VIDEO WEIR TECHNOLOGY PILOT PROJECT
FINAL PROJECT REPORT
2007– 2010 FALL CHINOOK SALMON ESCAPEMENTS
COTTONWOOD, COW AND BEAR CREEKS,
SHASTA AND TEHAMA COUNTY, CA

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WESTERN SHASTA RESOURCE CONSERVATION DISTRICT

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INTRODUCTION

PURPOSE OF PILOT PROJECT

The fall-run Chinook salmon (*Oncorhynchus tshawytscha*) fishery is one of the most economically important fisheries in California, contributing $7.5 million to local economies in 2006 (Doug Killam, California Department of Fish and Game, 2010). In order to manage coast-wide fisheries resources (i.e. ocean and in-river harvest management needs) and to interpret fishery responses to habitat restoration activities, State and Federal fisheries agencies need accurate population stock assessments. To meet these needs, monitoring projects have been developed that are reliable, efficient, and inexpensive. Information obtained from monitoring is critical in providing baseline population data.

Historically, monitoring fall-run Chinook salmon escapement was based on carcass counts, fish ladder counts at hatcheries and dams, and occasional aerial redd (salmon nest) surveys (California Department of Fish and Game 1956 and 2005). Carcass surveys involved counting spawned-out salmon carcasses several times during the spawning season (October-November). Biologists then multiplied the carcasses counted based on their judgment of the percentage of the population they actually observed. Similar estimates were made using aerial redd counts when no carcass surveys were conducted. An aerial redd survey was accomplished several times each spawning season using a small plane and pilot plus an observer, who would count the number of new salmon redds in the creek. The number of redds observed also would be multiplied, based on "best judgment." During the 1950's and 60's, this "estimation by best judgment" was sufficient for management purposes. After 1969, monitoring efforts were sporadic due to tight budgets and typically in response to a specific need (e.g. potential water storage projects, hatchery evaluations, etc). Today surveys use a more scientific methodology, but there are budget constraints, staffing shortages, logistics issues, and landowner trespass concerns, which continue to limit annual surveys.

A relatively new method for estimating fall-run Chinook populations uses video fish weir technology, whereby video cameras capture fish movement through either a temporary or permanent weir. The video fish weir stations provide opportunities to easily monitor salmon escapement in streams that have no current monitoring programs. The video technology also includes a method to correlate daily stream temperature and flow data with salmon movement, providing new insight on factors affecting salmon escapement.

The first video station in northern California was constructed in 2003 in Battle Creek and has been operated annually on that creek since that time. The data from the Battle Creek video station allowed biologists to compare results of a carcass mark-recapture study and hatchery counts to the video station results (CDFG, 2006). Over a three-year period the counts from the two independent methods were deemed similar, in that the video weir technology had the capacity to provide accurate information with less cost and less labor compared to accepted methodology (i.e. the mark-recapture monitoring technique).

PROJECT LOCATION

As a result of the success in Battle Creek, video station methodology was approved for use in other northern California watersheds. A pilot project was planned for the three largest streams in the Upper Sacramento Watershed that were not being consistently monitored: Cottonwood, Cow, and Bear Creeks. Figure 1 depicts the location of the three watersheds in relation to Redding. The first video station was installed in Cow Creek in 2006, followed by Cottonwood and Bear Creeks in 2007.

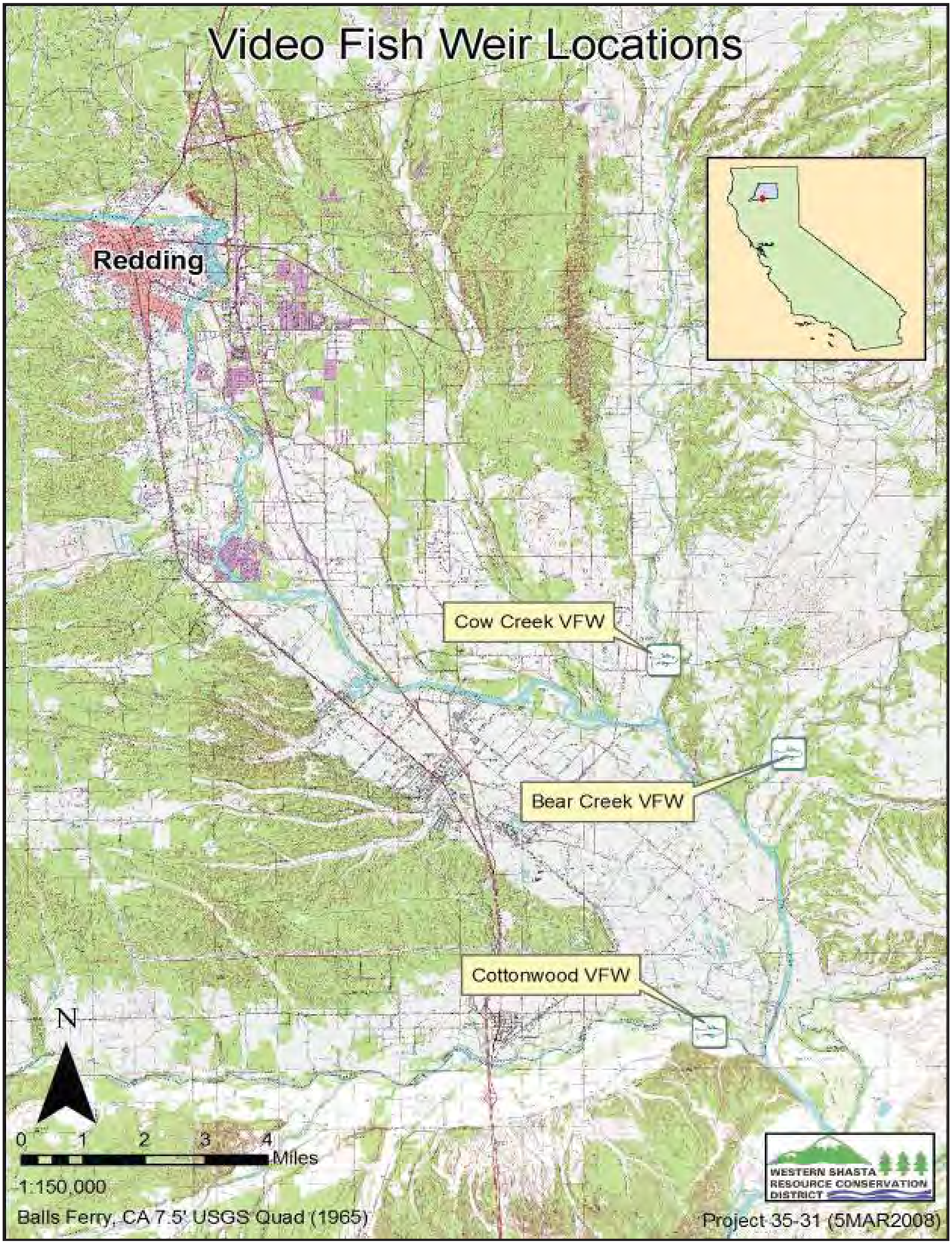

Figure 1. Video Fish Weir Project Location Map

Locating Video Station Sites

To determine the best location for the video weir stations, the following site criteria were used:

1. Limited public access to avoid vandalism and poaching opportunities.
2. A nearby power supply to run the station cameras and other electronics.
3. Close to the confluence of the creek with the Sacramento River so that most salmon would spawn above the site.
4. Landowner permission to construct and allow daily access to the video station.
5. Suitable stream geology to place the weir, such as a shallow, even, stream bottom.

Objectives of the Pilot Project

Main objectives of the pilot project were to:

- Obtain an estimate of fall-run Chinook escapement into Cottonwood, Cow, and Bear Creeks.
- Collect baseline data on salmon escapement that can be used to evaluate restoration activities occurring in the Cottonwood, Cow, and Bear Creek watersheds.
- Further test the accuracy and capacity of video weir/video data collection technology.

Funding

Funding for this project was provided in part by a Sport Fish Restoration Act (SFRA) Grant via the California Department of Fish and Game (CDFG) and by the Anadromous Fish Restoration Program, which is administered by the U.S. Fish and Wildlife Service (USFWS).

Cooperators

The three video stations were constructed and operated cooperatively by CDFG Red Bluff staff through the Sacramento River Salmon and Steelhead Assessment Project, the USFWS Red Bluff Office, the Western Shasta Resource Conservation District (WSRCD), and the Cottonwood Creek Watershed Group, the Cow Creek Watershed Management Group, and the Bear Creek Watershed Group.

WATERSHED FACTS AND WEIR LOCATIONS

COTTONWOOD CREEK WATERSHED FACTS

The *Cottonwood Creek Watershed Management Plan* (CH2MHILL, 2007) describes the watershed as follows:

> The Cottonwood Creek watershed lies within Shasta and Tehama counties on the northwest side of northern California's Central Valley. The lower two-thirds of the drainage area lie in Central Valley uplands, and the upstream portion includes the east slopes of the North Coast Mountain Range and Klamath Mountains and the southern slopes of the Trinity Mountains. The creek flows eastward through the valley to the Sacramento River, the confluence lying approximately 16 miles north of Red bluff and about 150 miles northwest of Sacramento. The pear-shaped watershed has three main tributaries: North Fork, Middle Fork (which flows along the Shasta-Tehama County line), and South Fork. The watershed drains approximately 938 square miles. With an annual runoff of 586,000 acre-feet, Cottonwood Creek is the third largest watershed tributary west of the Sacramento River. Cottonwood Creek is the largest undammed tributary in the upper Sacramento River basin and is a major source of sediment and gravel input to the Sacramento River.

COTTONWOOD CREEK WEIR LOCATION

The optimum location for the Cottonwood weir was ~0.5 miles upstream from the confluence with the Sacramento River, in a campground located within the gated residential community of Lake California. The site had an existing 120 volt incoming power supply for the equipment (Figure 2).

