



STUDY PLAN

Passage Assessment for Adult and Juvenile Salmonids in LOWER DEER 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 a salmonid passage study on lower Deer Creek, Tehama County, from the canyon mouth to the confluence with the Sacramento River. Salmonid passage at natural barriers in the study reach will be analyzed by the CDFW Water Branch with assistance from CDFW Northern Region. Temperature modeling will be conducted under contract with the U.S. Fish and Wildlife Service (USFWS). This study will be used to develop an instream flow recommendation that supports upstream passage of adult spring-run and fall-run Chinook salmon (*Oncorhynchus tshawytscha*), and steelhead (*O. mykiss*) through lower Deer Creek into the upper watershed, and downstream passage of juveniles to the Sacramento River.

The primary objective of this study is to identify flow levels needed instream for long-term protection and maintenance of adult and juvenile salmonid passage. Flow regimes necessary to provide unimpeded migration for adult salmonids are not accurately known, yet have been estimated to be about 50 cfs for planning purposes (McManus 2004; USFWS 1995). This instream flow study will be used to quantify what flow requirements will allow for unimpeded migration over natural passage barriers in lower Deer Creek.

Preliminary surveys identified several critical riffles as potential passage impediments to upstream migration of adult and downstream migration of juvenile salmonids. Critical Riffle Analyses, along with other appropriate methodologies for conducting fish passage assessments, will be used to identify the range of flows required for passage of salmonids through the lower reach. Additionally, water temperature and stage will be monitored throughout lower Deer Creek, in collaboration with USFWS, and stream temperatures will be modeled to determine what range of flows maintain suitable temperatures during key life stages of salmonids. Passage and temperature results will be combined to identify flow regimes protective of adult and juvenile salmon and steelhead in Deer Creek during migration periods. CDFW will transmit the resulting instream flow recommendations in accordance with the Public Resources Code (PRC) sections §10000–10005 to the State Water Resources Control Board for consideration as set forth in Section 1257.5 of the Water Code.

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1.0 Project Overview

1.1 Background

Deer Creek, in Tehama County, has been identified by the California Department of Fish and Wildlife (CDFW) as a high priority stream for instream flow assessment. It is one of only three streams supporting a self-sustaining wild population of Central Valley spring-run Chinook salmon (*Oncorhynchus tshawytscha*) (SRCS) in the Sacramento River watershed (NMFS 2009). The Central Valley SRCS Evolutionarily Significant Unit (ESU) is listed as threatened under the State and Federal Endangered Species Acts. The Deer Creek watershed is considered a conservation stronghold for the SRCS ESU (NMFS 2009). Deer Creek also supports Central Valley steelhead trout (*O. mykiss*) listed as threatened under the Federal Endangered Species Act, and fall-run Chinook salmon (FRCS), listed as a State Species of Special Concern.

The upper Deer Creek watershed contains prime holding and spawning habitat for SRCS, making passage through the lower valley section of the stream essential. However, upstream migration through Deer Creek may be impeded by habitat conditions in the valley floor. Insufficient instream flows and elevated water temperatures, especially during adult SRCS migration, have been consistently identified as limiting factors to anadromous fish production (Armentrout et al. 1998; DWR 2005; McEwan and Jackson 1996; Reynolds et al. 1993). Inadequate flows for adult salmonids occur when velocities are too high and depths are too low for fish passage and/or water temperatures are too high potentially causing direct or delayed mortality, and creating a thermal barrier to passage (Cramer and Hammack 1952; Harvey-Arrison 2008). Elevated temperatures and reduced flows also impact juvenile Chinook salmon and steelhead outmigration and can limit juvenile rearing in the lower valley section (DWR 2009).

Salmonid escapement in Deer Creek has been monitored intermittently since 1940, with annual records available since 1985 (Harvey 1997; Harvey-Arrison 2008). SRCS counts were made at Deer Creek Weir (located at RM 6.25) while it was operational from 1940 to 1948. Every year, the end of SRCS counts correlated with a lack of sufficient water below diversions and the onset of lethal water temperatures (Armentrout et al. 1998; Cramer and Hammack 1952). Cramer and Hammack (1952) reported that of the total 10,303 SRCS counted in 1945, 1946, and 1947, nearly 9 percent (864 salmon) died as a result of lethal water temperatures between the Deer Creek Weir and the downstream confluence with the Sacramento River. Other SRCS mortality incidents below diversions in Deer Creek have been reported and are most likely linked to thermal stress resulting from low flows (M. Johnson, pers. comm).

No flow assessments have previously been completed on Deer Creek. The primary objective of this study is to understand the flow and temperature regimes needed for adult and juvenile Chinook salmon and steelhead to migrate through the natural stream channel in the Sacramento Valley floor.

1.2 Deer Creek Watershed

Deer Creek, a tributary to the Sacramento River in Tehama County, originates near the summit of Butt Mountain in the Lassen National Forest at approximately 7,320 ft (2,231 m) in elevation (NMFS 2009) (Figure 1). Deer Creek flows for approximately 60 mi (9,605 km) in a southwesterly direction, passing through meadows and dense forests before descending rapidly through a steep rock canyon into the Sacramento Valley. Upon exiting the canyon, Deer Creek flows across the valley floor, and enters the Sacramento River approximately 1 mi (1.6 km) west of the town of Vina at an elevation of about 180 ft (54.8 m) (NMFS 2009). The watershed has a high potential for snowpack accumulation and spring snowmelt as a result of 40 percent of the basin being located above 4,000 ft (1,219.2 m) (DWR 2005). Annual precipitation ranges from 70 in (177.8 cm) in the upper watershed to 20 in (50.8 cm) on the valley floor (DWR 2005).

The upper Deer Creek watershed, referred to in this report as the area upstream of the canyon mouth, is located primarily on Lassen National Forest lands and is popular for hunting, fishing, hiking, and camping. Two natural falls are located in the upper Deer Creek Watershed. The Lower Falls has a functioning fish ladder; however, a recent assessment determined that the existing structure did not meet CDFW/NMFS fish passage criteria and therefore a fish passage assessment project is being planned at Lower Falls (USFWS 2012). Upper Deer Creek Falls represents the natural limit of anadromy for SRCS, and has a fish ladder that was operated from late-fall to early spring to allow steelhead migration (DCWC 1998); however, it is no longer opened (K. Gale, pers. comm.). The upper Deer Creek watershed also has private commercial timberlands with large private ranches in the mid- and lower-elevation areas. Irrigated agricultural lands on the valley floor are mainly pastures and orchards (SRWP 2010).

Two irrigation companies operate three diversion dams and four diversion ditches for agricultural use on Deer Creek between the canyon mouth and the Sacramento River (NMFS 2009). In 1923, the superior court adjudicated 100 percent of the flows in Deer Creek to Stanford Vina Ranch Irrigation Company (SVRIC) and Deer Creek Irrigation District (DCID), with SVRIC receiving 65 percent and DCID receiving 35 percent of the flow (Superior Court of the State of California 1923; Court Decree Number 4189 November 27, 1923 SVRIC vs. Charles Dicus). The irrigation companies have a combined maximum diversion rate estimated at 115 cfs (3.25 m³/s), as reported for 2010-2011 to the State Water Resources Control Board (State Water Board) electronic Water Rights Information Management System (eWRIMS).

