State of California
Natural Resources Agency
California Department of Fish and Wildlife

STUDY PLAN
Passage Assessment for Adult and Juvenile Chinook Salmon and Steelhead Trout in MILL CREEK, Tehama County

STUDY PLAN

June 2014

Preface

This study plan outlines the approach and methods that will be used by the California Department of Fish and Wildlife (CDFW) to conduct an adult and juvenile salmonid passage study on lower Mill Creek, Tehama County, from the Sacramento River confluence to the Upper Diversion Dam. Salmonid passage at natural barriers in the study reach will be analyzed by CDFW and a temperature model will be developed for the study reach under contract with the U.S. Fish and Wildlife Service (USFWS). This study, in conjunction with other relevant information, will be used to develop an instream flow recommendation that ensures adult and juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) passage through lower Mill Creek into the upper watershed.

The primary objective of this study is to identify flow levels needed for long-term protection and maintenance of adult and juvenile salmonid passage through lower Mill Creek. Two instream flow studies, Alley (1996) and Harvey-Arrison (2009), were conducted on Mill Creek in 1995 and 2008 respectively. Alley (1996) recommended flows ranging between 74 cubic feet per second and 157 cubic feet per second without annual channel modifications; Harvey-Arrison (2009) determined that water temperature rather than riffle depth limited the seasonal duration of adult migration in Mill Creek. While both the Alley (1996) and the Harvey-Arrison (2009) studies provide useful information, a need to refine the flow recommendation for salmonid migration based on current geomorphic conditions, without assumption or recommendation of annual channel modification, and considering temperature impacts was determined by CDFW.

This study will evaluate natural passage barriers from the Sacramento River confluence to the Upper Diversion Dam and conduct Critical Riffle Analysis on the most critical riffles identified as potential impediments to salmonid passage. Other approaches for assessing fish passage will be conducted if suitable methodologies, information, or data becomes available. Additionally, stream temperatures will be monitored and modeled, in collaboration with USFWS. Temperature and riffle passage study results will be combined to identify flow regimes necessary for passage of adult and juvenile Chinook salmon and steelhead trout through lower Mill Creek. CDFW will transmit the resulting instream flow regime as a flow recommendation, in accordance with the Public Resources Code (PRC) sections §10000- 10005, to the State Water Resources Control Board for consideration as set forth in 1257.5 of the Water Code.

For more information or questions about this study plan please contact:

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Contents

1.0 Project Overview

1.1 Background

The California Department of Fish and Wildlife (CDFW) identified Mill Creek as a high priority stream for instream flow assessment. Mill Creek, Tehama County, is one of three Sacramento River tributaries that support a self-sustaining, genetically distinct wild population of spring-run Chinook salmon (SRCS) (*Oncorhynchus tshawytscha*) (CDFG 1998; Johnson and Merrick 2012). The Central Valley Spring-run Chinook Salmon Evolutionarily Significant Unit (ESU) is state and federally listed as threatened, and Mill Creek has been identified as one of the essential streams for recovery and perpetuation of the wild stocks (Armentrout et al. 1998). Mill Creek also supports federally listed Central Valley steelhead trout (*O. mykiss*), and fall-run Chinook salmon (FRCS), a State Species of Special Concern.

Upper Mill Creek provides ideal cold water holding pools and spawning habitat for SRCS and steelhead trout. However, insufficient instream flows and elevated stream temperatures from March through July have limited the ability of adult SRCS to migrate through lower Mill Creek into the upper watershed (Armentrout et al. 1998; DWR 2005; McEwan and Jackson 1996; Reynolds et al. 1993). Additionally, adequate flows for passage of adult FRCS above Ward Diversion Dam between October and December do not always occur nor do flows from October through June necessary for juvenile Chinook salmon and steelhead trout out-migration (Johnson and Merrick 2012; USFWS, 2000).

1.2 Mill Creek Watershed

The Mill Creek watershed is approximately 134 mi^2 (216 km^2); it originates on the slopes of Lassen Peak and flows approximately 60 mi (97 km) west until it combines with the Sacramento River near the town of Los Molinos, Tehama County (Figure 1). Elevations in the watershed range from 8,000 ft (2,438 m) in Lassen Volcanic National Park to 200 ft (61 km) at the Sacramento River confluence. Annual average precipitation in the upper watershed is 60 in (125 cm) decreasing to 20 in (51 cm) in the lower watershed. Most of the flow in Mill Creek is dominated by glaciated snow melt from Mount Lassen, sometimes giving it a milky appearance in spring and summer (SRWP 2010).

Mill Creek SRCS spawning activity generally occurs between an elevation of 1,500 ft. (457.2 m) and 5,000 ft (1,524 m); this makes Mill Creek's spawning habitat among the highest in North America (USBR 2002; Yoshiyama et al. 2001). Some Mill Creek SRCS have been documented spawning at even greater elevation, near the boundary of Lassen Volcanic National Park (Killam and Johnson 2013; Reynolds et al. 1993; Yoshiyama et al. 2001). However, recent years have seen few to no SRCS at these highest habitats (Johnson personal communication).

Adult SRCS migration into upper Mill Creek generally occurs from late February through mid-July. Once SRCS enter the 20 mi (32 km) reach between the Lassen Volcanic National Park boundary and the Little Mill Creek confluence, they hold in deep pools throughout the summer and spawn between mid-August and early-October (CDFG 1998; Moyle 2002).

