SANTA FELICIA PROJECT
FERC LICENSE NO. 2153-012

# Study Plan to Characterize Geomorphic Effects of Santa Felicia Dam on Lower Piru Creek

OCTOBER 2010

UNITED WATER CONSERVATION DISTRICT
106 N. 8TH STREET
SANTA PAULA, CALIFORNIA 93060

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SECTION 1.0

# Introduction

This Study Plan has been prepared for the Santa Felicia Project (FERC Project No. 2153-012) to comply with *Reasonable and Prudent Alternative 1(a)* (RPA 1(a)) in Appendix B of the *Order Issuing the New License* dated September 12, 2008. The Project is located in eastern Ventura County approximately 5 miles north of Piru, California and is owned and operated by the United Water Conservation District (United *or* Licensee).

RPA 1(a) requires United to quantify the type, the amount, and extent of geomorphic effects of Santa Felicia Dam and its operations on the quality and quantity of steelhead habitat in Piru Creek downstream of the dam (lower Piru Creek). The lower Piru Creek area is presented in Figure 1. According to *Section 3.1 Report on Aquatic Resources* of the FERC Exhibit E relicensing documentation, aquatic habitat in lower Piru Creek is not conducive to the production and rearing of steelhead under current conditions due to poor habitat quality and limiting physical characteristics including poor quality spawning substrate, a lack of instream cover for refuge, a limited number of deep pools, and a lack of overhanging canopy. Spawning habitat is reportedly poor due to the limited amount of spawning gravel in lower Piru Creek and the presence of fine sediment which embeds available spawning gravels. Fine sediment deposition also affects rearing habitat by reducing instream cover (embeds larger substrate) and decreasing pool volumes and depths. Rearing habitat is also affected by the lack of canopy cover which further limits available refuge. In consideration of these issues, the objectives of the study plan are two-fold as follows:

- **Objective 1 -** Evaluate potential effects of Santa Felicia Dam and its operations on: a) the quantity, quality and availability of spawning gravel; b) the deposition and flushing of fine sediments; and, c) the adequacy of overbanking flows in supporting riparian vegetation along lower Piru Creek.

- **Objective 2 –** Based on the findings of Objective 1, determine the flow releases that are necessary to restore, or in the case of lower Piru Creek, enhance the geomorphic processes that promote a dynamic river ecosystem that will support steelhead trout including: a) mobilizing the streambed every 1-2 years to promote pool scour and mobilization of the coarse layer on riffles; b) flushing sand from the gravel framework during the spawning and rearing season; and, c) re-working the channel morphology via overbank flows at a frequency of approximately every 5 years.

The scope of work has been developed to build upon the existing information and data collected during the FERC hydroelectric relicensing process as provided in Exhibit E of the license application and involves the following:

- review and incorporate data into this study that was collected in 2004 during the FERC relicensing process;

- conduct a field reconnaissance survey to assess current, baseline conditions and select representative study sites;

- establish and monitor representative study sites to evaluate changes in channel geometry and substrate composition;

- conduct a spawning gravel inventory, collect bulk gravel samples, and perform a tracer gravel study to evaluate the amount and quality of spawning gravel and characterize gravel transport;
- collect hydraulic and sediment transport data during flow events;
- prepare hydraulic models for each study site to evaluate sediment transport conditions under varying flow conditions and assist in determining the magnitude of overbank flows required to re-work the channel morphology and support riparian vegetation; and,
- prepare a report that summarizes the methods and results of the study and, if warranted, provides recommendations for future actions.

United will implement the study plan after receiving written approval by NMFS.

This document provides background information to assist in understanding the Project and the physical characteristics of lower Piru Creek, the proposed scope of work and methods, and the proposed implementation schedule. The Study Plan is organized as follows:

- Section 2.0 provides background information regarding the Project and physical setting;
- Section 3.0 presents the proposed scope of work and methods;
- Section 4.0 discusses the proposed implementation schedule; and,
- Section 5.0 presents the references used in the development of this plan.

SECTION 2.0

# Project Description and Physical Setting

This section provides a description of the Project and the physical setting with regards the hydrology, geomorphology, and aquatic habitat in lower Piru Creek.

## 2.1 PROJECT DESCRIPTION

The Santa Felicia Project was constructed in 1955 and is used in conjunction with other United facilities to recharge downstream groundwater supplies in basins that have been depleted due to overdraft and to prevent saltwater intrusion in aquifers located near the Pacific Ocean. The Project is located along the lower reaches of Piru Creek which is a tributary to the Santa Clara River. The Project facilities include Santa Felicia Dam which is located approximately 6.2 miles upstream of the confluence with the Santa Clara River and consists of an earth-filled dam that is 200 feet high and 1,260 feet long. The water impounded by the dam forms Piru Reservoir which is a surface water reservoir with a maximum capacity of 87,187 acre-feet and a useable storage capacity of 67,669 acre-feet. During the winter and spring months, water is retained and stored in Piru Reservoir when downstream groundwater basins are at their fullest level. Conservation releases from Santa Felicia Dam are conducted in September and October of each year . The releases average approximately 270 cubic feet per second (cfs) and are designed to maximize the amount of water that reaches the Freeman Diversion Dam which is located on the Santa Clara River approximately 40 miles downstream of the Piru Creek confluence. The released water is used to recharge the coastal groundwater basins and supply agriculture with water.

## 2.2 OVERVIEW OF THE PIRU CREEK WATERSHED

The Piru Creek watershed encompasses approximately 500 square miles with the majority of the watershed situated within Ventura County and smaller portions within Los Angeles and Kern Counties. The watershed has a Mediterranean climate, with variable wet winters and hot, dry summers. The majority of precipitation falls during the winter months, generally between October and April. The average annual precipitation within the watershed is 19.8 inches per year. Topographic relief in the watershed is significant, with the majority of watershed covered by steep sided canyons and ridges and flat lands found in canyon bottoms and on top of ridgelines. Elevations within the watershed range from 8,831 feet mean sea level (msl) at the summit of Mount Pinos to approximately 647 feet msl at the confluence with the Santa Clara River near the town of Piru, California. Land use within the watershed consists of urban, agricultural, and open space land uses.

The watershed is characterized by broad alluvial subbasins alternating with gorges incised in bedrock, and, in general, the creek flows along structural trends (USGS 1968). The headwaters of the creek are located in Lockwood Valley within the Los Padres National Forest and the upper portion of the watershed consists of rugged, undisturbed terrain. From its headwaters, the creek meanders eastward approximately 30 miles while dropping 2,200 feet in elevation through a series of open valleys and steep gorges before reaching the Pyramid Reservoir. The watershed area contributing to Pyramid Reservoir is approximately 284 square miles (USGS 1968).

