LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

FISH PASSAGE FACILITIES ALTERNATIVES ASSESSMENT
WORKSHOP NO. 4

JANUARY 27, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Workshop No. 4

Wednesday, January 27, 2016
9:00 am to 12:00 pm

Meeting Notes

On January 27, 2016, Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) hosted the fourth Workshop (Workshop No. 4) for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment (the Study). This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting. Attachment A to this document includes the following meeting documents: agenda, sign-in sheets, presentation slides, and handouts.

Mr. John Devine (HDR, Inc. [HDR]), consultant to the Districts, welcomed Workshop participants. Attendees in the room and on the phone introduced themselves. The following individuals participated remotely: (1) Mr. Peter Barnes (State Water Resources Control Board); (2) Ms. Adrianne Carr (Bay Area Water Supply and Conservation Agency); (3) Ms. Jesse Deason (HDR); (4) Mr. Steve Edmondson (National Marine Fisheries Service [NMFS]); (5) Mr. Tim Heyne (California Department of Fish and Wildlife [CDFW]); (6) Mr. Tom Holley (NMFS); (7) Ms. Trudi Hughes (California League of Food Processors) and; (8) Mr. John Wooster (NMFS).

Mr. Devine asked if any Workshop participants would like to make opening remarks. No participants volunteered. Mr. Devine reviewed the meeting agenda. He stated that today's meeting is a follow-up to Workshop No. 3 (held on November 19, 2015; meeting notes and materials are available here on the La Grange Project Licensing Website), in which attendees agreed to begin implementation of an Upper Tuolumne River Reintroduction/Fish Passage Assessment Framework (Framework) as described and discussed at Workshop No. 2 (held on September 17, 2015; meeting notes and materials available here). Mr. Devine said that in Workshop No. 3, the Districts proposed a plan to implement the Framework; one of the items on today's agenda is to discuss and reach consensus on implementing that process.

Mr. Devine said implementing the Framework will require a fair amount of technical work, including preparing study plans and reviewing study reports. As such, the Districts are suggesting that a Technical Committee, made up of volunteers from this larger group (Plenary Group), be formed to assume some of the technical responsibilities of implementing the Framework. The Technical Committee would report to the Plenary Group (i.e., all Framework participants).

Mr. Devine said another purpose of today's meeting is to discuss studies to complete in 2016 to support the Framework. The Districts prepared a list of potential studies and had provided a list with abstracts prior to the Workshop. Mr. Devine added that this list of studies is intended to jump-start discussion about which studies would be most relevant to support the Framework. It is not intended that all studies be conducted. Mr. Devine said today's meeting also includes a presentation of what data exist for the reach under consideration for reintroduction, which is defined as the mainstem Tuolumne River upstream of the Don Pedro Reservoir to Early Intake and associated tributaries (accessible reaches of these tributaries) within this reach.

Mr. Devine asked for thoughts or comments on his remarks. There were none.

Mr. Devine summarized the discussions at Workshops No. 2 and No. 3 and noted that consensus had been reached on implementing the Framework. The Framework considers fish passage engineering to be but one of several key components of assessing fish reintroduction. The other components are ecological feasibility; biological constraints; and economic, regulatory, and effects on other uses.

Mr. Devine introduced Mr. Bao Le (HDR). Mr. Le presented slides on the goals of and schedule for the Framework. Mr. Le said the overarching goal of the Framework is to evaluate the feasibility of reintroducing anadromous salmonids into the upper Tuolumne River by applying a structured assessment process. The process is an integrated evaluation of ecological, biological, engineering, economic, regulatory, and other key considerations related to reintroduction. Mr. Le said that HDR estimates that implementing the Framework would require considerable effort and entail a phased approach. In order to be respectful of the level of effort asked of all participants, the Framework considers the use of a Technical Committee that reports to the Plenary Group. Mr. Le summarized activities proposed for Phase 1 and Phase 2. Mr. Le said the Districts would like to arrive at a consensus at today's meeting on use of the Framework implementation plan, the associated schedule, and use of a Technical Committee.

Mr. Devine said one goal of the Framework is to arrive at an information base that was developed through studies where all parties agreed on the study scope, methods, and data collected. Mr. Devine said the goal is to achieve this by providing all parties the opportunity to participate in study development, implementation, and reporting.

Mr. Le reviewed the Upper Tuolumne River Reintroduction/Fish Passage Assessment Framework Flow Chart (Flow Chart). Phase 1 and Phase 2 would each occur over approximately a one-year period.

Ms. Dana Ferreira (Office of U.S. Congressman Jeff Denham) asked who would participate on the Technical Committee. Mr. Le said all are welcome to participate on the Technical Committee. Individuals who are interested in participating should email Ms. Rose Staples (HDR) (Rose.Staples@hdrinc.com). Ms. Ferreira asked how a diverse and representative Technical Committee could be ensured if it is made up only of volunteers. Mr. Le said that, depending on who volunteers, the Districts may ask additional individuals to participate to ensure a broad representation.

Mr. John Buckley (Central Sierra Environmental Resource Center [CSERC]) said participation on the Technical Committee may not be possible for small organizations, such as CSERC, that have small staff sizes and do not have the resources to fund consultants to participate on their behalf. Mr. Buckley asked if support will be available for such groups to participate. Mr. Devine said the Technical Committee would meet via conference call, instead of in person, to help minimize the time commitment. Mr. Buckley said participation on the Technical Committee will require working with and discussing highly technical subject matter, such as PHABSIM and weighted usable area, and individuals who are considering participating on the Technical Committee should be aware of this.

Mr. Le reviewed the Flow Chart, Information Needs, and Potential Studies Table (Studies Table). In the beginning of 2016, the Plenary Group would identify which studies would be completed and which entity(ies) would be responsible for completing each study. Mr. Le stated that study plans would be developed and the studies would be completed from spring through fall. Also in 2016, the Technical Committee would need to develop reintroduction goals. Mr. Le said by the end of 2016, the results from the studies would be available to begin evaluating whether the reintroduction goals identified could be met (i.e., is reintroduction feasible?).