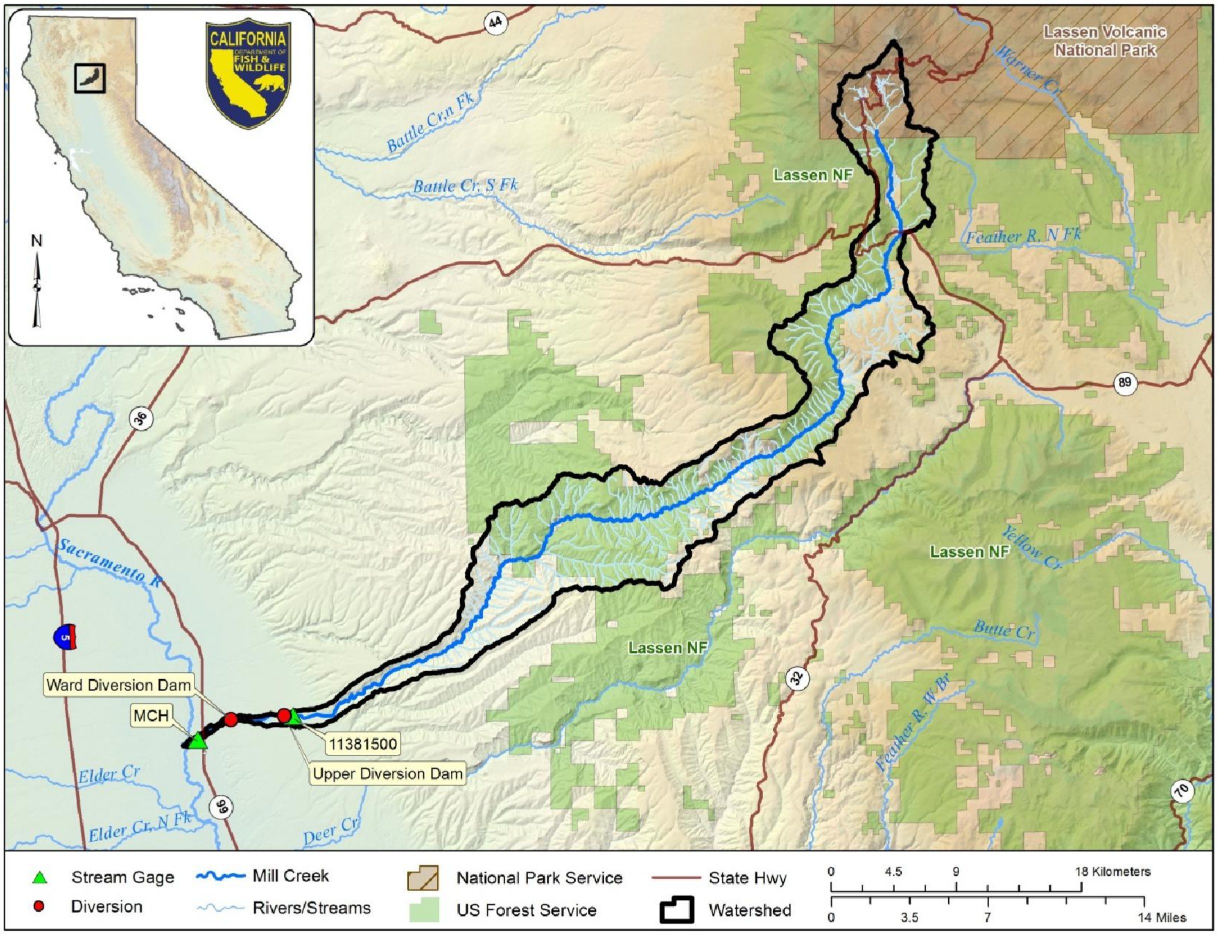

Figure 1. Mill Creek watershed.

There are two major water diversion dams on Mill Creek; Upper Diversion Dam and Ward Diversion Dam. Additionally, there are two siphons which do not divert water directly from Mill Creek but potentially inhibit fish passage. There are two stream gages on Mill Creek; the first, Mill Creek below HWY 99 (MCH) operated by CA Department of Water Resources is located below both major diversions while the second, USGS gage number 11381500 is located above all diversions (Figure 1).

1.3 Literature Review

Two instream flow studies and a fluvial geomorphic study have been conducted in the lower 5.25 river miles (8.5 km) of Mill Creek. Alley (1996) conducted a passage study in 1995 using Instream Flow Incremental Methodology (IFIM), Physical Habitat Simulation (PHABSIM). Alley (1996) collected data along two PHABSIM transects at three critical riffles identified and used a minimum depth criteria based on adult Chinook salmon body depth with the Thompson method depth criterion (Thompson 1972).

Alley (1996) recommended flows assuming annual riffle modification as well as flows for 1995 riffle conditions observed. Without annual riffle modification, Alley (1996) recommended a minimum flow of 157 cubic feet per second (cfs) in normal and wet years, 111 cfs in below normal years, and a flow of 74 cfs in critically dry years for passage of adult Chinook salmon. A flow of 27 cfs was recommended to maintain juvenile passage conditions. With annual channel maintenance, consisting of widening the critical riffles to a minimum of 5 ft (1.5 m) and dredging the critical riffles 0.6 ft (0.18 m) deeper than their current deepest point, Alley (1996) recommended a minimum flow for adult Chinook passage of 57 cfs for normal and wet water year types and 34 cfs for below normal, dry, and critically dry water year types. Alley (1996) also recommends that if the most critical riffles were modified annually, a flow of 20 cfs would be sufficient for out-migrating juveniles.

Harvey-Arrison (2009) conducted a four year passage study in 2008 to refine minimum flow requirements for adult Chinook salmon passage in dry years. Harvey-Arrison (2009) determined necessary habitat parameters for unimpaired passage of salmonids through observations of fish during pulse flow events and fish counts during migration periods. By using direct fish observation data and physical habitat data, Harvey-Arrison (2009) modified the riffle width excavation criteria of Alley (1996) from 5 ft (1.5 m) to 12 ft (3.7 m), the riffle depth criteria from 0.6 ft (0.18 m) deeper than their current deepest point to 0.56 ft (0.17 m) deeper, and defined an average velocity of 2.2 ft/sec (0.67 m/sec). By using acoustic and video monitoring data from concurrent SRCS escapement studies (Johnson et al. 2006; Killam et al. 2008; and Johnson et al. 2009) and real time hourly water temperature data from the MCH gage, Harvey-Arrison (2009) found that 99% of SRCS migration into Mill Creek occurred before instantaneous water temperature reached 67 °F (19.4 °C).

Kondolf (2001) conducted a fluvial geomorphology study in lower Mill Creek from the Sacramento River confluence up to what was the Clough Diversion Dam, located just downstream of the Upper Diversion Dam. During the floods of January 1997, Clough Diversion Dam failed causing a third of the dam to blow out and a large amount of sediment to be transported downstream. The remains of Clough Diversion Dam were fully removed in 2002 and replaced by a siphon. Kondolf (2001) focused his study from the sediment wedge left behind the old Clough Diversion Dam downstream to the Sacramento River confluence (4.75 RM). Kondolf (2001) describes the lower Mill Creek active alluvial channel as incised into cemented gravels with high bluffs that control lateral channel migration and limiting habitat along the study reach. He found that levees on both sides of the lower 3,000 ft (914 m) of Mill Creek constrict potential channel change by preventing flood events from forming low flow channels with a wider meander belt.

Alley (1996), Harvey-Arrison (2009), and Kondolf (2001) are valuable references that provide vital information pertaining to instream flow requirements of salmonids in Mill Creek. However, the application of the Thompson method criteria to PHABSIM transect data by Alley (1996) along with the realization that temperature may be the limiting factor to salmonid migration through lower Mill Creek (Harvey-Arrison 2009) has made it necessary for an additional study to be completed. This study will apply the Thompson depth criteria to data collected using the Critical Riffle Analysis method, which establishes transects along the riffle's shallowest course from bank to bank. It will also generate a temperature model of lower Mill Creek using the Stream Network Temperature Model (SNTEMP) to determine the relationship between flow and temperature within the channel. Should other methods of passage assessment or data pertaining to passage and temperature become available during this study, they may also be incorporated into this study.

1.4 Problem Statement

Mill Creek has been identified as a priority stream by CDFW for developing flow recommendations for adult and juvenile salmonid passage. Mill Creek is among the essential streams for recovery and perpetuation of wild stocks of SRCS (Armentrout et al. 1998). Upper Mill Creek provides ideal cold water holding pools and spawning habitat for SRCS and steelhead trout. Passage through the lower valley section of Mill Creek is essential for SRCS and steelhead trout to access the over summer holding and spawning habitat in the upper watershed. Passage in the lower valley is also crucial for FRCS to reach their spawning habitat upstream of Ward Diversion Dam. Insufficient flow and elevated stream temperatures have been identified as major factors limiting adult and juvenile salmonid migration through lower Mill Creek (Armentrout et al. 1998; DWR 2005; McEwan and Jackson 1996; Reynolds et al. 1993).