The creek continues south below Pyramid Dam approximately 15 miles through the Los Padres National Forest to Piru Reservoir. The watershed between Pyramid Dam and Piru Reservoir is more mountainous and contains fewer valley flats than the area situated upstream of Pyramid Dam (USGS 1968). Major tributaries to Piru Creek situated below Pyramid Reservoir include Agua Blanca Creek, which is located approximately one mile upstream from the Blue Point Campground, and Fish Creek, which is located approximately 3 miles below Frenchman's Flat just south of Pyramid Reservoir. The contributing watershed area to Piru Reservoir is approximately 425 square miles (USGS 1968).

Downstream of Piru Reservoir, the creek continues south approximately 6 miles to its confluence with the Santa Clara River. The lower portion of Piru Creek consists of a relatively low gradient, broad alluvial valley surrounded by agricultural land use. Lower Piru Creek has been altered from an intermittent drainage to a perennial drainage by sustained based flows since the completion of Santa Felicia Dam in 1956. Major tributaries below Piru Reservoir include Modelo Canyon, Holser Canyon, Lime Canyon, Blanchard Canyon, and five unnamed tributaries.

## 2.3 GEOLOGY AND SOILS

The Piru Creek watershed is located in the Transverse Ranges physiographic province. This geologic province is composed of parallel, east-west trending mountain ranges and sediment-filled valleys that are principally composed of a variety of consolidated marine and terrestrial sedimentary and volcanic rocks of Late Cretaceous through Quaternary age. The Transverse Ranges are relatively young in geological terms and are tectonically active with recent uplift and erosion. In general, the geology of the watershed consists of areas of highly erodible and highly resistant formations which results in broad alluvial subbasins alternating with gorges incised in bedrock (USGS 1968).

The basin is bisected by the northwest-trending San Gabriel Fault which intersects Piru Creek approximately two miles downstream of Pyramid Dam (USGS 1968). The portion of the watershed situated above Pyramid Dam, between the San Gabriel and San Andreas Faults, is formed by the Ridge stratigraphic basin (USGS 1968). This basin is composed of non-marine sedimentary groups of Miocene and Pliocene age which are generally soft and readily erodible (USGS 1968). The geology of the watershed situated between Pyramid Reservoir and Piru Reservoir is predominantly composed of Mesozoic granitic rock and Eocene marine sedimentary units and the geology of the watershed situated downstream of the Project is predominantly composed of Upper Miocene and Upper Pliocene marine units. The predominant formations within the watershed situated between Pyramid Dam and the Santa Clara River include the Sespe Formation comprised of interbedded sandstone and claystone and the Vaqueros Formation comprised of marine sedimentary strata. Other formations in the region include the Modelo, Pico, and San Pedro (Saugus) Formations.

Major soil formations occurring in the Project area include: cortina stony sandy loam, metz loamy sand, mocho clay loam, and anacapa sandy loam. These soil formations are predominantly derived from sedimentary parent rock and are typically found on valley floors and alluvial fans with slopes ranging from 2-15 percent. Coarse sand and gravel alluvium occurs throughout the Piru basin and extends to a depth of approximately 60 to 80 feet below ground surface. The underlying San Pedro Formation consists of permeable sand and gravel that reaches depths of approximately 8,000 feet below ground surface (UWCD 2000). Permeability is typically rapid to moderately rapid with slow surface runoff and the erosion hazard rating is moderate to high.

## 2.4 HYDROLOGY OF LOWER PIRU CREEK

The hydrology of lower Piru Creek is best described in terms of pre-Project and post-Project conditions. For lower Piru Creek, pre-Project conditions consist of the period prior to the construction of the Project in 1956 and post-Project conditions reflect the regulated flow regime associated with the operations of

Santa Felicia Dam and the Pyramid Reservoir Project, which was constructed in 1972. The following characterization of the hydrology is based on the information provided in *Section 2.3 Report on Hydrology* of the FERC Exhibit E relicensing documentation.

In lower Piru Creek, downstream of the Project, the pre-Project hydrology is best characterized as “flashy” with the highest flows occurring between January and April in response to seasonal storm events and the lowest flows occurring in July through October at the end of the dry season. In regards to the monthly mean streamflows, the highest occurred in March at approximately 207 cfs and lowest occurred in August at approximately 5.6 cfs. The results of the flood frequency analysis for pre-Project flows in lower Piru Creek indicated 2-year, 5-year, and 10-year recurrence interval flows of 2,086 cfs, 6,924 cfs, and 12,908 cfs, respectively.

An analysis of the post-Project hydrology for lower Piru Creek indicates more consistent flows year-round and a change in the timing of annual extreme flows in comparison to the pre-Project conditions. Under regulated conditions, the highest flows occur in September and October in response to the annual water releases and the lowest flows occur between December and March. In regards to the monthly mean streamflows, the highest occur in September at approximately 114 cfs and lowest occur in January at approximately 12.4 cfs. The results of the flood frequency analysis for post-Project flows in lower Piru Creek indicated 2-year, 5-year, and 10-year recurrence interval flows of 379 cfs, 521 cfs, and 618 cfs, respectively. It should be noted that the post-Project flood frequency analysis does not account for spills from Piru Reservoir since the USGS stream gauge is situated upstream of the confluence of the spillway and the creek. Since the commencement of Project operations in 1956, a total of eleven spill events (1969, 1978, 1979, 1980, 1983, 1992, 1993, 1995, 1998, 2005, and 2006) have occurred at the dam. The spill records indicate that total mean daily flows (i.e. releases and spills) in excess of 1,000 cfs occurred in lower Piru Creek in 1969, 1978, 1980, 1983, 1993, 1995, 1998, 2005, and 2006 for periods ranging from two days in 1983 to 16 days in 1993. Total mean daily flows between 500 and 1000 cfs occurred in each of the recorded spill years for periods ranging between two days in 1992 and 36 days in 1983.

## 2.5 GEOMORPHOLOGY OF LOWER PIRU CREEK

The geomorphology of lower Piru Creek was characterized during the FERC hydroelectric relicensing process and is presented in *Section 2.4 Report on Geomorphology* of the FERC Exhibit E relicensing documentation. The characterization included an evaluation of pre-Project and post-Project channel conditions, the segregation of lower Piru Creek into three representative stream reaches based on the planform and fluvial features of the channel, an estimate of bankfull discharge and riparian maintenance flows, and a description of the sediment transport regime. This information is summarized below. The stream reaches and referenced stationing along lower Piru Creek (based on distance from the confluence with the Santa Clara River which is designated as RM 0.0) are shown in Figure 1.

### 2.5.1 Evaluation of Pre-Project and Post-Project Channel Conditions

In 2004, an evaluation of the pre- and post-Project channel conditions in lower Piru Creek was conducted using aerial photographs. The pre-Project aerial photograph was taken approximately seven years prior to construction of the Project in March 1949 and the post-Project aerial photograph was taken in 2002. The pre-Project aerial photograph is presented in Figure 2 and the post-Project aerial photograph is shown in Figure 1.