In wet water years, sufficient flow for upstream migration of adult salmon is available. However, during periods of low flow these combined water rights can remove all of the water from the stream and impede fish passage. Diversions in the late spring and early summer have resulted in flows low enough to block passage of migrating adult SRCS (Armentrout et al. 1998). Flow in the lower 5 mi (8 km) of Deer Creek may be reduced to less than 5 cfs (0.14 m³/s) at times of intensive irrigation (Tompkins 2006).

An evaluation of the hydrograph by McManus (2004) for all water year types between 1920 and 2002 indicated that DCID and SVRIC's combined maximum diversion capacity exceeded the average mean daily flow in Deer Creek between July and October. During dry and critically dry years, their combined maximum diversion exceeded the mean daily flow as early as April,

coinciding with the SRCS migration period. This study seeks to quantify flows needed during periods of low flow to ensure salmon migration is possible through lower Deer Creek, (i.e., the river reach between the Sacramento River confluence and the canyon mouth).

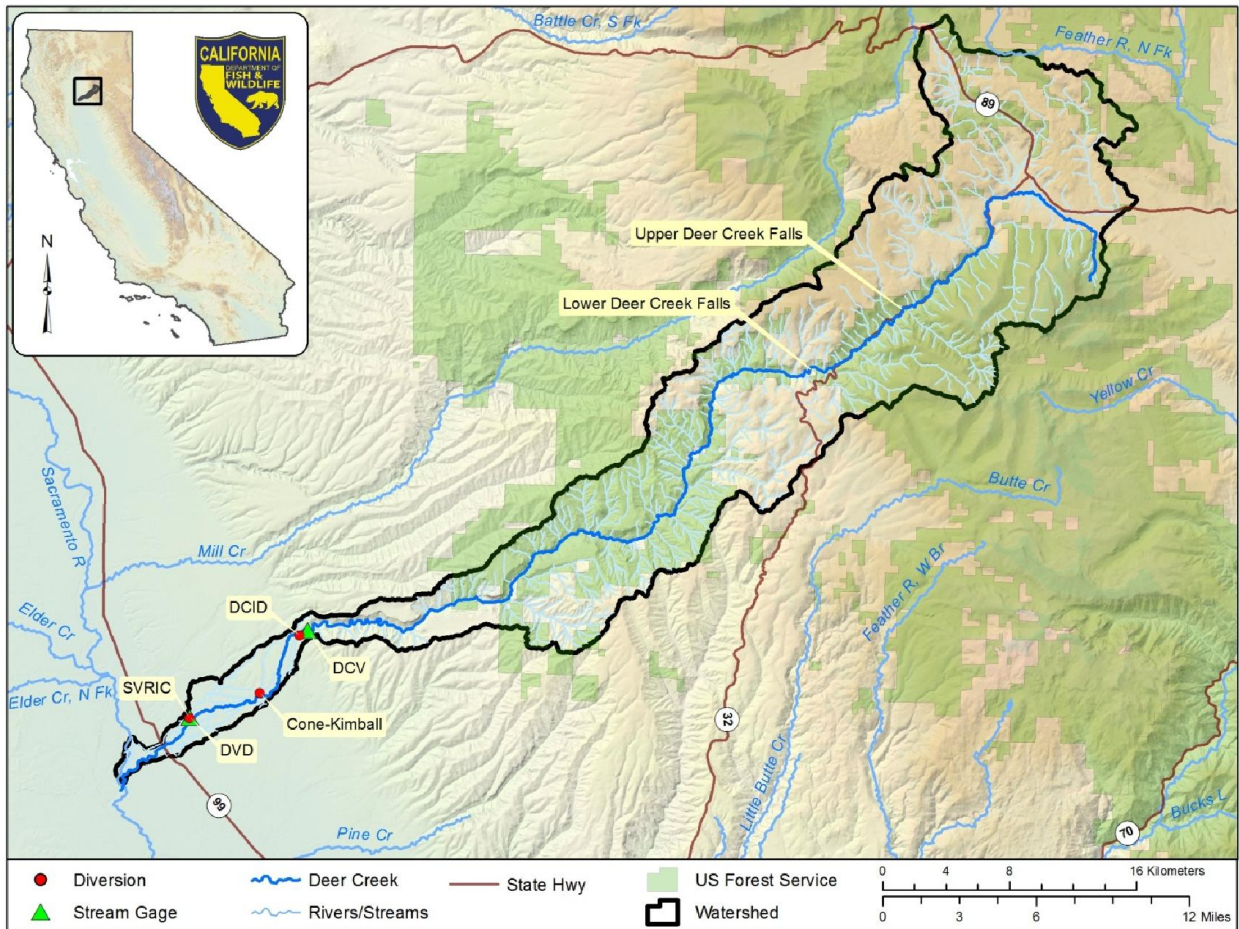


Figure 1. Deer Creek watershed map with points of interest.

1.3 Problem Statement

Insufficient stream flow and elevated water temperatures associated with low flows may impede salmonid migration and even lead to mortality in Deer Creek. Flow regimes necessary to provide unimpaired migration for adult salmonids are not accurately known, yet have been estimated to be 50 cfs (1.4 m³/s) for planning purposes (McManus 2004; USFWS 1995). There is a lack of data on lower Deer Creek related to the amount of water needed for passage of salmonids over critical riffles and other natural impediments. This instream flow study will be used to quantify what flow requirements will allow for adult and juvenile salmon and steelhead migration over natural passage barriers.

1.4 General Approach

Critical Riffle Analysis (CRA) and other appropriate methodologies for conducting fish passage assessments will be used to evaluate depth and minimum discharge rates needed for salmonid passage through critical riffle sites on lower Deer Creek. Critical riffles are the shallowest riffles in a stream that are most sensitive to changes in stream flow due to diminished water depth (CDFW 2013a). Stream temperatures will be monitored and modeled using a Stream Temperature Network (SNTEMP) Model to define upper temperature thresholds that cause a thermal barrier to migrating adult SRCS (see Appendix A: SNTEMP Model Study Plan).

The use of the CRA method requires that stream flows are sampled directly for depth, stage, discharge, and velocity. The CRA method is an empirical method and requires that three to six flows are sampled on the receding limb of the hydrograph, within the same water year. Unforeseen conditions altering flow patterns in the creek could delay data collection and the study schedule, and could postpone completion of the study until the following year.

1.5 Implications

This study will result in an instream flow recommendation for lower Deer Creek. This flow recommendation will be transmitted to the State Water Board in accordance with Public Resource Codes (PRC) §10000–10005. Additionally, these flow recommendations may be used to develop flow criteria to inform the flow objectives in high-priority tributaries in the Delta Watershed recommended by the Delta Plan (Delta Stewardship Council 2013).

2.0 Project Description

2.1 Goals and Objectives

The goal of this study is to determine what conditions (i.e., flow and temperature) are required for the protection of adult Chinook salmon and steelhead migration as well as juvenile salmonid emigration in Deer Creek. This will be achieved by developing relationships between flow, temperature, and passage criteria.

