on. Despite their maximizing the stream widths, probably the slightly greater acreage determined using the MESA protocol is due to our including swales and floodplain areas as part of a stream or watercourse.

3) **Misapplication of jurisdictional criteria**. Although the consultant's stream delineation map appears to account for nearly all the streams on the site regardless of jurisdictional considerations, their report cites a host of incorrect criteria for characterizing and identifying "jurisdictional streams" and thus, for determining the stream acreage potentially subject to project-related impacts, including:

   - The project delineation study incorrectly used the definition of a "stream" in Title 14, California Code of Regulations, Section 1.72 to characterize streams subject to CDFW jurisdiction. This definition of a stream is **not** used by the CDFW in general, nor specifically in the administration of F&GC Section 1600 et sequence.
   - Stream flow through a well-defined bed or channel with banks that also supports fish or other aquatic life.
   - A watercourse having a surface or subsurface flow regime that supports or has previously supported riparian vegetation.
   - Hydrogeomorphically distinct top-of-embankment to top-of-embankment limits (that is, the "well-defined bed and bank" criteria discussed in Chapter 2).

5.6.7 Conclusions and Recommendations-Palo Verde Mesa

We believe the methods these consultants used are consistent and reasonable, and they produced a realistic report of the area's watershed. Of the total 295 acres of Drainage C, the consultants' delineated 24 acres (8 percent) while, using the MESA protocols, we calculated 31 acres (10 percent)– a relatively small difference given the subtleties of the streams and surrounding landscape and the lack of guidance and protocols for mapping arid region streams. However, the jurisdictional area calculated by the consultants (and shown on their map) is greater than that which would have been produced had they applied the erroneous criteria they described in their report.

5.6.8 Recommendations

- The jurisdictional criteria specified in F&GC Section 1600 et sequence can only be applied once stream presence has been identified and the project design developed to a level of detail adequate to assess the project's potential impact.
- Project applicants should be encouraged to acknowledge this two-step process by: (1) accounting for all streams present in a project area as part of the initial site characterization used to inform project design in order to avoid streams present, and (2) use this map to characterize the extent of loss for streams that cannot be avoided.

5.7 Sites not Previously Delineated

5.8 Coxcomb Mountains Fan

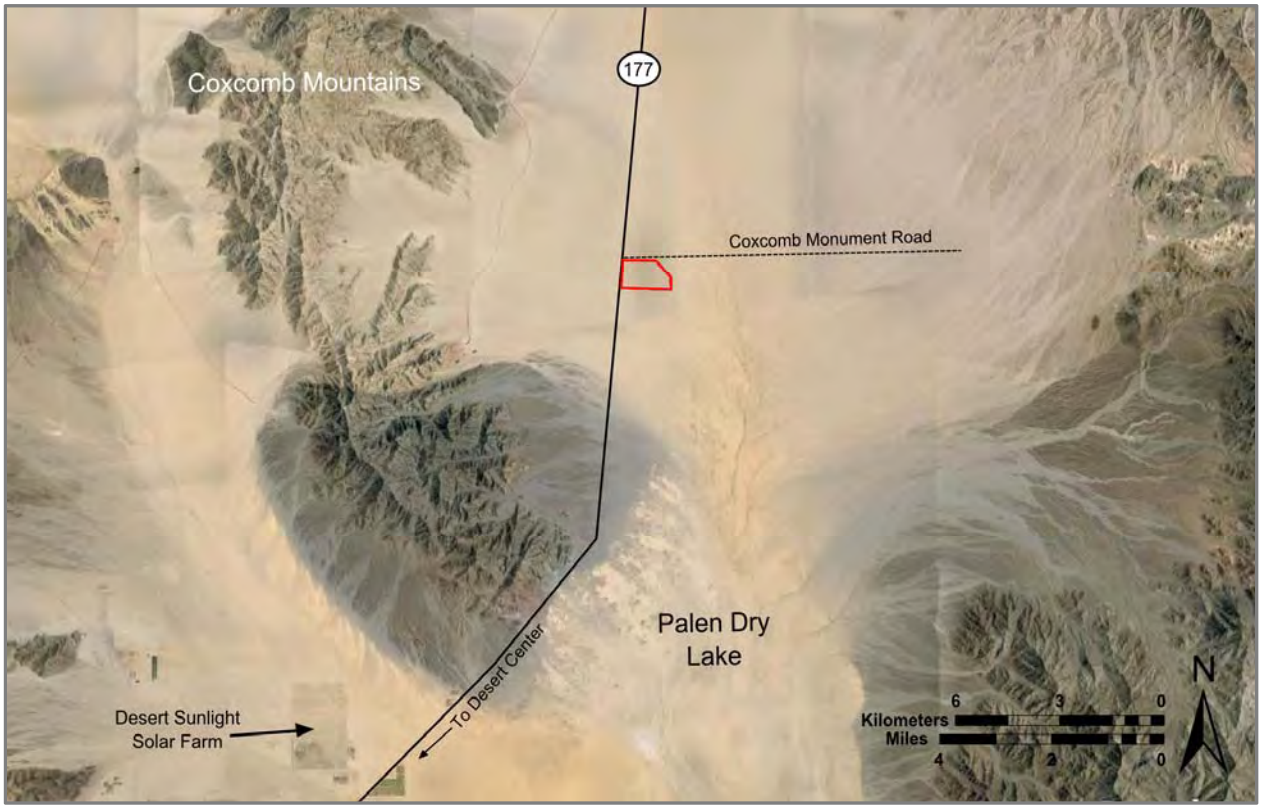
The lower Coxcomb Mountains fan delineation area (Fig. 1) illustrates the important role that substrate plays in channel/fan formation. In the other reference sites, channel walls are sufficiently indurated or bedload material is sufficiently coarse to form persistent, easily mappable channels. But here, the granite-derived sediment is non-cohesive, and coarse gravels are absent, so channel banks are non-cohesive and even minor flows can cause lateral channel migration and switching.

Our survey of the delineation area of the Coxcomb Mountains fan included four transects, six infiltrometer tests, and excavated seven soil pits.

5.8.1 Location

The Coxcomb Mountains fan drains the east side of Coxcomb Mountains of Riverside County where the Mojave and Colorado Deserts ecosystems meet. The site is 18 miles north of Desert Center along Highway 177 (Fig. 51).

Figure 51: Location of Coxcomb fan delineation area (in red), Riverside County. Image Google Earth.



5.8.2 Setting

The Coxcomb Mountains fan has low relief and drains internally, eastward toward Palen (dry) Lake and a belt of sand dunes to the north. The Coxcomb range is composed almost entirely granite, so nearly all of the sediment is pebble and sand-sized decomposed granite. The woody plants in the region are dominated by creosote. The delineation herein applies solely to the lower fan, down slope of Highway 177.

A levee constructed to protect the upslope side of Highway 177 is breeched on the west side (upstream) of the study area, forming a scale model of the overall lower fan. Upstream of the levee, a broad surface of shallow flows are concentrated into a narrow channel that has cut approximately 1 m into the fan exposing fine pebbles and sand in its banks. Within 30 m of the highway, the channel breaks into several well defined subsidiary channels 10 cm deep. Within 60 m of the highway, the drainage consists of a 100 m-wide zone of numerous, braided, 5 cm-deep channels. Within 100 m upslope of the highway, the channel forms are discontinuous and nearly completely lost; sheet flow appears to be the main fluvial process.

5.8.3 Uplands

Uplands rise 30 to 50 cm above most of the watercourse, and consist of nearly flat, former floodplains and terraces. They extend across the entire delineation area. The upland surface is covered with a discontinuous deflated layer of small pebbles 1 to 2 clasts thick. Although this surface is slightly darker than adjacent, fluvially active surfaces, its pebbles lack desert varnish (regardless of age, varnish tends to develop poorly on granitic clasts) or other indications of antiquity.

Soil pits show the uplands (Appx. B, soil pit CXB-SP-2A) consist of mudflow deposits containing moderately well developed, 2Bt, 2Bk horizons overlain by fluvial floodplain deposits having a weak A horizon. These features are consistent with a Holocene age.

Typical infiltration rates on the upland are approximately half that of the channel (Table 1), likely due to the underlying mudflow deposit.

Table 1: Typical infiltration values, Coxcomb Mountains fan

Geomorphic unit	Test number	Rate (cm/hr)
Upland	CXB-INF-2A	49.7
Island	CXB-INF-C	31.3
Channel	CXB-INF-D	116.9

Woody vegetation is small and sparse, consisting mainly of creosote with minor burro bush. There is a considerable amount of in-place deadwood beneath the creosote, indicating that runoff that does cross the uplands must be shallow. Low coppice dunes are common at the base of the woody vegetation; the dunes are usually extensively burrowed.

Nascent, shallow, upslope-migrating “proto” channels (Fig. 52) having numerous, low, headcuts are common and indicate that the lower fan is undergoing broad-scale erosion. These are formed by the concentration of runoff across the uplands cutting a new channel that forms a tributary to existing ones.

Indicators of overbank flooding including mud drapes from a recent (most likely early December, 2012) rain event are widespread, and extend over 30 m from defined channel boundaries.

Figure 52: Upland area with proto-channel; note headcut in middle foreground. View downstream, Coxcomb Mountains fan.