Both Alley (1996) and Harvey-Arrison (2009) recommend annual riffle modification for fish passage. Annual riffle modification may not be the appropriate long term management solution due to cost, potential permit requirements, timing requirements, and equipment and crew requirements. Additionally, annual channel modification may not completely address passage issues in the watershed since temperature, as a component of flow, may be limiting passage. Kondolf (2001) advises mechanical modification of the active stream channel should be avoided whenever possible. Therefore, this study will determine what flow regimes are necessary to ensure salmonid passage between the upper Mill Creek watershed and the Sacramento River confluence, considering the effects of flow volume on stream temperature, and without ongoing channel modification.

1.5 General Approach

Critical Riffle Analysis (CRA) will be used to evaluate minimum depth and maximum velocity rates needed for adult and juvenile salmonid passage through lower Mill Creek. Stream temperatures will be evaluated using Stream Temperature Network (SNTEMP) Model which defines upper temperature thresholds potentially causing a thermal barrier to migrating adult salmonids (Armour 1991; see Appendix A: SNTEMP Model Study Plan). The passage information resulting from this study will be used in conjunction with other relevant data or information to develop a flow recommendation for lower Mill Creek, as appropriate.

The use of the CRA method requires that three to six stream flows are sampled at varying targeted flows on the receding limb of the hydrograph for depth, stage, discharge, and velocity (CDFW 2013a). Climatic conditions or unforeseen hydraulic operations in the creek upstream of the study sites could impact sampling and the study schedule.

1.6 Implications
This study will contribute to an instream flow recommendation for lower Mill Creek. This flow recommendation will be transmitted to the State Water Resources Control Board (State Water Board) in accordance with Public Resource Codes (PRC) §10000 - 10005.

2.0 Project Description

2.1 Goals and Objectives
The goal of this study is to determine what instream flows are necessary to maintain adequate stream temperatures, water depths, and velocities over natural passage impediments for adult and juvenile salmonids in lower Mill Creek.

The objective of this study is to identify the relationship between stream flow and passage of adult and juvenile Chinook salmon and steelhead trout in lower Mill Creek. This will be accomplished by:

1. Identifying the relationship between stream flow and critical riffle depth and velocity using the CRA (CDFW 2013a) method and other accepted methods if they become available.

2. Identifying the minimum stream flow rates necessary for adult and juvenile Chinook salmon and steelhead trout to pass through the most depth sensitive critical riffles in lower Mill Creek.

3. Determining what stream flows will result in water temperatures that are adequate for migration of adult and juvenile SRCS, FRCS, and steelhead trout (Armour 1991; see Appendix A: SNTEMP Model Study Plan).

4. Producing a final technical report describing results of the study.

5. Transmittal of an instream flow recommendation to the State Water Board in accordance with Public Resources Code sections §10000- 10005.

2.2 Project Organization
Table 1. Project personnel affiliations, roles, and contact information.

Name (Affiliation)	**Role**	**Email**
Donald Baldwin (Water Branch)	Project Coordinator	Donald.Baldwin@wildlife.ca.gov
Paige Uttley (Water Branch)	Senior Env. Scientist	Paige.Uttley@wildlife.ca.gov
Mark Gard (USFWS)	Contractor	mark_gard@fws.gov

Name (Affiliation)	Role	Email
Robert Holmes (Water Branch)	QA Officer	Robert.Holmes@wildlife.ca.gov

Table 2. Project staff responsibilities.

Responsibilities	Staff
Instream Flow Study Plan	CDFW
Study Design and Approach	CDFW
Field Data Collection	
Field Reconnaissance and Riffle Selection	CDFW
Mesohabitat Mapping and Transect Selection	CDFW and USFWS
Fish Passage Assessment Data Collection	CDFW and USFWS
Temperature Model Data Collection	CDFW and USFWS
Data Analysis	
Fish Passage Assessment	CDFW
Temperature Model Construction and Calibration	CDFW and USFWS
Quality Assurance/Quality Control	CDFW and USFWS
Data Management and Reporting	CDFW and USFWS
Report Review	CDFW

2.3 Project Timeline

Table 3. Anticipated project activities timeline.

ACTIVITY	DATE
Preliminary Field Reconnaissance	June 2012 – May 2013
Study Site Selection	March 2014
Stakeholder Outreach	February 2014 – November 2015
Mesohabitat Mapping	March 2014
Critical Riffle Data Collection	March 2014 – September 2014
Temperature Model Instrument Installation and Data Collection	March 2014 – July 2014
Critical Riffle Analysis Assessment	April 2014 – October 2014
Temperature Model Construction and Analysis	August 2014 – October 2014
Draft Instream Flow Study Report	November 2014 – January 2015
Draft Temperature Model Report	November 2014 – January 2015
Final Instream Flow Study Report	February 2015
Final Temperature Model Report	July 2015
Review	August 2015 – October 2015
Flow Recommendation	November 2015

Table 4. Equipment required for each activity and source.

ACTIVITY / EQUIPMENT	PROVIDED BY
Mesohabitat Mapping: Garmin GPS unit Laser range finder	 CDFW CDFW
Flow Measurements: Marsh McBirney Flow Meter Top setting wading rod Transect measuring tapes Auto level	 CDFW CDFW CDFW CDFW

ACTIVITY / EQUIPMENT	PROVIDED BY
Stadia rods	CDFW
Critical Riffle Assessment: Garmin GPS unit Stadia rod Transect measuring tapes Rebar	 CDFW CDFW CDFW CDFW
Temperature Model Survey: Solinst Pressure Transducer Solinst Barometric Pressure Transducer Water temperature dataloggers Datalogger housing units	 USFWS USFWS CDFW CDFW

2.4 Coordination and Review Strategy

Staff from CDFW Water Branch will coordinate with Region 1 on CRA site selection and data collection and with USFWS on temperature model site selection, data collection, monitoring equipment installation, and model construction. Equipment will be provided by both USFWS and CDFW.

Sites are accessible via public access points and private roads. Notification letters were sent out to landowners and stakeholders in early March, 2014. Permission to access sites from private roads will be obtained from landowners prior to study initiation. Additionally, CDFW will provide advanced notification to landowners who have permitted access through their property each time a site visit is scheduled. CDFW is committed to working with local landowners and stakeholders to ensure that all study activities are not a burden conducted in a coordinated way to limit any unnecessary impacts.

CDFW Water Branch staff will work with Region 1 staff to develop stakeholder outreach activities. CDFW Region 1 and Water Branch staff will attend stakeholder meetings to inform interested parties of the Mill Creek study. This study plan will also be posted on the CDFW Water Branch website for public viewing (http://www.dfg.ca.gov/water/instream_flow.html).

2.5 Compliance Considerations

No Permits are needed to complete the proposed instream flow study in lower Mill Creek.

3.0 Project Design and Methodology

3.1 Study Design

Preliminary discussions, surveys, and site visits determined that reduced stream flows and associated water depth at shallow riffles between the Ward Diversion Dam and the Sacramento River confluence potentially limit hydrologic connectivity and impede salmonid passage through lower Mill Creek. At initiation of this study, CRA was determined to be the most appropriate method for assessing passage in lower Mill Creek because it directly analyzes the relationship between stream flows, water depth, and water velocity at depth sensitive riffle locations. Should new information and/or passage assessment methodologies become available to CDFW during this study, they may also be considered as additional analysis. Critical riffles are shallow riffles that are especially sensitive to changes in stream flow and considered to be depth sensitive. The most critical riffles were identified during reconnaissance surveys conducted between June 2012 and May 2013 and were selected for evaluation following methods in the CDFW CRA Standard Operating Procedure (SOP) (CDFW 2013a).