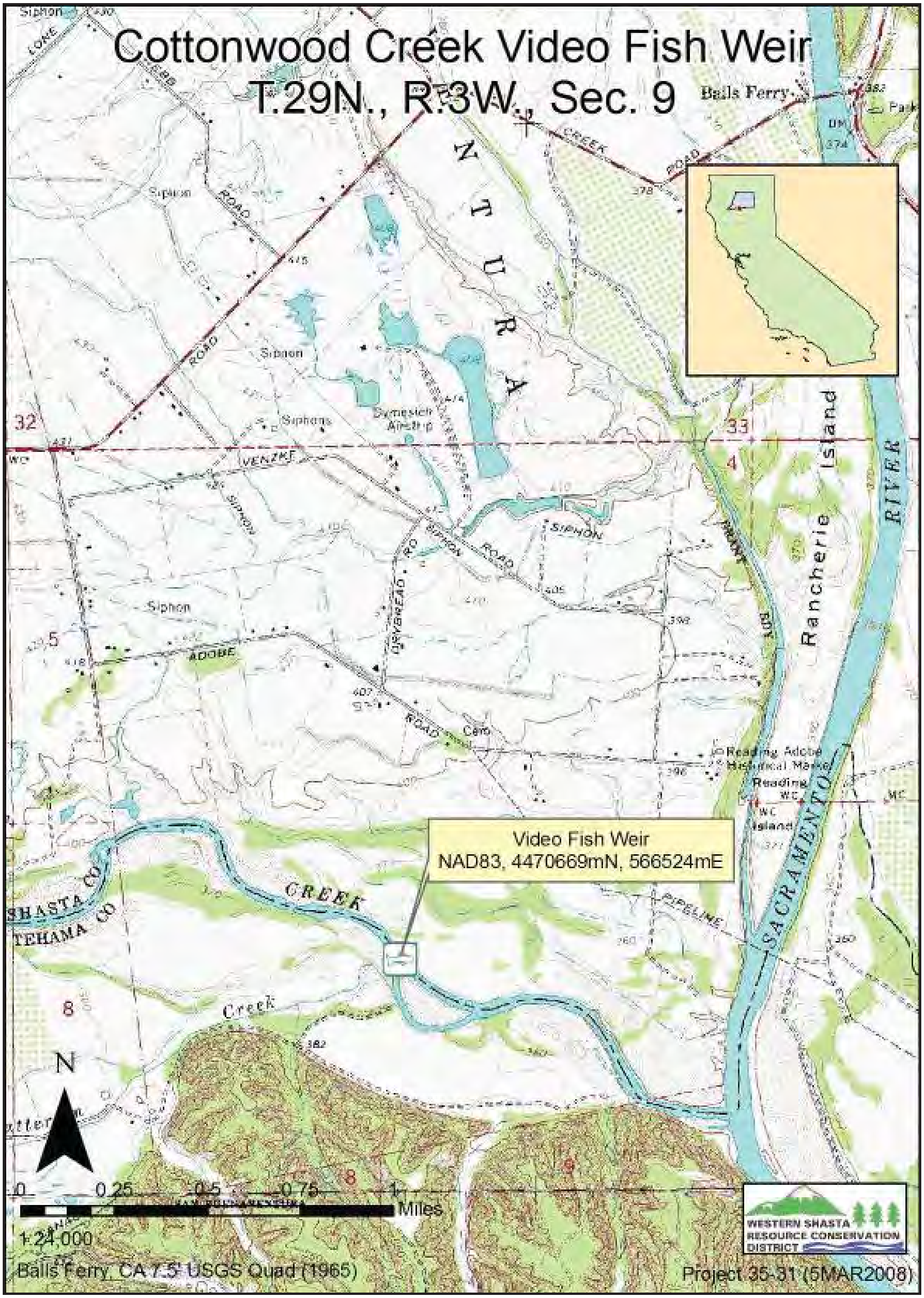

Figure 2. Map detailing the location of the video station on lower Cottonwood Creek.

Cow Creek Watershed Facts

The *Cow Creek Watershed Assessment* (SHN, 2001) describes the watershed as follows:

> The Cow Creek watershed is a generally uncontrolled tributary to the Sacramento River and is located in Shasta County on the eastern side of the Sacramento River downstream of Shasta Lake. No major water storage reservoir is located on Cow Creek. Several tributaries, which include Little Cow Creek (also known as North Cow Creek), Oak Run Creek, Clover Creek, Old Cow Creek, and South Cow Creek, flow in a southwesterly direction and form the main stem of Cow Creek in Millville. The lower third of the Cow Creek watershed falls within the Great Valley Geomorphic province with the remaining area encompassing portions of the Cascade Range and Klamath Mountains provinces. The watershed encompasses approximately 430 square miles.
>
> The topography of the Cow Creek Watershed varies significantly from the flat valley areas around the main stem to the mountainous upper reaches. Elevation of the watershed varies from 340 feet above sea level at the valley floor to over 7300 feet. Annual precipitation within the watershed ranges from about 25 inches in the valley areas to about 65 inches in the northeastern mountainous portion of the watershed. Average annual flow recorded between 1950 and 1998 is 503,180 acre feet.

Cow Creek Weir Location

The optimum location for the Cow Creek video weir station was on private land ~ 0.25 miles upstream of the Dersch Road crossing over the Sacramento River (Figure 3).

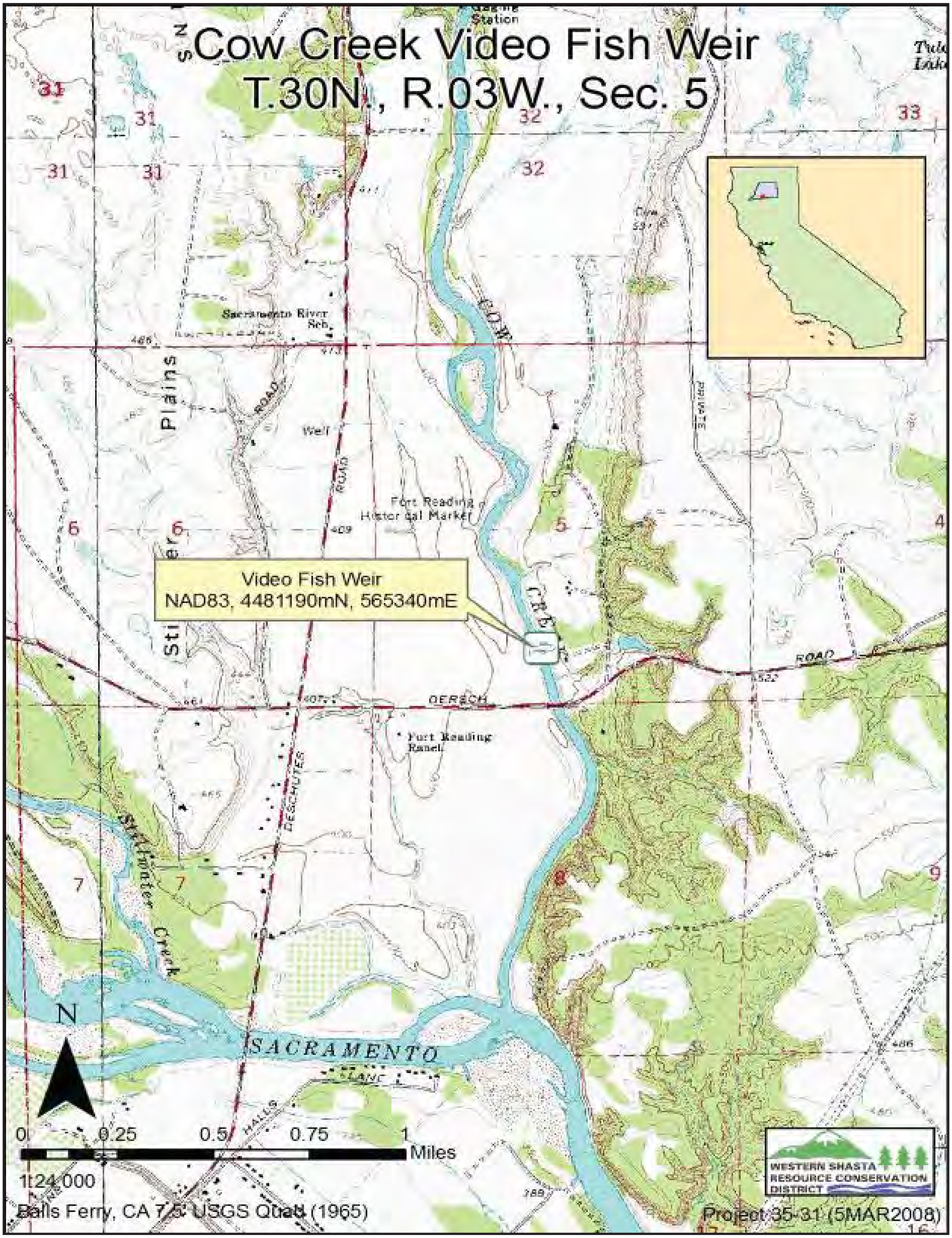

Figure 3. Map detailing the location of the Cow Creek video station.

Bear Creek Watershed Facts

The *Bear Creek Watershed Assessment* (ENPLAN, 2005) describes the watershed as follows:

> The Bear Creek watershed lies within Shasta County at the northern end of the California's Central Valley on the east side of the Sacramento River. The watershed is located between the Cow Creek watershed to the north and the Battle Creek watershed to the south. The watershed encompasses portions of the Cascade Range and the Great Valley geomorphic provinces. The elevation ranges from 360 feet at its confluence with the Sacramento River, to approximately 6,740 feet in the mountains to the east. The watershed's principal tributaries are North Fork Bear Creek, and South Fork Bear Creek. The Bear Creek watershed encompasses approximately 136 square miles. Average annual flows from 1959 – 1967 recorded in the main stem of Bear Creek at the Highway 44 Crossing was 715,312 acre feet.

Bear Creek Weir Location

The location of the Bear Creek weir was on private land upstream of the Parkville Road crossing, ~1.25 miles from the confluence with the Sacramento River.