5.8.4 Lower Fan

The lower fan consists of a broad, gently sloping plain of low-lying uplands crossed by shallow channels and watercourse complexes. Sediment is exclusively granitic-derived pebbles, granules, and sand; because of this fine grain size, the lower fan occurs about 2/3 down the fan in the "usual" position of a mid fan. Flow occurs in a few, through-going channels cut into uplands, but mainly as watercourse complexes.

Channels and Watercourse Complexes

Although several, through-going channels cross the site, watercourses consisting of networks of short channels that braid around low islands dominate (Fig. 53).

Islands rise 10 cm or so above the channels, and are usually associated with woody vegetation. Unlike on the uplands, coppice dunes here are rare and appear to be relict. There is little burrowing.

The upper surface of the islands is typically a deflation layer of unweathered pebbles and granule sand. In most places there is a thin mud layer. Soil pits (Appx. B, CXB-SP-2C) expose a lower mudflow and fluvial deposits having moderately developed soils (2Btk) indicating Holocene age, overlain by fluvial deposits with a weakly developed A horizon. The mudflows are similar to those on the upland indicating deposition in a similar, distal fan environment. The

stratigraphy indicates that the islands formed by erosion of the uplands, and subsequent deposition of fluvial sediment. Therefore, they lie within the jurisdictional watercourse.

Figure 53: Typical watercourse, lower Coxcomb Mountains fan. Note shallow channels and association of vegetation with islands. View downstream; Palen Mountains in background.

Despite their subsurface mud, the upper layers of the islands are composed of loose granitic sand and granules, so the channels tend to migrate laterally rather than incising. However, the mud makes infiltration on the islands similar to that of the uplands (Table 1) so water falling on or flowing over the islands would drain back into the channels.

Woody vegetation (creosote and burro brush), is considerably more robust and abundant than on the upland. Vegetation-channel alignments are not well developed because the channels migrate laterally so readily. Biotic soil crusts cover up to 5 percent of the surface.

Although some prominent channels cross the entire area, most channels are poorly defined, and discontinuous a few centimeters deep and a few tens of meters long, forming watercourse complexes. Channel banks are less than a few centimeters high, and are carved into the interfluves. Sediment in the channels is loose, granitic sand with few pebbles; mud is rare. Pits in the channel (CXB SP-2D) expose unweathered floodplain and channel deposits indicating that erosion and deposition are active.

Within the watercourse complex, medial bars and shallow scour holes are common, as is non-decomposed wrack on the woody vegetation, indicating that laterally spreading, out-of-channel flows are the operative processes. The entire width of the watercourse is an active fluvial system.

Infiltration in the channels is high (117.0 cm/hr-Table 1) due to the porous, sandy substrate. It is anticipated that such a high value would cause large seepage losses and thus, most flows would not extend to the lower fan. However, the considerably lower infiltration (34 cm/hr) on the uplands, its sparse vegetation, and its abundance of proto-channels, indicate that runoff from the uplands contributes to flow in the channels and watercourses.

Just beyond the delineation area in the lowest part of the fan, the channels turn southward and merge with a major, south-flowing, axial drainage that flows into Palen (dry) Lake. An active dune field picks up much of the fine sand and silt from the terminal fan and carries it southward.

5.8.5 Conclusions-Coxcomb Mountains Fan

- The mid and lower fan segments of the Coxcomb Mountains fan delineated here covers an area of approximately 261 acres and contains approximately 42 acres (16 percent) jurisdictional watercourse (Appx. A).
- Instead of the discrete channels that drain most fans, drainage on the Coxcomb fan occurs within broad, shallow, watercourse complexes identifiable by the presence of flow indicators.
- Runoff from the uplands is rapid and adds to flows in the channels and watercourse.
- Out-of-channel flows are common and channel positions are unstable. Because the banks are weak, channel positions may shift in a single high flow.
- Fluid mudflows are common and can block channels and cause them to migrate.
- Watercourses nourish an areally broad ecosystem with water, seeds, and organic matter.
- Fine sediment supports a dune field at the distal end of the fan. Blockage of water or sediment would deprive the dunes of sand.
- If native materials were to be used in drainage control, such as berms or dikes, their lack of cohesiveness would make them vulnerable to erosion during periodic flood events, such as that which breeched the berm upstream of Highway 177.

5.9 Silurian Hills Fan

The Silurian Hills-Silurian Lake site examined in this delineation, includes a northern area of mid-lower fan and playa, and a southern lower fan area of playa fringe, sand dunes, and drainage from Salt Creek. Our survey and delineation of the Silurian Hills fan included five transects, seven infiltrometer tests, and six soil pits.

5.9.1 Location

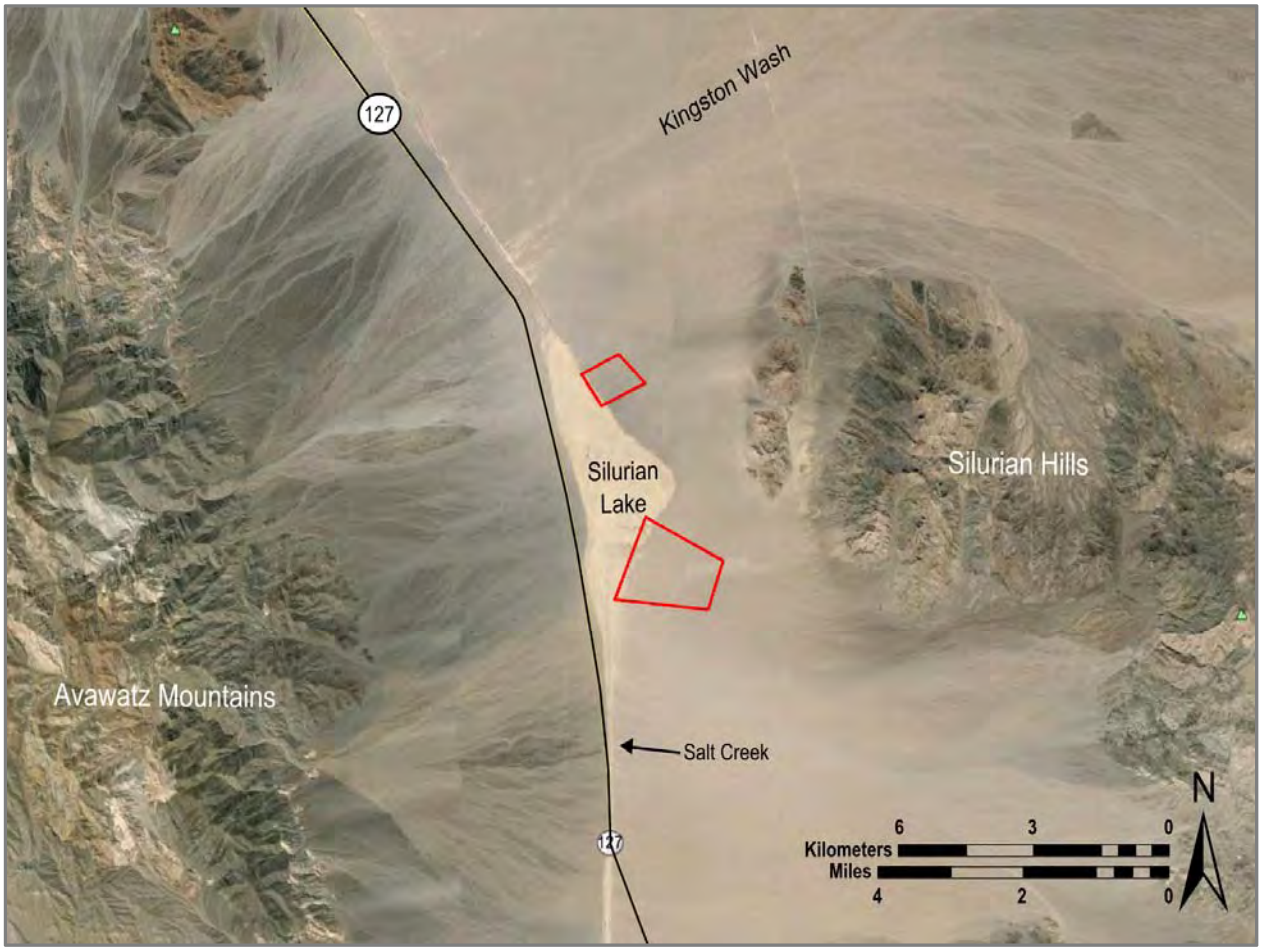
The Silurian Hills fan site is located 19 miles north of Baker, along Highway 127, in San Bernardino County, California between the Avawatz Mountains and Silurian Hills (Figs. 1 and 54). The fan drains west from the Silurian Hills into Silurian Lake playa, and is accessed east of the highway along tracks that crosses the playa in Sect 25, T.17 N., R.7 E., Silurian Hills 15-minute USGS topographic quadrangle. During wet periods, the lake is too wet to cross and may remain so for several weeks.

5.9.2 Setting

The Silurian Hills fan complex drains Paleozoic clastic and carbonate sedimentary bedrock into Silurian Lake. Much of the delineation areas consists of Pleistocene fan having a well developed pavement and Av soil horizon (Appx. B, soil pit SIL-SP-2A). Vegetation on the old fan surface is sparse and relict channels are fairly common. These are noted by subtle and rounded channel

margins, a lack of fluvial indicators, the presence of Av soil horizons, and the presence of unweathered fluvial sediment in the subsurface (Appx. B, soil pit SIL-SP-2A).