Mr. Edmondson asked how decisions will be made in the Technical Committee, such as by unanimous or majority vote, and what the relationship will be between the Technical Committee and the Plenary Group. Mr. Edmondson asked if the findings of the Technical Committee will be considered as binding or as recommendations. Mr. Devine said the Technical Committee will provide technical feedback to the Plenary Group and will make decisions internally by majority vote. The Technical Committee is a venue for collaboration; it cannot compel agreement, nor can it require or limit any parties' activities. Mr. Devine said there will likely be differences of opinion among Technical Committee members and it will be important that those differing opinions be documented. Mr. Devine said feedback from the Technical Committee would be considered by the Plenary Group as information sharing and there would not be a formal governance structure. Mr. Edmondson asked how the role and structure of the Technical Committee will be documented. Mr. Devine suggested that the Workshop No. 4 meeting notes be used to document this discussion. No individuals disagreed with Mr. Devine's suggestion.

An individual asked if the final Study Report will include a decision about fish reintroduction or if the report will simply present the issues and document the process. Mr. Devine said the latter is a more likely outcome, but the former would be ideal.

Mr. Le resumed his presentation. He noted that in order to remain on the proposed Framework schedule, the next Plenary Group meeting will be in mid-April.

Mr. Edmondson suggested that the Technical Committee's discussions and decisions be documented so that individuals who do not participate may still be kept aware of what happens on the Technical Committee. Mr. Devine agreed. Mr. Shelton (CDFW) said his staff is spread thin and completing some of the work via Technical Committee may make for more efficient meetings, but may also make it more difficult for small organizations to participate. Ms. Jennifer Shipman (Manufacturer's Council of the Central Valley) agreed with Mr. Shelton. Ms. Shipman said she supports the Framework and believes having a Technical Committee will result in a more transparent and efficient approach. Ms. Shipman suggested that individuals be allowed to provide written comments after Technical Committee meetings, to allow individuals unable to attend a chance to provide input to the process. No party disagreed with this.

Mr. Wooster asked Mr. Devine to summarize the relationship between the Framework and the Study. Mr. Devine explained that Technical Memorandum (TM) No. 1 issued in September 2015 (available online here) identified a number of information gaps that are required to move forward with developing engineering alternatives and reliable cost estimates. Mr. Devine provided examples of data gaps described in TM No. 1, such as what target fish species and population sizes should be considered when developing engineering alternatives. Mr. Devine said that by the end of 2016, the goal is to have all the information needed to produce the concept-level facility layouts that are realistic and defensible. In 2017, more detailed engineering alternatives assessments could be produced and modified if there were additional studies needed in 2017. Mr. Wooster asked how completing engineering alternatives analyses in 2017 will align with the La Grange Project Federal Energy Regulatory Commission (FERC) schedule. Mr. Devine said that once the Districts were provided the basic information requested in TM No. 1, issued to licensing participants in September 2015, they could begin conceptual engineering of alternatives. These could be sufficiently complete in 2016 to determine if a reservoir transit study is warranted. The FERC study schedule, as outlined in FERC's February 2, 2015 Study Plan Determination (SPD), adopted a two-year (2015 and 2016) study schedule, but also acknowledged that additional studies may be needed, presumably in 2017. Mr. Devine pointed out that the FERC-approved two-year La Grange barrier study already extends to September 2017 (see page B-6 of the SPD). Mr. Devine said the proposed schedule for implementing the Framework is not inconsistent with that FERC study schedule. Mr. Devine noted that FERC has not issued a schedule yet for submittal of a Draft or Final License Application. Mr. Devine said the Districts anticipate that FERC would be amenable to this process if the collaborative group is in agreement and working together. Mr. Devine indicated that he believes FERC is seeking cost estimates and concepts for fish passage that are realistic, reliable, and not built simply on a series of assumptions.

Mr. Wooster said the schedule in the Study Plan states engineering alternatives will be developed in 2016. Mr. Wooster said now that the engineering alternatives will not be developed until 2017, and therefore the reservoir transit study may not occur until 2018, this would be at odds with the schedule in the SPD. Mr. Devine said the reservoir transit study may possibly occur in 2018 but it is more likely that engineering alternatives can be sufficiently far along by the end of 2016/early 2017 to allow any reservoir transit study to take place in 2017, possibly along the same schedule as the FERC-approved La Grange barrier study. .

Mr. Edmondson said he sees a risk in FERC not concurring with a change to the schedule and the Plenary Group should have a good reason for changing the schedule. Mr. Devine stated that there currently is no FERC-specified schedule for filing a Draft and Final License Application for the La Grange Project. Mr. Devine pointed to the December 7, 2015 letter the Districts filed with FERC noting the inconsistency between the schedule in Scoping Document 2 and the SPD. He added that one reason for holding Workshop No. 4 prior to the La Grange Project Initial Study Report (ISR) meeting, scheduled for February 25, is to have the Plenary Group potentially come to agreement on an implementation schedule and then be able to document this agreement in Workshop No. 4 meeting notes and present the agreed-upon path forward at the ISR meeting and in the ISR meeting notes, which will all be filed with FERC. Mr. Devine said this would create an opportunity for FERC to accept this process and for FERC to understand the level of support for this process by the Workshop participants. Mr. Wooster said he believes the engineering-related Study should remain on track to reach a decision in 2017, regardless of whether a reservoir transit study is completed. Mr. Wooster said many studies proposed for 2016 will help refine the engineering analysis, but will not prevent the engineering analysis from moving forward at least conceptually. Mr. Devine said the Districts would entertain continuing to move ahead with engineering where possible, but that key questions remain, for example, the performance standards and expectations for the passage facilities. Mr. Devine said he believes the Plenary Group can arrive at answers based on good information prior to 2017 so that the Districts can move forward with all aspects of the engineering. Mr. Wooster reiterated he believes that the conceptual engineering can move forward without having to deviate from the schedule in the SPD.

Mr. Buckley said a challenging aspect of this schedule is the current lack of reintroduction goals. Mr. Buckley said the Districts would like an end result that minimizes cost and the amount of water that must be provided downstream, while other entities, such as the fish agencies, would like a significant improvement to the viability of salmon and steelhead in the Tuolumne River and increased flows. Mr. Buckley said that without a consensus on goals, it is difficult to come to agreement on schedule. Mr. Devine said the Districts agree with that, and hope that reintroduction goals will be established by mid-2016.

Mr. Edmondson said it may be helpful for some individuals at this meeting if Mr. Devine reviewed the steps in the engineering design process. Mr. Devine provided an overview of the engineering design process that will occur for the Study and described different types of volitional and non-volitional fish passage facilities.