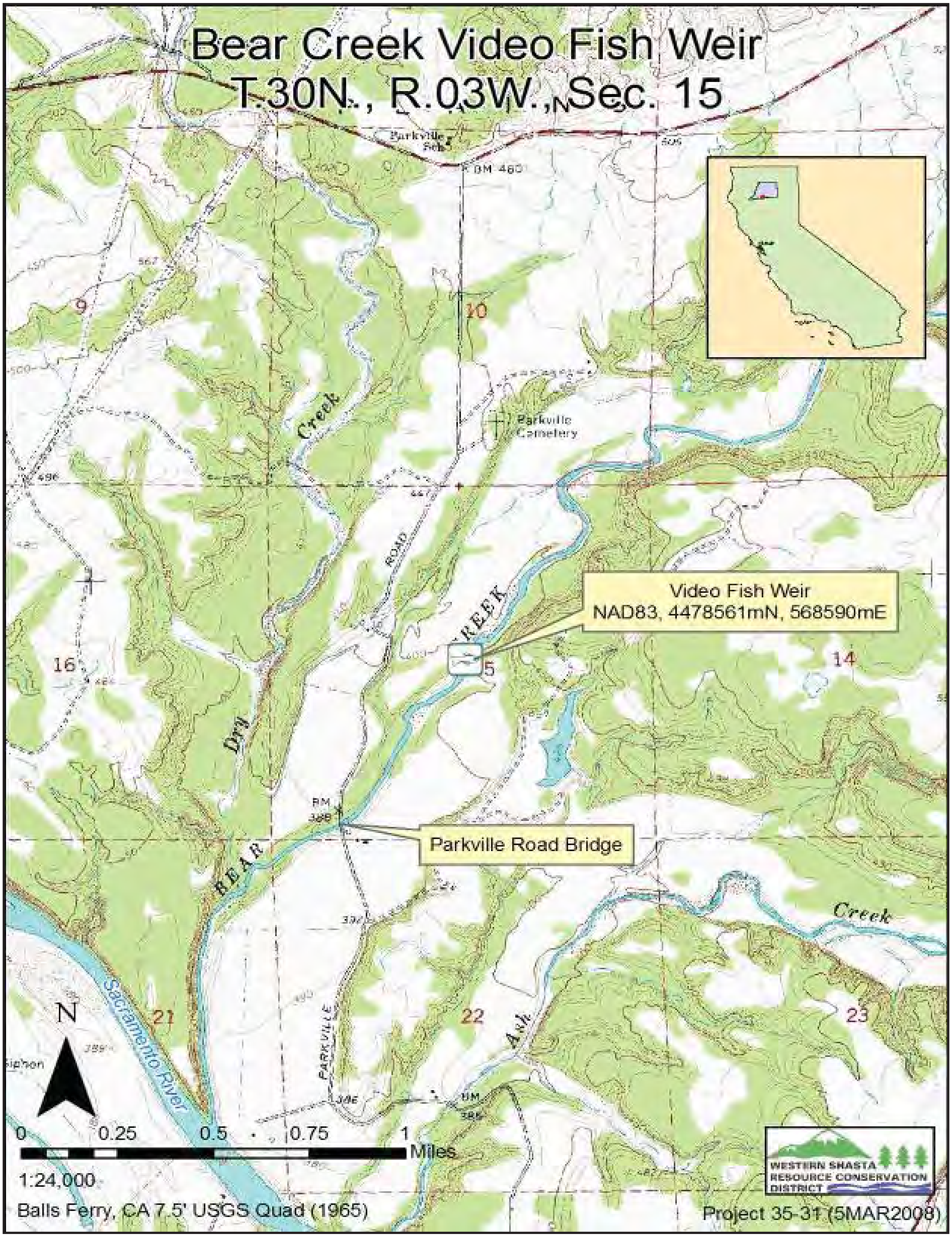

Figure 4. Map detailing the location of the video station on lower Bear Creek.

METHODS AND MATERIALS

As a pilot project, the experimental stations experienced slight changes over the years as video and DVD recording equipment progressed in quality and/or abilities. While certain equipment was originally selected as being "time tested" (DVR's became an invaluable tool for the project), other equipment was used and then abandoned (VCR's, Quad Processors, certain underwater cameras, etc). New underwater cameras were valuable to help identify adipose fin clips in 2009 (salmonids whose adipose fins were clipped off by hatcheries prior to release), but these cameras were not available earlier.

Each video station was comprised of two groups of commonly available equipment:

1. Electronics:
   - Power supply and back-up power supply
   - Overhead camera
   - Underwater camera(s)
   - Lights
   - Digital video recorders (DVRs)
2. Infrastructure:
   - Weir panels
   - Camera support cables
   - DVR lock box
   - Large white plates on the stream bed

POWER SUPPLY

The three video stations were located near a conventional "on-grid" power supply and, if necessary, a 120-volt transformer was installed to run the camera, lights, and equipment. Wiring was run from the power supply to the cameras and recording equipment. An accessible equipment lock box was set up to keep recording equipment safe from weather and vandalism. An in-line Ground Fault Interrupt Circuit (GFIC) device provided an automatic shut-off for the system should the power supply short out or contact any water.

A back-up power supply provided power for a 1-2 day period should an outage occur in the regular power supply (consisting of 6 linked 6-volt batteries provided a 12-volt DC power supply to a conventional computer battery backup system).

OVERHEAD CAMERA SYSTEM

Weatherproof black and white cameras were chosen to provide a high quality image in various lighting conditions. The camera was attached to the outside of a larger box that contained remote lighting and other wiring hookups. The camera box was suspended from two main galvanized steel cables directly over the fish passage opening (Figures 5 and 6). The end of the main cable closest to the DVR-battery box was designed to allow easy movement up and down with a mechanical "come-along" so the camera could be raised or lowered if the lighting needed an adjustment, or if camera cleaning was required. In previous years, the system required a 10 foot ladder to clean the cameras and change the lights.


Figure 5. Bear Creek video station power supply box. Cables were used to suspend the camera directly over the weir's fish passage opening. The equipment lock box was located to the right (not shown).

Figure 6. Camera box suspended over Bear Creek, looking upstream. Shown are three underwater cameras, the overhead camera, and the weir opening allowing fish passage.

The camera box was attached by ropes to the main cables, which reduced vibration caused by wind. Power cords and a camera co-axial cable were wired to an overhead support cable with short plastic coated utility wire and connected inside the station's DVR-battery box. Figure 7 shows the refurbished refrigerator used to secure and shelter the station's video equipment, electrical accessories and batteries.

Figure 7. The modified refrigerator contained the DVR's, power controls, equipment and storage boxes, monitor and batteries. The cable above the lock box is the anchoring cable to the two main cables suspending the camera over the creek.

UNDERWATER CAMERA SYSTEM

The underwater camera system was developed and refined over the years and became a standard tool in late 2008. In prior years the cameras were used sporadically and were not placed in standard locations. Since late 2008, three underwater cameras were typically installed on the white weir plate (background plates). The cameras could be color or black and white, depending on the objective at the time of set-up. Two cameras were installed in the middle near the lower edge of the plate and the view set to look across the plate for a side view of passing fish. White panels were installed along the sides so the fish would be silhouetted against a light background. The third camera was installed near the top of the weir plate to one side to look across the whole weir plate (Figures 6 and 8). The underwater cameras monitored upstream and downstream movement. The use of color cameras provided an additional means of identifying fish based on distinguishing color patterns, but the best color information was available only in bright light conditions. In low light levels, such as night time, the camera merely recorded a black and white image.

The cameras were protected inside a custom-made high grade PVC water-proofed capsule. The capsule was strapped to a 20-pound metal plate that was anchored in the creek bed to withstand any pressures from the current. The camera's video and power cable ran atop the weir panels, and once away from the creek, it was buried underground from that point to the lock box to deter vandalism.

The images from the cameras were recorded on both a DVR and a backup time lapse VCR to ensure continuous video coverage in the event of a malfunction. A small TV monitor was used to observe the image from the camera and to check the DVRs for proper operation throughout the season.

Figure 8. The underwater cameras were useful for monitoring up and down stream movement as well as species identification. The two cameras in the middle have a sideways view.

LIGHTS

Lighting for the video cameras was provided by two compact outdoor fluorescent spotlights mounted on the overhead cable system (visible in Figure 6). A photocell sensor, similar to those used on streetlights, turned the lights on at dusk and off at dawn. Crews checked the lights for proper operation by reviewing video footage from the previous morning during their daily weir maintenance.

WEIR SYSTEM

Weirs were designed and constructed to channel salmon into the camera's view without causing passage delay (Figure 6). The weirs were constructed of 10-foot x 1 1/8 inch steel pipes welded to uprights with 3-inch spaces between the pipes. Taller panels used 1 ¼ inch EMT conduit on the inner cross-members to lighten the overall weight of the finished panel. The horizontal pipe panels were designed to fit the depth of the creek at the weir site, e.g. panels in shallow water had only two or three cross members while panels in deeper water had more. The horizontal design and spacing between bars of the weir panels allowed leaves and sticks to pass downstream while preventing salmon from passing the weir unmonitored. Panels were secured with rebar stakes and specially designed "dog leg" fittings. The rebar stakes were driven vertically through the panel uprights and into the stream bottom. The dog leg fittings were bolted to the uprights and a "weir arm" was slid through the fitting and pounded into the stream bottom at a 45 degree angle downstream (Figure 9).

Figure 9. Construction of the weir. Dog leg fittings were bolted to the uprights and the "weir arm" slides through the fitting and was pounded into the stream bottom at a 45 degree angle downstream.

In sandy areas or areas susceptible to undercutting, a three-foot wide chain link fence was placed down under the weir panels to prevent scour during high flows. The weir panel was situated so that six inches of the underlayment fencing protruded upstream of the weir and the remainder was exposed downstream.

Two weir panels were placed along the outside edges of the white bottom plates just above the water surface. These guidance panels at the fish passage opening prevented fish from skirting around the ends of the weir (Figure 11).

White high-density polyethylene (HDPE) sheets were staked to the creek bottom below the overhead camera to create a background to improve viewing of the passing fish (Figure 10). The sheets had ¾-inch holes drilled around the perimeters to allow staking and a metal frame plate was bolted to the upstream edge of both sheets prior to placement in the creek. Twenty-four inch concrete form stakes, with a 2-inch washer welded to the top, secured the sheets.

A metal rectangle measuring 24-inches long by 12-inches wide was attached to the sheets allowing tape readers to approximate fish lengths (Figure 11). This rectangle was also designed with a custom welded "station brand" in the center. While viewing, tape readers were able to identify individual creek footage by the brand: BR= Bear Creek (Figure 11).

Figure 10. Construction of a weir included white high density polyethylene (HDPE) sheets staked to the creek bottom to make the observation of passing salmon easier.

Figure 11. Two weir panels were added to the fish passage opening to prevent fish from skirting around the ends of the weir. A metal rectangle measuring 24 x 12-inches allowed tape readers to approximate fish lengths as well as identify the creek: BR= Bear Creek.

VIDEO STATION OPERATION AND MAINTENANCE

Each video station was field-checked daily during operation. Activities included:

- Checking the DVR and monitor for correct operation and camera function.
- Checking power levels and normal operation of equipment (lights, DVRs, etc).
- Cleaning the weir and white plates of algae, debris, and carcasses.
- Recording comments and the time of visit in the station logbook.

COUNTING PROCEDURES

Each day was divided into 48 half-hour viewing periods. WSRCD and CDFG personnel reviewed DVR footage on a DVD player in the office. Any fish, regardless of species, that passed upstream or downstream of the upper end of the white plates was counted. In some instances, salmon that spawned adjacent to the weir area actively pursued other salmon both up and down through the opening while defending their spawning area. Fish moving downstream were subtracted from the total moving upstream for each period to maintain an accurate net upstream count. All DVRs recorded the time of fish passage, therefore, accurate determinations could be made regarding the daily timing of fish movements.