CDFW staff has also identified stream temperature as a potential limiting factor to adult and juvenile salmonid migration through lower Mill Creek. This instream flow study will assess the potential impacts of temperature by developing a correlation between stream flow and temperature using the temperature model SNTEMP (Armour 1991). The temperature modeling and model data collection has been contracted to the USFWS who will get assistance from CDFW staff. For more detail on the temperature modeling, see Appendix A: SNTEMP Model Study Plan.

Critical riffle site parameters will be recorded over a minimum of three to six sampling events to capture the full range of discharges needed to identify passage flows. See Appendix B for blank data sheet. Parameters for each critical riffle include:

- Staff gage stage height
- Left Bank Wetted Edge (LBWE)
- Right Bank Wetted Edge (RBWE)
- Total length of the transect from head pin to tail pin
- Depth and velocity at regular intervals along the transect (the number of intervals is dependent on the width of the riffle and must be sufficient to capture changes in depth)

Riffle depth and velocity measurements will be taken along the shallowest course from bank to bank during a minimum of three to six target flow events. Flow Duration Analysis (CDFW 2013b) is used to characterize the natural range of flows and subsequent target flows for data collection (Table 5). These target flows are based on unimpaired flow conditions from October 1928 to January 2014 at the USGS gage (USGS 11381500 MILL C NR LOS MOLINOS CA), located upstream of the Upper Diversion Dam (Figure 1). The Department of Water Resources owns and operates an additional stream gage downstream of the Highway 99 Bridge (CDEC Station ID: MCH; Mill Creek below HWY 99). While the MCH gage has been recording real time flow data since 1997 and temperature data since 2005, it could not be used to characterize impaired flow conditions as the Flow Duration Analysis SOP (CDFW 2013b) requires a minimum of 30 years of data for reliable exceedence generation.

CRA sampling will occur between March and July 2014, capturing target flows on the receding limb of the hydrograph and coinciding with occurrence of adult SRCS migration and juvenile SRCS, FRCS, and steelhead trout emigration through lower Mill Creek.

Table 5. Unimpaired target flows to be sampled at lower Mill Creek critical riffle sites. Flow exceedence data from USGS 11381500 gage, October 1928 to January 2014.

Percent Exceedence (%)	Target Flow (cfs)
20	410
35	275
50	180
65	130
80	110

Transects will be established by inserting a head pin on the left bank and a tail pin on the right bank (looking upstream). A measuring tape (0.1 ft) will be attached to the head pin, following the shallowest course across the critical riffle; the other end of the measuring tape will be attached to the tail pin. The measuring tape will be secured to rebar along the shallowest contour. Photographs of transects will be taken looking upstream and from head pin to tail pin during each site visit. Depth and velocity measurements will be taken at predetermined evenly spaced intervals along the measuring tape from head pin to tail pin. Data will be entered on CRA data sheets (Appendix B). Table 6 represents the CRA adult and juvenile Chinook salmon and steelhead trout passage criteria for depth and velocity. At least 25% of the transect length should meet the depth and velocity criteria and at least 10% of that should be contiguous. At each sampling event a site specific discharge measurement will be taken above or below the critical riffle to quantify actual discharge at the study site during CRA (CDFW 2013c).

Table 6. CRA adult and juvenile Chinook salmon and steelhead trout passage depth and velocity criteria. (Source: CDFW 2013a; Thompson 1972)

Species (Lifestage)	Depth Criteria	Velocity
Chinook (adult)	0.9 ft (0.27 m)	8.0 ft/sec (2.44 m/sec)
Steelhead (adult)	0.7 ft (0.21 m)	8.0 ft/sec (2.44 m/sec)
Trout (adult, 1-2+ steelhead)	0.4 ft (0.12 m)	4.0 ft/sec (1.22 m/sec)
Salmonid (young of the year juvenile)	0.3 ft (0.09 m)	———

Sampling bias will be minimized by using standardized methodology from the CDFW SOP manuals and field crew members will be trained to collect field data. If hydrologic conditions do not allow CRA sampling to capture identified target flows, portions or all of this study may be postponed until sufficient stream flows are available.

3.2 Identification of Study Reaches and Sampling Sites

The study reach, defined as lower Mill Creek, extends 5.4 river miles (RM) (8.7 km) from the Upper Diversion Dam downstream to the Sacramento River confluence (RM 0.0). The study reach was selected for instream flow assessment because of its importance as a salmonid migration corridor to the upper watershed as well as its susceptibility to low flow and high temperatures during certain times of the year.

Reconnaissance surveys were performed between the Upper Diversion Dam and the Sacramento River confluence in the early summers of 2012 and 2013. Riffles were identified throughout the study reach, numbered, recorded by GPS, and photographed. The shallowest thalweg depth was measured at each riffle and used along with historical knowledge of natural passage impediment, to select CRA study sites.

Based on its shallow thalweg depth and historical obstruction to salmonid passage, CR2 was identified as the primary site for adult and juvenile salmonid migration impediment for this study. Two more critical passage sites upstream of CR2 and downstream of the Ward Diversion Dam, CR4 and CR6 were also selected for CRA (Figure 2). CR4 is a broad crested riffle that empties into a set of steep steps, which converge into a run downstream. CR4 was identified by Region 1 as the next most limiting location to adult salmonid passage. CR6, located upstream of CR4, was also selected as limiting location characteristic of other shallow riffles present in lower Mill Creek. Under higher flow conditions, CR6 would not represent a limit to migration, but under the low flow conditions experienced downstream of the Ward Diversion Dam, CR6 can be limiting to adult salmonid passage. CR6 was selected over other characteristically representative shallow riffles because of its close proximity to CR4, making data collection more efficient.