Ms. Shipman asked when in the process the issue of predation will be considered. Mr. Devine said that if a floating surface collector was considered for Don Pedro Reservoir, predation in the reservoir would be evaluated to help estimate the likely success of the facility. Predation in the river below La Grange Diversion Dam would also be considered when estimating the likelihood of successful outmigration.

Ms. Shipman asked if fall-run Chinook salmon, spring-run Chinook salmon, and steelhead could use the same fish passage facilities. Mr. Devine said different species may be able to use the same facilities, but the facilities would need to be able to operate at different flow conditions because different species would arrive to the facilities at different times of the year. Mr. Devine said because fish size varies among species, the facilities would also need to be able to accommodate different fish sizes and run sizes.

Mr. Larry Byrd (MID) asked for clarification on the difference between "volitional" and "non-volitional" fish passage facilities. Mr. Devine replied that volitional means that fish can move upstream and/or downstream under their own power and motivation. For example, fish must "decide", and be sufficiently fit, to climb a fish ladder in order to migrate upstream past a barrier. In contrast, "trap and haul" fish passage requires that fish be collected, transported, and released under a schedule imposed by active intervention. Mr. Byrd said it may not be necessary to consider volitional upstream passage facilities, such as a fish ladder, because the fish that arrive at La Grange Diversion Dam do not have the energy to use such a facility. Mr. Devine said different species of upstream migrating fish will likely arrive at the facility in different conditions, which is another consideration of facilities design. Workshop participants discussed the possibility of using a combination of volitional and non-volitional facilities at a single project.

Mr. Buckley said the results of 2016 studies may be affected by the ongoing drought and effects of the Rim Fire. Mr. Buckley said because of the current anomalous conditions, study results may not be representative of what could be expected to occur over the course of a FERC license period. Mr. Devine said he agreed and that all parties would need to be cognizant of current conditions.

Mr. Devine reviewed the Flow Chart and Studies Table. Studies with an "X" are ongoing and studies with a "P" are suggested by the Districts' technical team. Mr. Le said the table does not differentiate between Phase 1 and Phase 2 studies, but the Districts think that studies deemed to be high priority for Phase 1 would be accomplished in 2016. Mr. Devine said the cost estimates are not firm but only indicative of the effort required to collect these data. Regarding the Habitat Typing and Characterization Study, Mr. Wooster said NMFS is conducting a study using remote sensing data and that some of the remote sensing depth data will be ground-truthed. Given NMFS' study, Mr. Wooster thought the Studies Table could be revised to state that this study is ongoing, and not proposed, with the caveat that depending on the study results, more habitat ground-truthing may be recommended. Mr. Wooster said the NMFS LiDAR study will assess the availability of holding pools and results will be available by the end of August 2016. While the NMFS LiDAR study will also complete a cursory assessment of spawning gravels, Mr. Wooster recommended that the Plenary Group still consider a separate spawning gravel study, as proposed by the Districts. Mr. Devine said that Workshop participants agreed to try to keep to a two-year timeframe. Workshop participants also agreed to implement the Technical Committee.

Mr. Patrick Koepele (Tuolumne River Trust [TRT]) said the question of what studies to complete seems like a question for the Technical Committee. Mr. Devine said the intent of the Technical Committee is to flesh out in greater detail the technical components of agreed-to studies through study plan development and, ultimately, review of study reports. Mr. Devine said the Plenary Group should consider the Studies Table and discuss what studies should occur in Phase 1.

Mr. Chris Shutes (California Sportfishing Protection Alliance) asked if there is existing data about benthic macroinvertebrates (BMI) for the study reach. Mr. Devine said there is very little information available and the information that does exist is dated.

Mr. Peter Drekmeier (TRT) said the City and County of San Francisco (CCSF) has completed many studies on the Early Intake stretch of the Tuolumne River and that results from those studies may be helpful for this effort. Mr. Devine said he has reviewed some of these studies and he believes that most of CCSF's work was completed upstream of Early Intake which is beyond the scope of the reintroduction assessment area. Mr. Bill Sears (CCSF) agreed with Mr. Devine's statement.

Mr. Buckley asked if the resource agencies requested the Swim Tunnel Study noted in the Studies Table. Mr. Devine said the study was placed in the list by the Districts' technical team and resource agency input was welcome. Mr. Le reiterated that the list of studies is not intended to be anything more than a set of ideas for discussion, not study recommendations from the Districts. Mr. Shelton said that while the Swim Tunnel study completed for the Don Pedro Project was good scientific research, it would not be used to inform decision-making in the relicensing proceeding. Mr. Shelton said performing similar swim tunnel studies on other rivers and tributaries would help to create a database of good scientific information, which then may help to give the results broad applicability.

Workshop participants agreed to have the first Technical Committee conference call on Tuesday, February 16, at 11:00 am Pacific. Mr. Devine said the purpose of this call will be to try to decide on what studies will be completed in 2016. Workshop participants decided against reserving the same day each month for Technical Committee calls.

Mr. Wooster proposed that an assessment of the potential impacts of climate change to the upper and lower Tuolumne River be added to the Studies Table. Mr. Wooster agreed to provide an abstract for this study.

Meeting breaks for 15 minutes.

Mr. Devine presented slides on the information currently available on the study reach. Mr. Shutes said the Technical Committee should research the historical presence of the target species in the upper Tuolumne River, as part of consolidating the existing information for the study reach. Mr. Shutes said this issue will likely come up in the future and it would be helpful to know which target species originally inhabited this stretch of river. Mr. Shutes and Mr. Lonnie Moore (citizen) volunteered to lead this effort. Workshop participants discussed the validity and value of using anecdotal historical information to determine historical presence and the importance of documenting how decisions are made regarding whether or not a species existed historically. Mr. Devine said that regardless of whether species may or may not have been present in the reach in the distant past, and in what numbers, the reintroduction success depends on the current and future conditions of the reach under study. Many changes have occurred in the watershed over the last 150 years, so anecdotal information would not be very useful. There was no objection to compiling that information and Mr. Devine asked Mr. Shutes if he would take the lead, and Mr. Shutes agreed.