DATA ADJUSTMENTS

Several factors affected the staff's ability to count every fish that moved into the watershed, including:

- fish spawning between the mouth of the creek and the weir;
- missing time periods due to floods (weir panels over-topped and/or turbid water);
- technical difficulties with the lights, cameras, DVD recorders, etc; or
- video reader error in species identification or actual count.

Redd surveys of fish spawning downstream of the weir were conducted by CDFG field biologists periodically during weir operations. Each redd was counted as two salmon each and added to the video season total count.

The video counts were adjusted by either adding fish or subtracting fish depending on the event that may have caused the potential discrepancy in fish tallies during that time period. Fish counts during floods and turbid water episodes or times when technical difficulties were experienced were estimated by Doug Killam of CDFG by assessing data of actual counts of fish passage in the days before and after the event (Doug Killam, CDFG, unpublished information, 2011).

CDFG personnel made quality control (QC) checks on all half-hour periods where fish passage counts were greater than nine. These QC checks happened more often in 2007 since there were greater numbers of fish than in 2008 and 2009. If counts for these periods were different from the original "reads," then a third count was made to determine a final count. Periods with less than 10 fish passing were stratified by the initial reader and by two types of counts: Type 0 was = 1 or less fish and Type 1 was = 2 to 9 fish. A random sub-sample of each initial reader's stratified Types of counts was reviewed for QC by Department Staff. An adjustment factor was created for each stratum (reader and Type) to adjust all type 0 and Type 1 counts (including the QC checks). The adjustment factor and original counts were multiplied (for each stratum) to determine a "final QC" count. This count was summed for each period to calculate the total salmon passage for the station.

QC completed datasheets were then transcribed into a Microsoft Excel file. Electronic spreadsheets were used to organize the data. Passage data was then transferred into a CDFG Microsoft Access database where it was analyzed by date, time, month and week.

WATER TEMPERATURE AND FLOW MEASUREMENTS

Water temperature data were collected using a thermograph (continuous data recorder) placed at or near each video station. Continuous water flow data for Cow and Cottonwood creeks were also compiled by accessing U.S. Geological Survey (USGS) stream gauge data on the internet (CA Data Exchange Center: **http://cdec.water.ca.gov/river/sacto-creeks1.html**). The Cow Creek gauging station is located approximately 2.0 miles upstream of the weir. The Cottonwood Creek gauging station is located approximately 1.7 miles upstream of the weir. There is no USGS gauging station on Bear Creek.

CHINOOK ESCAPEMENT DATA AND ANALYSIS

Daily fish passage data in ½ -hour increments and minimum and maximum daily water temperature data were collected each year of the pilot study for all three creeks. From this data the following information could be derived:

- Seasonal summary of fish passage by day, week and month, including peak day, week and month.
- Seasonal summary of fish passage by 24 hour period in ½ -hour periods, including peak time period.
- Water temperatures when fish were first seen and at peak migration time.
- Stream flows when fish were first seen and at peak migration time.

RESULTS

COTTONWOOD CREEK COMPARISON BY YEAR

The Cottonwood Creek station was operational for three consecutive years starting in fall 2007. The weir was generally operational in mid September and removed in December. Figures 12 through 14 show flow rates very likely helped influence fish passage, and few fish crossed the weir until flow rates were above 79 cubic feet per second (cfs). Irrigation diversions typically end in mid-October and a combination of increased water flow and decreasing temperatures (Appendix A) cause the initial spike in fish counts. The "y" axes are different on Figures 12 through 14 to allow for easier viewing of data due to the varying numbers of fish from year to year.

COTTONWOOD CREEK 2007 SEASONAL FISH PASSAGE AND WATER FLOW DATA

The Cottonwood Creek video weir station operated from September 17 to December 6, 2007. Dates and times when video weirs were down can be found in Appendix B. The 2007 final adjusted estimate of fall-run Chinook salmon that entered Cottonwood Creek was **1,250** (an adjusted count of 1,214 plus an additional 36 salmon that spawned immediately downstream of the station site. This additional number was based on the assumption that the 18 observed redds in that location represented 2 salmon per redd). The peak day count occurred on October 10, 2007 with 344 fish passing, a mean water temperature of 62.6^{o} F (60.7-65.0^{o}F), and a water flow of 79 cfs (Appendix C). The daily fish passage data and corresponding water flow in cfs are depicted in Figure 12.

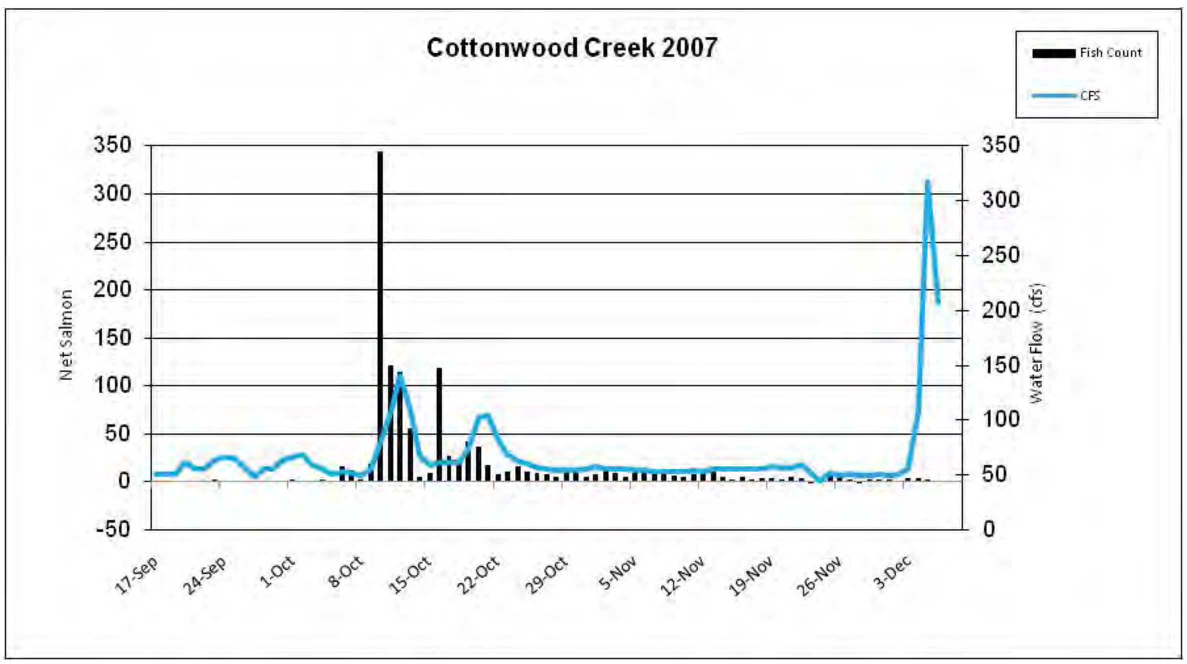

Figure 12. 2007 Total Daily Chinook Salmon Movement vs. Water Flow (cfs); Cottonwood Creek, Shasta County

COTTONWOOD CREEK 2008 SEASONAL FISH PASSAGE AND WATER FLOW DATA

The video station was operational from September 13 to December 29, 2008. Dates and times when video weirs were down can be found in Appendix B. The 2008 final adjusted estimate of fall-run Chinook salmon entering Cottonwood Creek was **510** (there were no salmon redds downstream of the weir in 2008). The peak day count occurred on October 15, 2008 with 41 fish passing, a mean water temperature of 62.5°F (58.7-66.2°F), and a water flow of 125 cfs (Appendix C). The daily fish passage data and corresponding water flow in cfs are depicted in Figure 13.

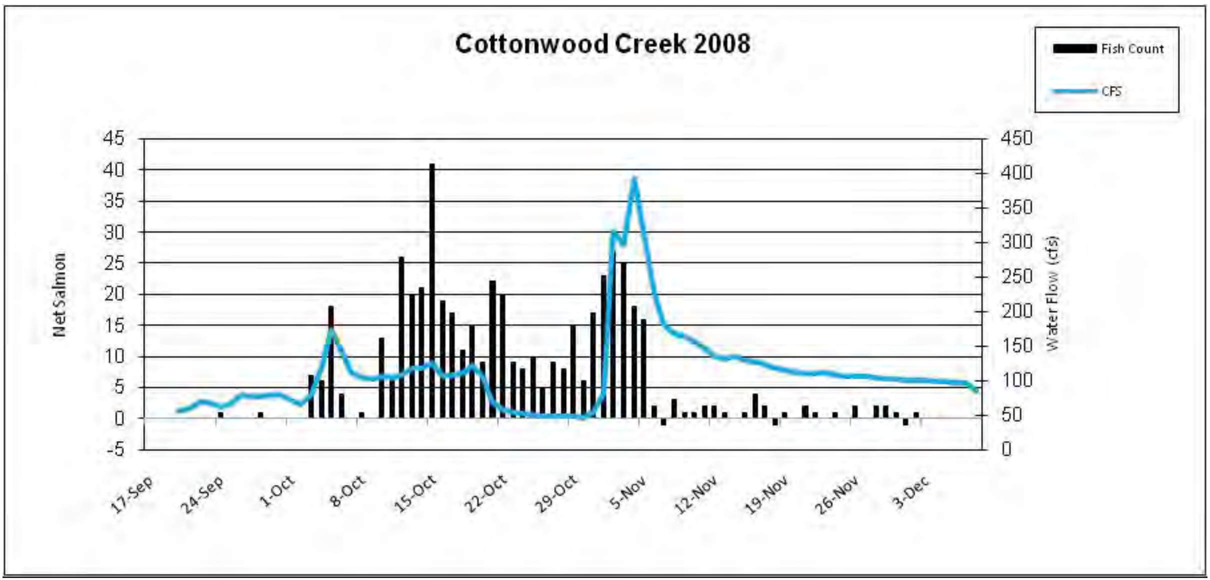

Figure 13. 2008 Total Daily Chinook Salmon Movement vs. Water Flow (cfs); Cottonwood Creek, Shasta County

COTTONWOOD CREEK 2009 SEASONAL FISH PASSAGE AND WATER FLOW CORRELATIONS

The video station was operational from September 21 to December 21, 2009. Dates and times when video weirs were down can be found in Appendix B. The 2009 final adjusted estimate of fall-run Chinook salmon entering Cottonwood Creek was **1,065** (an adjusted count of 1,055 plus an additional 10 salmon that spawned immediately downstream of the station site. This additional number was based on the assumption that the 5 observed redds in that location represented 2 salmon per redd). The peak day count occurred on October 13, 2009 with 171 fish passing, a mean water temperature of 62.9°F (60-66°F), and a water flow of 120 cfs (Appendix C). The daily fish passage data and corresponding water flow in cfs are depicted in Figure 14.