Figure 54: Location of Silurian Hills fan delineation areas (in red), San Bernardino County. Image Google Earth.



The upper fan drains westward through a narrow gap in the Silurian Hills, and the gradient is fairly steep. Because of this, flows are concentrated, carving numerous moderate-sized channels with relict fan surfaces stranded between (upland interfluves). Both debris and water flow deposits, mainly of cobble size, are represented. Indicators of fluvial activity are abundant.

The most distal part of the lower fan merges with the playa deposits along the east shore of Silurian Lake (Fig. 55). There, sheets of loose sediment predominate across the entire distal fan surface, separated by widely spaced and shallow (<5cm) channels containing graded granule deposits. Veneers of mud are widespread and preserve well an abundance of small mammal tracks.

Relief between the active channel bottoms and the tops of the relict fan surfaces is less than 10 cm. Numerous distributary channels indicate diverging flow. Many recent mud drapes and organic wrack show that flows have jumped the channels onto the relict fan surfaces indicating that most of the lower fan area is an active watercourse.

Springs (indicated by circular zones of spongy, moist soil) are common along the fan-playa fringe. In the north, they support concentrations of creosote, burro brush, and annuals but in the

south, they tend to be barren. There, dense, salt and soda crusts indicate the spring water is higher in dissolved solids than either the lake water or water draining from Salt Creek, and soil pits through the springs cut interbedded sand and silty clay densely cemented by salts.

Figure 55: Playa fringe, Silurian Hills fan, San Bernardino County. Vegetation associated with springs. View to south; Silurian Lake to right, Silurian Hills to left.

A soil pit (SIL-SP-4A) on the fan-playa fringe exposes interbedded gravel, sand, and silty clay deposits indicating a dynamic but overall drying sedimentary environment transitioning from moist (lacustrine and prograding fan) to arid (eolian).

Infiltration on the old fan surfaces is low (2.2 cm/hr), including in the relict channel (2.8 cm/hr), and it is very low on the playa fringe (1.8 cm/hr) indicating that rapid runoff is characteristic of this site (Table 2).

Table 2: Typical infiltration values, Silurian Hills fan

Geomorphic unit	Test number	Rate (cm/hr)
Playa fringe (north)	SIL-INF-4A	1.8
Relict channel (north)	SIL-INF-6A	2.8
Active channel (south)	SIL-INF-3B	41.3
Upland (south)	SIL-INF-2A	2.2

5.9.3 Northern Area

The northern area includes mid and lower fan areas forming a fairly uniform surface that grades into Silurian Lake. The mid-fan area has a markedly lower gradient than the upper fan. In the mid-fan area, shallow, active channels cut a relict fan surface, but relief is low, resembling a lower fan region, although the mid fan is some 40 m higher than the base level in Silurian Lake.

The lower fan is separated from the mid fan by a zone of chaotically incised channels and patches of oversized cobbles and boulders brought in by large floods. Included are clasts from the Kingston Peak and Crystal Springs Formations (and others) that do not occur in the Silurian

Hills. This, along with the southward bend of active channels in Kingston Wash to the north, indicates that the lower fan receives material from both the Silurian Hills and from the Kingston Range some 30 km northeast. Inclusion of drainage from Kingston Wash has created a belt of more classically mid-fan deposits and drainage features between the actual mid fan (which resembles a lower fan), and the true lower fan.

A number of relict channels also cross the relict fan surfaces, and are identified as such by the presence of an Av horizon beneath their surface layer, and weathered fluvial sediment beneath (Fig. 56) (Appx. B, soil pit SIL-SP-6A). The Av horizon indicates this channel is relict rather than dormant. Many of these have swales and small headcuts at their distal ends, and connect with active watercourses. This is most likely due to the presence of erodible sand underlying the desert pavement and Av horizons which have low infiltration rates. Runoff across the old fan surface drains into the relict channels (which also have low infiltration) reactivating them as swales where the runoff coalesces to generate stream flow. The concentrated flow cuts through the low-permeability upper layers and into the soft sand beneath, initiating head cuts, and flow into the adjoining stream.

Figure 56: Northern Silurian Hills fan showing relict channel in foreground (between dashed lines) on Pleistocene fan surface. Soil beneath surface of the relict channel has a well developed Av horizon and weathered fluvial sediment. View to southwest, Silurian Lake in background. Botanist for scale.

Vegetation (mainly creosote) in this area is sparse on the fan surfaces but abundant, robust, and strongly aligned along the shallow channels indicating a preference for the more persistent subsurface flow that occurs there. Infiltration in active channels (41.3 cm/hr) is more than an order of magnitude greater and hence, the active channels are important conduits for subsurface needed to water the vegetation, and no doubt accounts for the strong alignment of vegetation with active channels.

The old (Pleistocene) fan surfaces contain many circular mounds of uniform, fine sand brought to the surface by burrowing. The mounds are 3-4 m in diameter and have a relief of 15 cm or so. The mounds demonstrate the abundance of this material beneath the surface pavement,

indicating that the older fan transgressed across a former dune surface. As well, despite their coarse surface pavement, the old fans provide ecologically important, soft sediment that does not occur in the active drainage system, which is mainly gravel.

5.9.4 Southern Area

The southern area is similar to the lower fan to the north, except: (1) there has been, and is, a complex hydrologic interaction between the fan, Salt Creek which drains northward into Silurian Lake, and the lake; (2) flow from the fan is less and is entirely from the Silurian Hills; and (3) there is considerably more eolian sediment both in the form of coppice dunes and as reworked sediment in the channels.

The up-slope part of the fan has well defined, though shallow, through-going channels cutting an old fan surface, and prominent watercourses of discreet, prominent channels and discontinuous channels (Fig. 57). The channel and bank sediment is mainly gravel and (eolian) silty sand. Although the banks are moderately well defined, channel switching is common and indicators of out-of-channel flow are abundant. Vegetation is robust and well aligned with the through-going channels, but is scattered across the watercourse areas.

Figure 57: Southern Silurian Hills fan with well developed, active channel in watercourse. Note alignment of vegetation with channel margin, compared to old (Pleistocene) fan surface. Silurian Lake in background. View downstream to northwest; Avawatz Mountains on skyline.

At the fan's distal end, west-directed drainage is truncated and merges with north-directed drainage along Salt Creek. Most of the channels become buried by eolian sand but are subsequently re-formed during high-flow events. Woody and herbaceous vegetation is also fairly abundant along discontinuous and topographically higher secondary channels of Salt Creek. At the extreme northwest corner, relict channels appear as discontinuous lines of vegetation in the sand, and there are many small depressions (ponds when wet) surrounded by herbaceous vegetation in the dune field—an unusual feature. The vegetation is most likely supported by subsurface water from Salt Creek flowing through permeable sandy substrate above the upper, clayey layer of the playa which has very low permeability.

5.9.5 Conclusions-Silurian Hills Fan

- The area of the northern Silurian Hills fan delineated here covers approximately 191 acres while the southern area covers 675.5 acres. Using an average of 1 m width for all single-thread streams, the northern area contains 29.5 acres of jurisdictional streams and watercourses (15 percent), while the southern area contains 77.5 acres of jurisdictional streams and watercourses (11 percent).
- The northern area receives significant drainage from Kingston Wash to the north. Because of the low infiltration of the old fan surface, and the additional input of water from Kingston Wash the north receives larger (and more frequent?) flooding than would be expected based on its mid- and lower fan position.
- Drainage in the north occurs mainly along through-going, single-thread channels, but in the south, it is dispersed throughout broad watercourses.
- Vegetation in the north is sparse, and concentrated along the stream channels. In the south, it is dispersed. Modifications of drainage will affect the vegetation distribution and viability.
- An old, fan surface of desert pavement, having low infiltration covers much of the area, but is most widespread in the north. The fan surface, and underlying beds of soft, eolian sand are a stable but workable substrate important habitat for burrowing organisms.
- The northern area includes numerous relict channels that were excluded from the calculation of jurisdictional area. These channels all display evidence of their antiquity.
- Drainage in the south occurs mainly along broad, active watercourses where out-of-channel flows are common.
- Fresh-water springs are abundant along the entire playa fringe and support groves of woody vegetation. These springs are undoubtedly fed by subsurface flow through the Silurian Hills fan which emerges when it encounters the low-permeability playa deposits of Silurian Lake. Re-routing fan drainage will decrease the volume of water available to support the springs and associated vegetation.
- In the south, eolian sand buries the fan-playa fringe and channels of Salt Creek. However, the dune field is unusually verdant owing to water that flows along the shallow interface between the sand and underlying playa clay.