The 1949 photograph depicts a relatively unstable channel with very little riparian vegetation. Significant braiding and evidence of lateral migration is present throughout the lower reach of the creek downstream of the Project. The lower portion of Piru Creek near the confluence with the Santa Clara River is much larger than the present day channel and appears to laterally migrate throughout present day agricultural fields. The channel appears to meander through the valley with remnant and high flow/side channels present between River Miles (RMs) 1.7 and 3.0 and significant braiding occurs between RMs 4.3 and 5.3.

In contrast to the 1949 aerial photograph, the 2002 photograph depicts a relatively stable channel with a well vegetated riparian corridor between RMs 1.3 and 6.0. The lower portion of the channel near the confluence with the Santa Clara River has been confined by agricultural fields, but still appears to braid and laterally migrate in this area. The regulated flow regime in lower Piru Creek appears to have allowed encroachment of the channel by riparian vegetation and stabilized the channel.

### 2.5.2 Stream Reach Classification

Rosgen Level I and II methodologies (Rosgen 1996) were used to stratify lower Piru Creek into three representative stream reaches according to the Rosgen classification system (Rosgen 1996). The stream reaches and associated stationing along lower Piru Creek are shown in Figure 1 and are described below.

*RM 0.0 to RM 1.7 - Rosgen D3-Type Channel*

This reach was designated as a Rosgen D3-type channel that may be trending towards an F-type channel as a result of channelization. The channel is described as consisting of a relatively wide and shallow braided channel with plane bed/pool-riffle morphology. Sediment storage is present in floodplain areas and in lateral and mid-channel bars. The streambanks along this reach are primarily composed of silt/clay and sand and are unstable in areas with slumping occurring. Riparian vegetation in this reach is primarily composed of alder, willow, mulefat, and perennial herbaceous species which are situated along the streambanks, in floodplain and bar areas, and between braided channels. The density of riparian vegetation ranges from low in the lower portion of this reach below the railroad trestle at RM 1.30 to high between RM 1.30 and RM 1.70. Pebble count results along this reach indicate a D16 particle size in the sand/fines range (less than 2 mm), a D50 particle size in the very coarse gravel range (between 45 and 64 mm), and a D80 particle size in the small cobble range (between 90 and 128 mm). Field observations of embeddedness indicate that the gravel and cobbles are significantly embedded by sand and fines. The grain size analysis results of a fine sediment sample collected in this reach indicated a composition of approximately 24 percent sand and 76 percent silt/clay.

*RM 1.7 to RM 3.0 –Rosgen C4/C6-Type Channel*

This reach was designated as a Rosgen C4/C6-type channel with a relatively wide and shallow channel with plane bed/pool-riffle morphology. High flow/side channels are present throughout the reach. Rancho Temescal diverts water in the lower end of this reach by pumping water from an impound located at approximately RM 1.7. The influence of this impound extends from approximately RM 1.7 to RM 1.9. Sediment storage is present in floodplain areas and bars. Riparian vegetation is present at a moderate to high density and consists of willow, alder, mulefat, and perennial herbaceous species which are present along the streambanks, floodplain areas, and between channels. Pebble count results along this reach indicate a D16 particle size in the sand/fines range (less than 2 mm), a D50 particle size ranging between the sand/fines range (less than 2 mm) and the very coarse gravel range (between 32 and 45 mm), and a D80 particle size ranging between the coarse gravel range (between 22.6 and 32 mm) and the small cobble range (between 90 and 128 mm). Field observations of embeddedness indicate that the gravel and cobbles are significantly embedded by sand and fines. The grain size analysis results of a fine sediment sample collected in this reach indicated a composition of approximately 1.0 percent gravel, 94 percent sand, and 5.0 percent silt/clay.

*RM 3.0 to RM 6.0 –Rosgen Bc3-Type Channel*

This reach was designated as a Rosgen Bc3-type channel with a relatively wide and shallow channel with plane bed/pool-riffle morphology. High flow/side channels are present throughout much of this reach with the exception of between approximately RMs 3.1 and 3.5 which flows between a steep bedrock slope along the left bank and a constructed levee along the right bank and RMs 4.0 and 4.2 which flows between Piru Canyon Road on the left bank and a steep bedrock slope on the right bank. Sediment storage is present in floodplain areas and bars. The streambanks appear relatively stable with some unstable areas along the release channel situated downstream of the dam. Riparian vegetation is present at a moderate to high density and consists of willows, shrubs, and perennial herbaceous species which are primarily present along the streambanks, floodplain areas, and between channels. Pebble count results along this reach indicate a D16 particle size between the sand/fines range (less than 2 mm) and the medium gravel range (between 11.3 and 16 mm), D50 particle sizes ranging the coarse gravel range (between 22.6 and 32 mm) and the small cobble range (between 64 and 90 mm), and D80 particle sizes ranging between the small cobble range (between 90 and 128 mm) and the large cobble range (between 128 and 180 mm). Field observations of embeddedness indicate that the gravel and cobbles are moderately embedded by sand and fines. The grain size analysis results of fine sediment samples collected in this reach indicated a composition primarily within the sand range with minor percentages of silt/clay.

### 2.5.3 Bankfull Flow Estimates

The present day bankfull discharge was estimated at each of the four study sites included in the FERC relicensing effort. Bankfull discharge was determined using the definition of bankfull flow provided in Leopold et al. (1992) as the "channel forming flow or effective discharge", and taken for most alluvial streams as the 1.5- to 2-year recurrence interval flow in a flood frequency analysis. This also corresponds to the "effective discharge" of Wolman and Miller (1960). These discharge estimates were developed using the flood-frequency analysis data presented in *Section 2.3 Report on Hydrology* of the FERC Exhibit E relicensing documentation and the field identified bankfull elevations at the surveyed cross-sections at each of the four study sites. The bankfull discharge estimates were calculated using a hydraulic model, HEC-RAS (version 3.1.2) developed by the U.S. Army Corps of Engineers.

The model results indicated bankfull flows ranging between 205 and 383 cfs which corresponded reasonably well with the calculated 1.5- and 2-year recurrence interval flows of approximately 200 and 379 cfs, respectively. In regards to riparian maintenance flows, field observations made during the qualitative reconnaissance surveys and quantitative studies indicate that flows in excess of the bankfull discharge begin to inundate riparian areas along the channel corridor. These observations in conjunction with the presence of a moderate to dense riparian corridor along much of the channel indicate that flows above the estimated bankfull discharge are sufficient for supporting riparian habitat.