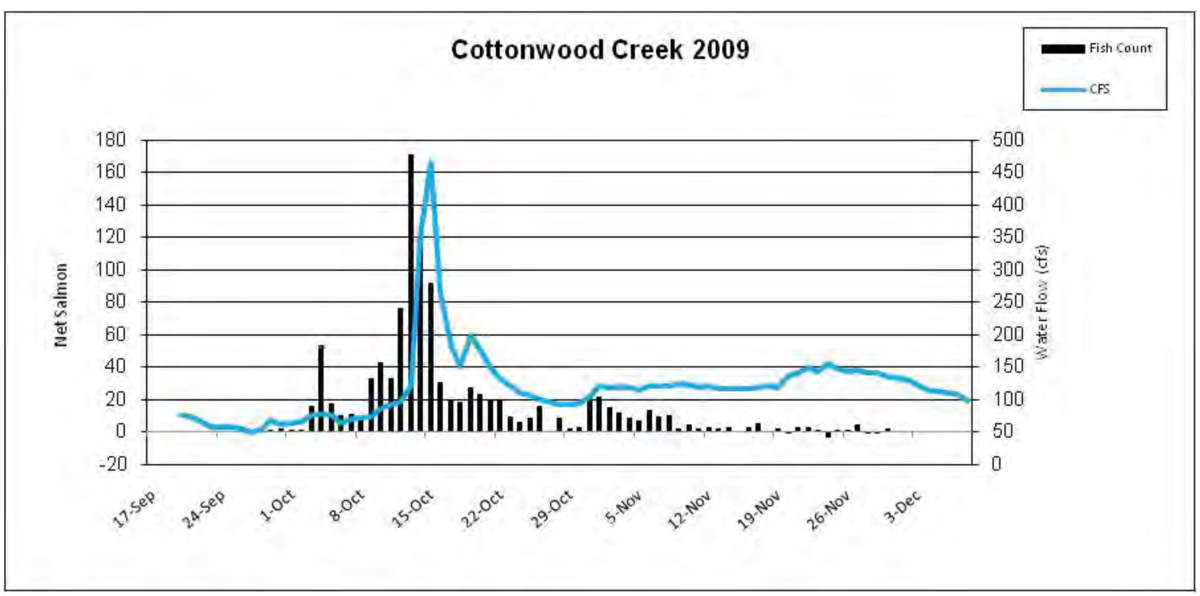

Figure 14. 2009 Total Daily Chinook Salmon Movement vs. Water Flow (cfs); *Cottonwood Creek, Shasta County*

COTTONWOOD CREEK 2007 – 2009 FISH PASSAGE PEAK WEEK AND MONTH

Table 1 provides Cottonwood Creek count data by month and week for 2007 – 2009. The data reveals peak passage for fall-run Chinook into Cottonwood Creek occurred in October, with the majority of fish passing in the middle of the month. Peak passage varies depending on water temperature and flow. The initial migration for the years 2007 – 2009 began in the first week of October each year (October 1 – 7). Average water temperatures were 64^{o}F (57-70.9^{o}F) in 2007 and 68^{o}F (63.29-74.21^{o}F) in 2008. In 2009 temperature data was only collected on October 1, 2009 due to a malfunction in the thermometer. The average water temperature on October 1, 2009 was 63.11^{o}F (61.94-64.52^{o}F). Average flows during the initial migration were 57.86 cfs (51-70 cfs) in 2007, 57.86 cfs (51-70 cfs) in 2008, and 57.86 cfs (51-70 cfs) in 2009. Data in the first and last week could be partial counts since the station was in operation only a portion of those weeks due to the timing of installation and removal of the weir.

Table 1. Summary of Fall-Run Chinook Salmon Passage 2007 – 2009, Shasta County, CA

Cottonwood Creek Monthly Chinook Salmon Summary			
	Total Fish Passage		
Month	2007	2008	2009
September	1	2	3
October	**1051**	**363**	**909**
November	153	138	130
December	9	7	13

Weekly Chinook Salmon Summary				
		Total Fish Passage		
Week	Dates	2007	2008	2009
38	Sep 17 - 23	1	0	0
39	Sept 24 - 30	0	2	3
40	Oct 1 - 7	28	35	109
41	Oct 8 - 14	**660***	88	**478***
42	Oct 15 - 21	270	**133***	229
43	Oct 22 - 28	63	69	66
44	Oct 29 - Nov 4	63	131	83
45	Nov 5 - 11	60	24	47
46	Nov 12 - 18	33	9	16
47	Nov 19 - 25	20	5	6
48	Nov 26 - Dec 2	8	7	5
49	Dec 3 - 9	8	0	0
50	Dec 10 - 16	NA	0	5
51	Dec 17 - 23	NA	4	8
52	Dec 24 - 30	NA	3	NA
Total		**1214**	**510**	**1055**

*peak passage times

Fish counts in Table 1 include only the number of fish that passed through the video weir.

Cottonwood Creek 2007 – 2009 Fish Passage by Time of Day

Because the weir plate was lighted 24 hours per day, a tally of fish movement by time of day was possible as shown by Figure 15. It appears fish movement was similar in 2008 and 2009, but it has little correlation to 2007. Without additional years of sampling data, it would be difficult to determine with certainty if there is a correlation between fish movement and time of day. What was observed in these three years was that peak movement during 2007 occurred between 12:00 noon and 6:00 PM while peak movement during 2008 and 2009 occurred between 6:00 PM and 11:00 PM.

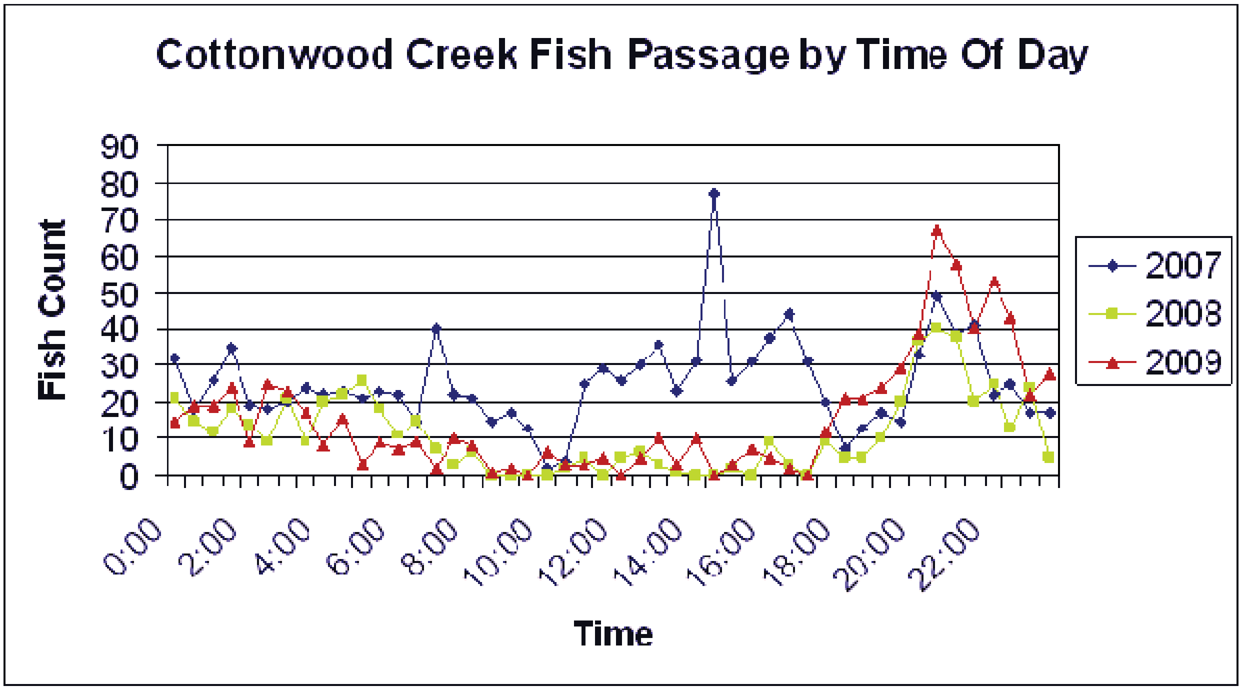

Figure 15. 2007-2009 Total Daily Chinook Salmon Movement by Time Of Day; Cottonwood Creek, Shasta County

COW CREEK COMPARISON BY YEAR

The Cow Creek station was operational for four consecutive years starting in 2006 (CDFG, 2007). However, the data presented in this section does not include 2006 data because there is no correlating data for 2006 in Cottonwood and Bear Creeks. In 2007-2009 the weirs generally went in during the middle of September and were taken out towards the end of December. Figures 16 through 18 show flow rates very likely helped influence fish passage, and few fish crossed the weir until after the flow rates were above 50 cfs. Irrigation diversions typically end in mid-October and a combination of increased water flow and decreasing temperatures (Appendix A) cause the initial spike in fish counts. The "y" axes are different on Figures 16 through 18 to allow for easier viewing of data because the numbers of fish vary from year to year.

Cow Creek 2007 Seasonal Fish Passage and Water Flow Correlations

The video station was operational between September 20 and December 6, 2007. Dates and times when video weirs were down can be found in Appendix B. The 2007 final adjusted estimate of fall-run Chinook salmon that entered Cow Creek was **2,044** (an adjusted count of 2,038 plus an additional 6 salmon that spawned immediately downstream of the station site. This additional number was based on the assumption that the 3 observed redds in that location represented 2 salmon per redd). The peak day count occurred October 10, 2007 with 581 fish passing, a mean water temperature of 60.2^{o}F (58.8-

61.9°F), and a water flow of 90 cfs (Appendix C). The daily fish passage data and corresponding water flow in cfs are depicted in Figure 16.

