State of California

California Natural Resources Agency

DEPARTMENT OF WATER RESOURCES

Division of Integrated Regional Water Management

Northern Region Office

Clover Creek – Millville Diversion Fish Passage Project

Preliminary Engineering Technical Report

April 2013

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Fish Passage Improvement

Technical Information Record (TIR) – NRO-2013-01

This Technical Information Record is primarily a working paper and is subject to revision or replacement. Its primary use will be as a source of information for fish passage improvements at the Millville Diversion on Clover Creek near Millville, California. This investigation is part of the Cow Creek Fish Passage Improvement Project—a multifaceted plan to improve anadromous fish passage throughout the Cow Creek watershed.

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Millville Ditch Association
National Oceanic and Atmospheric Administration – National Marine Fisheries Service
Natural Resources Conservation Service
Western Shasta Resources Conservation District
United States Fish and Wildlife Service
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Contents

Figures

Tables

Plates

Appendices

Executive Summary

Portions of Clover Creek have received limited use by salmon and steelhead due to diversion structures that impede upstream and downstream fish migration. The California Department of Water Resources investigated the design of fish ladders to improve the upstream migration and a fish screen to minimize loss of downstream migrants. By providing passage, Chinook salmon and steelhead will have access to approximately ten miles of potential habitat for spawning and rearing.

The Millville Ditch Association has two diversion structures (a dam and inverted siphon) along Clover Creek. Both of the structures are required to provide water to the Millville Ditch Association's water users. The diversion dam and inverted siphon are significant fish passage barriers.

The proposed project involves constructing a new pool and weir fish ladder and an on-stream flat plate fish screen at the Millville Diversion dam structure and a pool and weir fish ladder and inverted siphon at the inverted siphon structure. The estimated cost for providing ladders, a fish screen, and an inverted siphon for the Millville Diversion is approximately $1.2 million.

Recommendations

The California Department of Water Resources has completed a preliminary engineering investigation of fish passage solutions at Millville Diversion on Clover Creek.

The Clover Creek Fish Passage Design Technical Team recommends moving forward with advanced engineering of the following:

- New Pool and Weir fish ladders; One fish ladder at the diversion dam, and one fish ladder at the inverted siphon area.
- New Fish Screen at the point of diversion
- New Inverted Siphon
- Structural improvements at the diversion dam and inverted siphon location

Certification

This preliminary engineering technical report has been prepared under my direction as the professional engineer in direct responsible charge of the work, in accordance with the provisions of the Professional Engineers Act of the State of California.

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Abbreviations and Acronyms

CCWA	Cow Creek Watershed Assessment
cfs	cubic feet per second
CMP	Corrugated Metal Pipe
CDFW	California Department of Fish and Wildlife (formerly known as California Department of Fish and Game)
DWR	California Department of Water Resources
EDF	Energy Dissipation Factor
ft-lb/sec/cf	foot–pounds per second per cubic foot
fps	feet per second
GPS	Global Positioning System
HEC-RAS	Hydrologic Engineering Center River Analysis System
NAVD	North American Vertical Datum
NMFS	National Marine Fisheries Service
NRCS	National Resource Conservation Service
sf	square feet
SSSG	Surface Saturated Dry Specific Gravity
USFWS	United States Fish and Wildlife Service
USGS	United States Geographical Survey
MDA	Millville Ditch Association
MOU	Memorandum of Understanding
TAC	Technical Advisory Committee
WSEL	Water Surface Elevation
WSRCD	Western Shasta Resource Conservation District

Introduction

The following report summarizes the findings of the California Department of Water Resources (DWR) preliminary engineering investigation of fish passage improvements at the Millville Diversion on Clover Creek near Millville, California. This investigation is part of the Cow Creek Fish Passage Improvement Project–a multifaceted plan to improve anadromous fish passage throughout the Cow Creek watershed.

The Millville Diversion consists of two structures, the diversion dam (dam) and inverted siphon (siphon) (Figure 1). The dam and siphon are the only known fish passage barriers on Clover Creek besides the 150-foot natural waterfall approximately 10 miles upstream of the dam. This investigation has led to a proposed project, which involves constructing a fish ladder and fish screen at the dam and a fish ladder and inverted siphon at the existing siphon location.

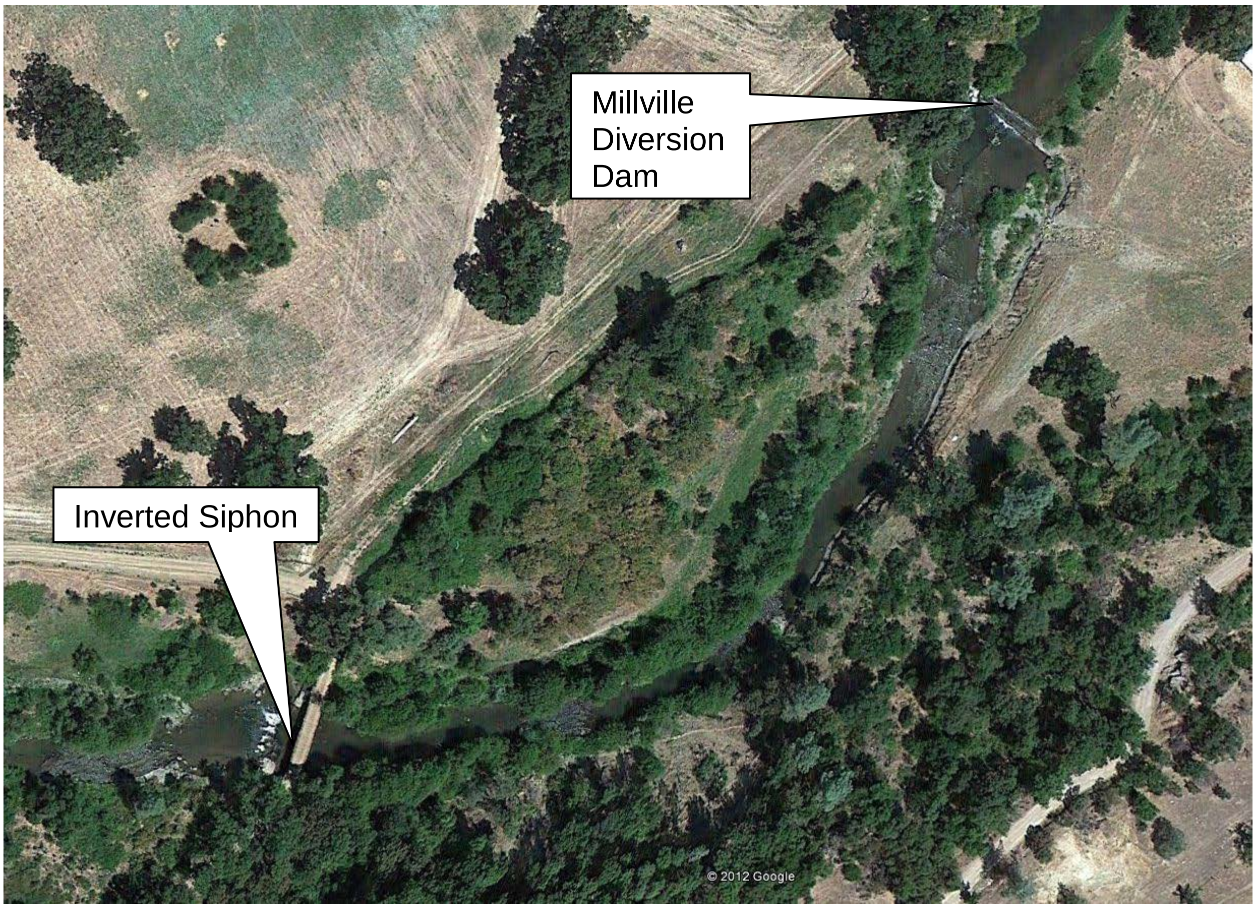

Figure 1. Google Earth Image of Millville Diversion Dam and Inverted Siphon (2011)

This engineering report includes a brief discussion of the alternative selection process, final design criteria, design and construction preliminary cost estimate, and preliminary engineering drawings. All alternatives were analyzed considering factors such as fish passage, water rights, operation and maintenance, location, condition of existing facilities, stream characteristics, stream hydrology, biological criteria, owner liability, and economics.

Project Location and Access

The project is located in the Cow Creek Watershed, about five miles east of Redding, California. The Cow Creek Watershed is located in Shasta County and is the first major eastside tributary to the Sacramento River below Keswick and Shasta Dams. Clover Creek is one of five main tributaries to Cow

Creek. The proposed project site is located approximately 3.5 miles upstream from Clover Creek's confluence with Cow Creek and, near the town of Millville, California (Figure 2). The dam and siphon can be identified on the United States Geological Survey, 7.5-minute series, Palo Cedro quadrangle in Section 6, Township 31 North, Range 2 West.

Access to the project site is via Brookdale Road from Whitmore Road off of Old 44 Drive in Millville, California. Brookdale Road travels northeast past an elementary school and through a residential neighborhood. There are two access routes to the project site, both located on Bar 11 Ranch property. The first access road is approximately 2 miles down Brookdale Road and will be used for heavy equipment crossing Clover Creek (via the existing ford). The second access road is just 500 feet further down Brookdale Road and will be used for other construction vehicles that are able to cross the existing bridge over Clover Creek (Sheet 1).

Project Background

Several fishery restoration plans have identified Cow Creek as high priority for fish passage improvements. The California Department of Fish and Wildlife (CDFW) (formerly known as California Department of Fish and Game) Steelhead Restoration and Management Plan for California (1996) identified Cow Creek as one of the four tributaries that offers the best opportunities for restoration of steelhead populations on the Upper Sacramento River. The 1998 Central Valley Project Improvement Act Tributary Production Enhancement Report, by CH2M Hill to Congress, identified unscreened diversions and unladdered diversion dams as two of the six factors that are limiting salmonid productions in Cow Creek. The United States Fish and Wildlife Service (USFWS) Restoration Plan for the Anadromous Fish Restoration Program (2001) identified screening diversions and improving passage at agricultural diversions as a restoration action to increase natural production of anadromous fish in the California's Central Valley.

The Cow Creek Ecological Management Unit is located in the North Sacramento Valley Ecological Management Zone as defined in the CALFED Ecosystem Restoration Program Plan, Volume II. This zone is important for the production of anadromous fish because of its location at the upper end of the Sacramento Valley.

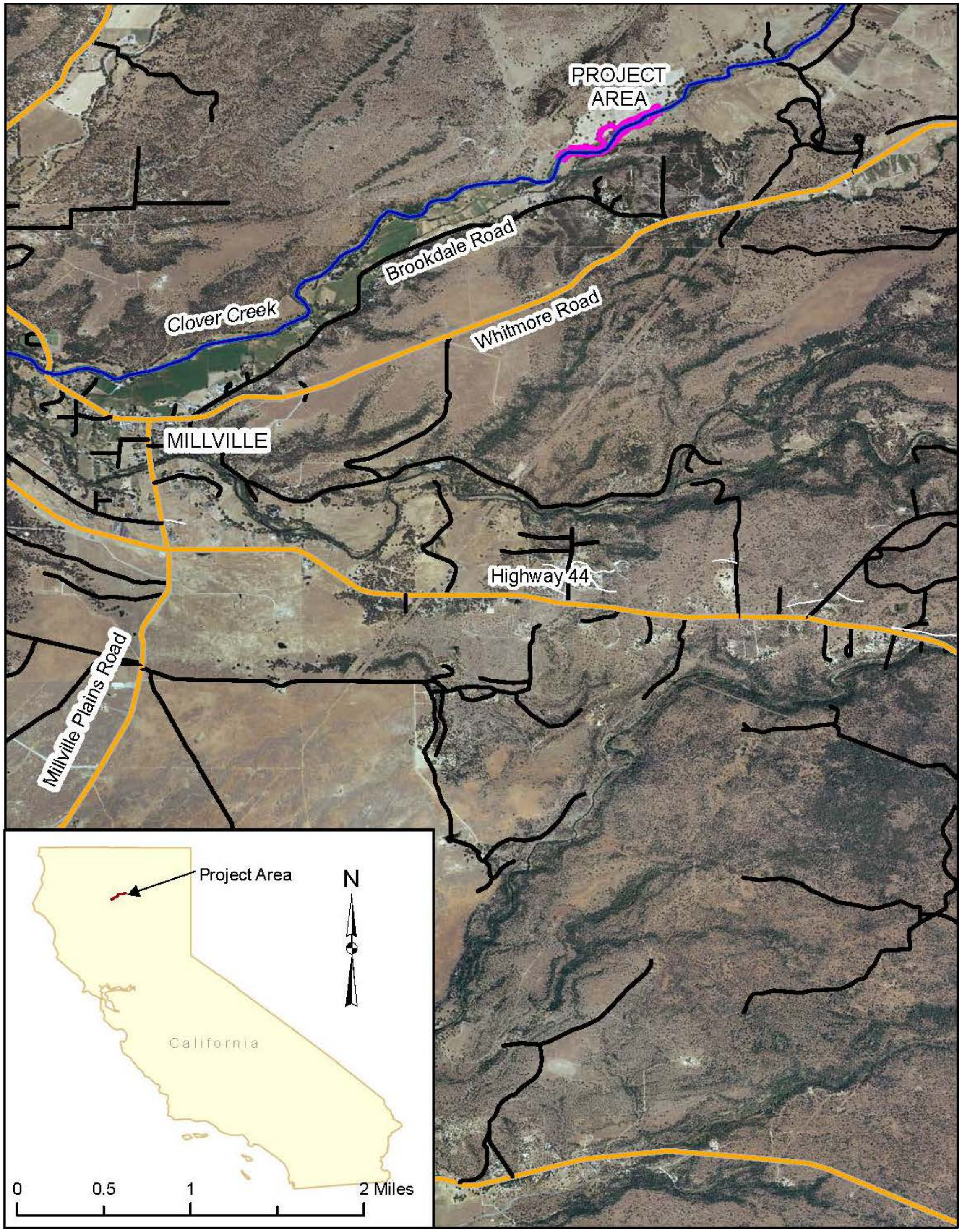

Figure 2. Location Map

Purpose and Need for Project

The Millville Diversion is the second largest on Clover Creek and the only diversion below the single natural barrier: a 150-foot waterfall. The diversion is owned and operated by the Millville Ditch Association (MDA). The diversion system consists of two main structures: a permanent concrete dam originally built in the 1920's with no fish screen or ladder, and an inverted siphon that crosses under the creek approximately 900 feet downstream of the dam.

The dam is about 85 feet long and 12 feet wide, with a height of 4.5 feet. Unscreened water is diverted on the right bank of the dam through a 30-inch diameter corrugated metal pipe (CMP) for about 125 feet. The water then empties into an earthen ditch for about 550 feet where it travels into a 30-inch diameter CMP and into the siphon. The siphon crosses under Clover Creek in a concrete encasement about 100 feet long by 10 feet wide where it terminates in the Millville Ditch (ditch) on the left bank of the creek.

Since the dam and siphon have been constructed, major incision has occurred in the channel, creating a fish passage impediment at both structures. The 1959 photo shown in Figure 3 represents the dam's appearance prior to channel incision. Today, the dam sits atop exposed bedrock, making the total height from the top of the dam to the channel bottom closer to 10 feet (Figure 4).

Figure 3. 1959 Photo of Millville Diversion Dam (Source: Glen Campbell 2006)

Figure 4. Millville Diversion Dam (July 2007)

Over time, incision has also occurred where the siphon crosses the creek, exposing the downstream side of the siphon and bedrock (Figure 5). The total height from the top of the concrete apron to the channel bottom is about 6.5 feet. Gunite has been used over time to help maintain the structural integrity of the siphon. During low flows, water is sheeting across the concrete apron which impedes fish passage due to the shallow water depth as well as the 4-foot head differential caused by the siphon.

The dam is impassible at all flows due to the major channel bed incision below the dam which creates a 6-foot water surface elevation (WSEL) difference. Several other factors have been identified as fish passage impediments:

- an unscreened diversion
- high velocity concentrated through the notch opening in the dam
- rebar protruding upwards through the notch in the dam
- high water temperatures
- low flow in the creek

Figure 5. Siphon structure on Clover Creek (May 2007)

The diversion entrance is not screened as shown in Figure 6. During irrigation season, all instream flow is concentrated through a notch in the dam located near the diversion entrance. The concentrated flows through the notch creates a velocity barrier to fish. The notch is about 5 feet wide with an adjustable height (adjusted with boards). The height of the notch is adjusted to divert water into the ditch. The notch has rebar protruding upwards and other sharp metal objects that would cause major injury to fish trying to migrate upstream or downstream through the notch (Figure 7).


Figure 6. Unscreened diversion entrance (April 2007)


Figure 7. Concentrated Flow Through Notch in Dam (April 2007)

Description of Investigation

This project was developed as a collaborative effort, with participation from many different disciplines, represented by local, State, and federal entities. A technical advisory committee (TAC) was formed with representatives from Western Shasta Resource Conservation District (WSRCD), USFWS, DWR, CDFW, National Resource Conservation Service (NRCS) and representatives from the MDA. The Clover Creek TAC was an interdisciplinary group made up of engineers, geologists, and environmental scientists that were involved with the design process and instrumental with the selection of the preferred alternative.

Since 2005, the TAC held meetings, multiple field visits, tours, and discussions with the landowner and the MDA to discuss the project. Field investigations and surveys were completed to determine existing conditions and to help determine possible impacts. Alternatives were discussed and ideas pursued or discarded based on merit and group consensus until a preferred alternative was selected.

During the design process, several surveys and investigations were conducted. The surveys and investigations conducted include, but are not limited to, the following: target species investigation, water rights investigation, topographic survey, hydrologic and hydraulic investigation, geological investigation, botanical survey, habitat typing survey, structural analysis survey and environmental review.

Target Species Investigation

The target species in Clover Creek is primarily all life stages of fall-run Chinook salmon, but also includes late fall-run Chinook salmon and Central Valley steelhead (steelhead). Due to high water temperatures and low flows in the creek when juveniles could be present, it is not desirable to have them rearing in the creek. Because of these conditions, National Marine Fisheries Service (NMFS) has given its concurrence that this project does not need to provide for upstream juvenile passage.

Late fall-run Chinook salmon and steelhead have a potential for accessing Clover Creek but their presence and timing in the creek is not well documented. Fall-run Chinook salmon presence and timing, however, is well documented.

CDFW has operated a video monitoring weir, located in Cow Creek below tributary influences, since 2006. Based on six years of data, fall-run Chinook salmon enter Cow Creek during October and November (Figure 8). Late fall-run and steelhead are known to be in the system during December through March. The video weir is removed from the creek before high flow events in December.

Another species of concern that could occur in Cow Creek is the Pacific Lamprey. In 2012, the Pacific Lamprey Conservation Initiative was developed to promote the implementation of conservation measures for Pacific Lamprey in Alaska, Washington, Oregon, Idaho, and California. Although Pacific Lamprey were historically widespread along the West Coast of North America, their abundance is declining. Threats to Pacific Lamprey include, but are not limited to, restricted mainstem and tributary passage, reduced flows, dewatering of streams, stream and floodplain degredation, and degraded water quality (Columbia River Basin Lamprey Technical Workgroup 2004).

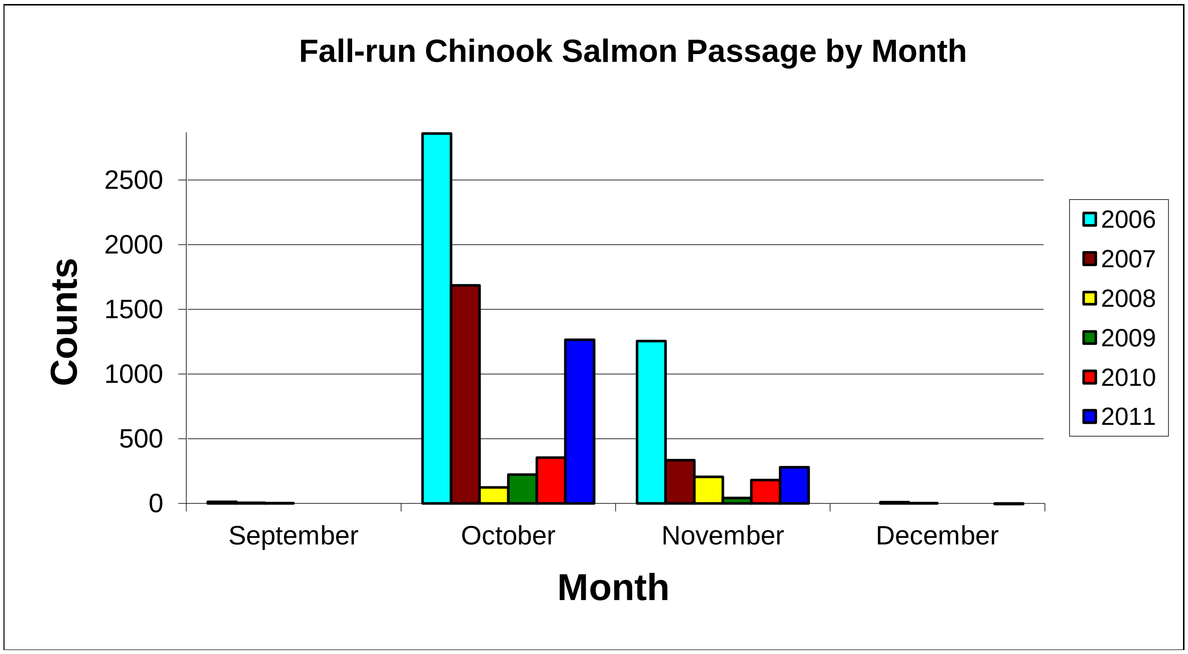

Figure 8. CDFW's video weir fall-run Chinook salmon counts (Source: CDFW 2011)

Water Rights Investigation

Water rights on the Clover Creek system were established under Judgment and Decree 6904, dated October 4, 1937. A maximum of 23.6 cubic feet per second (cfs) can currently be diverted from Clover Creek and its tributaries during the irrigation season from May 1 through October 31 of each year for domestic, stock watering, and irrigation purposes.

The actual decreed water right for MDA is 4.4 cfs. Mr. Oiler, a water right holder in MDA also owns property with decreed water rights upstream of the dam. These rights are not exercised at the upstream location but are diverted at the MDA ditch. Currently the MDA ditch is used to divert two different water rights (MDA and Mr. Oiler's). Therefore, the maximum water right at the MDA ditch is 6.5 cfs.

Additionally, according to the decree, when there is a surplus of water in Clover Creek above the flow necessary to supply all of the water rights on Clover Creek, the surplus may be apportioned among the parties. The total of all water rights in Clover Creek is 23.6 cfs. The MDA water right is 27.6 percent of the total water right; therefore, MDA could take 27.6 percent more water during higher creek flows. Therefore, the maximum amount of water that could be diverted into the MDA ditch is 8.2 cfs.

Surveying and Site Information

In May 2007, DWR staff conducted a topographic survey of the project area. Global position system (GPS) equipment were used to survey control monuments. The purpose of the control survey was to locate the site within the North American Datum of 1983, California State Plane, Zone 1, US Feet and establish elevations relative to North American Vertical Datum of 1988, US Feet.

Total stations, automatic levels and survey grade real-time kinematic GPS equipment was used to collect survey data. The data collected included ground shots, existing structures, thalweg points, water surface elevations and cross sections in Clover Creek. This data was used to create a 1-foot contour map and a longitudinal profile for a portion of the creek (Figure 9).

The longitudinal profile was used in the geologic investigation and design process and covered a distance of 6,000 feet over an elevation difference of 34 feet. The overall slope of the channel was estimated to be 0.0057 feet per foot.

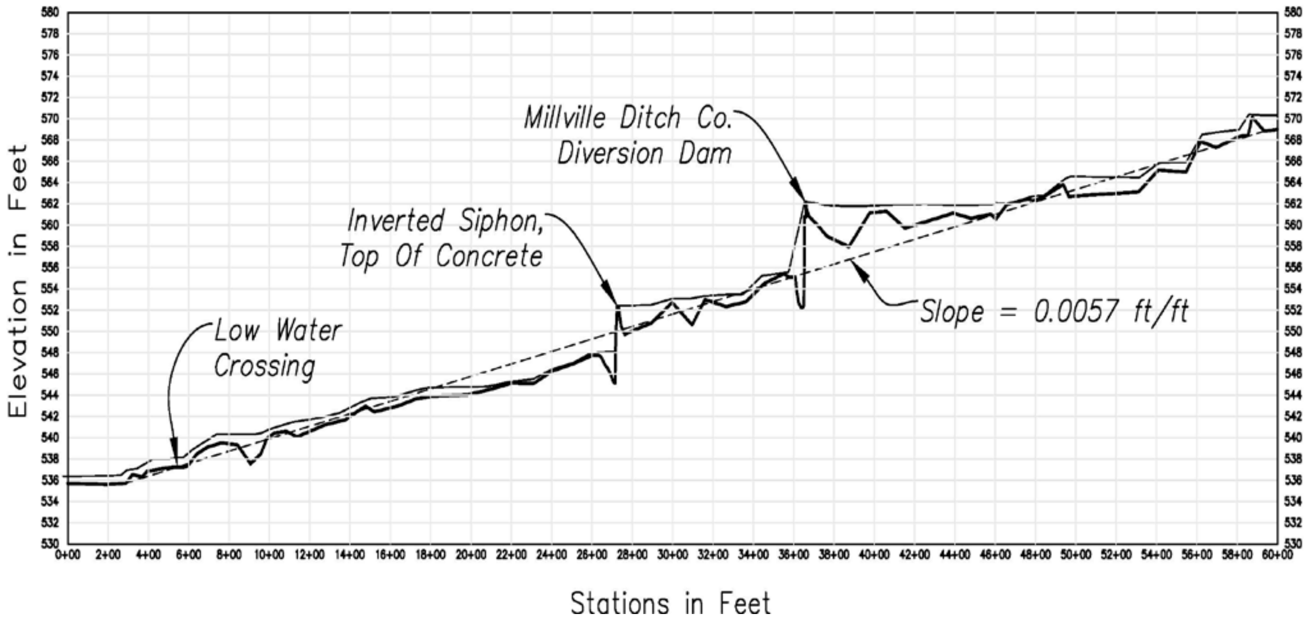

Figure 9. Clover Creek Long Profile

Hydrologic Investigation

The hydrologic investigation included analyzing the historical flow data in the Cow Creek Watershed, creating an estimated hydrograph for Clover Creek, analyzing measured flow and water temperature in Clover Creek, and determining fish passage flows. This information was used in the design of the fish passage structures.

Historical Flow Data

A United States Geographical Survey (USGS) stream gage (#11372700) existed on Clover Creek from May 17, 1957, to September 30, 1959. The Clover Creek gage was located approximately 15 miles upstream of the project site. An existing USGS stream gage (#11374000) in Cow Creek below all tributary influences has been collecting flow data dating back to 1949. Because of the limited amount of data for Clover Creek, an estimated hydrograph was developed for Clover Creek using flow data from the Cow Creek stream gage.

Estimated Hydrograph

According to the Cow Creek Watershed Assessment (CCWA) report, Clover Creek watershed encompasses 13 percent of the entire Cow Creek Watershed. From the report, average precipitation maps of the Cow Creek Watershed were analyzed. The annual precipitation zones were equally distributed over the entire watershed which indicates uniform distribution. The entire flow in Cow Creek is measured below all tributary influences including Clover Creek. Because Clover Creek encompasses 13 percent of the Cow Creek watershed, and the precipitation zones indicate uniform distribution over the Cow Creek watershed, the average daily flow in Clover Creek was estimated by multiplying the average daily flow in Cow Creek by 13 percent.

In order to determine the estimated flows in Clover Creek, the approved mean daily flow from October 1, 1949, through September 31, 2011, was downloaded from the USGS website (gaging station #11374000 in Cow Creek). The mean daily flow in Clover Creek was estimated by taking 13 percent of the mean daily flow in Cow Creek. An estimated hydrograph of Clover Creek was developed (Figure 10). The method to estimate flows was verified by several recent flow measurements.

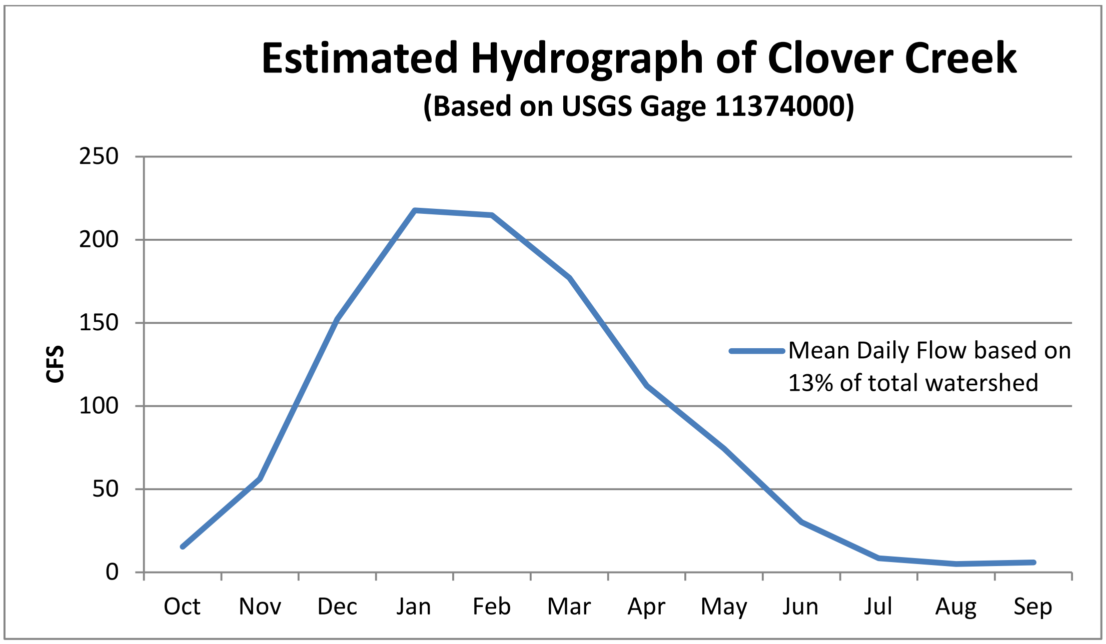

Figure 10. Estimated Hydrograph of Clover Creek

Measured Flow

CDFW has been monitoring flow and water temperature data in Clover Creek at the Old Highway 44 Bridge from 2008 to present. The Old Highway 44 Bridge is located about 3 miles downstream from the project site. The flow was recorded by a Price Type AA current meter, and the water temperature and ambient temperatures were also recorded as shown in Table 1.

The actual flow data measured in Clover Creek by CDFW was analyzed to see what percent of flow was actually measured based on the total flow in Cow Creek. Based on the 24 days over a range of 4 years, the average flow was 13 percent, the median was 14 percent with a standard deviation of 4.6. This analysis was used to verify that the method used to estimate flow in Clover Creek was appropriate.

Table 1. Temperature and Flow Data in Clover Creek (CDFW 2011)

Date	Time	CFS	Water Temperature	Air Temperature	Notes
05/13/2008	0800	24.00	61.0	N/A	
05/20/2008	0800	24.00	74.0	N/A	
10/14/2008	1645	1.80	62.0	N/A	
10/21/2008	1645	2.00	58.0	N/A	
10/30/2008	1600	2.00	53.0	N/A	
11/03/2008	1320	48.00	53.0	51.0	
11/14/2008	1520	14.35	56.0	N/A	
12/05/2008	0835	10.90	42.0	36.0	
12/12/2008	0836	14.20	38.0	35.0	
01/08/2009	1504	42.90	44.0	55.0	
01/14/2009	1610	41.40	44.0	56.0	
01/23/2009	1515	49.50	47.0	61.0	
02/11/2009	1515	94.00	47.0	49.0	
02/18/2009	1711	254.00	48.0	52.0	
03/27/2009	0840	53.90	53.0	60.0	
04/21/2009	1450	31.10	70.0	94.0	Diversion in
05/09/2009	1600	69.42	63.5	83.0	
05/22/2009	1600	24.10	74.0	93.0	
06/19/2009	0910	10.36	72.0	N/A	
10/05/2009	1315	2.49	57.0	N/A	
10/15/2009	0835	15.42	59.0	60.0	
05/06/2010	0805	48.48	50.5	52.0	
01/20/2011	0830	70.57	52.0	N/A	
06/13/2011	0815	110.04	52.0	68.0	

Fish Passage Flows

According to the CDFW California Salmonid Stream Habitat Restoration Manual, the upper fish passage flow limit for adult anadromous salmonids is defined as the 1 percent exceedance flow. The 1 percent exceedance flow is the discharge that is equaled or exceeded in the stream an average of 1 percent of the days for the indicated periods. For all adult salmonids, the lower fish passage flow equals the 50 percent exceedance flow. An estimated flow duration curve for Clover Creek was created for Water Years 1950 through 2011 (Figure 11).

The 1 percent and 50 percent exceedance flows for fall-run migration period are 400 cfs and 15 cfs, respectively. The 1 percent and 50 percent exceedance flows for late fall-run Chinook salmon and steelhead migration period are 1,400 cfs and 80 cfs, respectively.

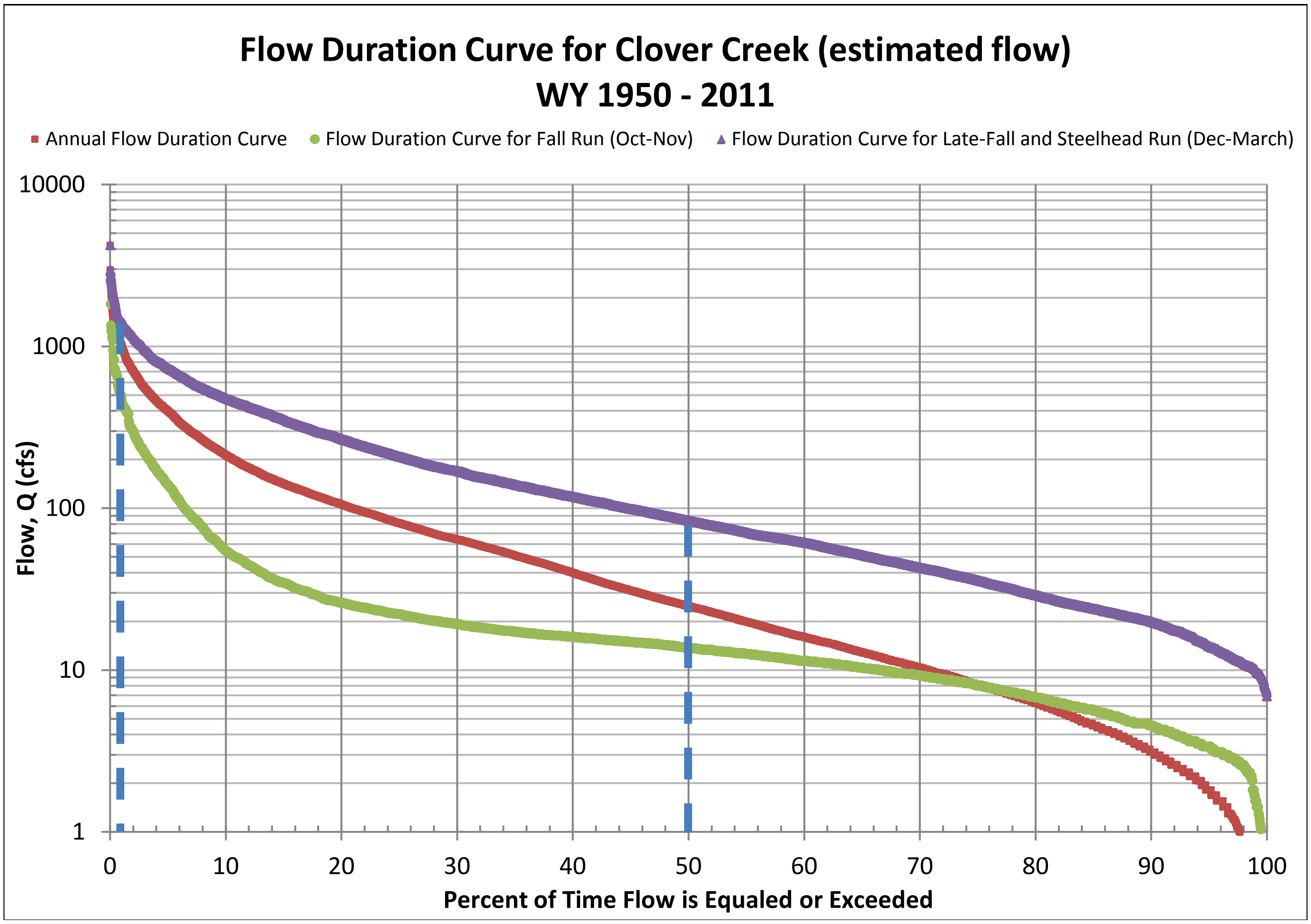

Figure 11. Estimated Flow Duration Curve for Clover Creek

The design low flow is 10 cfs, but the fish ladder will operate at flows down to 2 cfs, as recommended by the TAC due to low flows during the fall-run migration. The high flow design is 400 cfs, which accommodates fall-run passage 99 percent of the time, and late-fall and steelhead passage 88 percent of the time.

Hydraulic Model

A one-dimensional hydraulic model was developed for the project to analyze current and proposed conditions. Surveyed cross sections were imported into the Hydrologic Engineering Center River Analysis System (HEC-RAS version 4.1.0, 2010). The hydraulic model predicts water surface elevations, flow velocity, water depths, and other hydraulic parameters.

A total of 52 cross sections covering a distance of roughly 2,700 feet were used in the analysis. The cross sections were surveyed in 2007 and updated in 2012 near the dam and siphon area, where most of the incision occurs.

Roughness coefficients were assigned to left overbank, channel, and right overbank for each cross section. Generally, the left and right overbanks were assigned a Manning's value of 0.07 and the channel ranged from 0.033 to 0.05 due to the complexity of the channel.

The steady flow analysis requires user-input flow data and boundary conditions. This analysis used the known WSEL boundary condition. Water surface elevations were surveyed during the estimated 10 cfs flow regime and the measured 165 cfs flow regime. A mixed regime steady flow analysis was computed for fish passage flows, ranging from 2 cfs to 400 cfs. A flow of 3,000 cfs was also analyzed and was the maximum flow that was contained within the cross-sectional data. Flows above 3,000 cfs crossed outside of the cross sectional data and was not included in the analysis.

The model was calibrated to the 165 flow regime. The WSEL profile matched within 0.25 feet of the observed WSEL. The WSELs analyzed for the proposed condition suggest no significant changes will occur due to the construction of the proposed project. Velocity and stream power were also analyzed around the existing structures to determine the effects of the project on the existing structures. The analysis indicates no degradation to the existing structures is likely to occur due to the construction of the proposed project. The final design engineer should conduct a more detailed scour analysis because HEC-RAS is not necessarily the best model to predict scour conditions.

Geologic Investigation

Several geologists from various agencies visited the Clover Creek site to analyze existing geologic conditions of the stream. DWR geologists investigated the potential impacts associated with the removal of the dam and siphon. NRCS geologists investigated a cross-vane step-pool structure natural channel alternative. CDFW geologists provided guidance on the analyses and analyzed the geological impacts of the alternatives. Also included in this investigation, was density testing of local large rock that may be used for rock slope protection for the project.

Alternative Analysis

In 2007, DWR geologists conducted a geologic investigation on the potential impacts with removal of the dam (Appendix A). The dam structure is constructed on bedrock of the Cretaceous Chico Formation. This formation consists mainly of siltstone that is very friable and slakes when exposed to air and sunlight. The undercutting on the downstream side of the dam and the plunge pool that has developed is evidence of this (Figure 12).

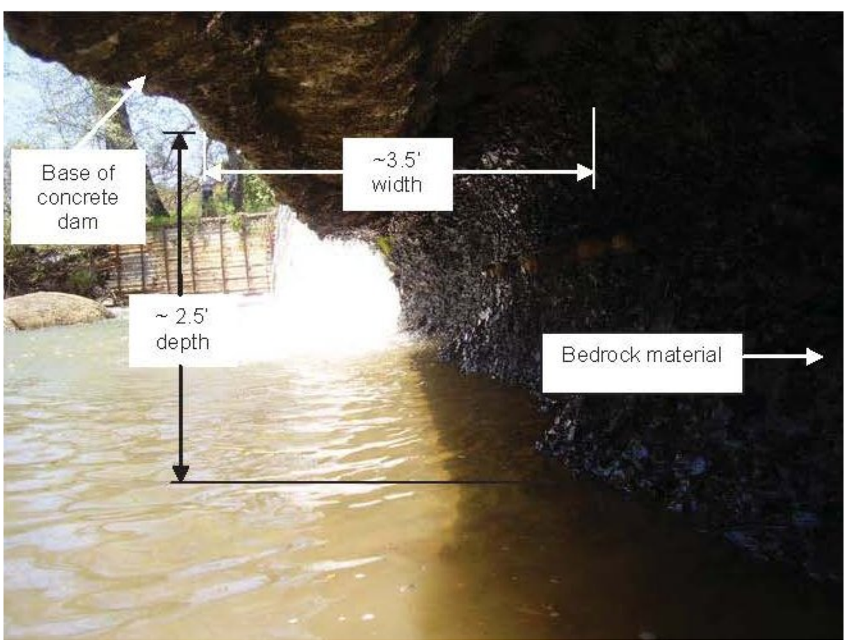

Figure 12. Photo of Undercutting on Downstream Side of the Dam (May 2007)

DWR determined that about 800 cubic yards of sediment was stored behind the dam. If the dam was removed, sediment could fill the plunge pool below the dam or get transported downstream. The creek has a potential for headcutting if the dam were removed.

At the siphon, very little alluvium was observed entrapped behind the siphon. Removal of the siphon would not result in a large amount of sediment being washed downstream. It is possible that localized head cutting and scour into the siltstone bedrock could undercut the footing of the upstream bridge pier due to the friable nature of the bedrock.

There was not a consensus among the geologists related to the geomorphic response related to the removal of the structures. The lack of consensus was due to the unreliable sandstone beds that have a high potential for incision and headcutting. Therefore, in 2008, an NRCS geologist was invited to the site to analyze the geologic conditions and provide insight on possible alternatives for fish passage.

NRCS provided a cursory analysis of the existing geologic conditions and a brief description of a natural channel alternative. The recommended natural channel alternative included using cross-vane step-pool structures to allow for fish passage over the existing structures. A report summarizing the site condition and recommendations on building a natural channel alternative is discussed in Appendix B.

Rock Density Testing

As part of this project, large rock is needed for certain design elements and NRCS suggested we utilize existing rock from Bar 11 Ranch. The NRCS had utilized existing rock on Bar 11 Ranch for past stream restoration activities, and the landowner is supportive. The rock harvesting area is identified on Sheet 1.

The weight and size of the rock are essential factors in resisting erosive water forces. Typically, rock having surface saturated dry specific gravity (SSSG) above 2.6 is suitable rock slope protection material (Reclamation 2001). The TAC determined that the local rock should be tested to ensure a minimum SSSG of 2.6 is met.

Three rocks of varying sizes were gathered from the rock harvesting area and tested by DWR Bryte Lab in August 2012. A SSSG test (ASTM D6473-10) was performed on all three rocks identified as largest, smooth, and angular. The three rocks, largest, smooth, and angular had specific gravity values of 2.75, 2.76, and 2.69, respectively. The average specific gravity of the rocks was determined to be 2.74. The final design engineer will determine if the local rock meets all the required rock slope protection criteria.

Botanical Investigation

In 2007, DWR environmental scientist visited the project site to assess the impacts to the existing vegetation if the dam and siphon were to be removed. A list of all plant species adjacent to the siphon, dam site, and terrace meadow observed on July 26, 2007, is provided in the memorandum in Appendix C. The probable project effects were determined to be insignificant.

If the siphon were to be removed, probable effects would be that the existing vegetation would migrate down to the new water's edge. If the dam were to be removed, there would be little to no effects on the existing terrace. The terrace has been disconnected from the stream for many decades due to downcutting of the stream. The vegetation upstream of the dam site would have limited effects. If the diversion ditch was eliminated, the substantial ribbon of wetland or riparian vegetation along much of its length would be effected. Much of the small to medium sized trees, shrubs, vines, and herbaceous species lining the ditch would most likely die off, especially in areas having no other water supply to their root zones.

Habitat Typing Survey

Based on the geology of Clover Creek, the minimal fish habitat at the project area, low flow, and temperature concerns, the TAC determined it was necessary to conduct a salmonid habitat assessment upstream of the project area to determine the benefit of providing fish passage. A habitat assessment was conducted by DWR, CDFW and USFWS staff between the years of 2008-2011. The Clover Creek Habitat Assessment report was completed in August 2012 (Appendix D). The assessment included describing the type and distribution of habitat units, quantifying the aerial extents of gravels and patch sizes suitable for spawning, and gathering data on other factors that impact successful spawning, rearing, and holding. These factors include, but are not limited to, cover and habitat complexity, embeddeness, coarse woody material, and percentage of exposed bedrock.

The assessment concluded that the 10 miles of habitat existing above the dam is marginal at best. Extensive restoration efforts would need to be implemented in order to adequately supply enough habitat for a healthy salmonid population.

Structural Analysis Investigation

A cursory structural analysis was conducted on May 20, 2012, to assess whether fish passage facilities could be constructed at two locations on Clover Creek without reducing the structural stability of the existing siphon and dam (Appendix E). The scope of the investigation included three assessments:

- Determine whether existing soils are capable of supporting the new and existing structures.
- Identify basic methods for constructing fish passage facilities which will not weaken the existing dam, siphon, or bridge structures.
- Identify possible retrofit measures to strengthen and stabilize the existing dam, siphon, and bridge structures.

The scope of work did not address the possible effects of higher scour potential and forces on the existing structures as a result of constructing new facilities, or retrofit measures to the existing structures.

The strength of the concrete at the siphon encasement and dam were tested using a Schmidt Hammer. Visual observations of the siphon encasement and Schmidt Hammer test results were inconclusive with regards to the present stability of the structure and strength of concrete. The concrete strength of the dam appears to be very satisfactory, but it is an important parameter that should be investigated in more detail during final design. Concrete cores should be tested to confirm the condition and strength.

It is feasible to construct the fish passage facilities without adversely affecting the stability of the existing structures, provided the construction does not significantly disturb the existing siphon. DWR recommends the following measures be taken to strengthen and increase stability of the existing structures:

- Patch areas of erosion underneath the siphon and dam with concrete.
- Fill scour holes around bridge piers with concrete.
- Fill scour holes at the embankment with suitably sized rock slope protection.
- Fill the existing siphon with concrete.
- Place rock slope protection in the downstream scour holes at the siphon and dam.

Project Alternatives

Alternatives Considered

During the investigation, many factors were analyzed such as fish passage, operation and maintenance, condition of existing facilities, stream characteristics, stream hydrology, biological criteria, owner liability, and economics. Four alternatives are described below:

- Alternative 1: Dam and Siphon Removal–This alternative consists of removing the dam and siphon structures, installing a fish friendly pump in the channel, replacing the bridge, and installing solar panels to offset power costs related to pumping.