5.10 Avawatz Mountains- Sheep Creek and Pipeline Wash Fans

5.10.1 Location

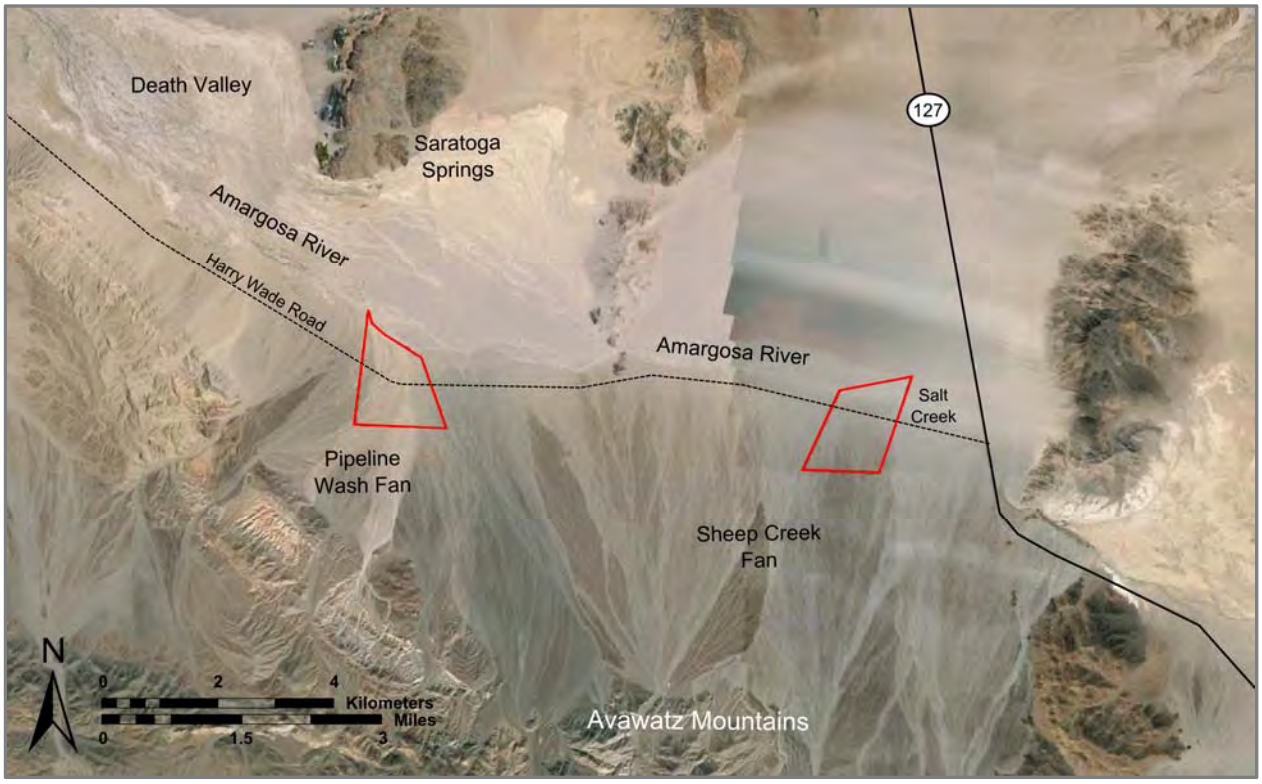
Sheep Creek and Pipeline Wash fan delineation areas (Figs. 1 and 58), lie on the northern flank of the Avawatz Mountains in southern Death Valley, in San Bernardino County in T. 17 and 18 N., R. 6 E., on the Avawatz Pass 15-minute USGS topographic quadrangle. The fans are traversed by the Harry Wade Road, accessible from Highway 127.

5.10.2 Setting

Both the Sheep Creek and Pipeline Wash fans have high relief and drain into the Amargosa River, which flows westward into Death Valley (Fig. 58). Sheep Creek fan drains a large, steep

run-off area that extends far into the range that is underlain by hard bedrock that produces coarse, granular sediment. Pipeline Wash drains a limited source area of fairly low relief underlain by hard bedrock and highly erodible, fine-grained, Tertiary sediments so its sediment has abundant mud.

Figure 58: Location of Sheep Creek fan and Pipeline Wash delineation areas, San Bernardino County. Image Google Earth.



Although Sheep Creek fan and Pipeline Wash adjoin one another on the north flank of the Avawatz Mountains, their geomorphology, drainage characteristics, and sediment load and type differ markedly, underscoring the importance of conducting detailed ground investigations during delineation surveys. During this course of study and delineation here, we surveyed eight cross sections, conducted five infiltration tests, and excavated four soil pits.

5.10.3 Sheep Creek Fan

Sheep Creek fan, covering nearly 44 km^2, is the largest fan in the range. Its headwaters extend nearly across the entire range, and drain solely diorite bedrock. The fan consists of prominent upper, mid, and lower fan segments of differing ages ranging from Plio-Pleistocene to modern.

The upper fan consists of a deeply incised but otherwise undisturbed older fan surface of Pleistocene age. Indicators of antiquity--and thus of fluvial inactivity--are well developed including: reduction of bar-and-swale morphology to single clast, rocks fractured in place, dark desert varnish and clast rubification, Av soil horizon over a dark red cambic-argillic B soil horizon, and stage II+ petrocalcic (caliche) horizons. Vegetation is sparse on the older fan surface, but is abundant in the younger washes that cut the fan and include features indicating recent water and debris flows.

The mid and lower segments of the Sheep Creek fan were delineated herein. The area covers an area of approximately 493 acres and extends across Harry Wade Road to the confluence of Salt Creek with the Amargosa River (Fig. 58).

To complete our delineation, we surveyed four transects: one south of the road, and three north of it where the channels are much less well defined. We also completed two infiltrometer tests, and two soil pits.

Mid Sheep Creek fan consists of well defined, active channels that have incised into an older Pleistocene fan surface. The channels and their lateral extents are easy to delineate because they are mainly single thread and even the braids are well defined. On top of the fan surfaces, the reactivated, relict channels that have begun to act as source area swales to active channels are more subtle as elements of the modern watershed, and must be identified by their fluvial indicators.

Pleistocene fan deposits form prominent terraces, most prominently in the mid-fan area. These surfaces have a full range of indicators of their antiquity including well developed desert pavement, dark rock varnish and rubification, in-situ rock weathering, and soils having Av, cambic-argillic B, and petrocalcic horizons (Fig 59).

Figure 59: Mid Sheep Creek fan, view toward Avawatz Mountains, San Bernardino County. Pleistocene fan surface in foreground.

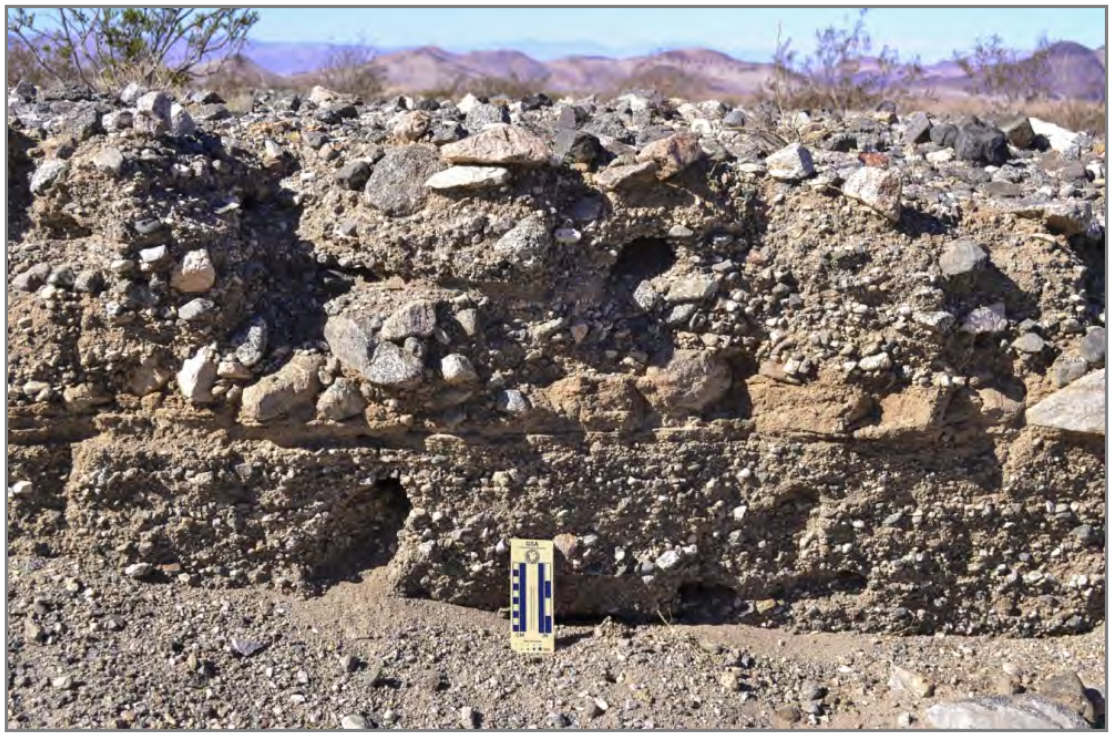
Because of this, infiltration on the old fan surfaces is very low (2.7 cm/hr) so runoff is high (Table 3), and vegetation is sparse, and mostly associated with shallow swales, as discussed below.

Table 3: Typical infiltration values, Sheep Creek fan

Geomorphic unit	Test number	Rate (cm/hr)
Pleistocene fan upland	SCF-INF-2A	2.7
Channel	SCF-INF-2B	215.2

Active channels are well defined and deeply incised into the Pleistocene fans (Fig. 60). Mostly, the channels are single thread, but in several areas, particularly in the west where the relief is low, they form small braids.