Mr. Devine asked what target species NMFS thinks should be considered. Mr. Edmondson said NMFS believes fall-run Chinook salmon, spring-run Chinook salmon, and steelhead should be considered. Mr. Edmondson said there is no evidence to suggest that fall-run Chinook were not historically in the study reach, and the extent of demarcation between fall-run Chinook and spring-run Chinook is unknown, therefore NMFS could not find a reason to not include fall-run Chinook. Mr. Devine asked if NMFS had considered the generally poor condition fall-run Chinook are in at the end of their upstream migration to the Lower Tuolumne River and what additional effects the stress of collecting and trucking the fish may have on survival and/or productivity. Mr. Shelton said CDFW agrees that the condition of fall-run Chinook at the end of their upstream migration is indicative of the condition of Tuolumne River. Mr. Shelton said CDFW believes that in most years, fall-run Chinook at the end of the run are in poor condition; however, with more water and non-flow measures, the condition of the fish will improve. Mr. Shelton said CDFW agrees that this process should look at all three fish species. Mr. Shelton said CDFW is cognizant that the Districts do not have unlimited funding and CDFW would like to help defer costs. Mr. Shutes said he had spoken with commercial fishermen and they are interested in reintroducing fall-run Chinook to the upper Tuolumne River. Mr. Shutes said the study should consider capturing fall-run Chinook further downstream than the other two species and should consider passing only those fish in good condition. Mr. Shutes said the study should also consider that fall-run Chinook will likely spawn further downstream than spring-run Chinook, which means that fall-run Chinook will not have to travel as far to get to the downstream passage facility. Mr. Devine stated that in order to more fully explore this proposal, it may be appropriate to move this item into the Technical Committee. Mr. Devine asked if there were concerns about interbreeding between fall-run and spring-run Chinook and competition for limited spawning habitat. Mr. Wooster indicated the resource agencies had meetings on this subject and decided that all three species should be considered. The basic reasoning came down to "why wouldn't we consider" fall-run.

Ms. Ferreira asked NMFS to describe how the agency considers economics and cost when deciding to require fish passage at a project. Mr. Edmondson said that NMFS requests studies through the FERC process and that licensees generally conduct the studies as part of the proceeding. Mr. Edmondson said NMFS provided a summary of how it considers economics in the July 7, 2015 letter to California State Assembly Member Kristin Olsen. Mr. Edmondson said in these types of processes, NMFS first determines whether there is a barrier to fish passage and whether providing passage around the barrier would produce a benefit. Mr. Edmondson said the next step is studying the availability of suitable habitat and whether fish passage is necessary for species recovery, recreational or commercial fishing purposes, or to prevent species extinction. Mr. Edmondson said NMFS's analysis is qualitative in nature. Mr. Edmondson said NMFS performed an economic analysis for the Klamath Project (FERC No. 2802) but that this analysis was part of a Secretarial Determination and different from the FERC process. He will provide a link to reports.

Mr. Devine presented slides describing the information the Districts have been able to locate relevant to the resources and conditions in the study reach (Attachment A). After the presentation, the Workshop adjourned.

ACTION ITEMS

1. Mr. Wooster will provide an abstract for the proposed assessment of climate change impacts to the Tuolumne River.
2. Mr. Shutes will take the lead on compiling information about the historical presence of target species in the upper watershed.
3. Mr. Edmondson will provide a link to the Klamath Project economic analysis and the Districts will send this link to Workshop participants (complete; link to Klamath Project economic analysis).

La Grange Hydroelectric Project
Reintroduction/Fish Passage Assessment Framework
Workshop No. 4

Wednesday, January 27, 2016 -- 9:00 am to 12:00 pm
MID Office, 1231 11th Street, Modesto, California
Conference Line: 1-866-583-7984; Passcode: 814-0607
Join Lync Meeting: https://meet.hdrinc.com/jenna.borovansky/3D64F0F5

Meeting Objectives:

1. Discuss and approve the proposed Upper Tuolumne River Reintroduction/Fish Passage Assessment Framework (Reintroduction Framework) goals and schedule.
2. Present and discuss existing information, information needs, and potential preliminary studies for 2016.

TIME	TOPIC
9:00 am – 9:10 am	Introduction of Participants (All)
9:10 am – 9:30 am	Opening Remarks (All) Review Agenda and Meeting Objectives (All) Overview of Upper Tuolumne River Reintroduction Framework (Districts)
9:30 am – 10:00 am	Reintroduction Assessment Framework Goals and Schedule (All) a. Proposed goals by year (2016-2017) b. Summary of 2016 proposed schedule, meetings, and potential use of a technical subcommittee c. Discuss and decide: -Assessment Framework goals, schedule and meetings -Use of a technical subcommittee
10:00 am – 10:45 am	Potential 2016 Studies and Discussion of Biological Goals and Objectives of the Reintroduction Program (All) a. Potential 2016 studies discussion b. Schedule for identifying reintroduction program biological goals and objectives
10:45 am – 11:00 am	Break
11:00 am – 11:45 am	Upper Tuolumne River: Existing Information and Information Gaps Discussion (Districts) a. NMFS studies – schedule of availability b. Barriers, temperature, habitat, and hydrology summaries c. Other information
11:45 am – 12:00 pm	Next Steps (All) a. Schedule b. Action items

Modesto Irrigation District

La Grange Fish Passage
Workshop No. 4
Wednesday, January 27, 2016
9:00 a.m. – 12:00 p.m.

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PLEASE SIGN IN

	Name	Organization	Telephone No.	E-mail	Time In
1.	Ron Yoshiyama	San Francisco			
2.	George Morrow	Jim Brisco Ent			46
3.	Gretchen Murphey	CDFW			08Y
4.	Brandon McMillan	TID			46
5.	Scott Wilcox	Stillwater			47
6.	Jennifer Shipman	MCCV			3
7.	Ray Dure	Public			53
8.	W. Sears	SF.			55
9.	John Buckley	CSERC			55
10.	Peter Drekmeier	TRT			57
11.	GARTH STAPLEY	BEE			9
12.	Connie Moore	Citizen			

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Modesto Irrigation District

La Grange Fish Passage
Workshop No. 4
Wednesday, January 27, 2016
9:00 a.m. – 12:00 p.m.