- Alternative 2: Natural Channel–This alternative consists of constructing a natural channel over the existing dam and siphon using step-pool structures, and screening the existing diversion.

- Alternative 3: Fish Ladders–This alternative consists of constructing fish ladders at the dam and siphon, screening the existing diversion, replacing the siphon, and increasing the stability of existing structures.

- Alternative 4: Do Nothing

Alternative 1 was abandoned due to concerns of the anticipated geomorphic response related to removing the structures (dam and siphon). The anticipated geomorphic response (incision) could negatively affect the tailwater control for the fish friendly pump. The incision could create conditions such that the pump would not be compliant with fish screening criteria as well as not being able to meet the MDA's water right.

Alternative 2 was abandoned due to concerns related to the geologic conditions of the stream channel and banks. It was uncertain whether the step-pool structures would remain in place or not. The stream banks are highly erodible, and the stream bed is likely to incise in the future, making it difficult to ensure the step-pools structures function as designed.

Alternative 3 was the preferred alternative and was carried through preliminary design. This alternative consists of pool and weir type fish ladders at the dam and siphon locations. A recommended 2-foot incision is incorporated into the fish ladder design to incorporate future incision. The diversion will be screened with an on-stream flat plate fish screen located on the right bank of the creek upstream of the dam. A new siphon will be constructed upstream of the bridge piers. The TAC determined that the structural enhancements were crucial to the longevity of the fish passage structures and are essential components of the project as it moves forward through final design.

Alternative 4 was abandoned because it does not meet the goal of providing unimpeded passage over the dam and siphon.

Summary of Findings

The selected alternative includes constructing a pool and weir fish ladder at the dam and siphon location, constructing an on-stream flat plate fish screen, constructing an inverted siphon, and making structural improvements at the dam and siphon. The fish passage design guidelines and structural components of the preferred alternative are described in the following sections.

Pool and Weir Fish Ladders

A pool and weir fish ladder consists of a series of pools separated by weirs at consecutively higher elevations. The shape and elevation of the weirs control the hydraulics within the fish ladder. The primary limitation of the pool and weir fish ladder is the narrow range of operating flows. There are two hydraulic conditions that are important in the design of the ladder, the flow regime (plunging versus streaming) and turbulence.

The normal flow pattern in a pool and weir fish ladder is plunging flow. Plunging flow is where water flows over the weir creating a nappe that plunges downward to the next pool downstream. As flows increase, hydraulic instability occurs through a range of transitional flows until eventually a streaming flow occurs.

At the high design flow, the fish ladder flow should be plunging and turbulence should be limited. Hydraulic instability such as surging and oscillations in the water surface elevation often occur in the transition between the upper range of plunging flow and the lower range of streaming flow (Bell 1991). The flow at which the transition occurs from plunging to streaming depends on the geometry of the pool, the flow, and the head differential between pools (CDFW 2010).

The volume in each pool must be adequate to dissipate all the energy without being too turbulent for fish to hold and move through it (CDFW 2010). The Energy Dissipation Factor (EDF) equation is used to determine the pool volume. The suggested maximum EDF for Pacific Salmon is 4.0 foot–pounds per second per cubic foot (ft-lb/sec/cf).

In order to determine the fish passage range of flows, a flow duration curve was developed for Clover Creek. As previously discussed in the Fish Passage Flows section, the upper flow range is 400 cfs which accommodates 99 percent of migrating fall-run Chinook salmon during the peak migration timing of October and November.

When determining the fish ladder range of flows, fish passage guidelines recommend a minimum of 10 percent of the total creek flow be conveyed through the fish ladder. Because a pool and weir fish ladder operates within a narrow range of flow, CDFW recommended the ladders be designed to convey less than 10 percent of the creek at high flow in order to accommodate a wider range of flows.

According to the pool and weir fish ladder design standards the maximum head differential between any two pools or across any structure should not exceed 1 foot. Due to the geologic condition of this creek, the probability for incision to occur is high. The TAC agreed that the design should include the possibility for a 1-foot incision at the dam area and a 2-foot incision at the siphon area as recommended by CDFW.

CDFW has developed a draft engineering checklist for fish passage projects. The checklist was developed to provide guidance on the type of information required for CDFW fisheries engineering staff to complete reviews of project designs for fish passage and screening projects at water diversions. The checklist for Millville Diversion fish passage facilities is located in Appendix F.

Dam Fish Ladder Sizing and Configuration

The dam is a fish barrier that creates about a 6-foot head differential during low flows.
Adding the 1-foot incision as recommended by CDFW, a 7-foot head differential was used to design the fish ladder at the dam. This resulted in an extra pool and baffle for the fish ladder design.

By adding the seventh baffle (sixth pool), a backwater condition will exist at the fish ladder entrance. The backwater condition could cause a fish passage delay due to lack of attraction flow. To help ensure there is adequate attraction flow (until incision occurs), the seventh baffle was designed as a 12-inch vertical slot. Creating a smaller flow area at the fish ladder entrance should increase the velocity and flow pattern such that fish are attracted to the ladder.

The transitional flow between plunging and streaming flow regimes were analyzed using the Equation XII-9 and graph from the California Salmonid Stream Habitat Restoration Manual. Based on several factors such as the length of pool, height of the weir, fish ladder slope, and width of fish ladder, the transitional flow was determined. The transitional flow was estimated to occur at about 30 cfs. However, the transitional flow can be increased by 25 percent by rounding or chamfering the downstream weir edges. Therefore, the transitional flow could occur at about 37 cfs in the fish ladder.

The design high flow used for the fish ladder at the dam was 400 cfs. The anticipated flow in the fish ladder is about 30 cfs when there is 400 cfs in the creek and a 6-inch tall flashboard is placed in the 3-foot wide low flow weir. In order to meet the EDF requirement at 400 cfs, the internal pool dimension was determined to be 8 feet wide by 10 feet long with a maximum depth of 5.7 feet. Table 2 reveals the different flow regimes for the pool and weir fish ladder at the dam.

Table 2. Flow Regimes in Dam Fish Ladder

Estimated Creek Flow (cfs)	Depth of flow over weirs (ft)	Ladder Flow (cfs)	Dam Flow (cfs)	Percent of Flow in Ladder (%)	EDF	Comments
10	1	10	0	100%	1.7	Design Low Flow
20	1.2	11	13	55%	1.8	
40	1.3	12	30	30%	1.9	
60	1.4	13	49	22%	2.0	
80	1.5	14	68	18%	2.1	
165	1.9	21	148	13%	2.8	
400	2.6	30	370	8%	3.4	Design High Flow with 6 inch board in low flow weir

The proposed dam fish ladder is about 70 feet long and consists of six pools with seven baffles (Sheet 8). Six of the baffles consist of a 3-foot wide low flow weir and a 5-foot wide sloped high flow weir to accommodate head fluctuations of up to 3 feet. The sloped weir is angled 112 degrees (Sheet 9). The seventh baffle, located at the entrance to the fish ladder, is a 12-inch vertical slot to help create attraction flow. An entrance pool will be excavated down to a minimum elevation of 553 feet to create a 3-foot deep pool during low flows.

The 3-foot wide low flow weirs are located along the right side of the fish ladder for ease of operation and maintenance as well as to provide increased sweeping velocities past the fish screen during low flows. The exit weir, where water enters the fish ladder, was set 1 foot below the elevation of the dam at 561 feet. (See Baffle 1 on Sheet 8.) This 1-foot lowering was to help maintain the thalweg on the right side of the channel where the fish ladder and screen are located.

The existing thalweg of the creek upstream of the dam is along the right bank due to the existing notch in the dam. The fish ladder was placed on the right side of the dam through the existing notch to ensure efficient flow in the ladder during low flow. The ladder has a 45 degree bend to direct flow towards the center of the channel which should help fish find the entrance. The angled pool was extended to accommodate for possible upwelling.

The fish ladder wall at the fish ladder exit where flow enters the fish ladder is set at elevation 566 feet which allows for about 2 feet of freeboard during high flows. As flows increase to 2,000 cfs and above, water will overtop the fish ladder structure. At 2,000 cfs in Clover Creek, a 5-foot head differential still exists at the dam. During the review process, NMFS requested raising the fish ladder wall to allow for 3 feet of freeboard during high flows (Appendix G). This should be incorporated during the final design.

Rock slope protection is included along all sides of the fish ladder as recommended by the structural analysis. This will help minimize possible erosion along the fish ladder walls.

Dam Fish Ladder Operation and Maintenance

The dam fish ladder was designed to have low operation and maintenance while providing good fish passage. The primary operation for the dam fish ladder is to ensure a maximum elevation drop of 1 foot (or less) between pools. A 5.6-foot head differential exists during low flow and will be distributed across 7 baffles which equates to a drop of about 0.8 of a foot per pool.

Adjustments to the fish ladder can be made by placing flashboards in the low flow, 3-foot wide weir (Sheet 9). Adjustments are needed at both low flow and high flow events. During low flow, flashboards can be used to increase the low flow water surface elevation to aid in the operation of the fish screen and water delivery system. During high flow, flashboards can be used to reduce the amount of water entering the fish ladder to minimize turbulence in the fish ladder. Flashboards can also be placed in the 12-inch vertical slot at the fish ladder entrance to ensure adequate attraction flow exists.

As incision occurs, a maximum 1-foot head differential between pools will exist. Flashboards might be needed in the 12-inch vertical slot to ensure adequate attraction flow and depth. Further adjustments can be made in the 3-foot wide weir as indicated above.

When maintenance to the ladder is required, flashboards can be used to dewater the structure. Flashboards (about 9.5 feet wide) can be placed 3 feet upstream of the fish ladder exit (Sheet 8). Water must be pumped out of the pools in order to completely dewater the fish ladder otherwise a minimum depth of 2 to 3 feet will exist in the each pool.

The amount of sediment that moves down the system during high flow events will determine how often maintenance will be required. Pool and weir type fish ladders with no orifices can accumulate sediment and debris. The accumulation of sediment and debris can affect the hydraulics of the ladder. Because the vertical slot opening in this design continues to the invert of the floor, most sediment should find a path out of the first pool, unless the sediment or debris is larger than the 12-inch slot. Based on the geology in Clover Creek and the habitat typing survey, Clover Creek is sediment limited; thus, it is not anticipated the ladder will require frequent maintenance.

Inverted Siphon Fish Ladder Sizing and Configuration

The inverted siphon at the bridge location is a fish barrier that creates about a 4-foot head differential during low flows. Incorporating the possible two feet of incision, as recommended by CDFW, a 6-foot head differential was used to design the fish ladder at the siphon. This resulted in two extra pools and baffles for the fish ladder design.

By adding the extra pools and baffles, a backwater condition will exist in the lower portion of the fish ladder. The backwater condition could cause a fish passage delay due to lack of attraction flow. To help ensure there is adequate attraction flow (until incision occurs), the seventh baffle was designed as a 12-inch vertical slot. Creating a smaller flow area at the fish ladder entrance should increase the velocity and flow pattern such that fish are attracted to the ladder.

The transitional flow between plunging and streaming flow regimes were analyzed using the Equation XII-9 and graph from the California Salmonid Stream Habitat Restoration Manual. Based on several factors such as the length of pool, height of the weir, fish ladder slope, and width of fish ladder, the transitional flow was determined. The transitional flow was estimated to occur at about 15 cfs. However, the transitional flow can be increased by 25 percent by rounding or chamfering the downstream weir edges. Therefore, the transitional flow could occur at about 19 cfs in the fish ladder.

The pool volume was based on the high flow of 400 cfs. The design high flow for the siphon fish ladder is 22 cfs which accounts for 6 percent of the 400 cfs high flow design criteria. In order to maintain an EDF of 4.0 ft-lb/sec/cf or less, the pool volume internal dimension was determined as 6 feet wide by 8 feet long pools with a maximum depth of 5 feet.

The proposed pool and weir fish ladder is about 50 feet long and consists of 5 pools with 6 baffles (Sheet 3). Five of the baffles consist of a 2-foot wide low flow weir and a 4-foot wide high flow weir while the sixth baffle, located at the fish ladder entrance, is a 12-inch vertical slot to help create attraction flow. Table 3 reveals the different flow regimes for the pool and weir fish ladder.

Table 3. Flow Regimes in Siphon Fish Ladder

Estimated Creek Flow (cfs)	Depth of flow over weirs (ft)	Ladder Flow (cfs)	Dam Flow (cfs)	Percent of Flow in Ladder (%)	EDF	Comments
10	0.6	3	7	30%	0.9	Design Low Flow
20	0.7	4	16	20%	1.1	
40	0.9	5	35	14%	1.4	
60	1.0	6	54	10%	1.6	
80	1.1	7	73	9%	1.6	
165	1.4	11	154	7%	2.4	
400	1.5	22	374	6%	3.6	Design High Flow with 6-inch board in low flow weir.

Attraction flow is an important part of a fish ladder; therefore, extra pools are not desirable because of the backwater effect at the fish ladder entrance during current conditions. In order to incorporate the two feet of incision without compromising the attraction flow, flashboards will be used permanently in baffles two through five until incision occurs (Sheet 4). The use of the flashboards will create a situation where the first two weirs will be at the same elevation, thus eliminating 1 foot of drop, but backwater will still be a concern. The vertical slot entrance pool will help create attraction flow due to the constricting 12-inch slot. Once the 2-foot incision occurs, the flashboards will be removed and the ladder will operate as a "normal" pool and weir fish ladder with no backwater concerns.

The fish ladder was placed along the right bank of the creek where it is out of the main flow (Sheet 2). The ladder has a 45-degree bend to direct flow towards the center of the channel which should help fish find the entrance. The angled pool was extended to accommodate for possible upwelling. The bank along the upstream right bank will need to be sloped back and excavated to direct flow into the ladder. Due to the backwater effect from the existing siphon concrete apron and the little sediment built up behind the apron, it is anticipated the low flow channel will stay open. There is a possibility that sediment could deposit in the low flow channel, which would require some maintenance to ensure water flows in the fish ladder. A retaining wall is incorporated on the upstream right bank to help support the bank from lowering of the channel bottom to elevation 550.0 feet.

An entrance pool will need to be excavated to a minimum elevation of 544.4 feet to create a 3-foot deep pool at low flow. The fish ladder walls are extended up to elevation 555.5 feet at the fish ladder exit where the flow enters the fish ladder. As flows in the creek increase above 1,600 cfs, flows will overtop the fish ladder. At 1,600 cfs in Clover Creek, a 2.8-foot head differential exists at the siphon.

Rock slope protection is included along all sides of the fish ladder as recommended by the structural analysis. This will help minimize possible erosion along the fish ladder walls.

Siphon Fish Ladder Operation and Maintenance

The siphon fish ladder was designed to have low operation and maintenance while providing good fish passage. The primary operation for the siphon fish ladder, before incision occurs, will be to ensure the flashboards are in place and attraction flow exists at the entrance. Flashboards might be needed in the 12-inch entrance slot to increase the head difference at the downstream end of the fish ladder so that attraction flow is achieved.

As water enters the fish ladder exit and the flashboards are installed in baffles two through five, the water surface elevation between the first two baffles does not change. Not until incision occurs and the flashboards are removed, will a 1-foot drop exist between the first two baffles. During this scenario, the existing 4-foot head difference during low flow will be distributed across 5 baffles which equates to a head differential of 0.8 of a foot between pools. Further adjustments can be made by placing flashboards in the 2-foot wide weir, if needed, to ensure proper hydraulics in the fish ladder.

When a total of 2 feet of incision occurs at the siphon area, all flashboards will be removed and a 1-foot head differential will exist throughout each pool creating a total head differential of 6 feet.

When maintenance is required, flashboards can be used to dewater the structure. Flashboards about 6.5 feet wide can be placed 3 feet upstream of the fish ladder exit (Sheet 3). Water must be pumped out of the pools in order to completely dewater the fish ladder otherwise a minimum depth of 2-3 feet will exist in the each pool.

The amount of sediment that moves down the system during high flow events will determine how often maintenance will be required. Pool and weir type fish ladders with no orifices can accumulate sediment and debris which will affect the hydraulics of the ladder if too much buildup occurs. Because the vertical slot opening continues to the invert of the floor, most sediment should find a path out of the first pool, unless the sediment or debris is larger than the 12-inch slot. Based on the geology and the habitat typing survey, Clover Creek is sediment limited; thus, it is not anticipated the ladder will require frequent maintenance.

Fish Screen

Sizing and Configuration

The proposed preliminary on-stream flat plate fish screen design and required surface area of the screen were determined using the CDFW Fish Screening criteria for steelhead trout, and National Oceanic and Atmospheric Administration (NOAA) Fisheries Fish Screening criteria for anadromous salmonids. With a maximum allowable approach velocity of 0.33 feet per second (fps) (for continually cleaned screens in streams and rivers) and a maximum diversion of 8.2 cfs, the required wetted screen area is about 25 square feet (sf). Adding 25 percent (6.25 sf) to the required wetted area to compensate for reduction of screen area due to structural members, the required screen area becomes 31 sf.

The recommended sweeping velocity should be at least twice the approach velocity of 0.66 fps and less than 3 fps. For screens longer than 6 feet, sweeping velocity must not decrease along the length of the screen. Based on the HEC modeling, the one-dimensional velocity along the right bank at the fish screen location ranges from 0.5 to 2.7 fps for flows ranging from 10 to 600 cfs, respectively. Because of the gentle channel slope and slow velocities, the sweeping velocity criteria may not be met during certain flow conditions, depending on the amount of water being diverted. The 3-foot wide low flow exit weir in the fish ladder, where water enters the fish ladder, was set 1 foot below the elevation of the dam at 561 feet. This one-foot lowering was to help maintain the thalweg on the right side of the channel where the fish ladder and screen are located. The low flow weir of the fish ladder was placed along the right side of the ladder to help increase sweeping velocities across the fish screen face during low flow.

Sheet 10 shows the plan and profile view of the fish screen layout. The fish screen will have a continually cleaning apparatus, which uses a sweeping brush powered by a paddle wheel located behind the screen (to be designed during final design). The screen face will consist of removable wedgewire panels. The screen consists of two panels measuring 8 feet wide by 2 feet tall, totaling a screen area of 32 sf. The screen invert will be elevated 1 foot above the concrete slab to prevent sediment from interfering with fish screen operations.

WSELs in Clover Creek at the fish screen location are controlled by the top of the dam, located approximately 40 feet downstream at elevation 562 feet. The invert elevation for the proposed screen is 560 feet so that the fish screen will be submerged during low flow operations. In order to meet the maximum diversion of 8.2 cfs and stay within operating criteria, the screen face should be submerged 2 feet. As water levels decrease, so does the amount of water delivered to MDA.

The fish screen structure walls are 7 feet tall and at an elevation of 566 feet. Flows 2,000 cfs or greater will overtop the fish screen structure. Steel grating, shown on Sheet 10, will be used to cover the entire screen structure to provide safety and to exclude debris. The grating will also be used as a walkway to access the fish screen for maintenance activities.

A headgate at the diversion entrance will be used to control water into the existing ditch and will be used to dewater the existing ditch and siphon. The headgate is located downstream of the screen face and is part of the fish screen structure (Sheet 10).

Operation and Maintenance

The fish screen was designed to have low operation and maintenance while providing excellent fish passage. MDA will operate and maintain the fish screen structure after construction.

Operational requirements will include site visits to ensure the screen cleaning equipment is functioning properly and to adjust flow into MDA ditch via the headgate. Maintenance responsibilities include periodically replacing the brush cleaning system components, occasionally cleaning sediment from the screen bay, and possibly replacing a screen face due to unforeseeable circumstances.

If a maintenance problem occurs that requires the screen to be removed from service, the structure can be dewatered while repairs are made. Included in this design are dewatering panels that can be installed on the outside wall of the fish screen bays. When the fish screens are removed and dewatering panels are placed, water can be drained out through the culvert via the headgate or pumped out if necessary.

Inverted Siphon

The existing siphon consists of a 30-inch diameter CMP approximately 205 feet long. The pipe is encased in concrete where it passes underneath Clover Creek on the downstream side of a privately owned railcar bridge. Portions of the pipe within the floodplain are also encased in concrete, but because it is partially buried, the exact extent of the concrete is not known.

This project proposes to replace the existing siphon with a new siphon on the upstream side of the existing bridge. The new siphon will be approximately 240 feet long and encased in concrete where it passes beneath the creek and floodplain. The following report sections describe the details of the proposed inverted siphon. See Sheet 5 for plan and profile views.

Sizing and Configuration

Overview

The proposed inverted siphon will consist of several features including a headwall structure, several sections of siphon pipe, a vertical riser, and an exit structure. These structures will be described in detail in the following sections.

Entrance Structure

The upstream end of the siphon will be a concrete headwall structure with a trash rack and a recessed floor (Sheet 6). The trash rack will prevent large debris from entering the structure and the recessed floor will serve as a collection basin for sediment. The collection basin will need to be periodically cleaned to prevent excess debris from entering the siphon pipe. This structure will also have a headgate to shut off the water to the system. The headgate will not be used to control the flow of water; flow control will be provided by a separate headgate at the fish screen. The existing ditch will need to be realigned slightly to accommodate the new three-sided headwall structure which will be oriented at a slightly different angle than the current one-walled structure.

First Pipe Segment

Immediately downstream of the entrance structure is a 55-foot section of buried pipe set at 1 percent slope in the downstream direction (Sheet 6). The new pipe will be a 24-inch smooth-walled pipe. The new pipe should be backfilled with at least two feet of earth cover or to existing grade, whichever is greater. The existing 30-inch CMP will be abandoned or decommissioned as described elsewhere in this document.

Head Loss and Pipe Size

By replacing the larger and relatively high-friction 30-inch CMP with a smooth-walled plastic pipe measuring 24 inches in diameter, the same amount of water can be delivered with virtually identical head losses. Figure 13 shows the estimated head losses for a 30-inch CMP in good condition compared to a 24-inch smooth-walled plastic pipe. The figure somewhat underestimates the head loss for the existing 30-inch pipe because the pipe is not in good condition.

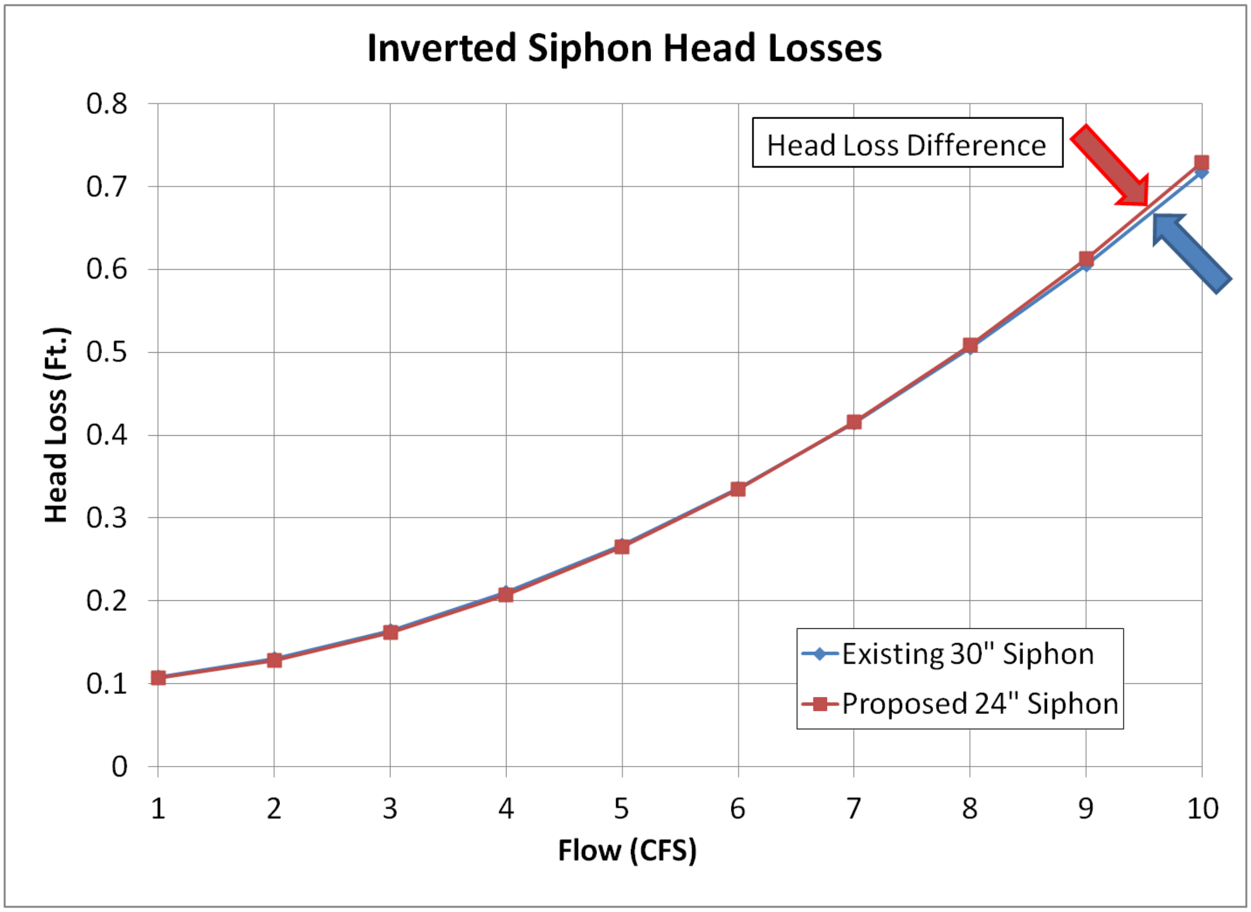

Figure 13. Estimated head losses for 30-inch CMP and 24-inch smooth pipe

According to the calculations it takes a flow of nearly 10 cfs for the head losses in the two pipes to be noticeably different, and even at this discharge, the difference is only 0.03 feet. In its current condition, the existing siphon experiences approximately 1 foot of head loss at moderate flows. It is known that the existing siphon noticeably leaks, but it is unknown what other factors may contribute to the large head loss.

Second, Third, and Fourth Pipe Segments

After the first section of buried pipe, the siphon will enter the channel and will be encased in 1-foot of concrete on all sides for its protection. The pipe will continue down the bank of the creek for approximately 17 feet at roughly the same grade as the existing ground to minimize excavation quantities. The next 19 feet of pipe will be buried just beneath the 2:1 sloping bank that will be constructed for the fish ladder portion of this project. The fourth section of pipe will be approximately 83 feet long and pass under the creek with the top of the pipe encasement approximately equal to the thalweg elevation of the creek. This fourth section of pipe will have an approximate 0.5 percent of slope towards the base of the vertical riser (Sheet 6).

The alignment of the fourth section of pipe will be located just upstream of the existing concrete apron under the railcar bridge and at a slightly lower elevation. It is believed that the type of incision that has occurred on the downstream side of the existing siphon will not occur at the proposed siphon's location because the existing apron will prevent the type of plunging flow that allowed the downstream incision to occur.

Vertical Riser

After passing under the creek, the fourth pipe section will be connected to a vertical riser. The riser, much like the previous pipe sections, will be a concrete encased plastic pipe (Sheet 6). A vertical riser is necessary because the topography on the upstream side of the bridge does not allow a configuration like the existing approximately 1:1 sloping concrete encased pipe on the downstream side of the bridge.

Excavation and concrete cutting will be required to construct the lowest elevation portion of the riser. The bottom portion of the riser will be a sump that is two feet deeper than the invert of the fourth section of pipe where the two features connect. The upper portion of the riser will not be buried, so this concrete will need to be reinforced to withstand impacts from debris that may be transported down the creek during storm events or flood flows. The riser will be connected to the bridge abutment for additional strength.

The top of the riser will have an access hatch to facilitate cleaning. Cleaning will be discussed later in this document. The vertical riser, including the sump, will be approximately 20 feet tall, not including footings which will be designed by the final design engineer.

Fifth Pipe Segment

The fifth pipe section will be approximately 50 feet long and be sloped at approximately 0.5 percent from the vertical riser towards its exit (Sheet 6). There will be one horizontal angle-point in this pipe section to turn it under the roadway and towards the existing ditch. Siphon pipes under farm roads require a minimum of 2.0 feet of earth cover. With the proposed design, the top of the pipe will be approximately 2.3 feet below the existing roadway surface, but future grading or changes to the road may reduce the earth cover to an unacceptable level. DWR recommends that material excavated for the installation of the pipe be spread back on the road after the pipe is installed to increase the depth of earth cover.

Exit Structure

The fifth section of pipe will terminate in a concrete exit structure (Sheet 6). The exit structure will be located in the ditch just upstream of the existing Parshall Flume. The structure will have an angled wall on the right-hand side to redirect water flowing into the ditch parallel to the existing ditch alignment to minimize erosion on the right wall of the ditch.

Inverted Siphon Pipe General Details

The "plastic" siphon pipe will have smooth inner walls to reduce friction, but the actual material that the pipe is made of will be selected by the final design engineer. Types of pipe used may include high-density polyethylene, other types of polyethylene thermoplastics, or similar materials that meet the design specifications. The water velocity in the pipe is calculated to be approximately 2.0 feet per second under full design flow. It is desirable to have a higher water velocity; 3.5 to 10.0 feet per second is recommended, but there is not enough gradient at this site to increase the head differential and velocity, and a smaller pipe would not have the capacity to transport the entire water right for this diversion. It is anticipated that with the construction of the sediment basin at the entrance to the siphon that the cleaning requirements will be less for this new structure than they are for the existing structure. No sediment basin currently exists and the proposed pipe will have higher water velocity than the existing pipe.

Operation and Maintenance

If the siphon pipe becomes clogged with sediment or other debris there are a variety of methods available to clean it. These methods include pumping the sump out using a diaphragm pump or a trash pump or a combination of water jetting and pumping. Additional methods are available, but are not described in this document.

Basic diaphragm and trash pumps have the necessary suction head lift capacity to pump out the sump in the vertical riser, which is the lowest elevation point in the entire inverted siphon. Diaphragm pumps are ideal for muddy water, sludge, or any water with a high percentage of solids. Trash pumps will pump a higher volume of water more quickly, but do not handle sludge as well as diaphragm pumps do.

If more serious clogging is encountered, then water jetting may be required. A water jetting machine contains a pump and a high pressure hose that delivers water to a nozzle with jets facing forward and angled backwards. When the system is activated, the force of the water through the forward facing jets scour the obstruction and the rear-angled jets propel the nozzle forward. Water jetting is typically used on low gradient pipe systems and not all water jetting systems are powerful enough to discharge debris from a high gradient 24-inch pipe, so pumping of the loosened debris would probably also be required.

Regular cleaning of the trash rack and collection basin in the entrance structure will help prevent blockages or clogging of the siphon system.

Structural Improvements

Structural improvements at the dam and siphon areas were identified as recommended actions by the cursory structural analysis performed on the existing structures in Clover Creek. As discussed earlier in the Structural Analysis Investigation section, structural improvements recommended were filling in scour holes, using rock slope protection for various functions, and adding concrete below the dam, siphon, and bridge piers.

All concrete placed in channel should be protected with rock slope protection. Actual dimensions will be determined by final design engineer.

Dam Structural Improvements

Several structural improvements are recommended at the dam site including filling the voids under the dam with concrete, adding rock slope protection with concrete in the scour holes below the dam, and adding rock slope protection along the left bank. Sheet 9 illustrates the preliminary structural improvements proposed at the dam.

Filling the voids under the dam and adding rock slope protection in the downstream scour holes could help diminish the possibilities of the dam over-turning and slow down the rate of incision. Rock slope protection with concrete is being proposed below the dam to help dissipate energy. The addition of concrete is designed to help keep rocks in place. The transition from the 3:1 slope to the streambed should not be grouted to allow for adjustment and infilling. The actual features and dimensions will be determined by final design engineer.

The left bank of the dam is being eroded. This could be due to the flow pattern created by a concrete wall that is situated perpendicular to the flow which creates high velocity vectors towards the bank. Rock slope protection is being proposed as bank stabilization along the left bank at a 2:1 slope. The actual features and dimensions will be determined by final design engineer.

Siphon Structural Improvements

Several structural improvements are recommended at the siphon site including filling the voids under the siphon with concrete, adding rock slope protection with concrete in scour holes below the siphon, filling inverted siphon with concrete, and adding concrete to the bridge pier scour holes. Sheet 4 illustrates the preliminary structural improvement proposed at the siphon.

Filling the voids under the siphon with concrete and filling the siphon with concrete will help stabilize the siphon structure and ultimately protect the bridge piers. The bridge pier footings are being scoured and it is proposed to fill the voids with concrete to help stabilize the bridge. Rock slope protection with concrete is included as energy dissipation and help diminish incision. The transition from the 3:1 slope to the streambed should not be grouted to allow for adjustment and infilling. The actual features and dimensions will be determined by final design engineer.

Design and Construction Summary

Site Conditions and Assumptions

The preliminary drawings and layouts contained in this report will be refined during the final design process. Additional surveys and hydraulic analyses may be necessary because of changes in the site conditions since this investigation was conducted, and to gain additional information required for final design.

Codes and Standards

Final designs will be governed by the following criteria:

- Final structural designs will comply with the latest Uniform Building Code requirements.
- Final concrete designs will comply with the latest American Concrete Institute Building Code Requirements for Reinforced Concrete Design.
- All current applicable Cal OSHA safety standards will be met.
- All environmental permit conditions will be met.

Final Design Instructions

Final designs will adhere to the following criteria:

- An operations and maintenance manual should be made available prior to project completion.
- The elevations shown in drawings are based on North American Vertical Datum (NAVD) of 1988, US Feet. Descriptions and elevations of control points can be obtained from DWR.
- Actual concrete thickness, foundation requirements, and reinforcement requirements will be determined by the final design engineer.
- Actual rock slope protection thickness and key dimensions will be determined by the final design engineer.
- The cutoff walls and footings used for cost estimating purposes are not shown on the drawings. Actual dimensions will be determined by the final design engineer.
- All exposed concrete corners in the fish ladders shall be chamfered a minimum of 0.75 of an inch to allow for Pacific Lamprey passage.

Special Project Notes

The preliminary cost estimates for design and construction were based on preliminary engineering drawings and current industry standard construction costs. The quantities and costs illustrated in Table 4 are preliminary and not intended for bidding or construction purposes as final designs may result in changes to any or all quantities and costs. The final cost estimate will ultimately be determined by the final design engineer. Final designs will be subject for approval by the TAC.

The Clover Creek Fish Passage Project is located within a Federal Emergency Management Agency Zone A. Zone A is described as areas with a 1 percent annual chance of flooding and a 26 percent chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are determined. The construction of the fish passage structures within the low flow channel is not expected to raise the 100-year base flood elevation in Clover Creek. This must be verified in final design and the provisions of Chapter 44, Section 65.3 of the National Flood Insurance Program's Code of Federal Regulations must be met.

A memorandum of understanding (MOU) should be developed between CDFW and MDA to determine roles and responsibilities prior to construction of the project. In-stream flow requirements have not been determined and thus the entire creek can be diverted by water users. An operation manual for the structures should be included in the MOU.

Structural Investigation Recommendations

It was determined that longevity of structures would be improved with scour and erosion measures. DWR recommends the following measures be taken to strengthen and increase stability of the existing structures:

- Patch areas of erosion underneath the siphon and dam with concrete.
- Fill scour holes around bridge piers with concrete.
- Fill in scour holes at the embankment with suitably sized rock slope protection.
- Fill in the existing siphon with concrete.
- Place rock slope protection in the downstream scour holes at the siphon and dam.

Habitat Typing Recommendations

The habitat typing assessment concluded that the 10 miles of habitat that exists above the dam is marginal at best. Extensive restoration efforts would need to be implemented in order to adequately supply enough habitat for a healthy population.

Construction Summary

Construction access for this site is from Old Highway 44, left on Brookdale Rd approximately 2 miles to the Bar 11 Ranch (Sheet 1). Two access roads exist to the project site. The first access road travels through the Bar 11 Ranch and over the existing ford. The existing ford located downstream of the Millville Diversion could be used for large trucks and heavy equipment. The grade of the existing ford into and out of Clover Creek ranges from 8 to 12 percent.

The second access road travels through another portion of the Bar 11 Ranch and crosses over the creek via the existing bridge. Due to the poor condition of the bridge, it is not recommended for heavy construction equipment. This access road will be available for smaller vehicles and must remain open and clear of equipment for landowner use.

The existing roads are compacted dirt roads with oak trees scattered along the landscape and rolling terrain. Tree trimming and minor road improvements will be needed and are included in the cost estimate under the Access Road Improvements section. If the existing roads are damaged during construction, they must be repaired prior to project completion.

The limitations of construction, staging areas, and access roads should be marked and managed to prevent vehicular access outside the designated work zone. Potential staging areas have been delineated and are illustrated on Sheet 1.

Maintaining the ability to divert water into the Millville Ditch will be required during the construction project, specifically May through October. The construction area may be dewatered before and during construction activities. During the construction window, fish passage might not be a concern due to the possible low flow and high water temperatures as well as the existing fish passage impediments.

A low water crossing exists upstream of the dam (Sheet 1). Improvements to this crossing might be needed. If so, it was recommended by the TAC to use spawning sized gravel to improve the road. Once construction activities are complete, a notch in the gravel would be required to help restore natural flow patterns within Clover Creek. The final design engineer should determine the effects from adding spawning size gravel upstream of the proposed fish ladder and fish screen. There could be a high potential for most of the gravel to travel downstream into the fish ladder and increase maintenance activities.

Excavation will be required at the proposed project site. Excavated material will either be reused at the project site or hauled off to a disposal site, which will be determined by the contractor.

Removal of the existing CMP culvert and concrete headwall at the dam site is required. Removal of the concrete headwall and partial removal of the existing CMP culvert at the siphon site is also required. Excavated concrete free of steel could be broken up and placed in Clover Creek in the scour holes below the dam and siphon area. If placing concrete back in the channel is not acceptable by the fishery agencies, then the concrete shall be hauled off to a disposal site. The remaining rebar, steel, and other miscellaneous material shall be hauled off to a disposal site or salvage yard, which will be determined by the contractor.

Table 4. Preliminary Cost Estimate

ITEM	DESCRIPTION	QUANTITY	UNIT		UNIT COST		TOTAL COST
MISCELLANEOUS							
1	Mobilization/Demobilization	1	LS	$	50,000	$	50,000
2	Clearing and Grubbing	2	AC	$	10,000	$	20,000
3	Access Road Improvements	1	LS	$	10,000	$	10,000
4	Dewatering	1	LS	$	50,000	$	50,000
						$	**130,000**
INVERTED SIPHON							
5	Excavation	550	CY	$	20	$	11,000
6	24-inch DIA Smooth Pipe	250	LF	$	30	$	8,000
7	Sand Backfill	1	LS	$	1,000	$	1,000
8	24-inch DIA Canal Gate	1	EA	$	2,000	$	2,000
9	Concrete (Riser)	10	CY	$	800	$	8,000
10	Concrete (Inlet and Outlet)	17	CY	$	800	$	14,000
11	Concrete Cutting, Anchors, Etc.	1	LS	$	7,000	$	7,000
12	Concrete (Encased Siphon)	60	CY	$	800	$	48,000
13	Trash rack	1	EA	$	1,000	$	1,000
14	Remove Existing Headwall and CMP Culvert	60	LF	$	30	$	2,000
						$	**102,000**
STRUCTURAL IMPROVEMENTS AT SIPHON							
15	Excavation	30	CY	$	20	$	1,000
16	Concrete (Bridge Piers)	10	CY	$	800	$	8,000
17	Rock slope protection	300	CY	$	75	$	23,000
18	Rock Slope Protection Fabric	700	SF	$	5	$	4,000
19	Rock Slope Protection Concrete	50	CY	$	500	$	25,000
20	Concrete (fill existing siphon)	30	CY	$	500	$	15,000
						$	**76,000**
FISH LADDER AT SIPHON							
21	Excavation	700	CY	$	20	$	14,000
22	Concrete Cutting, Anchors, Etc.	1	LS	$	10,000	$	10,000
23	Concrete (Fish Ladder)	70	CY	$	800	$	56,000
24	Concrete (Retaining Wall)	3	CY	$	800	$	2,000
25	Flashboards (Dewatering)	40	SF	$	5	$	200
26	Flashboards (Weir)	50	SF	$	5	$	300
27	Metal Fabrication for Flashboards (Weir)	1	LS	$	250	$	300
						$	**83,000**

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
FISH LADDER AT DAM					
28	Excavation	560	CY	$ 20	$ 11,000
29	Concrete Cutting, Anchors, Etc.	1	LS	$ 10,000	$ 10,000
30	Concrete	112	CY	$ 800	$ 90,000
31	Flashboards (Dewatering)	80	SF	$ 5	$ 400
32	Flashboards (Weir)	30	SF	$ 5	$ 200
33	Remove Existing Metal Retaining Wall	50	LF	$ 20	$ 1,000
34	Remove Existing CMP Culvert and Headwall	125	LF	$ 30	$ 4,000
					$ 117,000
FISH SCREEN					
35	Excavation	700	CY	$ 20	$ 14,000
36	Concrete	45	CY	$ 800	$ 36,000
37	Wedgewire Fish Screen	32	SF	$ 200	$ 6,000
38	Screen Cleaning System	1	LS	$ 5,000	$ 5,000
39	Grating Platform	1200	LB	$ 5	$ 6,000
40	24-inch DIA Canal Gate	1	EA	$ 2,000	$ 2,000
41	24-inch DIA Smooth Pipe	150	LF	$ 30	$ 5,000
42	Sand Backfill	1	LS	$ 1,000	$ 1,000
43	Compacted Backfill	400	CY	$ 30	$ 12,000
44	Log Boom	1	LS	$ 2,500	$ 3,000
45	Dewatering Panels	165	LF	$ 10	$ 2,000
					$ 92,000
STRUCTURAL IMPROVEMENTS AT DAM					
46	Excavation	30	CY	$ 20	$ 1,000
47	Rock slope protection	400	CY	$ 75	$ 30,000
48	Rock Slope Protection Fabric	1,600	SF	$ 5	$ 8,000
49	Rock Slope Protection Concrete	100	CY	$ 500	$ 50,000
					$ 89,000
50	Construction Cost				$ 689,000
51	Contingency @ 25%				$ 172,000
52	Construction Cost Subtotal				**$ 861,000**
53	Engineering @ 15%				$ 129,000
54	Environmental @ 5%				$ 43,000
55	Construction Inspection @10%				$ 86,000
56	Contract Admin @ 5%				$ 43,000
57	Total				**$ 1,162,000**

All totals have been rounded to the nearest thousand, unless the total was under $500.