The primary objective of this study is to develop scientifically defensible information that can be used to develop a flow recommendation consistent with PRC §10000–10005, which assures that stream flow within Deer Creek is maintained at a level adequate for the long-term protection of salmonid populations. Through site specific evaluation, CDFW seeks to recommend stream flows consistent with existing minimum upstream passage depth criteria for salmon and steelhead (CDFW 2013a). This will be accomplished through:

1. Identification of the stream flow rates necessary for passage of adult and juvenile Chinook salmon and steelhead through representative critical riffles using CRA (CDFW 2013a) and other methodologies as appropriate;
2. Monitoring and modeling water temperature to identify thermal barriers to passage;

3. Analyzing fish passage assessment results to identify flow regimes associated with passage criteria for adult and juvenile salmon and steelhead;
4. Developing a final technical report describing results of the study as well as an instream flow recommendation; and
5. Transmittal of an instream flow recommendation to the State Water Board.

2.2 Project Organization

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

Name (Affiliation)	Role	Email
Diane Haas (Water Branch)	Project Coordinator	Diane.Haas@wildlife.ca.gov
Paige Uttley (Water Branch)	Senior Env. Scientist	Paige.Uttley@wildlife.ca.gov
Mark Gard (USFWS)	Contractor	mark_gard@fws.gov
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 Mesohabitat Mapping and Transect Selection Fish Passage Assessment Data Collection Temperature Model Data Collection	CDFW CDFW and USFWS CDFW and USFWS CDFW and USFWS
Data Analysis Fish Passage Assessment Temperature Model Construction and Calibration	CDFW 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. Project activities and anticipated timeline.

Activity	Date
Preliminary Field Reconnaissance	May 2013 – June 2013
Stakeholder Outreach	February 2014 – November 2015
Mesohabitat Mapping and Critical Riffle Selection	March 2014 – April 2014
Fish Passage Data Collection	March 2014 – September 2014
Temperature Model Instrument Installation and Data Collection	March 2014 – July 2014
Fish Passage Data 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
<u>Mesohabitat Mapping:</u> Garmin GPS unit Laser range finder	CDFW CDFW
<u>Flow Measurements:</u> Marsh McBirney Flow Meter Top setting wading rod Transect measuring tapes Auto level	CDFW CDFW CDFW CDFW

Activity / equipment	Provided by
Stadia rods	CDFW
<u>Critical Riffle Assessment:</u> Garmin GPS unit Stadia rod Marsh McBirney Flow Meter Transect measuring tapes Rebar	CDFW CDFW CDFW CDFW CDFW
<u>Temperature Model Survey:</u> Solinst Pressure Transducer Solinst Barometric Pressure Transducer Water temperature dataloggers Datalogger housing units	USFWS USFWS CDFW CDFW

2.4 Coordination and Review Strategy

Critical Riffle Analysis will be performed by the CDFW Water Branch with assistance from CDFW Northern Region (Region 1). Temperature modeling will be conducted under contract with the U.S. Fish and Wildlife Service (USFWS). CDFW staff will coordinate with USFWS on site selection and temperature model data collection schedule, monitoring equipment installation, model construction and summary, and study report. Equipment will be provided by USFWS and CDFW.

Sites are accessible via public access points and private roads. All landowners adjacent to Deer Creek will be notified of the studies prior to their initiation (notification letters mailed March 14, 2014) and permission to access sites from private roads will be obtained ahead of time.

If access to sites via private property is granted, CDFW will provide advanced notification to landowners prior to each visit. CDFW is committed to working with local landowners and stakeholders to ensure study activities are not an undue burden on landowners or to recreation in and along lower Deer Creek.

CDFW will conduct stakeholder outreach activities and will attend meetings with the stakeholders (i.e. irrigation districts, conservation groups and local community) to inform them of the Deer Creek study. This study plan will be posted on the CDFW Instream Flow Program 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.

3.0 Project Design and Methodology

3.1 Study Design

Critical passage sites are expected to be found at riffle areas. Riffles occur at grade changes in the channel and are characterized by exposed substrate and a broad channel width. The most critical areas (most flow and depth-sensitive riffles along the shallowest course) will be chosen as study sites. These riffles will be selected to evaluate their passage characteristics under natural flow conditions, which natural conditions are defined as conditions where the water surface elevation at the riffles is not affected by anthropomorphic activities like water diversions.

Reconnaissance surveys were conducted in May and June 2013 to assess the presence of critical riffles in lower Deer Creek. Critical riffles were identified following methods developed by Thompson (1972), with the shallowest path from bank to bank measured and recorded at riffles. Riffle locations were identified and recorded with a Global Positioning System (GPS) unit, and the greatest depth (thalweg) along each path was measured to 0.1 ft (3 cm). Due to access restrictions, two sections were not surveyed during the initial investigation. These sections, a short 0.2 mi (322 m) section directly upstream of the SVRIC Diversion Dam, and the section from the railroad bridge (RM 2.6) downstream to the confluence with the Sacramento River, were surveyed in March 2014 completing the assessment.

The shallowest critical riffle in a stream is the most sensitive to changes in stream flow due to diminished water depth. Shallow depth as a result of limited flow at this riffle is expected to be a deterrent to passage in the creek. Physical factors at critical salmonid passage sites will be analyzed following methods in the CDFW CRA Standard Operating Procedure (SOP) (CDFW 2013a), along with other appropriate passage assessment methodologies as new information or other accepted methods become available. Passage will be assessed by identifying pathways through the critical riffle where fish can migrate; measurements of depth and velocity will be repeated at decreasing flows until a single limiting pathway is exposed. Once a critical path is identified, physical parameters such as depth and velocity will be used to assess what flow levels within the stream are necessary to protect and maintain salmonid passage during critical life stages.

To best capture the variability in salmonid passage flows and to account for variations in riffle habitat, measurements will be taken at the three critical riffle sites determined to be the most depth sensitive and representative of the stream. At each of the critical riffles selected, critical riffle site parameters will be recorded over a four- to six-part sampling series on the falling limb of the hydrograph. These sampling events will be timed to capture the full range of discharges needed to adequately bracket and identify passage flows for Chinook salmon and steelhead during adult and juvenile life stages (CDFW 2013a). 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 headpin to tailpin;

- Depth and velocity measurements at regular intervals along the transect (number of intervals is dependent on width of the riffle and must be sufficient to capture changes in depth).

See Appendix B for CRA field data sheet.

In accordance with CDFW’s CRA SOP (CDFW 2013a), two criteria will be used to assess what flows are required to provide protective conditions of suitability for passage. These include:

1. At least 10% of the entire length of the transect must meet the minimum depth and maximum velocity criteria established for the target fish, contiguously; and
2. A total of at least 25% of the entire transect must be no more than the minimum depth and maximum velocity established for passage of the target fish.