Figure 60: Buried mudflow (center reddish-tan unit) in Pleistocene deposit exposed in mid-fan channel wall, Sheep Creek fan.



Relict channels are abundant on the Pleistocene surface. Many of these intersect the modern, fluvially active, incised channels show evidence that they are currently acting as drainage swales, collecting and concentrating flow off the old, low-permeable fan surface. These reactivated swales are lined with verdant burro brush and show a number of flow indicators such as small head cuts, scour, and fine gravel ramps. The size and number closer to the confluences with the active main channels where head cuts are most common, working their way upslope, eroding the swale banks and exposing the Pleistocene deposits as the protective pavement erodes away.

Harry Wade Road intersects the well defined drainage pattern, concentrating the flow into fewer channels that abruptly spill out of their banks forming wide areas of shallow, distributed flow. The Pleistocene surface in much of this area is scoured and buried by recent flows. Although the channels are less well defined than south of the road, vegetation-channel alignments are widespread. A few channels have become abandoned because of beheading by the road where their flow is redirected into other, prominent channels.

The lower fan, north of the Harry Wade Road, is fluvially active, and merges with deposits of the axial valley Amargosa River. The lower fan, below Harry Wade Road, is fundamentally different, and consists mainly of a network of shallow watercourses created by out-of-channel flow (Fig. 61). Because of the abundance of active eolian sand deposition, the watercourses may be misidentified as “terrestrial”, but careful observation of fluvial indicators within the channels demonstrates that this is not the case.

On the west side of Highway 127, the fan's distal end is deeply incised by Salt Creek. There, the channel bank is about 4 m high and exposes characteristic gray-green mixed distal debris flow and stream flow deposits nearly entirely derived from the diorite of the Avawatz Mountains, and about 5 percent reddish eolian deposits probably from sand and silt transported by the Amargosa River. Exposures in channel banks are of thin and planar beds but are laterally discontinuous, highly channeled, inversely and normally graded indicating a highly mobile stream environment whose flows readily migrated laterally and included debris flows, channel water flow, and sheet flow. The area provides clear evidence in the channel walls of vertical relationships replicating lateral depositional environments – a process important to consider in interpreting the geomorphic history of the site.

Figure 61: Lower fan area, Sheep Creek fan. View upstream showing, laterally mobile shallow channels. Older fan surface in right background.

At its confluence with the Amargosa River, the Sheep Creek channels are marked by prevalent head cuts up to 30 cm deep (Fig. 62). Deposits exposed in the walls are uniform pale tan in color, loose, and well graded, just like those in the active channels, indicating that the river fairly recently occupied its present course along the south side of its channel. Here too, Salt Creek braids and meets the Amargosa at grade.

The lower part of the delineation area is dominated by broad, weakly-defined channels forming watercourses that splay around active coppice dunes that are fed by sand blowing up from the Amargosa River. In this area too, are several abandoned channels that have been completely filled in by sand. The sand is of uniform grain size, has a well stratified structure, and is weakly cemented. Vegetation is commonly struggling or dead, and alignments are poorly defined along these channels. Although the active channels also receive eolian sand, it appears to wash out

during flow events because there are interstratified gravel deposits and vegetation is more robust.

Figure 62: Confluence of Sheep Creek fan (right) with Amargosa River (left). Sheep Creek channels cut into resistant Pleistocene fan deposits forming abrupt cliffs. Contrast with confluence of Pipeline Wash and the Amargosa River.

5.10.4 Pipeline Wash Fan

Pipeline Wash fan lies on the northern flank of the Avawatz Mountains in Sec. 13 and 24, T. 18N., R. 5E. on the Avawatz Pass 15-minute USGS topographic quadrangle, in San Bernardino County (Figs. 1 and 58). The toe of the fan merges with the Amargosa River, which flows westward then northward into Death Valley. Access is via the Harry Wade Road off Highway 127; from there, a track extends south to the head of the fan, and another crosses the toe of the fan north toward Saratoga Spring.

Pipeline Wash includes a variety of age indicators, well exposed cross sections, active and relict channels, and simple but well defined relations between stream channel location and the presence of typical Mojave vegetation.

Pipeline Wash drains diorite and lesser metavolcanic rocks as well as Tertiary-age, fine-grained and conglomeratic sediments producing a mixture of cobbles and pebbles, with minor sand, silt, and clay. The fan is segmented into a steep upper fan, and uniform mid and lower fans, and is fluvially active across most of its width. Only the mid and lower fan areas were included in the delineation where we completed four traverses, two soil pits and two infiltrometer tests.

Midfan

The mid-fan area upslope of the Harry Wade Road consists of well defined, braided channels incised into stratified deposits derived from the source area. In the channel banks and bottoms are a mixture of debris flow and stream flow deposits. Channels carry boulders to pebbles, and

show no indicators of antiquity or abandonment. Coppice dunes cover about 5 percent of the surface, concentrating on the roots of closely spaced and vigorous creosote bushes.

Infiltrometer tests at Pipeline Wash show an eroded mid-fan uplands at 28.2 cm/hr, slightly less that the channel (34.5 cm/hr) (Table 1).

The lower fan is well exposed north of the Harry Wade Road and along the road to Saratoga Spring. The surface is mainly fine grained with scattered pebbles and cobbles; boulders are absent. Although out-of-channel flow appears to be most common, there is abundant evidence for confined, channel flow (Fig. 63). Channels are shallow (less than a few cm) and often poorly defined due to infillings of eolian sand, but they are expressed by lenticular gravel bars and graded deposits of coarse sand, granules, and pebbles. About 20 percent of the bases of the widely scattered creosote (farther spaced than on the mid fan) have coppice dunes up to 0.5 m high that are extensively burrowed. Where intersected by the shallow (few centimeters) channels, scour around the bases of the creosote commonly extends into gravel, sand, and clayey silt substrate representing deposition by fluvial channel, floodplain, mudflows, and eolian dunes (Appx. B, soil pit PLW-SP-3A). Evidence for channel and out-of-channel flows this season is abundant. Overbank mud drapes and small (<10 m^2) ponds filled by desiccated mud (mud cracks) are common.

Table 4: Typical infiltration values, Pipeline Wash fan

Geomorphic unit	Test number	Rate (cm/hr)
Upland	PLW-INF-3A	28.2
Channel	PLW-INF-3B	34.5

Figure 63: Lower Pipeline Wash fan, view southwest towards Avawatz Mountains.

At its most distal end, the north-draining channels of Pipeline Wash bend westward and merge with the low (<1m) natural levees built by the Amargosa River. Here, vegetation is particularly sparse, and small dunes have concentrated sand carried along the river. Sand blows across the entire lower fan, and at least part way up the lower fan, and with subsequent flows, is washed back down toward the river.

5.10.5 Conclusions-Avawatz Mountains, Sheep Creek and Pipeline Wash Fans

- The mid and lower fan segments of Sheep Creek fan covers an area of approximately 492.5 acres and includes approximately 152 acres (31percent) of jurisdictional watercourse (Appx. A). The acreage of jurisdictional watercourse is large, because it includes 60 acres of the south side of the Amargosa River and Salt Creek, which are entirely jurisdictional. If these areas were excluded, the values become: total area = 432.5 acres and jurisdictional watercourse = 92.0 acres (21percent).

  The mid- and lower-fan segments of Pipeline Wash fan cover an area of approximately 492.5 acres and contains approximately 111 acres (23 percent) jurisdictional watercourse.

- Although Sheep Creek fan and Pipeline Wash adjoin one another on the north flank of the Avawatz Mountains, their geomorphology, drainage characteristics, and sediment load and type differ markedly and underscore the need for careful fieldwork.

- Sheep Creek fan drains a large, steep, runoff area that extends far into the range, underlain by hard bedrock that produce coarse, granular sediment. Pipeline Wash drains a limited source area of fairly low relief underlain by hard bedrock and highly erodible, fine-grained, Tertiary strata. Sediment in Pipeline Wash includes abundant mud including in the mid-fan area.

- Uplands at Sheep Creek fan consist of well indurated, Pleistocene fan deposits that extend to the Amargosa River while; active channels are deeply incised and laterally stable. Uplands at Pipeline Wash extend only slightly above the active channels adding little stability to the drainage pattern. The uplands are completely buried at the distal end.

- Infiltration on the Sheep Creek uplands is negligible (2.7 cm/hr) indicating that runoff from the old fan (which covers a large part of the area) would contribute significantly to the flow which has reactivated relict channels now forming drainage swales (and draining water into the main channels). This process is much more common on the Sheep Creek fan than on Pipeline Wash where infiltration on the upland interfluve is 10 times greater so runoff from the uplands at Pipeline Wash contributes less water to the channels.

- Channel infiltration at Sheep Creek (215.2) is six times that of Pipeline Wash (34.5 cm/hr). This underscores the importance of the type of rock in the headwaters. At Sheep Creek it is mainly hard diorite and metavolcanic rock, while at Pipeline Wash there is abundant soft, sedimentary rock. Therefore, the channels at Sheep Creek tend to be coarse, cobble gravel while those at Pipeline Wash are fine pebble, sand, and silt. This affects the flows. The same volume of water is more likely to infiltrate into the bed of Sheep Creek channels, but will more likely flow the entire length of Pipeline Wash into

the Amargosa River. As well, mudflows are more common in Pipeline Wash than they are in Sheep Creek.