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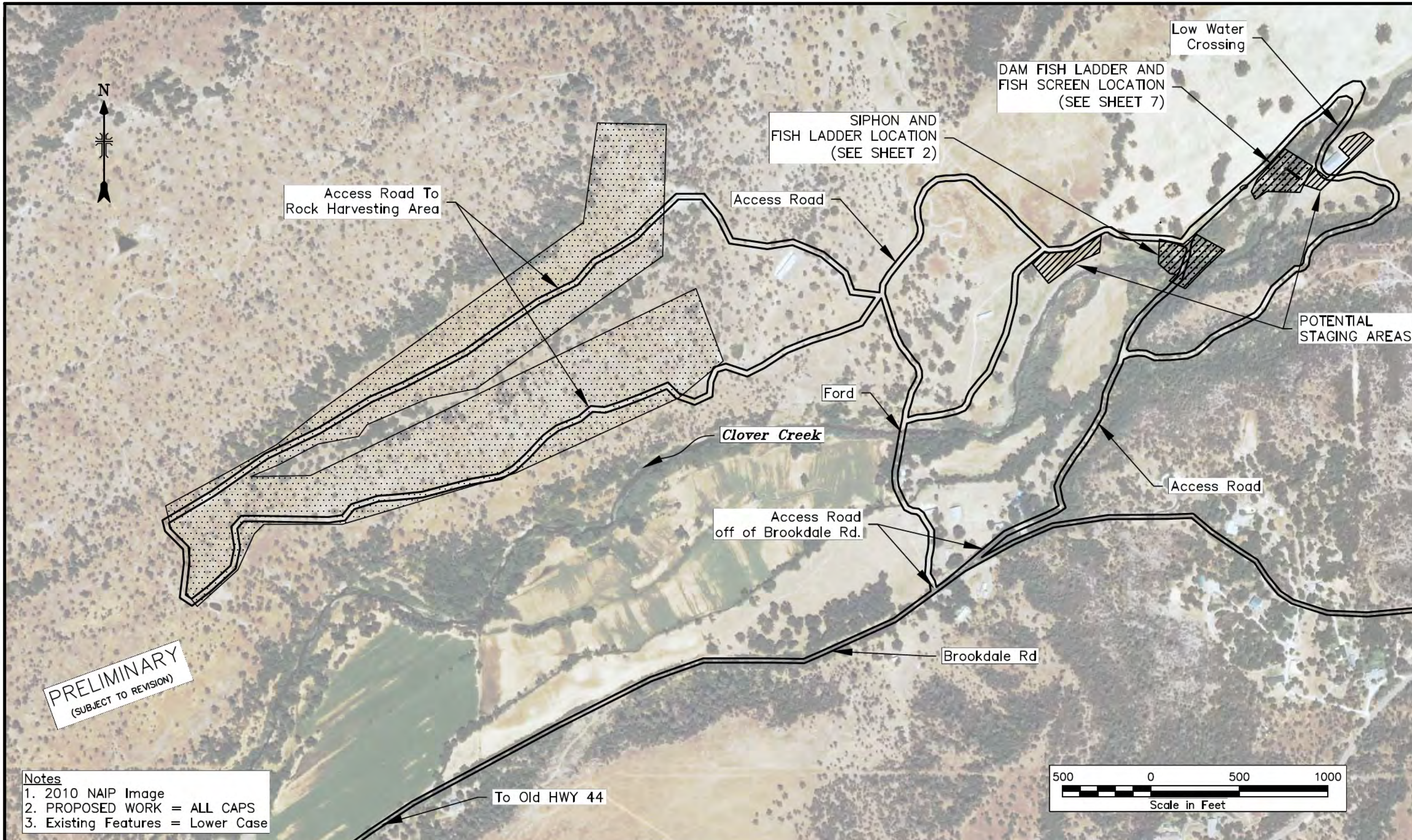


CLOVER CREEK FISH PASSAGE PROJECT
Millville, California

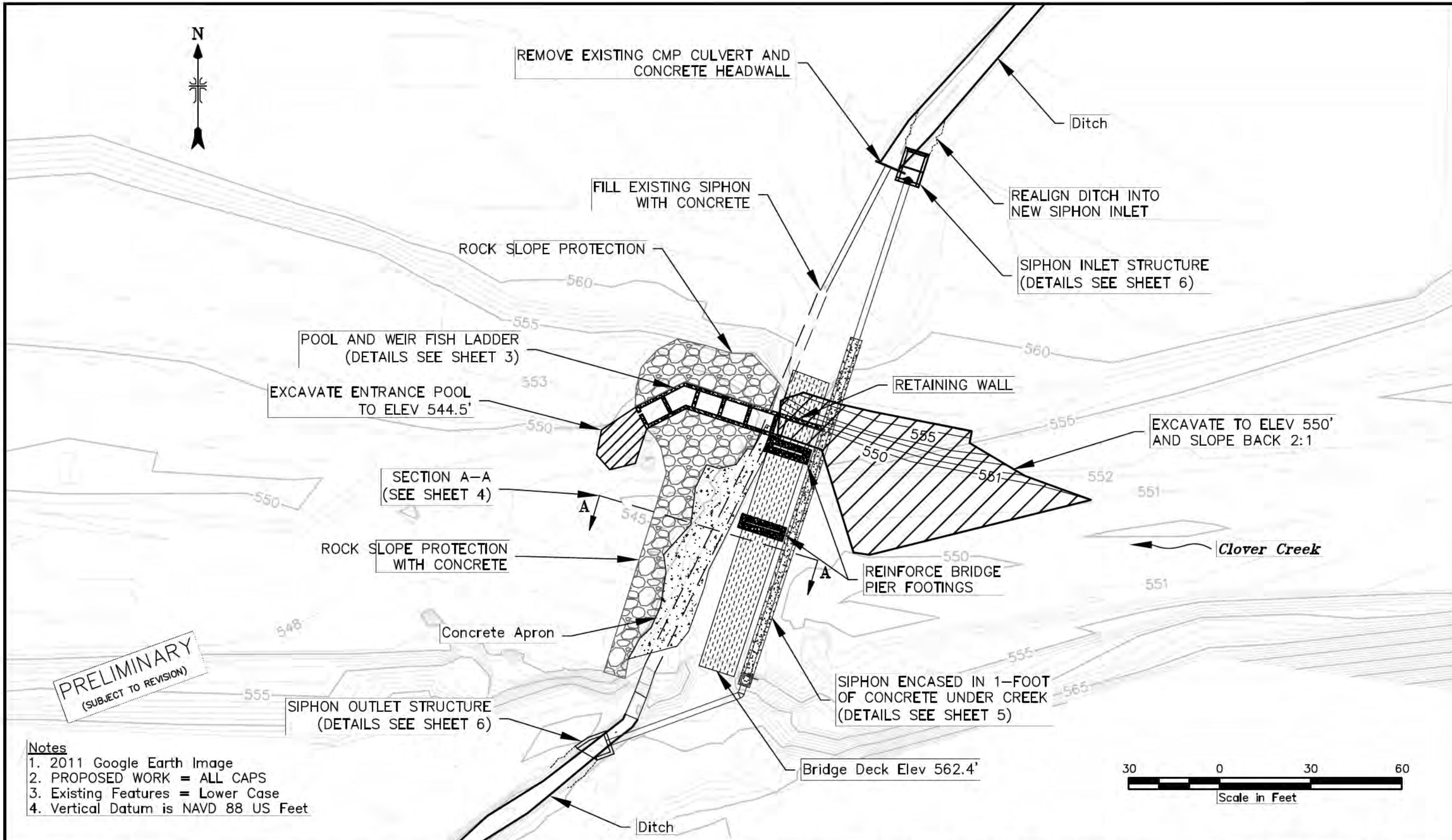
GENERAL PLAN

CALIFORNIA NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN REGION OFFICE

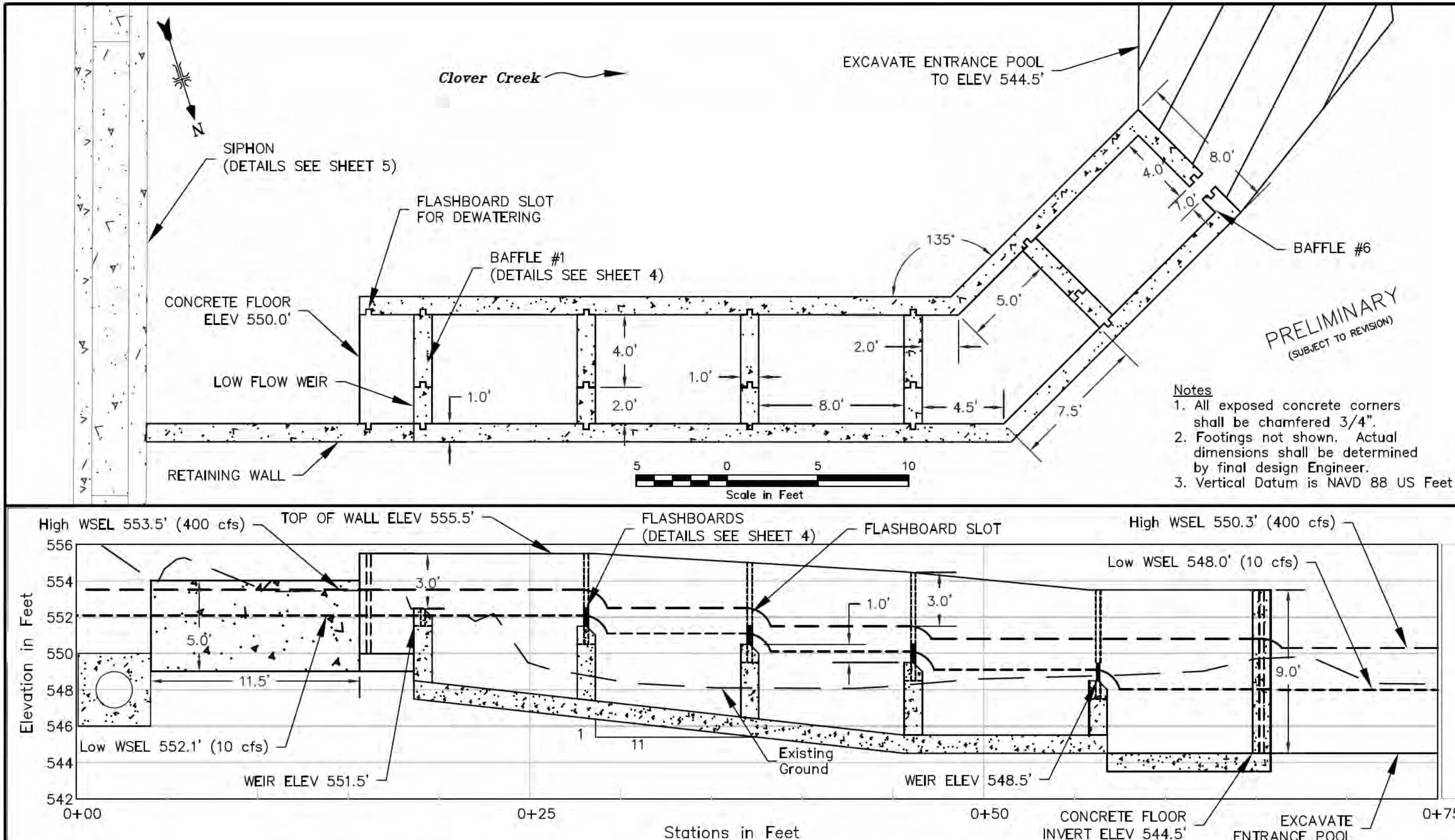
Drawn By:
Nancy Snodgrass
PE#CA69019

Revision Date: December 18, 2012

Sheet 1 of 10



CLOVER CREEK FISH PASSAGE PROJECT Millville, California	SIPHON AND FISH LADDER SITE PLAN	CALIFORNIA NATURAL RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN REGION OFFICE Revision Date: December 18, 2012	Drawn By: Nancy Snodgrass PE#CA69019 Sheet 2 of 10



Notes

1. All exposed concrete corners shall be chamfered 3/4".
2. Footings not shown. Actual dimensions shall be determined by final design Engineer.
3. Vertical Datum is NAVD 88 US Feet

CLOVER CREEK FISH PASSAGE PROJECT
Millville, California

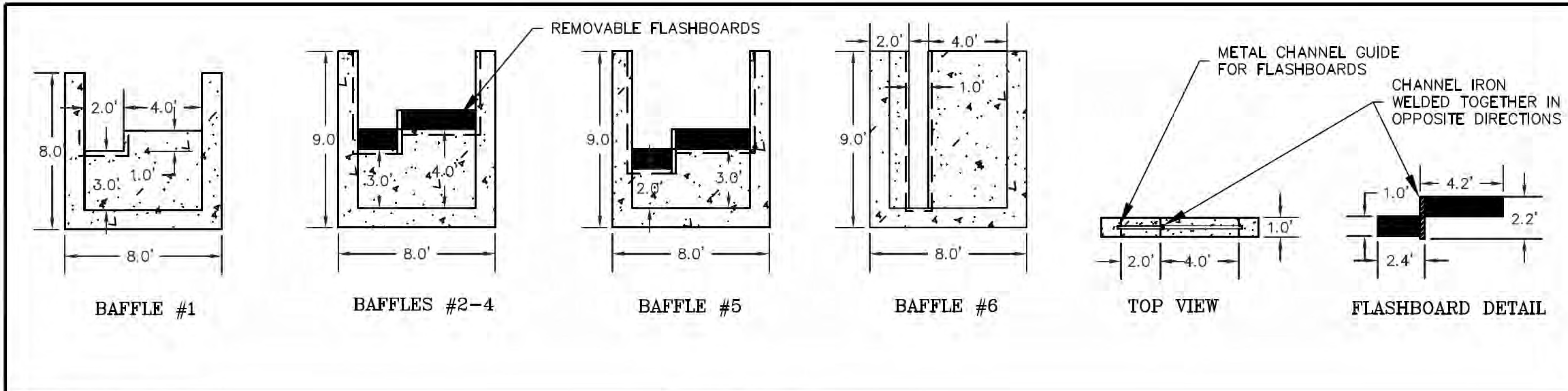
FISH LADDER AT SIPHON AREA
PLAN AND PROFILE VIEW

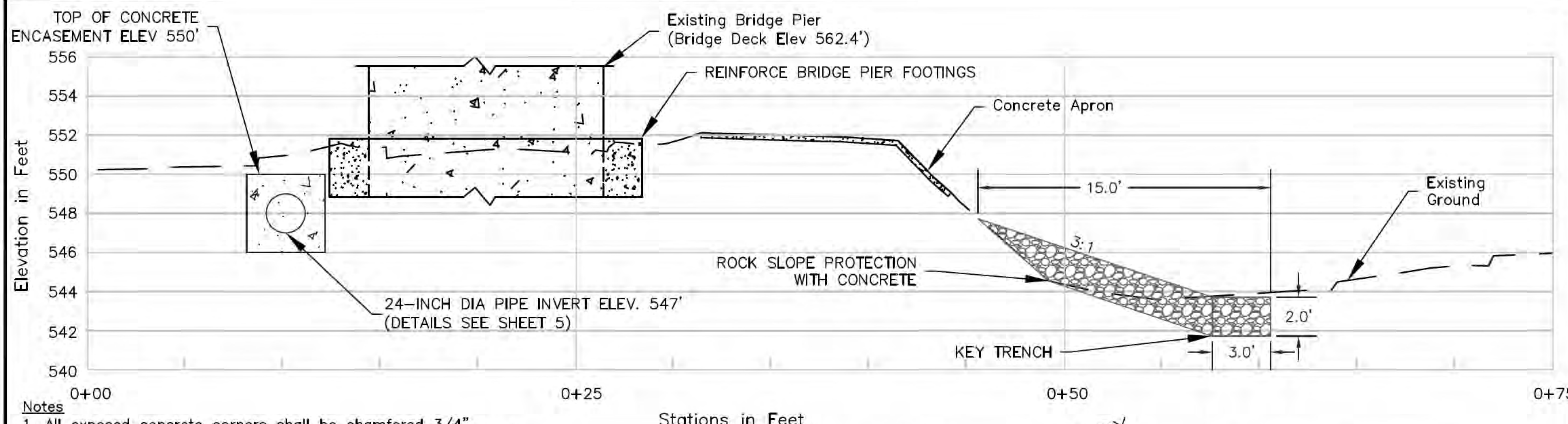
CALIFORNIA NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN REGION OFFICE

Drawn By:
Nancy Snodgrass
PE#CA69019

Revision Date: December 18, 2012

Sheet 3 of 10



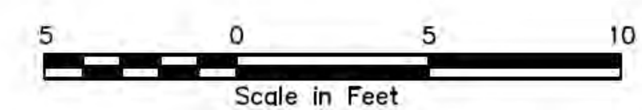


Notes

1. All exposed concrete corners shall be chamfered 3/4".
2. Footings not shown. Actual dimensions shall be determined by final design Engineer.
3. Vertical Datum is NAVD 88 US Feet.
4. Rock Slope Protection actual dimensions shall be determined by final design Engineer.

SECTION A–A

PRELIMINARY (SUBJECT TO REVISION)



CLOVER CREEK FISH PASSAGE PROJECT
Millville, California

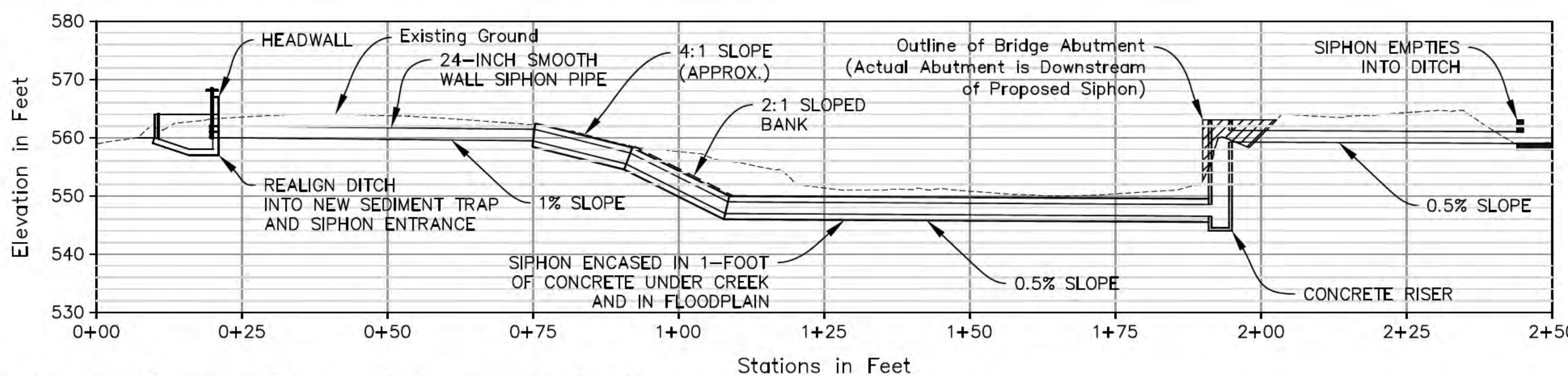
SIPHON FISH LADDER DETAILS AND SECTION A–A

CALIFORNIA NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN REGION OFFICE

Revision Date: December 18, 2012

Drawn By: Nancy Snodgrass PE#CA69019

Sheet 4 of 10

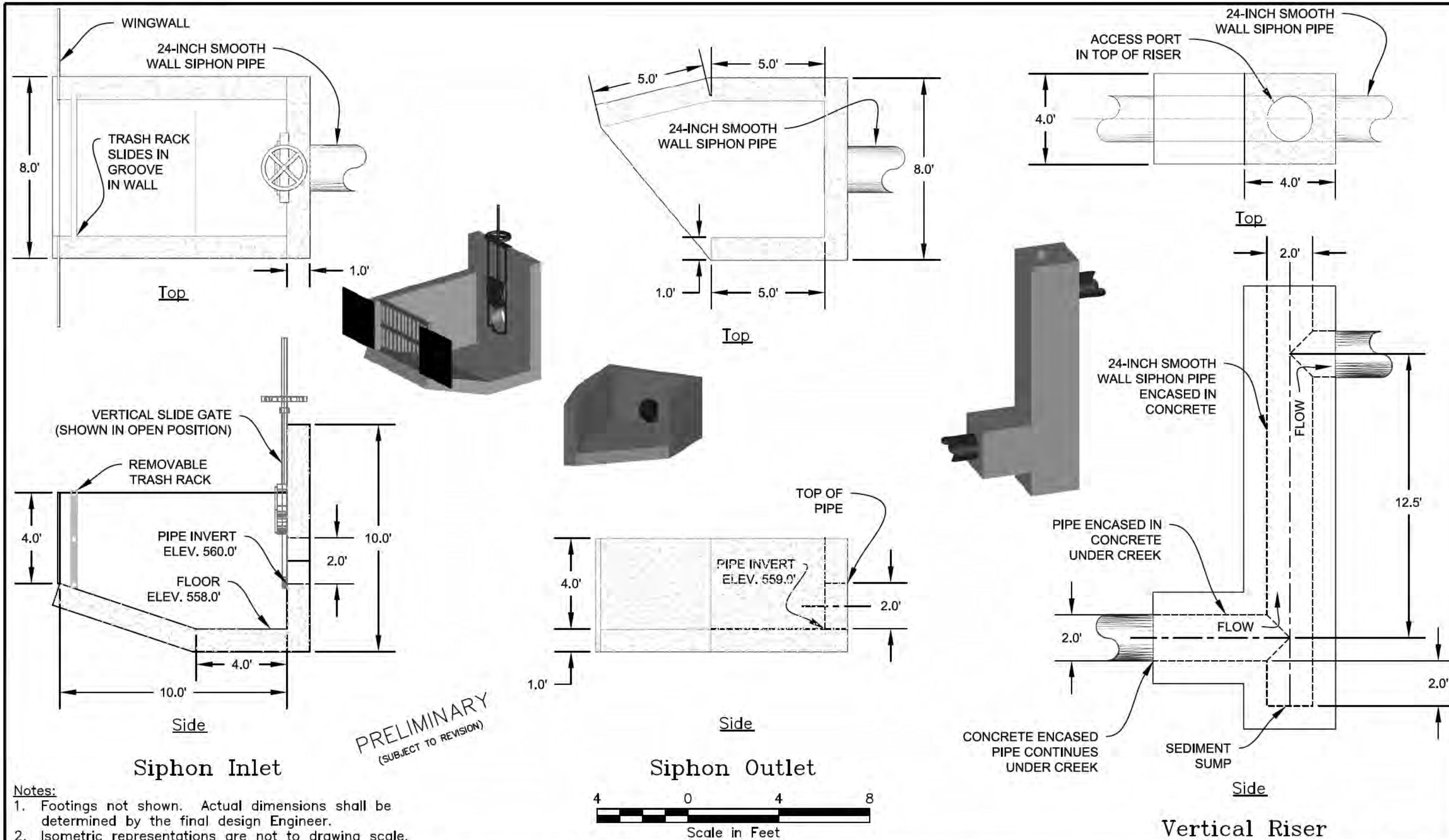


Notes:

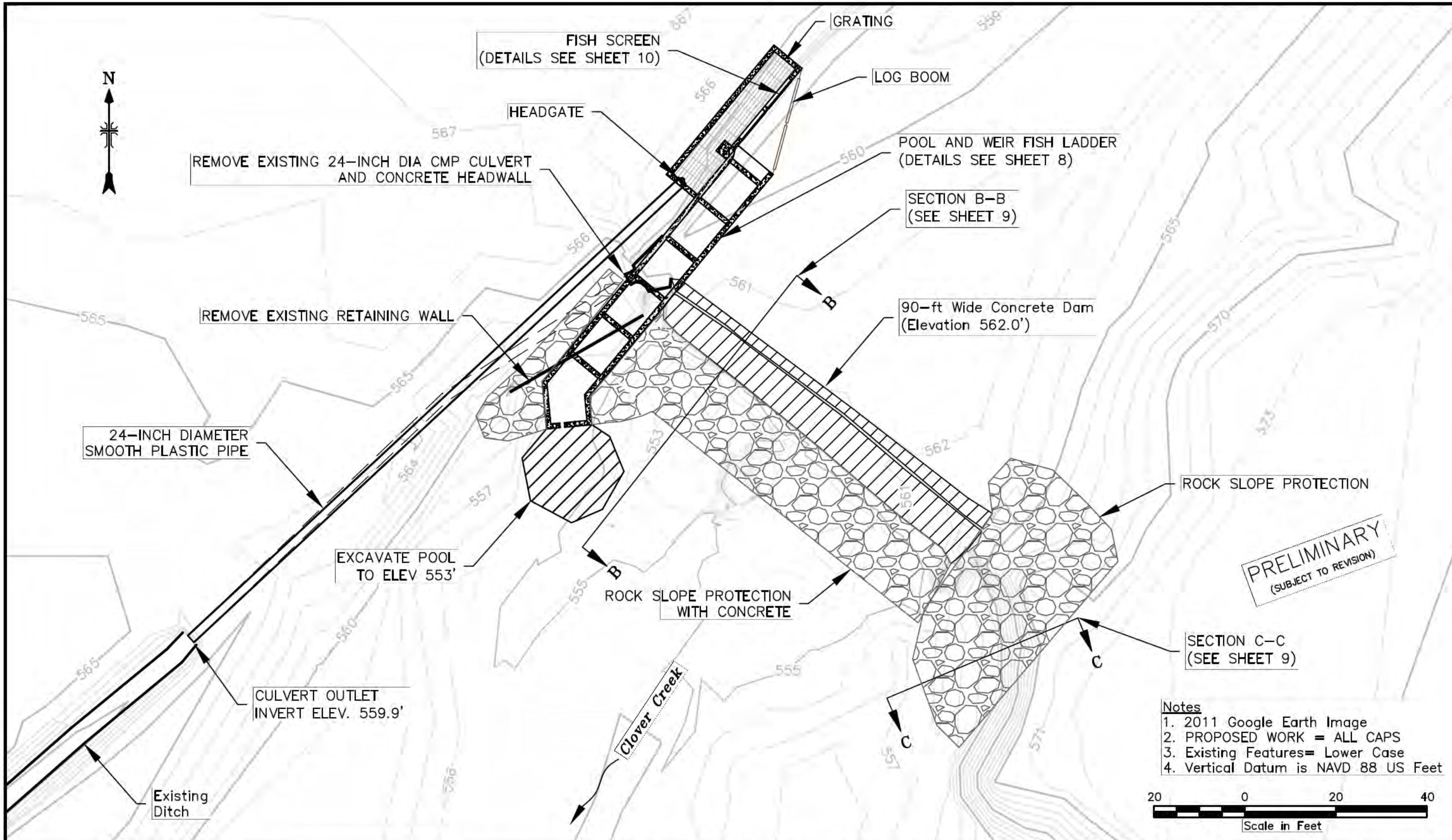
1. Head loss through a 24" smooth wall pipe is estimated to be approximately 0.5 feet for 8.25 cfs. This is the same head loss as is estimated to occur in a 30 inch corrugated metal pipe in good condition.
2. PROPOSED WORK = ALL CAPS
3. Existing Features = Lower Case
4. Vertical Datum is NAVD 88 US Feet

PRELIMINARY (SUBJECT TO REVISION)

CLOVER CREEK FISH PASSAGE PROJECT Millville, California	Siphon Plan and Profile	CALIFORNIA NATURAL RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN REGION OFFICE	Drawn By: S. Kennedy C63801
		Revision Date: December 18, 2012	Sheet 5 of 10



CLOVER CREEK FISH PASSAGE PROJECT Millville, California	Siphon Structures Details	CALIFORNIA NATURAL RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN REGION OFFICE	Drawn By: S. Kennedy C63801
		Revision Date: October 4, 2012	Sheet 6 of 10



CLOVER CREEK FISH PASSAGE PROJECT
Millville, California

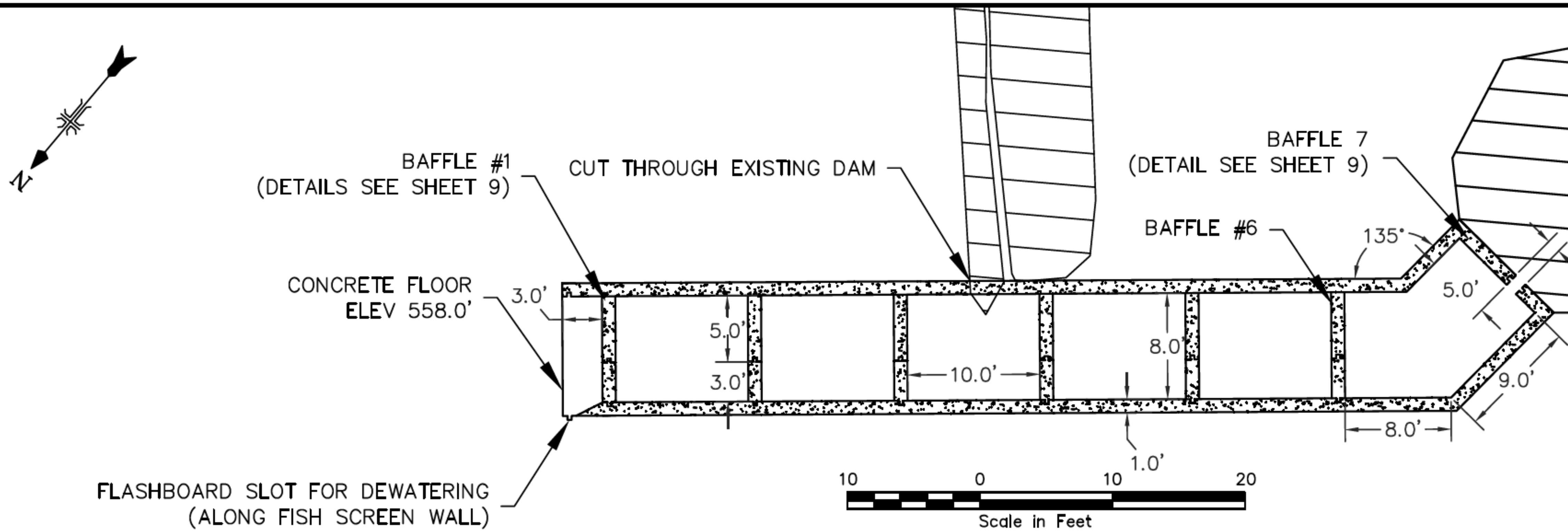
DAM FISH LADDER & FISH SCREEN
SITE PLAN

CALIFORNIA NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN REGION OFFICE

Revision Date: December 18, 2012

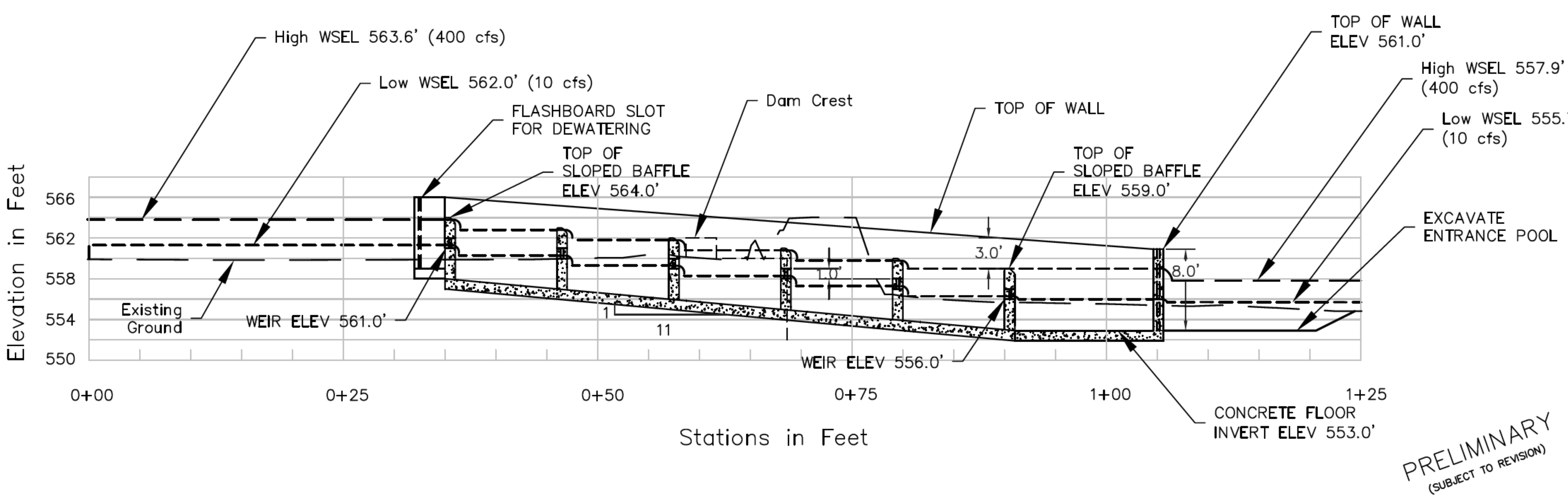
Drawn By:
Nancy Snodgrass
PE#CA69019

Sheet 7 of 10

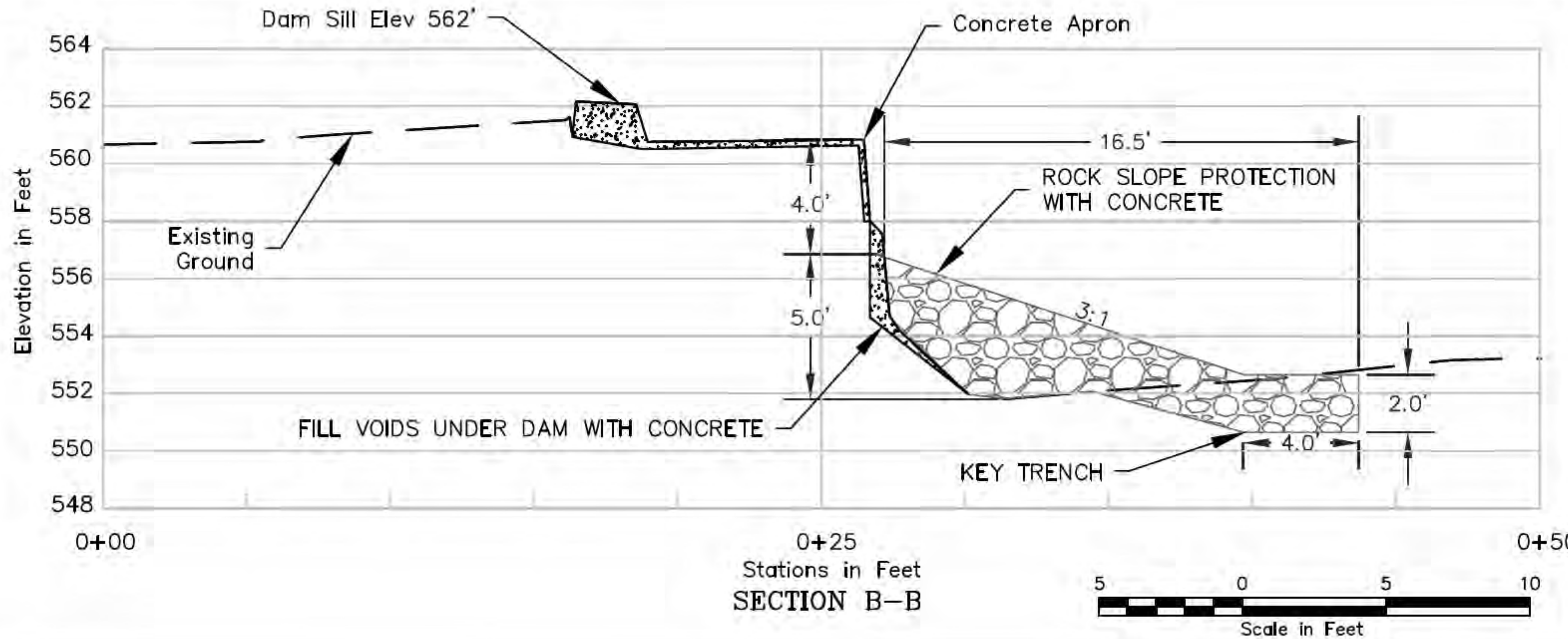


Notes

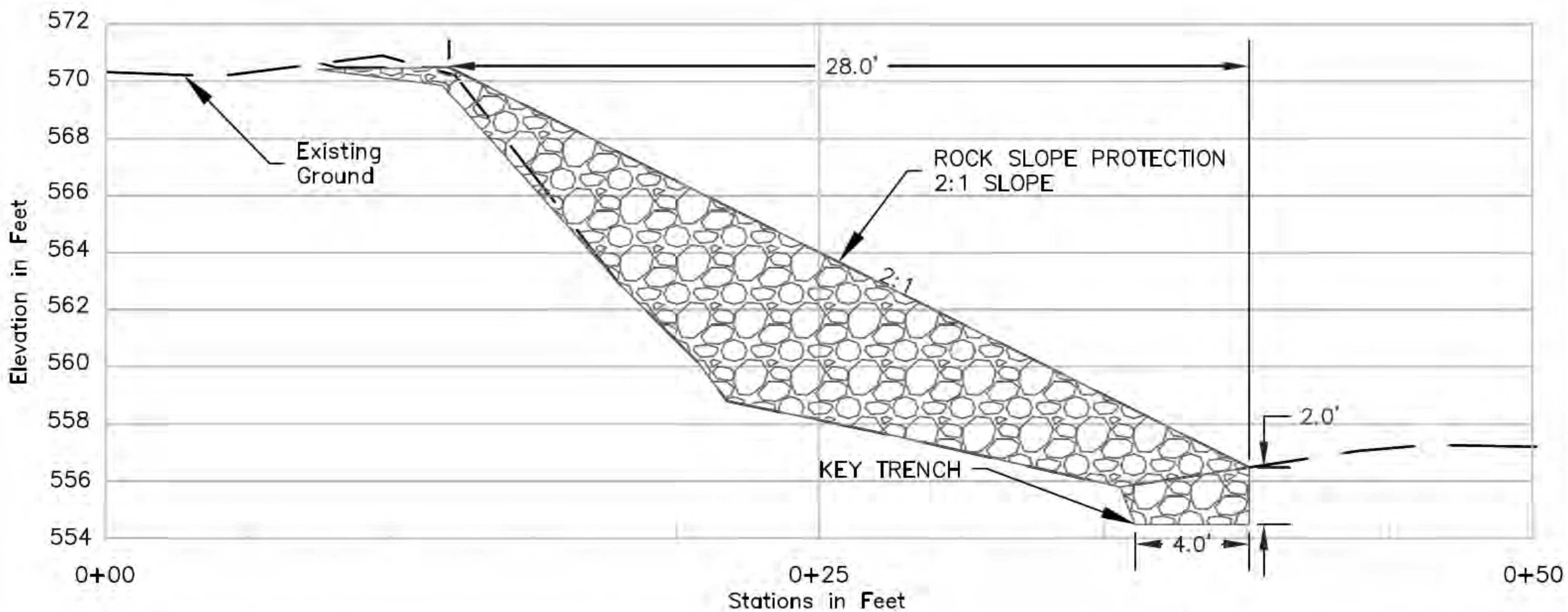
1. PROPOSED WORK = ALL CAPS
2. Existing Features = Lower Case
3. All exposed concrete corners shall be chamfered 3/4".
4. Footings not shown. Actual dimensions shall be determined by final design Engineer.
5. Vertical Datum is NAVD 88 US Feet



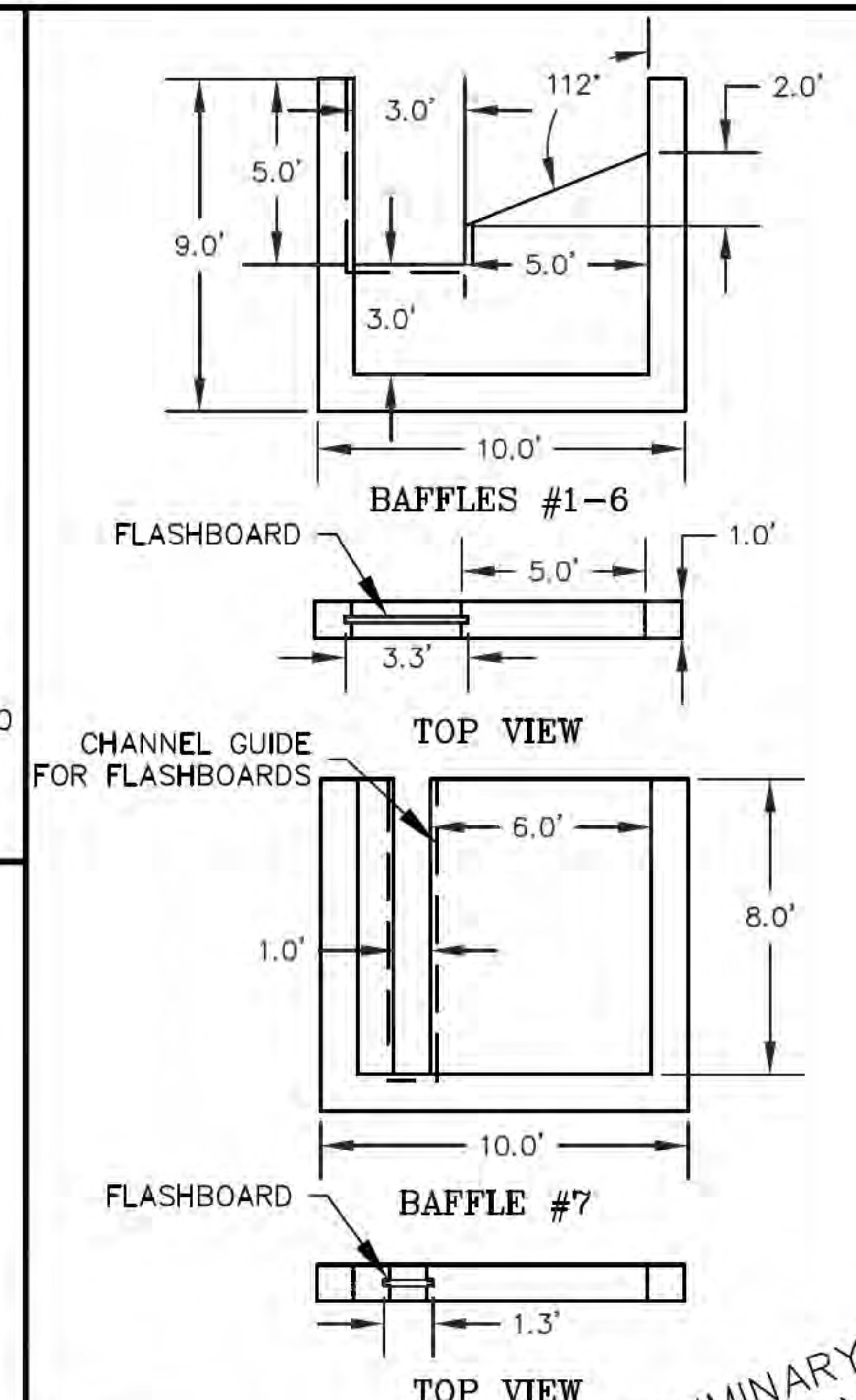
CLOVER CREEK FISH PASSAGE PROJECT Millville, California	DAM FISH LADDER PLAN AND PROFILE VIEW	CALIFORNIA NATURAL RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN REGION OFFICE	Drawn By: Nancy Snodgrass PE#CA69019
		Revision Date: December 18, 2012	Sheet 8 of 10



SECTION B–B



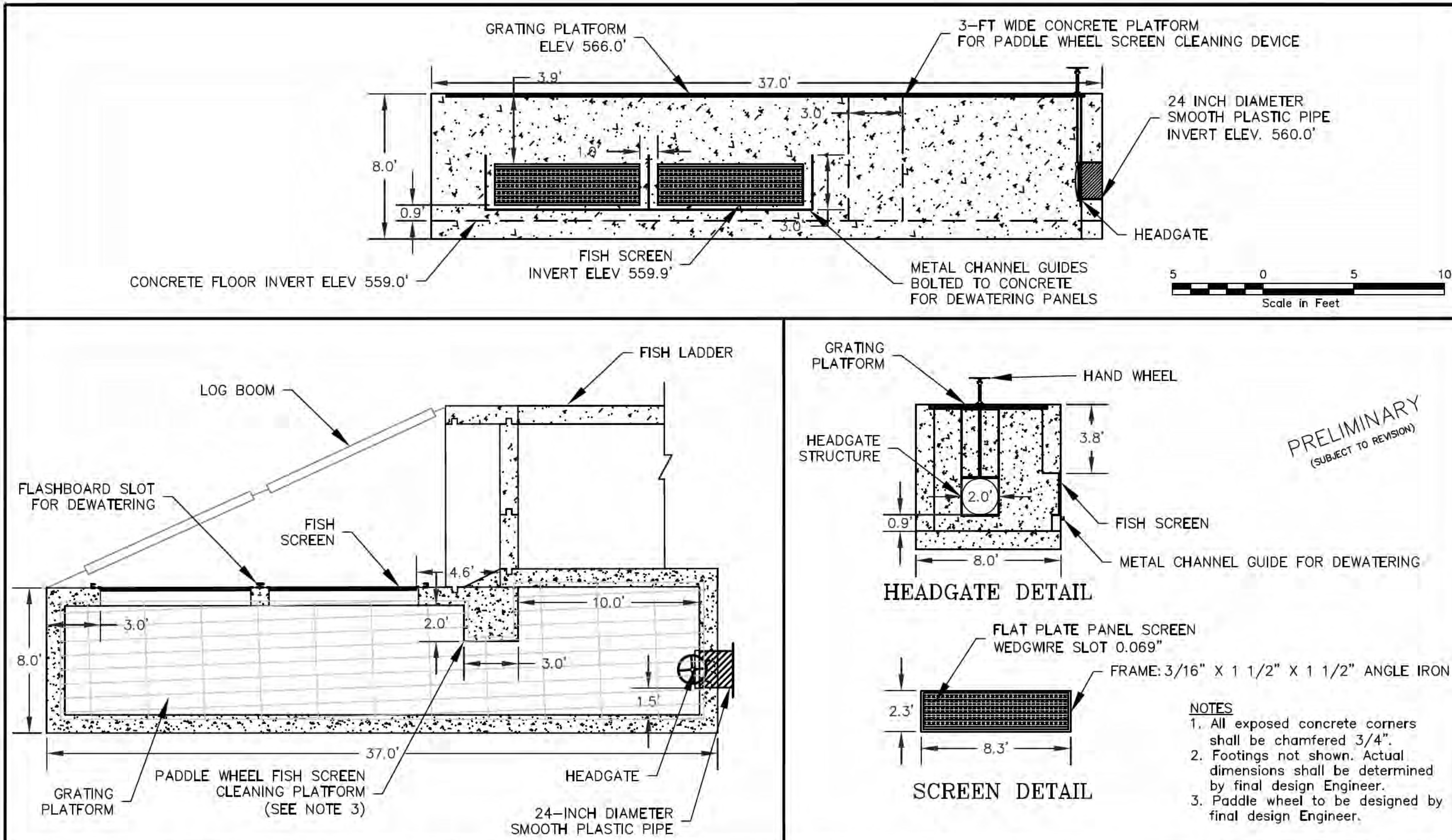
SECTION C–C



PRELIMINARY
(SUBJECT TO REVISION)

Notes
1. PROPOSED WORK = ALL CAPS
2. Existing Features = Lower Case
3. All exposed concrete corners shall be chamfered 3/4".
4. Footings not shown. Actual dimensions shall be determined by final design Engineer.
5. Rock Slope Protection actual dimensions shall be determined by final design Engineer.
6. Vertical Datum is NAVD 88 US Feet.

CLOVER CREEK FISH PASSAGE PROJECT Millville, California	DAM FISH LADDER DETAILS AND SECTION VIEWS B–B AND C–C	CALIFORNIA NATURAL RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN REGION OFFICE Revision Date: December 18, 2012	Drawn By: Nancy Snodgrass PE#CA69019 Sheet 9 of 10



CLOVER CREEK FISH PASSAGE PROJECT
Millville, California

FISH SCREEN DETAILS

CALIFORNIA NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN REGION OFFICE

Drawn By:
Nancy Snodgrass
PE#CA69019

Revision Date: December 18, 2012

Sheet 10 of 10

APPENDIX A

DWR Geologic Investigation of Potential Impacts from Removal of Millville Dam

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INTEROFFICE MEMORANDUM

TO: BRUCE ROSS

FROM: GLEN GORDON

SUBJECT: CLOVER CREEK DIVERSION DAM – FISH PASSAGE PROJECT

DATE: 2/6/2012

CC:

In the vicinity of the Clover Creek diversion structure the creek cut through 3 distinct terrace levels within a narrow (~1/4 mile wide) alluvial filled section of valley ~ 5 miles upstream of its confluence with Cow Creek. The geographically highest of these terraces is the Pleistocene Lower Modesto Formation with the Pleistocene Upper Modesto Formation being the intermediate and recent flood plain deposits making up the lowest terrace level. Presently, at this location, Clover Creek is a bedrock incised channel with a channel bottom comprising mainly of bedrock with small patches of gravels. In recent times this has not always been the case. A 1959 photo of the dam shows gravel lined channel downstream of the dam and an old meander scroll of the stream downstream of the dam indicates the base level use to be several feet higher with a channel formed in the terrace deposits.

The Millville Ditch – Clover Creek diversion dam structure is constructed on bedrock of the Cretaceous Chico Formation. At the current foundation the Chico Formation consist mainly of a greenish gray (10Y 6/1; 10Y 4/1 moist) siltstone that is weakly cemented with calcite. Even though the siltstone is slightly weathered to fresh the siltstone is very friable and slakes when exposed to air and sunlight. Layered within the siltstone are 1 to 4-in thick slightly weathered calcite cemented greenish gray (10Y 6/1; 10Y 5/1 moist) fine grained sandstone beds ~ 2-ft apart. These sandstone beds are moderately hard with moderately spaced fractures (.3 – 1-ft spacing) perpendicular to bedding. The friable nature of the siltstone and the spacing of fractures of the sandstone beds allow the bedrock to be slightly susceptible to erosion. The undercutting on the downstream side of the dam and the plunge pool that has developed are evidence of this. Just downstream of the dam the bedding strikes perpendicular to the stream flow (125° to 90°) and dips ~ 5° to the SW-S at a steeper gradient than the stream channel. It is suspected if the dam were removed that the stream has a potential to slightly head cut upstream. This would probably be limited to ~ 500 ft upstream where a 1-ft thick slightly weathered calcite cemented fine grained sandstone bed of the Chico Formation crosses the channel. This sandstone bed is moderately hard with widely spaced fractures (1 – 3-ft spacing) perpendicular to bedding. It strikes roughly perpendicular to the stream flow (345°) and dips ~ 4° to the SW at a steeper gradient than the stream channel. Because of the thickness of this bed and wider spacing of its fractures it offers more resistance to erosion and head cutting.

