CENTRAL VALLEY PROJECT IMPROVEMENT ACT
FISHERIES INVESTIGATIONS

Annual Progress Report
Fiscal Year 2019

U.S. Fish and Wildlife Service
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Prepared by staff of
The Anadromous Fish Restoration Program
PREFACE

The following is the Annual Progress Report, Central Valley Project Improvement Act Fisheries Investigations. The purpose of these investigations is to provide scientific information to other CVPIA programs to use in assessing fisheries restoration actions. The purpose of this report is to provide an update on the Anadromous Fish Restoration Program’s CVPIA-funded activities and accomplishments during fiscal year 2019 to interested stakeholders.

The field work described herein was conducted by Mark Gard, Rick Williams, Kes Benn, Paul Cadrett, Shawn Sanders, Tim Scully and Derek Rupert.

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OVERVIEW

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act provided for enactment of all reasonable efforts to double sustainable natural production of anadromous fish stocks including the four runs of Chinook salmon (fall, late-fall, winter, and spring), steelhead trout, white and green sturgeon, American shad and striped bass. In 2019, the following fisheries investigation tasks (Figure 1) were selected for study: 1) Paynes Creek upstream passage study; 2) Mill Creek Ward Dam fish ladder passage assessment; 3) Mill Creek Upper Dam fish ladder passage assessment; 4) Antelope Creek floodplain feasibility study; 5) Clear Creek Paige Bar experimental gravel augmentation monitoring; 6) North Fork Cottonwood Creek water temperature model; 7) North Fork Cottonwood Creek Bee Diversion Dam data collection; 8) Tuolumne River Bobcat Flat redd survey; 9) Lower Deer Creek Falls post-restoration monitoring; 10) Merced River floodplain restoration projects data collection; 11) Feather River Sunset Pumps topographic data collection; and 12) Central Valley Structured Decision Model technical support.

We performed the following fisheries investigations to assess fisheries restoration actions:

1) In FY 2019, we developed relationships between stream flows and upstream passage on Paynes Creek.
2) We collected topographic data at the Mill Creek Ward Dam fish ladder project.
3) We developed a hydraulic model at the Mill Creek Upper Dam fish ladder project to evaluate upstream passage at this location.
4) We conducted a feasibility study of potential floodplain restoration actions on Antelope Creek.
5) We collected data to quantify the amount of rearing habitat created by the Clear Creek Paige Bar experimental gravel augmentation.
6) We validated a water temperature model on North Fork Cottonwood Creek.
7) We collected topographic data to use in designing a solution to the upstream passage barrier on North Fork Cottonwood Creek at the Bee Diversion Dam.
8) We conducted a fall-run Chinook salmon redd survey for the Tuolumne River Bobcat Flat restoration project.
9) We conducted post-restoration monitoring of the Lower Deer Creek Falls fish ladder.
10) We collected depth, velocity and topographic data for Merced River floodplain restoration projects.
11) We collected topographic data for the Feather River Sunset Pumps upstream passage project.
12) We reviewed the Central Valley Structured Decision Model to identify needed changes to the model and sources of data that could be used to improve the parameterization of the model.

The results of these scientific investigations were provided to other CVPIA programs. The following sections summarize the twelve project activities that were performed between October 2018 and September 2019.
Figure 1
Fiscal Year 2019 Fisheries Investigation Tasks
FISHERIES INVESTIGATIONS

Paynes Creek Upstream Passage Assessment

Methods

The purpose of this task was to assess flows needed for upstream passage of anadromous salmonids through critical riffles in Paynes Creek, using the methods of CDFW (2015). This methodology was selected because preliminary information indicated that upstream passage is likely the critical life stage for instream flows in Paynes Creek. The concern is that some upstream migrating fish may not be able to migrate to suitable spawning habitat if they are blocked by shallow water at a riffle. Paynes Creek from Bend Irrigation District diversion to the Sacramento River was surveyed on February 11-12, 2019, at flows of 107.9-112.8 cfs, to identify and rank critical riffles. The riffles were ranked based on depth and width, with the highest ranked riffles being the shallowest and longest. Three of the highest-ranked riffles (Figure 2) were selected for study. Data for the critical riffle analysis (CRA) were collected as a four-part field sampling series, on the receding limb of the hydrograph as flows declined. The sampling events were timed to capture the full range of discharges necessary to adequately bracket and identify passage flows for fall-run Chinook salmon and steelhead adults and juvenile salmonids on Paynes Creek (Table 1).

Once a riffle was identified for critical riffle analysis, the transect was established, marked on each bank with flagging and rebar, and photographed. A discharge measurement was taken onsite. Onsite discharge measurements were made following procedures of Rantz (1982). A transect was established at each critical riffle running along the shallowest course of the riffle from bank to bank using a measuring tape. The transects are not linear, but instead follow the contours of the riffle along its shallowest course from bank to bank. The critical riffle transect was established during the first sampling event, and then was used repeatedly for each subsequent sampling event at different flows. Staff waded the riffle and determined the shallowest course from bank to bank. Several 2.5 ft pieces of 0.5 inch diameter rebar were hammered into the riffle contour, and a wind-up, light-weight measuring tape was attached to the rebar. The headpin (rebar) for each critical riffle transect is located on the left bank of the river looking upstream, and the tail pin (rebar) on right bank looking upstream. The headpin serves as the starting point for each critical riffle water depth measurement, starting from zero feet, and the tail pin serves as the end point of the measurements. Once head- and tail pins are in place, a wind-up, light-weight measuring tape is attached to the base of the headpin. The tape is then extended working across the riffle, following the contour of shallowest course until reaching the tail pin, where the tape is then attached to the tail pin. This process is followed for each subsequent sampling event.
**Table 1**