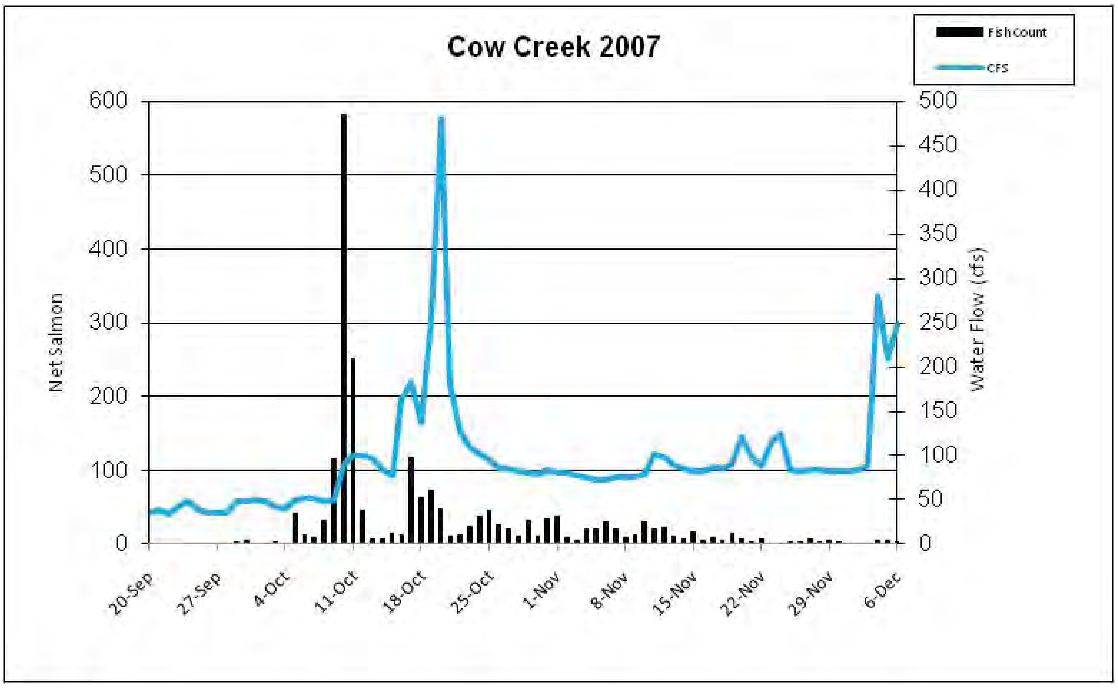

Figure 16. 2007 Total Daily Chinook Salmon Movement vs. Water Flow (cfs); Cow Creek, Shasta County

COW CREEK 2008 SEASONAL FISH PASSAGE AND WATER FLOW CORRELATIONS

The video station was operational between September 13 and December 18, 2008. Dates and times when video weirs were down can be found in Appendix B. The 2008 final adjusted estimate of fall-run Chinook salmon that entered Cow Creek was **478** (there were no salmon redds downstream of the weir in 2008). The peak day count occurred on November 1, 2008 with 130 fish passing, a mean water temperature of 58.3°F (57.8-59.9°F), and a water flow of 89 cfs (Appendix C). The daily fish passage data and corresponding water flow in cfs are depicted in Figure 17.

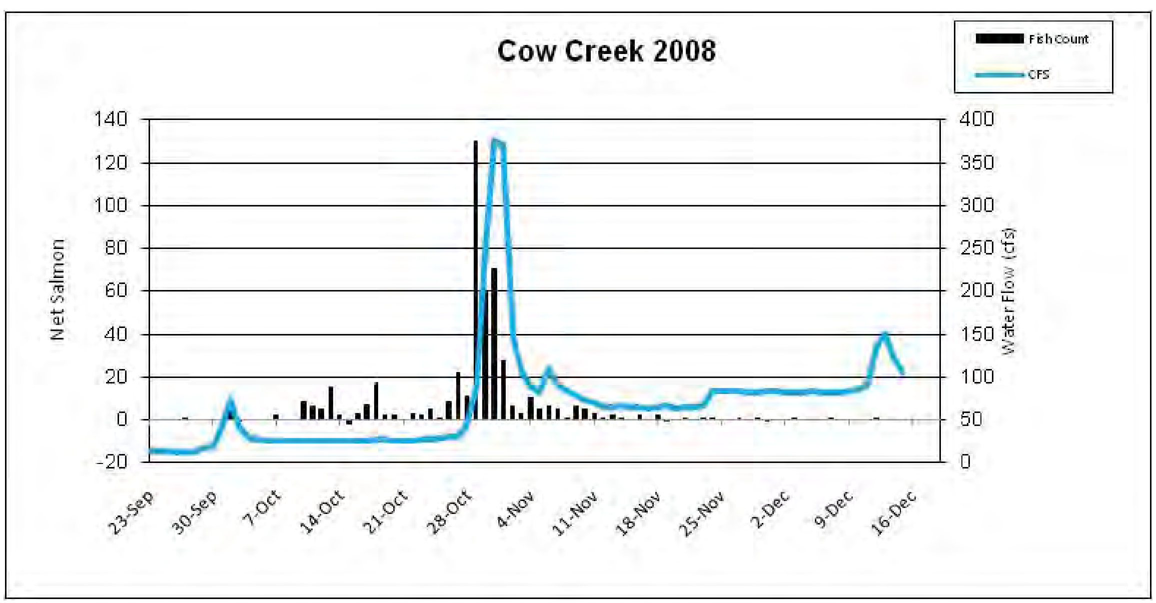

Figure 17. 2008 Total Daily Chinook Salmon Movement vs. Water Flow (cfs); Cow Creek, Shasta County

COW CREEK 2009 SEASONAL FISH PASSAGE AND WATER FLOW CORRELATIONS

The video station was operational between September 23 and December 21, 2009. Dates and times when video weirs were down can be found in Appendix B. The 2009 final adjusted estimate of fall-run Chinook salmon that entered Cow Creek was **265** (there were no salmon redds downstream of the weir in 2009). The peak day count occurred on October 13, 2009 with 37 fish passing, a mean water temperature of 58.7°F (57.7-59.7°F), and a water flow of 50 cfs (Appendix C). The daily fish passage data and corresponding water flow in cfs are depicted in Figure 18.

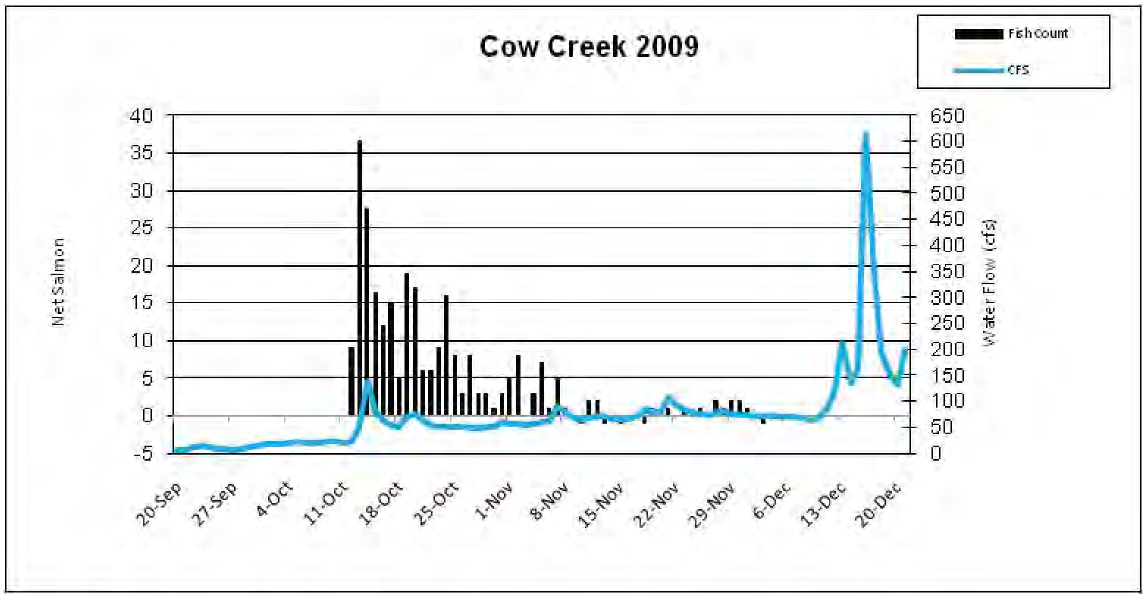

Figure 18. 2009 Total Daily Chinook Salmon Movement vs. Water Flow (cfs); Cow Creek, Shasta County

COW CREEK 2007 – 2009 FISH PASSAGE PEAK WEEK AND MONTH

Table 2 provides count data for each month and week for the years 2007 – 2009. The data reveals the peak passage for the fall-run in Cow Creek was similar in 2007 and 2009 and occurred in October, with the majority of fish passing in the middle of the month. 2008 was extremely dry fall where the flow in Cow Creek did not exceed 50 cfs until November 1, one month later than in 2007 and two weeks later than in 2009. This delay in flow could have been caused by heavy diversions above the weir, which would affect fall flows in the creek. The initial migration began the weeks of September 24 – 30, 2007; October 1 – 7, 2008, and October 8 – 14, 2009. Average water temperatures were 65.4°F (57.7-71.6°F) in 2007, 67.86°F (61.85-74.99°F) in 2008, and 61.71°F (57.64-67.33°F) in 2009. Average flows during the initial migrations were 41.71 cfs (36-49 cfs) in 2007, 32.86 cfs (12-73 cfs) in 2008, and 42.43 cfs (21-138 cfs) in 2009. Data in the first and last week could be partial counts since the station was in operation only a portion of those weeks due to the timing of installation and removal of the weir.

Table 2. Summary of Fall-Run Chinook Passage 2007 - 2009, Cow Creek, Shasta County, CA

Cow Creek Monthly Chinook Salmon Summary			
	Total Fish Passage		
Month	2007	2008	2009
September	6	1	0
October	**1687**	124	**224**
November	334	**351**	41
December	11	2	0

Weekly Chinook Salmon Summary				
		Total Fish Passage		
Week	Dates	2007	2008	2009
38	Sep 17 - 23	0	0	0
39	Sept 24 - 30	6	1	0
40	Oct 1 - 7	64	5	0
41	Oct 8 - 14	**1035***	16	73
42	Oct 15 - 21	336	47	**91***
43	Oct 22 - 28	117	15	53
44	Oct 29 - Nov 4	144	**329***	23
45	Nov 5 - 11	143	37	15
46	Nov 12 - 18	75	18	-1
47	Nov 19 - 25	31	4	4
48	Nov 26 - Dec 2	16	4	8
49	Dec 3 - 9	11	0	-1
50	Dec 10 - 16	NA	2	0
51	Dec 17 - 23	NA	0	0
Total		**2038**	**478**	**265**

*peak passage times

Fish counts in Table 2 include only the number of fish that passed through the video weir.

COW CREEK 2007 – 2009 FISH PASSAGE BY TIME OF DAY

Because the weir plate was lighted 24 hours per day, a tally of fish movement by time of day was possible as shown by Figure 19 below. A casual observation of the graph shows no obvious pattern over three years. Without additional years of sampling data, it would be difficult to determine with certainty if there is a correlation between fish movement and time of day. What was observed in these three years was that peak movement during 2007 occurred during daylight hours, which was similar in Cottonwood Creek. There did not appear to be a correlation between movement and time of day during 2008 and 2009.