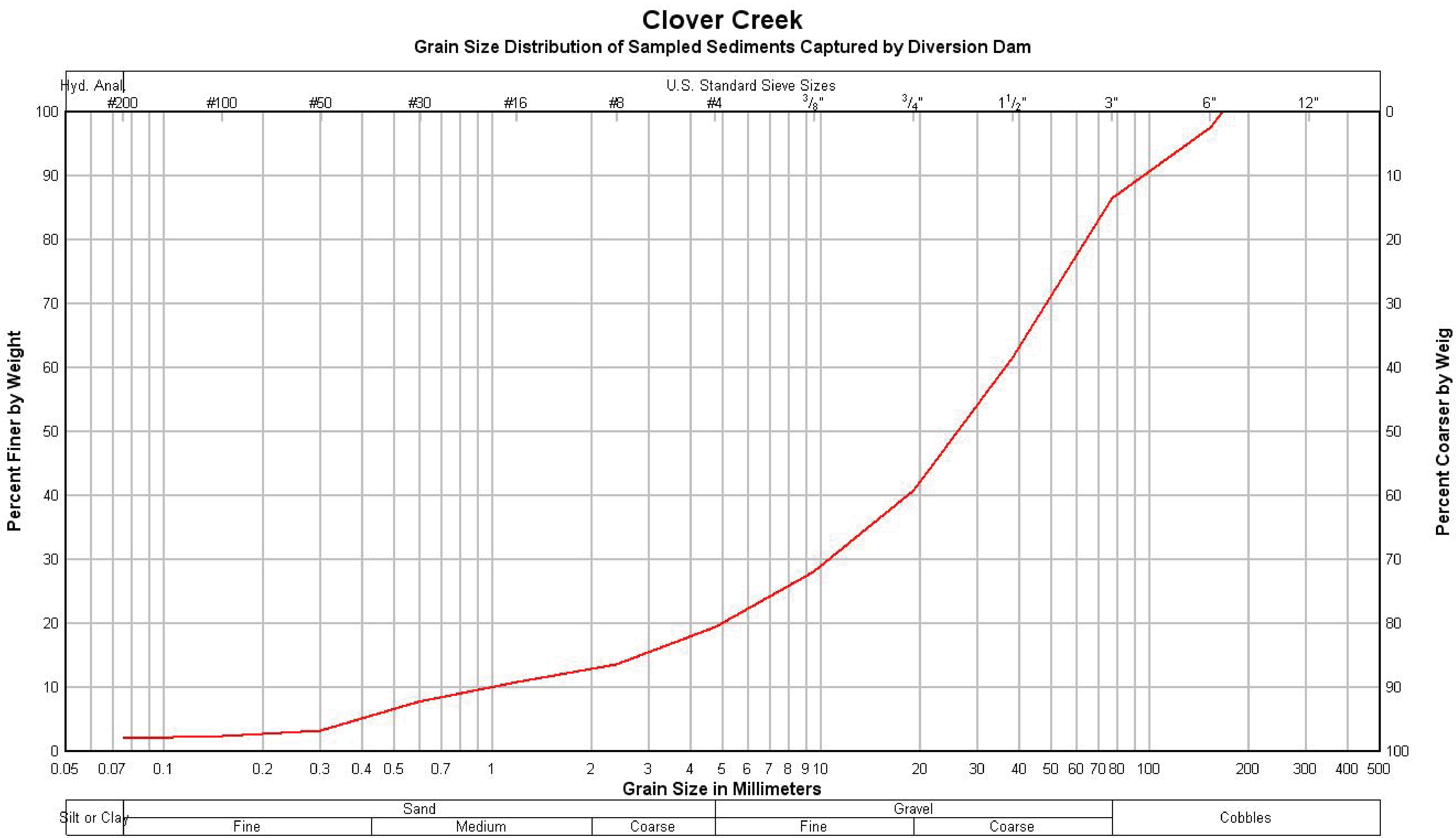
Above the left abutment, the Pleistocene Lower Modesto Formation lies on top of the Chico Formation with an angular unconformable contact. This contact is roughly the same elevation as the top of the downstream wing wall of the dam. This terrace 2 ½ to 5-ft thick is well graded and comprised of cobbles, gravel, sand, silt and clay (GW-GC). This unit has been eroded into but it is unclear if it was scoured or if the underlying siltstone eroded out first causing it to collapse.

The right abutment was obscured by entrance structure of the Millville Ditch and a steel wing wall built to protect it. So based on observations of adjacent topography it appears that this abutment is constructed in more recent floodplain channel deposits of fine sands, silts and clays.

The amount of sediments contained upstream of the dam was calculated to be 800 CY and is comprised (by wt.) of 14% cobble, 67% gravels, 17% sand and 2% silts and clays (for more detailed breakouts see attached table and Grain Size Distribution Curve Graph). Locally derived siltstone slabs intermixed within the sediments (visual estimated to be ~ 5% of volume) were excluded from the sample because it is suspected they would readily fall apart once transported. It is suspected if the dam were removed much of sediment would infill the plunge pool below the dam with the remainder being added to the sediment depleted channel immediately downstream of the dam.

At the siphon crossing very little alluvium was observed entrapped behind the siphon. Removal of the siphon would not result in a large amount of sediment being washed downstream. It's possible that localized head cutting and scour into the siltstone bedrock at this crossing could undercut the footing of the upstream bridge pier footing due to the friable nature of the bedrock.

It was asked "If dam was removed, what would be the impacts to the existing adjacent meadow/trees/plants?" Not being a botanist the following is non scientific speculation. The base flow just upstream of the dam would be ~ 4-ft lower upstream of the dam. Not knowing what type of plants are adjacent to the upstream side of the dam but noticing similar looking plants surviving on higher terraces both upstream and downstream of the dam it is expected these plants will survive if the dam were removed.


Clover Creek
Grain Size Distribution of Sampled Sediments Captured by Diversion Dam
Hyd. Anal.
U.S. Standard Sieve Sizes
#200
#100
#50
#30
#16
#8
#4
3/8"
3/4"
1 1/2"
3"
6"
12"
Percent Finer by Weight
Percent Coarser by Weig
Grain Size in Millimeters
Silt or Clay
Sand
Fine
Medium
Coarse
Gravel
Fine
Coarse
Cobbles

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Date Sieved (Field) : 5/24/2007 Project: Clover Creek Fish Passage Sample #: CC-1
Total Sample Weight (lbs) : 700.31 Site Location: Millville Ditch – Clover Creek diversion dam structure
Date Sieved (Office -< #4) : 5/29/2007

	Size Range	Sieve Size (mm)	Weight/Seive (lbs)	% of Sample	% Retained	% Passing
Wet Sieve (Field)	6 1/2" Max *	165.1			0.0	100.0
	> 6"	152.4	16.7	2.4	2.4	97.6
	3 - 6"	76.2	77.9	11.1	13.5	86.5
	1 1/2 - 3"	38.1	173.4	24.8	38.3	61.7
	3/4 - 1 1/2"	19.05	145.8	20.8	59.1	40.9
	3/8 -3/4"	9.423	89.2	12.7	71.8	28.2
	#4 - 3/8"	4.75	61.0	8.7	80.5	19.5
Dry Sieve (Office)	# 8 - # 4	2.36	40.5	5.8	86.3	13.7
	# 16 - # 8	1.18	19.7	2.8	89.1	10.9
	# 30 - # 16	0.589	21.5	3.1	92.2	7.8
	# 50 - # 30	0.297	31.3	4.5	96.7	3.3
	# 100 - # 50	0.15	6.6	0.9	97.6	2.4
	# 200 - # 100	0.075	2.5	0.4	98.0	2.0
	< # 200		14.3	2.0	100.0	0.0
	Totals		700.3	100.0		

Notes:
Locally derived siltstone slabs intermixed within the sediments (Visual estimated to be ~ 5% of volume) were excluded from the sample because it is suspected they would readily fall apart once transported.

Sample was obtained by digging eight 5-gallon samples (Four each from 15 ft and 50 ft upstream of dam). Samples were obtained within active channel and a 30-in stilling well was used to limit loss of fines.

Sample was wet sieved in the field with size # 4 and larger being separated and weighed at site. The water used in the wet sieving process was re-circulated to limit the loss of fines. By weighting aliquots of the sieving recirculation water compared to the same volume of clean stream water an average of .315 lbs/gallon of silt and clays remained in suspension while wet sieving (40 gallons was used). This silt and clay was decanted with the water at the end of the sieving process. Thus 12.6 lbs was added to the dry fraction < #200 included in the Total Weight < #4 (dry).

Particles finer than the No. 4 mesh sieve were bagged and subsequently air dried at the office. After drying, the sample was weighed and split by the quartering method to obtain a representative sample.

Sample Size meets or exceeds 5% criteria established by Church et al (1987) for required sample quantity for the largest b-axis length within the sample.


1-ft thick
Sandstone bed
crosses stream

APPENDIX B

Clover Creek Interdisciplinary Assessment: Natural Channel Alternative

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Report: Clover Creek Interdisciplinary Assessment

Date of Report: November 14, 2008

Summary points:

After further review of critical bed profile inverts taken from the DWR Clover Creek Longitudinal Profile along the Clover Creek, the invert at the Millville Dam is at the approximate elevation of 562.5 feet and the invert at the top of concrete over the siphon is at 552.3 feet. This is an over all grade change of 10.3 feet over a distance of ~920 feet (slope gradient: .011 ft/ft or 1.11 percent). The overall average slope from the low water crossing at station 5+00 to station 60+00 is 0.0057ft/ft or 0.57% slope.

This represents a 0.57% slope over a distance of 5,500 feet. As of this report, I do not have the valley slope but my estimate based on the overall bed slope, very low sinuosity stream (less than 1.1) and the floodplain height relative to bed elevations the valley slope is likely about ~ +0.6% slope. This is relevant because valley slope and bed slope relative to sinuosity are important geomorphic features that impact overall stability – particularly in alluvial systems. Headcuts severely impact this physical feature.

Typically, without incision, in a stable alluvial pool-riffle system the relationship between the valley slope and water surface slope should be approximately about the ratio of the sinuosity of the channel length/down valley length. The channel slope is about twice the valley slope over the down-cut section between the siphon crossing and the Millville Ditch dam diversion.

With a 920 foot segment of 1.1 percent slope there is approximately double the stable form slope (0.57% vs. 1.1%). This does not include the steep section below the siphon. I recommend that the over-steepened stream bed below the siphon be addressed that similar considerations be given to the section between station 27+50 (inverted siphon) to approximately station 17+50. The present slope in this 1000 foot segment is .0088ft/ft or 0.88%.

Geomorphic Site Description: The Clover Creek Stream between the Millville Ditch Diversion Dam and the top of concrete siphon structures characterized as an Stage three CEM Schumm with alternating F1–F6 (Geomorphic Stream Type) – thin sandstone and siltstone complex. This is primarily due to fact that the existing streambed has been eroded well below the Pleistocene-Holocene alluvial layers down to what has been classified as the late cretaceous layer of alternating beds of sandstone and siltstone weakly cemented with calcite.

Upon loss of the alternate fine sandstone beds, which are also calcite cemented with common fracture lines, another substantial layer of siltstone becomes exposed to extraordinary high bed shear stress (τ_c), especially at concentrated flood stage shear stress.

Figure 1: Upper Pleistocene alluvial formed above alternating Cretaceous Chico Formation- must upper surface- probably some Holocene alleviation morphogenesis

Figure 2: Alternating layers of jointed beds with common sandstone jointed fractures (Cretaceous Chico Formation)

The sandstone portions of the beds (according to the G. Gordon 10/31/2008 geologic stratigraphy analysis of corridor bed report) are characterized as having a 1 to 4 inch thickness. The highest jointed sandstone bed within the Chico Cretaceous formation, of which I am standing on in Figure 2, has a width of up to 10 inches and yet, it has given way to incisional bed erosion processes since the 1952 (based on 1953 aerial photo interpretation).

Figure 3: 1959 photo from opposite bank indicating substantial amount of alluvial material with considerably higher streambed elevation.
- 2008 photo reference point

Figure 4: Millville Dam Site on opposite site take from top of diversion- November, 2008

Conclusion:

Based on the jointed- natural fractures and recent past loss of thicker sandstone beds, the thinner layer of sandstone layers located upstream are only short term bed control for the extreme incisional long profile adjustment that will occur shortly after the dam diversion removal.

The concentrated flows and the associated shear stress at the various flood stages above channel formative flows (1.5Q bankfull) are extreme. A planning alternative including multiple large rock step-pool – checking is a longer term approach to bed stability. The two most critical structural elements to such a design are the size and extent of the bank keys associated with the grade checks (AKA – cross step vanes) and the depth of footer into the siltstone layer.

I believe large rock footers (4 feet or greater diameter of a basalt type or other high density rock) or double-set footers would sustain the high stage flows while easily allowing for salmonid passage for fall chinook and summer steelhead. I would recommend that the step-pool cross vane style checks Figure 5 below considered as an alternative. Preferably maintain a range 1.0 ft of drop or less from cross vane to cross vane. If gaps in header rocks are used then it is recommended that a second set of footer by used. There should be no gaps on vane arms (Figure 6). Cross-vanes with longer arm length and multiple steps can be used.

Because Clover Creek is an entrenched F1-F6 stream type it is essential to build rock keys to the top of the banks instead of just the sills as indicated in Figures 5 and 6.

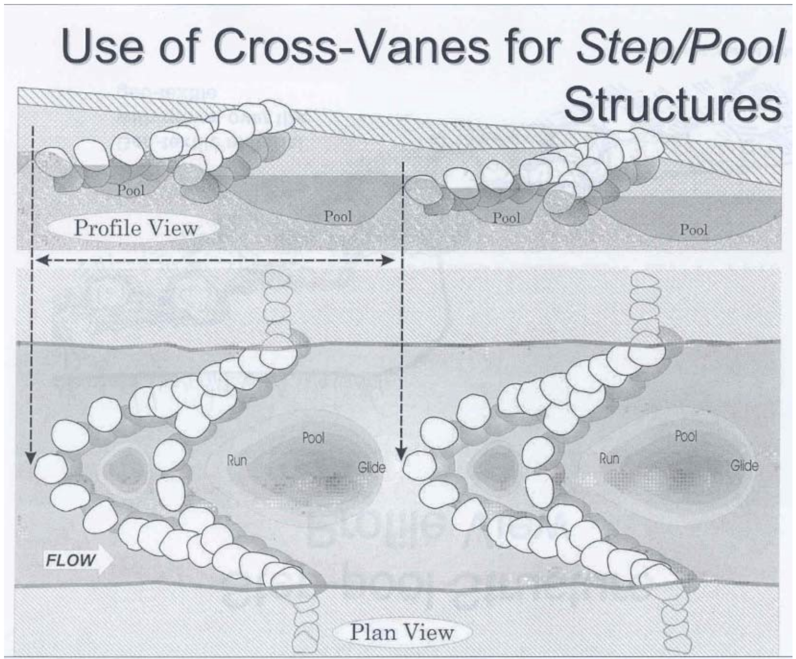

Figure 5: Cross-vane step-pool structures – can use double footer set and/or multiple cross steps with longer vane arms

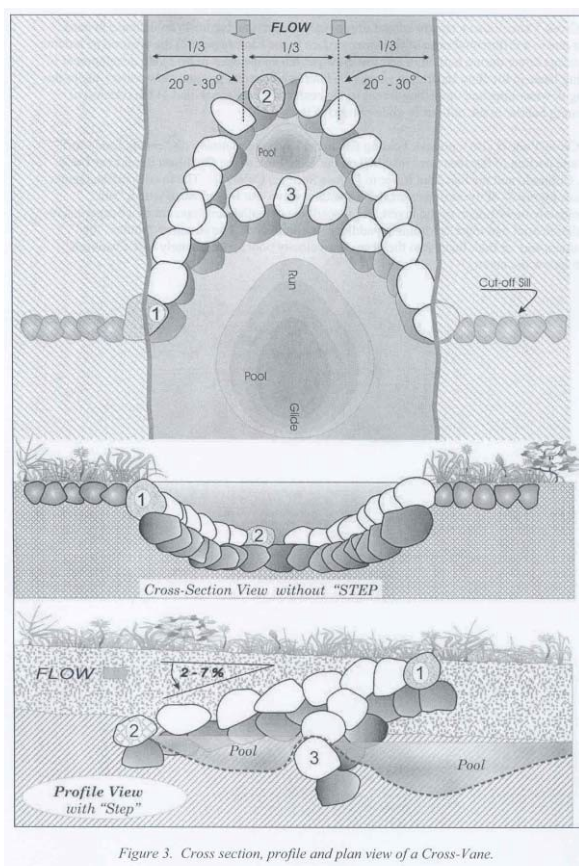

Figure 6: Cross section: profile and plan view of a cross vane

Regardless of the structure type chosen it is suggested that the following criteria be addressed in the design

1. depth–velocity requirements by species and age class including desirable pool depth
2. what are the limiting factors- as described by the fish biologist and have those factors been addressed by the proposed design. The design must address limiting factors conditions- cross-vane- step-pool or chute design.
3. Appropriate width to depth ratio for each structure to transport loads.

Fewer cross-vanes but with multiple cross steps are less expensive and the steps themselves can have alternative off-set inverts to provide better resting and holding refugia throughout lower stages of flows.

As discussed at the November 4th meeting the total number of vanes, computed scour depths and treatment segment can be determined by a more in-depth longitudinal profile analysis.

I appreciate the opportunity to work with the multi-agency technical review teams at the site.

Thank you,

W. Barry Southerland, Ph.D.
Fluvial Geomorphologist, CPESC #514
West National Technology Support Center
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APPENDIX C

Botanical Investigation

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M e m o r a n d u m

Date: 10/1/2007

To: Nancy Snodgrass

From: Barbara Castro
Department of Water Resources

Subject: Clover Creek Dam Removal – Botanical Investigation – (1) text
[note: (2) photo pages is a separate associated document]

Vegetation Overview

The Clover Creek/Millville Ditch siphon and damsite are located along a riparian strip within lower Cascade foothill oak savanna vegetation. Adjacent terraces are vegetated with mature Valley oak savanna, while the surrounding foothills support Blue oak savanna and a mosaic of denser mixed-oak/gray pine woodlands, chaparral shrublands and open grasslands. All are native plant communities; however, their open grassland understories consist mostly of non-native European grasses and weedy forbs. The riparian vegetation lining the creek edges consists of almost all native woody and herbaceous species, but also includes some non-native species due to long-term settlement and agricultural use of this area. The site is at 560 ft elevation and receives an average annual precipitation of approximately 35 inches per year.

Project site history: The terrace meadow on the north side of this part of Clover Creek was disced and dry-land farmed for decades, but not since the 1950s. The terrace has been grazed in more recent decades. There is a cattle stockyard across the creek from the meadow. Flooding on this terrace has been infrequent, the last time being in the 1970s. The dam was built in 1956; in the 1960s, there were no alders downstream of the dam. A 1959 photo shows open land at and just below the dam, and dense woody vegetation just upstream of the dam on the north bank. [site history source: project manager]

Existing plant species

A list of all plant species observed on July 26, 2007 at and adjacent to the siphon, dam site and the terrace meadow is included at the end of this memo.

SIPHON: At the siphon site, streamside vegetation consists of shrubby mixed woody riparian forest species: upstream are thick willows, alder, cottonwood saplings, and blackberry. Openings on the upstream gravel bar also contain herbaceous species such as mulefat and mugwort. Downstream are all the same species in both thick and more open patches with some weedy species such as white sweet-clover. Both up and downstream, a lower terrace has blackberry, scattered mature willows, and weedy forbs such as Bermuda-grass, sweet-clover and bird's-foot trefoil. All of these species are water- and moisture dependent. Upper bank edges support large and young valley oaks, Osage orange trees, and some grapevines. Very large, mature to senescent elderberry shrubs are also present both up and downstream of the siphon site on and near the upper bank edges. Between the siphon and the dam, they are part of an elderberry-buckeye woodland strip at the edge of the adjacent terrace. Species of the upper terrace edge are dependent upon a generally moderate, moist environment with periodic soil saturation, but do not require not high adjacent water levels, and can tolerate dry periods.

DAM: At the dam site, riparian vegetation is spotty and recent in origin. In the several yards downstream of the dam in the "plungepool" area, the banks are both open or have scattered weedy herbaceous growth. Dense shrubby willows with a few young alders line the right bank starting 20 or more feet downstream of the dam. Upstream, small clumps of young alders and small rows or patches of emergent wetland species (rush, tules) occupy the edges of the ponded area behind the dam. No mature riparian forest has become established on either bank, along the portion of Clover Creek influenced by the dam. There is less vegetation on the upstream right bank at present than in a 1959 photo of the same site.

SURNAME DWR 155 (Rev 4/02)				

TERRACE MEADOW: The meadow on the adjacent floodplain terrace is mainly occupied by a very open valley oak savanna. The herbaceous layer was probably originally a diverse grassland of perennial and annual native grasses and forbs, but has been converted to weedy non-native annual grasses such as foxtail chess, hedgehog-dogtail, medusahead, some wild oats. The terrace has also become dominated by a large invasion of yellow star-thistle. Along the edge adjacent to Clover Creek, starting a bit upstream from the siphon site, is a 30 to 60 feet wide band of buckeye with some elderberry mixed in. These are large, mature shrubs, most the size of small trees (most over 25 ft tall), many decades old.

Project assumptions

Based on the Clover Creek Profile provided and discussions with the geomorphologists, it is assumed that if the diversion dam were removed, the water level would drop about 4 feet upstream and would not change appreciably downstream of the dam site. If the siphon and associated concrete were removed, it is estimated that the water level upstream of the siphon location would gradually decline, over a reach of 50-60 feet, to a level about 3 feet lower than at present; the water level would not change appreciably downstream.

Probable project effects

SIPHON: If the siphon were removed, very little vegetation would be affected, because the area of greatest drop in water level would occur underneath the bridge. This is due to the siphon's location at the downstream edge of the bridge. Upstream of the bridge, an insignificant drop in water level (perhaps 1 foot) would not be expected to cause death of any of the present vegetation. The blackberries, alders, willows etc. would most probably migrate down to the new water's edge to fill up that space, and would easily adapt to any short-term changes as the stream adjusts its flow. Downstream of the siphon, the sparser weedy vegetation and patchy mulefat would not be affected since the water level would not be appreciably different than at present. None of the buckeyes or other mature woody vegetation upstream of the bridge should be affected.

DAM: If the dam were removed, and the water level in the existing pool area above the dam dropped about 4 feet, to flow freely downstream, the following effects would be expected to the vegetation:

Terrace meadow: I would expect no effects to the terrace vegetation. This floodplain terrace has been disconnected from the stream for many decades due to downcutting of the stream. Its source of water is groundwater flowing down from the adjacent watershed, not Clover Creek (Bruce Ross, pers. comm.). The existing species and individuals pre-date the dam, so were not and are not now dependent upon Clover Creek water. This probably includes the large buckeyes growing within 50 ft of the creek bank. No effects would occur to the herbaceous plants within the meadow, since no creek water reaches their root-zone.

Dam site: No vegetation downstream of the dam would be affected, since water levels there would remain about the same after dam removal. In the upstream area influenced by the dam, any riparian vegetation growing at the immediate edge of the pool above the dam would most likely die. In my opinion, this would be limited to

1. the clumps of alders just upstream of the diversion structure
2. a short, narrow strip of emergent-wetland sedges and rushes just upstream of these alders
3. a small clump of two dead and dying alders several feet upstream from the rushes
4. possibly a row of buckeyes very near the creek starting a few yards upstream of the diversion
5. a patch of tules (small wetland) with a stunted alder clump at the south end of the dam
6. a few small willows and one small alder on the south bank a few yards upstream of the wetland.

All of these can be viewed in attached photos in section #3, Vegetation just upstream from dam.

MILLVILLE DITCH: If the diversion into this ditch is eliminated, the ditch would dry up and cease to be a water supply to a narrow, spotty but sometimes substantial ribbon of wetland or riparian vegetation along much of its length. Much of the small to medium-sized trees, shrubs, vines and herbaceous species lining the ditch could die off, in areas with no other water supply to their root zones.

Rare plant habitat assessment

A review of the CNDDB spatial layer for rare, threatened or endangered plant species indicates that the only species of concern potential for the Clover Creek geographical area is Silky cryptantha (*Cryptantha crinita*), which requires gravelly washes and gravel bars which are dry and exposed after mid-April. At present, the project area does not appear to support this microhabitat; however, because the species does occur on nearby South Cow Creek, the project site should be checked in late April for this species prior to use of heavy equipment or other disturbance of the gravelly portions of the creek bed. Other rare plant species potential to this vicinity are known only from the vernal pool and vernally moist, stony upland habitats on the Millville Plains, which are not present at or adjacent to the project site.

Table 1. Plant Species Observed at Clover Creek dam removal site - July 26, 2007		
Scientific name	**Common name**	**life-form**
* = non-native		T=tree; S=shrub;
		H=herb; G=grass
		V=vine;A=aquatic
Riparian edges		
Alnus rhombifolia	White alder	T
Populus fremontii	Fremont cottonwood	T
Salix gooddingii	Black willow	T
Vitis californica	California wild grape	V
Baccharis salicifolia	Mulefat	S
*Rubus discolor**	Himalayan blackberry	S
Salix exigua	Sandbar willow	S
Salix lasiolepis	Arroyo willow	S
Salix lucida ssp. *lasiandra*	Yellow willow	S
Artemisia douglasiana	Mugwort	H
*Melilotus albus**	White sweet-clover	H
Juncus sp.	Rush	A
Scirpus tabernae-montani	Soft-stemmed tule	A
Riparian/dry terrace transition		
Aesculus californica	California buckeye	T
*Maclura pomifera**	Osage orange	T
Sambucus mexicana	Elderberry	S
*Lotus corniculatus**	Bird's-foot trefoil	H
*Cynodon dactylon**	Bermuda-grass	G
Upper terrace meadow		
Aesculus californica	California buckeye	T
Quercus lobata	Valley oak	T
Quercus wislizenii	Interior live oak	T
Brassica sp.*	Wild mustard	H
*Centaurea solstitialis**	Yellow star-thistle	H
*Avena fatua**	Wild oats	G
Bromus madritensis ssp. *madritensis**	Foxtail chess	G
*Bromus mollis**	Soft chess	G
*Cynosurus echinatus**	Hedgehog dogtail	G
*Taeniatherum caput-medusae**	Medusahead	G

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APPENDIX D

Clover Creek Habitat Assessment Report

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Clover Creek Habitat Assessment

August 2012




Department of Water Resources Fish Passage Improvement Program

Prepared by:

April McEwen, Environmental Scientist
John Kleinfelter, Environmental Scientist
Kevin Marr, Environmental Scientist

Prepared under the supervision of:

A. Marc Commandatore, Senior Environmental Scientist
Sara Denzler, Environmental Program Manager

Acknowledgements

The Fish Passage Improvement Program would like to acknowledge the cooperation, collaboration, and assistance of many individuals and agencies in conducting the Clover Creek stream habitat assessment and producing this report. This assessment would not have been possible without landowner cooperation and private property access.

Fieldwork was conducted by DWR's John Kleinfelter, James Newcomb, Kevin Marr, Trevor Greene, Megan Sheely, and Colin Hanley with assistance from CDFG's Tricia Bratcher, Doug Killam, Matt Johnson, and Andrew Jensen. Brenda Olson (USFWS) provided protocol training for field personnel. GIS maps were created by Harry Spanglet, April McEwen, and Trevor Greene.

California Department of Water Resources

John Kleinfelter, James Newcomb, Trevor Greene, Kevin Marr, Megan Sheely, Colin Hanley, Harry Spanglet, April McEwen, A. Marc Commandatore, Sara Denzler

California Department of Fish and Game

Patricia Bratcher, Matt Johnson, Andrew Jensen, Doug Killam, Mike Berry, and Eda Eggeman

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Western Shasta Resource Conservation District

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Natural Resource Conservation Service

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Cooperative Landowners

Clyde and Helen Greco, John and Christine McArthur, Chad and Thelma Oilar, Paul Traficante, Bar Eleven Partnership, Tim DeAtley

Contents

Introduction

The California Department of Water Resources (DWR) Fish Passage Improvement Program (FPIP) completed a stream habitat assessment on approximately eight miles of Clover Creek in 2008-2011. Information was collected to characterize the type of habitat that exists upstream of Millville Diversion Dam (MDD). The MDD, built in the 1920's, is a structural barrier to upstream anadromous fish migration. The habitat assessment was completed between the MDD and Clover Creek Falls, a 150 ft tall natural waterfall barrier located approximately ten miles upstream of the dam. This project was funded by the California Department of Fish and Game (CDFG) (Ecosystem Restoration Program Contract Agreement E1083004) to assist in their decision-making process regarding the proposed effort to provide anadromous fish access to habitat upstream of the MDD.

Watershed Description

Clover Creek (8-digit Hydrologic Unit Code: 18020118) is one of five major tributaries to Cow Creek and is located in Shasta County at the northern end of California's Central Valley. Clover Creek is 27.5 miles long. There is approximately 10 miles of stream between Clover Creek Falls and the MDD, although only approximately eight miles were assessed due to access constraints. The Clover Creek watershed originates at Clover Mountain (elevation: 5,500 feet) and drains approximately 54 mi^2 (~35,000 acres) or 13% of the Cow Creek watershed. Clover Creek does not currently have a stream gauge to monitor hydrometric measurements of water surface elevation (stage) and volumetric discharge (flow). However, a regression analysis was developed by the U.S. Fish and Wildlife Service to estimate Clover Creek flows (USFWS 2009) and is discussed further in the 'Methods' section of this report.

Land use within the watershed is largely characterized by three main types: agriculture/grazing, commercial forest, and rural residential. Land use adjacent to the portion of Clover Creek assessed in this report (lower watershed) consists primarily (>70%) of agriculture/grazing. Upper watershed land use is primarily characterized by agriculture/grazing and commercial forest used for timber harvesting (see Figure 3-1 in SHN 2001). There are 23 diversion points in the Clover Creek System; the majority existing in the upper half of the watershed and above Clover Creek Falls (see Figure 5-9 in SHN 2001). Clover Creek water quality is listed by the U.S. Environmental Protection Agency (EPA) and the California State Water Resource Control Board as impaired for pathogens. The leading cause of impairment is bacteria and the most probable source(s) contributing to impairment is listed as agriculture/grazing (USEPA 2004). Water temperature has been identified as a limiting factor to Chinook salmon and Central Valley steelhead abundance in the Cow Creek watershed (SHN 2001). Impaired water quality combined with elevated water temperatures can have a major effect on the ability of a stream to provide adequate habitat for spawning and early juvenile rearing, as well as disrupt migration routines. High water temperatures have primarily been observed in the lower reaches of Cow Creek tributaries and are likely a function of higher air temperatures occurring at lower elevations combined with reduced flows from diversions and land use, introduction of tailwater returns, and reduced riparian canopy (Hannaford 2000, SHN 2001).

Clover Creek is located within the geographical boundaries of National Marine Fisheries Service (NMFS) designated critical habitat for Central Valley steelhead. Central Valley steelhead are listed as threatened under the federal Endangered Species Act (ESA). Although the percentage of Central Valley steelhead utilizing Clover Creek is unknown (SHN 2001), Clover Creek is currently listed by the NMFS as Central Valley steelhead spawning grounds (NMFS 2009). Cow Creek watershed's annual steelhead spawning population was estimated in 1965 to be approximately 500 steelhead, although current populations are expected to be much lower (SHN 2001). Current steelhead populations have not been estimated, and it is unknown how many steelhead return to Clover Creek each year. The migration period of Central Valley steelhead[1] into the Cow Creek watershed has not been determined but is typically dependent on increasing flows during the late fall and winter from November – February (SHN 2001).

In addition to Central Valley steelhead, two runs of Chinook salmon (fall run, late-fall run) are known to spawn in Clover Creek[2] (CBDP 2000). Both runs are ESA listed species of concern and California State Species of Concern. Data related to Chinook spawning and population estimates within the Cow Creek watershed are very limited (SHN 2001). However, recent observations of fall run Chinook spawning below the MDD verify salmonids are returning to Clover Creek to spawn (Jensen et al. 2012). The migration period of fall run and late-fall run Chinook salmon occurs from June – December and October-April, respectively, with peak migration occurring in September - October and December, respectively (Yoshiyama, Fisher, Moyle 1998). The fall-run and late-fall run spawning period occurs from late September – December and early January – April, respectively, with peak spawning occurring in October– November and February – March, respectively.

Regulatory Background

Restoring and establishing available critical habitat for salmonid migration, spawning, and rearing are essential components of the (NMFS) recovery strategy to reverse trends towards extinction.

> *"Critical habitat for listed salmonids is comprised of physical and biological features essential to the conservation of the species including: space for the individual and population growth and for normal behavior; cover; sites for breeding, reproduction and rearing of offspring; and habitats protected from disturbance or are representative of the historical geographical and ecological distribution of the species. The primary constituent elements considered essential for the conservation of listed Central Valley salmonids are: (1) freshwater spawning sites; (2) freshwater rearing sites; (3) freshwater migration corridors; (4) estuarine areas; (5) nearshore marine areas; and (6) offshore marine areas" (NMFS 2009, p.18-19).*

The CALFED Bay-Delta Program (CALFED) includes a programmatic element, the Ecosystem Restoration Program Plan (ERPP) that identifies several ecological management zones. Clover Creek is within the

---

[1] Steelhead can be classified into two races, winter and summer steelhead, depending on migration timing. Only winter steelhead occur in the Sacramento River tributaries and mainstem. However, due to genetic modification and the influence of water temperature and flow impacts, Central Valley steelhead can currently be found in fresh water year-round (SHN 2001).

[2] The Cow Creek watershed is not part of the present range and distribution of spring and winter run Chinook salmon, although spring run may have been part of the historic distribution and range (SHN 2001). In addition, Clover Creek conditions are not suitable for late-fall run Chinook to finish their rearing through the summer months. However, they likely spawn in Clover Creek when conditions are suitable and migrate to the Sacramento River to rear when conditions in Clover Creek become unfavorable (A. Jensen, pers comm).

Cow Creek Ecological Management Unit (EMU), a subunit of the Northern Sacramento Valley Ecological Management Zone (CBDP 2000). The *ERPP Final Programmatic EIS/EIR Technical Appendix* summarizes the restoration vision for Clover Creek including "reducing adverse effects of timber harvest, erosion, and cattle grazing on the stream and riparian system and maintaining or restoring stream flows during important periods of the year to allow fish migration, spawning, and rearing of fall run Chinook salmon and steelhead trout" (CBDP 2000, p. 197). The Clover Creek habitat assessment was funded by Propositions 50 and 84 and addresses ERP Goals 1 and 3 (ERPP Year 12 Annual Report, July 2011).

The Cow Creek watershed is also identified in the Central Valley Project Improvement Act (CVPIA) (USFWS 1992), and the CVPIA Anadromous Fish Restoration Program (AFRP) has restoration objectives for the watershed (USFWS 2001). A primary goal of the CVPIA and AFRP is to double natural production of anadromous fish populations in California's Central Valley rivers on a long-term sustainable basis (Section 3406(b)(1)] of the CVPIA, USFWS 1992). Pursuant to this goal, the U.S. Fish and Wildlife Service (USFWS) and CDFG are examining opportunities to increase Chinook salmon and steelhead populations throughout the northern Sacramento River valley. Although accurate counts are not available, it is believed that current salmonid populations are far below historic numbers (NMFS 2009, Yoshiyama 1998). According to the CDFG, the Cow Creek watershed has the potential to support 5,000 to 10,000 fall-run Chinook salmon, and a minimal number of steelhead (SHN 2001).

Project Objectives and Methods

A current project proposal to modify the MDD and its associated siphon would allow upstream migration and access to an additional 10 miles of Clover Creek. The habitat assessment of those additional 10 stream miles is useful in: characterizing existing habitat conditions, quantifying the abundance and quality of habitat, and identifying limiting factors and opportunities for restoration. The FPIP task objectives and survey methods used to conduct the Clover Creek habitat assessment are discussed below.

Objectives

The Clover Creek habitat assessment objectives can be found in Task 2 of the Ecosystem Restoration Program Contract Agreement Number E1083004.

1. Complete stream habitat assessments on eight miles of Clover Creek upstream of the Millville Diversion and downstream of Clover Creek Falls.
2. Summarize habitat data in report form.
3. Produce Geographic Information System (GIS) maps to summarize and quantify habitat types.

The objective of the stream habitat assessment was to identify habitat types and characterize habitat conditions for target species (Chinook salmon and Central Valley steelhead). Characterization of those habitat conditions was guided by and limited to the parameters described in the "Stream Habitat Classification and Inventory Procedures for Northern California" (McCain et al. 1997, Appendix A), while an additional protocol (Appendix B) created by the United States Forest Service (USFS) guided applied methods. The purpose of this habitat assessment and report is not to provide information related to the feasibility of modifying the MDD or associated actions but to summarize habitat data describing the stream reach above the MDD (see Objective 2). Likewise, the assessment does not include a detailed

Clover Creek watershed assessment or specify restoration actions, although observations are detailed that may assist stakeholders in identifying and prioritizing restoration opportunities.

Methods

Methods used to meet each objective are discussed below. The protocols that guided habitat data collection were determined in collaboration with USFWS and CDFG staff and are identified in ERP Contract Agreement Number E1083004, Task 2.

Objective 1. Complete stream habitat assessments on approximately eight miles of Clover Creek upstream of the Millville Diversion Dam and downstream of Clover Creek Falls.

Stream Habitat Assessment Timing and Locations

Stream habitat assessments of approximately eight miles of Clover Creek were conducted during the following time periods: November 5, 19-21 in 2008, October 7-8 in 2009, August 8-11, 22-25, October 4, 19, 26-27 in 2011. The broad range of time between survey efforts was due to changes in project personnel, funding availability, and weather conditions. Although the majority of stream habitat between Clover Creek Falls and the MDD was assessed, approximately two miles of stream adjacent to the Shufelberger property was not assessed because landowner access was not provided (see Appendix E, Figure A for assessment location).

Estimation of Clover Creek Flows

While there are no stream gauges and detailed history of flow measurements on Clover Creek, a regression analysis was conducted by the USFWS to estimate Clover Creek flows (USFWS 2009). The USFWS collected flow measurements in 2008-2011, which were used to develop flow regression equations correlated to the Cow Creek United States Geological Survey (USGS) gauge near Millville, California (#11374000). Regression analysis was used to estimate Clover Creek flows on the dates of the assessment and are available in Table 2.

Protocols and Sampling Methods

Defining the number and type of habitat units in a reach is important to understanding the type of habitat available to salmonids (e.g., pools offer holding and early juvenile rearing habitat). Habitat typing gives information on the sequence, distribution, and availability of habitat. The United States Forest Service's technical bulletin *Stream Habitat Classification and Inventory Procedures for Northern California* (McCain et al. 1990) classifies 22 (common to Northern California) habitat types according to channel morphology within three main units (categories) that proceed from shallow to deep water: riffles, runs, and pools (Appendix A). During the 2008 surveys, field personnel encountered many low gradient areas consisting primarily of swift moving water flowing over shallow bedrock substrate and therefore recorded an additional habitat type termed bedrock sheet (BRS). These habitat areas had been scoured of all complex substrate (e.g., sand, gravel, cobble, boulders); otherwise they would have been most similar to low gradient riffle (LGR) habitat types. In order to categorize the entire stream reach into three habitat categories and for data comparability and analysis purposes, all BRS types (14 total occurrences) were relabeled as LGR habitat types and compose 10% of all riffle habitat types.

Important habitat variables such as instream cover (canopy, large woody debris), substrate composition, flow, riparian vegetation and condition, and water quality are limiting factors that have major implications on the quality and functional value of a stream reach as salmonid habitat (Kerwin 2001, NMFS 1996). The Klamath National Forest Aquatic Habitat Assessment Protocol FY93 (Appendix B) was used to collect data on several important habitat variables. Additional data was collected at pools only (per protocol guidance). Table 1 shows the habitat variables and the lateral location of assessment within the stream channel.

TABLE 1. SPATIAL LOCATION OF HABITAT ASSESSMENT WITHIN THE CHANNEL		
Habitat	***Habitat Variables***	***Lateral Channel Location of Variable Assessment***
All Habitat Types	Habitat Type Length, exposed bedrock %, gravel substrate[3] area	Wetted Perimeter
	LWD, gravel substrate area (ocular estimate)	Bankfull Perimeter
Pools	Maximum depth, riffle crest depth, in-stream cover, cover/habitat complexity	Wetted Perimeter
Index Reaches	Mean bankfull width/depth, substrate composition, cobble embeddedness %, shade %, exposed bedrock %	Bankfull Perimeter
Index Reaches: Riffles and Pool Tail-outs only	Fines %	Bankfull Perimeter

Eight "index" reaches were selected in order to conduct a more detailed assessment of Clover Creek habitat. Index reach length was determined based upon the average bankfull channel width at that location (*index reach length = average bankfull width (rounded to nearest ft) x 10*). Due to time and shoreline access constraints, each mile of stream between Clover Creek Falls and MDD was not represented by detailed index reach assessments. Within the eight index reach assessments conducted, ten evenly spaced transects were delineated perpendicular to the stream channel and spanned the channel's bankfull width. Detailed assessment methods can be found in Appendix B. Canopy closure (closure density over the stream or shade) percentages were estimated using a spherical densitometer along transects. Data collection and analysis of canopy closure followed riparian habitat evaluation methods developed by Platts et al. (1987).

Objective 2. Summarize habitat data in report form.

Descriptive statistics were used to characterize the type, frequency, and proportion of habitat types and to summarize important habitat variables found within index reaches. To gain a more accurate perspective of in-stream habitat proportion and distribution, stream and habitat type length were used to calculate most descriptive statistics. Habitat type occurrence values were also provided for general

[3] Gravel substrate was measured within the wetted perimeter in all habitat types. Outside the wetted perimeter, field personnel also recorded ocular estimates of gravel substrate area occurring within the bankfull channel. These additional gravel estimates are discussed in the 'Results' section of this report and can be found in Figure 7. Gravel within the bankfull channel represents gravel potentially available for recruitment or for utilization by spawning salmonids at higher flows than those estimated to occur on assessment dates.

information purposes. Residual pool depth values were obtained by subtracting riffle crest depth from maximum pool depth.

Objective 3. Produce Geographic Information System (GIS) maps to summarize and quantify habitat types.

Base maps of the Clover Creek watershed were created with Esri ArcGIS v. 10.1 Geographic Information System (GIS) software using spatial data layers that show: USGS 7.5 topographic maps, Shasta County assessor's parcel data, the USGS National Hydrography Dataset, and 2010 aerial photographs from the USDA National Agriculture Imagery Program (NAIP). Global Positioning System (GPS) units were used to record locations of waypoints that were used in mapping habitat types.

A line shapefile layer representing Clover Creek was digitized from a NAIP 2010 base map. In reaches where shoreline tree cover on the aerial imagery made it difficult to accurately digitize the stream channel, USGS topographic quadrangles were used for increased precision. A dynamic segmentation process based on habitat unit lengths recorded on data sheets, combined with GPS waypoints collected in the field, was used to assign habitat types and categories to the Clover Creek line. A subset of GPS waypoints was used to verify the accuracy of the dynamic segmentation process.

Results and Discussion

Estimation of Clover Creek Flows

Estimated Clover Creek flows on the survey dates are given in Table 2. Throughout the assessment, Clover Creek flow rates allowed clear identification of habitat types and safe field assessment conditions. Even though low flows can create difficulties in differentiating habitat types, habitat assessments were able to be completed by observing channel characteristics such as shape/slope, residual depth, and substrate. Stream flows ranged from 15.8 cubic feet per second (cfs) to 25.4 cfs and were sufficient for identification of habitat types. The estimated flows and assessment dates shown in Table 2 are significant because several assessments occurred during the peak spawning period (Oct-Nov) for fall-run Chinook salmon and in the earliest steelhead migration window. Therefore, the habitat conditions witnessed in October and November are a snapshot of flow and habitat conditions that spawning fall-run Chinook salmon would experience. In fact, on October 19, 2011, fall-run Chinook salmon were observed spawning 50 ft downstream from the MDD (Jensen et al. 2012) at an estimated 22.7 cfs (Table 2).

TABLE 2. ESTIMATED DAILY AVERAGE CLOVER CREEK FLOWS ON ASSESSMENT DATES

Assessment Date	***Clover Creek Flows (cfs) ****
Nov 5, 2008	25.4
Nov 19, 2008	19.3
Nov 20, 2008	19.3
Nov 21, 2008	19.4
Oct 7, 2009	15.6
Oct 8, 2009	15.8
Aug 8, 2011	21.3

Aug 9, 2011	21.1
Aug 10, 2011	21.1
Aug 22, 2011	19.9
Aug 23, 2011	19.7
Aug 24, 2011	19.7
Aug 25, 2011	19.7
Oct 4, 2011	20.0
Oct 19, 2011	**22.7**
Oct 26, 2011	21.8
Oct 27, 2011	21.9
*Flows estimated using regression analysis (USFWS 2009).	

Stream Areal Description

The total length of stream surveyed including all side channels and intermittent channels was approximately 42,934 ft (8.13 mi) (Table 3). Average bankfull width was 45 ft (13.82 m) (n=19), with a range of 20 - 88 ft. Mean channel slope was 1.5% (n=15) with a range from 0.5-5%. Side channel lengths were also measured in the field and represent intermittent channels that are inundated periodically. The side channel measurements are not an estimate of available or potential floodplain habitat. Descriptive statistics are provided for other parameters according to habitat category: riffles, pools, and runs (Table 3).

TABLE 3. HABITAT CATEGORY DESCRIPTIVE STATISTICS					
Stream Reach	***Calculation***	***Habitat Type Categories***			***Total***
		Riffles	Pools	Runs	
All Assessed Habitat	Total Length (ft)	10749	4658	27527	42934
	Percent Habitat (%)	25	11	64	100
	Occurrences	138	56	184	378
	Mean Depth (ft)*	0.7	3.3	1.2	n/a
	Mean Depth SE**	0.1	0.2	0.2	n/a
	Wetted Width (ft)	30	30	33	n/a
	Wetted Width SE**	0.1	5.8	2.3	n/a
Side Channels	Total Length (ft)	1747	1166	668	3581
Index Reach Habitat Types	Total Number Assessed	10	1	16	27
*Mean Depth was calculated at every 5th habitat category encountered. **SE (Standard Error of the Mean=Sample estimate of population standard deviation/sqrt(n)					

Habitat Types

Out of a possible 22 habitat types described in the habitat typing protocol *Stream Habitat Classification and Inventory Procedures for Northern California*, 18 were observed during the stream habitat assessment. The occurrence of habitat types and their relative proportion (by stream length) within each habitat category are provided in Table 4 (also see Figure 1).

TABLE 4. HABITAT TYPE OCCURRENCE AND HABITAT CATEGORY LENGTH PROPORTION					
Habitat Category	***Habitat Type***	***Acronym***	***Occurrence***	***Percent Occurrence***	***Category Proportion (Length)****
Riffles	Low Gradient Riffles**	LGR	130	34	0.96
	High Gradient Riffles	HGR	3	1	0.03
	Cascade	CAS	5	1	0.01
	TOTAL RIFFLES	**--**	**138**	**36**	**1**
Pools	Secondary Channel Pool	SCP	13	3	0.21
	Backwater Pool Root Wad Formed	BWPr	2	1	0.02
	Backwater Pool Log Formed	BWPl	1	0	0.01
	Plunge Pool	PLP	5	1	0.05
	Lateral Scour Pool Root Wad Formed	LSPr	6	2	0.10
	Lateral Scour Pool Bedrock Formed	LSPbe	3	1	0.03
	Dammed Pool	DPL	3	1	0.15
	Mid Channel Pool	MCP	18	5	0.37
	Channel Confluence Pool	CCP	2	1	0.03
	Lateral Scour Pool Boulder Formed	LSPbo	1	0	0.02
	Corner Pool	CRP	1	0	0.01
	Trench / Chute	TRC	1	0	0.01
	TOTAL POOLS	**--**	**56**	**15**	**1**
Runs	Glides	GLD	66	17	0.43
	Run	RUN	89	24	0.36
	Step Run	SRN	29	8	0.21
	TOTAL RUNS	**--**	**184**	**49**	**1**
Total		**18**	**378**	**100**	**3**
*Category Proportion (Length) = Stream length of individual habitat type/total stream length of habitat category (e.g., stream length of low gradient riffles (LGR)/total stream length of all riffles=0.96. I.e., LGR make up 96% of all riffles). **Low Gradient Riffle occurrence and proportion by length include bedrock sheet (BRS) habitat types.					