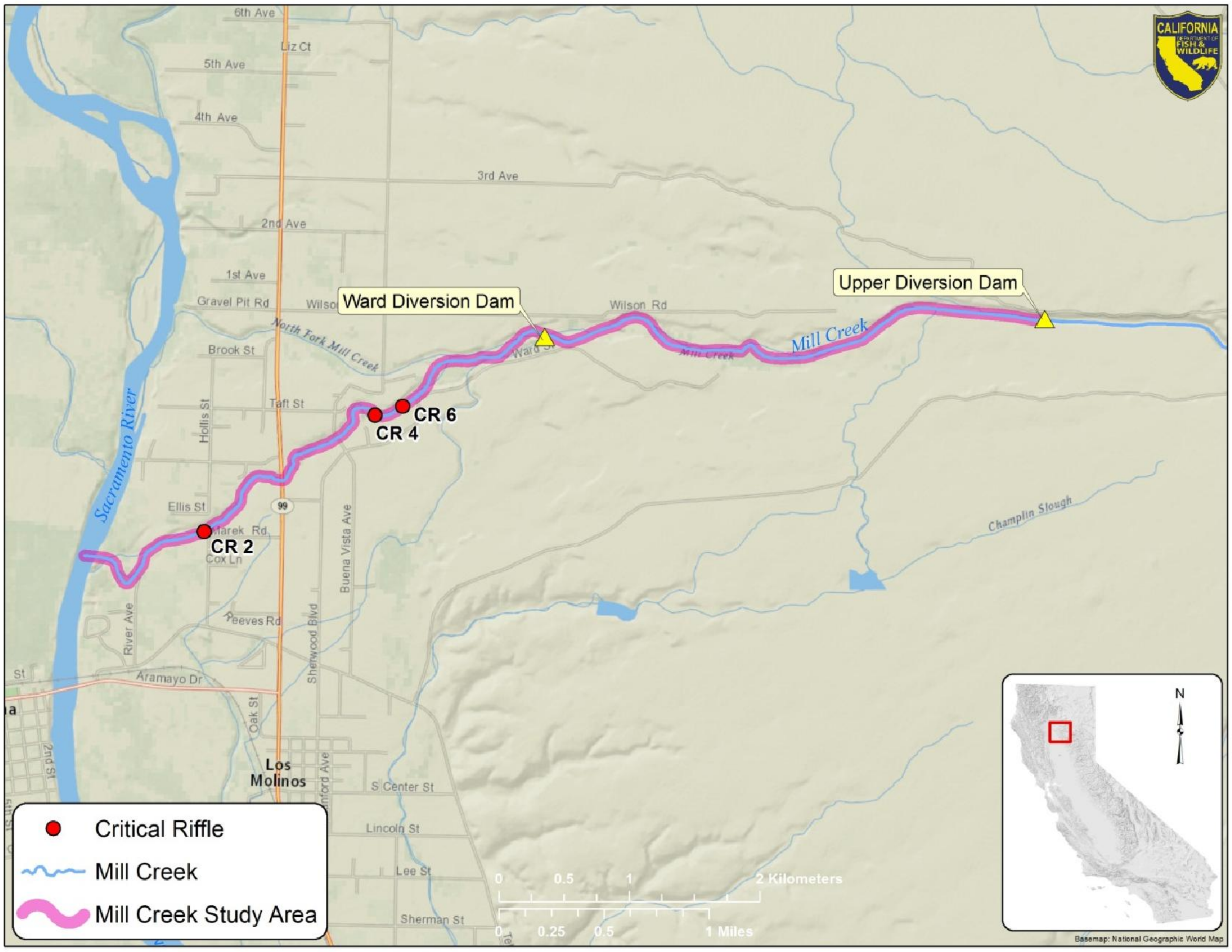

Figure 2. Instream flow study area on lower Mill Creek from the Sacramento River confluence to the Upper Diversion Dam.

In conjunction with USFWS, CDFW will conduct a temperature model study in lower Mill Creek from the Upper Diversion Dam downstream to the Sacramento River confluence using SNTEMP (Bartholow 1989). The model will be used to evaluate what stream flows may be necessary to maintain appropriate stream temperatures for adult salmonid migration in lower Mill Creek. The study area will be divided into three assessment reaches for temperature modeling based on changes in hydrology. The temperature model study reaches on lower Mill Creek are delineated in Figure 3 and described in Table 7. Pressure transducers and temperature loggers will be installed in each study reach to monitor continuous stream stage and temperature. See Appendix A: SNTEMP Model Study Plan for more details on the temperature modeling portion of the study.

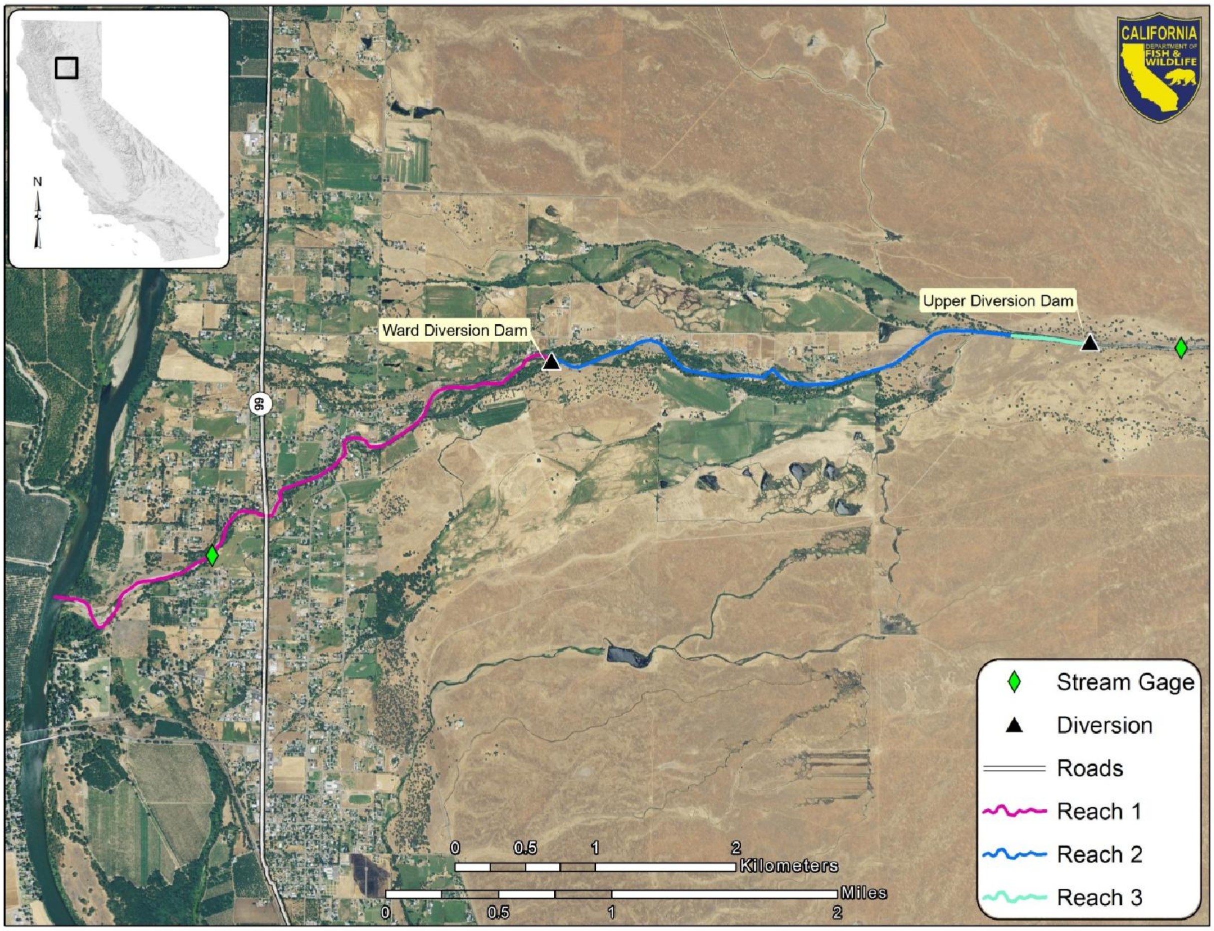

Figure 3. Temperature model study reaches 1 – 3 on lower Mill Creek.

Table 7. Lower Mill Creek temperature model study reaches from Sacramento River confluence upstream to Upper Diversion Dam.

Reach #	Begin	End
1	Sacramento River Confluence	Ward Diversion Dam
2	Ward Diversion Dam	Main canal fish screen return flow
3	Main canal fish screen return flow	Upper Diversion Dam

3.3 Biology

Anadromous fish in Mill Creek include SRCS, FRCS, late FRCS (*Oncorhynchus tshawytscha*), Central Valley steelhead trout (*O. mykis*), and pacific lamprey (*Entosphenus tridentatus*). Resident fish found in Mill Creek include rainbow trout (*O. mykiss*), brown trout (*Salmo trutta*), riffle sculpin (*Cottus gulosus*), hard head minnow (*Mylopharodon conocephalus*), Sacramento pike minnow (*Ptychocheilus grandis*), Sacramento sucker (*Catostomous occidentalis*), California roach (*Hesperoleucus symmetricus*), speckled dace (*Rhinichthys osculus*), tule perch (*Hysterocarpus traskii traskii*), smallmouth bass (*Micropterus dolomieu*), and green sunfish (*Lepomis cyanellus*) (USFWS 2000).