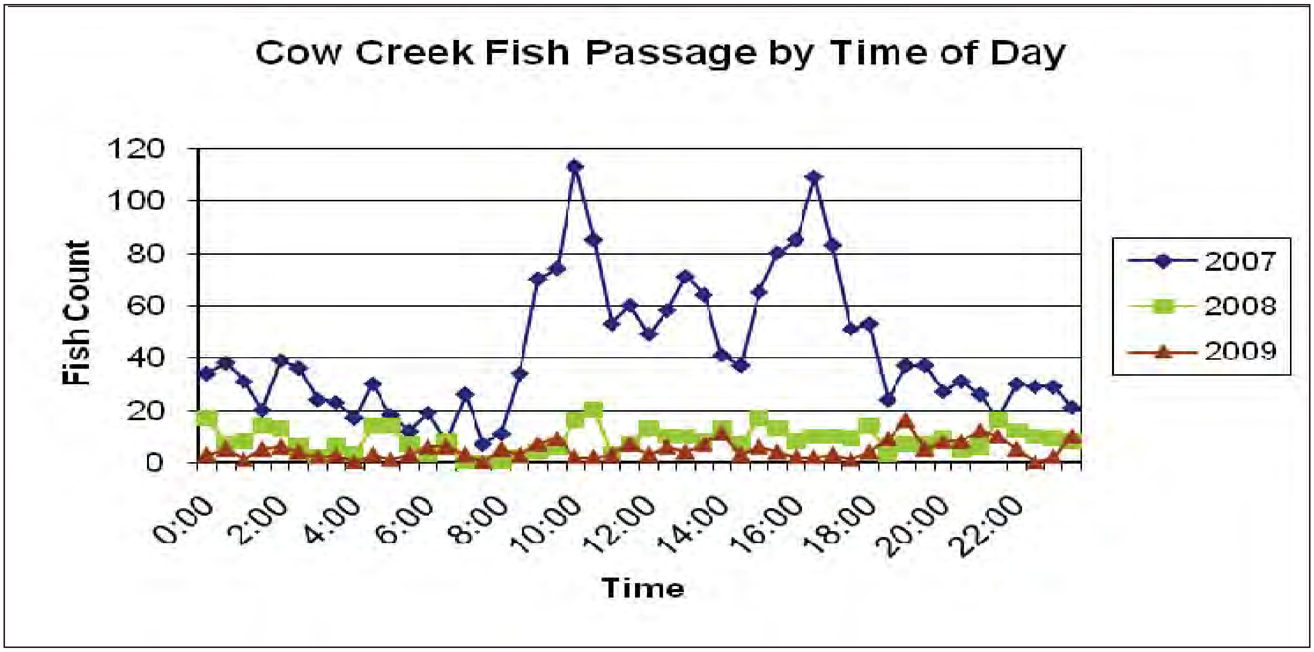

Figure 19. 2007 - 2009 Total Daily Chinook Salmon Movement by Time Of Day; Cow Creek, Shasta County

BEAR CREEK COMPARISON BY YEAR

The Bear Creek station was operational for three consecutive years starting in fall 2007. The weirs generally were installed in the middle of September and were removed towards the end of December. However, contrary to the periods in which the Cow and Cottonwood Creek video weirs were operated, Bear Creek's video weir was left in longer during the 2008 and 2009 monitoring periods to assess the ability to detect and document Central Valley steelhead (*Oncorhynchus mykiss*).

Bear Creek did not have flow data like other creeks in the study. Figures 20 through 22 show that decreasing temperatures, associated with increased flow, very likely helped influence fish passage, as was seen in Cottonwood and Cow Creeks. Irrigation diversions typically end in mid-October and a combination of increased water flow and decreasing temperatures (Appendix A) caused the initial spike in fish counts. The "y" axes are different on Figures 20 through 22 to allow for easier viewing of data because of the varying numbers of fish from year to year.

BEAR CREEK 2007 SEASONAL FISH PASSAGE AND WATER TEMPERATURE CORRELATIONS

The video station was operational between September 20 and December 17, 2007. The 2007 final adjusted estimate of fall-run Chinook salmon that entered Bear Creek was **140** (an adjusted count of 136 plus an additional 4 salmon that spawned immediately downstream of the station site. This additional number was based on the assumption that the 2 observed redds in that location represented 2 salmon per redd). The peak day count occurred on October 20, 2007 with 44 fish passing, a mean water temperature of 55.6^{o}F (53.5-57.4^{o}F). The daily fish passage data and corresponding water temperature are depicted in Figure 20. September 29 was the first day that the mean water temperature fell to 60^{o}F.

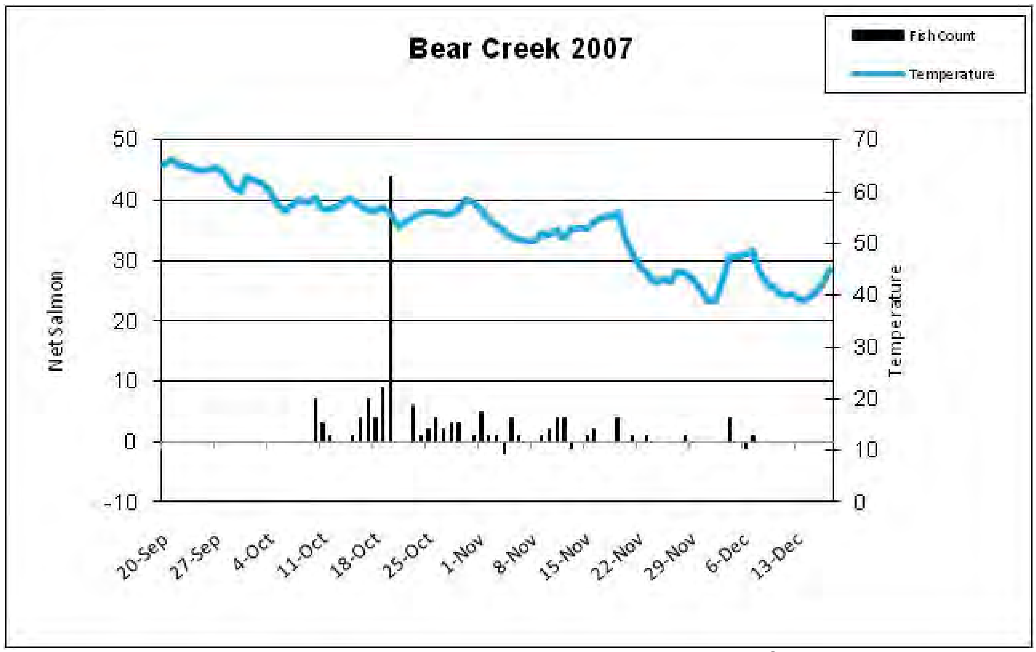

Figure 20. 2007 Total Daily Chinook Salmon Movement vs. Temperature (^{o}F); Bear Creek, Shasta County

BEAR CREEK 2008 SEASONAL FISH PASSAGE AND WATER TEMPERATURE CORRELATIONS

This year the video station was maintained through steelhead season. The video station was operational between September 23, 2008 and May 7, 2009. Dates and times when video weirs were down can be found in Appendix B. The 2008 final adjusted estimate of fall-run Chinook salmon that entered Bear Creek was **12** (there were 14 Chinook salmon counted in October and November, 2008. Two Chinook salmon were counted going downstream in March 2009, with one counted on March 5 and March 6, hence the reason for adjusting the fall-run estimate). The peak day count occurred on November 2, 2008 with 7 fish passing, a mean water temperature of 57.6^{o}F (57.0-58.2^{o}F). The daily fish passage data and corresponding water temperature in ^{o}F are depicted in Figure 21.

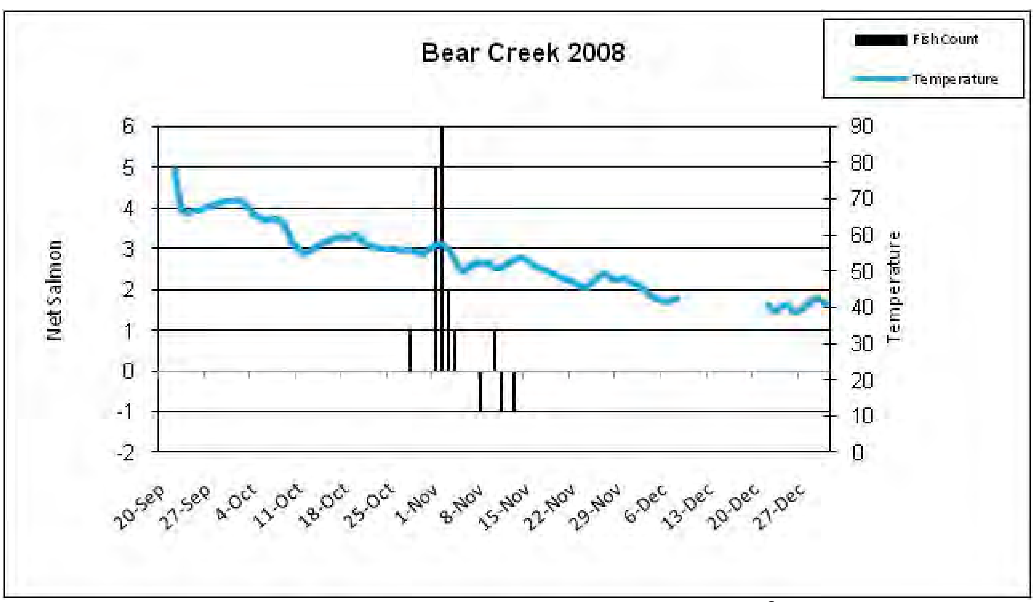

Figure 21. 2008 Total Daily Chinook Salmon Movement vs. Temperature (^{o}F); Bear Creek, Shasta County

BEAR CREEK 2009 SEASONAL FISH PASSAGE AND WATER TEMPERATURE CORRELATIONS

The video station was operational between September 13, 2009 and May 16, 2010. Dates and times when video weirs were down can be found in Appendix B. The 2009 final adjusted estimate of fall-run Chinook salmon that entered Bear Creek was **3** (there were 14 counted going upstream and 11 counted going downstream in a long season stretching between October 14, 2009 and February 28, 2010). The fall-run peak day count occurred on October 14, 2009 with 4 fish passing upstream. The mean water temperature was 63.8°F (61-66.6°F) on October 14, 2009. The daily fish passage data and corresponding water temperature in °F are depicted in Figure 22.