Habitat type categories consisted of riffles, pools, and runs. Runs comprised the majority of habitat types in the assessed stream reach (64%), while riffles were second (25%) and pools were least represented (11%) (see percent habitat in Table 3). A combination of riffles and runs comprised 89% of the length of assessed stream.

Runs

As the dominant habitat feature, runs were well distributed throughout the assessed portion of Clover Creek (Appendix E, Figure A) and between types of runs (Table 4). Field personnel noted that glides, the predominant type of run habitat, were characterized by very little habitat complexity or features that would provide in-stream cover (e.g., boulders, whitewater, undercut banks, LWD, terrestrial and aquatic vegetation). Glides were typically shallow with little surface agitation, and substrate was composed primarily of shallow bedrock sheets or lacked more complex substrate composition (e.g., sand, gravel, cobbles, boulders). Glide habitat is not commonly associated with spawning areas, but can be utilized as holding habitat for spawning adults (Bjornn and Reiser 1991).

Bank failures, also known as mass-wasting, landslides, and active bank erosion, were a frequent occurrence on Clover Creek. In 2008, field personnel measured the length of bank failures in the lower 3.1 miles of assessed habitat. Bank failure was evident in 27% of the 3.1 miles of stream where bank failure length was determined (0.84/3.1=27). The bank failures mainly ranged in height from 5 - 25 ft, although a 100 ft high bank failure was observed adjacent to the Oilar property. 85% of the total length of bank failures occurred adjacent to habitat units classified as glides (GLD within the "runs" category) or bedrock sheets (low-gradient riffles absent of all substrate). NMFS provides a streambank stability salmonid habitat condition rating of "poor" for stream reaches that have over 20% actively eroding shoreline (NMFS 1998 as cited in Kerwin 2001). Although stream bank stability and bank erosion were not measured on the higher reaches of Clover Creek, field personnel did note that upstream bank erosion was also significant and frequent.

Riffles

Low-gradient riffles (LGR) made up the majority of riffle habitat (96%). LGR are swift flowing stretches of turbulent water, further characterized by some partially exposed substrate that is usually cobble dominated in stream areas with gradient less than 4% (McCain et al. 1991). These areas deliver food to juvenile salmonids, and surface agitation may provide juvenile salmonids with cover from predators. However, transition of pool habitat into riffle habitat decreases rearing habitat and has been shown to cause a decrease in the relative proportion of older age salmonids (Hicks et al. 1991).

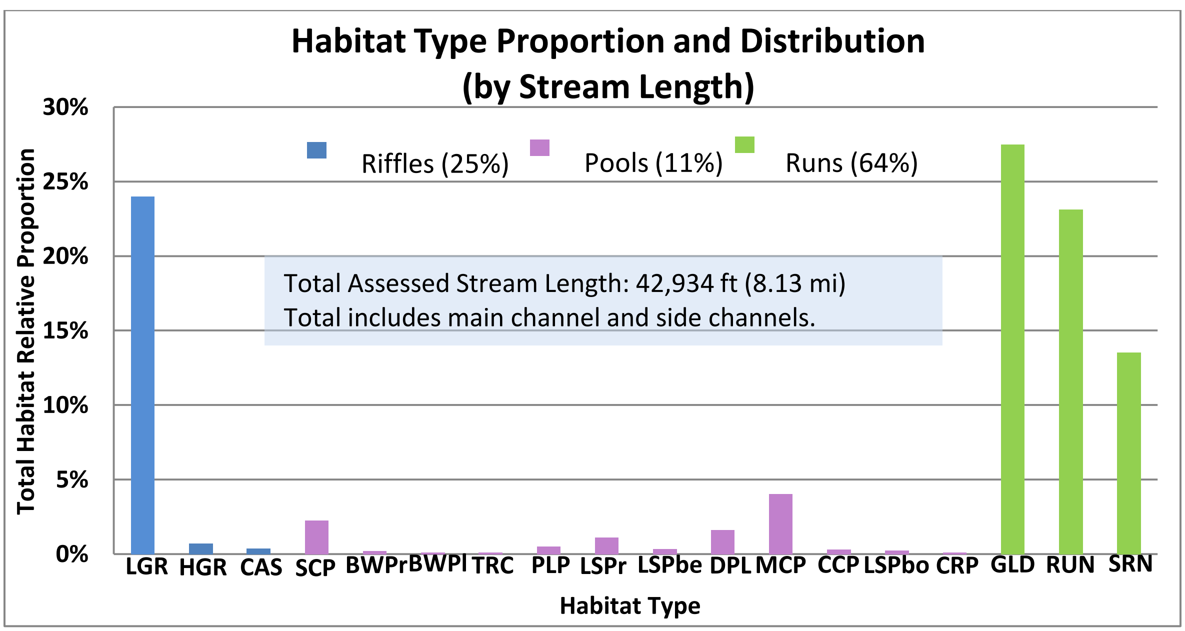

Figure 1. Habitat Type Proportion and Distribution, by Stream Length

Pools

Pools provide early juvenile rearing and holding habitat for salmonids and are an important component of a stream that provides overall high quality salmonid habitat. Generally, streams located in disturbed watersheds (i.e., heavily influenced by watershed land use) have a lower percentage of pool habitat as degradation of stream banks and increased sediment transfer leads to localized aggradation of deep stream areas (Hicks et al. 1991, Lisle 1982). Subsequently, the carrying capacity of rearing habitat for juvenile salmonids may be reduced as pool habitat area decreases (Bjornn et al. 1977 in Ligon et al. 1999).

Distribution

A diversity of pool types is needed to meet the requirements of salmonids at various life stages. In Clover Creek, pool habitat types were not well distributed across the 12 pool habitat types found. 73% of pool types were found in only three pool habitat types (mid-channel (37%), secondary channel (21%), dammed pool (15%) habitat). In contrast, the least represented pool habitat types found were backwater pool - log formed (0.90%), trench/chute (0.86%), and corner pools (1.0%). Backwater pool - boulder formed and lateral scour - log formed pools were not evident in any part of the stream reach surveyed. See Table 4 and Figure 1 for a proportionate distribution between pool types.

The assessed portion of Clover Creek also had a low occurrence frequency of seven pools per mile. The average measured bankfull width of Clover Creek was approximately 45 ft but ranged from 20 - 88 ft. NMFS (1998) recommends an occurrence standard of 26 pools per mile be used to define fair and good salmonid habitat condition in channels that are 50 ft wide. NMFS (1998) recommendations for channels ranging in bankfull width (BFW) from 20 – 100 ft are 56 – 18 pools per mile (56 p/mi: 20 ft BFW; 18 p/mi: 100 ft BFW).

Pool Depth and In-Stream Cover

Standards for pool depth related to properly functioning salmonid habitat conditions are not well defined. NMFS (1998) provides a vague "good" habitat quality standard that requires "sufficient pools with greater than 1 m (3.28 ft) depth with good cover and cool water". Pool depth is also used as an indicator of channel condition as it is linked to stream bank erosion and subsequent pool aggradation (Kerwin 2001). It should be noted that maximum pool depth is related to water level and changes frequently depending on existing flow conditions. Residual pool depth represents the depth at which a pool would be completely filled but water would not flow past the downstream riffle crest. Residual pool depth is therefore independent of flow and river stage (water level) (Lisle 1987). Both maximum and residual pool depths are given in Figures 2 and 3.

Figures 2-4 are box and whisker plots showing the 25^{th} percentile, median (where the box splits), and 75^{th} percentile with minimum and maximum for residual pool depths and pool in-stream cover values. The majority (75%) of pools in Clover Creek at the time of assessment had a maximum depth greater than 3 ft deep (Figure 2). However, the majority of residual pool depths were below 3.1 ft (Figure 3). One large outlier existed in the pool at the base of Clover Creek Falls. This pool was not assessed, although field personnel said it was probably 6-8 ft deep and on average appeared to be approximately 10-12 ft wide. Of all the pools assessed, field personnel noted this pool would provide excellent habitat for salmonids as it was well oxygenated, had cool water temperatures, was deep, and had good cover from boulders, whitewater, and other sub-surface features such as bedrock ledges.

Seventy five percent of pools had less than 30% in-stream cover (Figure 4). In-stream cover was determined through ocular estimation of the percentage of the pool that was covered by the following eight in-stream features: undercut banks, small woody debris, large woody debris, terrestrial vegetation, aquatic vegetation, whitewater, boulders, and bedrock ledges.

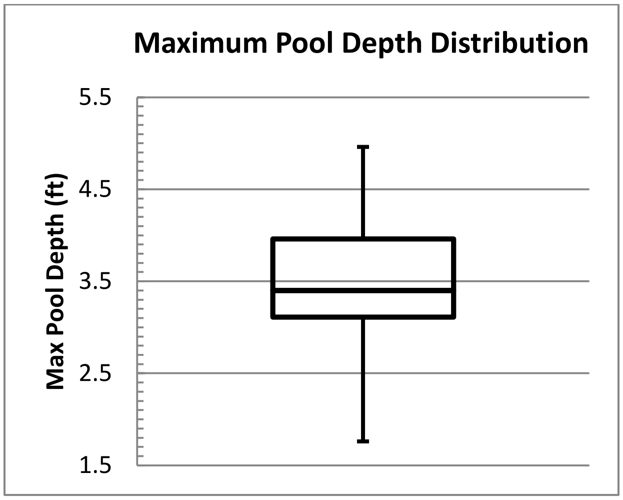

Figure 2. Maximum Pool Depth Distribution

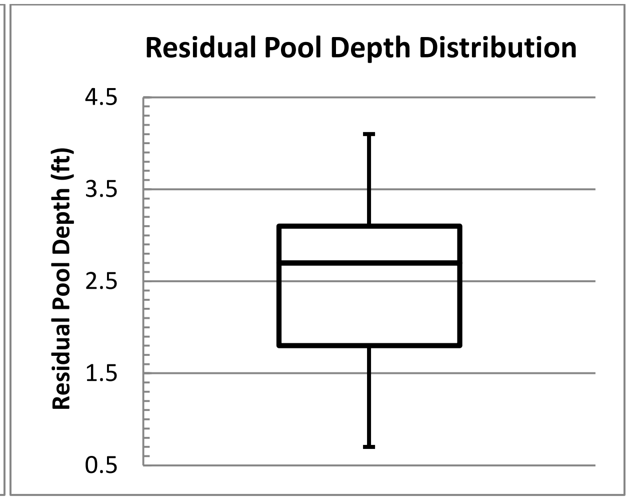

Figure 3. Residual Pool Depth Distribution

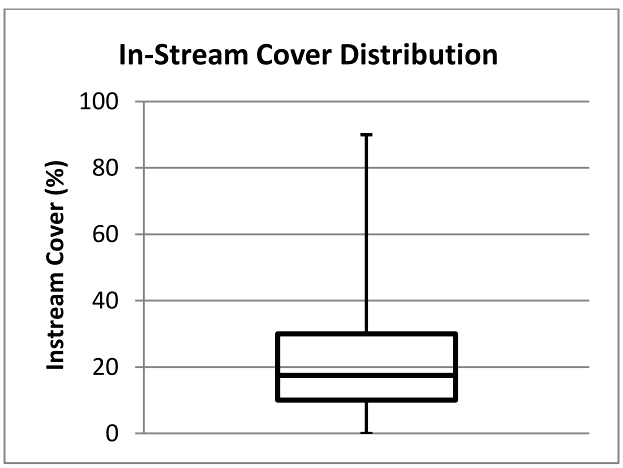

Figure 4. Pool In-stream Cover Distribution

Cover/Habitat Complexity

Pool cover/habitat complexity or the distribution of in-stream cover percentage across multiple features (see Pool Depth and Cover) was categorized into low, medium, and high complexity ratings based on protocol guidance. For example, if a pool only had in-stream cover provided by undercut banks (i.e., one feature), then it was determined to have "low" habitat complexity while a pool with three or more features was rated as having "high" quality habitat complexity. The majority of pools (48%) had medium cover complexity (two – three features) and 14% had high quality habitat complexity (Figure 5). The majority of complexity consisted of terrestrial vegetation, undercut banks, and boulders.

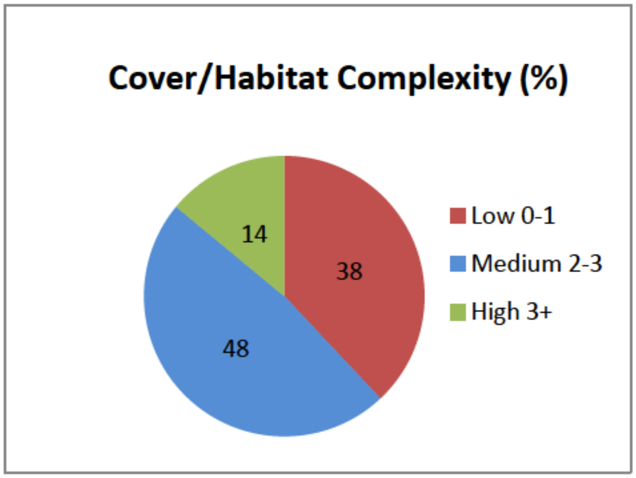

Figure 5. Pool Cover Complexity

Spawning Habitat

Several factors influence successful spawning, incubation, and fry emergence (Ligon et al. 1999). These factors include substrate size composition, the degree appropriately sized substrate are embedded in fine sediments, rate of intergravel flow (or percolation rate of water through the substrate), and water temperature, depth, and velocity. Gravel size substrate is suitable for spawning as it is small enough to be moved in redd creation and allows intergravel flow, providing incubating eggs and alevin with essential elements such as better water quality, dissolved oxygen, and food. If high quality substrate is not available or is embedded, spawning salmon may still spawn and juvenile rearing may occur but there is generally a significant reduction in survival rates due to factors such as entombment (the obstruction of alevin emergence), bacterial growth, and thermal factors (higher water temperatures and decreased dissolved oxygen) (Geist and Dauble 1998).

Spawning Gravel

In this assessment, gravel size substrate was used as a surrogate for spawning habitat availability and was measured within the wetted perimeter at each sampling station throughout the assessed reach. In addition, field personnel noted ocular estimates of gravel patches outside the wetted perimeter but within the bankfull channel. However, this single surrogate should be used with caution in predicting spawning potential as other essential site elements are required by salmonids (e.g., intergravel/hyporheic flow) (Geist and Dauble 1998, Geist et al. 2001). As a result, the area suitable for spawning is generally less than the total area of substrate suitable for spawning in a stream (Bjornn and Reiser 1991). Other predictors of spawning potential were not investigated given project scope and limitations.

Figure 6 shows the sum of area (ft^2) and area per mile within the wetted channel containing gravel sized (protocol size class: 2-64mm) substrate and the distribution of that area between riffles, pools, and runs. This figure represents the gravel potentially available to spawning salmonids at flow conditions on the survey dates. Figure 7 shows the sum of additional gravel substrate area (ft^2) and area per mile that would be available to salmonids during flow events that would fill the bankfull channel. It also represents gravel with potential for recruitment and transport to suitable spawning areas (e.g., pool tail-outs). This bankfull estimation of gravel sized substrate (Figure 7) was based on ocular estimates from 24 habitat types where field personnel noted additional gravel above the wetted perimeter but within the bankfull perimeter. The amount of additional gravel available within the bankfull channel almost doubles the amount of gravel within the wetted channel alone (i.e., the gravel available at flows between 15-26 cfs). There were also an additional 11 habitat types where surveyors noted gravel recruitment potential but did not specify a quantitative amount. However, we do not know at what flows the bankfull channel would be filled and if high flow events would provide other suitable spawning conditions for targeted salmonids (most likely late-fall run Chinook and steelhead). Potential spawning habitat may be further limited in the context of gravel patch size, location, water temperature, and velocity (Bjornn and Reiser 1991).

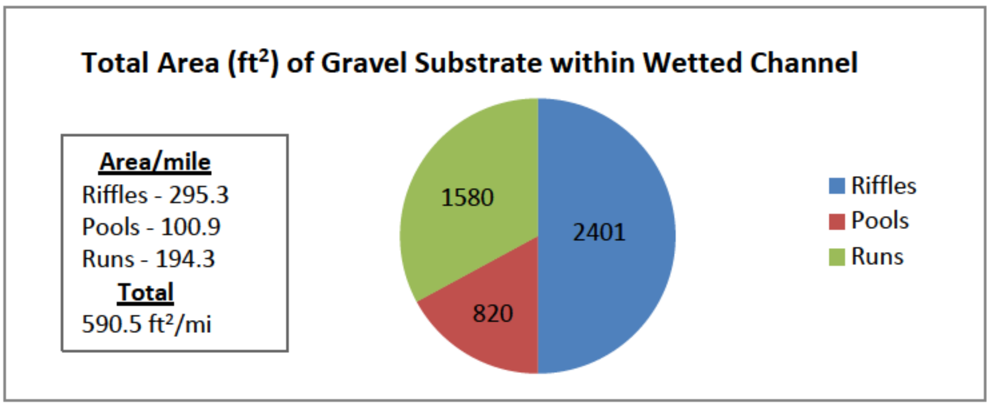

Figure 6. Total Area of Gravel Substrate[4] within Wetted Channel

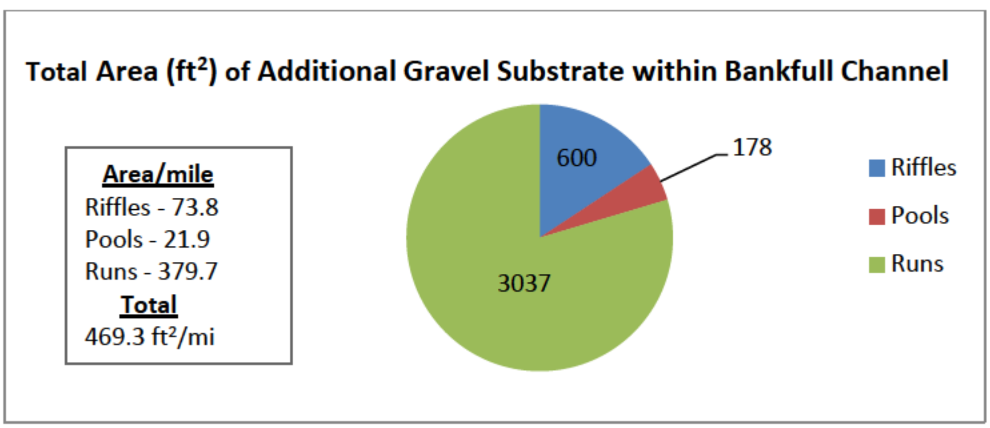

Figure 7. Total Area of Additional Gravel Substrate within Bankfull Channel

[4] In some portions of the wetted channel, gravel was present but not recorded for the following reasons: substantial embeddedness and gravel completely armored with cobbles and larger rocks. However, small amounts of gravel without the previous stated limitations were recorded. These small gravel amounts included gravel found in less than 1 ft^2 aggregation within isolated pockets and between cobbles and boulders (Kleinfelter, J. report draft update).

Spawning Gravel Patch Size

Gravel patch size was measured because spawning Chinook and Central Valley steelhead have patch size requirements for redd construction. Redd size ranges from approximately 0.84-15 m^2 (3-50 ft^2) for Chinook salmon (Burner 1951, Bjornn and Reiser 1991) and 2.4-11.2 m2 (8-37 ft^2) for steelhead (Orcutt 1968, Gallagher and Gallagher 2005). It appears that spawning patch size is heavily dependent on the size of the female (Bjornn and Reiser 1991). Various researchers have observed minimum patch sizes to be in the range of 6-22 ft^2 (Orcutt 1968, Bjornn and Reiser 1991). Burner (1951) recommends a minimum area of 20.1 m^2 (37 ft^2) per spawning pair.

Limited data exists on the size of Chinook and steelhead in the Cow Creek watershed, and the size of spawning salmonids in Clover Creek has not been documented (SHN 2001). Therefore, we chose to focus on patch sizes greater than the smallest patch size (6 ft^2) documented in related literature to estimate the occurrence of gravel patches with potential utility to spawning salmonids. Overall, the vast majority (79%) of habitat did not have any gravel size substrate in patch sizes potentially usable by salmonids[5]. Patch size distribution within the remaining 21% of Clover Creek habitat that contained gravel patches greater than 6 ft^2 can be seen in Figure 8.

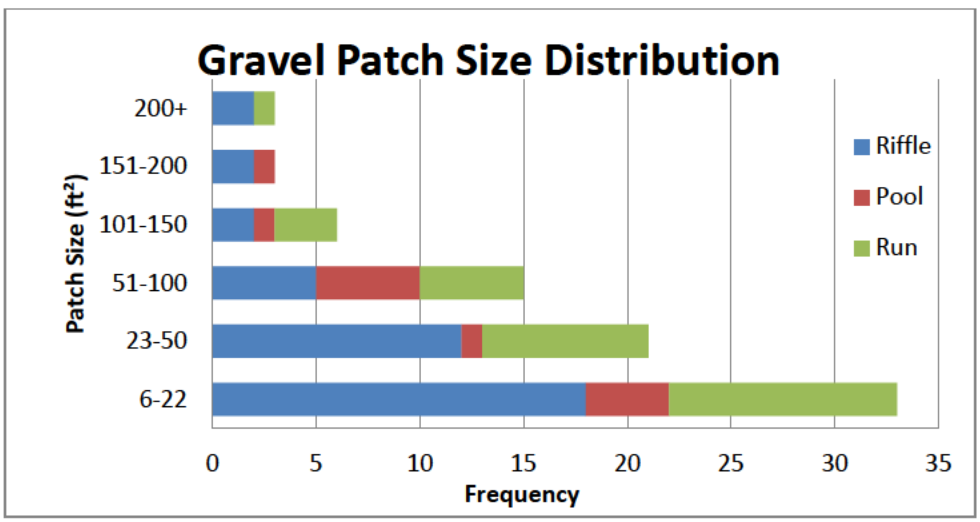

Figure 8. Gravel Patch Size Distribution

Large Woody Debris (LWD)

Large Woody Debris (LWD)[6] was measured and recorded throughout all habitat types. LWD is defined as tree trunks, branches, whole trees, etc. that interact and are generally located within the active stream channel. Scientific literature generally defines LWD minimum size dimensions as wood with a diameter of 4 in and length of 3 ft (Opperman et al. 2006), although various sizes may have different functional roles (e.g., ability to trap sediments, re-shape the channel, and to provide cover, protection, and food

[5] There were eight habitat units that had a gravel patch = 5 ft^2, which were not included. Field personnel noted all gravel recorded in patches of 5 ft^2 did not occur in aggregate (i.e., in a patch) but was distributed throughout the habitat type in small pockets. Also see footnote 4.

[6] Also called Coarse Woody Material (CWM) in the protocol.

for salmonids). Clover Creek's LWD consisted mostly of smaller sized wood (Table 5). Larger (>18in x >24 ft) LWD was not well represented (6% of total LWD) and occasionally existed in aggregate (i.e., logjams or large piles of wood) on the side of the stream channel but within the bankfull extent. The location of LWD within the stream channel suggests large flow events are capable of relocating large wood to the stream's perimeter, thereby reducing its in-stream functional value to salmonids (e.g., creating and backwatering pools, providing complexity and cover). This inference is supported by the low distribution of pool diversity and extremely low occurrence of backwater pools - log formed (less than 1%). Overall, the assessed portion of Clover Creek had 55 single pieces/mile and approximately three pieces in the >18in diameter x >24 ft length size category per mile (sum of the grey cells/8.13 mi). Key pieces that would remain stable either due to location or size were not determined.

TABLE 5. LWD SINGLE PIECE FREQUENCY AND SIZE DISTRIBUTION				
Length	***Diameter***			
	4-18"D	18-24"D	>24"D	Total LWD (row sum)
3 - 24 ft	305	49	10	364
25 - 50 ft	53	17	6	76
>50 ft	2	3	1	6
Total LWD (col sum)	360	69	17	446
LWD/ Mile*	44.3	8.5	2.1	55
*8.13 total miles assessed				

Percent Exposed Bedrock

The percentage of exposed bedrock was estimated in all habitat categories throughout the Clover Creek habitat assessment. Table 6 shows the percentage of bedrock that comprised the length of riffles, runs, and pools. These percentages were obtained by dividing the bedrock length (Row 1) by the total length of assessed stream (Row 2). While this information could not be compared against quality standards for salmonid habitat condition, it should be noted that although this is a low-gradient stream, 9% of complex substrate (e.g., sand, gravel, cobbles, boulders) has been scoured away. The amount of total bedrock substrate provided in Table 6 should not be confused with the amount of bedrock estimated within index reaches surveys (Figure 9).

TABLE 6. PERCENTAGE OF BEDROCK SUBSTRATE				
	Riffles	***Runs***	***Pools***	***Total***
Bedrock Length (ft)	751	3039	232	4022
Total Length Assessed Stream (ft)	10749	27527	4658	42934
Percent of Bedrock (%)	7	11	5	9

Index Reaches

A detailed assessment of habitat variables was conducted along ten evenly spaced transects within eight index reaches. A summary of this data can be viewed in Appendix C.

Substrate Size Composition

Pebble counts (n=100) conducted along every other transect (n=5, excluding pools) were used to determine substrate composition size class and distribution within index reaches (n=8) (Figure 9). Also see earlier discussion about Spawning Habitat.

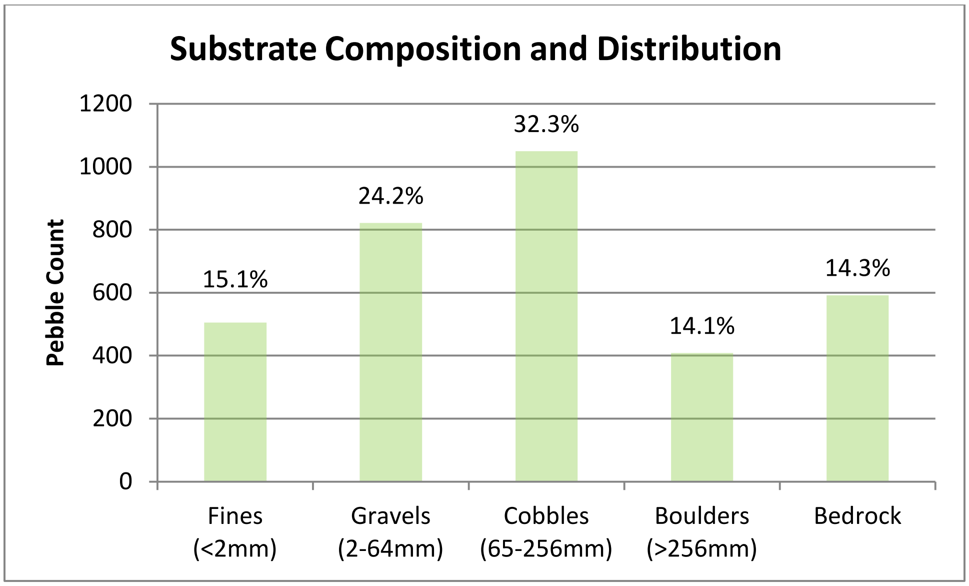

Figure 9. Index Reach Substrate Composition and Distribution

Embeddedness

Embeddedness, a simple but commonly used method for evaluating salmonid spawning habitat quality, was estimated by picking up ten cobble-sized rocks and recording the percentage of rock that was buried in fine sediments. Rocks were chosen at random and were not necessarily in straight line transects. Embeddedness was measured primarily in riffles and pool tail outs occurring within an index reach but was also measured in index reaches B and D, which consisted mostly of run habitat. When more than one riffle or pool occurred in an index reach, embeddedness was measured at each occurrence.

Figure 10 shows embeddedness values in Clover Creek ranged from 10-40%, with an overall average of 25% (pool and run habitat types -average <25%; riffle – 29%; total average – 25%). Cobble embeddedness less than 25% indicates good spawning habitat (CDFG 1998).

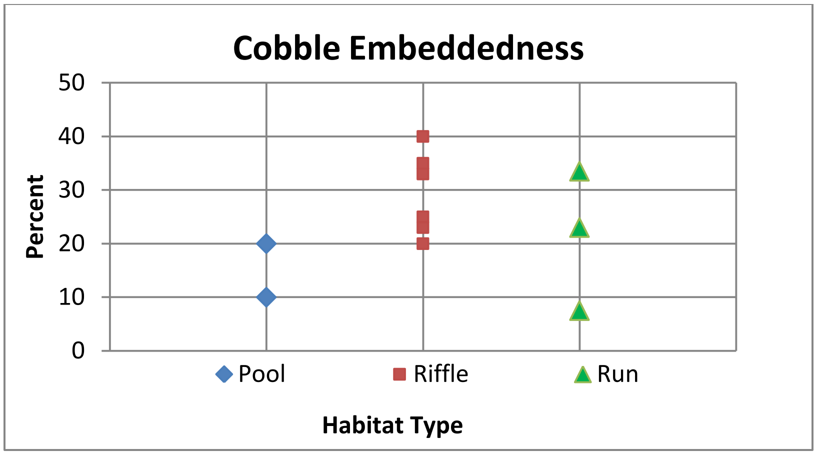

Figure 10. Index Reach Cobble Embeddedness

Fines

The percentage of fines in gravel substrates has a limiting effect on intergravel flow and subsequently the amount of gravel suitable for spawning (Healey 1991). The average percentage of fine sediments found in each index reach can be found in Appendix C. Overall, the highest percentage of fines (17.7%) was found in low-gradient riffles in Index Reach B (Appendix C). However, the second highest percentage of fines was 13.3%, two index reaches had a percentage of 0% and 1%, and all other index reaches show a percentage of <12%. According to NMFS' (1996) habitat condition standards, habitat with >17%, 12-17%, <12% of fines (diameter less than 0.85mm) can be rated as poor, fair, and good habitat, respectively (NMFS 1996 in Kerwin 2001). Taking into consideration the substrate size we used (per protocol) to define fine sediment was <2mm (i.e., included sediments >0.85mm and <2mm) and the NMFS standards, fine sediments did not appear to be a limiting factor to Clover Creek's habitat condition. One index reach was in poor condition, one in fair condition, and six in good condition related to fines. It is also logical that fine sediments would not be a limiting factor since coarser substrate is dominant throughout the reach, while smaller substrate (gravel and sand) appears to get flushed downstream during high flow events.

Canopy Cover (Shade)

Mean percent of riparian shade for each index reach (encompassing possibly more than one habitat category) is provided in Appendix C. Shade values range from 26-69% (standard deviation 14.68) out of a possible 100% canopy closure. Thus, it is probable that shade values vary dramatically throughout the entire Clover Creek reach with some areas having poor, fair, and good shade cover depending on the width of riparian buffer.

Summary

DWR FPIP assessed stream habitat on approximately eight miles of Clover Creek to characterize habitat conditions for salmonids. The assessment included describing the type and distribution of habitat units, quantifying the areal extent of gravels and patch sizes suitable for spawning, and gathering data on other factors that impact successful spawning, rearing, and holding, including: cover and habitat complexity, embeddedness, coarse woody material, and percent exposed bedrock.

Overall, runs were the dominant habitat type and pools were the least represented. The majority of pools in Clover Creek were formed by mid-channel scour and lacked sufficient in-stream cover and high habitat complexity. Based on a spawning suitability surrogate of gravel sized substrate presence and patch size greater than 6 ft^2, 79% of Clover Creek habitat did not have gravel size substrate occurring in a patch size potentially large enough to be utilized by a spawning pair of Chinook salmon or Central Valley steelhead. Within the 21% of habitat where gravel did occur in an adequate patch size, additional limiting spawning suitability factors (e.g., intergravel flow) (Geist et al. 2001) were not determined.

At the flows we witnessed during the assessment, there is some potential for gravel recruitment from within the bankfull perimeter (see Figure 7). Above the bankfull perimeter, gravel recruitment appears to be limited and appears to come primarily from stream bank erosion and complete bank failure (i.e., mass-wasting). Detailed assessments in index reaches show that substrate composition is comprised of mainly coarser substrate (>64mm) and 14.3% of the channel bottom had been scoured either down to bedrock or was devoid of other types of substrate (Figure 9). Embeddedness at pool tail-outs (n=2) within the index reaches was below 25% and in the limited sampling size did not appear to be a limiting factor for spawning potential.

This habitat classification information descriptively stratifies Clover Creek habitat units to provide stakeholders with information related to habitat type and conditions for Chinook salmon and Central Valley steelhead upstream of the MDD. This information can also be used to draw attention to the influence of watershed land use on habitat availability and function from the perspective of salmonids that may utilize it in the future. From a systems perspective, inter-related factors such as channel incision, stream bank erosion, loss of habitat complexity, lack of floodplain (lateral) connectivity, changes in peak flow events (i.e., as a result of increased overland flow), and historical or extant watershed use (e.g., timber harvesting, agriculture/grazing) create or exacerbate factors that can limit suitable spawning habitat. These factors combined with natural variation and high flow events appear to play a significant role in the availability and suitability of salmonid habitat in Clover Creek.

Recent observations of fall-run Chinook below the MDD show there are salmonids accessing the Clover Creek system that could potentially utilize any existing habitat above the MDD once access is provided. The results of this habitat assessment do not predict the number of salmonids that could spawn in the limited existing habitat observed. The results and field observations suggest targeted restoration actions would be necessary to improve properly functioning creek processes. Stakeholders could consider actions (e.g. limiting livestock access to reduce erosion, stabilizing eroding shoreline, reconnecting the stream channel to its floodplain) to restore impaired habitat-forming biophysical processes. Restoring biophysical processes may assist in expanding Clover Creek habitat utility and function for salmonids at

various life stages. Identification of the relative importance of factors that limit the amount of properly functioning salmonid habitat (including those not investigated in this assessment) is recommended as an initial planning strategy to prioritize potential habitat restoration opportunities in the Clover Creek watershed. Most of this information can be garnered from a synthesis of existing information including the data derived from FPIP's habitat assessment of Clover Creek, other information related to watershed hydrology and geomorphology (e.g. flood events, channel incision), riparian condition, and watershed land use.

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Appendix A. Stream Habitat Classification and Inventory Procedures For Northern California

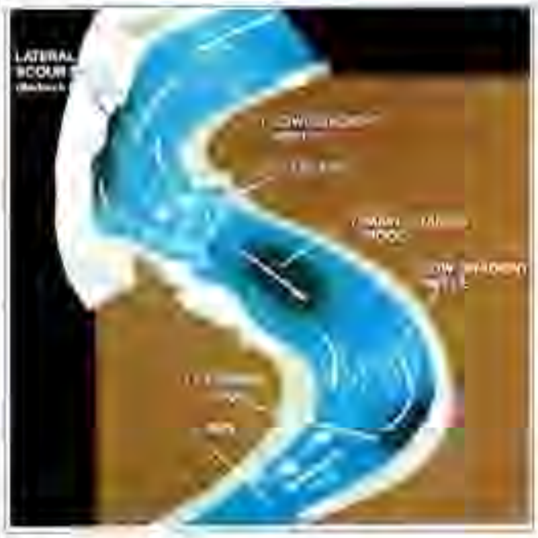


Figure 1. Illustrated above are habitat types in association with channel features such as : logs, boulders, gradient, bedrock and meanders.

Present day fishery management is very complex, involving several different agencies, user groups and land managers. While millions of dollars are being spent annually to restore and enhance anadromous fisheries, man's effect on stream habitat is increasing through the ever growing demands on timber, water, and other resources. A key to effectively protecting, maintaining, restoring, and enhancing anadromous fisheries in light of these demands is an understanding of the relationships between physical habitat parameters (e.g. channel morphology) and fish production factors (food and habitat requirements) for all age classes of each species for the duration of stream residency. Habitat requirements of anadromous salmonids rearing in streams are known to differ between species, age classes, and seasons (Everest and Chapman, 1972; Reiser and Bjornn, 1979).

Because of the diversity in management groups, several different habitat survey or assessment techniques are employed in northern California. This lack of standardization complicates the comparison of information between agencies and often creates barriers in developing and implementing efficient management strategies. This bulletin outlines a standardized habitat assessment procedure with built in flexibility to be workable with varying budgets and manpower.

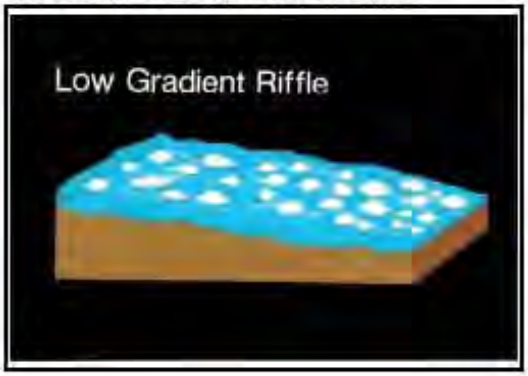
Background

This system of naming habitat is derived from work on stream channel morphology, pool-riffle and step-pool formation, and fish habitat utilization in western Washington and Oregon (Bisson et al., 1981; Sullivan, 1986; Grant et al., in review). The development of pool-riffle or step-pool sequences is a fundamental stream channel process (Ying 1971). These main channel features, along with others fitted by smaller scale local effects (e.g. logjams and slides), can be recognized as distinct channel units or habitat types. A total of 22 habitat types have been identified and delineated in northern California to date as the refinement of the system continues *(figure 2, following pages)*.

Figure 3 illustrates how the 22 types are classified. Three categories (proceeding from shallow to deep water) are riffles, runs and pools. All of the 22 types are members of the 3 main categories. Riffles are differentiated on the basis of water surface gradient. Pools are differentiated at two levels: (1) the position of the pool in the stream channel (secondary channel, backwater, lateral, or main channel), and then (2) the cause of the scour (obstruction, blockage, constriction, or merging flows) . Run habitat types have low gradients, and are differentiated on the basis of depth and velocity. The five-pointed star plots of each type in *Table 1* illustrate the ratio of five physical habitat variables (mean depth, width, and length, and area and volume) for Hurdygurdy Creek, California. The eastern of the starplot describes the "mean shape" of the habitat types. Types with similar star plots have similar morphometry.

Generally, a given stream won't contain all 22 habitat types, instead the mix will be dominated by a few habitat types which are reflective of the overall channel gradient, flow regime, cross-sectional profile, and substrate particle site. (Grant et al. in review) found that the mix of habitat types in western Cascade streams with gradients in excess of 2% and large boulder substrate consisted of 4 types: pool, riffle, rapid, and cascade. Bisson et al. (1981) recognized 14 distinct habitat types in small streams with gradients less than 2%. Basins that exhibit a wide range in channel gradient will also have a broad mix of habitat types. Stratifying

Figure 2. List of 22 habitat types in Northern California

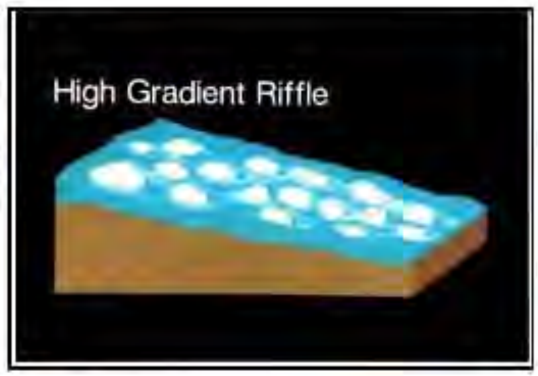


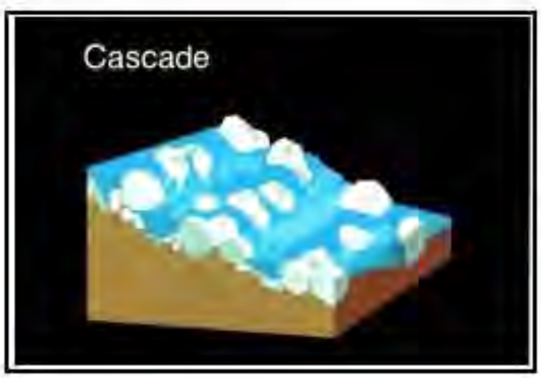
1 -- Low Gradient Riffles "LGR"

Shallow reaches with swiftly flowing, turbulent water with some partially exposed substrate. Gradient <4%, substrate is usually cobble dominated.

2 -- High Gradient Riffles "HGR"

Steep reaches of moderately deep, swift, and very turbulent water. Amount of exposed substrate is relatively great. Gradient is >4%, and substrate is boulder dominated.





3 -- Cascade "CAS"

The steepest riffle habitat, consists of alternating small waterfalls and shallow pools. Substrate is usually bedrock and boulders.

4 -- Secondary Channel Pool "SCP"

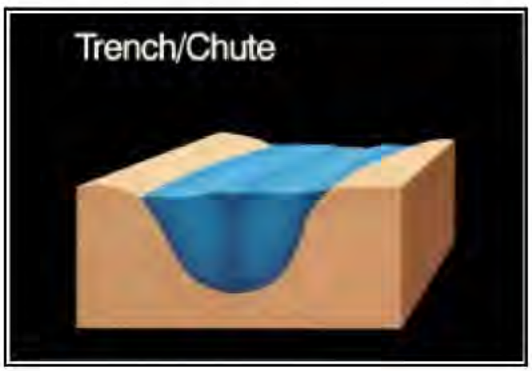
Pools formed outside of the average wetted channel. During summer these pools will dry up or have very little flow. Mainly associated with gravel bars and may contain sand and silt substrates.

5 -- Backwater Pool "BWP"
Boulder Formed

Found along channel margins and caused by eddies around obstructions such as boulders, rootwads, or woody debris. These pools are usually shallow and are dominated by fine-grain substrates. Current velocities are quite low.

6 -- Backwater Pool "BWP"
Root Wad Formed

7 -- Backwater Pool "BWP"
Log Formed

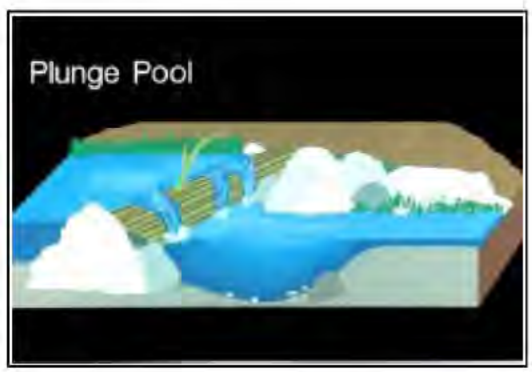


8 -- Trench/Chute "TRC"

Channel cross sections typically U-shaped with bedrock or coarse grained bottom flanked by bedrock walls. Current velocities are swift and the direction of flow is uniform. May be pool-like.

9 -- Plunge Pool "PLP"

Found where stream passes over a complete or nearly complete channel obstruction and drops steeply into the streambed below, scouring out a depression, often large and deep. Substrate size is highly variable.



10 -- Lateral Scour "LSP" Log Formed

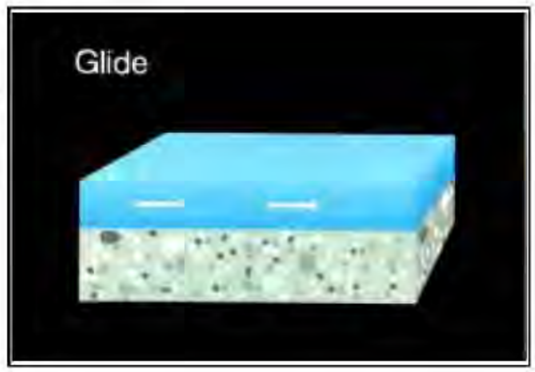
Formed by flow impinging against one stream bank or against a partial channel obstruction. The associated scour is confined to <60% of wetted channel width. Channel obstructions include rootwads, woody debris, boulders, and bedrock.

11 -- Lateral Scour Pool "LSP" Root Wad Formed

12 -- Lateral Scour Pool "LSP" Bedrock Formed

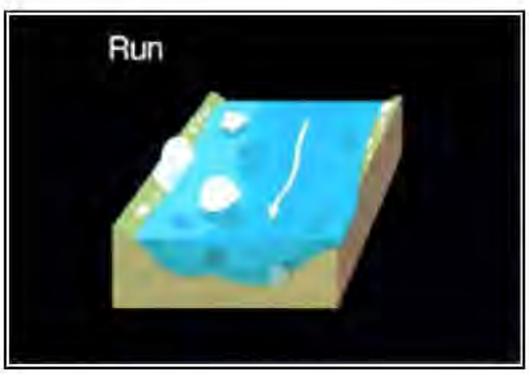
13 -- Dammed Pool "DPL"

Water impounded from a complete or nearly complete channel blockage (debris jams, rock landslides or beaver dams). Substrate tends toward smaller gravels and sand.



14 -- Glides "GLD"

A wide shallow pool flowing smoothly and gently, with low to moderate velocities and little or no surface turbulence. Substrate usually consists of cobble, gravel and sand.



15 -- Run "RUN"

Swiftly flowing reaches with little surface agitation and no major flow obstructions. Often appears as flooded riffles. Typical substrates are gravel, cobble and boulders.

16 -- Step Run "SRN"

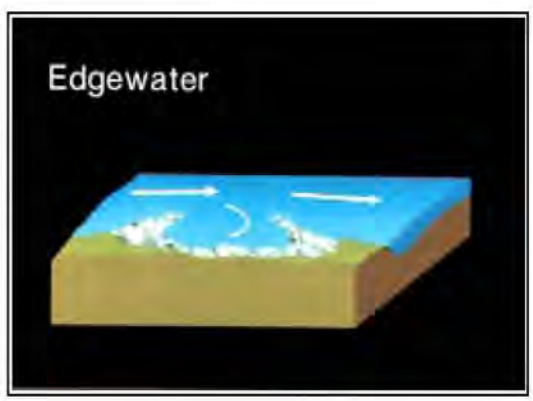
A sequence of runs separated by short riffle steps. Substrates are usually cobble and boulder dominated.

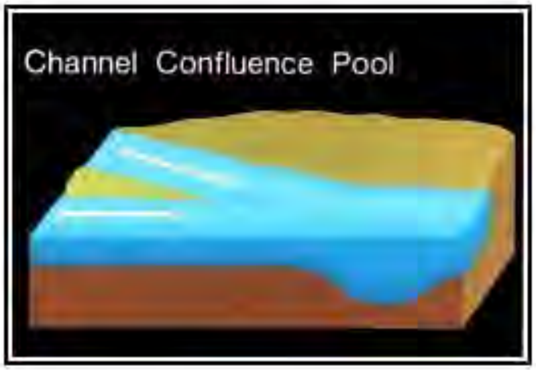
17 -- Mid-Channel Pool "MCP"

Large pools formed by mid-channel scour. The scour hole encompasses more than 60% of the wetted channel. Water velocity is slow, and the substrate is highly variable.