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

<table>
<thead>
<tr>
<th>Species and Life Stage</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fall Run Chinook Salmon</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Adult</td>
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<tr>
<td>Juvenile</td>
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<tr>
<td><strong>Steelhead</strong></td>
<td></td>
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<tr>
<td>Adult</td>
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<td></td>
</tr>
<tr>
<td>Juvenile</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Source: Matt Johnson, California Department of Fish and Wildlife, 2016.
Five nearby streams (Mill, Deer, Battle, Cow and Cottonwood Creeks) were assessed to determine which stream had flows that were best correlated with Paynes Creek. The Cow Creek flow gage (USGS No. 11374000) had the highest correlation with Paynes Creek flows. Specifically, a regression equation of Paynes Creek flows with flows from the Cow Creek gage had an $R^2$ value of 0.85. As a result, the Cow Creek flow gage was used to assess whether flow levels changed during the data collection. Depths were measured every two feet along the transect. A stadia rod (with scale to 100ths of a foot) was used to measure depth along each transect. After measuring water depths, the data were recorded in a field notebook for each distance across the transect. Careful attention was taken to record water depths at individual locations as the fish would encounter and use them.

In accordance with CDFW (2015), depth and velocity criteria were used to assess critical riffles; criteria are presented below in Table 2. A site is deemed passable when a combination of minimum stream flow depths and wetted widths are greater than conditions specified by two evaluation parameters: the percentage of the total transect width meeting the life stage-specific depth criteria and the contiguous percentage of the transect width meeting the life stage-specific depth criteria (Thompson 1972). The more stringent of the two criteria are used to establish passage flows. 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 (ft/s) is considered appropriate for adult Chinook salmon and steelhead (Thompson 1972; Table 2). 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 criteria for adult Chinook salmon, adult Steelhead, and juvenile salmonids are 0.9 ft, 0.7 ft, and 0.3 ft, respectively (CDFW 2015; Table 2). Where migration timing overlaps (see Table 1), the deeper body depth criteria must take precedence to protect all species and life stages present.

<table>
<thead>
<tr>
<th>Species (Life stage)</th>
<th>Minimum depth (ft)</th>
<th>Maximum Velocity (ft/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook Salmon (adult)</td>
<td>0.9</td>
<td>8.0</td>
</tr>
<tr>
<td>Steelhead (adult)</td>
<td>0.7</td>
<td>8.0</td>
</tr>
<tr>
<td>Salmonid (young-of-year/juvenile)</td>
<td>0.3</td>
<td>---</td>
</tr>
</tbody>
</table>

Results

The three riffles were sampled four times between April 8 and July 15, 2019 at flows ranging from 3.4 to 99.3 cfs (representing the 38.8th to 85.6th percentile annual flows for Paynes Creek, Table 3). The fastest velocity measured for any of the riffles was 3.27 ft/s. Photos, including latitudes and longitudes of the riffles, and regressions are shown in Appendix A. For Riffles 2 and 5, there were multiple flows with zero width for depths ≥ 0.9 feet. Accordingly, we only used the highest flow with a zero width in the regressions for those criteria. For Riffle 2 for contiguous juvenile passage and for Riffle 5 for total juvenile passage there was not a linear relationship over the entire range of flows. As a result, we only used the lowest three flows for these regressions.

As shown in Table 4, Riffle 2 (with a length of 146 feet) was the most critical riffle for upstream passage, while Riffle 5 was the least critical riffle for upstream passage. Mean monthly flows (based on the 17 year period of record (1949-1966) of daily average flows for USGS Gage 113775001) and known diversions and diversion rates for Paynes Creek, as per SWRCB (2015), are shown in Table 5 and Figure 3. The above results can be used to establish flows for upstream passage in Paynes Creek.

Discussion

Riffle 2 is very long and needs very high flows to ensure adult Chinook upstream passage that correspond to an 89.6 percentile exceedance flow. There is more uncertainty in the Riffle 2 adult Chinook upstream passage flow than for the other riffles and species/life stages, since this flow represented the largest extrapolation beyond the measured flows. The mean monthly flows in Table 4 likely represent impaired flows, since USGS Gage 11377500 was located downstream of all diversions. The next step in developing instream flow requirements for Paynes Creek is to address water temperature data, since the availability of suitable water temperatures is a consideration in developing instream flow requirements.

Table 3
Sampling dates, flows and exceedances

<table>
<thead>
<tr>
<th>Date</th>
<th>Flow (cfs)</th>
<th>Exceedance</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/8, 11/19</td>
<td>92.8-99.3</td>
<td>85-85.6%</td>
</tr>
<tr>
<td>5/6/19</td>
<td>13.5</td>
<td>56%</td>
</tr>
<tr>
<td>6/10/19</td>
<td>11.8</td>
<td>54%</td>
</tr>
<tr>
<td>7/15/19</td>
<td>3.4</td>
<td>38.3%</td>
</tr>
</tbody>
</table>

Table 4
Flow needed at the 3 study riffles to ensure passage of adult and juvenile salmonids

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Riffle 2</th>
<th>Riffle 5</th>
<th>Riffle 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult Chinook Total Width</td>
<td>163</td>
<td>75</td>
<td>140</td>
</tr>
<tr>
<td>Adult Chinook Contiguous Width</td>
<td>144</td>
<td>87</td>
<td>113</td>
</tr>
<tr>
<td>Adult Steelhead Total Width</td>
<td>101</td>
<td>54</td>
<td>107</td>
</tr>
<tr>
<td>Adult Steelhead Contiguous Width</td>
<td>103</td>
<td>69</td>
<td>113</td>
</tr>
<tr>
<td>Juvenile Salmonid Total Width</td>
<td>31</td>
<td>7.3</td>
<td>35</td>
</tr>
<tr>
<td>Juvenile Salmonid Contiguous Width</td>
<td>18.4</td>
<td>9</td>
<td>92</td>
</tr>
</tbody>
</table>