The total width and longest contiguous portion of the transect meeting minimum depth and maximum velocity criteria are measured, for each transect, during each sampling series (Thompson 1972). The minimum depth criteria used in CRA is based on the water depth needed for a salmonid to adequately navigate over a critical riffle with sufficient clearance underneath it, so that contact with the streambed and abrasion are minimized (R2 Resource Consultants 2008). The minimum depth passage criterion for adult Chinook salmon (0.9 ft) is inclusive of the minimum depth for juvenile Chinook salmon, and adult and juvenile steelhead trout (CDFW 2013a). The minimum depth criteria for adult Chinook salmon can therefore serve as a proxy for the other species and life stages present in the stream (i.e., steelhead trout and juvenile salmonids). Passage velocities have been established based on the perceived swimming abilities of salmon and trout to pass over barriers. A maximum passage velocity of 8.0 feet per second (fps) is considered appropriate for adult Chinook salmon and steelhead trout while a lower velocity between 1.0 and 1.5 fps is recommended for rearing juvenile salmonids over riffles (Thompson 1972). Once depth and velocity data has been collected at an appropriate range of flows on each transect, the results will be analyzed to determine what flow regime will maintain and protect adult and juvenile salmonid passage (Table 5).

Table 5. Minimum depth and maximum velocity criteria for adult and juvenile salmonid passage.

Species	Minimum depth (ft)	Maximum Velocity (ft/sec)
Chinook Salmon (adult)	0.9	8.0
Steelhead (adult)	0.7	8.0
Trout (adult, including 1-2+ juvenile steelhead)	0.4	4.0
Salmonid (young of year juvenile)	0.3	4.0

Source: CDFW 2013a; Thompson 1972.

In conjunction with USFWS, CDFW will conduct a temperature model in lower Deer Creek using SNTMP (Bartholow 1989). The model will be used to determine what stream flows are necessary to maintain temperatures in agreement with Chinook salmon migration criteria (Table 5) in lower Deer Creek. Temperature loggers will be installed throughout the study reaches,

from the DCID diversion downstream to the confluence with the Sacramento River, to monitor continuous stream temperature and determine when stream temperature exceeds adult Chinook salmon migration criteria. The study area will be divided into assessment reaches for temperature modeling based on changes in hydrology and stream gradient. See Appendix A: SNTMP Model Study Plan for more details on the temperature modeling portion of the study.

Sampling bias will be minimized by using standardized methodology from the CDFW SOP manuals. Additionally, field workers will use standardized coding for substrate and cover and will be sufficiently trained in the field prior to data collection.

Data collected in the field will be reviewed and entered into electronic spreadsheets as soon as staff return to the office. 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 and USFWS to schedule additional field data collection.

Drought conditions and increased diversion rates may delay this study if low flow conditions do not allow target flows to be met. Changes in site access permissions may also postpone this study.

3.2 Identification of Study Reaches and Sampling Sites

The study reach, defined as lower Deer Creek, extends from the canyon mouth at the DCID Diversion Dam (RM 11.8) downstream to the confluence with the Sacramento River (RM 0.0) (Figure 2).

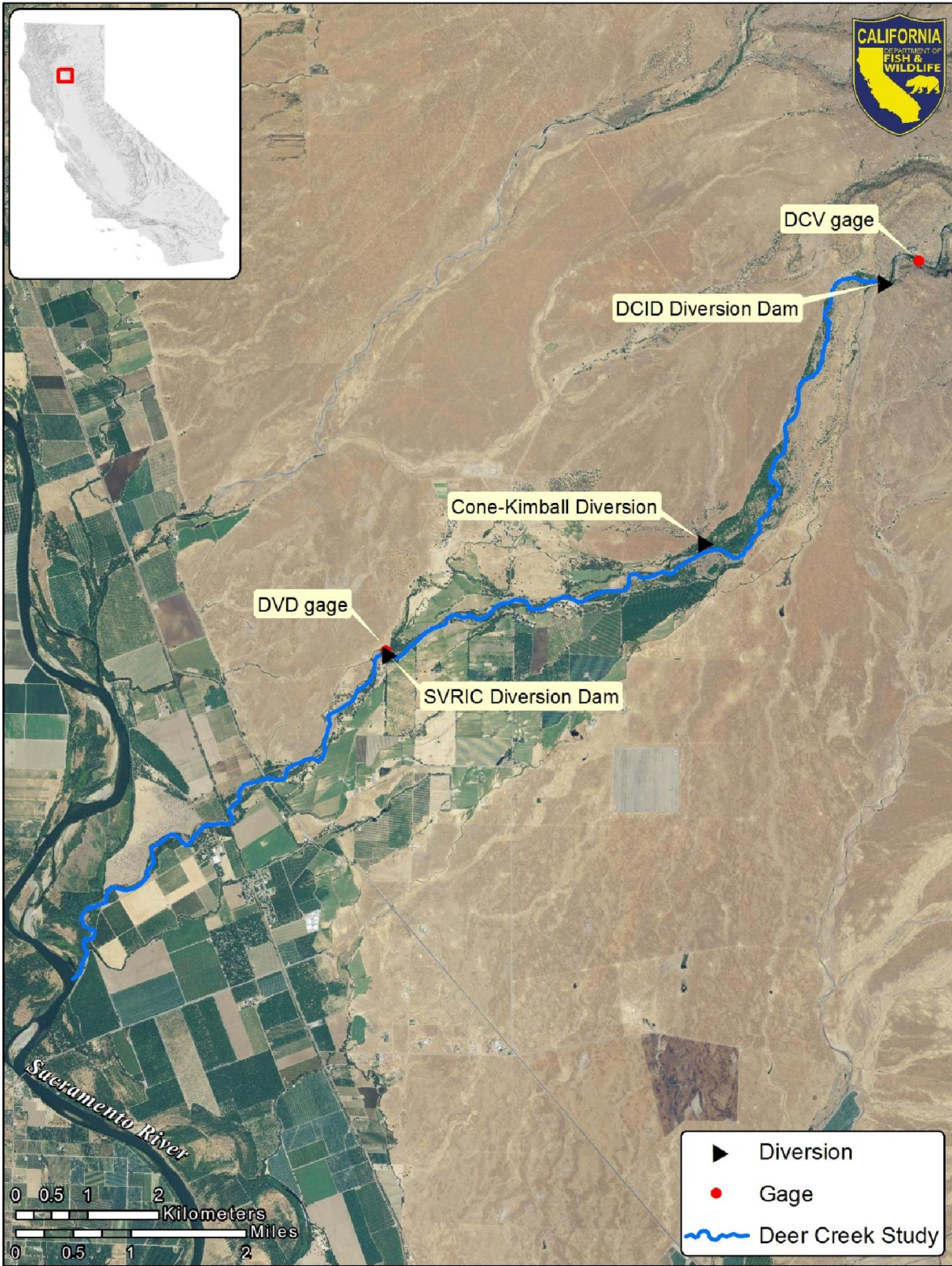


Figure 2. Map of lower Deer Creek with points of interest.

The critical riffles with the shallowest minimum thalweg depths (0.4-0.6 ft) were each located downstream of the SVRIC Diversion Dam. Upstream of the SVRIC Diversion Dam, the critical riffles were less depth sensitive (0.7-0.9 ft minimum thalweg depth). The three depth sensitive critical riffles with the most shallow minimum thalweg depths were selected as sample sites for CRA (Figure 3).