PLEASE SIGN IN

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	Name	Organization	Telephone No.	E-mail	Time In
13.	MARCO MORENO	WCR			
14.	Joe Sallaberry				
15.	Paul Zeek	Asm. Kristin Olsen			
16.	Allen Zanker	Zanker Farms			
17.	John Shelton	CDFW			
18.	DANA FERREIRA	CONG. DENHAM			
19.	Chris Shutes	CSPA			
20.	DAVID WHITE	ALLIANCE			
21.	Helen Condit	Senator Cannella			
22.	[illegible]	Farmer			
23.	Zac Jackson	USFWS			05
24.	Patrick Koepele	TRT			45

Information Needs and Potential Studies to Inform Reintroduction Assessment Framework For Discussion and Review by Collaborative Group

Framework Category	Studies	On-going and Potential Studies for 2016[1]	Cost Estimate	Schedule for Draft Report
Ecological	Limiting Factors Analysis and Carrying Capacity		$340,000	December 2017
Ecological	Reservoir Transit Study		$500,000	
Ecological	Interactions with Existing Aquatic Communities		$250,000	
Ecological	Source Population Assessment		NMFS lead?	
Ecological	Method of Colonization		$60,000	
Ecological	Genetics Assessment of Existing and Source Populations (NMFS has study on-going)	X	NMFS lead	April 2017
Biological	Habitat Typing and Characterization[2]	P	$240,000	Nov/Dec 2016
Biological	Upstream Migration Barriers	X	$220,000	Nov/Dec 2016
Biological	Instream Flow – Habitat Assessment: PHABSIM		$300,000[3]	
Biological	Water Temperature Monitoring and Modeling	X	$350,000	Nov/Dec 2016
Biological	Spawning Gravel Study	P	$140,000	Nov/Dec 2016
Biological	Macroinvertebrate Study		$220,000	
Biological	Swim Tunnel Study of Upper River *O. mykiss*		$450,000	
Economic, Regulatory, and Other Key Considerations	Regulatory Evaluation of Reintroduction (ESA Status, BLM/USFS Management Plans, Wild and Scenic, etc)	P	$50,000	October 2016
Economic, Regulatory, and Other Key Considerations	Socioeconomic Scoping and Issues Identification/ Preliminary Evaluation of Impacts on Tuolumne River Uses/Users	P	$50,000	October 2016
Economic, Regulatory, and Other Key Considerations	Hatchery Practices Review, including current Don Pedro related practices.		$50,000	

Draft Study Abstracts

Limiting Factors Analysis and Carrying Capacity

A limiting factors analysis (LFA) is a useful tool to identify and fill information gaps related to physical and biological factors controlling population dynamics of one or more target species. This type of analysis has been used extensively in California and the Pacific Northwest to identify habitat conditions, ecological interactions, and other factors that constrain salmonid population production potential. The LFA proposed herein would test hypotheses regarding potential factors that that could limit the ability of the upper Tuolumne River to support viable populations of reintroduced Chinook salmon and O. mykiss. The data analyzed and synthesized as part of a LFA can also include an analysis of carrying capacity, to determine the number of individuals of each freshwater life stage that can be supported by the available habitat. The results of a LFA provide valuable insight into possible effects of current or historical riverine habitat conditions on salmonid populations (or reintroduced populations), allowing managers evaluate

[1] X = Ongoing study; P = Potential additional 2016 study for consideration by collaborative group
[2] Habitat typing and characterization study proposal does not explicitly include habitat components being collected by NMFS; however, the NMFS data should be discussed in overall Assessment Framework.
[3] The geographic scope and amount of available information needs to be confirmed to refine scope and cost estimate.

reintroduction potential, focus future management activities, help prioritize actions, and/or refine the current understanding of limitations of the ecosystem.

Reservoir Transit Study

As detailed in FERC's study plan determination, if the fish passage facilities assessment indicate that the most feasible concept alternative for fish passage would involve either upstream or downstream passage through the project reservoirs (i.e., La Grange or Don Pedro reservoirs), a study would be required to evaluate the technical and biological feasibility of upstream (adults) or downstream (juvenile) movement of anadromous fish (as appropriate) through the project's reservoirs. Until feasible concept alternatives have been selected, the scope of this study cannot be accurately identified.

Interactions with Existing Aquatic Communities

Evaluating potential interactions with existing species in the target area is a factor that can impact reintroduction success. This constraint includes predatory and competitive interactions with other species and populations. Often times, habitat in target areas have changed from historic conditions. Consequently, aquatic communities present in target reintroduction areas may be comprised of non-native species or native invaders that have filled these available niches. Furthermore, intraspecific competition is possible if a population of the target species is already present in the target reach (i.e., *O. mykiss*). This assessment would identify the potential interactions of target reintroduction species with the existing aquatic community in the target reach and characterize the potential risks/benefits to the reintroduction program.

Source Population Assessment

Consideration of genetic and ecological characteristics of a source population is important to assessing the probability of a successful reintroduction. Ecological factors such as life history, morphological, and behavioral traits compatible with the target area will increase the probability of a successful reintroduction. Source populations that are genetically similar to the historic population may also maximize the benefits and reduce the risks of reintroduction. This assessment would identify factors that should be considered when identifying viable source populations, potential sources, associated pros and cons of each, and constraints of utilizing each source, if any.

Method of Colonization Assessment

Colonization approaches (i.e., natural, transplants, and hatchery releases) differ in the effects on the parameters that are used to assess the success or failure of a reintroduction. Method of colonization also has implications for the infrastructure and operations needed to support a reintroduction program. As such, identifying early in the process the lowest-risk strategy for colonization will be a critical component of assessing risks, constraints, and benefits of any reintroduction program.

Genetics Assessment of Existing and Source Populations

NMFS is conducting a study of the upper river *O. mykiss* fishery genetics. Request a schedule and information update for the group.

Habitat Typing and Characterization

Habitat mapping quantifies the type, amount, and location of river habitat types available to reintroduced anadromous salmonids of all life stages. Habitat mapping would be conducted in the field and remotely using standardized methodologies. The frequency and area of each habitat type (e.g., pool, riffle, run) would be tabulated and where potential holding pools for spring-run salmon occur, the size, depth, and vertical thermal profile of the pools will be measured to determine possible holding capacity, stratification of the pools (if any), and thermal suitability. Additional (remote) mapping tasks will include assessments of channel gradient, width, habitat areas, etc. This baseline information provides the template for many other evaluations and is critical for assessing the feasibility of reintroduction. For example, data on habitat type, area, and distribution are required to assess potential Chinook salmon and steelhead adult holding capacity, spawning habitat potential, and juvenile rearing capacity.