18 -- Edgewater "EGW"

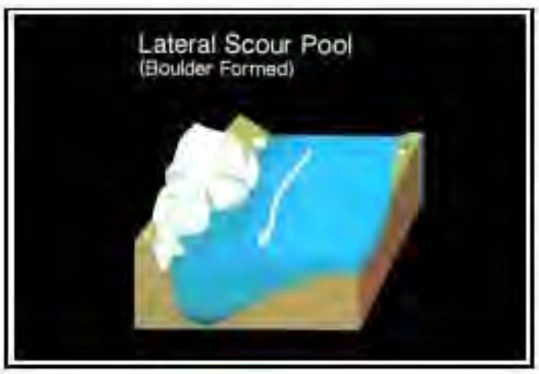
Quiet, shallow area found along the margins of the stream, typically associated with riffles. Water velocity is low and sometimes lacking. Substrate varies from cobbles to boulders.





19 – Channel Confluence Pool "CCP"

Large pools formed at the confluence of two or more channels. Scour can be due to plunges, lateral obstructions or downscour at the channel intersections. Velocity and turbulence are usually greater than those in other pool types.



20 -- Lateral Scour Pool "LSP" Boulder Formed

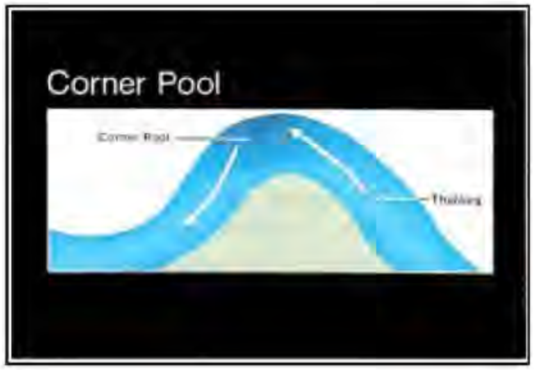
Formed by flow impinging against boulders that create a partial channel obstruction. The associated scour is confined to < 60% of wetted channel width.

21 – Pocket Water "POW"

A section of swift flowing stream containing numerous boulders or other large obstuctions which create eddies or scour holes (pockets) behind the obstructions.

22 -- Corner Pool "CRP"

Lateral scour pools formed at a bend in the channel. These pools are common in lowland valley bottoms where stream banks consist of alluvium and lack hard obstructions.



such a basin by gradient and confinement is therefore suggested to aid in predicting the location of certain habitat types (see Rosgen, 1985).

Procedures

Inventory Scale

In assessing habitat for a stream reach or an entire basin, the intent is to gather information that will adequately describe the area of interest. Conducting a habitat inventory can be time consuming, so work must be carried out quickly and efficiently. The level or scale of inventory to be employed is dependent on the project objectives. We have employed this system at two scales: basin level and project level. Basin level habitat classification is on the scale of a stream's naturally occurring pool-riffle-run units, where habitat unit size depends on stream size and order . As a general rule in a basin level inventory, homogeneous areas of habitat that are approximately equal or greater in length than one channel width are recognized as distinct habitat units. In comparison, project level habitat assessment operates on a scale of less than one channel width for use on reaches of intense management or study. Project level habitat typing is used to evaluate and quantify changes in habitat as the result of fish habitat restoration/enhancement projects *(figure 4)*. This information, in combination with juvenile rearing population estimates or spawning ground surveys, documents and quantifies the project's ability to provide the necessary habitats for fish production. Project level habitat size delineation depends on the nature and objectives of the particular study or work being done, which depends on the niche, size, life stage(s), etc. of the targeted species. Both levels use the same habitat types *(figure 2)*.

Data Collection

Habitat typing can be accomplished efficiently by two or three field people. Describing and measuring all 22 habitat types is very labor intensive; an average of one mile per day can be accomplished by trained surveyors. Decisions are best reached by a consensus among the team after a discussion of the facts. This approach balances out the biases inherent in each observer and insures quality in the data collected.

The basic method of habitat typing is relatively simple. Starting at the mouth of a stream and working upstream insures a known starting point. Use a measuring device (tape, rod, optical rangefinder, or hip chain) to measure mean length and width of each unit.

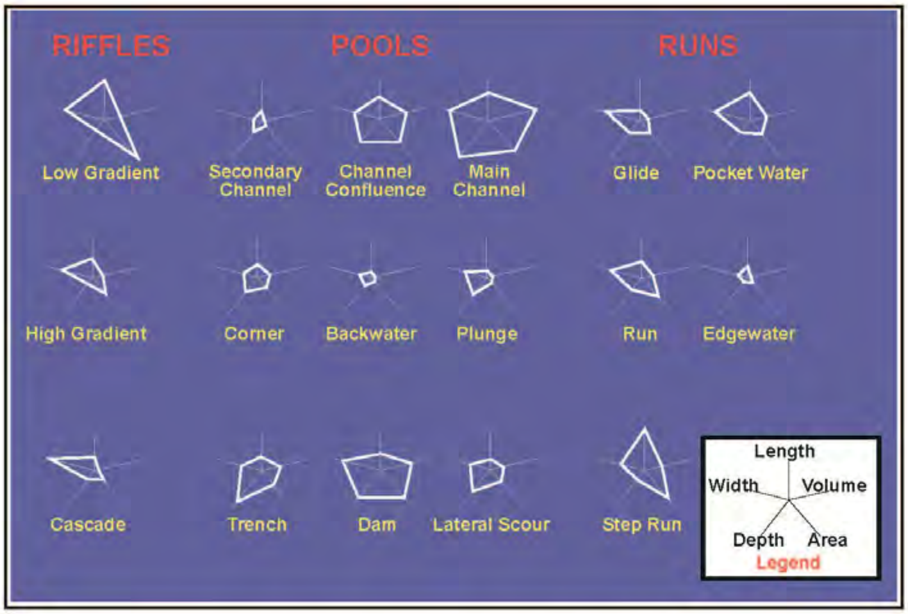


Table 1 --
Starplots of 5 main physical habitat variables. These show ratios of: mean depth, width, length, area and volume for each habitat type. Examples are from Hurdygurdy Creek, CA for Decker et al. 1984.

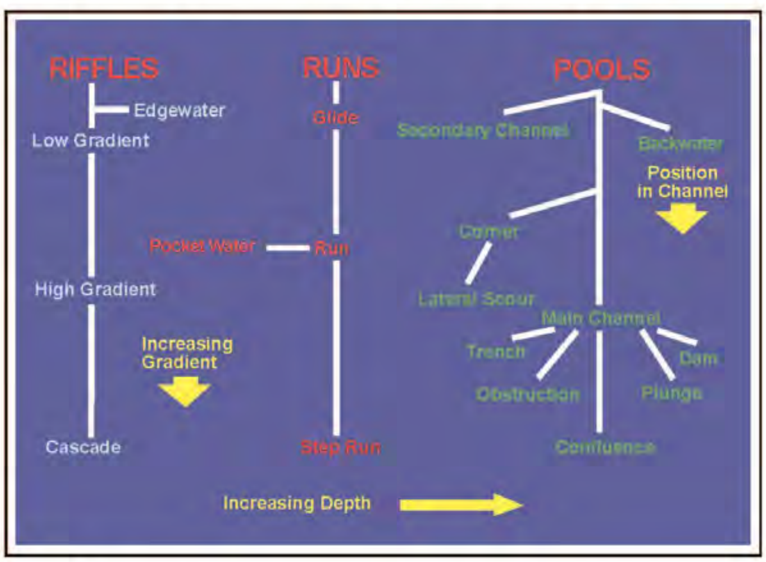


Figure 3 --
A diagram of the habitat classification system used for inventory in northern California.

Three to five width measurements are sufficient. Along each width measurement transect use a gradient leveling rod (or similar device) to take several depth measurements from bank to bank and estim ate mean depth. If a significant port ion (>10%) of the measured habitat includes exposed boulders and/ or islands, that portion should be estimated and subtracted from calculations of area (total area - exposed area = wetted area) . Other variables such as stream substrate, in-stream cover elements and abundance, canopy cover, riparian quality, etc. can be collected along with the habitat type data.

As with any classification system an occasional habitat unit may not fit distinctly into any one habiat type. In an inventory, a certain amount of subjective decision making is involved and accuracy depends heavily on a basic understanding of stream processes, a good knowledge of the classification system, and consistency (see Beschta and Platts, 1986; Lisle, 1986; and Ying, 1971).

Discussion

The basin level habitat classification and inventory procedures will provide a channel descriptor of fish habitat availability (number, length, area, volume) and its relationship to channel features. Measurement of all 22 types gives a clear picture of the streams make-up, the type and quantity of scour forming material (logs,

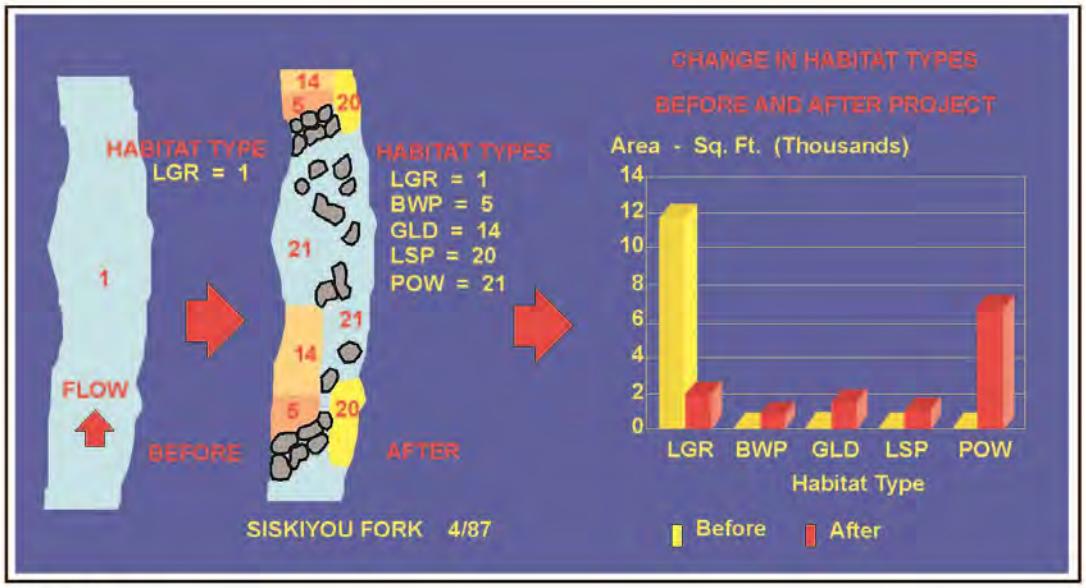


Figure 4 --
Project level habitat typing is utilized to quantify changes in specific habitat types resulting from habitat restoration/ enhancement work.

boulders, bedrock, etc.) that governs the mix and availability of certain habitat units. When pairing this informatiotion with population estimates per habitat unit and with fish-habitat relationship studies, the manager has the basic data for limiting factor analysis and fish production estimates *(figure 5)*.

Fish-Habitat Relationship Studies

Models are being developed and tested by the Fish Habitat Relationships (FHR) program of the USFS to aid in predicting potential fish production in a basin. Physical and biological habitat variables such as depth, velocity, substrate, cover, temperature, and food availability are being investigated in terms of their relation and relative importance to fish distribution, abundance, and community structure. The links between biological attributes such as food availability, survival, growth, age structure and physical habitat attributes such as water velocity and temperature, channel morphology, substrate particle size distribution, and habitat complexity can help managers predict the potential impacts on the fishery from watershed disturbances (logging, mining, grazing, hillslope failures and slides). The database needed to build such a predictive model must include a standardized basin level inventory of fish populations and habitat availability (Parsons, 1984) . Figure 6 illustrates seasonal critical habitat needs for different fish species and life stages, serving as a basis for determining factors limiting fish production and planning habitat restoration/ enhancement projects.

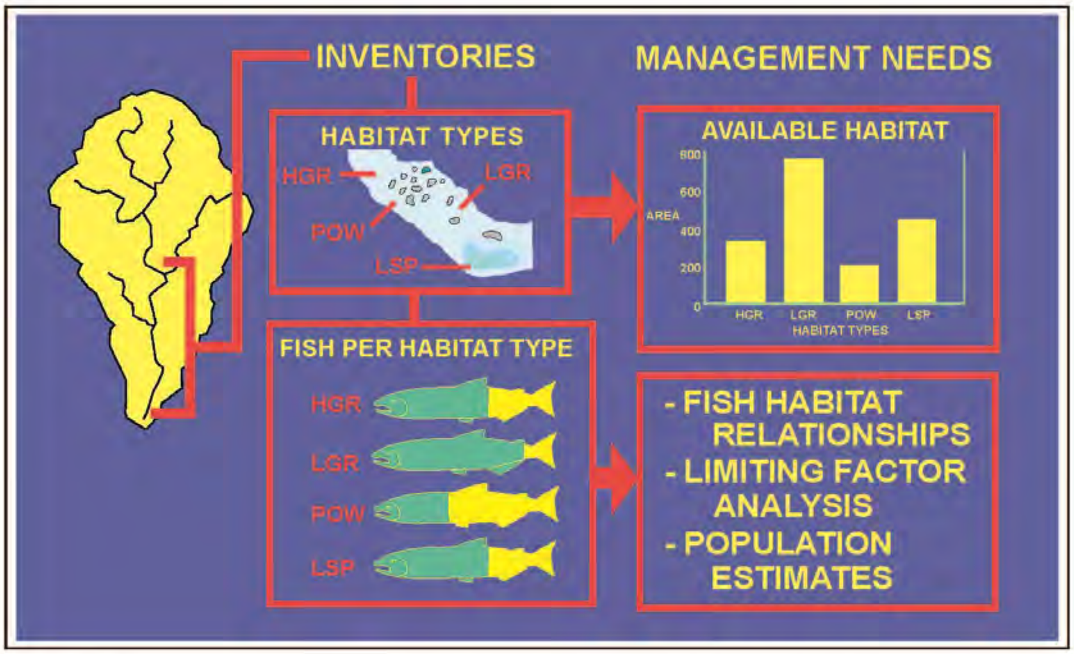


Figure 5 --
Habitat typing inventories, in conjunction with population estimates per habitat units, provide fishery managers with basic information (habitat availability, watershed fish production) for evaluating the status and potential of the watershed to produce fish.

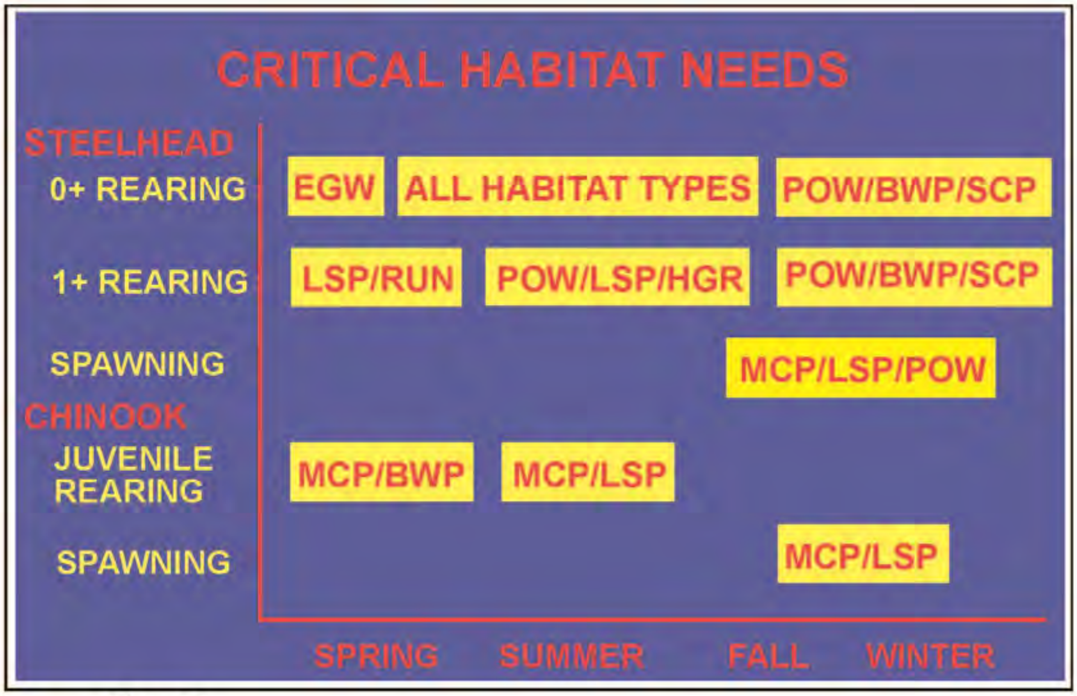


Figure 6 --
An example of seasonal habitat needs for different life stages of anadromous salmonids.

Conclusion

Habitat classification and inventories can be applied at different scales or levels and can provide basic information with which to determine the availability and importance of habitats to fish, and therefore further our understanding of fish-habitat relationships. Development of fish-habitat relationship models will increase the value of habitat information to both researchers and managers by allowing insight into their relative importance and function of physical and biological habitat parameters in the ecology of stream fishes. Aquatic habitat inventory information can serve as valuable baseline data. For example, project level habitat type information provides the habitat restoration/ enhancement project designer with insight on the relationship between channel features and habitat development, and allows projects to be evaluated by quantifying the changes in habitat created by the project. Basin level information can enable researchers to develop sampling schemes based on natural habitat units.

There is a need for standardized methods in collecting stream habitat inventory information. Our fishery resources cross several management jurisdictional boundaries. Therefore, proper use and management of this resource requires responsible agencies to communicate and work together through shared information.

Appendix B. Habitat Assessment Protocol FY93

Habitat Assessment Protocol FY93

The following information describes the Aquatic Habitat Assessment protocol used on the Klamath National Forest during FY93. This protocol is intended to act as a reference for field investigators and those performing data analysis. It is not intended as a surrogate for technical training.

Several changes have been made from the FY92 protocol. The most prominent of these changes are in the sampling approach and departure from use of ocular estimation techniques. There are also two, two-sided forms necessary for recording data. This has resulted in an integrated approach in record keeping during the biological and physical assessment phases.

The FY93 protocol relies upon data collected in three ways: (1) a continuous basis, (2) stratified systematic interval, and (3) random index reach selection. This approach fits the data collection schedule to the spatial properties displayed by individual parameters while minimizing sample size.

For each data parameter described, a short description of the measurement technique, sampling interval, and data record is provided. Parameters are described as the occur on the data forms and grouped according to sampling method.

All spaces on the data sheet must be accounted for. There will be no blank spaces, zeroes or null (---) must be in every field.

I. Continuously Recorded Data

Header Information :

Enter information for all fields on every sheet. Be sure to note time when temperatures are taken. Circle name of crew person recording data.

Adjusted Station :

This field is the only field that does not get filled out on the stream. This is used to adjust station numbers when two or more crews are working the same stream in tandem (one crew starting at the mouth, and the other starting at a known point upstream). Denotes consecutive order of habitat stations from mouth of stream.

Field Station :

This is a unique number, starting with "1" and continuing throughout the survey. All habitat units must have a station number. Braided channels will be denoted as decimals (12.1, 12.2, etc.).

<u>% Slope :</u>

This is the average water slope in the channel. The reading may extend over several habitat units. Measured from water surface to water surface.

<u>Bankfull Channel Width :</u>

Enter the channel width occupied at bankfull discharge water surface elevation. This is the channel forming (channel maintaining) discharge represented by a recurrence interval of approximately 1.5 years.

<u>Channel Type :</u>

Enter the alpha numeric code which best describes the channel type using Rosgen classification. When describing channel type, a minimum reach length of approximately 30 times the bankfull width provides a good general guideline.

<u>Sample # :</u>

Enter the unique number for the sample. This is the dive unit number and is recorded on flagging to mark the boundary of the unit. This is a unique number starting with "1" and continuing throughout the survey. The sample is derived by systematic occurrence (generally 1:4 or 1:5) after an initial random start.

<u>Habitat Type :</u>

Enter the habitat type number. Use the Region 5 key to determine habitat type. Do not create new habitat types. Twenty-five (25) habitat types are distinguishable for FY93.

<u>Spawning Area :</u>

Determine the number of square feet of actual spawning area in the habitat unit. Species and size of gravel will be dependant upon criteria set by the District biologist.

<u>Mean Length :</u>

Measure mean habitat unit length along thalweg, record to nearest foot. Habitat length <u>must</u> be recorded for all stations.

II. Continuous Data Record (Pools Only)

Max Depth :

Measure and record the max depth occurring within the habitat unit to the nearest tenth of a foot. (Note: Shaded areas represent data taken and recorded for pool habitats only.)

Riffle Crest Depth :

This measurement is only taken at the tail of a pool where the surface flow beaks into the riffle. This measure is used to determine residual pool depth.

Instream Cover-Total % :

Determine the percentage of the habitat unit that has overhead cover.

Undercut banks, swd, lwd, terrestrial vegetation, aquatic vegetation, white water, boulders, bedrock ledges : Breakdown the Instream cover into its component parts. The sum of these 8 components must equal 100.

Cover Complexity :

Enter: 1 for low complexity, 2 for moderate complexity, or 3 for high complexity.

In general, one cover component alone will rate Low complexity, two to three components will rate Moderate complexity, and more than three components will rate High. Examples of highly complex cover may include rootwads, logjams and willow rootwads associated with it.

III. Index Reach Parameters (Random Selection)

Index reaches are selected on a random basis from within the channel stratum (channel type and size) being described. In general, it is desirable to select a minimum of three index sections per channel stratum or approximately two per mile as a sampling baseline. Other sampling schedules (ie systematic dive unit selection) are maintained through index section.

The Index Section length is determined from the average bankfull channel width within the stratum to be described. Round the average bankfull width to the nearest 10 feet and multiply by 10 to calculate the Index Section length. For example, an average BF width of 23 feet would produce an index reach equaling 200 feet in length.

Given your calculation of Index Section length, you then need to estimate the location of each of 10 evenly spaced transects perpendicular to the channel within the section. Canopy closure estimates will be made at each of the 10 transects. Using the index sample above (200 feet) you would select transects at 20 foot intervals starting at 20 feet. Note that the "local" block on the reverse side of form B is meant to correspond to the transect location in feet within the Index Section (ie. 20, 40, 60.....). The "station" block below "local" corresponds to the habitat unit station number the transect falls within (it is possible to have multiple transects with the same station number). There is space provided (form B) to perform 5 pebble counts, although a minimum of 3 are necessary. Perform these counts within the habitat unit type the transect falls within, noting the station number as before. Choose these transects systematically from the 10 canopy closure transects.

Substrate Composition :

Collect, measure (across the intermediate axis), and record (using dot tally) the size class of 100 pebbles within sample habitat units and bankfull elevation (Form B). Record the number of total occurrences by pebble size class as fines, gravel, cobble, boulder/bedrock (Form A).

Percent Bedrock :

Ocularly estimate the surface area occupied by bedrock within bankfull channel within habitat unit described by accompanying pebble count.

% Substrate Embeddedness :

Take this observation only in pool tail outs and in low gradient riffles. Estimate the surface area covered by fines on ten samples of the substrate to determine the degree of embeddedness. A pool tail must be less than 3' in depth. Bedrock will be excluded and treated as a null value.

Percent Shade (Canopy Closure):

Percent shade will be estimated from canopy closure measurements using a spherical densiometer at each of 10 transects determined as described above (Form B). Enter the corrected canopy closure measurement from transect corresponding to the appropriate field station (Form A). Record the average of the transects where more than one occur within a station.

Percent Evergreen :

Estimate the percentage of the riparian vegetation that is evergreen (conifer, live oak, pacific madrone, etc.). Observation will be limited to the up and downstream unit boundaries extended 200 ft up each slope from the bankfull width. Estimated by crown cover, not the number of trees.

Percent Deciduous :

Estimate the percentage of the riparian vegetation that is deciduous (alder, maple, willow, black oak, etc.). Observation will be limited to the up and downstream unit boundaries extended 200 ft from the bankfull width. Estimated by crown cover, not the number of trees.

Fines :

Enter the number of grid intersects which correspond to substrate particle diameters less than 2 mm diameter in riffle habitat and pool tail outs from a total of 49 possible intersects. Record the number of "fines" intersects for each of 3 random frame tosses within the wetted habitat perimeter (form A).

LWD Recruitment (#'s) :

Determine the number of trees greater than 24" (west side) and 18" (east side) recruitable to the stream channel. Standing at the stream margin, face perpendicular to the channel bank, view through the clinometer with one eye while using the other eye to focus on the base of standing trees meeting the diameter criteria stated above. Standing at the same spot, elevate the clinometer to the top of the tree(s) and take a reading. When the difference between to base and top readings equals or exceeds 100% the tree is counted as in. Using this method record the total number of trees from both slopes which are recruitable throughout the length of the Index Reach.

IV. Form B.

Header Information :

Enter information for all fields on **every** sheet. Be sure to note time when temperatures are taken.

Adjusted Station :

This field is the only field that does not get filled out on the stream. This is used to adjust station numbers when two or more crews are working the same stream in tandem (one crew starting at the mouth, and the other starting at a known point upstream).

Field Station :

This is a unique number, starting with "1" and continuing throughout the survey. All habitat units must have a station number. Braided channels will be denoted a decimals (12.1, 12.2 etc.).

Habitat Type :

Enter the same habitat type recorded for the station on Form A.

Percent Exposed Substrate:

Enter the percentage of the habitat unit area that has substrate that is above the existing water level within the wetted perimeter.

Mean Width, Depth :

Enter the average values. Length and width are taken to the nearest foot. Average and max depth is taken to the nearest tenth. To determine average depth, divide the habitat into three and take three to four measurements along the transect.

Course Woody Material :

Maintain a continuous record (dot tally) of all wood meeting the minimum size criteria (4"x39") by dimension class occurring within the lateral bankfull margin. Count all pieces of wood that have any portion (meeting minimum size criteria) within BF, measuring the entire piece length (not just the portion within BF). Also, tally pieces as single or aggregate (3 or more). This record is maintained through the beginning of a sample (dive) unit (ie. the station number provides an address for the CWM talley preceeding it to the last sample). At the start of a sample unit a new CWM tally is initiated.

Biological Observations (fish counts) :

Record the observers initials in the column heading their fish counts, and dive start time. Indicate with an "R" counts which are performed as two-pass or replicates. Otherwise, all counts are assumed to be single pass. Record the number of individuals by species and age-class observed within the sample unit.

Comments :

The comment field is a very important portion of the data. Certain guidelines to its use are needed to make it effective. Data entry people will not interpret or correct statements. Make use of full sentences and keywords wherever possible. Cryptic comments are not appropriate. Be sure to include structural conditions in comment for habitat units that have enhancements. Keywords will be employed to assist in using the data collected.

HT Tally :

Maintain an accurate count of habitat types surveyed so that the proper number of habitat units are sampled.

Rosgen Channel Class :

When the channel classification changes, check off the appropriate values for observations made.

Channel Cross Section :

Every time the channel type changes, a cross section, drawn to scale must be included.

Guidelines for Keyword Use

1. Keywords are not substitutes for a complete description of the feature.

2. Avoid comments that are cryptic. Be concise and clear. One word comments and comments like "lots of fish" are inadequate.

3 .Use keywords in the comments field whenever possible.

4. The comments field and maps must correspond. Always include known geographic features in the comment field to tie the habitat unit to it.

5. Note amphibians in the comment field. This is to determine presence or absence of species.

6. New keywords may be added to the list as needed by the biologist. Please recommend words that will assist in finding important data.

Recommended Key Words

Keyword	**Use**
Weir	Man-made weir. Always note what the weir is made of (boulders, logs, gabions, etc)
Group	Man-made boulder, boulder-rootwad groups. These may be typed as POW (pocket water), but not in all instances.
Deflector	Man-made deflectors of any kind. These may be typed into several different habitat types, depending on their location.
Cover	Any man-made cover structure. Describe stream location, condition, and type of structure.

****** NOTE: Always include structure condition information in comments. ******

Trib	Confluence of a tributary. Include stream name, flow estimate, temperature. Also indicate if the tributary is an intermittent, perennial, or ephemeral stream. Be sure to note whether it enters the stream on the left or right.
Bridge	Note road number, type of construction, and any effects on the stream channel.
LWC	Low Water Crossing. Be sure to note impact to the stream, and a measure of how often it is being used; continuous use, occasional, rarely.
Falls	Waterfalls. The description should also have the keyword `barrier' in it if applicable.
Dredge	Location of dredging activity. The dredge does not have to be present, just the indications of its use.
Mining	Mining activity that is out of the stream, but may be affecting the riparian areas. The name of the claim would be good to include in the comments field.
Camp	Obvious campsites that are being regularly used by the public. This includes campgrounds as well as seasonal primitive sites. Include campground name.

Recommended Key Words (continued)

Keyword	Use
Culvert	Include culverts that are tributary, as well as those that the stream flows through. Note potential barriers, and erosion problems.
Diversion	Include vital information: Amount of flow diverted (CFS), barrier potential, presence of screens.
Barrier	Fully describe the barrier or potential barrier. Include what the barrier is formed by, height, affected species, etc.
Frog	Note the presence of frogs and a count if possible. Include tailed frogs seen in direct observation.
LWD	Large Woody Debris--24" x 10' in minimum length, rootwads with stumps greater than 24" (West Side). Or 12" x 10' in minimum length, rootwads with stumps greater than 12" (East Side).
Topo	Enter comment for shde created by topographic features, as opposed to vegetation created shade.

Habitat Typing Survey Form A

Date:__/__/___ Stream:____________________ Crew: ____________________________.
Temperature: AM=H_2O _____ Air ____ Time_____ Noon= H_2O____ Air ____ Time _____ .
AM____ Flow _______ PM _____ Flow _____ Legal: T ___ R ___ Sec ___ River Mile ____.

Adjusted Station										
Field Station										
Slope (Avg)										
Bankfull Channel Width										
Channel Type										
Sample #										
Habitat Type										
Spawning Area (m^2)										
Mean Length (m)										
Max Depth (m)										
Riffle Crest Depth (m)										
Instream Cover Total										
undercut banks										
swd (d<1.0 ft)										
lwd (d>1.0 ft, RW)										
terr. vegt. (ht 1.0 ft)										
aqua. vegt										
white water										
boulders (d≥1.0 ft)										
bedrock ledges										
Cover Complexity										
# Fines (<2mm)										
# Gravel (2-64mm)										
# Cobble (65-256 mm)										
# Boulder/bedrock (>256mm)										
Percent Bedrock										
Substrate Embeddedness										
Percent Shade										
Percent Evergreen										
Percent Deciduous										
Fines: # intersects rif #1										
rif #2										
rif #3										
LWD Recruitment (#'s)										
Comments:										

rif	
run	
pool	

Habitat Typing Survey Form B

Date:__/___/___ Stream:______________________ Crew: ____________________________.
Temperature: AM=H_2O____ Air ____ Time_____ NOON= H_2O ____ Air _____ Time______.
Legal:T ___ R____ Sec ____ River Mile_____ .

Adjusted Station									
Field Station									
Habitat Type									
Percent Exposed Substrate									
Mean Width (m)									
Mean Depth (m)									
Coarse Woody Material ∞	0.1m	0.46	0.61	0.1m	0.46	0.61	0.1m	0.46	0.61
1 – 2m									
2 - 4									
4 - 8									
8 - 11									
11 – 15									
15 – 23									
23 – 38									
38 – 53									
53 – 76									
76+									
single piece									
aggregate									
Observer									
Dive Time (start of dive)									
# Chinook 0+									
# Steelhead 0+									
# Steelhead 1+									
# Coho 0+									
# Brook Trout 0+									
# Brook Trout 1+									
# Chinook Adult									
# Steelhead Adult									
Comments:									

Canopy Closure

Obtain variance estimates for Canopy Closure by sampling 10 transects within designated reach. Hold densiometer level, 12 inches above water surface and count the number of line intersect points intercepting vegetation at each of 4 locations along transect.

	Number Intersect Points Intercepting Vegetation									
Local:										
Station:										
RR										
MU										
MD										
RL										
Sum										
x 1.5										
Adj										
CC										

Substrate Composition ---- Pebble Count

Collect, measure (across the intermediate axis), and record (using dot tally) 100 pebbles at each sample location.

Pebble Count						
Particle	Metric (mm)	Station Number				
Fines/Sand	<2					
Gravels	2 – 64					
Cobbles	64 – 256					
Boulders	>256					
Bedrock						
	Total:					

Appendix C: Index Reach Data Summary

Index Reach		A					B			C			D			
Date		11/20/08					11/5/08			8/10/11			8/11/11			
Habitat Type		1	15	14	1	14	23	1	14	15	14	16	1	15	6	1
Adjusted Station		22	21	20	19	18	64	63	62	183	184	185	202	203	204	205
Total Length	*Ft*	110	53	233	29	235	99	124	424	202	91	258	69	287	41	110
Temp Time		9:30 AM					10:30 AM			9:20 AM			9:30 AM			
Water Temp	*°C*	5					8			15			14			
Air Temp	*°C*	13					14			22			20			
Bankfull Width	*Ft*	50					60			49			53			
Reach Length	*Ft*	500					600			490			530			
Surface Area	*Ft²*	25000					36000			24010			28090			
Percent Shade	*%*	38.5					26			68.7			52.7			
% bedrock	*%*	0	0	0	0	0	0	40	0	35	95	60	0	35	0	70
Sub. Embed. (%)	*%*							40					20		20	25
Fines (%)		13.3					17.7						6.4			
GPS Point mE		573723					574658			580718			581283			
GPS Point mN		4492210					4492953			4497635			4497780			
Photos		1	2	3	4	5	6	7,8	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Index Reach	Comments
A	22: Complex habitat type see photos1-5; 20:length from GIS pt 48. Small riffle 1/2 way through the glide; 18:length from GIS pt 50; side channel that starts at log jam only at higher flows.
B	63: Pebble counts average of 2 sets; 62: Long glide with average depth of 3'. Length adjusted to 424 (393+31) 1/13/09;
C	183: On LB near top of stream is 10'x8' LCP; 184: GLD uniform bottom, no cover, yet surface looks like a run; 185: SRN above GLD, not bedrock bottom, more boulders, trench & cover more complex; steep eroded bank LB in middle 50' of run.
D	202: Started at LGR below access road crossing on Oilar property. GPS WP#15; 203: Small riffle in middle of run ~40' long w/ ~25ft2 spawning gravel; 205: Riffle descends into bedrock chute for 20' then into a bedrock dominated riffle (index reach ends 36' short of top of riffle not including bedrock chute)

Index Reach		E				F				G			H
Date		10/27/11				10/27/11				10/26/11			10/26/11
Habitat Type		15	1	15	1	1	15	1	15	14	15	14	16
Adjusted Station		224	225	226	227	IR-B1	IR-B2	IR-B3	IR-B4	IR-C1	IR-C2	IR-C3	297
Total Length	*Ft*	86	41	273	65	32	35	45	211	96	96	128	360
Temp Time		2:30 PM				11:00 AM				4:45 PM			10:30 AM
Water Temp	°C	7				5				8			6
Air Temp	°C	17				15				16			17
Bankfull Width	*Ft*	43				32				32			36
Reach Length	*Ft*	430				320				320			360
Surface Area	*Ft²*	18490				10240				10240			12960
Percent Shade	*%*	46.3				53.9				64.6			34.9
% bedrock	*%*	0	10	0	0	0	0	0	0	0	0	0	0
Sub. Embed. (%)	*%*		35		33		33.5		23				7.5
Fines (%)		11.3				4							1
GPS Point mE		582031				582428				582602			583101
GPS Point mN		4498157				4498904				4499596			4500237
Photos		10	11,12	13	14, 15	AS unknown 16-22				AS unknown 23-25			26-30

Index Reach	Comments
E	Transects 1-3 are w/in DS run @ start of index, transitions into glide (glide lumped with run not seperate habitat unit). Transect 3 is @ interface of Run @ start of reach & LGR above run. Transect 4 is in LGR above DS Run @ beginning of Index Reach; Transect 10 is 30' into the LGR @ US end of Index Reach. LGR is 65' long.
F	GPS WP10 @DS end photo 17. @US end stream splits equally around island & flows into LB on both channels & has eroded the bank to about 25' & scoured large holes or semi-caves into the LB. (photos 18,19); photo 16 is from transect 3 US; Gravel between transect 5-7 fairly scattered among cobble & boulders & not enough area for suitable spawning bed, but gravels are present in pebble count. above transect 7 has 35'x5' gravel bed (w/spawning gravel) on LB (photo 22).
G	GPS @ US end of reach; short cascade in middle of run (photo IRG_3); %Bedrock at transect #1, #3: 16%, 40% respectively
H	Is the FS above the LGR that is immediately above the very long (760' step run) %bedrock recorded along transects #1, #3, #5, #7, #9: 2%, 1%, 26%, 51%, 0% respectively

Appendix D: Photographs
Index Reach A


Photo: 1


Photo: 2


Photo: 3


Photo: 4


Photo: 5

Index Reach B

Photo: 6

Photo: 7

Photo: 8

Photo: 9

Index Reach E

Photo: 10

Photo: 11

Photo: 12

Photo: 13

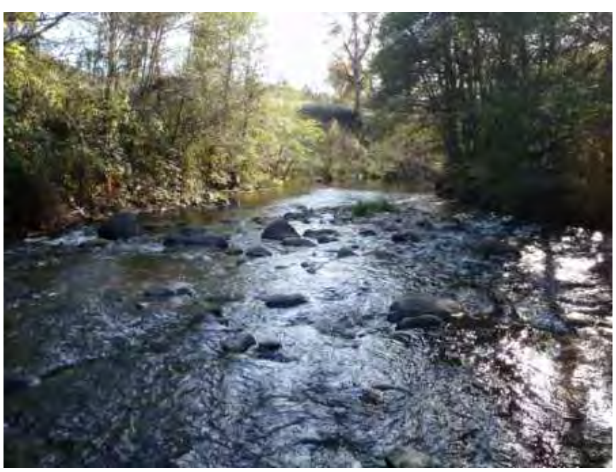


Photo: 14

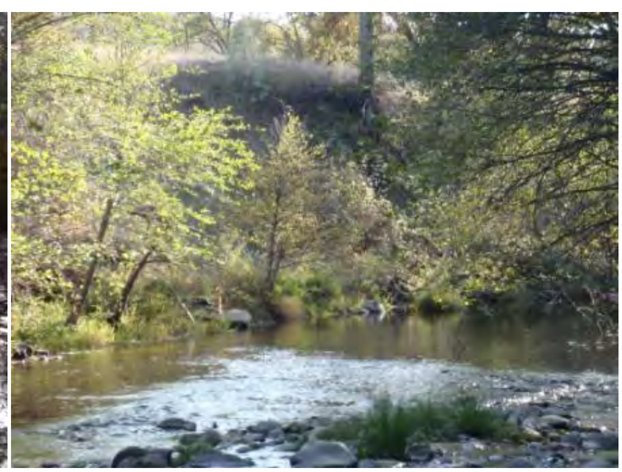


Photo: 15

Index Reach F

Photo: 16

Photo: 17

Photo: 18

Photo: 19

Photo: 20

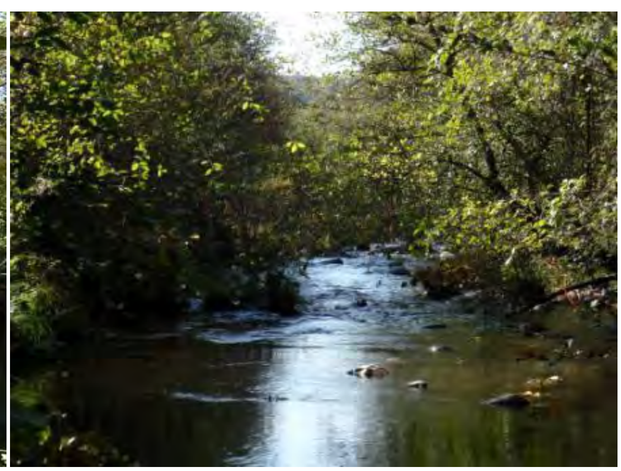


Photo: 21

Index Reach F (cont.)

Photo: 22

Index Reach G

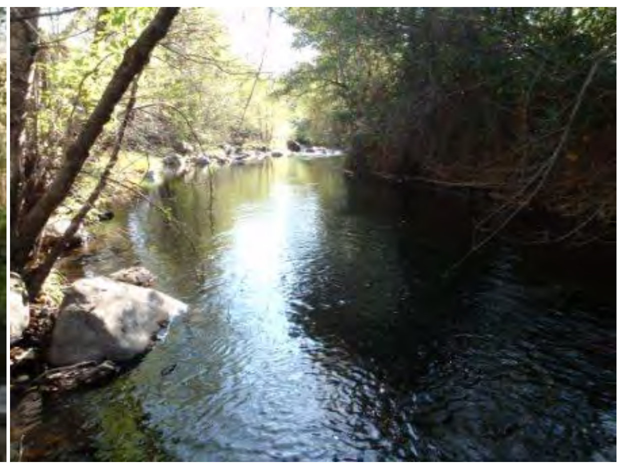


Photo: 23

Photo: 24

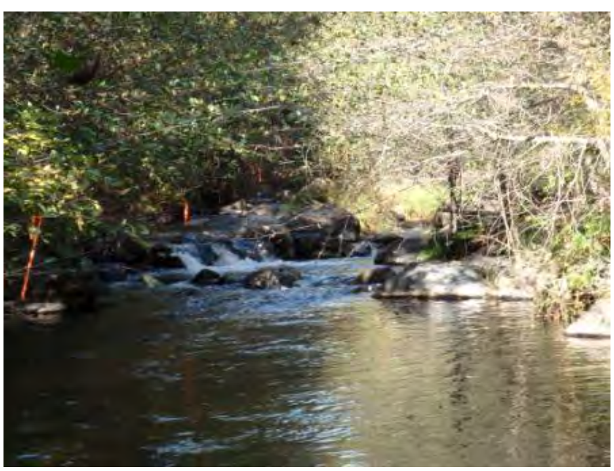


Photo: 25

Index Reach H

Photo: 26

Photo: 27

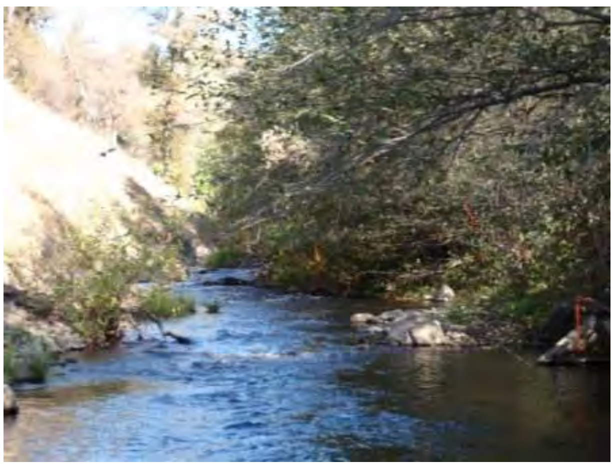
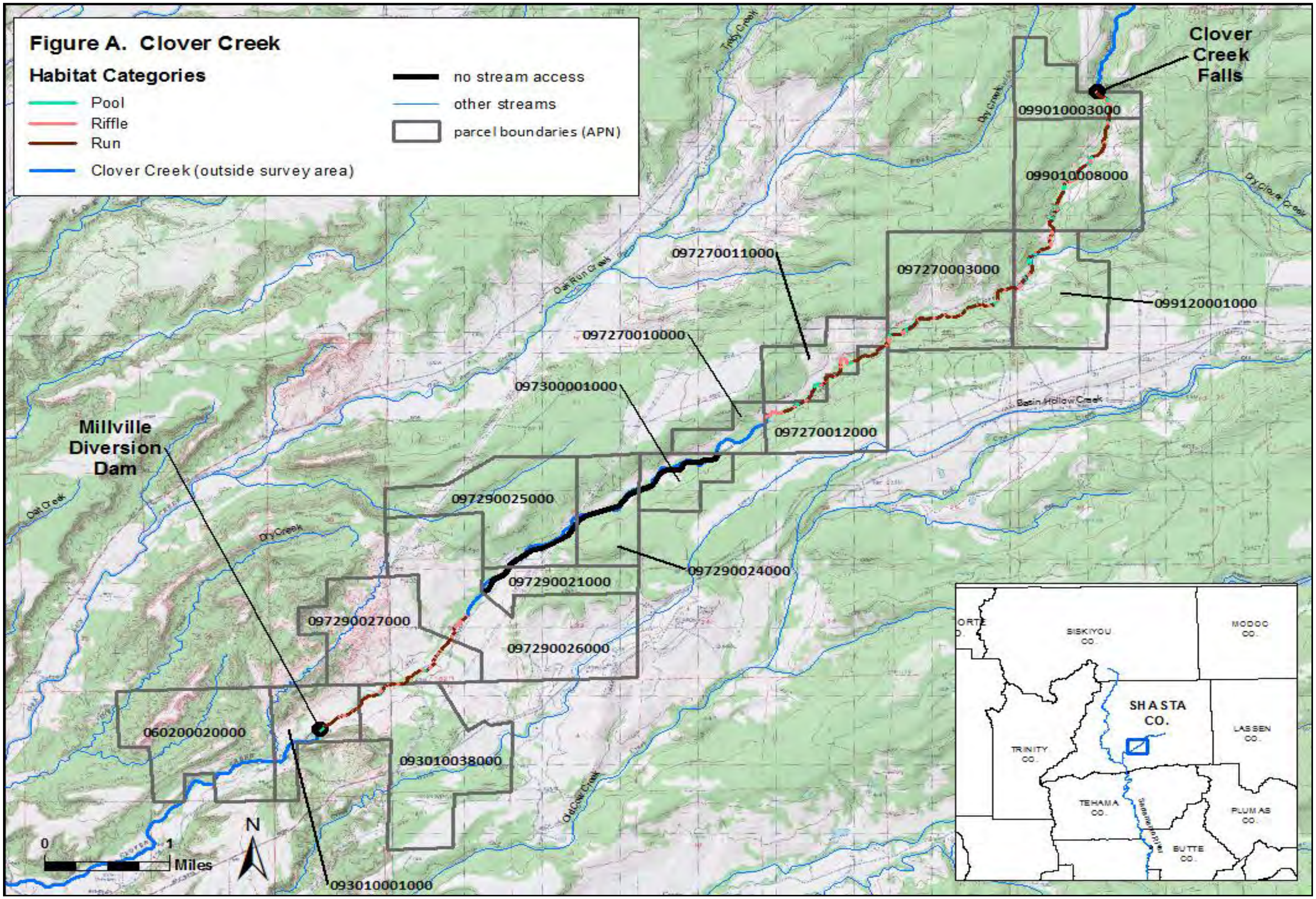


Photo: 28

Photo: 29

Photo: 30

Appendix E: Clover Creek Overview and Habitat Map



APPENDIX E

Cursory Structural Analysis of Existing Dam and Siphon

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State of California | California Natural Resources Agency

Memorandum

Date: May 24, 2012

To: Teresa Connor, Senior Engineer
Northern Region Office
Division of Integrated Regional Water Management

Ray Morin, Senior Engineer
Structures Section
Civil Engineering Branch
Division of Engineering

From: **Department of Water Resources**

Subject: Clover Creek Fish Passage Assessment

Executive Summary

On March 14, 2012 the Northern Region Office (NRO) requested the Division of Engineering's (DOE) Structures Section to perform a cursory assessment to determine the structural feasibility of constructing fish passage facilities at two locations on Clover Creek, near Millville, CA, where a concrete dam and siphon encased in concrete cross the creek, creating barriers to fish passage. A requirement of the assessment is that the current stability and strength of the existing structures (the dam, siphon, and bridge) not be reduced as the result of construction.