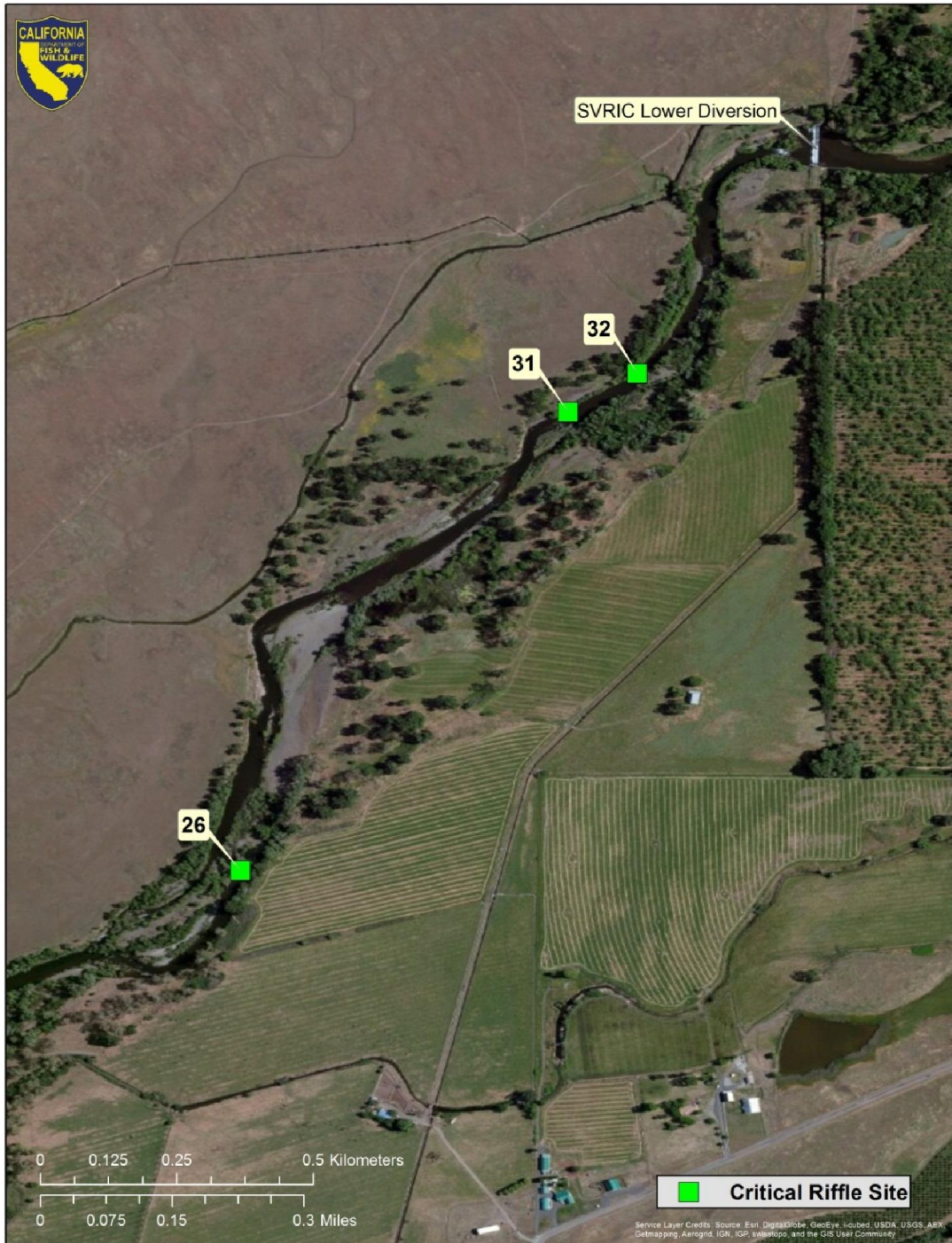


Figure 3. Map of critical riffle sites on lower Deer Creek.

3.3 Biology

Deer Creek provides approximately 42 mi (67.5 km) of anadromous salmonid habitat, and is one of only three streams supporting a self-sustaining, genetically distinct wild population of Central Valley SRCS (CDFG 1998; NMFS 2009). Migrating adult SRCS enter Deer Creek from late-February through early-July (Table 6), and hold over the summer in pools in the upper watershed (Johnson and Merrick 2013). SRCS begin spawning in late September, from near the mouth of the canyon upstream to the natural limit of anadromy at Upper Deer Creek Falls, a distance of approximately 30 mi (48.2 km) (Armentrout et al. 1998).

Adult FRCS migrate upstream into Deer Creek during the late fall after seasonal rains have increased stream flow (DCWC 1998). Spawning occurs in the lower reaches of Deer Creek, with most of the adult fish spawning in the valley floor (from the DCID diversion downstream to the Southern Pacific Railroad Bridge). When flows are lower than normal, FRCS adults can be limited to the stream section below SVRIC diversion dam (Cramer and Hammack 1952).

Steelhead have not been well studied on Deer Creek. Based on fish counts in Mill Creek, steelhead adults begin migrating with the onset of the first heavy run-off in the fall and ends when flows diminish (Hallock 1989). Adult steelhead migrate further upstream on Deer Creek than Chinook salmon, and spawn in the winter shortly after migration (DCWC 1998).

See the Fish Population Characterization section of the Deer Creek Existing Conditions Report (DCWC 1998) for lists of resident native species and exotic species known to occur in Deer Creek.

Table 6. Adult migration and juvenile emigration timing for salmonids in Deer Creek. Shading indicates timing span, with darker shading indicating months of peak movement.

Species and Lifestage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SRCS												
Adult												
Juvenile												
FRCS												
Adult												
Juvenile												
Steelhead												
Adult												
Juvenile												

Source: Johnson and Merrick 2012; USFWS 1999.

3.4 Hydrology

The Deer Creek watershed drains 208 mi² (538.7 km²) and has a mean daily discharge of 323 cfs (9.1 m³/s) (Tompkins and Kondolf 2007). Deer Creek produces on average 233,700 acre-feet of water per year (USGS 2013). The majority of annual flow events occur December through February, during which peak flows are dominated by rain-on-snow events (NMFS 2009). Deer Creek maintains a perennial flow as it travels from the upper mountains, meadows, and canyons to the valley floor (McManus 2004).

Two stream flow gage stations are present in Deer Creek near the study reach (Figure 2). The U.S. Geological Survey (USGS) operates gage number 11383500 (CDEC station ID: Deer Creek near Vina, DCV), located upstream of the DCID Diversion Dam at RM 12.3 (USGS 2013). The Deer Creek adjudicated flow is based on measurements at this gage, which has reported mean daily flow since 1911. Water temperature records at this gage began in 1998. The California Department of Water Resources (DWR) operates the other gage, located just below the SVRIC Diversion Dam at RM 5.0 (CDEC station ID: Deer Creek below Stanford Vina Dam, DVD). The gage started reporting in 1997, with reliable water temperature records available since 1998. Records for both gages can be accessed at the California Data Exchange Center (CDEC) website.

Target flows for sampling in Deer Creek have been determined using the CDFW SOP for Flow Duration Analysis (CDFW 2013c). Daily exceedence flows are estimated using data from the USGS gage 11383500 described above. Exceedence flows are used to select the range of target flows needed for data collection at the critical riffle sites (Table 7; Figure 4).

Table 7. Target flows to be sampled at the critical riffles sites based on discharge at the USGS (DCV) gage.