<u>Upstream Migration Barriers</u>

Little information exists to reliably assess the current quantity and quality of suitable habitat for the adult, egg, fry and juvenile life stages of anadromous salmonid species that may be considered for reintroduction in the Upper Tuolumne River watershed (i.e., above the Don Pedro Project). Prior to assessing the quality/suitability of habitat for target species, an assessment of barriers (both complete and partial) to upstream anadromous salmonid migration must first be conducted to identify the quantity of habitat that is accessible. This assessment would utilize relevant prior studies, desktop analyses, and field surveys to characterize and document the physical structure of barriers in the mainstem Tuloumne River and its tributaries upstream of the Don Pedro Project Boundary. Note that this study was requested by NMFS but per FERC's determination, was not required to be conducted by the Districts as part of the La Grange licensing process. However, to more fully support licensing participants in their development of information to supplement fish passage and reintroduction assessments, and to foster collaboration among all parties, the Districts have opted to conduct an upstream migration barriers assessment.

<u>Instream Flow – Habitat Assessment: PHABSIM</u>

Hydraulic models such as the Physical Habitat Simulation (PHABSIM) system are widely used and accepted tools used to produce quantitative estimates of the amount (quantity and quality) of habitat available to fish at a range of stream flows. Using measured physical channel characteristics for representative habitat types or reaches, PHABSIM modeling incorporates habitat suitability relationships for the target fish species and life stage to produce estimates of weighted usable area (WUA) in relation to stream flow. Results of PHABSIM modeling can be combined with data from habitat mapping and water temperature modeling to provide estimates of habitat availability and suitability for target species and associated life stages throughout the project area at a range of flows. Additionally, the analysis would include an evaluation of the effect of fluctuating flows on habitat value, due to the frequent peaking operations in the upper Tuolumne River. This could be evaluated by comparing habitat values on a small time-step using the high and low flows within the fluctuation range. Water temperature data would also be overlaid with the PHABSIM results to evaluate how the total amount of habitat is affected by thermal rather than physical habitat conditions.

<u>Water Temperature Monitoring and Modeling</u>

The assessment of suitable habitat quality for the adult, egg, fry and juvenile life stages of anadromous salmonid species that may be considered for reintroduction in the Upper Tuolumne River watershed (i.e., above the Don Pedro Project) is dependent upon both physical and thermal characteristics. This study would use existing and additional data to characterize the thermal regimes of the upper Tuolumne River and tributaries from the Don Pedro Project Boundary to CCSF's Early Intake to characterize locations where temperatures may be suitable for anadromous salmonid species considered for reintroduction. The study would include the development of a computer model to simulate existing thermal conditions in the study area. Note that this study was requested by NMFS but per FERC's determination, was not required to be conducted by the Districts as part of the La Grange licensing process. However, to more fully support licensing participants in their development of information to supplement fish passage and reintroduction assessments, and to foster collaboration among all parties, the Districts have opted to conduct an upstream migration barriers assessment.

<u>Spawning Gravel Study</u>

Spawning gravel mapping quantifies the amount, location, and suitability of gravel available for spawning by reintroduced anadromous salmonids. In a confined, high gradient river channel dominated by large substrates (boulder, cobble, bedrock) like the upper Tuolumne River, spawning gravel distribution is typically patchy and overall abundance may be low. Initial evaluation of aerial photographs and an on-river reconnaissance survey indicate this is may be the case in portions of the Tuolumne River between Wards Ferry and Early Intake. Because successful spawning and fry production are dependent on the abundance and suitability of accessible spawning gravel, spawning gravel mapping is a critical component for assessing the feasibility of reintroduction. This information is a key part of any evaluation of the factors likely to limit production and viability of an existing or reintroduced salmonid population (i.e., a limiting factors or carrying capacity analysis).

<u>Macroinvertebrate Study</u>

Drifting and benthic macroinvertebrates (BMI) are the primary food source for rearing salmonids in fresh water habitats. Growth of juvenile anadromous salmonids during their freshwater rearing period is critical for their survival during outmigration and ocean phases, as well as to the overall viability of the population. Studies have shown a strong relationship between the size at which juvenile salmon and steelhead migrate to the ocean and the probability that they return to fresh water to spawn. Macroinvertebrate sampling provides a measure of food availability during this important life history period. Information on macroinvertebrate prey resource availability is therefore a key component of any evaluation of the factors likely to limit production and viability of an existing or reintroduced salmonid population (i.e., a limiting factors analysis).

<u>Swim Tunnel Study of Upper River O. mykiss</u>

Thermal acclimation among fish species dates back to the 1940’s and since 2001, thermal adaptation at the population level and among a wide variety of fish species has been convincingly supported in the peer-reviewed scientific literature. Included in this evidence base are salmon and trout species. The objective of this study would be to determine the thermal performance of the subadult *O. mykiss* population inhabiting the upper Tuolumne River to assess any local adjustments in thermal performance. The study would test the hypothesis that the *O.mykiss* population in the Upper Tuolumne River (i.e., above the Don Pedro Project Reservoir) is locally adjusted to relatively warm thermal conditions that may exist during the summer. Results of the study would be used to support habitat suitability and temperature modeling assessments.

<u>Hatchery Practices Review, including current Don Pedro related practices</u>

Assessing historic and current hatchery practices in the upper Tuolumne River will be necessary to evaluate potential risks to reintroduction. Risks include but are not limited to evolutionary (homogenization or reduced fitness), ecological (competition, predation, etc.) and disease issues. Results of the review will identify past and current hatchery practices in the reintroduction area as well as connected areas (i.e., Don Pedro Reservoir), potential risks of past/present hatchery programs to a reintroduction program, and recommendations to address identified risks.

<u>Regulatory Evaluation of Reintroduction</u>

The Upper Tuolumne River watershed spans several land management agencies' jurisdictions and there are management plans and regulations in place based on established resource management objectives (e.g., Wild and Scenic Management Plan, Forest Plan, BLM Management Plan). The compatibility of the potential reintroduction of *O.mykiss* and/or spring run Chinook will be evaluated relative to these current management objectives. The potential reintroduction of Endangered Species Act (ESA) listed species may overlay additional management objectives and a new regulatory framework in the upper Tuolumne River. This evaluation will include compiling and reviewing all relevant and potentially relevant existing management plans for the upper Tuolumne River and the Don Pedro Reservoir. In addition, applicable recovery plans and ESA regulations and potential population status classifications for the reintroduced species will be summarized. Responsible resource management agencies will be contacted to determine the most recent guidance documents for the study area.