Table 5
Paynes Creek Mean Monthly Flows and Diversions

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean Monthly Flows (cfs)</th>
<th>Mean Monthly Diversions (cfs)$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>204</td>
<td>0.22</td>
</tr>
<tr>
<td>February</td>
<td>232</td>
<td>0.22</td>
</tr>
<tr>
<td>March</td>
<td>108</td>
<td>0.22</td>
</tr>
<tr>
<td>April</td>
<td>81</td>
<td>0.36</td>
</tr>
<tr>
<td>May</td>
<td>22</td>
<td>1.90</td>
</tr>
<tr>
<td>June</td>
<td>6.6</td>
<td>1.90</td>
</tr>
<tr>
<td>July</td>
<td>1</td>
<td>2.32</td>
</tr>
<tr>
<td>August</td>
<td>0.41</td>
<td>2.20</td>
</tr>
<tr>
<td>September</td>
<td>1.5</td>
<td>1.79</td>
</tr>
<tr>
<td>October</td>
<td>10</td>
<td>0.88</td>
</tr>
<tr>
<td>November</td>
<td>38</td>
<td>0.22</td>
</tr>
<tr>
<td>December</td>
<td>151</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Figure 3
Paynes Creek Monthly Diversions

$^2$ From SWRCB (2015). Includes all diversions on Paynes Creek.
Mill Creek Ward Dam Fish Ladder Passage Assessment

Methods

The goal of this task was to collect topography following the mechanical removal of a large cobble bar\(^3\) upstream of the new 2015 Ward Dam fish ladder that causes an upstream passage impediment. Data were collected for the site using two survey-grade Real Time Kinematic Global Positioning System (RTK GPS) units.

Results

Topographic data were collected on October 26, 2018. A total of 2,519 data points were collected (Figure 4).

Discussion

The topographic data will help to inform investigations into a solution to upstream fish passage at Ward Dam.

\(^3\) The cobble bar seems to have been formed during a five-year flow event in March 2016, and reformed during an additional five-year flow event in February 2017 and a 1.5-year flow event in March 2018. There was an annual removal of that bar from 2016 on.
Mill Creek Upper Dam Fish Ladder Passage Assessment

Methods

The goal of this task was to develop a SRH-2D model of Mill Creek in the vicinity of Upper Dam to determine if a proposed new fish ladder at Upper Dam would result in deposition of cobbles upstream of the ladder, as has occurred for Ward Dam. On October 23-25, 2018, we collected 9,778 topography data points extending from 1,600 feet upstream of Upper Dam to 1,230 feet downstream of Upper Dam using two RTK GPS units (Figure 5). This data were supplemented by topography data collected by NHC for designing the new fish ladder, as well as six pre-restoration transects that we surveyed in 2016. On February 13, 2019, we measured a water surface elevation at the upstream end of the model using a RTK GPS unit, at a flow of 2,830 cfs, to calibrate the SRH-2D model. The downstream end of the survey was the downstream-most transect, located 1,230 feet downstream of Upper Dam, of a HEC-RAS model developed for the design of the new fish ladder. The survey below the dam included, going from downstream to upstream, a run, riffle and pool. The survey upstream of the dam included, going from downstream to upstream, a glide, pool, riffle and run.

A comma delimited file of topography data was produced to input into the Surface-water Modeling System (SMS, ver. 12.2.6 64 bit) software. For the proposed new fish ladder, the topography data were modified to incorporate the new fish ladder. A computational mesh was developed in SMS by first defining polygons based on aerial photography. Five material types were defined for the polygons, per Pasternack (2011): 1) overbank; 2) Upper Dam; 3) glide/run; 4) pool/canal and 5) high gradient riffle. Manning’s n values for the first two polygons were
taken from the HEC-RAS model, while Manning’s n values for the next two polygons were based on pebble counts. Manning’s n values for the last polygon were based on visual observation of substrate size during data collection (Table 6). Paving meshes with 3 feet by 3 feet square mesh elements were used for the entire site. The scatter dataset was interpolated to the computational mesh using the inverse distance weighted interpolation option in SMS. The resulting computational mesh was used as an input to SRH-2D Version 3.2.0 (USBR, Denver, CO), with a downstream boundary condition from the HEC-RAS model. The fixed-bed version of SRH-2D was run at the five-year flow of 9,180 cfs, for existing conditions and the proposed new fish ladder.

<table>
<thead>
<tr>
<th>Polygon</th>
<th>Roughness Element</th>
<th>Manning’s n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overbank</td>
<td>Vegetation</td>
<td>0.0425</td>
</tr>
<tr>
<td>Upper Dam</td>
<td>Concrete</td>
<td>0.016</td>
</tr>
<tr>
<td>Glide and Run</td>
<td>Small Cobble</td>
<td>0.026</td>
</tr>
<tr>
<td>Pool and Canal</td>
<td>Sand</td>
<td>0.025</td>
</tr>
<tr>
<td>Riffle</td>
<td>Large Cobble</td>
<td>0.032</td>
</tr>
</tbody>
</table>

Parameters for the mobile bed version of SRH-2D were based on pebble counts that we made as part of the pre-restoration monitoring in 2016. The Wilcock equation was used for sediment capacity. Since sediment supply data is not available for Mill Creek, we used the sediment capacity option for the upstream sediment input boundary condition, where the amount of sediment coming in at the upstream boundary is set equal to the capacity of the channel at that location to carry sediment. The output of the fixed bed version of SRH-2D was used as the initial condition for the mobile bed model.