Mill Creek supports a self-sustaining, genetically distinct wild population of Central Valley SRCS (DWR 2005; NOAA 2009; Reynolds 1993). Migrating adult SRCS enter Mill Creek as sexually immature fish from late February through mid-July (Table 8), holding in deep pools of the upper watershed until spawning occurs between mid-August and early October (Moyle 2002). The Mill Creek SRCS average spawning population from 1960 to 2003 was 882 fish with a high population of 3,500 in 1975 and a low of 61 in 1993 (DWR 2005). The 2012 Mill Creek video station estimated 768 SRCS (Killam and Johnson 2013).

FRCS enter Mill Creek from early October through December to spawn in the valley section of lower Mill Creek. FRCS population estimates have dropped from 16,000 in 1950 to 150 spawners in 1965. The FRCS population estimates in Mill Creek for 2012 were 893 fish (Killam and Johnson 2013). There was an egg taking station on lower Mill Creek between 1902 and 1945 that shipped FRCS eggs to other areas. The egg taking station closed in 1945 when the Coleman National Fish Hatchery opened on Battle Creek (Reynolds 1993).

Steelhead trout spawn in the upper Mill Creek watershed, entering the creek from October through June with peak runs in February and November. Steelhead trout annual populations averaged 1,100 fish in both 1953 and 1965 population surveys; however, present numbers have since dropped dramatically only reaching the low hundreds (Reynolds 1993; USFWS 2000). From September 29, 2011 to July 2, 2012, 110 steelhead trout were counted at the Mill Creek video monitoring station (Killam and Johnson 2013).

Table 8. Salmonid lifestage periodicity table for lower Mill Creek. Gray is presence, black is peak presence. (Source: USFWS, 2000)

Species and Lifestage	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
SRCS												
Adult												
Juvenile												
FRCS												
Adult												
Juvenile												
Steelhead												
Adult												
Juvenile												

3.4 Hydrology

Mill Creek's hydrology is extremely variable as a result of the large influence both rainfall and snowmelt have on the timing and amount of runoff in the watershed. Average daily flows, monthly mean flows, and average annual peak flows are all variable with flows and variability lowest in September, increasing through October and November, and decreasing again in late spring and summer (Kondolf 2001). Analysis of the distribution of peak flows in Mill Creek by Kondolf (2001) concluded that there is a 90% chance that a flow event equal to 2,000 cfs or more will occur at least once a winter. Stream flows in Mill Creek usually peak during heavy winter rains in December and February and again as a result of spring snowmelt in April and May (USDA 1992; USFWS 2000).

Two diversion dams, Upper Diversion Dam and Ward Diversion Dam, are owned and operated by Los Molinos Mutual Water Company (LMMWC) on Mill Creek (Figure 2). When combined, the maximum diversion rates from these two diversion dams can exceed Mill Creek's natural flows, especially during summer and early fall (USFWS 2000). In 1997, the Clough Diversion Dam (RM 4.75) was damaged in a flood forcing it to be completely removed in 2002. Clough Diversion Dam was replaced with a siphon that captures water from the Main Canal through a pipe 10 ft (3 m) under Mill Creek and fills a canal on the south side of Mill Creek (USBR 2002). An additional siphon located downstream of the Ward Diversion Dam also crosses the creek; although it doesn't divert water directly from Mill Creek, it may pose a passage issue under low flow conditions.

3.5 Connectivity
Mill Creek dries up in the late summer most years downstream of the Highway 99 bridge, disconnecting the upper watershed from the Sacramento River. Only during extremely wet water years does Mill Creek maintain flow and connectivity from the Sacramento River confluence through the upper watershed.

3.6 Geomorphology
Mill Creek headwaters flow from the volcanic southern slopes of Lassen Peak into narrow, steep canyon gorge before entering Sacramento Valley and the Sacramento River (Kondolf 2001; USPR 2002). The upper reaches of Mill Creek flow through the volcanic strata of the Tuscan formation. Once Mill Creek emerges from the Lassen foothills it enters the cemented alluvial fan deposits of the Riverbank formation which comprise the Sacramento Valley. Finally, the lowest 4.5 mi (7.2 km) of Mill Creek is cemented gravels of the Red Bluff formation and older terrace gravels (Kondolf 2001). The lowest 3,000 ft (914.4 m) of Mill Creek stream channel is bound by levees on both sides, this has restricted high flow events from creating low flow meandering stream channels. The results are long, wide gravel bars with steep bar lobe fronts influencing stream channel hydraulics that are critical for fish passage at low flows (Kondolf 2001).

3.7 Water Quality
Mill Creek water quality is considered to be very good and the upper watershed remains cold year round. Most of the flow in Mill Creek is dominated by glaciated snow melt from Mount Lassen, sometimes giving it a milky appearance in spring and summer. In the late spring and summer, water temperatures in lower Mill Creek downstream of diversions can reach over 80°F (29.4°C), exceeding the estimated lethal limits for salmonids of 72°F (22.2°C).

4.0 Quality Assurance/Quality Control

4.1 Sampling Procedure (Standard Operating Procedures)

CRA data collection will be completed consistent with the applicable CDFW SOP (CDFW 2013a). Velocity and discharge measurements will be completed consistent with the applicable CDFW SOP (CDFW 2013c). For consistency, field crew members will be trained to collect field data.

Field crews will review the Mill Creek Health and Safety Plan prior to beginning fieldwork.

4.2 Quality Objective and Criteria

The calibration of equipment necessary to conduct flow measurements will follow the subsequent procedures to ensure sample accuracy. Field crew will calibrate Marsh-McBirney flow meters each day prior to use in the field as described in the Discharge Measurements SOP (CDFW 2013c).

Quality assurance and control (QA/QC) will be performed in the field and in the office by reviewing completed field data sheets for errors and missed data. Missing data or data in error will be reported to the Project Coordinator for evaluation.

4.3 Corrective Actions

Missing data or data in error will be reported to the Project Coordinator for evaluation. If new or replacement data is required, the Project Coordinator will coordinate with staff to schedule additional field data collection during the current hydrologic season. Copies of completed field data sheets will be stored separately from originals. Field data will be entered into electronic spreadsheets and prepared for analysis.

5.0 Data Management and Reporting

5.1 Data Validation

Data entry will be performed by USFWS and CDFW Water Branch staff. Water Branch will check CRA data. USFWS will download data from field instruments and check the temperature model data. All data generated by this project will be maintained in both field logbooks and electronic spreadsheet formats.

Instream flow studies can be impacted by changing conditions. High flow events can mobilize bed load, shifting stream beds and altering identified critical riffle sites. Additionally, annual hydrological conditions rarely follow historical averages. To assess potential variability at critical riffle sites, data will be collected at three representative riffles.

5.2 Data Storage and Reporting

Water Branch staff will assess the data for the CRA. USFWS staff will conduct the data reduction and analysis for the water temperature modeling.