<u>Socioeconomic Scoping and Issue Identification/Preliminary Evaluation of Impacts on Tuolumne River Uses/Users</u>

Current management of the Don Pedro Reservoir and upper Tuolumne River supports a wide range of resources, uses, and users. The upper watershed includes the Tuolumne Wild & Scenic River segment managed for several outstanding resource values and is utilized by commercial and private recreational boaters. Other uses include the City and County of San Francisco's Hetch Hetchy Project operations, private timber practices, and a recreational fishery. Don Pedro Reservoir has an active house boating and recreational fishery; county government and businesses rely upon the economic activities supported by the upper watershed. This evaluation will conduct a comprehensive survey of uses in the upper watershed and identify potential issues for consideration in the reintroduction assessment. A literature survey and review of existing information from the Don Pedro Recreation Agency, county and federal land management agencies and other sources will be conducted. Surveys and/or focus groups will be used to verify and expand upon available information on the multiple existing uses of the watershed that could be impacted by a fish reintroduction program.

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La Grange Hydroelectric Project

Upper Tuolumne River Reintroduction/Fish Passage Assessment Framework

Goals and Schedule

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Overarching Framework Goal

Evaluate feasibility of reintroducing anadromous salmonids into the Upper Tuolumne River by applying a structured assessment process. The process is an integrated evaluation of ecological, biological, engineering, economic, regulatory, and other key considerations related to the reintroduction.

Framework Implementation

- Framework implementation over 2.5 years
- Phased approach to information/data collection and analysis
- Phased approach allows for key assessment points over the implementation period
- Use of technical subcommittee

Framework Goals By Year

- **2016 (Phase 1)**
  - Compile and share existing information, identify data gaps and needed studies
  - Implement 2016 studies – ecological, biological, regulatory and potential uses/user impacts
  - Develop overall reintroduction goals related to ESA Recovery planning
  - Develop Phase 1 evaluation approach

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Framework Goals By Year

- **2017 (Phase 1/2)**
  - 2016 studies information available
  - Conduct Phase 1 reintroduction evaluation using study results and developed reintroduction goals
  - **Key Assessment Milestone** – can ESA reintroduction goals be met (i.e., can success be achieved?)

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Framework Goals By Year

- **2017 (Phase 2)**
  - If reintroduction deemed achievable based on Phase 1 (i.e., no fatal flaws), move to Phase 2.
  - Scope/conduct 2017 studies – additional biological, ecological studies, re-engage fish passage engineering, socioeconomics, other resource/user impacts
  - Develop Phase 2 evaluation approach

Framework Goals By Year

- **2018 (Phase 2 continued)**
  - 2017 studies information available
  - Conduct Phase 2 reintroduction evaluation
  - **Key Assessment Milestone** – can ESA reintroduction goals be met (i.e., can success be achieved?)
  - Final reporting

Discussion and Decisions

- Framework implementation approach
- Schedule and meetings
- Use of a technical subcommittee

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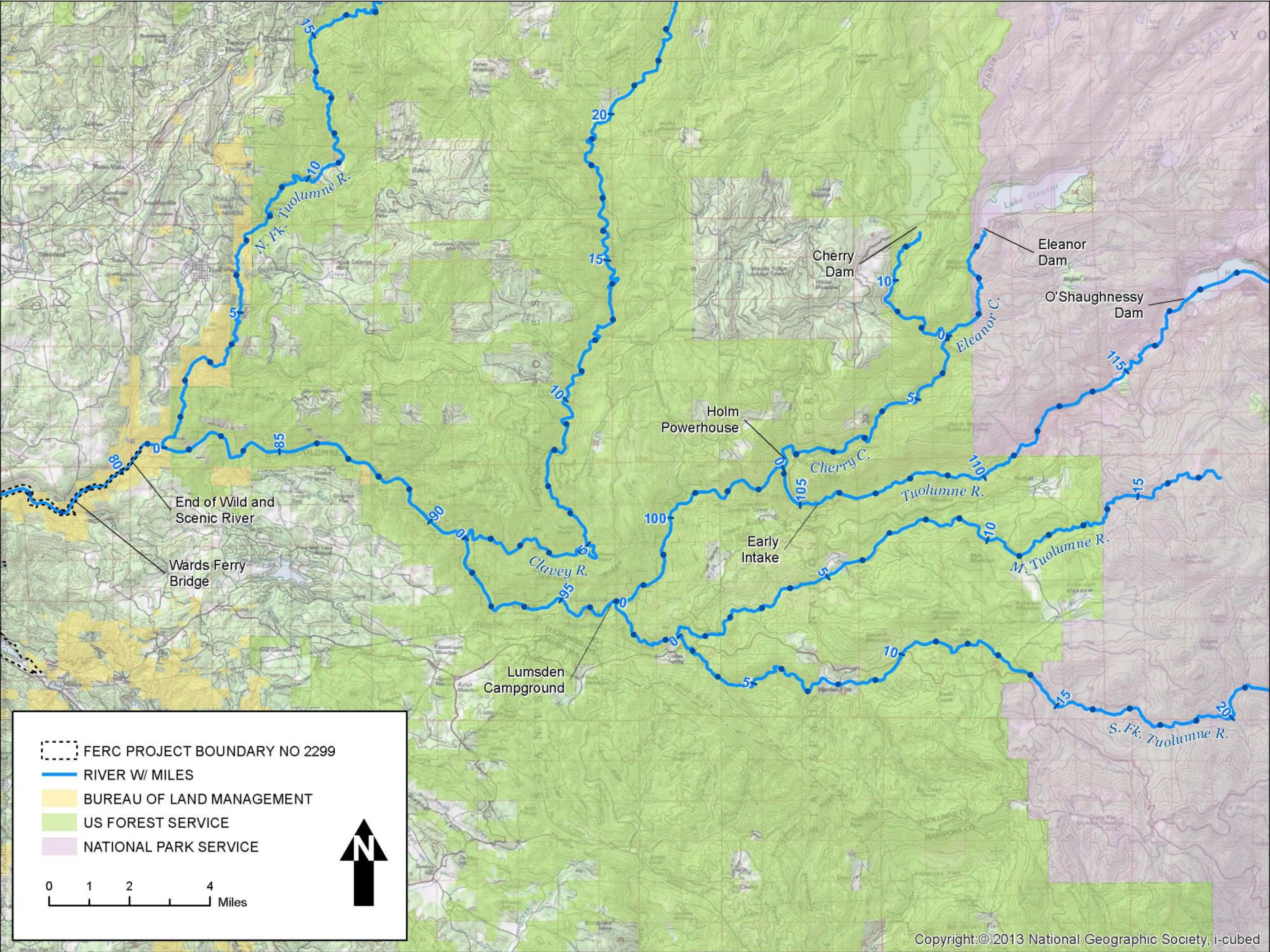
La Grange Hydroelectric Project
FERC No. 14581