- Channels in Sheep Creek tend to be well formed and discrete, becoming less so in the most downstream sections. Flows appear to be vigorous and extend to the Amargosa River. Channels in Pipeline Wash are poorly demarked overall, and are prone to lateral migration. Flows include abundant, fluid mud. Because infiltration losses are high, flow may cease before reaching the Amargosa River.
- Although coppice dunes occur in lowermost Sheep Creek fan, many are relict while the entire lower part of Pipeline Wash is an active coppice dune field.
- The southernmost position of the Amargosa River at Sheep Creek fan is buttressed by well indurated, Pleistocene fan deposits there. But the Amargosa River has migrated at least 50 m south of its present position across the toe of Pipeline Wash during Holocene time. There is no physical barrier to prevent this from occurring again during high flood.

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APPENDIX A:
Delineation Maps of the Six Reference Areas Using MESA Protocol

APPENDIX B:
Soil Logs

APPENDIX C:
Infiltration Data

APPENDIX D:
Episodic Stream Indicator Data Sheet

APPENDIX E:
Glossary

The terms below paraphrase a variety of sources relevant to stream ecology, geomorphology and hydrology modified so as to be relevant to arid landscapes (Alluvial Fan Task Force 2010a, 2010b; Bates and Jackson 1984; Blair and McPherson 1994; CDFW 2010; Elzinga et al.1998; North and Davidson 2011; Picard and High 1973; Sawyer et al 2009; Wilson and Moore 1998).

A Soil Horizon — Uppermost mineral soil horizon characterized by paler color than parent material, and obliteration of its structure. Zone of downward leaching of mineral matter but may be enriched with eolian dust to form Av horizon (see below). Unlike in humid areas, arid A horizons have little organic matter.

Abandoned channel — Stream channels that no longer convey water and sediment from the upland drainage basin. See *Relict*.

Active channel — A channel receiving frequent enough flow to leave physical or biological evidence of fluvial activity on the landscape.

Absolute cover — A measure of the percent of ground covered by the crowns of all live perennial and shrub species within a sample area as viewed from above. Compare to *relative cover.*

Abundance — The relative amount of a species in a particular ecosystem. Measures of plant abundance are approximated by counting the number of individuals in a sample area. Qualitative descriptors of relative abundance of a species might include terms such as "rare," "occasional," "common," and "abundant". A given species might occur in both uplands and fluvially active units, but may be abundant in one and rare or occasional in the other.

Algal crusts — Biotic crusts composed of water-stable soil aggregates held together predominantly by algae but also fungi, lichens or mosses and the substances they produce; algal crusts occur predominantly in areas prone to water ponding. See *Biotic soil crusts.*

Alluvial fan — Gently sloping fan-shaped landforms that form where steep, confined mountain streams flow out onto a mountain front. They often resemble extended fans when viewed on maps or aerial photographs, but their morphology can be irregular forms bounded laterally by adjacent fans, bedrock outcrops, and relict fan surfaces.

Alluvial fan apex	The point at which an alluvial fan is last confined within the mountain front
Alluvial fan apron	The continuous, blanket-like deposit of alluvium formed by coalescing alluvial fans at the base of mountain ranges
Alluvial plain	A plain formed by the deposition of water-transported sediment.
Alluvium	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.
Anthropogenic disturbances or influences	Disturbances or influences caused by or attributed to humans.
Av Horizon	Soil horizon characterized by the dominance of vesicular pores, typically of lighter color than the underlying soil horizons. Vesicular pores are formed in the silt- to fine sand-rich eolian material through cyclic-wetting and drying. Air bubbles trapped during wetting expand as the surface is heated during drying leaving imprints as discontinuous, spherical vesicular pores. Av horizons indicate soils thousands of years in age and so indicate stabilized surfaces no longer subject to fluvial processes.
Avulsion	A sudden cutting off or separation of land by a flood or by an abrupt change in the course of a stream, as by a stream breaking through a meander or by a sudden change in flow direction whereby the stream deserts its current channel to join or form another.
Axial valley stream	A stream of an intermontane valley, flowing in the deepest part of the valley and parallel to its longest dimension.
Bajada	A broad, continuous alluvial slope or gently inclined depositional surface extending 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, including its vegetation that confines or otherwise defines the outermost boundary of a lake, or stream, when its waters rise to the highest level of confinement.
Bankfull flow	The flow that fills the active channel to a stage above which any further increase flows across the floodplain and spreads to topographically higher secondary channels and (or) floodplains.

Bar and Bar types	A general term for a ridge-like accumulation of sand, gravel, or other alluvial material formed in the channel, along the banks, or at the mouth of a stream where a decrease in velocity induces deposition. Examples include**:** point bars formed on the inside of meander channels; mid-channel bars formed within the channel.
Bar and Swale morphology	Shallow stream- or debris-flow channels separated by ridges of gravel and cobble.
Beach ridge	A low, essentially continuous mound of beach or beach and dune material (sand, gravel, organic debris) on the backshore of a beach beyond the present limit of waves.
Bedload	The part of the total stream sediment load that is moved on or immediately above the stream bed, such as the larger, heavier boulders, pebbles, gravels; the part of the load that is not continuously in suspension.
Bifurcated flow	The separation or branching of a stream into one or more parts.
Biotic community	The animal and plant life of a region.
Biotic soil crusts	Biological soil crusts that occur predominantly on dunes, alluvial slopes, and other areas that do not pond water. Water-stable soil aggregates held together by algae, fungi, lichens or mosses and the substances they produce; an intimate association between soil particles and cyanobacteria, algae, microfungi, lichens, and bryophytes (in different proportions) which live within or in the top of the uppermost millimeters of soil. Distinguished from “physical soil crusts,” or abiotic crusts such as salt crusts
Bioturbation	The reworking of sediment by organisms, such as small mammal burrows and the burrow “apron” or tailings.
Bk and Bt Horizons	In soil development, the B horizon is the "zone of accumulation". It consists of mineral layers which may contain concentrations of clay or minerals such as iron or aluminum oxides or organic material leached from the overlying A horizon, and which formed in place. It is defined by having a distinctly different structure or consistency to the A horizon above and the horizons below. They usually have stronger colors than the A and C horizons.

Bw Horizon	B soil horizon with notable reddening of hue due to in-situ oxidation of iron-bearing minerals; may include development of soil structure.
Boulder	A somewhat rounded, detached rock mass larger than a cobble, having a diameter greater than 256 mm.
	Elevated sandy deposits between channels.
Braided channel	A watercourse with multiple active shallow channels that divide and rejoin to form a pattern of gently curved channel segments separated by exposed ephemeral islands or channel bars.
Caliche	Calcium carbonate-rich deposit in soils of arid and semi-arid regions that is formed by the capillary rise of carbonate-bearing water toward the surface where it is deposited by evaporation.
Cca Horizon	C soil horizon enriched by secondary carbonate exceeding that of the parent material; shows as coatings, concretions, or soft masses.
Cambic-argillic (B) Horizon	Mineral B soil horizon characterized by a texture of clayey very fine sand or finer, a soil structure rather than rock structure, and clay accumulation, usually as coatings on the surface of particles or pores, or as bridges between sand grains.
Carbonate	A rock consisting chiefly of carbonate minerals, such as limestone or dolomite; sediment formed by the biotic or abiotic precipitation from aqueous solution of carbonates of calcium, magnesium, or iron.
Carbonate etching	Microsolution grooves and pitting on the surface of carbonate rocks.
Channel	A defined course along which water flows perennially or episodically. Channels may be active during every runoff event or spatially or temporally dormant features within a larger watercourse that receive water periodically during higher flows.
Clasts	An individual grain, or fragment of a sediment or rock, produced by the mechanical or chemical disintegration of a larger rock mass.
Clay	A detrital particle finer than silt and smaller than 0.0625 mm.

Cobble An often rounded rock fragment larger than a pebble and smaller than a boulder, having a diameter in the range of 64-256 mm.

Co-dominant species Two or more abundant species with high percent cover in relation to other species with the highest percent cover. Co-dominant species are generally defined as those with at least 30% relative cover. See also *dominant species, relative cover, and absolute cover*.

Compound channel Channels characterized by a single meandering, low-flow channel nested within a larger watercourse defined by a frequently shifting, channel network. The most common channel form for larger streams on dryland regions.

Confined flow Water flowing in stream channels, and retained between channel banks. The term *channelized flow* is here reserved for various forms of channel engineering, such as straightening and deepening, levee construction, or for flood management.

Coppice dunes Accumulations of sand at the base of small trees or shrubs.

Debris flow A moving mass of rock fragments, soil, and mud, more than half of the particles being larger than sand size.

Deflation Removal or "blowing out" of fine-grained sediment by the wind.

Density (vegetation) As used here, a measure of the total number of individual shrubs and perennials (all species combined) within a sample area. In the absence of defined plots and plot counts, simple qualitative descriptors of density may be used to compare two different units (upland units vs. watercourse complex or fluvially active units). These might include "same", "slightly greater than (or less than)", and "significantly greater than (or less than)".

Desert pavement A closely packed stony surface generally composed of a layer of angular or subrounded gravels one or two stones thick sitting on a layer of finer stone-free, eolian-derived fine sediment.