USFWS staff will prepare the temperature model section of the report. Water Branch staff will incorporate the temperature study results into the Mill Creek instream flow final report and post to the CDFW website. CDFW will store the hard copies and electronic data.

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Appendix A. SNTEMP Model Study Plan

USFWS Study Plan for Mill Creek SNTEMP Model

Contents

Foreword

Mill Creek, Tehama County, is one of three Sacramento River tributaries that support a self-sustaining wild population of spring-run Chinook salmon (SRCS) *Oncorhynchus tshawytscha*. Although the population of SRCS is self-sustaining, there is a concern that increased stream temperatures in lower Mill Creek, especially during low water years, cause a thermal barrier that may limit adult SRCS migration opportunity (Harvey-Arrison 2009, DWR 2005, and SRWP 2010). Harvey-Arrison (2009) monitored stream temperature effects on migrating adult SRCS in lower Mill Creek from 2006 to 2008 and found that 99 percent of SRCS migration occurred when minimum daily stream temperatures measured at the MCH gauge were less than or equal to 67°F (19.4 °C). Additionally, Harvey-Arrison (2009) presumed that SRCS migration ended when minimum daily stream temperatures were greater than 66 °F (18.8 °C) for seven consecutive days. To assess the effects of stream flow on stream temperature and to better understand the impact of these temperatures on SRCS migration, the U. S. Fish and Wildlife Service (USFWS) in conjunction with California Department of Fish and Wildlife (CDFW) will conduct a temperature model study on lower Mill Creek using Stream Network Temperature Model (SNTEMP).

The temperature model will comprise lower Mill Creek from the Upper Diversion Dam (RM 5.39) downstream to the Sacramento River confluence (RM 0.00). This section of lower Mill Creek will be divided into two study reaches based on hydrology, gradient, water diversions and returns. The goal of the temperature model study on lower Mill Creek is to develop a relationship between stream temperature and streamflow. This study will determine what streamflows are needed to maintain acceptable stream temperatures for adult SRCS migration to occur from lower Mill Creek into upper Mill Creek as well as provide temperature information applicable to FRCS, steelhead trout, and salmonid juvenile emigration.

Stream temperature model results will be used in conjunction with Critical Riffle Analysis (CRA) results to develop a flow recommendation for salmonid passage through lower Mill Creek.

1.0 Project Overview

1.1 Overview

Stream temperature has been identified as a potential limiting factor to adult and juvenile salmonid migration in Sacramento River tributaries. To evaluate if temperature is causing a migration barrier, California Department of Fish and Wildlife (CDFW) is interested in developing a correlation between stream flow and temperature. U.S. Fish and Wildlife Service (USFWS) have been contracted by CDFW to develop a water temperature model, including the collection of data needed to develop and calibrate the model.

1.2 Problem Statement

Stream temperature influences fish migration, spawning, timing and success of incubation, maturation and growth, competition, and disease and parasite proliferation (Annear 2004). To better understand the influence of water temperature on salmonids, a temperature model will be used to determine the relationship between water temperatures and stream flow, while taking into account other physical processes, such as heat transport and flux, solar radiation and shade, and meteorological variables.

1.3 General Approach

The conceptual approach for the temperature study is to apply the Stream Network Temperature Model (SNTEMP) (Theurer et al. 1984) to a stream network. The SNTEMP model is a standard method for water temperature modeling used in instream flow studies (Annear et al. 2004). The SNTEMP model was designed to predict the average daily water temperature and diurnal fluctuations in water temperatures throughout a stream system network. The SNTEMP model includes four submodels: (1) heat transport model, (2) heat flux model, (3) solar model, and (4) shade model. Inputs required by the model include measured water temperatures, meteorological data, solar radiation, shading, flow data, and stream geometry data. The SNTEMP model requires that the stream network be divided into reaches, each of which needs to have a uniform flow, stream azimuth, and slope.

SNTEMP is a robust incremental modeling technique. The only uncertainties associated with its use in this project are whether a sufficient range of flows and water temperatures can be sampled and potential loss or malfunctions of temperature and pressure loggers. Since the SNTEMP model is a mechanistic-based model, reasonably accurate predictions can be made to extrapolate to conditions that are outside the range of measured values, reducing the first uncertainty.

2.0 Project Description

2.1 Goals and Objectives

The objective of the temperature study is to determine what streamflows will result in water temperatures that are adequate for upstream passage of adult salmonids during low flow periods. The use of an SNTEMP model will answer this question through its ability to assess the potential impacts of multiple stream flows on temperature, developing a relationship between water temperature and stream flow within the stream system.

The goal of the temperature study is to determine what streamflows will result in water temperatures that are adequate for upstream passage of adult salmonids.

2.2 Project Organization

Project Personnel:
Mark Gard, USFWS – project manager, field crew lead, modeler, QA Officer;
Rick Williams, USFWS – field crew lead;
CDFW staff – field crew members.

Roles and Responsibilities: Mark Gard will be responsible for overall project management and for leading one of two field crews. He will also conduct the water temperature modeling, ensuring QA procedures are followed, and prepare a final temperature results report. Rick Williams' role will be to lead the second field crew. CDFW staff's roles will be to assist in collecting field data under direction of the field crew lead(s).

2.3 Project Timeline

The tasks comprising this study are: field data collection, water temperature modeling, and preparation of a final technical report. Field data collection will take place from March through July 2014. Water temperature modeling will take place from August through October 2014. A draft final report will be provided to CDFW early 2015.

There should be sufficient funding within the existing contract to provide for all of the resource needs for this project.

The project portion timeline is as follows:

- March through July 2014-Field activities will include conducting habitat mapping, installing water temperature and pressure transducers, collecting bed elevation cross-sectional profiles and stage/discharge relationships, and collecting riparian vegetation shading data.
- August through October 2014- Office activities will include developing stream width/streamflow relationships, compiling input data files for the SNTEMP model, model calibration, and SNTEMP model simulations.
- November 2014 to January 2015- Office activities will consist of preparing a draft final report. It is anticipated that the final report will be completed July 2015.

The only travel will be associated with the field activities.

Equipment required for the temperature model includes:

Equipment	Have	Need to Order
Flow Measurement		
Auto level, stadia rods, tape, GPS unit, wading rod, velocity meter	x	
Temperature Measurement		
Water temperature dataloggers	x	
Pressure transducers and barometer		x
Clinometer	x	

2.4 Coordination and Review Strategy

To the extent possible, entities or stakeholders which might have an interest in the results and interpretation of temperature passage criteria will be involved in study scoping and implementation.

To promote coordination, this study plan will be distributed for review and comments among interested CDFW staff, other interested agencies such as NMFS, and other interested groups and scientists. The project coordinator will facilitate and coordinate this review and address comments when appropriate.

3.0 Project Design and Methodology

3.1 Study Design

The sampling design has three nested levels: 1) stream reach, 2) mesohabitat unit (riffle, run, pool or glide), and 3) transect.

1) Stream reach parameters include stream flow (from existing gages, pressure transducers, and flow measurements), water temperature (measured with water temperature data loggers), and the elevation and upstream distance at the end of each reach (to be obtained from GIS databases).
2) Mesohabitat mapping will be conducted to select transect locations and to weight transects based on the percentage of each mesohabitat type in each reach.
3) Transect data (bed elevation profiles and stage-discharge measurements) will be used to develop relationships between streamflow and stream geometry parameters (stream width and hydraulic retardence).