### 2.5.4 Sediment Transport Regime

The following presents a description of the sediment sources in lower Piru Creek and a conceptual framework of the sediment transport regime as described in *Section 2.4 Report on Geomorphology* of the FERC Exhibit E relicensing documentation.

*Sediment Supply*

The sediment supply to lower Piru Creek is limited as both Pyramid Reservoir and Piru Reservoir trap sediment transported from the upper Piru Creek Watershed. Since the UWCD does not sluice sediments from Piru Reservoir, sediment supply to lower Piru Creek is derived from sources situated downstream of the Project. A USGS study conducted in 1968 indicated an average sedimentation rate within the Piru

Creek Watershed of 0.58 acre-feet per square mile per year (USGS 1968). Application of this estimate to the watershed area situated downstream of the Project (approximately 15 square miles) yields an average sedimentation rate of approximately 8.7 acre-feet per year. The primary sources of sediment supply to lower Piru Creek consist of in-channel sources associated with channel incision and bank erosion, sediment delivered by tributaries and small drainages situated downstream of the Project, direct input by surface erosional processes, and drainage associated with development in the lower watershed.

In regards to in-channel sediment sources, the most prominent areas of bank erosion and channel incision were observed between approximately RMs 0.0 and 1.3, and RMs 5.4 and 6.0. The reach situated between RMs 0.0 and 1.3 flows adjacent to agricultural property and the streambanks are unstable in areas with active slumping occurring. These streambanks are primarily composed of fine-grained material. The reach situated between RMs 5.4 and 6.0 consists of the release channel from Santa Felicia Dam and appears to be incised. The streambanks are comprised of alluvial and colluvial material and are unstable in areas. These areas appear to deliver a range of substrate including fines, sand, gravels, and cobbles.

The tributaries and small drainages situated downstream of the Project likely represent the most significant source of sediment to lower Piru Creek. These tributaries include Modelo Canyon, Holser Canyon, Blanchard Canyon, Lime Canyon, and five unnamed drainages. The drainages are intermittent with surface flows occurring in response to seasonal rainfall events. Accordingly, sediment delivery from these areas is primarily limited to the wet season between November and April of each year. Based on observations during field reconnaissance surveys, Holser Canyon and an unnamed drainage situated directly below the dam deliver the highest volumes of sediment to lower Piru Creek. These drainages as well as the other local drainages appear to primarily contribute fine silts, sands, and to a lesser degree small gravels.

Besides tributary inputs, several areas adjacent to the creek provide direct sediment inputs due to surface erosional processes. The most prominent areas of localized surface erosion occur between RMs 3.0 and 3.6 and RMs 4.0 and 4.5. Steep bedrock slopes are present along the left bank between RMs 3.0 and 3.6 and the right bank between RMs 4.0 and 4.5. These bedrock slopes are composed of weathered mudstone and active erosion was observed in these areas. Surface erosional processes along these slopes including direct precipitation, overland flow, and wind deliver primarily fines, sand, and gravel material but also larger substrate directly to the stream channel. Surface erosion also occurs in other areas throughout the lower Piru Creek primarily in areas with little vegetation.

In addition to the aforementioned sediment supply sources, drainage from developed areas also contributes sediment to the channel. These areas include culverts associated with roadways, drainage along unpaved roads, and drainage from agricultural operations along the lower Piru Creek channel.

*Conceptual Framework of Sediment Transport Regime*

In general, the sediment transport regime in lower Piru Creek is characterized by sediment accumulation in the channel during the wet season and sediment mobilization and transport during spill events in extremely wet years and annual water releases which typically occur between August and October of each year. The majority of sediment is delivered to the channel during the wet season by the tributaries and unnamed drainages situated below the Project and surface erosional processes. This sediment primarily consists of silts and sands with some gravels. During the wet season, flows in lower Piru Creek are limited to the flow releases from the Project with the exception of spill events and runoff from the watershed situated below the Project. Typically, these flows are not sufficient to transport the sediment through lower Piru Creek at the time of delivery, so the sediment accumulates until a spill event occurs or annual water releases mobilize sediment and transport it through the system although the degree of sediment mobility during conservation releases is unknown.

## 2.6 AQUATIC HABITAT

Aquatic habitat in lower Piru Creek was characterized during the FERC hydroelectric relicensing process and is presented in *3.1 Report on Aquatic Resources* of the FERC Exhibit E relicensing documentation. The description of aquatic habitat was based on the results from a habitat survey conducted in August 2003. The estimated flow at the time of the habitat survey was 6.0 cubic feet per second (cfs) (USGS 2004). Aquatic habitat results from data collected in 2003 are not currently valid as a result of the 2005 spill event that dramatically altered the morphology of lower Piru Creek. Regardless, these results characterize habitat conditions that occurred in the absence of flushing flows (substantial spill event) since 1998. The results of the 2003 survey are summarized below.

*Mesohabitat*

The primary habitat composition within lower Piru Creek was riffles (32.0 percent), runs (32.0 percent) and scour pools (36.0 percent). Although the proportion of riffle habitat was 32.0 percent, these habitats were the limiting functional mesohabitat type in lower Piru Creek based on the low percentage of high quality riffles. The representative riffle habitat in lower Piru Creek can be characterized as low gradient (between one percent and two percent), layered with fine particulate organic matter (FPOM) and silts, and with little turbulence at lower flows. Water temperatures ranged from 16.5 to 29.5°C during the August 2003 habitat assessment in lower Piru Creek.

*Pools*

The mean pool depth for the majority of pools in lower Piru Creek was 1.5 feet with a range of 0.3 feet to 4.0 feet. The mean maximum depth for all pools in lower Piru Creek was 2.6 feet with a range of 0.5 feet to 6.0 feet. The average length of pool habitat ranged was 124.8 feet with a range of 10.0 feet to 922.0 feet. On average the pools were shallow and inundated with FPOM and silts. Pools in the upper reach of lower Piru Creek (the release channel and the borrow area) were deeper than those downstream. These deeper pools (three to six feet deep) also consisted of deep undercuts scoured by the presence of exposed root wads.

*Cover*

Instream cover available for fish in lower Piru Creek was limited in quantity due to highly embedded large substrate and a lack of undercut banks, surface turbulence, and terrestrial vegetation. Instream cover that was present in lower Piru Creek during the survey consisted primarily of boulders, small woody debris, and aquatic vegetation with few undercut banks. Although lower Piru Creek is densely bordered with riparian vegetation, most of the channel lacks canopy cover. On average, canopy cover was less than five percent within lower Piru Creek compared to a range from less than five percent to 80 percent within the release channel.

*Substrate*

The dominant substrate in lower Piru Creek consisted of boulder and cobble. At the time of the survey, this substrate was highly embedded with FPOM and fine sediment. This exposed substrate was still highly embedded after the UWCD conservation release. Based on observations at the Instream Flow survey sites, the Piru Fire (October 2003), which burned 63,991 acres, increased the amount of fine sediment in lower Piru Creek.