**Results**

The topography data indicated that the Mill Creek channel downstream of Upper Dam has downcut since 2016 (Figure 6), while there were no significant aggredation or erosion upstream of Upper Dam. We were able to calibrate the SRH-2D model for existing conditions, with the simulated water surface elevation (WSEL) at the upstream boundary at 2,830 cfs only 0.01 feet higher than the measured WSEL. The mobile bed version of SRH-2D predicted uniform aggredation upstream of the dam of approximately 1 foot for both present (Figure 7) and proposed (Figure 8) conditions. Thus, the model does not predict that formation of a cobble bar at the fish ladder exit would occur with the proposed new fish ladder. However, the model does predict significant deposition of material (up to 5 feet) in the upper half of the proposed new fish ladder.
**Discussion**

While channel aggradation does not appear to be an issue at the exit of the proposed new fish ladder, channel incision downstream of Upper Dam would require reexamination of the plans for the new fish ladder to ensure that at low flows, the drop over the downstream weir will still meet the NMFS fish passage criterion of 0.5 feet. If the current proposed design no longer meets the above criterion, additional pools and weir would need to be added to the design. The fixed bed SRH-2D model could be used to evaluate this issue by running it at the low design flow. In addition, consideration is needed for operations of the fish ladder to address deposition of material in the fish ladder pools.
Figure 7
Predicted channel change under existing conditions. Positive values indicate erosion while negative values indicate deposition.

Figure 8
Predicted channel change under proposed conditions. Positive values indicate erosion while negative values indicate deposition.
Antelope Creek Floodplain Feasibility Study

Methods

The goal of this task was to develop a HEC-RAS model to assess the current extent of floodplain inundation in the Antelope Creek watershed and to develop alternatives to improve aquatic and terrestrial habitat while developing feasible solutions to the flooding problem on Antelope Creek that are sensitive to the needs and values of the local landowners. HEC-RAS models are typically developed using a combination of in-channel cross-sections and Light Detection and Ranging (LIDAR) data. The resulting HEC-RAS model is then used with LIDAR data to generate floodplain inundation. The first step in this task was to determine what existing sources of data were available. Inquiries with CDWR, CALTRANS and FEMA indicated that there were no existing HEC-RAS models for Antelope Creek. We obtained LIDAR data from CDWR, but this data was limited to the portion of the watershed downstream of Cone Grove Road. USGS Digital Elevation Model (DEM) data was used for a preliminary representation of the topography upstream of Cone Grove Road4. The geographic extent of the Antelope Creek HEC-RAS model will be from the Sacramento River to upstream of all distributaries (Figure 9). Antelope Creek has four distributaries: Butler Slough, Craig Creek, Mill Race Creek and New Creek (Stillwater Sciences et al. 2011). In turn, Mill Race and New Creeks are tributaries of Salt Creek. Antelope Creek, Butler Slough, Craig Creek and Salt Creek flow directly into the Sacramento River. Little Antelope Creek will be treated in the HEC-RAS model as an additional flow source to Antelope Creek. The number of river miles for each stream in the HEC-RAS model are shown in Table 7.

Our investigations indicated that there were limited sources of in-channel cross-sections for the Antelope Creek watershed, specifically: 1) as-built surveys for bridge crossings; 2) topography data that we collected in 2012 at the Antelope Creek/Craig Creek junction; and 3) cross-section data that were collected by Stillwater Sciences for a critical riffle study of Antelope and Craig Creeks. We obtained as-built surveys from CALTRANS and the Tehama County Department of Public Works. For the Stillwater Science data to be usable for a HEC-RAS model, we needed to shoot in their controls with our RTK-GPS equipment. We can use the LIDAR data as a data source for the Mill Race Creek in-channel cross-sections, since Mill Race Creek was entirely dry at the time that the LIDAR data was collected. In FY-18, we completed data collection for portions of the streams where we have approval for access.

Results

In FY-19, we began development of the HEC-RAS model. The model will be a combined 1D/2D model, with 1D in the channels and 2D on the floodplains.

4 USGS DEM data has limited utility for floodplain delineation because the vertical accuracy is 5 ft and the horizontal resolution is 25 ft. In contrast, LIDAR data typically has a vertical accuracy of 0.5 ft and a horizontal resolution of 3 ft.
Figure 9
Geographic Extent of Antelope Creek HEC-RAS Model
### Table 7
Length of Streams to be Modeled for Antelope Creek HEC-RAS model

<table>
<thead>
<tr>
<th>Stream</th>
<th>Stream Length (Miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antelope Creek</td>
<td>10</td>
</tr>
<tr>
<td>Butler Slough</td>
<td>5.4</td>
</tr>
<tr>
<td>Craig Creek</td>
<td>2</td>
</tr>
<tr>
<td>Mill Race Creek</td>
<td>4.3</td>
</tr>
<tr>
<td>New Creek</td>
<td>3.2</td>
</tr>
<tr>
<td>Salt Creek</td>
<td>2</td>
</tr>
</tbody>
</table>