Desert varnish A dark coating 2 to 500 microns thick that forms on rocks at and near the surface by precipitation of clay and iron and/or manganese oxides forming red and black varnishes, respectively. The varnish thickness increases with time if abrasion or burial do not occur. Clasts on fan surfaces that have been inactive for long periods of time have darker and

	thicker coatings of varnish than younger surfaces. Indicator of antiquity.
Diorite	Coarse-grained, igneous rock. Similar in texture to granite, but medium dark color due to abundance of hornblende. Very hard.
Discontinuous channel	A channel along which fluvial processes change from degradation to aggradation and a well-defined channel form is periodically lost along the stream length.
Distributary channels, flow, streams, or patterns	Channels flowing away from the main stream and generally 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.
Dominant species	An abundant species with a higher percent vegetative cover relative to other species. In this case, only perennial and shrub species are considered because the percent cover and density of annuals is highly variable due to variable and unpredictable rainfall. Dominant species are typically defined as those with at least 50% *relative* cover within the sample area.
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 attendant stream function.
Drainage network or system	All the streams and other water bodies that drain a region and contribute flow to larger stream or lake.
Ecohydrology	The interplay between ecological and hydrological processes from molecular to river basin scales. An essential component of eco-hydrology is a rigorous understanding of hydrobiology, from ecosystem properties, dynamics and functions to modeling of abiotic and biotic interactions at the basin scale.
Ecohydrological or Ecological integrity	Ecohydrological integrity expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships to the local hydrology are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes.
Ecosystem	A spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries.

Eolian	Pertaining to the wind; especially such deposits as dune sand, and of sedimentary structures such as wind-formed ripple marks, or of erosion and deposition accomplished by the wind.
Episodic stream	Streams having intermittent or ephemeral flow that are dry or have very low flow over decadal time scales. Large events that convey flow and/or sediment to affect channel morphology occur infrequently (i.e., once or twice per decade).
Ephemeral stream	A stream that flows in direct response to and only during and shortly after precipitation events. Their beds are always above the elevation of the water table, and stormwater runoff is their primary source of water. Ephemeral streams include normally dry arid or semi-arid region desert washes and arroyos. See *Episodic stream.*
Evaporitic crusts	Thin crusts of minerals (e.g., salts, carbonates, nitrates) that precipitate from water solutions as these solutions evaporate.
First- or Second-order Streams	Relative to stream order. The smallest and second smallest tributary to downstream watercourses. See *Stream Order.*
Fish and Wildlife	All wild animals, birds, plants, fish, amphibians, invertebrates, reptiles, and related ecological communities, including the habitat upon which they depend for continued viability (FGC Division 5, Chapter 1, section 45, and Division 2, Chapter 1, section 711.2(a), respectively). Fish means wild fish, mollusks, crustaceans, invertebrates, or amphibians, including any part, spawn or ova thereof (FGC, Division 5, Chapter 1, section 45).
Flood water	A body of water that overtops its natural or artificial confines and that covers land not normally under water; flows that escape from the usual channels under conditions that do not ordinarily occur.
Floodplain	A floodplain is a relatively flat area of land associated with a stream and over which water and sediment from the parent stream flows when the capacity of the channel is exceeded. Floodplains parallel stream channels but may also occur at the terminal end of a stream where the channel joins an *axial valley stream*, transitions into a *playa*, or the channel ends and its stream flow disappears into the ground to join the groundwater of the area. Not every stream is associated with a floodplain, but where floodplains occur they are considered integral to stream function and to define the outermost bounds of a watercourse in cross section and length. Floodplains and their surfaces are defined by the lateral extent of water that overflows subordinate channels but that has not escaped the main watercourse.

Flow lineation	Linear grooves in a streambed or accumulations of materials (e.g., sand, pebbles) that are aligned in the direction of stream flow.
Fluvial	Of or pertaining to rivers and streams.
Geomorphic processes	The earth processes that influence the landscape and, in the case of streams, shape channel form through sediment movement, erosion, and deposition.
Granule	A rock fragment larger than a very coarse sand grain and smaller than a pebble, having a diameter in the range of 2-4 mm.
Gravel	Unconsolidated accumulation of typically rounded rock fragments consisting predominantly of particles larger than sand (>2 mm), such as granules, pebbles, cobbles, and boulders, or any combination.
Gravel bar	See *Bar* and *Bar Types*.
Gravel or Pebble ramp	A ramp-shaped deposit of gravel that accumulates on the upstream side of vegetation in or along a stream channel; an indicator or stream flow and sediment transport.
Headcut	An abrupt, vertical drop in the bed of a stream channel that is actively eroding upstream (or in a headward direction).
Headwater	The source or sources and upper part of a stream, including the upper drainage basin.
Holocene	The geological epoch that began at the end of the Pleistocene (around 12,000 to 11,500 years ago) and continues to the present.
Imbricated clasts	Overlapping clasts, as tiles on a roof or scales on a fish.
Infiltration	Rate (in cm/hr) that water seeps into soil. Used to estimate runoff and stream recharge during rainfall events. Similar to permeability.
In-situ	In place.
Interfluve	Relatively undissected, fluvially inactive, upland or ridge between adjacent stream channels flowing in the same direction.
Intermittent stream	A stream that flows only at certain times of the year, as when it receives water from groundwater, or from surface sources like springs or snow-melt. Runoff from rainfall is a supplemental source of water for streamflow. See *Episodic stream.*

Island	Elevated body of land that is periodically surrounded by and isolated from the upland landscape by water. Islands are part of the watercourse unless their landscape and ecosystem characteristics differ from those of the watercourse, and there is minimal physical or biological exchange between them and the stream.
Levee (natural)	A long, broad, low ridge of gravel, sand, and silt deposited by a stream on its floodplain along the banks of the channel.
Limestone	A sedimentary rock that is chiefly calcium carbonate (calcite).
Low-flow channel	The topographically lowest stream channel or the dominant subchannel within a compound channel watercourse.
Matrix & matrix-supported	The fine-grained sediment (usually silt and clay) enclosing, or filling the spaces between the large grains or particles of a sediment or sedimentary rock.
Meander, Meandering	The curve or winding of a stream channel in its alluvial valley.
Metamorphic & Metamorphosed	Mineralogical, chemical, and structural adjustments of rocks to temperatures and pressures imposed at depth. Usually makes rocks harder and coarser grained. Metavolcanic = metamorphosed volcanic.
Mid-channel bars	See *Bar* and *Bar Types*.
Mud cracks	An irregular fracture in a crudely polygonal pattern formed by the shrinkage of clay and silt, (or mud), during drying; also referred to as *shrinkage cracks* or *desiccation cracks*.
Mud drapes	A thin layer of clay and silt deposited on top of coarser sediment during waning stream flows.
Mudflow	A general term for a mass-movement landform and a process characterized by a flowing mass of predominantly fine-grained earth material possessing a high degree of fluidity during movement.
Optically stimulated luminescence	An optical dating method that relies on the assumption that the mineral grains were sufficiently exposed to sunlight before they were buried. Ages can be determined typically from 300 to 100,000 years before the present.

Ordinary High Water For the purposes of determining the Waters of the US (as administered by the US Army Corps of Engineers for purposes of compliance with Section 404 of the Clean Water Act), the term is defined as "that line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas."

Out-of-channel flow Stream flow that exceeds channel capacity and overflows onto the floodplain areas that parallel a stream channel or occur at the terminal end of a stream channel. See *Floodplain*.

In low relief areas along the lower alluvial fan apron or alluvial plain where the capacity of individual channels is exceeded, out-of-channel flows may coalesce and spread out in a thin, relatively uniform expanse of shallow flooding that appears similar to *overland flow* and *sheetflooding* but is a distinct flood level that overflows onto the floodplain areas that define the outermost bounds of a watercourse in cross section and in length. Out-of-channel flows do not include extraordinary flood waters that have escaped from the watercourse to inundate lands not normally submerged, and that do not return to the watercourse.

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. See *Sheet flow* and *Sheetflood.*

Pavement A closely packed stony surface generally composed of a layer of angular or subrounded gravels one or two stones thick sitting on a layer of finer stone-free, eolian-derived fine sediment. See also *desert pavement.*

Pebble A general term for a small, roundish stone; a rock fragment larger than a granule and smaller than a cobble, having a diameter in the range of 4-64 mm.

Percent Total Vegetative Cover As used here, a measure of the percent of ground covered by the crowns of all live perennial and shrub species within a sample area as viewed from above (see also *absolute cover*). Use the sample "Percent Landscape Cover Diagrams" attached to the data sheet to estimate total vegetative cover.

Perennial As used here, an herbaceous plant lacking woody tissue that lives for more than two years. The term is often used to differentiate a plant from

shorter-lived annuals (a one-year life cycle) and biennials (a two-year life cycle).

Perennial stream — A stream that flows continuously during a year of normal rainfall; groundwater is the primary source of water for streamflow, and runoff from rainfall is a supplemental source.

Permeability — Rate of movement of groundwater through porous substrate.

Petrocalcic horizons and calcification — The accumulation of secondary calcium carbonate in the sediments, voids, or crevices within soils or bedrock below the surface in semiarid regions due to soil-forming processes or ground-water evaporation. The accumulation of calcium carbonate in arid and semiarid region soils is characterized by the following stages of development:

Stage I. The carbonate accumulation consists of a horizon with a few filamentary deposits or thin coatings of carbonates.