*Spawning Gravel*

Spawning gravel was sparse in lower Piru Creek during the August 2003 habitat survey. As stated previously, most habitat units were layered with FPOM and fine sediment. Gravel substrate that was observed was of poor quality for spawning because of excess fine sediments. Due to the presence of fine sediment throughout most of lower Piru Creek, the amount of spawnable gravel available to steelhead or resident rainbow trout during the time of the survey was close to zero.

SECTION 3.0

# Scope of Work and Methods

This section presents the proposed scope of work and implementation methods.

The objective of the study plan is two-fold. First, it will evaluate the potential effects of Santa Felicia Dam and its operations on: 1) the quantity, quality and availability of spawning gravel; 2) the deposition and flushing of fine sediments; and, 3) the adequacy of overbanking flows in supporting riparian vegetation along lower Piru Creek. Then, the results of this evaluation will be used determine the flow releases that are necessary to restore, or in the case of lower Piru Creek, enhance the geomorphic processes that promote a dynamic river ecosystem that will support steelhead trout including: a) mobilizing the streambed every 1-2 years to promote pool scour and mobilization of the coarse layer on riffles; b) flushing sand from the gravel framework during spawning and rearing season; and, c) re-working the channel morphology via overbank flows at a frequency of approximately every 5 years.

The scope of work has been developed to build upon the existing information and data collected during the FERC hydroelectric relicensing process as provided in Exhibit E of the license application and involves the following:

- review and incorporate data into this study that was collected in 2004 during the FERC relicensing process;
- conduct a field reconnaissance survey to assess current, baseline conditions and select representative study sites;
- establish and monitor representative study sites to evaluate changes in channel geometry and substrate composition;
- conduct a spawning gravel inventory, collect bulk gravel samples, and perform a tracer gravel study to evaluate the amount and quality of spawning gravel and characterize gravel transport;
- collect hydraulic and sediment transport data during flow events;
- prepare hydraulic models for each study site to evaluate sediment transport conditions under varying flow conditions and assist in determining the magnitude of overbank flows required to re-work the channel morphology and support riparian vegetation; and,
- prepare a report that summarizes the methods and results of the study and, if warranted, provides recommendations for future actions.

United intends to hire a consulting firm with appropriate expertise in geomorphology and hydraulic modeling to implement the study plan. United will work closely with the consultant during all phases of implementation and will coordinate with NMFS, as needed, to ensure compliance with the intent of the study plan and its objectives.

## 3.1 FIELD RECONNAISSANCE AND SELECTION OF STUDY SITES

A field reconnaissance survey of lower Piru Creek will be conducted to assess and characterize current stream conditions and select representative study sites. The survey will include characterizing general channel conditions such as substrate within the channel, planform, and other fluvial features and evaluating conditions relative to the geomorphic characterization that was provided in *Section 2.4 Report on Geomorphology* of the FERC Exhibit E relicensing documentation. Based on the reach classifications provided in the 2004 relicensing studies, the consultant will identify appropriate study sites. It is anticipated that one study site will be established in each of the three geomorphic reaches (i.e., the D3-type reach situated between RMs 0.0 and 1.7, the C4/C6-type reach situated between RMs 1.7 and 3.0, and the Bc3-type reach situated between RMs 3.0 and 6.0). Each study site will consist of one pool and one riffle. The study sites will be selected based on the following criteria: safe access, physical geomorphic features, quality of steelhead spawning and rearing habitat, representativeness of channel type in consideration of upstream and downstream conditions, and proximity to previous study sites.

## 3.2 QUANTITATIVE FIELD STUDIES

Following completion of the field reconnaissance survey, the following quantitative field studies will be conducted.

### 3.2.1 Cross-Section and Long Profile Surveys

Cross-section and longitudinal profile surveys will be conducted at each study site to characterize general channel conditions, evaluate changes in channel geometry, and assist in hydraulic model preparation. The surveys will include six cross-sections (at the riffle head, center, and tail and at the pool head, center, and tail), one longitudinal profile, and additional survey points within the pool habitat at each study site. The surveys will be conducted during low flow conditions when the channel can be safely accessed and traversed.

The cross-sections will be measured from left bank to right bank, looking downstream, and will be surveyed to the elevation of the floodprone width, using a total station and prism or an engineer's level and rod. Ground elevations will be surveyed at approximately one to two foot intervals along the cross-section and at all significant slope breaks or geomorphic features. Bankfull indicators will also be identified and surveyed. The consultant will use the protocols outlined in Harrelson et. al., (1994) and Rosgen (1996) to select field indicators. These indicators include topographic breaks in bank slope, the rooting elevation of perennial woody riparian vegetation, elevation of bank undercutting, significant changes in particle size of the bank material, and the height of depositional features within the active channel, such as unvegetated bars. Streambanks upstream and downstream of each cross-section will be carefully examined to establish continuity of the indicators. If multiple cross-sections are established at a site, then the elevations of each cross-section will be tied to a common datum.

The longitudinal profile will be surveyed over a distance of approximately 10 times the bankfull channel width and will include the channel thalweg and water surface elevation at each survey point. The survey will be conducted using a total station and prism or an engineer's level and rod. During the survey, the channel geomorphic/habitat feature (i.e., pool, riffle, run) at each point will be recorded.

Finally, additional survey points will be collected within the pool habitat at each study site to provide sufficient data for generating topographic contour maps of each pool. These data will be used to evaluate fine sediment scour/deposition following flow events.

### 3.2.2 Pebble Counts

Sediment characteristics at each study site will be analyzed by conducting a pebble count of the bed surface particle size. The pebble count will follow the modified Wolman (1954) pebble count method. Particles will be randomly selected across the bankfull channel using the “first blind touch” method. Each particle will be measured on the intermediate axis (b-axis) using a ruler. Particle sizes greater than 256 mm will be classified as a boulder and all clay, silt, and sand-sized particles will be classified as “less than 2mm”. The pebble count data will be used to prepare cumulative particle size distribution curves, and the final classification of dominant particle size (i.e., sand, gravel, cobble, or boulder) for each study site will be determined by calculating the most frequent particle size class present (as represented in the frequency histograms). The pebble count data will be collected at the same time as the cross-section and longitudinal profile surveys under low flow conditions when the channel can be safely accessed and traversed.

#### 3.2.3 Gravel Inventory, Bulk Sampling, and Gravel Transport

The amount and quality of available spawning gravel will be characterized by conducting a spawning gravel inventory, inter-gravel sand deposition inventory, and collecting bulk samples of the spawning gravels. In addition, gravel transport will be evaluated using tracer gravels and scour chains. Finally, if feasible, infiltration bags will be installed in riffle habitat to evaluate sand infiltration dynamics at locations where tracer gravel studies are being conducted. These activities will be conducted during low flow conditions when the channel can be safely accessed and traversed.