### Discussion

For land parcels whose owners did not grant us survey access, the only option we will have is to interpolate cross-sections between the areas we have been able to survey. As a result, the accuracy of the model will be diminished in those areas. The largest data gap is for Antelope Creek upstream of Cone Grove Park and New Creek upstream of Cone Grove Road, where we did not have landowner permission for access. Three options were identified to address this data gap: 1) have the upstream extent of the HEC-RAS model be at Cone Grove Road/Cone Grove Park; 2) use data collected by Davids Engineering in the vicinity of Edwards Dam for the in-channel portions of the HEC-RAS transects, with interpolation used for the intervening area; and 3) have CDFW staff collect HEC-RAS data upstream of Cone Grove Road/Cone Grove Park. The first alternative would not allow for development of alternatives upstream of Cone Grove Road/Cone Grove Park. The second alternative would result in reduced accuracy of the HEC-RAS model for most of the area upstream of Cone Grove Road/Cone Grove Park due to interpolation. Further, the first two alternatives would not allow for Mill Race Creek to be included in the HEC-RAS model, since the inflow to Mill Race Creek could not be calculated without inclusion of the distributary junction in the HEC-RAS model. Implementation of the third alternative is based on the assumption that CDFW could get landowner permission for access to Edwards Ranch. After this data gap is addressed, the HEC-RAS model will be completed in FY-20. LIDAR data may be collected in FY-20 for the portion of the watershed upstream of Cone Grove Road through the USGS 3DEP program, but would likely require $1,000 of CVPIA seed funding.
Clear Creek Paige Bar Monitoring

Methods

The purpose of this task was to quantify the increase in rearing habitat from construction of the Paige Bar experimental gravel augmentation. We established a 2,180 foot long study site that included the entire Paige Bar experimental gravel augmentation. A transect was placed at the upstream and downstream end of the study site, with pressure transducers installed at each transect. A barometer was installed near the upstream end of the site to correct the pressure transducer data for atmospheric pressure. The downstream transect pressure transducer data was used to provide water surface elevations as an input to a 2-D hydraulic and habitat model, River2D (Steffler and Blackburn 2002). The pressure transducer data from the upstream transect was used to calibrate the 2-D model – bed roughnesses are adjusted until the water surface elevation predicted by River2D matches the measured water surface elevation. Transect pins (headpins and tailpins) were marked on each stream bank above the 1,200 cfs water surface level using rebar driven into the ground. Survey flagging was used to mark the locations of each pin. Vertical benchmarks were established for each transect to serve as the vertical elevations to which all elevations (streambed and water surface) were referenced. Vertical benchmarks consisted of lag bolts driven into trees. The data collected on the upstream and downstream transect included: 1) water surface elevations (WSELS), measured to the nearest 0.01 foot (0.003 m) using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bank-full discharge surveyed to the nearest 0.1 foot (0.031 m); 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification (Tables 8 and 9) at these same locations and also where dry ground elevations were surveyed.

The horizontal and vertical coordinates of a control, consisting of a rebar driven into the ground, were determined by a static survey with a GPS receiver. Subsequently, the base station for our RTK GPS system was set up over the control, with the RTK GPS rovers used to collect topography data within most of the site and to establish the elevations of the vertical benchmarks. The remaining topography was collected using a robotic total station and stadia rod. We also collected substrate and cover data for each topographic point collected with the survey-grade RTK GPS unit or total station and stadia rod. The RTK GPS and total station data had an accuracy of 0.1 foot horizontally and vertically.

Results

In FY-19, we completed collecting in-channel pre and post-restoration topography data and have completed collecting approximately half of the floodplain topography data, which is the same for both pre and post-restoration. The in-channel post-restoration topography data will also serve as the as-built survey for this project. In FY-20, we will complete collection of the floodplain topography data and model the amount of pre and post-restoration juvenile habitat at flows ranging from 50 to 1,200 cfs.
Table 8
Substrate Descriptors and Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Particle Size (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>Sand/Silt</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>1</td>
<td>Small Gravel</td>
<td>0.1 – 1</td>
</tr>
<tr>
<td>1.2</td>
<td>Medium Gravel</td>
<td>1 – 2</td>
</tr>
<tr>
<td>1.3</td>
<td>Medium/Large Gravel</td>
<td>1 – 3</td>
</tr>
<tr>
<td>2.3</td>
<td>Large Gravel</td>
<td>2 – 3</td>
</tr>
<tr>
<td>2.4</td>
<td>Gravel/Cobble</td>
<td>2 – 4</td>
</tr>
<tr>
<td>3.4</td>
<td>Small Cobble</td>
<td>3 – 4</td>
</tr>
<tr>
<td>3.5</td>
<td>Small Cobble</td>
<td>3 – 5</td>
</tr>
<tr>
<td>4.6</td>
<td>Medium Cobble</td>
<td>4 – 6</td>
</tr>
<tr>
<td>6.8</td>
<td>Large Cobble</td>
<td>6 – 8</td>
</tr>
<tr>
<td>8</td>
<td>Large Cobble</td>
<td>8 – 10</td>
</tr>
<tr>
<td>9</td>
<td>Boulder/Bedrock</td>
<td>&gt; 12</td>
</tr>
<tr>
<td>10</td>
<td>Large Cobble</td>
<td>10 – 12</td>
</tr>
</tbody>
</table>

Discussion

The results of this investigation, based on the analysis in FY-20, will quantify the amount of spring-run Chinook salmon and steelhead fry and juvenile habitat created by the Paige Bar experimental gravel augmentation.
Table 9
Cover Coding System

<table>
<thead>
<tr>
<th>Cover Category</th>
<th>Cover Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>No cover</td>
<td>0.1</td>
</tr>
<tr>
<td>Cobble</td>
<td>1</td>
</tr>
<tr>
<td>Boulder</td>
<td>2</td>
</tr>
<tr>
<td>Fine woody vegetation (&lt; 1&quot; diameter)</td>
<td>3</td>
</tr>
<tr>
<td>Fine woody vegetation + overhead</td>
<td>3.7</td>
</tr>
<tr>
<td>Branches</td>
<td>4</td>
</tr>
<tr>
<td>Branches + overhead</td>
<td>4.7</td>
</tr>
<tr>
<td>Log (&gt; 1' diameter)</td>
<td>5</td>
</tr>
<tr>
<td>Log + overhead</td>
<td>5.7</td>
</tr>
<tr>
<td>Overhead cover (&gt; 2' above substrate)</td>
<td>7</td>
</tr>
<tr>
<td>Undercut bank</td>
<td>8</td>
</tr>
<tr>
<td>Aquatic vegetation</td>
<td>9</td>
</tr>
<tr>
<td>Aquatic vegetation + overhead</td>
<td>9.7</td>
</tr>
<tr>
<td>Rip-rap</td>
<td>10</td>
</tr>
</tbody>
</table>