EXCEEDENCE PERCENTAGE	TARGET FLOW (CFS)
20%	421
35%	232
50%	147
65%	116
80%	93

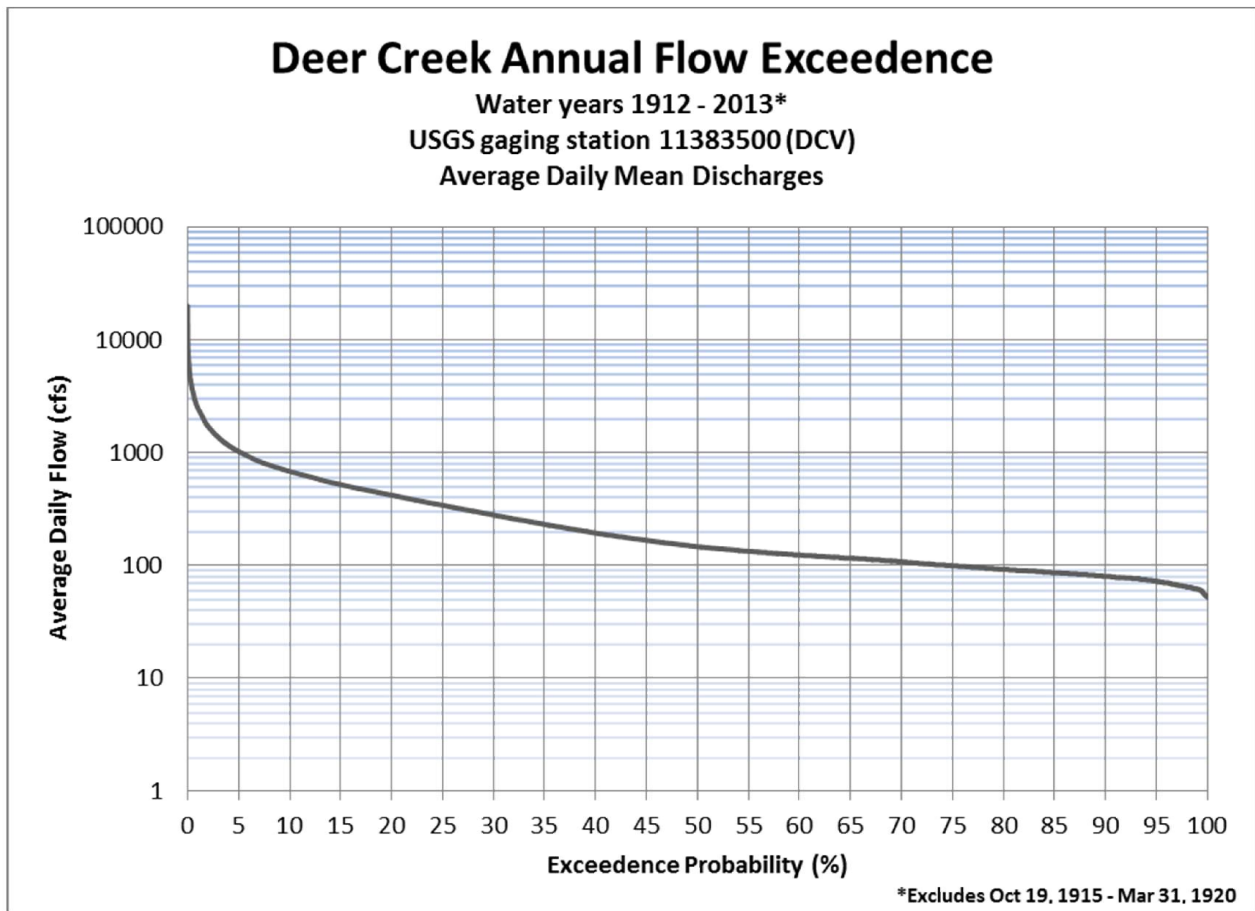


Figure 4. Annual flow exceedence probability curve for Deer Creek during 1912-2013 water years.

3.5 Connectivity

It is thought that changes in stream flow and associated water depth and temperatures could be limiting the hydrologic connectivity of riverine habitats and inhibiting critical salmonid life history strategies in lower Deer Creek. Adequate water depths of sufficient width are necessary to identify passage flows and promote passage of adult and juvenile salmonids at critically shallow riffle sites. Critical riffles are shallow areas sensitive to changes in stream flow due to lowered water depth. Critical riffles present in lower Deer Creek are potential barriers to upstream and downstream passage; possibly impeding adult SRCS movement to and from holding and spawning areas, impeding adult FRCS and steelhead trout migration from the Sacramento River into the upper watershed, hindering smolt outmigration to the Sacramento River prior to the onset of lethal water temperatures, and preventing rearing juveniles from moving between adequate summer freshwater rearing habitats (CDFW 2013a).

3.6 Geomorphology

The upper Deer Creek watershed is relatively narrow in shape with moderate to steep slopes. Deer Creek flows from upper meadows into a deeply incised canyon composed of ancient volcanic mudflows of the Tuscan Formation (Ely 1994 as cited in Tompkins and Kondolf 2007). Immediately downstream of the canyon (RM 10.5), Deer Creek flows onto its alluvial fan, with an average slope of 0.5 percent (DCWC et al. 2011). The upper section of the alluvial fan is composed of the Riverbank Formation, Red Bluff Formation, and older terrace gravels (Tompkins and Kondolf 2007).

The natural, unconfined condition of lower Deer Creek is a high-energy, dynamic system, featuring a narrow, shaded low flow channel with relatively natural flow, sediment transport and large woody debris (DCWC et al. 2011; Tompkins 2006). Following the completion of the U.S. Army Corps of Engineers flood control project (i.e. levees and channel clearing) in 1949, the complexity of the channel, riparian, and flood corridor was noticeably altered and Deer Creek developed simplified channel and riparian conditions (DCWC et al. 2011). Lower Deer Creek is presently characterized by “long reaches without significant topographic diversity on the channel bed, limited riparian vegetation (especially adjacent to the low flow channel), minimal large woody debris, and few pockets of spawnable-size gravels, all possible symptoms of reduced floodplain connectivity” (Tompkins 2006, p. 16). Further, occasional maintenance bulldozing and dredging of the creek along with scouring impacts from concentrated high flows due to the flood control levees has resulted in coarsened bed materials and cemented gravels (DCWC et al. 2011). These conditions have likely impacted salmonids in Deer Creek by affecting spawning and rearing habitat and passage of adult and juvenile SRCS and steelhead in the lower alluvial reach (Tompkins 2006).

3.7 Water Quality

In general, the water quality in upper Deer Creek is considered excellent. However, water temperatures may pose a threat to salmonids during late spring and summer periods of low flow. Harvey-Arrison (2008) reported that SRCS migration in 2007, considered a dry water year, may have been truncated by water flow and temperature conditions. Acceptable water temperatures for upstream migration range from 57°F (13.9°C) to 67°F (19.4°C), with migrating and holding

salmon preferring temperatures less than 60°F (15.6°C) (DCWC 1998). Water temperatures ranging from 66-75°F (19-23.9°C) have been measured in lower Deer Creek and appear to be causing a thermal blockage to the upstream migration of adult Chinook salmon (Carter 2005). Cramer and Hammack (1952) reported that water temperatures lethal to migrating salmon, 81-82°F (27.2-27.8°C), occur every summer in lower Deer Creek. Gage data from the DWR stream flow gage, DVD, indicates that summer water temperatures in lower Deer Creek have continued to reach lethal levels over the past 15 years (Figure 5). A seven day average of the daily maximum temperature 64°F (18°C) is considered to be the temperature threshold for unimpaired adult salmon and trout migration (EPA 2003; CDFG 2010).