The spawning gravel inventory will be conducted along a 0.5-mile representative section within each of the three stream reaches specified in the 2004 Exhibit E relicensing documentation. These reaches consist of the D3-type reach situated between RMs 0.0 and 1.7, the C4/C6-type reach situated between RMs 1.7 and 3.0, and the Bc3-type reach situated between RMs 3.0 and 6.0. The inventory will consist of estimating the surface area of spawning gravel within the bankfull channel width along each survey section. For this survey, spawning gravel will follow Reiser and Bjorn (1979) which specifies gravel sizes used by spawning trout ranging from 6 to 52 mm. A fiberglass tape will be used to measure the average dimensions of each gravel deposit, where possible. In areas of the channel that are not accessible or wadable, the surface area of the gravel deposit will be visually estimated. In addition to the surface area, surficial sand deposits in riffles along the gravel inventory reach will be mapped using a total station or differential GPS and other relevant parameters will be recorded such as the habitat type, embeddedness, and whether the deposit was wet or dry at the time of the survey.

Two bulk samples of spawning gravels will be collected within each spawning gravel survey section included in the spawning gravel inventory. The samples will be used to characterize the quality of spawning gravel and will be collected from the surface layer (2 times the $D_{84}$). During sample collection, visual observations of gradation changes with depth will be documented. The sample site locations will be identified during the spawning gravel inventory to include pool tail-outs, low gradient riffles, and/or pocket gravels. The samples will be used to provide a quantitative measure of particle size composition including the portion that is comprised of fine sediments. The particle size composition will be compared to information provided in professional fisheries literature for gravel diameters and proportional amount of fines in order to estimate the relative capacity of the sampled spawning gravels to support reproductive success.

Finally, at least one location within each spawning gravel survey section will be selected to evaluate gravel transport using tracer gravels and scour chains. At each location, a minimum of 50-gravel size particles will be collected, measured, painted, and placed back into the channel in their original locations. In addition, a scour chain will be installed at each location to evaluate scour depth and subsequent deposition associated with flow events. If it is not feasible to install scour chains due to site conditions (i.e., substrate composition and degree of bed armoring), gravel will be painted in-situ using kevlar-enhanced epoxy coating. The gravel will be painted along taglines and different colored epoxy will be used for each transect. Finally, depending on the availability of the required materials and the site conditions (i.e., substrate composition and degree of bed armoring), infiltration bags may be used to evaluate sand infiltration dynamics (Lisle 1991). If feasible, an unbounded, cylindrical hole will be excavated below the armor layer and a collapsed infiltration bag will be placed at the bottom of the hole.

The hole will then be backfilled with clean gravel (i.e., containing no fine material) and the armor layer will be replaced.

Following the conservation releases and flow events, the study locations will be revisited to determine if the tracer gravels were mobilized and evaluate scour depth and deposition. At each study location, the tracer gravels will be measured and placed back into the channel. If particles were mobilized, then a survey will be conducted to locate the mobilized particles to determine the particle size and the distance that it was transported. Potential scour and deposition will be evaluated by measuring the length of scour chain lying horizontal to the streambed and the depth of sediment overlying the inflection point of the chain on the streambed. If infiltration bags are used, then the bags will be removed following selected flow events and the fine sediment content within the gravel backfill material will be measured to determine the volume and size of fine material that has accumulated in the hole.

### 3.2.4 Hydraulic and Sediment Transport Data

During the conservation releases, hydraulic and sediment transport data will be collected at each study site to assist in the development of a hydraulic model and characterization of sediment transport conditions. The hydraulic data will consist of water surface elevations relative to the datum established at each study site. If conditions allow, velocity measurements will be collected across the wetted channel at each riffle cross-section location using a Marsh-McBirney or similar-type flow meter. A crest-stage gage and/or a staff gage will be installed at each study site location and will be used to collect stage-discharge data during flow events.

Sediment transport data will also be collected during flow events. Suspended sediment and bedload transport data will be collected across the wetted channel at accessible riffle cross-section locations using a DH-48 handheld sampler and Helley-Smith bedload sampler, respectively. In addition, if feasible, two to four Bunte-type traps will be installed at the downstream end of riffle habitat at each study site to collect bedload transport data. Since existing knowledge regarding sediment transport in lower Piru Creek is limited, there is a concern regarding potential clogging and/or burial or stranding of the Bunte-type traps during flow events which would limit the utility of the data collected by this method. Accordingly, the feasibility and effectiveness of using these traps will be evaluated at the time of implementation based on site conditions.

If possible, the hydraulic and sediment transport data will be collected over a range in flows to assist in establishing a stage-discharge relationship and characterizing the sediment transport regime under different flow conditions.

## 3.3 HYDRAULIC MODEL

The field data will be used to develop a hydraulic model for each study site to assist in characterizing hydraulic conditions over a range of flows. The modeling will be performed using HEC-RAS (version 4.0) which was developed by the U.S. Army Corps of Engineers. The HEC-RAS model calculates water surface profiles for steady, gradually varied flow. The computational procedure is based on a one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation), and contraction-expansion of the channel geometry. The energy gradient and water surface profiles are calculated as a step-backwater by the model. The model requires inputs for channel geometry, a roughness coefficient to account for flow resistance, and a gradient.

The channel geometry and slope data used in the HEC-RAS modeling will be derived from the cross-sections and longitudinal profile surveys conducted as part of the quantitative field studies. At study sites with multiple cross-sections, the cross-sections will be tied to a common elevation datum and the distance between each cross-section will be measured. The longitudinal profile surveys conducted at each study site will be used to obtain water surface and streambed slope. The stage-discharge data collected during flow events will be used to calibrate the models by adjusting the Manning's n-values at each study site so that the modeled water surface profiles match the measured water surface elevations as closely as possible.

## 3.4 DATA ANALYSIS

The empirical data collected during the quantitative field studies will be evaluated to characterize the potential impacts associated with fine sediment deposition and the amount and quality of spawning gravel in lower Piru Creek. The hydraulic models for each study site will be used to characterize sediment transport conditions including the flows required to mobilize the streambed and flush sand from gravels and assist in determining the magnitude for overbank flows required to re-work the channel morphology and support riparian vegetation.