North Fork Cottonwood Creek Flows Investigation

Methods

The purpose of this task was to develop a Stream Network Temperature Model (SNTEMP) water temperature model for North Fork Cottonwood Creek (Figure 10) to use in identifying opportunities for restoration or negotiations on flow management in North Fork Cottonwood Creek to improve summer water temperatures for spring-run Chinook salmon adult holding. In FY-18, we completed data collection and development and calibration of the SNTEMP model. In FY-19, we validated the SNTEMP model by comparing the simulated water temperatures at the downstream end of the model with water temperatures measured by CDFW for the period of June 16 to November 3, 2018. The validation of the model was evaluated based on the following criteria: 1) average error less than 1.8 degrees Fahrenheit (1 degree Celsius); and 2) maximum error less than 2.7 degrees Fahrenheit (1.5 degree Celsius) from Kimmerer and Carpenter (1989). Validation was also evaluated by the following criteria identified in the StreamTemp help files:
1) Correlation Coefficient (R-Squared) as close to 1.0 as possible; 2) Mean Error as close to zero as possible; 3) Probable Error equal to or less than 0.5; 4) Maximum Error equal to or less than 1.5 degrees; 5) Number of Predicted Errors Greater than 1.0 degrees less than 10%; and 6) Bias minimal.

**Results**

The validated model met the average error but did not meet the maximum error criterion from Kimmerer and Carpenter (1989) for mean daily average water temperature, nor did it meet the criteria for 7 Day Average Daily Maximum (7DADM) (Appendix B, Table B-1). The validated model had a correlation coefficient of 0.9602, a mean error of -1.0798, a probable error of 1.5207, a maximum error of -5.3506, 71.63 % of the predicted errors greater than 1.0, and a bias of 0.1281. The errors are acceptable, since they were similar to those during calibration.
Discussion

Performance of the validated SNTEMP model was comparable to performance of the model during calibration. The SNTEMP model should be useful in identifying opportunities for restoration or negotiations on flow management in North Fork Cottonwood Creek to improve summer water temperatures for spring-run Chinook salmon adult holding. For example, curtailment of Igo Ono Community Service District diversions from June 25 to August 15 would result in attainment of a 76 degree F criterion\(^5\). Alternatively, dredging Rainbow Lake to increase storage capacity might provide the ability to supplement impaired flows during this time period without the need to curtail diversions.

Bee Diversion Dam Data Collection

Methods

The purpose of this task was to collect topographic data at the Bee Diversion Dam on North Fork Cottonwood Creek to develop a reconnaissance-level design to solve the upstream passage barrier at this location. We established the coordinates for a control, located on top of the head gate, with static surveys with a GPS unit. Data were collected for the site using a total station and stadia rod. We also measured a water surface elevation profile with an autolevel and stadia rod and a corresponding discharge.

Results

Coordinates of the control\(^6\), in California State Plane Zone I, NAD83 feet, NAVD88, are N = 2054695.124, E = 6380474.026, Elev = 1028.651. Topographic data were collected on August 5-7, 2019. A total of 1495 data points were collected, extending from 115 feet upstream to 474 feet downstream of the dam (Figure 11). The water surface elevation profile, at a flow of 15.9 cfs, is shown in Figure 12. The topographic data were transmitted to Kathie Muse and Tricia Bratcher to be used in developing a design to solve the upstream passage barrier at this location.

\(^5\) This is the highest daily maximum water temperature where adult spring-run are observed holding in Beegum Creek, a tributary to Middle Fork Cottonwood Creek (D. Killam, CDFW, personal communication).

Figure 11
Bee Diversion Streambed Topographic Data

Figure 12
Bee Diversion Water Surface Elevation Profile at 15.9 cfs – Station 0 is at the diversion dam

Discussion

The data from this effort should serve as a good baseline topographic survey for developing a design to solve the upstream passage barrier at this location.
Bobcat Flat Redd Survey

Methods

The purpose of this task was to conduct post-restoration biological monitoring of the Bobcat Flat restoration site on Tuolumne River. Three sites in the restoration area and six reference sites (Benn and Gard 2019) were surveyed for fall-run Chinook salmon redds on December 17 – 20, 2018. Locations of redds, as well as unoccupied locations, were recorded with a RTK GPS unit. Data collected for each redd consisted of depth, velocity, substrate and redd dimensions. Substrate was recorded for three locations (upstream of the redd, next to the redd, and in the redd tailspill. We also recorded the direction and distance of the depth and velocity measurement location from the pit of the redd. Depth, velocity and substrate data were collected for unoccupied locations. In addition, we performed static surveys with GPS units at the control we established in 2017 for the Bobcat East restoration project and at an existing control (DESIGNATION - T 679, PID - HS2178) that was used as an initial location for the Bobcat East surveys.

Results

There were a total of five redds in the three sites in the restoration area and a total of five redds in the six reference sites. Depths, velocities and substrates for the redds fell within the range of unoccupied data. The results of the static surveys were as follows: FWS Control NAVD 88 ORTHO HEIGHT – 148.34 feet, SPC CA 3 - 2,052,207.13 6,551,304.43 sFT; existing control NAVD 88 ORTHO HEIGHT – 217.17 feet, SPC CA 3 - 2,057,178.82 6,528,865.10 sFT.