The evaluation determined that it is feasible to construct the fish passage facilities without adversely affecting the stability of the existing structures, provided the construction does not significantly disturb the existing siphon. If the construction includes partial removal of the siphon encasement and/or concrete and soil over the encasement, additional measures may be needed to strengthen and stabilize the existing siphon structure.

The evaluation also identified measures to strengthen and increase stability of the existing structures. These include filling in scour holes around the bridge piers with concrete, patching areas of erosion underneath the siphon and dam with concrete, filling in scour holes at the embankment with suitably sized rock revetment, filling in the siphon with concrete, and either constructing a concrete drop structure immediately downstream of the dam and siphon or placing rock revetment in the downstream scour holes.

Existing Conditions

Clover Creek dam, siphon, and bridge are located in Section 6, Township 31 North, Range 2 West, approximately 10 miles below a natural barrier created by Clover

SURNAME
DWR 155 (Rev 7/11) | Morin 5/24/12 | |

Creek Falls. Both the dam and siphon extend across the creek, creating barriers to fish passage at the two locations.

The dam sits on bedrock and is about 85 feet long and 12 feet wide, with a height of about 4.5 feet. Below the dam is a scour hole where the height from crest of dam to the downstream channel bottom is approximately 10 feet.

As shown in Photos 1 and 2, the bedrock underneath the dam has been eroded along the downstream side. The left embankment at the dam also shows evidence of erosion.

Photo 1 - Millville Diversion Dam, 2007 (Source: NRO)

Photo 2 - Millville Diversion Dam, looking upstream, 2007 (Source: NRO)

Located downstream of the dam are the bridge and siphon. The bridge superstructure has a wooden deck supported at two abutments and three piers. There is evidence of scour around the center pier, as shown in Photo 3.

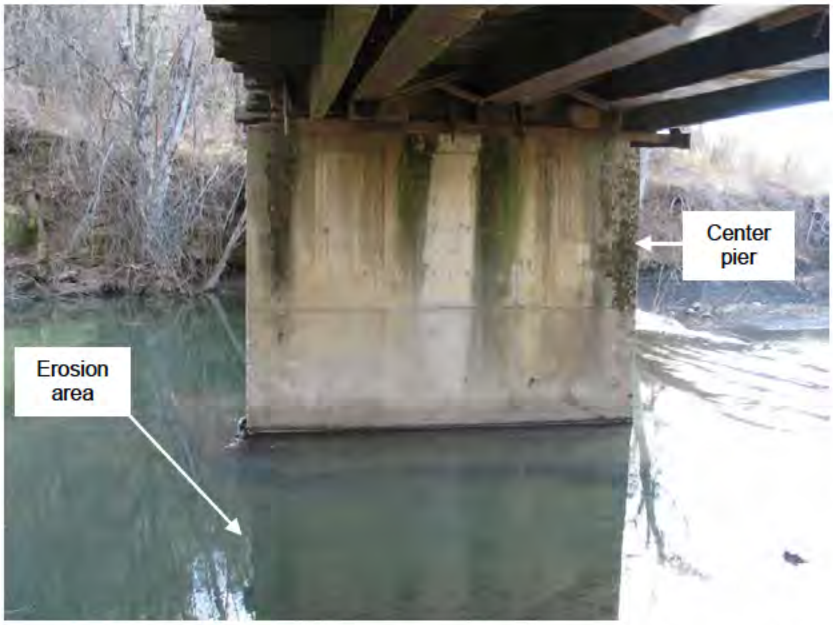

Photo 3 - Millville Bridge Right Center Pier, 2012 (Source: NRO)

Located immediately downstream of the bridge is an inverted siphon encased in concrete. The siphon is a 30-inch-diameter corrugated metal pipe, and the concrete encasement is 130 feet long by 10 feet wide by 5 feet high. The encasement crossing was originally buried. Over time, erosion of the stream material has uncovered the encasement such that there is normally about a 5-foot drop between top of encasement and downstream water surface. The owner of the siphon and bridge has indicated that, over the years, concrete material has been placed over the original encasement as protection measures against erosion. See Photo 4 below.

Photo 4 - Millville Bridge and Inverted Siphon, 4/20/12

Purpose of Assessment

The purpose of this cursory assessment is to determine the structural feasibility of constructing fish passage facilities at two locations where a dam and a siphon cross the creek, creating barriers to fish passage. A requirement of the assessment is that the current stability and strength of the existing structures (the dam, siphon, and bridge) not be reduced as the result of construction.

Scope of Investigation

The scope of the investigation includes (1) determining if the existing soils are capable of supporting the new and existing structures, (2) indentifying basic methods for constructing fish passage facilities which will not weaken the existing dam, siphon, and bridge, and (3) identifying possible retrofit measures to strengthen and stabilize the existing dam, siphon, and bridge structures. The scope of work does not address the possible effects of higher scour potential and forces on the existing structures as a result of constructing new facilities and/or retrofit measures to the existing structures.

Evaluation Process

DOE conducted an initial evaluation by reviewing available photos, hydrology reports, and geology memoranda, and discussing concerns of constructing the proposed fish passage facilities with Northern Region Office staff. Preliminary strategies for assessing the current stability of the existing structures were also developed. These strategies included: examining the condition of the existing dam, siphon, and bridge piers for cracks and differential movement; examining the extent of erosion around the existing structures; and taking Schmidt Hammer rebound readings on the existing siphon encasement and dam to determine if the existing concrete may be suitable for structurally attaching new structures.

After the initial evaluation, DOE met with staff from NRO, Department of Fish and Game (DFG), and local owner of the existing siphon and bridge on April 20, 2012, and performed an inspection of the dam, siphon, and bridge. As requested by NRO, a licensed geotechnical engineer (Mitch Tyler) and licensed civil engineer (Scott Yomogida) with structural design experience from DOE performed the inspection.

To estimate the concrete compressive strength of the dam and siphon encasement, rebound measurements were taken on the structures using a Schmidt Hammer.

Discussion of Site Visit

On May 20, 2012, the creek water levels were too high to visually inspect the extent of erosion around and underneath most of the downstream side of the dam and siphon encasement. The water levels also covered most of the exposed surfaces, which limited the surface areas suitable for testing with the Schmidt Hammer.

At the dam, apparent erosion on the exposed side and top concrete surfaces of the dam was observed, as shown in Photos 5 and 7. The erosion was most pronounced on the top surface, as shown in Photo 5, and less pronounced on the side surface. Two lines of exposed, corroded longitudinal rebar were also observed running along the top surface; corroded transverse reinforcement at about a foot on center was also observed between the longitudinal rebar.

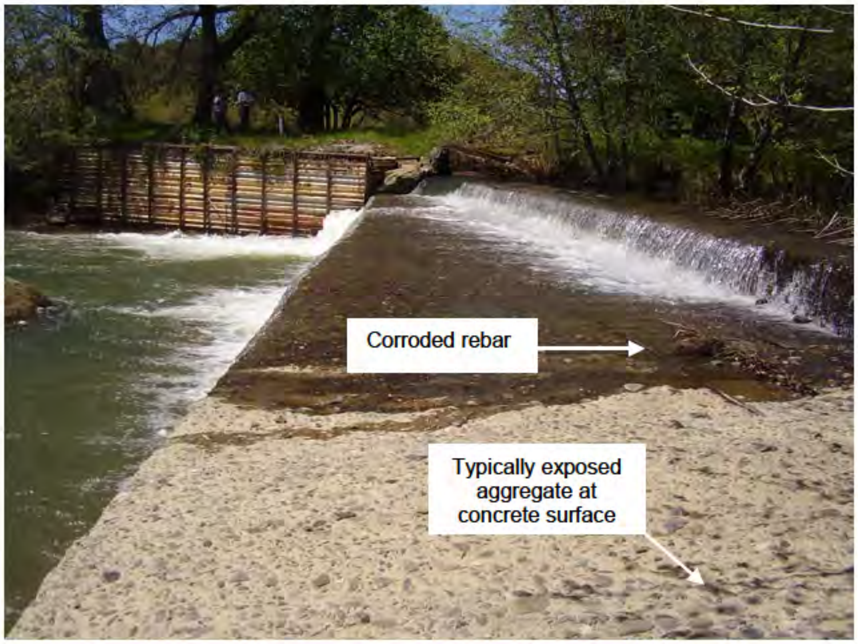

Photo 5 - Millville Diversion Dam, Delamination on Dam Surface, 4/20/12

As shown in Photo 6, the width of scour underneath the dam near the left embankment was measured to be about 3.5 feet.

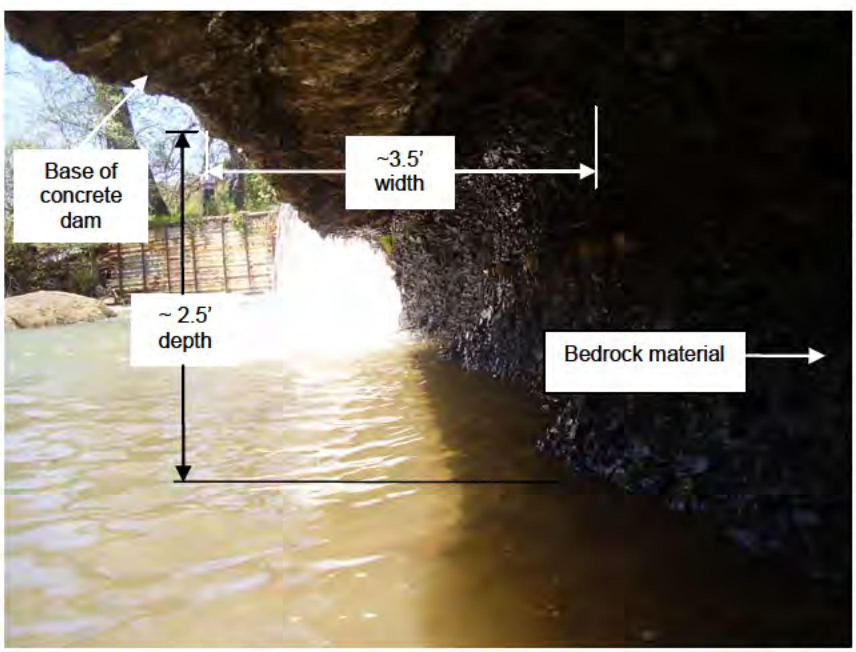

Photo 6 - Millville Diversion Dam, Scour Underneath Downstream End of Dam, 4/20/12. (Standing near left bank looking across base of dam)

At the same location the depth of scour between base of concrete dam and bottom of scour was measured to be about 2.5 feet. .

By visual inspection from inside the scour looking across the base of dam, the width of scour along the dam varied between approximately 2 to 3.5 feet. A single line of rebar protruding from the base of the concrete dam about a foot upstream from the downstream face was also observed. By visual inspection, the rebar was estimated to be #4 bars spaced at about 8 feet on center

From inside the scour area the pick side of a hammer was struck against the wet bedrock material shown in Photo 6. The wet material easily broke off in about ½- to 1-inch pieces. The base of the concrete dam was also struck with a hammer - no material was observed to break away, and clear ringing was heard (no hollow sounds were heard).

To estimate the dam's concrete compressive strength, readings were taken using a Schmidt Hammer. Due to limited availability of dry, smooth concrete surfaces, readings were limited to three spots, as shown in Photo 7. Also shown in Photo 7 are three pieces of embedded wood observed at the downstream side surface of the dam.

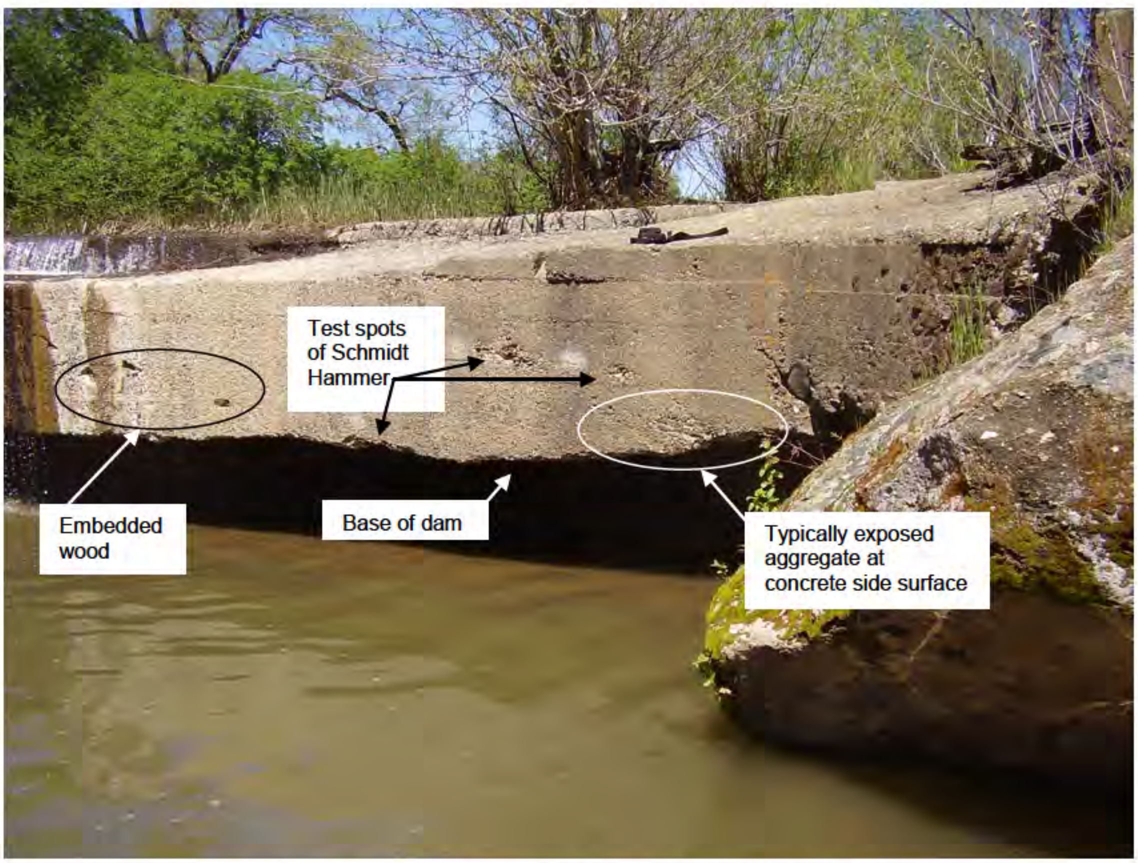

Photo 7 - Millville Diversion Dam at Left Bank, 4/20/12

The Schmidt Hammer (Model N/NR) test readings taken on the dam are summarized in Table 1. The average compressive strength of concrete was determined to be approximately 4,070 psi.

Table 1: Schmidt Hammer Readings on Dam

Rebound Reading	Estimated f'_c (psi)	Number of Reading Occurrences
25	2,050	1
28	2,600	2
29	2,800	1
32	3,350	2
34	3,700	3
35	4,000	2
37	4,350	1
40	5,000	1
42	5,450	3
51	7,600	1

During the site visit, the DFG representative identified the approximate alignment of the proposed new fish ladder to be downstream of the dam and along the right bank. The representative said that the fish ladder alignment may either cut through the diversion entrance or go around the diversion entrance through the right embankment. Furthermore, a fish screen at the diversion entrance may need to be provided if the water diversion facilities and siphon are not abandoned. See Photo 8.

Photo 8 - Millville Diversion Dam at Right Bank, 2012 (Source: NRO)

The bridge and the encased inverted siphon structure are located downstream of the diversion dam.

At the downstream end of the center pier, apparent erosion was observed on the exposed surface (see Photo 9). The scour hole was also observed around the center pier, as shown in Photo 9. The apparent surface of the pier footing was observed at the bottom of the scour hole.

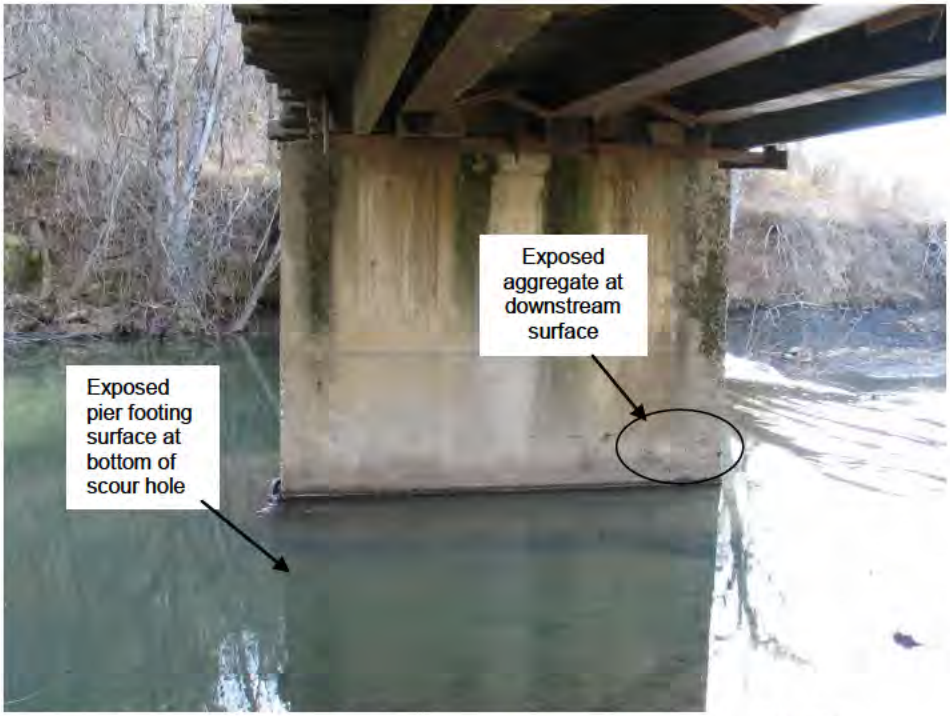

Photo 9 – Millville Bridge Center Pier, 2012 (Source: NRO)

Located immediately downstream of the bridge is the inverted siphon. Because most of the siphon encasement was submerged by creek flow, the extent of the erosion around the siphon encasement could not be examined. As shown in Photo 10, the creek appears to be flowing over a concrete apron which covers the streambed soil and the encasement. Apparent erosion was observed on most of the apron surface whereby large areas had exposed aggregate.

Due to limited availability of dry, smooth concrete surfaces on the encasement structure, Schmidt Hammer testing was limited to a small area at the right bank. It was not clear whether the area of concrete was part of the original 10-foot by 5-foot encasement or a later concrete placement. (During the site visit, a person who identified himself as the owner of the siphon and bridge said that, over the years, concrete material has been placed over the original encasement as protection measures against erosion. He said that he was not able to determine if the testing area was part of the original encasement, explaining that the subsequent concrete placements had occurred before he became owner of the structures.)

NRO staff identified the approximate location of the proposed fish passage facilities at the siphon, as shown in Photo 10. NRO indicated that only a fish ladder would be required at this site. In order to construct the fish ladder, portions of the encasement, as well as concrete apron and underlying soil, may need to be removed.

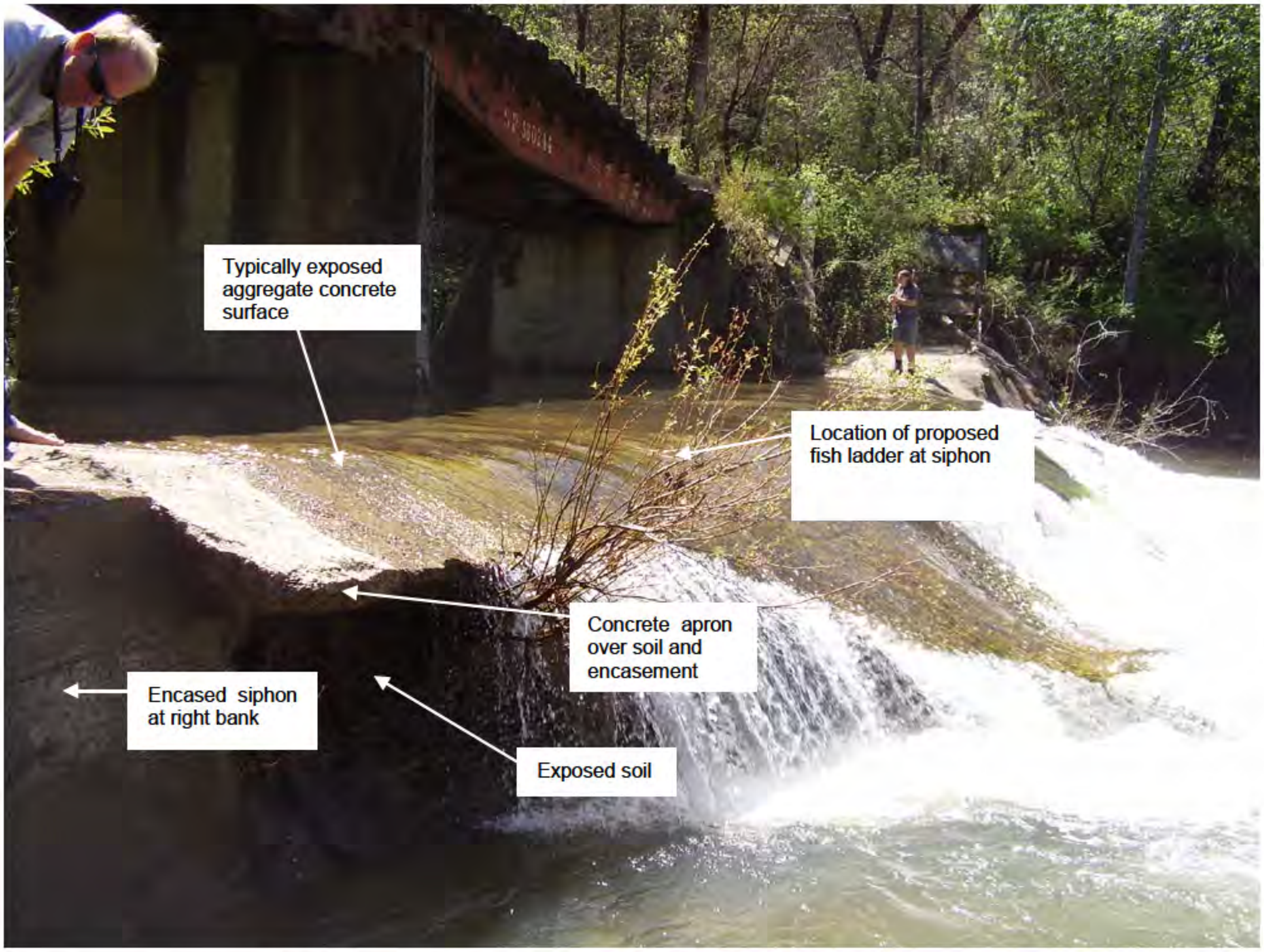

Photo 10 – Millville Bridge and Inverted Siphon, 5/20/12

The Schmidt Hammer test readings taken at the siphon encasement are summarized in Table 2. The average compressive strength of concrete was determined to be approximately 5,170 psi.

Table 2: Schmidt Hammer Readings at Encasement

Rebound Reading	Estimated f'_c (psi)	Number of Rebound Occurrences
34	3,700	2
37	4,350	1
40	5,000	1
41	5,200	1
42	5,500	1
43	5,700	5
45	6,100	1

NRO staff indicates that when the siphon is in use water leaks through the encasement.

Site Geology and Foundation Assessment

Clover Creek in the vicinity of the Millville Ditch diversion dam and siphon is primarily a bedrock-incised channel with occasional gravel, cobble and boulder deposits. The bedrock consists of thinly bedded, weakly cemented and moderately hard siltstone and claystone that is interbedded with occasional thin, relatively hard sandstone layers. The claystone/siltstone bedrock is intensely fractured and friable. The site conditions are well described in two interoffice memoranda by DWR and DFG dated 2/6/2012 and 6/2/2008.

Large plunge pools have formed immediately downstream of both the dam and siphon, and the downstream sides of both structures are being undercut by scour. At the dam site, bank erosion on the left abutment is substantial, and a smaller scoured area is forming on the right bank just below the siphon. There are two theories for the erosion expressed in the memos mentioned above. One cause could be that by changing the flows in the stream, the structures themselves are largely responsible for the erosion. Another cause might be that the structures are acting as “hard points” inhibiting regional erosion and headcutting within the Sacramento River system due to construction and management of Shasta Dam.

Regardless of the cause of streambed and bank erosion, the fractured and friable nature of the bedrock makes it susceptible to erosion by concentrated or high flows. Accordingly, structures founded within the active channel or anchored into the banks should be armored with riprap or designed with other erosion control measures. Based on cursory site observations, DOE estimates the allowable bearing capacity for the siltstone/claystone bedrock will be in range of 5,000 psf to 10,000 psf, and possibly higher, if appropriate testing and/or investigation is conducted to verify. As a reference, NAVFAC Design Manual 7.02 indicates an appropriate presumptive allowable bearing pressure for this foundation material would be in the range of 5 to 10 tons per square foot. Thus, the foundation material should be able to accommodate the new, relatively small structures supported on spread footings without undue complications.

Evaluation Results

The exposed concrete surfaces of the dam, bridge pier, and siphon encasement all show signs of erosion where large areas of aggregate are now exposed at the surfaces. The eroded areas appear to occur where the surfaces are in contact with creek water where there are typically higher velocities and turbulence. The likely cause of the surface erosion is the erosive force of the creek flow and/or exposure to slightly corrosive chemical constituents in the creek water.

Visual observations of the dam suggest that the dam is stable, as no differential movement of the structure nor excessive cracking was observed. However, further erosion around and underneath the structure could undermine overturning stability, as well as lead to structural failure as the support length along the bottom of the structure is reduced. Moreover, Schmidt Hammer test results suggest that the strength of the existing concrete may be adequate for structurally attaching new structures such as new fish passage facilities and/or erosion control measures. The limited number of soundings taken on and underneath the dam also suggests solid material. Although as-built drawings were not available, longitudinal and transverse reinforcement found at the top surface indicates the dam contains steel reinforcement as a strength component. Rebar was also observed protruding from the downstream base of the dam, but we surmise this may have been initially driven into foundation rock prior to concrete placement and primarily used) to support the rebar and concrete forms.

The dam does not appear to be keyed into the embankments, thus the embankments do not appear to materially contribute to its stability. This and the apparent sound condition of the dam indicates constructing the fish ladder either through or around the diversion entrance, as well as, the fish screen at the diversion entrance should not reduce the stability and strength of the dam as a whole, provided the new structures are not designed to rely on their connection to the dam for their stability. However, to increase dam stability, several remedial measures should be considered, including:

1. Patch eroded areas underneath the dam with concrete. Structurally connect the patched areas to the base of the dam using dowels.

2. Fill in scour holes at the left bank with suitably sized rock revetment.

3. Construct a concrete drop structure immediately downstream of the dam to help prevent erosion from progressing upstream to the structure, or place rock revetment downstream of the dam.

Preliminary estimate of the dam's concrete compressive strength indicates the new concrete structures could be structurally attached to the dam using conventional means, such as shear keys or dowels. As noted earlier, the structures would need to be stable on their own or rely on the dam for support only to the extent indicated by design calculations. To confirm the concrete strength, concrete core samples and testing should be considered.

Visual observations of the siphon encasement as well as Schmidt Hammer test results were inconclusive with regards to the present stability of the structure and strength of concrete. However, erosion around and underneath the structure could undermine overturning stability, as well as lead to structural failure as the support length along the bottom of the structure is reduced.

Construction of the fish ladder at the siphon includes two options which entail either cutting through the encasement or building over the top of the encasement. Both options appear feasible however, it is not clear if the siphon encasement is deriving some of its stability by being fixed at the two embankments (in which case, cutting the encasement could reduce the stability of the structure). Moreover, removal of the concrete apron over the encasement may reduce the overall stability of the encasement as the dead load on the encasement and/or the resisting downstream lateral soil pressure may be reduced.

To increase the stability of the siphon, several remedial measures should be considered, including:

1. Patch areas of erosion underneath the encasement with concrete, and if the siphon can be abandoned, backfill the siphon with concrete to provide additional dead weight for stability as well as a degree of protection against pipe corrosion.
2. Fill in scour holes at the embankment with suitably sized rock revetment.
3. Construct a concrete drop structure immediately downstream of the siphon to help prevent erosion from progressing upstream to the siphon, or place rock revetment downstream of the siphon.

Preliminary estimation of the encasement's concrete compressive strength was inconclusive. Recommend further testing to determine the structural adequacy of the existing concrete before structurally attaching new structures.

Conclusions and Recommendations

From a bearing capacity standpoint, the creek bedrock is suitable for supporting new fish passage structures. At both the dam and siphon locations, fish passage facilities founded on spread footings will likely attain a high factor of safety against bearing failure. However, structures founded within the active channel or anchored into the banks should be armored with riprap or designed with other erosion control measures to ensure bearing surfaces are not eroded.

The dam structure appears to be intact and in a condition to accommodate the new fish passage structures without adversely impacting its stability. If the new structures are attached to the dam, they should be designed to be stable without relying on support from the adjacent dam structure unless calculations show the dam can support additional loads. The area around the dam is in need of repairs, and we recommend performing the three remedial measures noted in the Evaluation Results section even if the new fish passage facility is not pursued.

The dam's concrete strength was estimated, and it appears to be very satisfactory, but this is an important parameter that should be investigated in more detail. We recommend concrete cores be taken and tested to confirm its condition and strength.

For the siphon encasement, it is not clear if the encasement is deriving some of its stability through being fixed at the two embankments; therefore, cutting the encasement to accommodate the new fish ladder could reduce the stability and strength of the structure. Furthermore, removal of the concrete apron over the encasement and any around the encasement may also reduce the encasement's stability. If the new fish ladder is attached to the siphon encasement, it should be designed to be stable without relying on support from the encasement unless calculations show the encasement can support additional loads. The area around the encasement is in need of repairs, and we recommend performing remedial measures 1, 2, and 3, noted in the Evaluation Results section even if the new fish ladder is not pursued.

A possible consequence of constructing the new fish passage facilities is the potential for increased scour around the piers which could ultimately lead to destabilization of the bridge. To maintain the current stability of the piers, we recommend filling in the scour holes around the bridge piers with concrete to prevent increase in the extent of scour.

The extent of surface erosion on the piers, dam, and encasement apron does not appear to be an immediate threat to stability and strength of the existing structures.

References

1. Interoffice Technical Memorandum, Clover Creek Dam Removal (draft memorandum), Mark Smelser, Department of Fish and Game, June 2, 2008.
2. Interoffice Memorandum, Clover Creek Diversion Dam, Fish Passage Project, Bruce Ross, Department of Water Resources, February 6, 2012.

If you have any questions or wish to discuss this evaluation in further detail, please contact me at (916) 654- 5813, or have your staff contact Scott Yomogida at (916) 653-0232.

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APPENDIX F

CDFW Draft Checklist

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Project Specific Requirements
CDFW Fisheries Engineering Review Checklist

The following document provides design information required for CDFW fisheries engineering staff to conduct a review of project designs for fish passage and screening structures at the Millville Diversion on Clover Creek near Millville, California. The Clover Creek Fish Passage Project consists of constructing two pool and weir fish ladders and an on-stream flat plate fish screen.

Fish Screen

1. **Target species and life stages to be protected at proposed screening site (e.g. will steelhead rainbow trout fry be present?) (NMFS pg. 4-5)**

   The target species in Clover Creek is primarily all life stages of fall-run Chinook salmon, but also includes late fall-run Chinook salmon and Central Valley steelhead. Due to high water temperatures and low flows in the creek when juveniles could be present, it is not desirable to have them rearing in the creek. Because of these conditions, National Marine Fisheries Service (NMFS) has given its concurrence that this project does not need to provide for upstream juvenile passage.

   The fall-run migration period is during October and November whereas late fall-run and steelhead could be in the system during December through March.

2. **Fish screen structure placement (e.g. on-stream, in-canal, in-reservoir, or pumped) (NMFS pg. 3)**

   The screen face will be located on-stream, parallel to the flow aligned with the right bank. A smooth transition between the bank and screen face was designed to help minimize eddies and unfavorable flow patterns in the vicinity of the screen face.

3. **Records of diversion flows and stream flows, including maximums and minimums, during irrigation season (NMFS pg. 2)**

   Diversion flows and stream flows are not recorded in Clover Creek. Clover Creek's estimated mean daily flow was calculated using mean daily flows from USGS gaging station identification number 11374000 (Cow Creek Near Millville) from water years 1950 through 2011. A hydrograph was created and is shown in Figure 1. More information on how Clover Creek flows were estimated is discussed in the Hydrologic Investigation section of the report.

   Millville Diversion is part of the State Watermaster Service Program in which DWR monitors the decreed water right discussed in Water Rights Investigation section of the report. The maximum amount of water MDA could divert ranges from 6.5 cfs up to 8.2 cfs, depending on the amount of surplus water available in Clover Creek. The diversion flow is measured by reading the stage in a 2-foot wide Parshal Flume but is not recorded. An incomplete record of gage heights at the Millville Diversion was collected by the watermaster. A total of 17 days over 6 years was recorded. The maximum diversion flow of 9.3 cfs was recorded on May 24, 2001, and the minimum diversion flow was 0 cfs on May 1, 2003, with an average of 4.5 cfs.

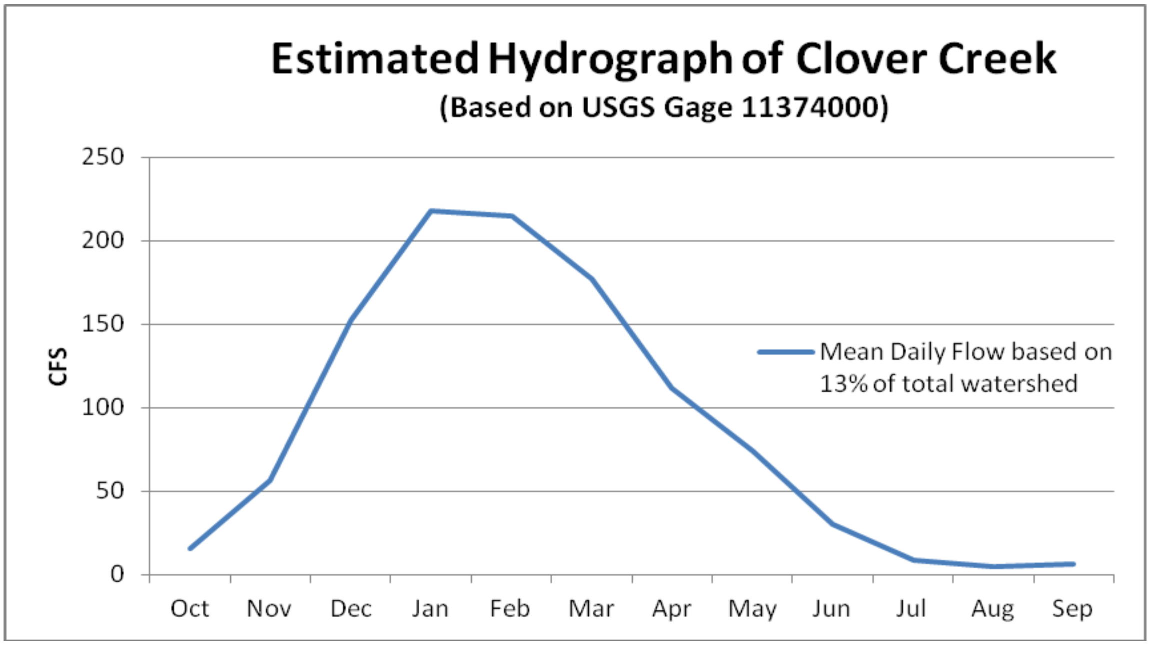

Figure 1. Estimated Hydrograph for Clover Creek

4. Stream flow vs. depth rating curve at diversion intake (NMFS pg. 2)

A one-dimensional hydraulic model (HEC-RAS v. 4.1.0) was used to analyze current and proposed conditions. A stream flow versus depth rating curve for the proposed conditions at the diversion intake was developed using HEC-RAS (Figure 2).

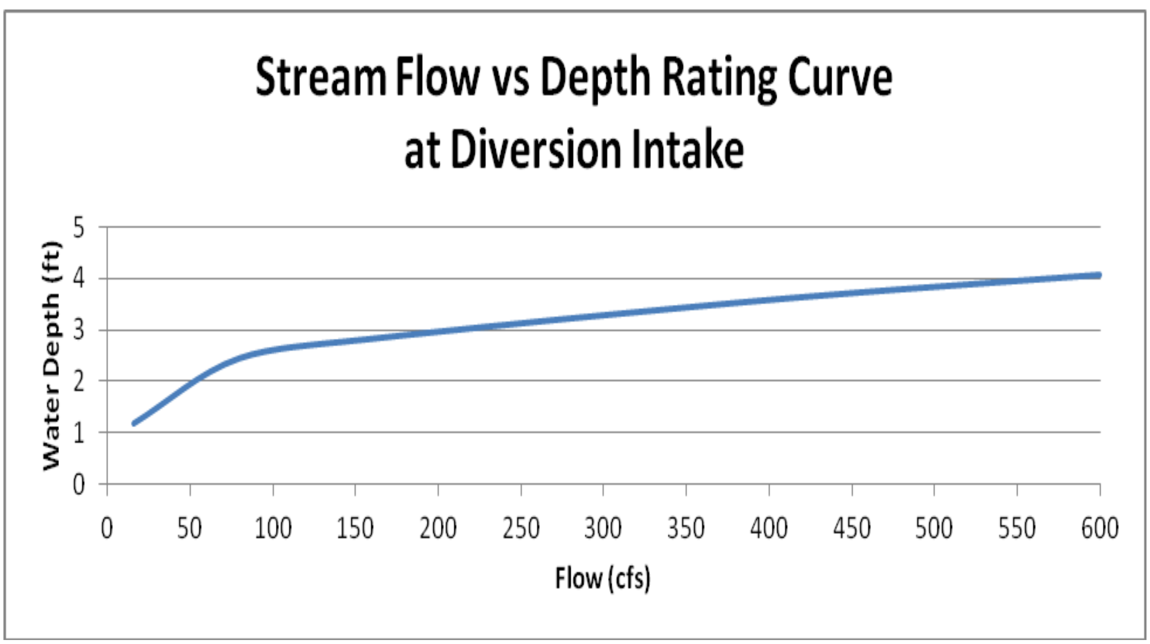

Figure 2. Stream Flow versus Depth Rating Curve

5. **Description of fish screen openings, including porosity and dimensions of round, square, or slotted openings (NMFS pg. 5-6)**

   The fish screen material will be made of a stainless steel profile bar type with slotted openings not to exceed 0.0689 inches and a minimum open area of 27 percent.

6. **Applicable approach velocity and sweeping velocity criteria (NMFS pg. 4-5)**

   Approach velocity for active screens in streams and rivers shall not exceed 0.33 fps. The recommended sweeping velocity shall be twice the approach velocity of 0.66 fps.

7. **Fish screen area calculation performed in accordance with DFG Fish Screening Criteria (6/19/00)**

   With a maximum allowable approach velocity of 0.33 fps (for continually cleaned screens in streams and rivers) and a maximum diversion of 8.2 cfs, the required wetted screen area is about 25 square feet (sf). Adding 25 percent (6.25 sf) to the required wetted area to compensate for reduction of screen area due to structural members, the required screen area becomes 32 sf.

8. **Water depth and approach velocity calculations in front of the fish screen throughout range of diversion flows (NMFS pg 3-4)**

   Figure 3 shows the diversion rates over the expected range of water surface elevations in the creek. The approach velocity through the fish screen was also plotted and was calculated by reducing the area of the screen area by 25 percent to compensate for structural members.

   The Operations and Maintenance manual will state that each diverter will need to lower the headgate or modify the louver settings when the diversion rate exceeds the decreed diversion rate.

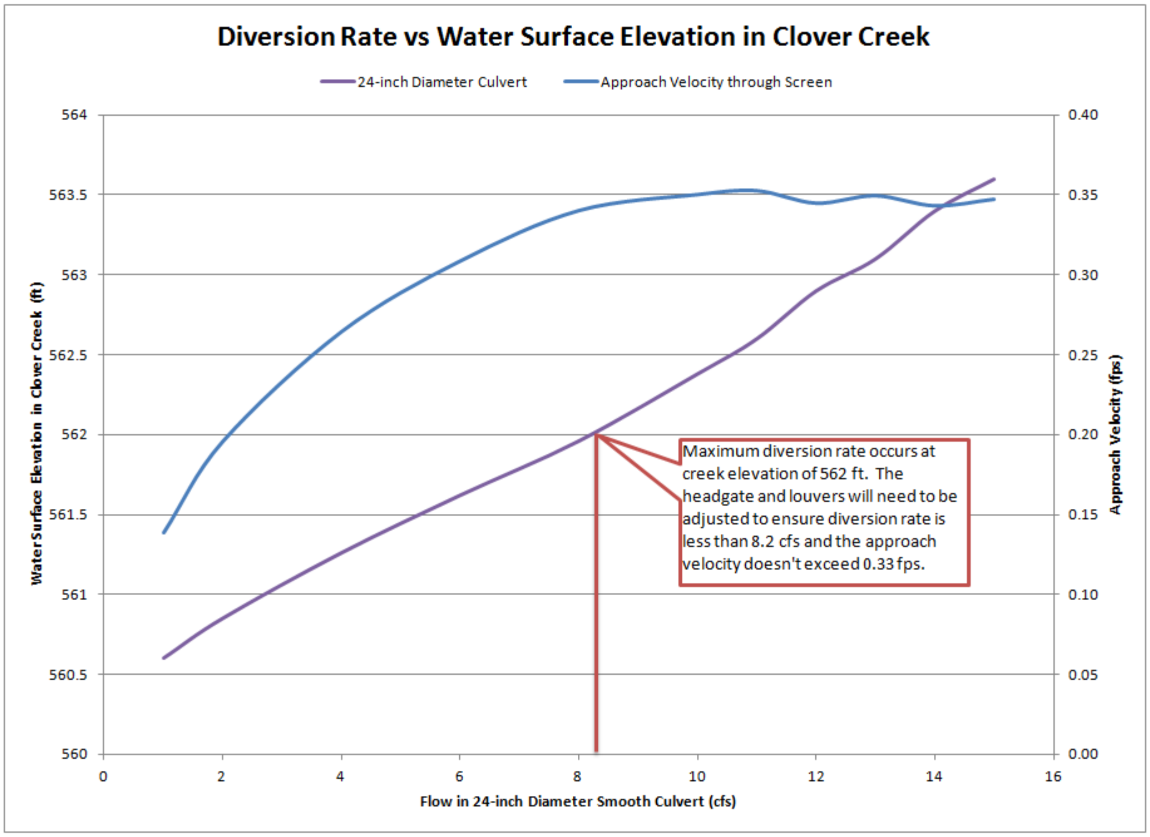

Figure 3. Diversion Rate vs Water Surface Elevation in Clover Creek

9. Evidence that flow uniformity criterion will be met (NMFS pg. 5)

The screen design must provide for uniform flow distribution over the surface of the screen, thereby minimizing approach velocity. To promote uniform flow, the channel should be relatively uniform for at least four times the width of the channel (WDFW 2000).

The channel width at the proposed screen location is about 75 feet wide. The channel is relatively uniform for at least 300 feet upstream of the screen area. The thalweg of the channel is along the right bank. The existing flow condition is fairly uniform along the proposed location of the screen (right bank). The placement of the fish passage structures should not significantly alter the flow conditions.

Adjustable baffles or louvers can be used behind the screen face to help alleviate areas of high concentrated flow and high velocity on the screen also known as “hot spots.” Baffles were not included in this design phase, but should be included during final design.

10. Sweeping velocity calculations at several locations along the length of the screen throughout range of diversion and bypass flows (NMFS pg. 5)

Based on HEC-RAS results, the sweeping velocity at the fish screen along the right bank ranges from 0.5 to 2.7 fps for flows ranging from 10 cfs to 600 cfs, respectively. The low flow weir in the fish ladder located just downstream of the screen was placed along the right bank to help increase sweeping velocities across the screen face during low flow.

11. Screen exposure time calculation (NMFS pg. 7)

The maximum allowable exposure time for juvenile salmonids along a screen face is 60 seconds. The screen exposure time was calculated by dividing the length of the screen (16 feet long) by the sweeping velocity at low flow. Based on the HEC-RAS modeling, the low flow sweeping velocity was 0.5 fps at 10 cfs in Clover Creek. The screen exposure time was estimated at 32 seconds during the low flow scenario.

12. Velocity calculations between end of screen and bypass entrance (NMFS pg. 7)

Not applicable–There is no bypass system.

13. Flow depth calculations within bypass conduit and in stream at bypass outlet at minimum bypass flow (NMFS pg. 8-9)

Not applicable–There is no bypass system.

14. Estimated bypass flow needed to meet fish screen criteria (cfs).(NMFS pgs. 5, 7, and 8)

Not applicable–There is no bypass system.

15. Velocity calculations in stream at bypass outlet (NMFS pg. 8)

Not applicable–There is no bypass system.

16. Drop height and impact velocity calculation at bypass outlet, if applicable (NMFS pg. 9)

Not applicable–There is no bypass system.

17. For paddle wheel driven cleaning systems, fish screen area calculations showing passive screening criteria are met when paddle wheel driven wipers no longer operate

The fish screen was designed to accommodate 25 percent structural members (or blockage) with an approach velocity of 0.33 fps. If the paddlewheel-driven cleaning system fails, the approach velocity will exceed the 0.08 fps criteria for screens which are not self cleaning.

18. Description of fish screen cleaning mechanism, including proposed frequency of cleaning

A paddlewheel powered brush system will be used for the fish screen cleaning mechanism. The final design features, including the cleaning frequency, will be done by the final design engineer.

19. Assessment of sediment transport/scour conditions at fish screen for on channel installations (NMFS pg. 2)

The streambed near the proposed fish screen location is mainly bedrock of the Chico Formation. Upstream of the dam in the main channel, a sediment wedge has built up over time and consists of fine silt and gravels. The current alignment of the thalweg falls along the right bank where the fish screen will be located. Currently, the thalweg is clear of sediment which suggests that the existing sediment transport rate is enough to keep sediment suspended through the fish screen location.

A cursory analysis of the sediment transport and scour conditions were analyzed using HEC-RAS. Shear stresses were analyzed for flows ranging from 165 cfs to 3,000 cfs for both existing and proposed conditions. The shear stress along the right bank for existing and proposed conditions ranged from 0.02 psf to 0.3 psf and 0.04 psf to 0.3 psf, respectively. A change in the rate of sediment deposition and scour at the screen location is not anticipated due to the relatively small change in shear stress between existing conditions and proposed conditions.