The current understanding of the sediment transport regime in lower Piru Creek is that fine sediment is delivered to the channel during the wet season when flows in lower Piru Creek are not sufficient to transport the material through the system. Accordingly, the fine sediment accumulates and impairs aquatic habitat until it is flushed through the system by spill events or to a lesser degree during annual water releases. The cross-section surveys, bulk sample data, scour chain measurements, pebble counts, mapping of sand deposits, suspended/bedload transport data will be used to evaluate and refine the current characterization of the sediment transport regime. The cross-section survey data for the three monitoring events at each study site will be used to evaluate and quantify changes in channel geometry that could result from the deposition and scour of fine sediment. The scour chain data will also be used to evaluate changes in the streambed elevation due to degradation and/or aggradation. Scour depth will be evaluated by measuring the length of scour chain lying horizontal to the streambed during each of the three monitoring events and comparing it to the length exposed during the previous event and deposition will be evaluated by measuring the depth of sediment overlying the inflection point of the chain on the streambed and comparing it to the previous event. The pebble count and bulk sample data will be used to determine potential changes in substrate composition and embeddeness following the conservation releases and the wet season. Finally, the sediment transport data will be used to characterize the volume and particle sizes that are transported at different flows.

According to *Section 3.1 Report on Aquatic Resources* of the FERC Exhibit E relicensing documentation, spawning gravel is sparse in lower Piru Creek and, where present, the quality of spawnable gravel is impaired due to fine sediment deposition. The spawning gravel inventory data will be used to characterize the amount of available spawning gravel within the representative survey reaches and determine whether annual conservation releases and flows during the wet season affect the amount of available spawning gravel. In addition, the tracer gravel data will be used to determine whether the conservation release flows are sufficient to mobilize and transport spawning gravels. The bulk sample data will be used to characterize the quality of spawning gravel by comparing the gravel diameters and proportional amount of fines and determine whether the quality changes following the conservation releases and the wet season.

The empirical data collected during the field studies and the hydraulic models for each study site will be used to characterize sediment transport for sand and gravel with the objective of determining the duration and magnitude of flows required to mobilize the streambed every 1-2 years and flush sand from the gravel framework. In addition, the data will be used to determine the magnitude for overbank flows required to re-work the channel morphology and support riparian vegetation.

### 3.5 REPORTING

Following completion of the field studies and data analysis activities, United and its consultant will prepare a report that provides the study methods and findings including recommendations for flushing and overbank flows. If warranted, the report will also provide recommendations for future actions such as monitoring or additional studies. The report will include figures presenting the study area and locations, tables summarizing the collected data, cross-section and long profiles, sediment transport and hydraulic model results, applicable photographs, and field notes.

SECTION 4.0

# Proposed Implementation Schedule

United will implement the study plan following receipt of written approval from NMFS. The following is a proposed, general implementation schedule. The specific implementation schedule will be developed in coordination with NMFS and, if desired, will coincide with other activities (e.g., specific flow release events and monitoring associated with flows).

| Study Component | Activities | Implementation Period |
|---|---|---|
| Field Reconnaissance Survey | Characterize current conditions and select representative study sites | Year 1: Summer/Fall - Prior to Flow Releases |
| Pre-Flow Release/Event Surveys | At selected representative study sites, conduct cross-section and longitudinal profile surveys and pebble counts and install crest-stage/staff gages. In addition, conduct spawning gravel inventory, collect bulk gravel samples, setup tracer gravel study, and, if feasible, install scour chain and infiltration bags. | Year 1: Summer/Fall - Prior to Flow Releases and/or Wet-Season Flow Events |
| Flow Event Data Collection | Collect stage/discharge data and suspended sediment/bedload transport data. After flows from a monitored runoff event decrease, then revisit tracer gravel study sites to determine if gravels have been transported and, if so, the distance transported and measure scour/deposition using the scour chains. | Years 1-2: Fall/Winter - During Flow Releases and/or Wet-Season Flow Events |
| Post-Flow Release/Event Surveys | At selected representative study sites, conduct cross-section and longitudinal profile surveys to evaluate potential changes in substrate and channel geometry due to scour or deposition and pebble counts to determine potential changes in channel substrate. In addition, revisit tracer gravel study sites to determine if gravels have been transported and, if so, the distance transported, measure scour/deposition using the scour chains, and remove sand infiltration bags. | Year 2: Spring/Summer - Following Flow Releases and/or Wet-Season Flow Events |
| Data Analysis | Reduce and analyze collected data and prepare hydraulic model | Year 2: Summer/Fall |
| Report Submittal | | Years 2-3: Fall/Winter |

SECTION 5.0

# References


Harrelson, C., C.L. Rawlins, and J.C. Potyondy. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. General Technical Report RM-245.

Lisle, T.E. and R.E. Eads. 1991. Methods to Measure Sedimentation of Spawning Gravels. USDA Forest Service, Pacific Southwest Research Station.

Reiser, D.W. and T.C. Bjornn. 1979. Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Northwest America. USDA Forest Service, Pacific Northwest.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

U.S. Geological Service (USGS). 2004. Gage Data for Piru Creek (Station # 11110000, 11109800,11109600,11109550,and11109525).Website:http://waterdata.usgs.gov/nwis/