Discussion

The sample size for spawning was too low to be able to make any conclusions regarding post-restoration biological monitoring. As such, any future post-restoration monitoring should continue to focus on fry and juvenile rearing, as described in Benn and Gard (2019).

Lower Deer Creek Falls Fish Ladder Post-restoration Monitoring

Methods

The goal of this task was to assess the operation of a new fish ladder at Lower Deer Creek Falls (LDCF) and develop a rating curve for Deer Creek at the fish ladder entrance. Water surface elevations were measured at the fish ladder entrance at three flows (58.8, 122.9 and 205.3 cfs). The stage of zero flow for Deer Creek at the fish ladder entrance was also measured to use in developing the rating curve. For the latter two Deer Creek flows, we also measured the flow entering the fish ladder. We also measured water surface elevations in each pool of the fish ladder at the highest flow. NMFS fish ladder criteria are to have no more than a one foot drop between pools, and to have at least 10% of the river flow going through the fish ladder (NMFS 2001).
Results

We were able to develop a rating curve for Deer Creek at the fish ladder entrance for flows ranging from 23 to 499 cfs. The flows entering the fish ladder were 7.5 – 7.9 cfs, representing 4 – 6% of the flow of Deer Creek. As shown in Figure 13, six of the weirs had water surface elevation drops exceeding one foot. At the time of the measurements, all of the fish ladder flow was going through the orifices, with the exception of the downstream-most weir, which was fully backwatered from Deer Creek.

![Figure 13](image)

Lower Deer Creek Falls Fish Ladder Water Surface Elevation drops. Weirs are ordered from downstream to upstream.

Discussion

After a staff gage is installed at the fish ladder entrance, we will tie it in to the rating curve, so that Deer Creek flows can be determined by visual inspection of the staff gage. Although the fish ladder is not meeting the NMFS water surface elevation drop criterion, the fish ladder is operating well, and we were unable to identify any way to further fine tune the operation of the ladder. The percentage of flow going through the fish ladder is acceptable, given how well it has been passing spring-run Chinook salmon adults.
Merced River Floodplain Restoration Projects Data Collection

Methods

The purpose of this task was to collect topography, depth and velocity data to use in designing and evaluating floodplain and in-channel restoration sites on the Merced River. Topographic, depth and velocity data were collected using a combination of an Acoustic Doppler Current Profiler (ADCP) and a survey-grade RTK GPS unit. For each traverse with the ADCP, the RTK GPS was used to record the horizontal location and WSEL at the starting and ending location of each traverse, while the ADCP provided depths, velocities and distances across the traverse. The WSEL of each ADCP traverse is then used together with the depths from the ADCP to determine the bed elevation of each point along the traverse.

Results

Topographic, depth and velocity data were collected for Above Henderson Park and MID Drought Project on March 11-12, 2019. A total of 5,187 data points were collected. Flows were too low to collect the same data for the Merced River Ranch restoration project. The data were provided to Rocko Brown from Cramer Fish Sciences.

Discussion

The data from this effort should serve as a good baseline topographic survey for developing floodplain and in-channel restoration designs and evaluating floodplain and in-channel restoration projects on the Merced River.

Feather River Sunset Pumps Data Collection

Methods

The purpose of this task was to collect updated topography data for the Sunset Pumps upstream passage project, given the high flows on the Feather River since we had collected topography data in 2015. Topography data from dry and shallow areas were collected with RTK GPS units, while topography data for deep areas were collected using the methods described above for the Merced River.

Results

Topographic data were collected on December 14, 2018 and January 28, 2019. A total of 5,659 data points were collected, extending from 1500 feet above the weir to 1900 feet below the weir. The data were provided to Amanda Ott of CDWR to use in developing conceptual designs of alternative for fish passage at Sunset Pumps.
Discussion

The data from this effort should serve as a good updated topography dataset to develop conceptual designs of alternative for fish passage at Sunset Pumps.

Central Valley Structured Decision Model Evaluation

Methods

The purpose of this task was to develop new sources of data to improve the parameterization of the Central Valley Structured Decision Model (Peterson et al. 2014). Efforts on this task in FY-19 focused on floodplain habitat for the 26 streams in the Structured Decision Model (SDM). The original SDM had floodplain habitat values that were largely based on expert opinion and did not vary with flow. In previous years, we used simplified HEC-RAS models that were extracted from the CDWR Central Valley Flood Evaluation and Delineation (CVFED) Program. HEC-RAS models (CDWR 2015) to develop flow-floodplain area relationships. We also sought out other sources of HEC-RAS models to develop flow-floodplain area relationships for streams that were not modeled by the CVFED program.