20. Specific information describing the type of corrosion-resistant screening material, bypass control/pipe and other materials that will directly affect fish. (NMFS pg. 6-8)

The recommended screen material is Type 304 stainless steel to prevent surface corrosion which could lead to clogging of the screen face.

21. Design drawings showing site topography, and dimensions of fish screen structure in plan, elevation, longitudinal profile, and cross-sectional views along with important component details.

See design drawing Sheets 7 and 10 contained in the report for details.

22. Any additional information which may be required to show that screen will meet current DFG/NMFS screening criteria.

No additional information is required.

23. Operation and maintenance plan which includes preventive and corrective maintenance procedures, inspection and reporting requirements, maintenance logs, etc.

The fish screen was designed to have low operation and maintenance while providing good fish passage. MDA will operate and maintain the fish screen structure.

Operational requirements will include site visits to ensure the screen cleaning equipment is functioning properly and to control flow into MDA ditch via the headgate. Maintenance responsibilities will include periodically replacing the brush cleaning system components, occasionally cleaning sediment from the screen bay, and possibly replacing a screen face if damaged or not functioning correctly.

If a maintenance problem occurs that requires the screen to be removed from service, the structure can be dewatered while repairs are made. The dewatering panels can be installed on the outside wall of the fish screen bays. When the fish screens are removed and dewatering panels are placed, water can be drained out through the culvert via the headgate or pumped out if necessary.

An operation and maintenance plan will be drafted by the final design engineer.

24. Post construction evaluation and monitoring plan.

Post-project monitoring may consist of an evaluation of migrating adult salmonids, bird monitoring, water quality and geomorphic monitoring and analyses in Clover Creek. The USFWS, NRCS, and CDFG will also participate in post-monitoring as funding is available. Project monitoring is recognized as a necessity to determine the success of this project and of future fish passage opportunities in the watershed.

The TAC is currently working on developing the post-project monitoring plan.

Dam Fish Ladder

1. **Explanation as to why the specific fish passage design was selected, including a discussion of the elements considered when designing the fish ladder entrance.**

   A pool and weir fish ladder was determined to be the best practical fish passage design for the Millville Diversion Dam in Clover Creek. See the Alternatives section of the report for a more detailed discussion regarding the various fish passage alternatives considered for this project.

   Several elements were considered during the design of the fish ladder: geologic conditions (existing and future), debris load, pool volume, attraction flow, range of flows in the fish ladder, operation and maintenance, and cost. See the Pool and Weir Fish Ladders section within the report for more information related to the elements considered during the design process.

2. **Target species, life stages and migration timing at project site.**

   The target species in Clover Creek is primarily all life stages of fall-run Chinook salmon, but also includes late fall-run Chinook salmon and Central Valley steelhead. Due to high water temperatures and low flows in the creek when juveniles could be present, it is not desirable to have them rearing in the creek. Because of these conditions, NMFS has given its concurrence that this project does not need to provide for upstream juvenile passage.

   The fall-run migration period is during October and November whereas late fall-run and steelhead could be in the system during December through March.

   For more information related to the target species, life stages, and migration timing, see the Target Species Investigation section of the report.

3. **Calculation of lower and upper fish passage stream flows for each lifestage and species**

   An estimated flow duration curve for Clover Creek was created using mean daily flows from USGS gaging station identification number 11374000 (Cow Creek Near Millville) from water years 1950 through 2011. Clover Creek flows were estimated by taking 13 percent of the mean daily flow recorded. For more information on how this curve was developed, please see the Hydrologic Investigation section in the report.

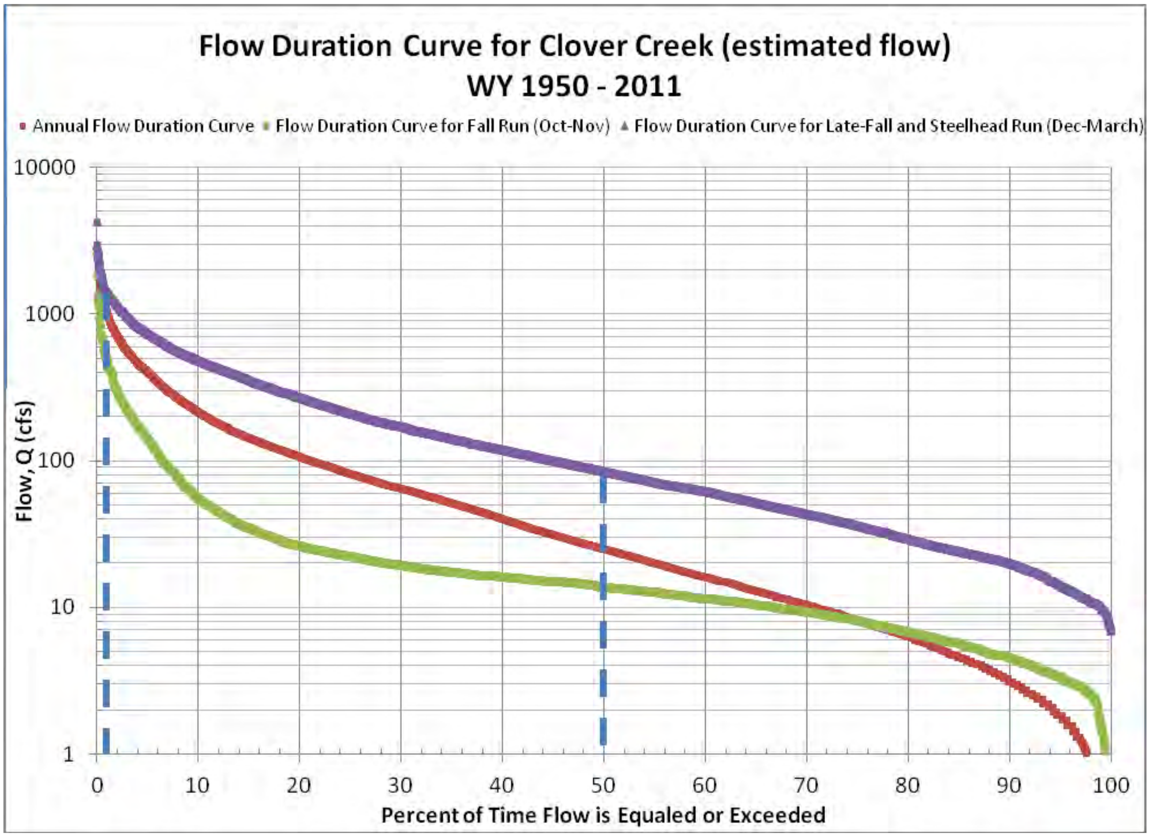

Figure 3. Estimated Flow Duration Curve for Clover Creek

The 1 percent exceedance flow and 50 percent exceedance flow for adult fall-run Chinook salmon migration period is 400 cfs and 15 cfs, respectively (Figure 3). The 1 percent exceedance flow and 50 percent exceedance flow for adult Late fall-run Chinook salmon and steelhead migration period is 1,400 cfs and 80 cfs, respectively (Figure 3).

The design low flow is 10 cfs, but the fish ladder will operate at flows down to 2 cfs, as recommended by the TAC due to low flows during the fall run migration. The high flow design is 400 cfs which accommodates fall run passage 99 percent of the time, and late-fall and steelhead passage 88 percent of the time.

4. Calculation showing attraction flow rates are appropriate

As recommended by CDFW, an extra baffle was designed in the fish ladder for potential future incision. To help alleviate backwater conditions at the fish ladder entrance, a 12-inch wide vertical slot was incorporated into the design. Attraction flows were analyzed by determining the velocity through the 12-inch wide vertical slot over a range of flows in the fish ladder.

The orifice equation was used to determine the head differential. As shown in Table 1, the velocities range from about 1 fps to 4 fps for flows ranging from 2 cfs to 17 cfs in the fish ladder. The velocity jetting through the vertical slot during the design high flow of 30 cfs, is estimated at about 6 fps.

Table 1. Entrance Velocities in the Dam Fish Ladder

Q Ladder (cfs)	Q Channel (cfs)	Depth in Pool (ft)	Entrance Velocity (fps)
2	10	2.7	1
7	20	2.9	2
11	40	3.1	3
12	60	3.3	3
13	80	3.5	4
17	165	4.0	4
30	400	4.9	6

5. Rating curves for headwater and tailwater conditions

The following graph represents the headwater and tailwater condition for the proposed fish ladder. The maximum head difference is about 5.8 feet and the minimum head difference is about 4.6 feet.

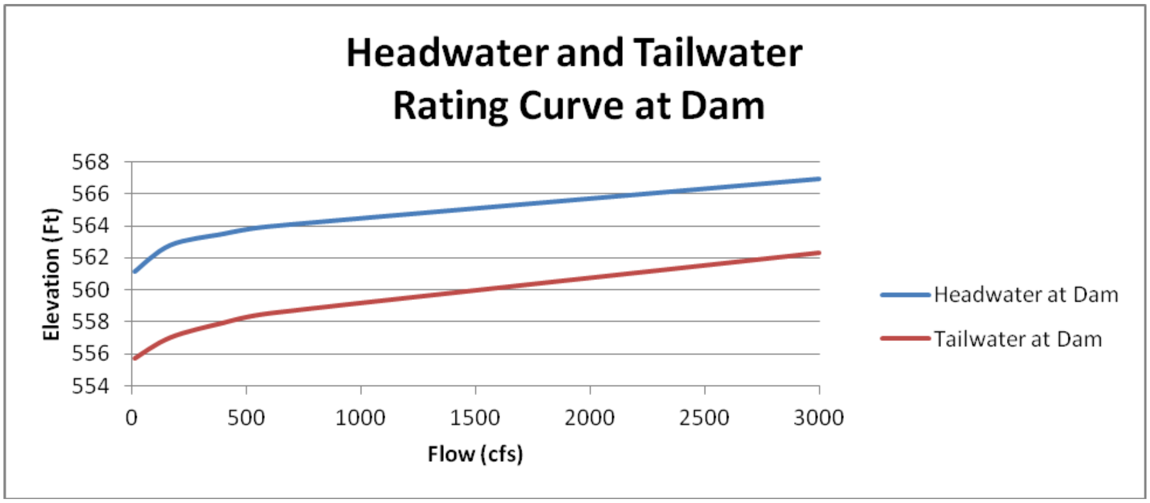

Figure 4. Headwater and Tailwater Rating Curve at the Dam

6. Hydraulic analysis of flow through the fish ladder demonstrating that the ladder functions properly over the anticipated range of stream and ladder flows.

The water depth over the weirs, flow rate in the fish ladder, percent of flow in the fish ladder, and the transitional flow between plunging and streaming flow regimes were analyzed using Equation XII-9 and graph from the California Salmonid Stream Habitat Restoration Manual (Table 2). The transitional flow was determined based on several factors such as the length of pool, height of the weir, fish ladder slope, and width of fish ladder,. The transitional flow was estimated to occur at about 30 cfs. However, the transitional flow can be increased by 25 percent by rounding or chamfering the downstream weir edges. Therefore, the transitional flow could occur at about 37 cfs in the fish ladder.

Table 2. Hydraulic Analysis of Flow Through the Dam Fish Ladder

Estimated Creek Flow (cfs)	Depth of flow over weirs (ft)	Ladder Flow (cfs)	Dam Flow (cfs)	Percent of Flow in Ladder (%)	EDF	Comments
2	0.4	2	0	100	0.5	Design Low Flow
20	1.2	10	10	50	1.8	
40	1.3	11	29	29	1.8	
60	1.4	12	48	21	1.9	
80	1.5	14	66	17	2.0	
165	1.9	21	144	12	2.8	
400	2.1	30	370	8	3.7	Design High Flow

7. Energy dissipation factor calculations at maximum design flow in fish ladder pools

The suggested Energy Dissipation Factor (EDF) for pool style fish ladders is a maximum of 4.0 ft-lb/sec/cf. The EDF in the fish ladder during the maximum design flow is 3.7 ft-lb/sec/cf.

The EDF was calculated using the 30 cfs design high flow, a 0.8-foot head differential, and an effective volume of 8 feet wide by 10 feet long by 5.5 feet deep. The DFG Salmonid Stream Habitat Restoration Manual recommends not using pool lengths greater than 8 feet and depths greater than 4 feet for the effective volume in the EDF equation. For this project, DFG personnel recommended using the entire pool volume instead of the restricted 8 feet by 4 feet.

8. Water stage calculations showing fishway has 3 ft freeboard to keep leaping fish in ladder

See design drawing Sheet 8 in the report for the water surface elevation profile throughout the fish ladder with respect to the top the fish ladder to ensure the 3 feet of freeboard. As indicated in the drawings, a 3-foot freeboard exists throughout the fish ladder during low flow. The freeboard varies from just over 2 to 3 feet during the design high flow of 30 cfs in the fish ladder.

It was recommended by NMFS engineers to ensure a 3 ft freeboard under all operating flows. The walls should be raised to meet this criteria during final design.

9. Flow patterns and in-stream velocities at entrance to fishway

Figure 5 represents the velocities in channel based on the proposed conditions from HEC-RAS at the cross section that intersects the fish ladder entrance. The entrance to the fish ladder is located along the right bank as indicated on the graph. The velocity along the right bank is not the same velocity exiting the ladder, but it is the same as the velocity along the right bank below the dam.

The in-stream velocities at the fish ladder entrance are much less than the velocities exiting the fish ladder. The velocities exiting the fish ladder range from about 1 fps at low flow to about 6 fps at high flow of 400 cfs in Clover Creek. The increased velocities at the fish ladder entrance will act as an attraction to guide fish to the entrance of the fish ladder.

The entrance to the fish ladder is skewed at a 45 degree angle such that the flow exiting the fish ladder will penetrate into the tailwater pool to a greater extent than if aligned perpendicularly to the flow.

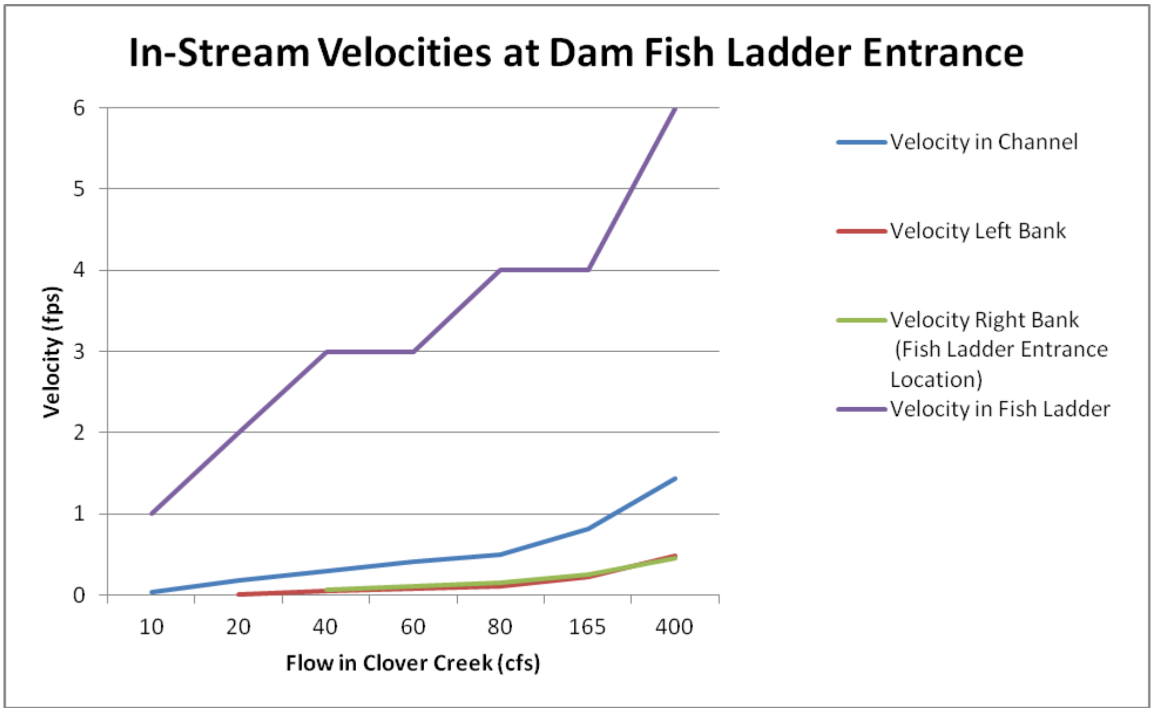

Figure 5. In-Stream Velocities at the Dam Fish Ladder Entrance

10. Geotechnical information may be necessary to ensure project design is structurally appropriate.

A cursory structural analysis was conducted to assess whether fish passage facilities could be constructed on Clover Creek without reducing the structural stability of the existing dam and siphon and whether or not the existing soils are capable of supporting the fish passage structures. The evaluation determined that it is feasible to construct the fish passage facilities without adversely affecting the stability of the existing structures, provided the construction does not significantly disturb the existing siphon. The evaluation also determined that from a bearing capacity standpoint, the creek bedrock is suitable for supporting new fish passage structures. At both the dam and siphon locations, fish passage facilities founded on spread footings will likely attain a high factor of safety against bearing failure. See Appendix E to view the cursory structural analysis summary memorandum.

Geotechnical information may be necessary during final design to ensure project design is structurally appropriate.

11. Design drawings showing site topography, and structural dimensions in plan, elevation, longitudinal profile, and cross-sectional views along with important component details.

See design drawings within the report for details (Sheets 7, 8, and 9.)

12. Maintenance plan which includes preventative and corrective measures, assignment of personnel for maintenance during/after storms, inspection and reporting requirements, maintenance logs, etc.

The dam fish ladder was designed to have low operation and maintenance while providing good fish passage. The primary operation for the dam fish ladder is to ensure a maximum 1-foot elevation drop (or less) between pools. An approximate 6-foot head differential exists during low flow and will be distributed across 7 baffles, which equates to a drop of about 0.8 feet per pool.

The low flow 3-foot wide weir can be adjusted by placing flashboards in the weir (Sheet 9). These adjustments will increase the low flow water surface elevation to aid in the operation of the fish screen and water delivery system. Flashboards can also be placed in the 12-inch vertical slot at the fish ladder entrance to ensure adequate attraction flow exists. Adequate attraction flow should exist when there is a 1-foot head differential across the 12-inch vertical slot.

As incision occurs, a maximum 1-foot head differential between pools will exist. Flashboards might be needed in the 12-inch vertical slot to ensure adequate attraction flow and depth. Further adjustments can be made in the 3-foot wide weir as indicated above.

When maintenance to the ladder is required, flashboards can be used to dewater the structure. Flashboards about 9.5 feet wide can be placed 3 feet upstream of the fish ladder exit (Sheet 8). Water must be pumped out of the pools in order to completely dewater the fish ladder otherwise a minimum depth of 2 to 3 feet will exist in the each pool.

The amount of sediment that moves down the system during high flow events will determine how often maintenance will be required. Pool and weir type fish ladders with no orifices can accumulate sediment and debris which will affect the hydraulics of the ladder if too much buildup of sediment occurs. Because the vertical slot opening continues to the invert of the floor, most sediment should find a path out of the first pool, unless the sediment or debris is larger than the 12-inch slot. Based on the geology in Clover Creek and the habitat typing survey, Clover Creek is sediment limited; thus, it is not anticipated the ladder will require frequent maintenance.

An operation and maintenance plan will be drafted by the final design engineer.

13. If the ladder contains operational components, such as adjustable weirs, multiple entrances, etc., the plans should include an Operations Manual and 1 page operations guide that will be kept on site.

An operation and maintenance plan will be drafted by the final design engineer that will include discussion related to the adjustable weirs.

14. Post construction evaluation and monitoring plan.

Post-project monitoring may consist of an evaluation of migrating adult salmonids, bird monitoring, and water quality and geomorphic monitoring and analyses in Clover Creek. The USFWS, NRCS, and CDFG will also participate in post-monitoring as funding is available. The monitoring of this project is recognized as a necessity to determine success of this project and of future fish passage opportunities in the watershed.

The TAC is currently working on developing the post-project monitoring plan.

Siphon Fish Ladder

1. **Explanation as to why the specific fish passage design was selected, including a discussion of the elements considered when designing the fish ladder entrance.**

    A pool and weir fish ladder was determined to be the best practical fish passage design for the Millville Siphon in Clover Creek. See the Alternatives section of the report for a more detailed discussion regarding the various fish passage alternatives considered for this project.

    Several elements were considered during the design of the fish ladder such as geologic conditions (existing and future), debris load, pool volume, attraction flow, range of flows in the fish ladder, operation and maintenance, and cost. See the Pool and Weir Fish Ladders section within the report for more information related to the elements considered during the design process.

2. **Target species, life stages and migration timing at project site.**

    See Dam Fish Ladder section.

3. **Calculation of lower and upper fish passage stream flows for each lifestage and species**

    See Dam Fish Ladder section.

4. **Calculation showing attraction flow rates are appropriate**

    As recommended by CDFW, two extra baffles were designed in the fish ladder to account for the possibility of 2 feet of incision occurring in the future. To help alleviate backwater conditions at the fish ladder entrance during current conditions, removable flashboards and a 12-inch wide vertical entrance slot was incorporated in the design.

    Removable flashboards will be used permanently in baffles 2 through 5 until incision occurs (Sheet 4). The use of the flashboards will create a situation where the first two weirs will be at the same elevation, thus eliminating 1 foot of drop, but backwater conditions will still be a concern. The vertical slot entrance pool will help create attraction flow due to the constricting 12-inch slot.

    Attraction flows were analyzed by determining the velocity through the 12-inch wide vertical slot over a range of flows in the fish ladder. As shown in Table 3, the velocities range from about 1 fps to 2 fps for flows ranging from 3 cfs to 11 cfs in the fish ladder. The velocity jetting through the vertical slot during the design high flow of 22 cfs is estimated at about 4 fps.

Table 3. Entrance Velocities in the Siphon Fish Ladder

Q Ladder (cfs)	Q Channel (cfs)	Depth in Pool (ft)	Entrance Velocity (fps)
3	10	3.5	1
4	20	3.7	1
5	40	3.9	1
6	60	4.1	2
7	80	4.3	2
11	165	4.8	2
22	400	5.8	4

5. Rating curves for headwater and tailwater conditions

Figure 6 represents the headwater and tailwater condition for the proposed fish ladder at the siphon over a range of flows. The maximum head difference is about 4.1 feet and the minimum head difference is about 2.4 feet.

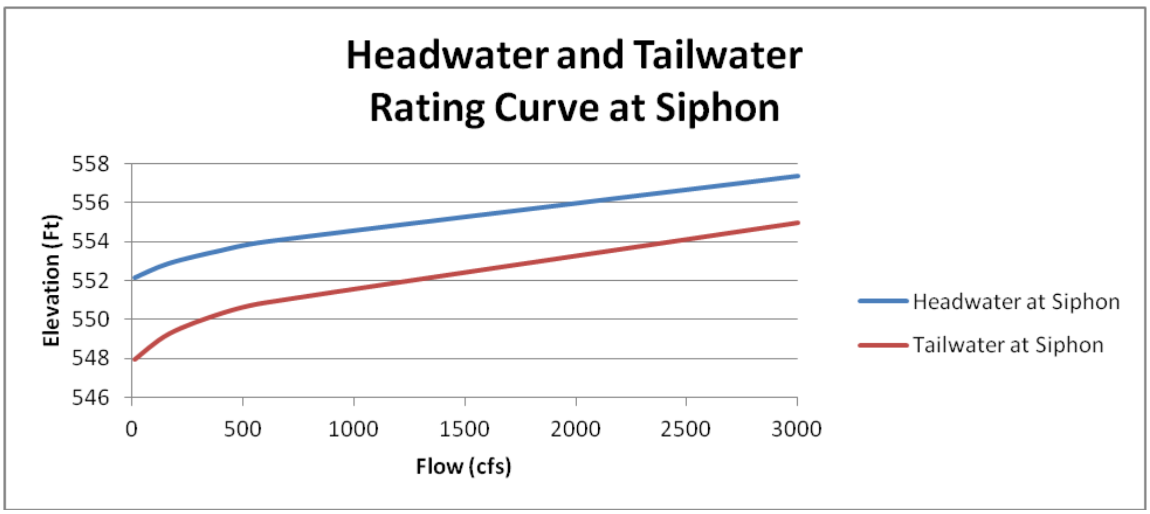

Figure 6. Headwater and Tailwater Rating Curve at the Siphon

6. Hydraulic analysis of flow through the fish ladder demonstrating that the ladder functions properly over the anticipated range of stream and ladder flows.

The transitional flow between plunging and streaming flow regimes were analyzed using Equation XII-9 and graph from the California Salmonid Stream Habitat Restoration Manual. The transitional flow was determined based on several factors such as the length of pool, height of the weir, fish ladder slope, and width of fish ladder. The transitional flow was estimated to occur at about 15 cfs. However, the transitional flow can be increased by 25 percent by rounding or chamfering the downstream weir edges. Therefore, the transitional flow could occur at about 19 cfs in the fish ladder.

The water depth over the weirs, flow rate in the fish ladder, percent of flow in the fish ladder, and the transitional flow between plunging and streaming flow regimes were analyzed using Equation XII-9 and graph from the California Salmonid Stream Habitat Restoration Manual (Table 4). The transitional flow of 19 cfs in the fish ladder occurs during a flow regime of about 300 cfs in Clover Creek with an EDF of 3.7. Flashboards can be used in the fish ladder at flows above 300 cfs in Clover Creek to decrease flows in the fish ladder in order to help diminish turbulence due to transitional flows and to help maintain a maximum EDF value of 4.0 ft-lb/sec/cf.

Table 4. Hydraulic Analysis of Flow through the Siphon Fish Ladder

Estimated Creek Flow (cfs)	Depth of flow over weirs (ft)	Ladder Flow (cfs)	Dam Flow (cfs)	Percent of Flow in Ladder (%)	EDF	Comments
2	0.5	2	0	100	0.7	Design Low Flow
20	0.7	4	16	20	1.1	
40	0.9	5	35	13	1.4	
60	1.0	6	54	10	1.6	
80	1.1	7	73	9	1.6	
165	1.4	11	154	7	2.4	
400	1.5	22	378	6	3.6	Design High Flow

7. Energy dissipation factor calculations at maximum design flow in fish ladder pools

EDF was calculated using the 22 cfs design high flow, a 0.6 ft head differential, and an effective pool volume of 6 feet wide by 8 feet long by 5 feet deep. The DFG Salmonid Stream Habitat Restoration Manual recommends not using pool lengths greater than 8 feet and depths greater than 4 feet for the effective volume in the EDF equation. For this project, CDFW recommended using the entire pool volume instead of the restricted 8 by 4 feet.

8. Water stage calculations showing fishway has 3 ft freeboard to keep leaping fish in ladder

Sheet 3 in the report shows the water surface elevation profile throughout fish ladder with respect to top of wall of fish ladder to ensure 3 feet of freeboard. As indicated in the drawings, a 3-foot freeboard exists during low flow. A 2-foot freeboard exists at the fish ladder exit and increases downstream in the fish ladder to a 3-foot freeboard at the fish ladder entrance during the design high flow of 22 cfs in the fish ladder.

It was recommended by NMFS engineers to ensure a 3 ft freeboard under all operating flows. The walls should be raised to meet this criteria during final design.

9. Flow patterns and in-stream velocities at entrance to fishway

Figure 7 represents the velocities in channel based on the proposed conditions from HEC-RAS at the cross section that intersects the fish ladder entrance. The entrance to the fish ladder is located along the right bank. The velocity along the right bank is not the same velocity exiting the ladder, but it is the same as the velocity along the right bank below the dam.

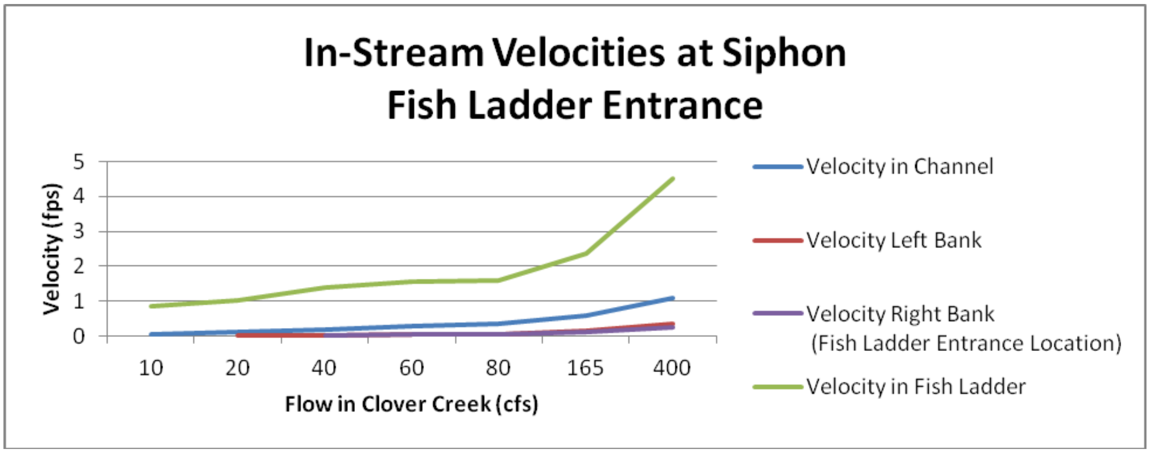

Figure 7. In-Stream Velocities at the Siphon Fish Ladder Entrance

The in-stream velocities at the fish ladder entrance are much less than the velocities exiting the fish ladder. The velocities exiting the fish ladder range from about 1 fps at low flow to about 5 fps at high flow of 400 cfs in Clover Creek. The increased velocities at the fish ladder entrance will act as an attraction to guide fish to the entrance of the fish ladder.

The entrance to the fish ladder is skewed at a 45 degree angle such that the flow exiting the fish ladder will penetrate into the tailwater pool to a greater extent than if aligned perpendicularly to the flow.

10. Geotechnical information may be necessary to ensure project design is structurally appropriate.

A cursory structural analysis was conducted to assess whether fish passage facilities could be constructed on Clover Creek without reducing the structural stability of the existing dam siphon and whether or not the existing soils are capable of supporting the fish passage structures. The evaluation determined that it is feasible to construct the fish passage facilities without adversely affecting the stability of the existing structures, provided the construction does not significantly disturb the existing siphon. The evaluation also determined that from a bearing capacity standpoint, the creek bedrock is suitable for supporting new fish passage structures. At both the dam and siphon locations, fish passage facilities founded on spread footings will likely attain a high factor of safety against bearing failure. See Appendix E to view the cursory structural analysis summary memorandum.

Geotechnical information may be necessary during final design to ensure project design is structurally appropriate.

11. Design drawings showing site topography, and structural dimensions in plan, elevation, longitudinal profile, and cross-sectional views along with important component details.

See Sheets 2 through 4 of the report for details.

12. Maintenance plan which includes preventative and corrective measures, assignment of personnel for maintenance during/after storms, inspection and reporting requirements, maintenance logs, etc.

The siphon fish ladder was designed to have low operation and maintenance while providing good fish passage. The primary operation for the siphon fish ladder, before incision occurs, will be to ensure the flashboards are in place and attraction flow exists at the entrance. Flashboards might be needed in the 12-inch entrance slot to increase the head difference at the downstream end of the fish ladder so that attraction flow is achieved.

As water enters the fish ladder exit, and the flashboards are installed in baffles 2 through 5, the water surface elevation between the first two baffles does not change. Not until incision occurs, and the flashboards are removed, will a 1-ft drop exist between the first two baffles. During this scenario, the existing 4-foot head difference during low flow will be distributed across 5 baffles which equates to a 0.8-foot head differential between pools. Further adjustments can be made by placing flashboards in the 2-foot wide weir, as needed, to ensure proper hydraulics in the fish ladder.

When a total of 2 feet of incision occurs at the siphon area, all flashboards will be removed and a 1-foot head differential will exist throughout each pool creating a total head differential of 6 feet.

When maintenance is required, flashboards can be used to dewater the structure. Flashboards about 6.5 ft wide can be placed 3-ft upstream of the fish ladder exit (Sheet 3). Water must be pumped out of the pools in order to completely dewater the fish ladder otherwise a minimum depth of 2-3 feet will exist in the each pool.

The amount of sediment that moves down the system during high flow events will determine how often maintenance will be required. Pool and weir type fish ladders with no orifices can accumulate sediment and debris which will affect the hydraulics of the ladder if too much buildup occurs. Because the vertical slot opening continues to the invert of the floor, most sediment should find a path out of the first pool, unless the sediment or debris is larger than the 12-inch slot. Based on the geology in Clover Creek and the habitat typing survey, Clover Creek is sediment limited thus it is not anticipated the ladder will require frequent maintenance.

An operation and maintenance plan will be drafted by the final design engineer.

13. If the ladder contains operational components, such as adjustable weirs, multiple entrances, etc., the plans should include an Operations Manual and 1 page operations guide that will be kept on site.

An operation and maintenance plan will be drafted by the final design engineer that will include discussion related to the adjustable weirs.

14. Post construction evaluation and monitoring plan.

Post-project monitoring may consist of an evaluation of migrating adult salmonids, bird monitoring and, water quality and geomorphic monitoring and analyses in Clover Creek. The USFWS, NRCS, and CDFG will also participate in post-monitoring as funding is available. The monitoring of this project is recognized as a necessity to determine success of this project and of future fish passage opportunities in the watershed.

The TAC is currently working on developing the post-project monitoring plan.

APPENDIX G

DWR Response to NOAA Fisheries' Comments

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APPENDIX G

DWR's Response to NOAA Fisheries' Comments on Preliminary Design for Clover Creek / Millville Diversion Fish Passage Project

By:
Steve Thomas, P.E.
steve.thomas@noaa.gov

Review of:
Preliminary Engineering Technical Report, December 2012
Design Drawings (10 sheets)
CDFW project checklists for two fish ladders and one fish screen

Preliminary Engineering Technical Report.

1. **Page 19: Water Rights**
   There are some discrepancies in the amount of water expected to be diverted from the facility. The diversion serves MDA and Oiler water rights for a total of 6.5 cfs which is 27.6% of 23.6 cfs, the total water rights on Clover Creek. The report states when there is surplus water the ditch could take up to 27.6% more water, i.e. up to 8.2 cfs. It seems the ditch should be able to take up to an additional 27.6% of surplus flows, not an additional 27.6% of its water right; therefore the maximum diversion rate would depend on the amount of surplus water in the creek and the capacity of the diversion pipe and ditch. A smooth walled plastic pipe on a 1% slope (page 40) would have a capacity far in excess of 8.2 cfs.

   How will diversion rates be limited to 8.2 cfs? If there is a chance the diversion will take more than 8.2 cfs the screen should be sized for the larger amount.

   > Adjustments will be made to the headgate and louvers to ensure the maximum diversion rate is limited to 8.2 cfs or less. The existing Parshall Flume will be used to verify the amount of water being diverted and whether or not adjustments to the headgate are needed.

2. **Page 34, paragraph 3**
   the report states, "Depending on the amount of sediment that moves down the system during high flow events will depend on how often maintenance will be required." Woody debris may require a larger maintenance demand than sediment. The fishway must be kept clear of woody debris to provide unimpeded passage, especially during and after storm events when fish passage is needed and debris is most likely to accumulate in the fishway.

   > The Operation and Maintenance manual will state that the diverters will be required to ensure the fishway is clear of any debris.

3. **Page 35, Table 3.**
   The EDF exceeds the design value at the high fish passage flow. Why isn't the ladder at the siphon the same size as the one at the dam? Both need to accommodate the same flows and meet the same criteria.

   A 6-inch tall flashboard must be placed in both the dam and siphon ladder during high flow in order to meet the EDF criteria.

   The TAC recommended placing the ladder at the siphon as far on the right of the channel as possible to keep the ladder out of the main channel. To accommodate this recommendation, the ladder had to decrease in size to fit in that area.

   In addition, the head differential is much less at the siphon than at the dam–3 and 6 feet at 400 cfs, respectively. Fish are currently able to negotiate over the siphon structure at some flows; however, the dam is a complete barrier. Both ladders are able to operate at flows up to 400 cfs while meeting the EDF criteria.

4. **Page 36,**
   Using flashboards in the vertical slot entrance will help create a stronger jet of water to attract fish to the fish ladder, although doing so may decrease the flow through the ladder at some flows. All flashboards will need to be customized for each slot to optimize the performance of the fish ladder. A fish passage engineer familiar with the design and operation of fish ladders should set up the ladder for the expected range of flows at the earliest opportunity.

   DWR and CDFW staff are planning to set up the ladder for the expected range of flows as soon as possible after construction.

5. **Page 37, paragraph 4**
   The report states the screens will need 2 ft of depth to meet the design approach criterion of 0.33 fps. Will the hydraulics of the diversion allow more than 8.2 cfs into the pipe with a water depth of 2 ft?

   No—The screen area and the culvert were sized to meet the maximum diversion rate at 2 feet of depth.

   The report states that as water levels in the creek decrease, so does the amount of water delivered to MDA. Do flow rates decrease proportionally to wetted screen area? The report should have a hydraulic analysis of the intake pipe to show diversion rates over the expected range of water surface elevations in the creek.

   Figure 1 shows the diversion rates over the expected range of water surface elevations in the creek. The approach velocity through the fish screen was also plotted. The approach velocity through the screen was calculated by reducing the area of the actual screen area by 25 percent to compensate for structural members.

   The Operation and Maintenance manual will state that MDA will need to lower the headgate or modify the louver settings when the water being diverted exceeds their allowable diversion rate.

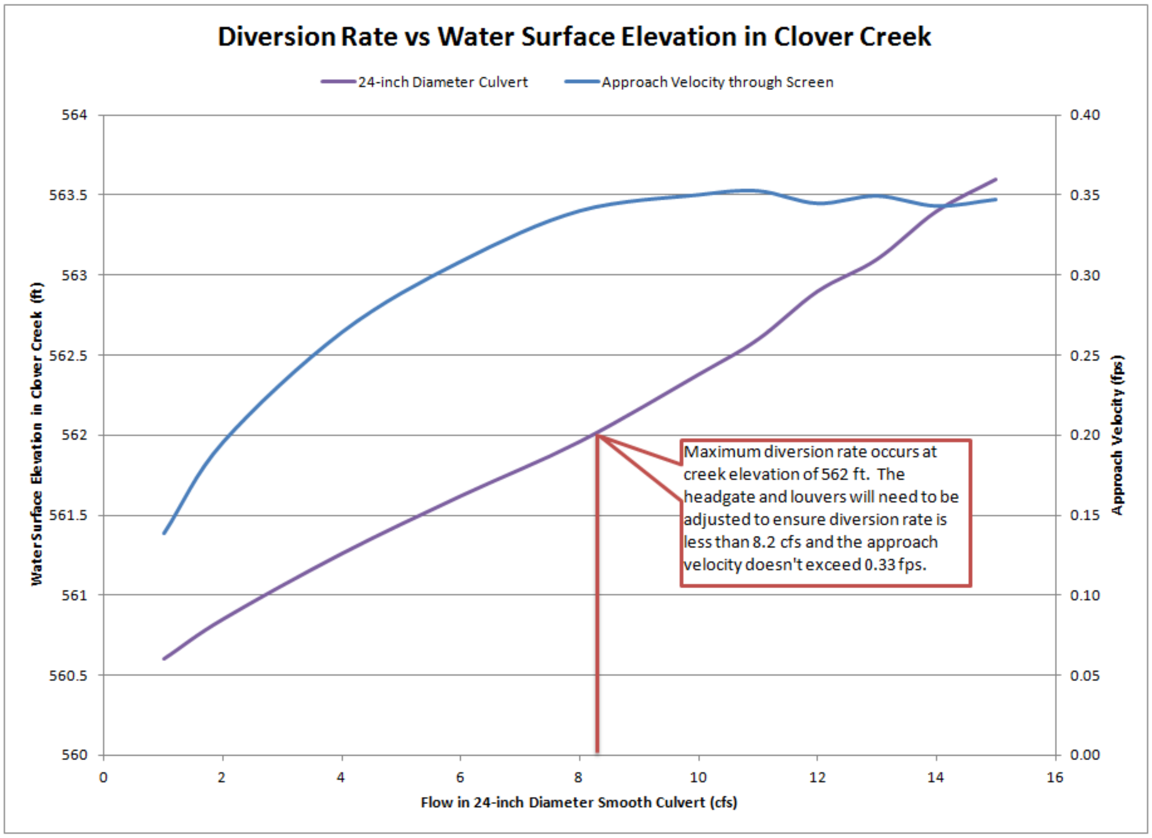

Figure 1. Diversion Rate versus Water Surface Elevation in Clover Creek.

6. **Page 38, paragraph 1**
   Details of screen panels, screen panel slots, and dewatering panels and their slots, should be included in the next level of design submittal.

   The details will be completed during the final design phase.

7. **If the headgate at the diversion entrance will be used to limit diversion rates to 8.2 cfs, some means of preventing the gate from opening fully should be included to ensure approach velocities are not exceeded.**

   The details will be completed during the final design phase.

Design Drawings

1. **Sheet 3: Fish ladder at siphon**
   The dimensions are not consistent between the plan and profile views. The plan view shows 8 ft long pools and 1 ft thick weirs for a slope of 1:9, but the profile view shows a foundation slope of 1:11.

   The actual slope is 1:9 and has been fixed in the drawings.

2. **Sheet 3: Fish ladder at siphon**
   The ladder provides only 2 ft of freeboard at the high fish passage design flow, but the criterion is 3 ft. Can the side walls be raised one foot to meet this criterion?

   The TAC expressed concern about reducing the flood flow capacity under the bridge, so the design included a ladder with the smallest footprint possible. Raising the walls one foot to meet criteria was re-analyzed and results show 0.05 of a foot increase in water surface elevation at 3,000 cfs. This is not a significant impact; thus, the walls should be raised one foot during final design to meet criteria.

3. **Sheet 10: Fish screen**
   The design should include some means of tuning the screen to achieve uniform approach velocities over all wetted screen area. The proposed design has none.

   Including louvers behind the screen face should be incorporated into the final design to help eliminate "hot spots" along the screen face.

CDFW Checklist

Comments included in margins of the checklist and summarized below.

Fish Screen Checklist

1. **Item 8, comments ST1-ST3: Same comment as made above regarding the capacity of the diversion system and the amount of wetted screen area provided. How will diversion rates be limited to a given flow, and will there always be sufficient wetted screen area for the diversion rate? The report should provide a chart showing diversion rate versus water surface elevation in the creek with a clean screen.**

   Please see Figure 1.

2. **Item 9, comment ST4: some means of adjusting approach velocities should be included in the design. This could be as simple as channels or stop log slots into which baffles may be installed after a hydraulic evaluation of the project.**

   This should be included and evaluated during final design.

3. **Item 17, comment ST5: The statement doesn't answer the question. If the paddle wheel-driven cleaning system fails will there be enough screen area to meet the CDFW passively cleaned screen criteria, i.e. and approach velocity of 0.08 fps? Please check with CDFW to receive a variance from this criterion if appropriate.**

   The required fish screen area was increased by 25 percent to account for structural members (or blockage) with an approach velocity of 0.33 fps. If the paddle wheel-driven cleaning system fails, the approach velocity will exceed the 0.08 fps criteria for screens which are not self cleaning. The Operation and Maintenance manual will state who will be required to inspect and maintain the fish screen and ladders.

4. **Item 23, comments ST6 & ST7: The screen will require regular inspections and maintenance. CDFW screen shop personnel can give a reasonable estimate of how much maintenance will be required. It is my understanding that paddle wheel-driven screen cleaning systems should be inspected several times each week. Also, the diversion owner/operator should maintain a log of maintenance records.**

   The Operation and Maintenance manual will specify the responsible party for inspecting and maintaining the fish screen and ladders.

Dam Fish Ladder

1. **Item 7, comment ST8: EDF values were calculated using 0.8 ft of head differential across each baffle, but the ladder is expected to be operated at 1.0 ft head differential in the future. The ladder should be designed to meet the current EDF criterion under all conditions foreseen in the life of the project, i.e. 4.0 ft-lbs / s / ft^3 at 1.0 ft of head differential. The proposed design does not meet this criterion at the high fish passage flow.**

   The fish ladder at the dam was designed to accommodate a "potential" 1-foot incision according to CDFW recommendation. EDF values for current conditions have been met, but as incision occurs, the EDF will be increased to 4.3 ft-lbs/s/cf. When an incision of 1 foot does occur, the ladder will function at a reduced high flow rate than originally designed in order to meet the 4.0 ft-lbs/s/cf criteria.

   After incision occurs, a flow of 300 cfs and a 6-inch flashboard in the low flow weir would meet the 4.0 ft-lbs/s/cf criteria. At this creek flow, the flow in the fish ladder would be about 25 cfs, which accommodates about 8 percent of the design high flow in the fish ladder.

2. **Item 8, comment ST9: The criterion requires 3 feet of freeboard in the ladder but the design has only 2 feet of freeboard at the high fish passage flow; therefore, the ladder design does not meet this criterion.**

   Walls in the fish ladder should be raised during final design to meet the 3-foot freeboard criteria.

   Item 12, comment ST10: Woody debris removal will also be required, especially soon after high flow events. The ladder must be inspected regularly during high flow events during the passage season to ensure passage is always available to fish.

   The Operation and Maintenance manual will specify the responsible party for inspecting and maintaining the fish screen and ladders.

Siphon Fish Ladder

1. **Item 6, comment ST11: It seems this ladder is undersized. It must operate under the same conditions as the ladder at the dam, but is significantly smaller. It will operate in streaming flow within the fish passage window, and the EDF criterion will not be met at all fish passage flows.**

   The siphon fish ladder is smaller than the dam fish ladder due to the topographic footprint available. The TAC recommended placing the fish ladder along the right bank of the creek. Due to the bridge abutments, there is minimal amount of space to place the ladder, so the fish ladder had to be reduced in size.

   In addition, the head differential is much less at the siphon than at the dam—3 and 6 feet at 400 cfs, respectively. Fish are currently able to negotiate over the siphon structure at some flows; however, the dam is a complete barrier. Both ladders are able to operate at flows up to 400 cfs while meeting the EDF criteria.

2. **Item 7, comment ST12: The EDF values were calculated assuming only 0.6 ft head differential at each baffle, but the ladder is expected to operate at 1.0 ft of head differential in the future.**

   In order to accommodate a flow of 400 cfs in Clover Creek, the EDF was pushed to 4.4 ft-lbs/s/cf for current conditions. This would be the worst case scenario if no adjustments to the fish ladder occurred. In order to stay within the criteria, a 6-inch flashboard should be placed in the low flow weir to achieve an EDF value of 3.6 ft-lbs/s/cf. As incision occurs (possibly up to 2 feet), the EDF value increases to 6.8 ft-lbs/s/cf for a flow of 400 cfs. At which time, the high flow capacity in the fish ladder will be less than the original design to meet the 4.0 ft-lbs/s/cf criteria.

   After incision occurs, a flow of 300 cfs, with flashboards blocking the low flow weir, would achieve an EDF value of 3.8 ft-lbs/s/cf criteria. At this creek flow, the flow in the fish ladder would be about 14 cfs in the fish ladder, which accommodates about 5 percent of the design high flow in the fish ladder.