Stage II. Few to common carbonate nodules with K-fabric are formed; they may be soft or indurated.

Stage III. Is characterized by numerous, commonly cemented or indurated carbonate nodules carbonate impregnation and cementation. At the end of stage III, the internodular matrix also is impregnated and plugged with carbonates; the horizon has then a continuous K-fabric and is cemented.

Stage IV. A continuous, indurated calcic horizon that is cemented by calcium carbonate, and in some places, with magnesium carbonate, and includes deposition of one or more almost pure carbonate laminae on top of the cemented horizon.

Plant community — An assemblage of one to many plant species distinct in species composition or structure from other adjacent groupings or assemblages. Often influenced by a specific combination of environmental characteristics such as soil moisture, climate, and soil chemistry.

Playa and Playa lake — A playa is a dry, flat area at the lowest part of an undrained desert basin. It is largely free of vegetation and underlain by stratified clay, silt, or sand, and commonly by soluble salts. A playa lake is an intermittent lake in an arid or semiarid region, covering or occupying a playa in the wet season but subsequently drying up.

Pleistocene — The geologic time period (epoch) from 2,588,000 to 11,700 years before the present time.

Plio-Pleistocene — Geologic time period including the Pliocene and Pleistocene, 5,000,000 to 11,700 years before present.

Professional Geologist California state law requires that studies of geological processes and/or materials that affect the public health, safety, welfare, or financial worth of a property be conducted by a licensed Professional Geologist with a college degree in the discipline, and expertise in work experience as demonstrated by passage of a State-administered qualifying examination. Business and Professions Code section 6700 et seq. (Prof. Engineers Act) and/or section 7800 et seq. (Geologists and Geophysicists Act).

Prograding (fan) Alluvial fan advancing away from its source. Indicates increase in water flow, drying of lake (if fan extends into lake), or relative uplift of source.

Proto-channel Informal term referring to the early stage of a channel's formation. Usually recognized as a linear depression and headcuts.

Protocols Detailed study plans that provide the rationale and instructions for carrying out actions. Protocols consist of a narrative, standard operating procedures, and supplementary materials.

Quaternary The geologic time period from 2.588 million years ago to the present.

Radiocarbon dating (or simply carbon dating) is a dating technique that uses the decay of carbon-14 to estimate the age of organic materials, such as wood and leather, up to about 58,000 to 62,000 years.

Recurrence interval The average time interval between the occurrences of a hydrological event of a given or greater magnitude.

Relative cover A measure of the relative cover of a species in relation to that of other species within the sample area. Compare to *absolute cover*.

Relict landform
Relict channel A landform remnant that has survived after the processes responsible for its formation have ceased; a channel or remnant of a channel that is no longer part of an active fluvial process. Includes features of antiquity.

Ripples Relatively small bed forms that are exposed on bed surfaces of modern sediments and bedding plane surfaces of sedimentary rocks due to the interaction of a moving fluid (air or water) with a mobile substrate (mostly sand-size sediment).

Resiliency The capacity of an ecosystem to experience disturbance without losing its essential character and becoming something else; the capacity of a particular ecological attribute or process to recover to its former reference state or function after exposure to a temporary disturbance and/or stressor. The ability of a natural ecosystem to restore its structure following acute or chronic disturbance. Resilience is a dynamic property that varies in relation to environmental conditions.

River See *Stream*.

Rock varnish A dark coating from 2 to 500 microns thick that forms on rocks at and near the surface by precipitation of clay and iron and/or manganese oxides forming red and black varnishes, respectively. The thickness or the coating increases with time if abrasion or burial of the rock surface do not occur. As a result, clasts on alluvial fan surfaces that have been inactive for long periods of time have darker and thicker coatings of varnish than younger surfaces.

Rubification A soil development in which iron is released from primary minerals to form free iron oxides that coat rocks or particles in soils with a thin reddish film.

Runoff The part of precipitation appearing as surface flow in streams.

Average rates of surface water generating runoff in the Mojave Desert have been estimated to have a recurrence interval of 2.6 to 7.3 years (Griffiths et al. 2006)

Sand A detrital rock fragment or mineral particle smaller than a granule and larger than a coarse silt grain, having a diameter in the range of 0.0625 to 2 mm.

Secondary channel Topographically higher channels within a watercourse that carry water only during higher flows. Also known as overflow or high-flow channels.

Scour The concentrated clearing and digging action of flowing water that removes sediment from a streambed; the process of erosion that is controlled by the velocity of water flowing in a channel.

Sediment Loose, unconsolidated fragmental material that originates from weathering of rocks and is transported or deposited by air or water, ice, or as precipitation from solution (salts, calcium carbonate); e.g. sand, gravel, silt, mud, alluvium; the alluvial material (e.g., silt, sand, gravel) carried by a stream.

Sediment plastering Sand and gravel deposits adhered to stream banks by passing flows; distinct from the stream bank deposit itself, and indicative of more recent sediment transport.

Sediment ramps A ramp-shaped deposit of gravel or sand that accumulates on the upstream side of vegetation or boulders in or along a stream channel; an indicator or stream flow and sediment transport.

Sheetflood A broad expanse of moving, storm-borne water that spreads as a thin, continuous, relatively uniform layer over a large area in an arid region and that is not confined to well-defined channels; its distance of flow is short and its duration is measured in minutes or hours. Sheetfloods usually occur before runoff is sufficient to promote channel flow, or after a period of sudden and heavy rainfall. See *Out-of-channel flow.*

Sheet flow or Sheetwash 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. See *Overland Flow.*

Shrub A woody species that generally has two to several stems from the base, giving it a broad crown, and is usually less than 5 meters in height.

Silt A sediment particle smaller than a very fine sand grain and larger than coarse clay, having a diameter in the range of 0.004 to 0.0625 mm.

Single-thread channel A stream where flow is restricted to a single, discrete channel.

Soil Unconsolidated mineral or organic material on the surface of the earth that has been subjected to and shows effects genetic and environmental factors of: climate (water and temperature effects, micro- and macro-organisms, conditioned by relief, and acting on the parent material over time. Soil development begins when the surface of a deposit is stabilized, is no longer episodically buried by fluvial or eolian depositional processes, and is undergoing little erosion.

Soil Crusts See *Algal crusts* and *Biotic soil crusts*.

Splay deposits A low energy, deltaic deposit, oriented perpendicular to a main channel, formed by a break in a natural levee during flood stage.

Stream A body of water that flows perennially or episodically and that is defined by the area in which water currently flows, or has flowed, over a given course during the historic hydrologic regime, and where the width of its course can reasonably be identified by physical or biological indicators." The historic hydrologic regime is defined here as circa 1800 to the present.

Stream order A measure of the position of a stream (defined as the reach between successive tributaries) within the hierarchy of the *drainage network*. First-order streams have unbranched tributaries; a second-order stream is a stream after the junction of the first tributary, and so on.

Surface rounding The subdued, rounded landscape that is developed over time by wind and surface runoff in the absence of fluvial activity. Generally indicates an old landform.

Suspended sediment The total stream sediment load that is carried in suspension above the stream bed, consisting mainly of clay, silt and fine 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.

Terrestrial processes Upland processes dominated by non-fluvial, landscape-shaping mechanisms of wind, surface runoff, weathering, and soil development. *See Upland.*

Terrace One of a series of level surfaces in a stream valley, flanking and paralleling 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 (and higher) stage of erosion or deposition.

Tertiary The geologic time period from 65 million to 1.806 million years ago.

Transmission losses The water loss due to seepage of surface flow into the unconsolidated sediment of the channel bed and banks.

Uplands The higher ground dominated by terrestrial – or non-fluvial – processes that is above a watercourse and the high water level of a stream.

Vesicular A horizon See *Av horizon.*

Wash A broad, shallow, sandy or gravelly, and normally dry bed of an intermittent or ephemeral stream. See S*tream*.

Watercourse A complex of channels in which water currently flows, or has flowed over a given course as defined by the topography that confines the water to this course when the water rises to its highest level. Where present, low-flow channels, active channels, banks associated with these channels, and floodplains lie within the bounds of this larger channel designated the watercourse to discriminate between it and but smaller subordinate features that lie within its bounds.

Waters of the State "Any surface water or groundwater, including saline waters, within the boundaries of the state" (Water Code section 13050(e). Broadly construed to include all waters within the state's boundaries, whether private or public, including waters in both natural and artificial channels. Includes: all "waters of the United States", all surface waters that are not "waters

Watershed An area of land that drains water, sediment, and dissolved materials to a common outlet.

Wrack A waterborne deposit mainly of sand, gravel, organic detritus and other debris; a linear deposit along the banks of a stream, and less organized where the deposit is precipitated by its capture by complex vegetation or rock.

Wrinkle marks Small, discontinuous, more or less parallel ridges and hollows. Orderliness of the pattern varies from poor to good, giving the appearance of small, linear ripple marks; formed in loose, fine grained sand deposits on high point bars and longitudinal bars, and on floodplains.

APPENDIX F:
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California Energy Commission: http://www.energy.ca.gov/

Mojave Desert Eco-region Assessment:
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APPEMDIX G:
MESA Field Guide