Bed elevation profiles and stage measurements will be made using differential leveling. Flow measurements will be made with a tape, wading rod and velocity meter. Meteorological parameters (air temperature, relative humidity, daily wind speed and cloud cover during daylight hours), apply to the entire stream network and will be obtained from internet sources.

Stage measurements, for developing rating tables at transect and pressure transducers, need to be made at least three flows ranging over an order of magnitude to have sufficiently accurate rating tables. The rating tables can then be used to predict flows based on pressure transducer measurements and to predict stream width/flow relationships over the range of flows simulated. Similarly, water temperature measurements need to be conducted for a range of conditions to enable the water temperature model to be adequate calibrated, so that water temperatures can be predicted under the desired range of stream flows and meterological conditions.

Additional fieldwork will be scheduled as needed to make up for missed field observations. Two water temperature loggers will be installed at each location in case one logger is lost or stolen. To eliminate sampling bias, Mark Guard lead will be present at each sampling event and will oversee data collection as needed. In addition, one set of methods will be consistently used.

3.2 Selection

Locations of pressure transducers within each stream reach will be determined based on accessibility but will generally be located at points along the creek where flow is expected to change (i.e., from a diversion or tributary confluence). Water temperature data loggers will be placed at the upstream end of the stream network and at the downstream end of each stream reach. Stream reaches will be established based on the locations of stream water diversions and returns, stream hydrology and gradient. The number of sample sites (transects) will be determined based on mesohabitat mapping and will be located within each stream reach.

Water temperatures and pressure will be measured continuously over the sampling season and recorded every 15 minutes to provide a complete flow and water temperature dataset for calibration of the SNTEMP model. Flow measurements will be made at least three times at each pressure transducer to develop a sufficiently accurate rating table to predict flows from the pressure transducer data. Habitat mapping, bed profiles, and shading data will be collected once, since these parameters do not vary temporally. Water surface elevations will be measured for each transect at least three times to enable stream width/flow relationships to be predicted over the range of flows simulated.

4.0 Quality Assurance/Quality Control

4.1 Sampling Procedure (Standard Operating Procedures)

Mesohabitat mapping will be conducted by walking from the Upper Diversion Dam downstream to the Sacramento River confluence and marking the downstream end of each mesohabitat unit with a GPS unit. Mesohabitat mapping will be based on the following mesohabitat definitions:

Habitat Type	Definition
Pool	Primary determinant is downstream control - thalweg gets deeper as go upstream from bottom of pool. Fine and uniform substrate, below average water velocity, above average depth, tranquil water surface. Depth is not used to determine whether a mesohabitat unit is a pool.
Glide	Primary determinants are no turbulence (surface smooth, slow and laminar) and no downstream control. Low gradient, substrate uniform across channel width and composed of small gravel and/or sand/silt, depth below average and similar across channel width, below average water velocities, generally associated with tails of pools or heads of riffles, width of channel tends to spread out, thalweg has relatively uniform slope going downstream.

Habitat Type	Definition
Run	Primary determinants are moderately turbulent and average depth. Moderate gradient, substrate a mix of particle sizes and composed of small cobble and gravel, with some large cobble and boulders, above average water velocities, usually slight gradient change from top to bottom, generally associated with downstream extent of riffles, thalweg has relatively uniform slope going downstream.
Riffle	Primary determinants are high gradient and turbulence. Below average depth, above average velocity, thalweg has relatively uniform slope going downstream, substrate of uniform size and composed of large gravel and/or cobble, change in gradient noticeable.

Water surface elevations will be measured to the nearest 0.01 foot (0.003 m) at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling). Streambed elevations will be surveyed to the nearest 0.1 foot (0.03 m) and to points above bankfull discharge. Water surface elevations (WSELs) will be measured along both banks and in the middle of each transect if conditions allow. Otherwise, the WSELs will be measured along both banks. If the WSELs measured for a transect are within 0.1 foot (0.03 m) of each other, the WSELs at each transect will be derived by averaging the two to three values. If the WSELs differ by greater than 0.1 foot (0.03 m), the WSEL for the transect will be selected based on which side of the transect was considered most representative of the flow conditions.

The highest simulated flow is equal to the mean unimpaired flow in the highest flow month. Water surface elevations will be collected at a minimum of three relatively evenly spaced calibration flows, spanning approximately an order of magnitude. The calibration flows will be selected so that the lowest simulated flow is no less than 0.4 of the lowest calibration flow and the highest simulated flow is at most 2.5 times the highest calibration flow.

4.2 Quality Objective and Criteria

The quality objectives to be applied to this study are for simulated WSELs to be within 0.1 foot (0.03 m) of measured WSELs, and for the mean error in predicted water temperatures to be less than 1 degree Fahrenheit.

Calibration of stage-discharge relationships will be conducted using a log-log regression. Calibration of the water temperature model will be conducted by adjusting ground level solar radiation and wind speed (Theurer et al. 1984).

The quality control procedures to be used to ensure the validity of bed and water surface elevation data will include cross-sectional plots and stage-discharge plots to identify anomalies in the data. The quality control procedures to be used to ensure the validity of water temperature and flow data will include intra and inter-reach comparisons. Mark Gard will conduct the data checks, which will be documented in electronic spreadsheet format.

4.3 Corrective Actions
If errors are encountered, Mark Gard will determine and implement corrective actions. These actions could include collecting additional data and/or eliminating erroneous data.

5.0 Data Management and Reporting

Field data will be collected by USFWS and staff from CDFW Water Branch with assistance from Region 1 and SWRCB staff if necessary. All data generated by this project will be maintained in both field log books or on field sheets and in electronic spreadsheet format. A final technical report will be prepared by USFWS, with assistance from CDFW.

5.1 Data Validation
The protocol and criteria to check raw bed and water surface elevation data will include cross-sectional plots and stage-discharge plots to identify anomalies in the data. The protocol and criteria to check raw water temperature and flow data will include intra and inter-reach comparisons. Mark Gard will do the data entry and checks, which will be documented in electronic spreadsheet format.

Limitations of the data may consist of whether a sufficient range of flows and water temperatures can be sampled and potential loss or malfunctions of temperature and pressure loggers.

5.2 Data Storage and Reporting
Mark Gard will conduct the data reduction and analysis for the water temperature modeling.

Mark Gard is responsible for preparing draft and final technical reports. The expected completion dates of the draft and final reports are, respectively, January and July 2015. CDFW staff will determine location of posting/publication.

Mark Gard is responsible for storing the data collected. At this time, there is no plan to upload the data to any servers, although this could be done upon request.

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Appendix B. Critical Riffle Analysis Field Data Sheet

Critical Riffle Analysis for Fish Passage in California

Standard Operating Procedure DFG-IFP-001

Stream Name:________________________ Page: ____________ of ____________

Reach:______________________________ Date: ____________________

Riffle Name:__________________________ Evaluator: ____________________

Riffle Description______________________ Recorder: ____________________

GPS Waypoint Range:_________________ Photo File Range: ____________________

HP to TP:________________

LBWE: ______________ RBWE: ______________ Time Start: ______________

Staff Gage Start: ______________ End: ______________ Time Stop: ______________

Notes: ____ Meter Number:___________

Station	Distance (ft)	Depth (ft)	Velocity (cfs)	Notes
1				
2				
3				
4				
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State of California
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