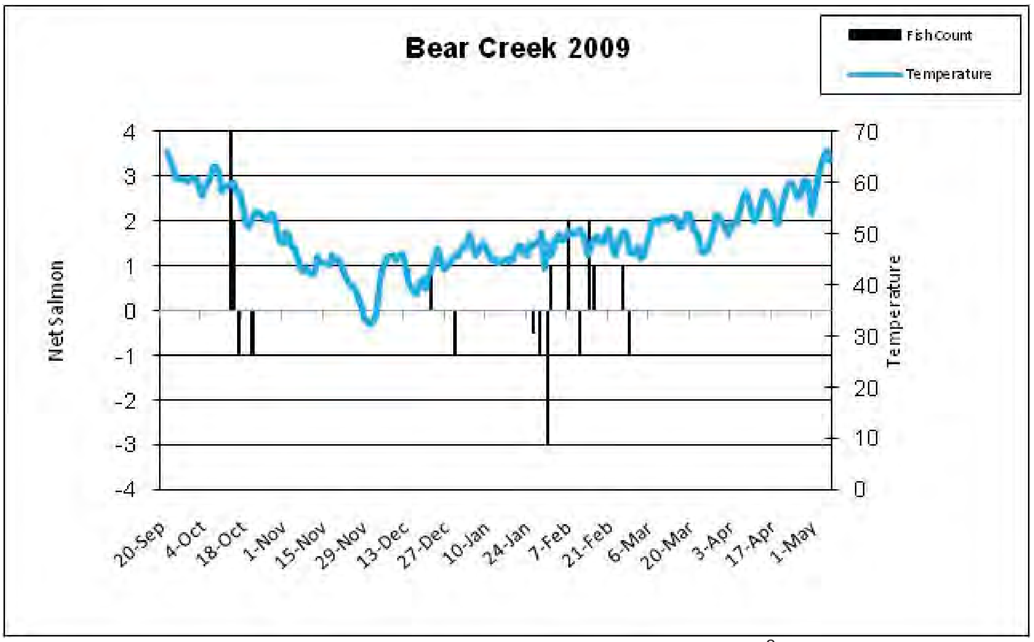

Figure 22. 2009 Total Daily Chinook Salmon Movement vs. Temperature (°F); Bear Creek, Shasta County

BEAR CREEK 2007 – 2009 FISH PASSAGE PEAK WEEK AND MONTH

Table 3 provides 2007 – 2009 count data by month and week. The video station was operational into late spring in 2008 and 2009; therefore comparisons with 2007 could only be made through December. Data reveals the peak passage for the fall-run at Bear Creek was similar in 2007 and 2009 and occurred in October, with the majority of fish passing in the middle of the month. Fish entered Bear Creek late in 2008, compared to 2007 and 2009, most likely due to low flows. Low salmon counts in 2008 and 2009 were similarly observed on Cow Creek. The initial migration began the weeks of October 8 – 14, 2007; October 22 – 28, 2008, and October 8 – 14, 2009. Average water temperatures were 57.71°F (54.61-62.79°F) in 2007, 56.26°F (53.08-60.56°F) in 2008, and 59.8°F (57.2-65.0°F) in 2009. Data in the first and last week could be partial counts since the station was in operation only a portion of those weeks due to the timing of installation and removal of the weir.

Table 3. Summary of Fall-Run Chinook Salmon Passage 2007–2009, Bear Creek, Shasta Co., CA

Bear Creek Monthly Chinook Salmon Summary			
	Total Fish Passage		
Month	2007	2008	2009
September	0	0	NA
October	**102**	1	**3**
November	30	**13**	0
December	4	0	0
January	-	0	-5
February	-	0	5
March	-	-2	NA

Weekly Chinook Salmon Summary				
		Total Fish Passage		
Week	Dates	2007	2008	2009
38	Sep 17 - 23	0	0	NA
39	Sept 24 - 30	0	0	NA
40	Oct 1 - 7	0	0	0
41	Oct 8 - 14	11	0	**4***
42	Oct 15 - 21	**69***	0	0
43	Oct 22 - 28	18	1	-1
44	Oct 29 - Nov 4	9	**15***	0
45	Nov 5 - 11	12	-1	0
46	Nov 12 - 18	6	-1	0
47	Nov 19 - 25	6	0	0
48	Nov 26 - Dec 2	1	0	0
49	Dec 3 - 9	4	0	0
50	Dec 10 - 16	0	0	0
51	Dec 17 - 23	0	0	1
52	Dec 24 - 30	NA	0	-1
	January	NA	0	-5
	February	NA	0	**5***
	March	NA	-2	NA
Total		**136**	**12**	**3**

*peak passage times

Fish counts in Table 3 include only the number of fish that passed through the video weir.

BEAR CREEK 2007 – 2009 FISH PASSAGE BY TIME OF DAY

Because the weir plate was lighted 24 hours per day, a tally of fish movement by time of day was possible (Figure 23). A casual observation of the data shows no obvious pattern between any of the three years. Without additional years of sampling data, it would be difficult to determine a correlation between fish movement and time of day with certainty. Peak movement during 2007 occurred during daylight hours, which was similar in Cottonwood and Cow creeks. With low fish counts during 2008 and 2009 there did not appear to a pattern between movement and a particular time of day.

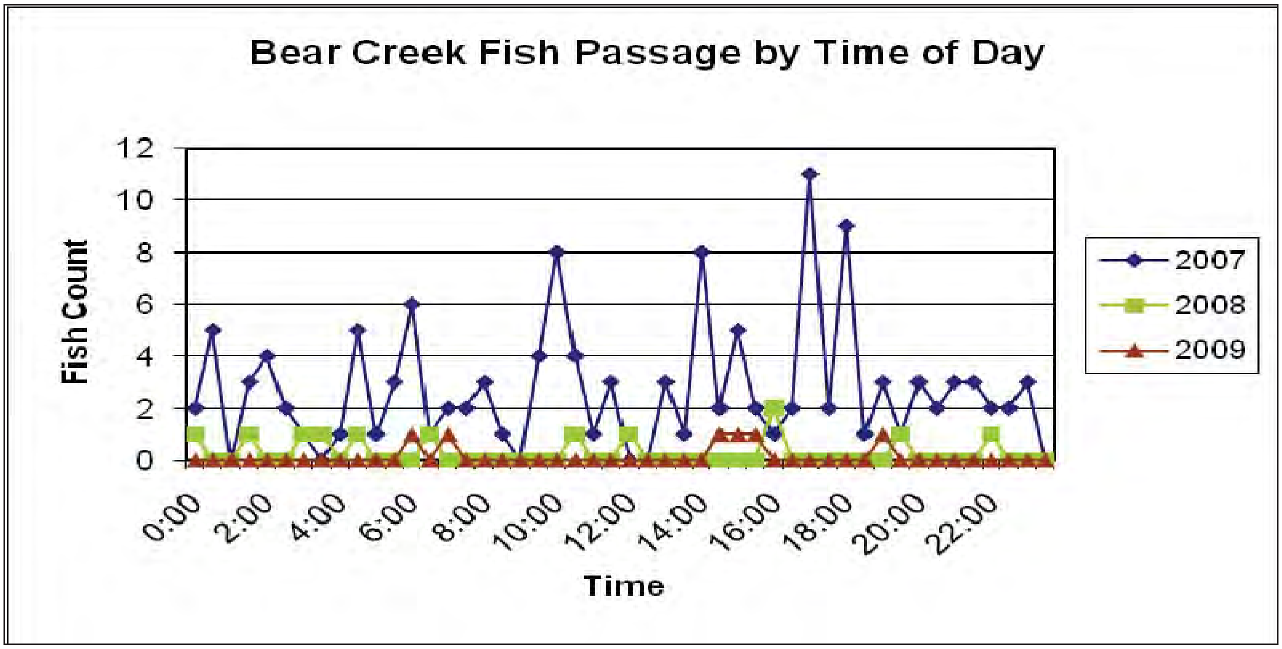

Figure 23. 2007 - 2009 Total Daily Chinook Salmon Movement by Time Of Day; Bear Creek, Shasta County.

DISCUSSION

Tables 4, 5, and 6 compare the Cottonwood, Cow, and Bear Creeks by year by the percent of time the video weirs were operational versus not operational. The reasons that the video weirs were not operational are noted in the tables. During non-operational times, the fish counts were estimated by CDFG using recent day counts to fill in the missing periods using an average formula for days before and after when counts were verifiable. The fish weirs were not operational due to the following reasons:

- Flooding and turbid water resulted in insufficient visibility for the counting and identification of fish.
- Video tape and camera malfunctions resulted in no data being recorded.
- Pacific Gas and Electric (PG&E) power outage resulted in no data being recorded.

Table 4
2007 Comparison of Creeks

Creek Name	Percent Operational	Percent Not Operational	Reason Not Operational
Cottonwood	96.1	3.9	Flooding/Turbid Water
Cow	97.2	2.8	Flooding/Turbid Water
Bear	99.7	0.3	Video Malfunction

Table 5
2008 Comparison of Creeks

Creek Name	Percent Operational	Percent Not Operational	Reason Not Operational
Cottonwood	96.9	3.1	Video Malfunction Turbid Water
Cow	94.7	5.3	Flooding/Turbid Water
Bear (2008-2009)	92.6	7.4	Camera/Video Malfunction Flooding/Turbid Water PG&E Power Outage

Table 6 2009 Comparison of Creeks			
Creek Name	**Percent Operational**	**Percent Not Operational**	**Reason Not Operational**
Cottonwood	93.4	6.6	Flooding/Turbid Water
Cow	89.7	10.3	Flooding/Turbid Water
Bear (2009-2010)	91.3	8.7	Flooding/Turbid Water Video Malfunction

RECOMMENDATIONS

The CDFG Red Bluff Office recommends that video weir stations continue to be used as a monitoring system on the Cottonwood, Cow, and Bear Creeks. Based on a comparison between video weir and mark-recapture counts, the use of video weirs is very feasible economically and in accuracy of fish counts. CDFG plans to implement video weir stations in many other creeks when funding is available. Improvements in camera, video, weir design, and power supply technology will continue to improve the video weir system, limiting the amount of time that the video weirs will be non-operational due to equipment malfunctions.

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Mr. Vince Shamoo and the Dubose Family for assistance with access to Bear Creek.

The WSRCD would like to thank Doug Killam of the CDFG Red Bluff Office, the other CDFG Red Bluff Office employees, and the Pacific States Marine Fisheries Commission employees in assisting with the fish weir installation, conducting maintenance on the fish weirs, and viewing the video data from the fish weirs.

The WSRCD and the CDFG Red Bluff Office would also like to thank the U. S. Fish and Wildlife Service, Red Bluff Office for funding to conduct these video fish weir surveys.

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APPENDICES

Appendix A
Temperature Data

Appendix B
Dates/Times Weirs Not Operational

Appendix C
Flow Data