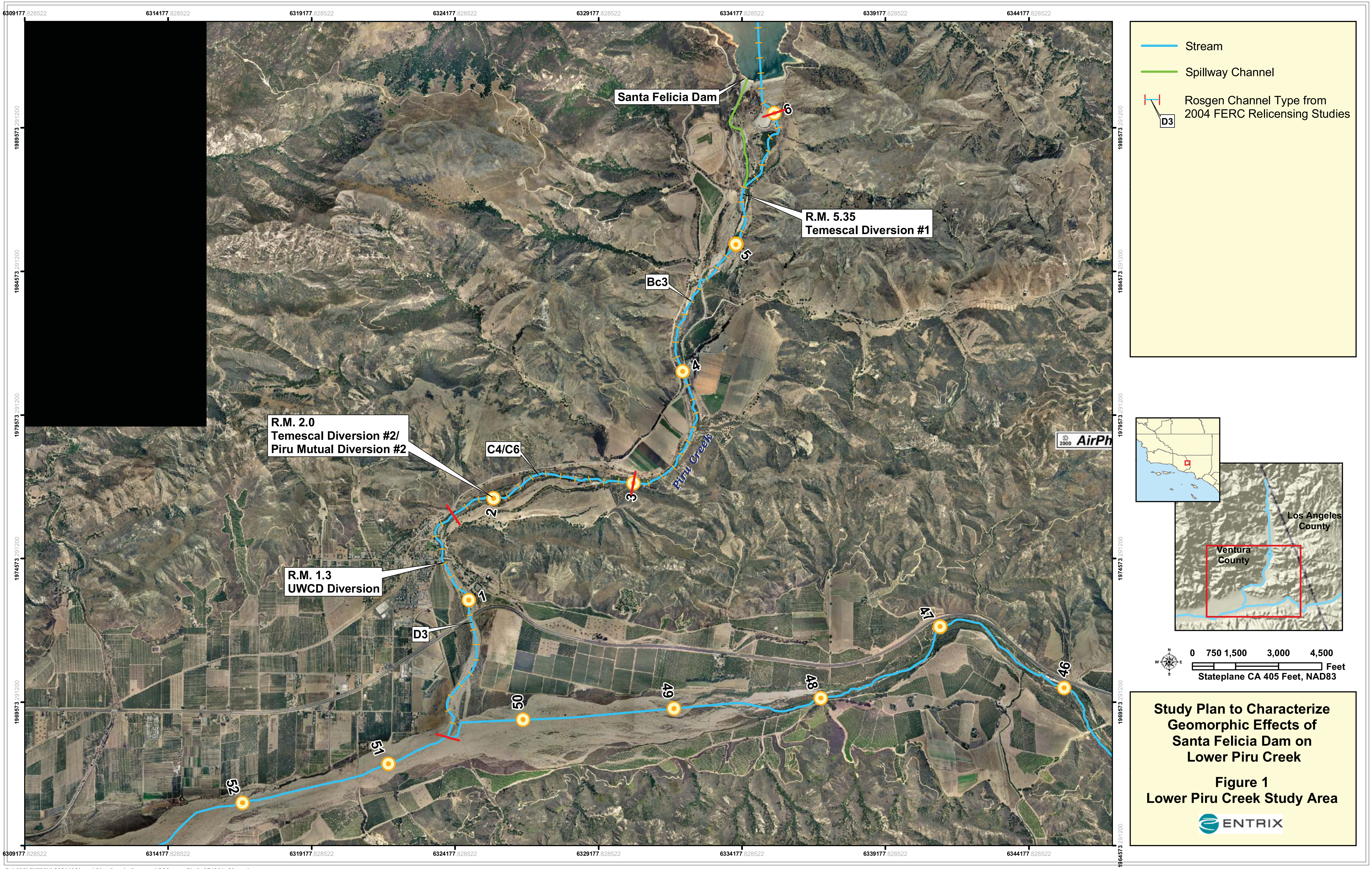
U.S. Geological Survey (USGS). 1968. Sedimentation in the Piru Creek Watershed, Southern California. Water Supply Paper 1798-E. 48 p.

United Water Conservation District. 2000. First State Consultation Document for the Relicense of the Santa Felicia Hydroelectric Project.

Wolman, MG, and JP Miller. 1960. Magnitude and Frequency of Forces in Geomorphic Processes. Journal of Geology 68(1):54-74.

Wolman, M.G.. 1954. A Method of Sampling Coarse River-Bed Material. Trans. Am. Geophys. Union, v. 35, p. 951-956.

# Figures




**Study Plan to Characterize Geomorphic Effects of Santa Felicia Dam on Lower Piru Creek**

**Figure 1**
**Lower Piru Creek Study Area**

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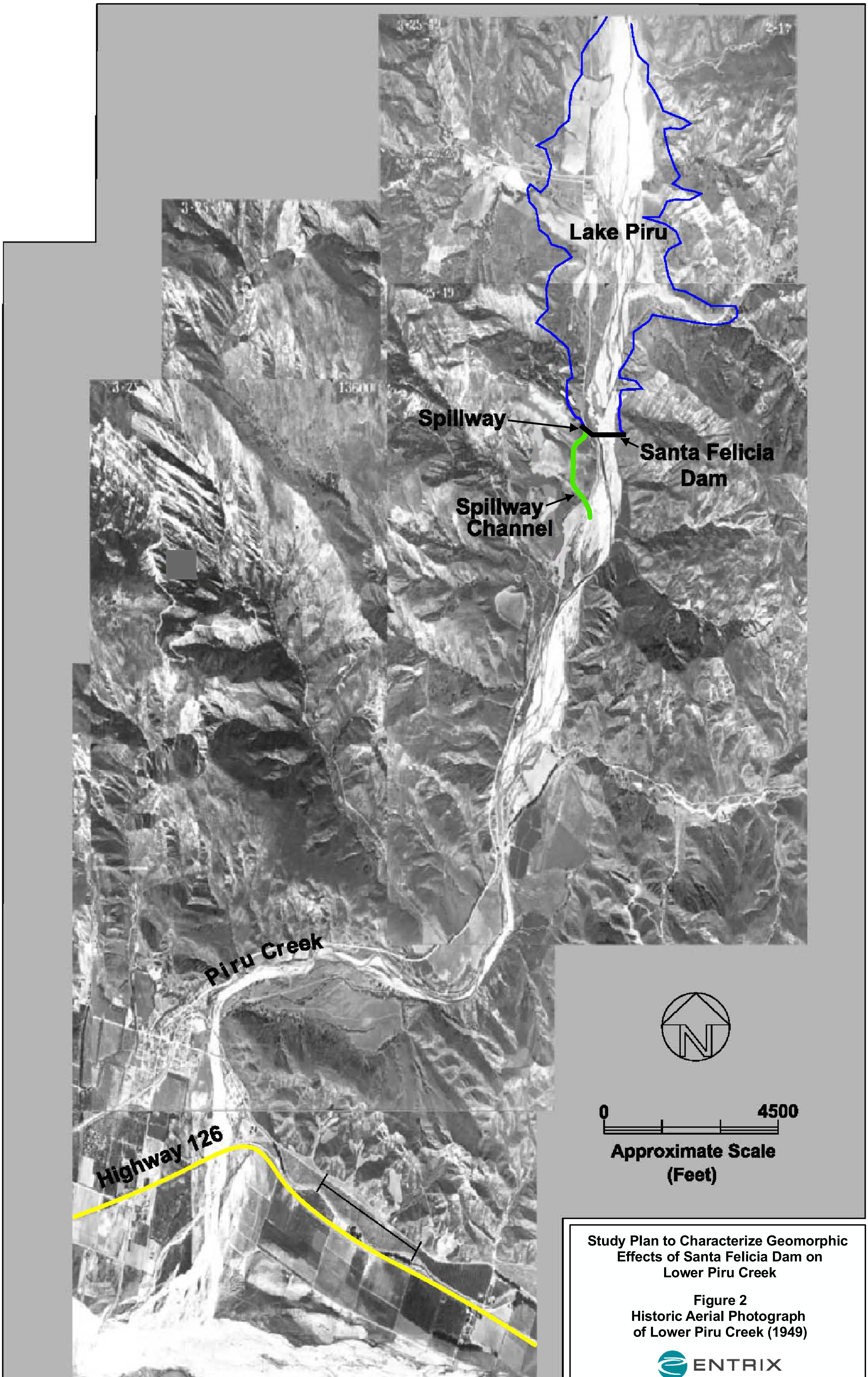


Study Plan to Characterize Geomorphic Effects of Santa Felicia Dam on Lower Piru Creek

Figure 2
Historic Aerial Photograph of Lower Piru Creek (1949)

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