In FY-19, we completed developing flow-floodplain area relationships for the Cosumnes and Mokelumne Rivers. The flow-floodplain area relationships for the Cosumnes River are based on a 1-D HEC-RAS model developed by UC Davis (Fleenor 2007). The flow-floodplain area relationships for the Mokelumne River were developed with a 2-D HEC-RAS model, using a topographic dataset provided by East Bay Municipal Utility District. The Mokelumne model was broken into seven reaches (Figure 14), based on the availability of stage-discharge relationships. The stage-discharge relationships for the downstream boundary conditions for Reaches 3-7 were based on 6-9 stage/discharge measurements provided by East Bay Municipal Utility District. The stage discharge relationship for the downstream boundary condition for Reach 1, which is tidally influenced, was generated from the UC Davis 1-D HEC-RAS model, which extended downstream to the confluence of North and South Mokelumne Rivers. The downstream boundary condition used for the UC Davis 1-D HEC-RAS model was 4.21 feet for all flows, the long-term average stage from USGS gage no. 11336930. For Reach 2, where the downstream boundary condition is tidally influenced at low flows, the downstream boundary condition was from the UC Davis 1-D HEC-RAS model for flows of 10 to 810 cfs, from three stage/discharge measurements for flows of 1,210 to 4,810 cfs, and from output of the Reach 1 2-D HEC-RAS model for flows of 5,210 to 11,610 cfs. The image classification tool in ArcMap was used to develop roughness shapefiles from ortho-rectified aerial photographs for the following land types: 1) open water (n = 0.03 – 0.043); 2) bare ground (n = 0.06); 3) vegetation (n = 0.10); and 4) wetlands (n = 0.20). The computational meshes had 20-foot elements in the channel and 20-50 foot elements in the floodplain (Table 10). The computational meshes for Reaches 1 and 2 were clipped to exclude the Cosumnes River watershed. The models were

---

7 The stage-discharge relationship at the downstream end of Reach 2 shifts dramatically for flows above 5,000 cfs, when levees in Reach 1 overtop.
calibrated (Table 10) to measured water surface elevations at the upstream end of each model. The models were run at flows from 10 to 11,610 cfs by 400 cfs increments. Total inundated polygons were created in 2-D HEC-RAS and exported to ArcMap to eliminate isolated off-channel areas. The results were overlaid with aerial photography in ArcMap to determine the flow at which floodplain inundation began for each reach (Table 10). Floodplain areas were calculated for each reach by subtracting the total inundated area at the floodplain initiation flow from the total inundated area at all higher flows. Floodplain areas for the reaches were summed to calculate the overall floodplain area for the Mokelumne River.

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8 DW = Diffusion Wave, FM = Full Momentum
Results

Figures 15 and 16 show the flow-floodplain relationships for, respectively, the Cosumnes and Mokelumne Rivers. The sharp increase in floodplain inundation at 5,000 cfs for the Mokelumne River reflects the overtopping of levees in the lower reaches.

![Cosumnes River Flow-Floodplain Area Relationship](image1)

![Mokelumne River Flow-Floodplain Area Relationship](image2)
Discussion

This information should be useful to the CVPIA fisheries Science Integration Team in their efforts to refine the Central Valley structured decision model. The Mokelumne River 2-D HEC-RAS model will also be useful to identify floodplain restoration sites.

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SWRCB (State Water Resources Control Board). 2015. 2010-2013 Average Demand Dataset - Updated February 20, 2015. Accessed from:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/analysis/

Appendix A
Paynes Creek Critical Riffle Study Photos and Regressions
Paynes Creek Riffle 2 at 99.3 cfs looking downstream

North Elevation

🌞 190°S (T) ☀ 40°16'45"N, 122°10'5"W ±16.4ft ▲ 411ft

08 Apr 2019, 13:30

Paynes Creek Riffle 2 at 3.4 cfs looking downstream

🌞 207°SW (T) ☀ 40°16'45"N, 122°10'5"W ±16.4ft ▲ 446ft

15 Jul 2019, 11:00:00
Paynes Creek Riffle 5 at 99.3 cfs looking downstream

North East Elevation

232°SW (T)  40°16'37"N, 122°10'15"W ±32.8ft ▲ 394ft

08 Apr 2019, 15:16

Paynes Creek Riffle 5 at 3.4 cfs looking downstream

237°SW (T)  40°16'37"N, 122°10'15"W ±32.8ft ▲ 390ft

15 Jul 2019, 14:23:10
Paynes Creek Riffle 7 at 92.8 cfs looking upstream

South East Elevation

331°NW (T)  40°16'31"N, 122°10'22"W ±16.4ft ▲ 388ft

Paynes Creek Riffle 7 at 3.4 cfs looking downstream

240°SW (T)  40°16'33"N, 122°10'21"W ±16.4ft ▲ 403ft
Paynes Creek Riffle 2 Regressions

\[ y = 0.001572x - 0.005796 \]
\[ R^2 = 0.990348 \]

\[ y = 0.000711x + 0.002191 \]
\[ R^2 = 0.988536 \]

\[ y = 0.002548x - 0.006182 \]
\[ R^2 = 0.999514 \]

\[ y = 0.000693x + 0.004491 \]
\[ R^2 = 0.968809 \]

\[ y = 0.005222x + 0.057755 \]
\[ R^2 = 0.988265 \]

\[ y = 0.005129x + 0.005724 \]
\[ R^2 = 0.772086 \]
Paynes Creek Riffle 5 Regressions

1. $y = 0.004066x - 0.054887$
   $R^2 = 1.000000$

2. $y = 0.001355x - 0.018286$
   $R^2 = 1.000000$

3. $y = 0.004729x - 0.005989$
   $R^2 = 0.997594$

4. $y = 0.001283x + 0.011257$
   $R^2 = 0.990408$

5. $y = 0.019328x + 0.104883$
   $R^2 = 0.909392$

6. $y = 0.001970x + 0.082312$
   $R^2 = 0.897452$
Appendix B
North Fork Cottonwood Creek Water Temperature Model Validation
Table B-1. Validated SNTEMP model performance.

<table>
<thead>
<tr>
<th>Parameter (° F)</th>
<th>Reach 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean error for daily mean temp</td>
<td>-1.08</td>
</tr>
<tr>
<td>Error range for daily mean temp</td>
<td>-5.351 – 4.473</td>
</tr>
<tr>
<td>Mean error for 7DADM</td>
<td>-3.31</td>
</tr>
<tr>
<td>Error range for 7DADM</td>
<td>-6.8 – 0.92</td>
</tr>
</tbody>
</table>