Deer Creek Water Quality Investigations, conducted by DWR from 1997 to 2000, indicated that during summer months, water temperatures did not become cool enough and therefore suitable for salmonids, until the middle of the canyon upstream of Ponderosa Way (DWR 2008). Monitoring and modeling water temperatures will help to determine what flow conditions in lower Deer Creek are required to assure that salmonids can reach thermal refugia (i.e. pools) in the upper reaches.

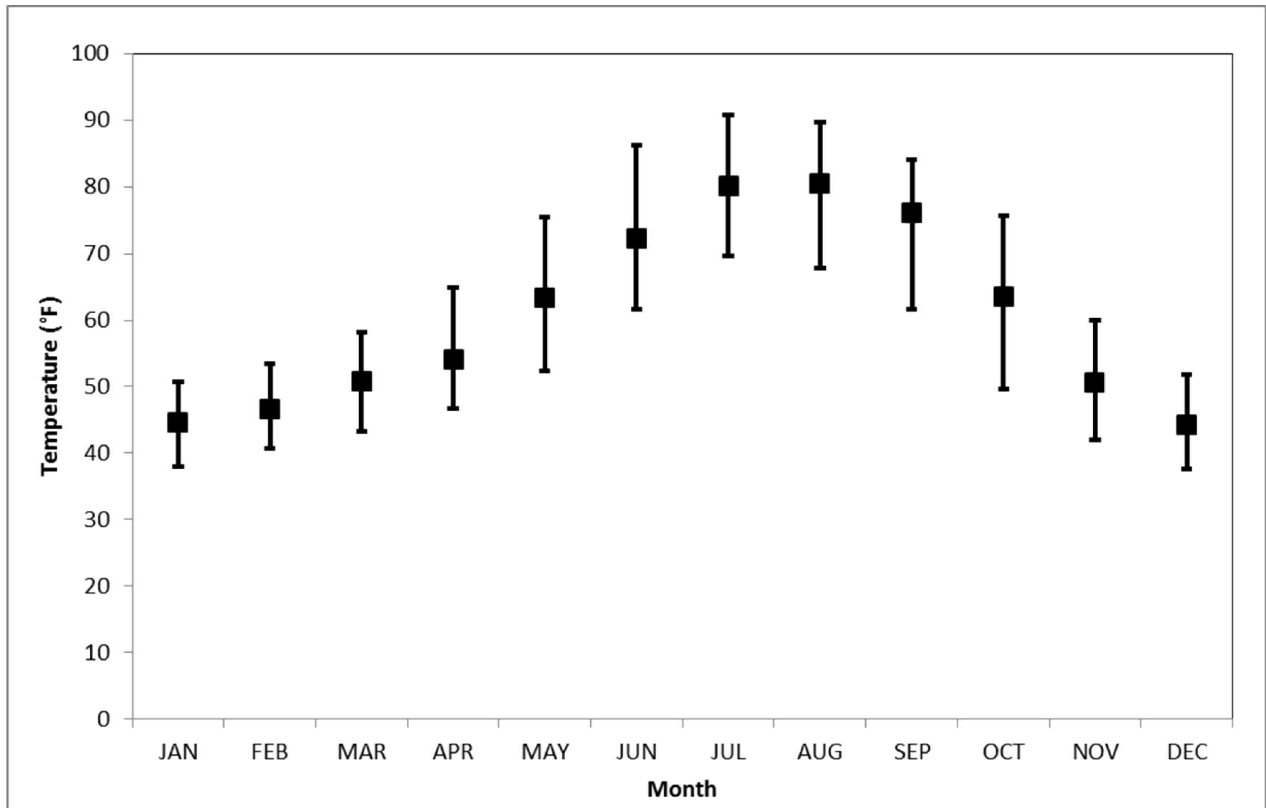


Figure 5. Average monthly water temperature range at DVD gage in lower Deer Creek from October 1998 through December 2013.

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 2013b).

Field crews will review the Deer 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. Marsh-McBirney flow meters will be calibrated each day by a field team member before use in the field as described in the Discharge Measurements SOP (CDFW 2013b).

Data collected as part of the CRA will be checked for errors and completeness upon return to the office. Data will be entered into electronic spreadsheets for analysis. Errors or missing data will be reported to the Project Coordinator.

4.3 Corrective Actions

If data collection errors or missing data are discovered, the Project Coordinator will review the issues with the appropriate Quality Assurance/Quality Control personnel to develop a plan for corrective action. Data collected will be reviewed upon return to the office so that resampling, if required, can be scheduled to occur during the current sampling season.

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 Critical Riffle 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, particularly high flow events that potentially mobilize bed load and shift stream beds. Additionally, annual hydrological conditions rarely follow historical averages. To counteract these uncertainties, data will be collected at multiple representative riffles, as opposed to a single site. Additional critical riffle sites have been identified in case data collection must be halted at a current site (as a result of changed conditions from a large event or limited access) and must be restarted in a new location.

5.2 Data Storage and Reporting

Water Branch staff will assess the data for 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 Deer 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 Deer Creek SNTEMP Model

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Foreword

Deer Creek, in Tehama County, is one of three Sacramento River tributaries that support a self-sustaining wild population of Central Valley spring-run Chinook salmon (SRCS), *Oncorhynchus tshawytscha*. The upper Deer Creek watershed contains prime holding and spawning habitat for SRCS. However, there are concerns that increased stream temperatures in lower Deer Creek, especially during low water years, cause a thermal barrier that may impede adult SRCS migration into the prime habitats of upper Deer Creek (Cramer and Hammack 1952; Harvey-Arrison 2008). Acceptable water temperatures for upstream migration range from 57°F-67°F (13.9°C-19.4°C) (DCWC 1998), yet every year, waters reach 81-82°F (27.2-27.8°C), which is lethal to migrating salmon (Cramer and Hammack 1952). To assess the relationship between stream flow and water temperature and to better understand the impact of these temperatures on SRCS migration, the U.S. Fish and Wildlife Service in conjunction with California Department of Fish and Wildlife will conduct a temperature study on lower Deer Creek using the Stream Network Temperature Model (SNTEMP).

The temperature model will comprise lower Deer Creek from the Deer Creek Irrigation District (DCID) Diversion Dam (RM 11.8) downstream to the Sacramento River confluence (RM 0.0). This section of lower Deer Creek will be divided into four study reaches based on hydrology, gradient, water diversions, and returns. This study will determine what stream flows are needed to maintain acceptable stream temperatures for adult SRCS migration into upper Deer Creek.

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

1.0 Project Overview

1.1 Overview

Stream temperature has been identified as a potential limiting factor to adult spring-run Chinook salmon (SRCS) 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 et al. 2004). To better understand the influence of water temperature on SRCS, 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 has 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 stream flows will result in water temperatures that are adequate for upstream passage of adult SRCS. 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 stream flows will result in water temperatures that are adequate for upstream passage of adult SRCS.

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, as well as for conducting the water temperature modeling, ensuring QA procedures are followed, and for preparing the final report for this project. Rick Williams' role will be to lead the second field crew. CDFW staff roles will be to assist in collecting field data under direction of the field crew lead.

2.3 Project Timeline

The tasks comprising this study are: field data collection, water temperature modeling, and preparation of a final 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 by January 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/stream flow relationships, compiling input data files for the SNTMP model, model calibration, and SNTMP 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
<i>Flow Measurement</i>		
Auto level, stadia rods, tape, GPS unit, wading rod, velocity meter	x	
<i>Temperature Measurement</i>		
Water temperature dataloggers	x	
Pressure transducers and barometer		x

2.4 Coordination and Review Strategy

CDFW Region 1 staff will lead stakeholder outreach activities. CDFW Region 1 and Water Branch staff will attend meetings with the stakeholders (i.e. irrigation districts, conservation groups and local community) to inform them of the Deer Creek study. This study plan will be posted on the CDFW Water Branch Instream Flow Program website (http://www.dfg.ca.gov/water/instream_flow.html).

3.0 Project Design and Methodology

3.1 Study Design

The sampling design has three nested levels: stream reach, mesohabitat unit (riffle, run, pool or glide) and transect. 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. Stream reach parameters include stream flow (from existing gages or pressure transducers and flow measurements), water temperature (measured with water

temperature dataloggers), and the elevation and upstream distance at the end of each reach (to be obtained from GIS databases). Mesohabitat mapping will be conducted to select transect locations and to weight transects based on the percentage of each mesohabitat type in each reach. Transect data (bed elevation profiles and stage-discharge measurements) will be used to develop relationships between stream flow and stream geometry parameters (stream width and hydraulic retardance). Water temperature is the only dependent variable; all other parameters identified above are independent variables. 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.

Stage measurements for developing rating tables at transects and pressure transducers will need to be made for at least three flows ranging over an order of magnitude to have sufficiently accurate rating tables to predict flows based on pressure transducer measurements, and to predict stream width/flow relationships over the range of flows to be simulated. Similarly, water temperature measurements need to be made for a typical range of conditions present during the year to enable the water temperature model to be adequately calibrated, so that water temperatures can be predicted under the desired range of stream flows and meteorological conditions.

Additional fieldwork will be scheduled as needed to make up for missed field observations. To eliminate sampling bias, the same field crew 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 Sample 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 dataloggers will be placed at the upstream end of the stream network and at the downstream end of each stream reach. Six stream reaches will be established based on the locations of stream water diversions and returns, stream hydrology and gradient (Figure 1). 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 SNTMP 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 (WSELs) 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.

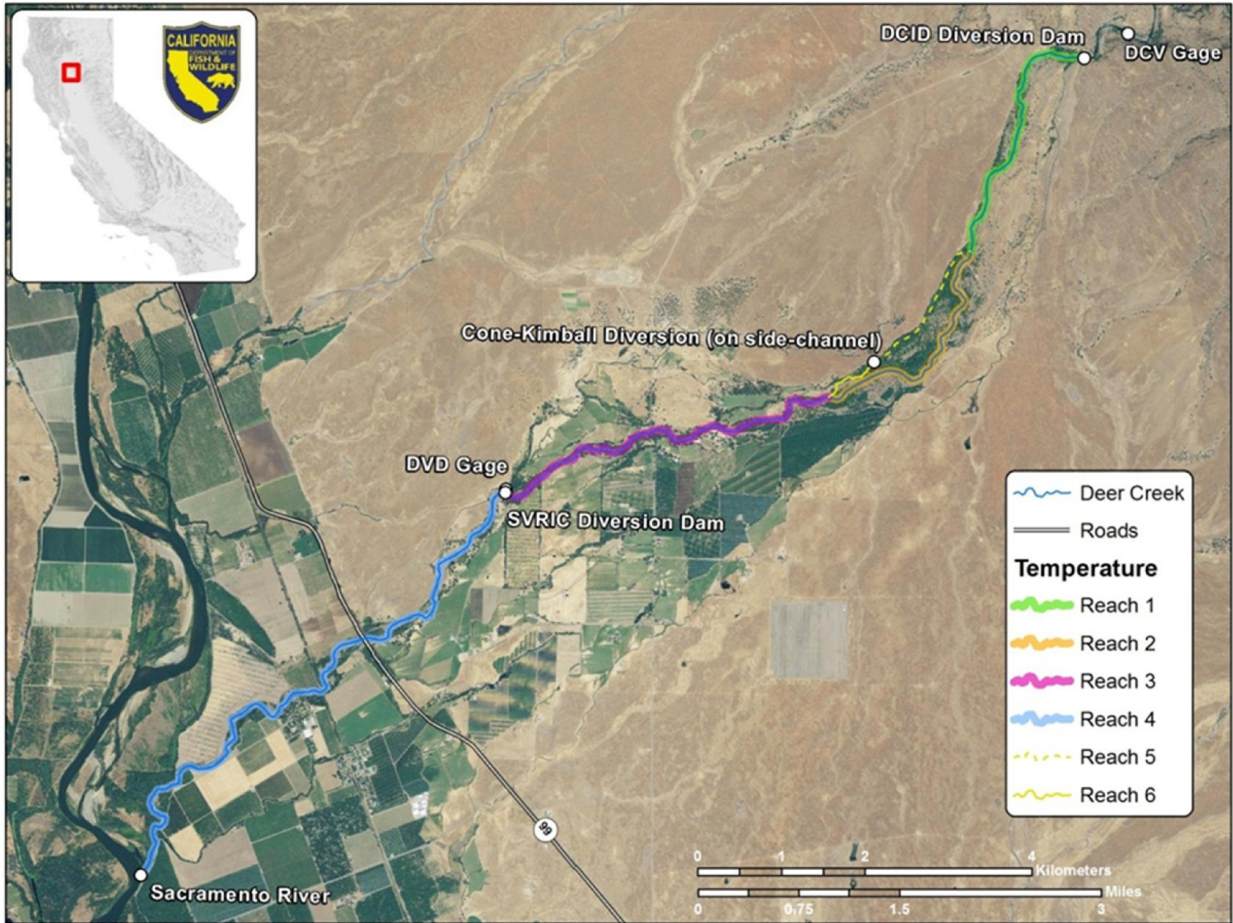


Figure 1: Map of Deer Creek temperature study reaches. Locations of diversion dams and gages are marked.

4.0 Quality Assurance/Quality Control

4.1 Sampling Procedure (Standard Operating Procedures)

Mesohabitat mapping will be conducted by walking downstream 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 you 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.
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.

WSELs will be measured to the nearest 0.01 foot at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling). Streambed elevations, to points above bankfull discharge, will be surveyed to the nearest 0.1 foot. 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 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, 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 the mean unimpaired flow in the highest flow month. WSELs 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 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 State Water Board 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 the 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 reports. The expected completion dates of the draft and final reports are, respectively, January and July 2015. Water Branch staff will post the final report to the CDFW website.

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				
5				
6				
7				
8				
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10				
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State of California
Natural Resources Agency
Department of Fish and Wildlife
Water Branch, Instream Flow Program
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