Description of Existing Environment



N. Fk. Tuolumne R.
Clavey R.
Cherry Dam
Eleanor Dam
O'Shaughnessy Dam
Eleanor C.
Holm Powerhouse
Cherry C.
Tuolumne R.
Early Intake
M. Tuolumne R.
S. Fk. Tuolumne R.
Lumsden Campground
End of Wild and Scenic River
Wards Ferry Bridge
FERC PROJECT BOUNDARY NO 2299
RIVER W/ MILES
BUREAU OF LAND MANAGEMENT
US FOREST SERVICE
NATIONAL PARK SERVICE
N
0 1 2 4
Miles
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Geomorphology

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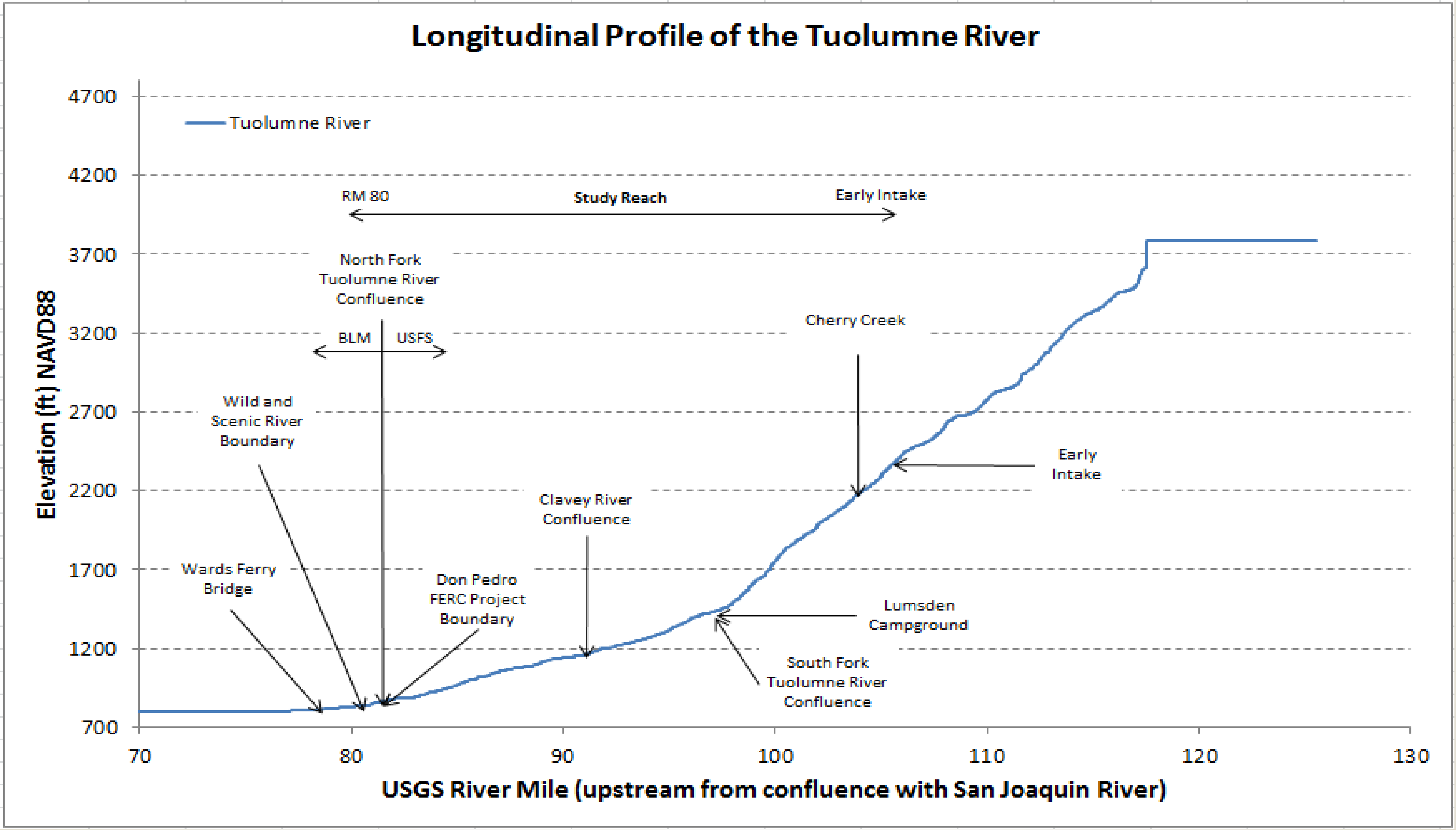

Mainstem TR Geomorphological Zones Table

PRELIMINARY

Main Stem Tuolumne River Geomorphological Zones					
Subreach	**RM**	**Length (mi)**	**Approx Change in Elev**	**Channel Gradient (%)**	**Description**
Wards Ferry to Clavey River	78.4 - 91	12.6	400 ft	0.6	Channel becomes semi-alluvial; large boulder bars and side channels are more common here than in upstream reaches.
Clavey River to South Fork Tuolumne River	91 - 97	6	300 ft	0.9	Boulder cascades separated by medium-length pools.
South Fork Tuolumne River to Early Intake	97 - 105.5	8.5	1100 ft	2.5	Deep pools separated by boulder cascades; confined by steep, bedrock canyon walls; some boulder alternate bars and few side channels.

Hydrology

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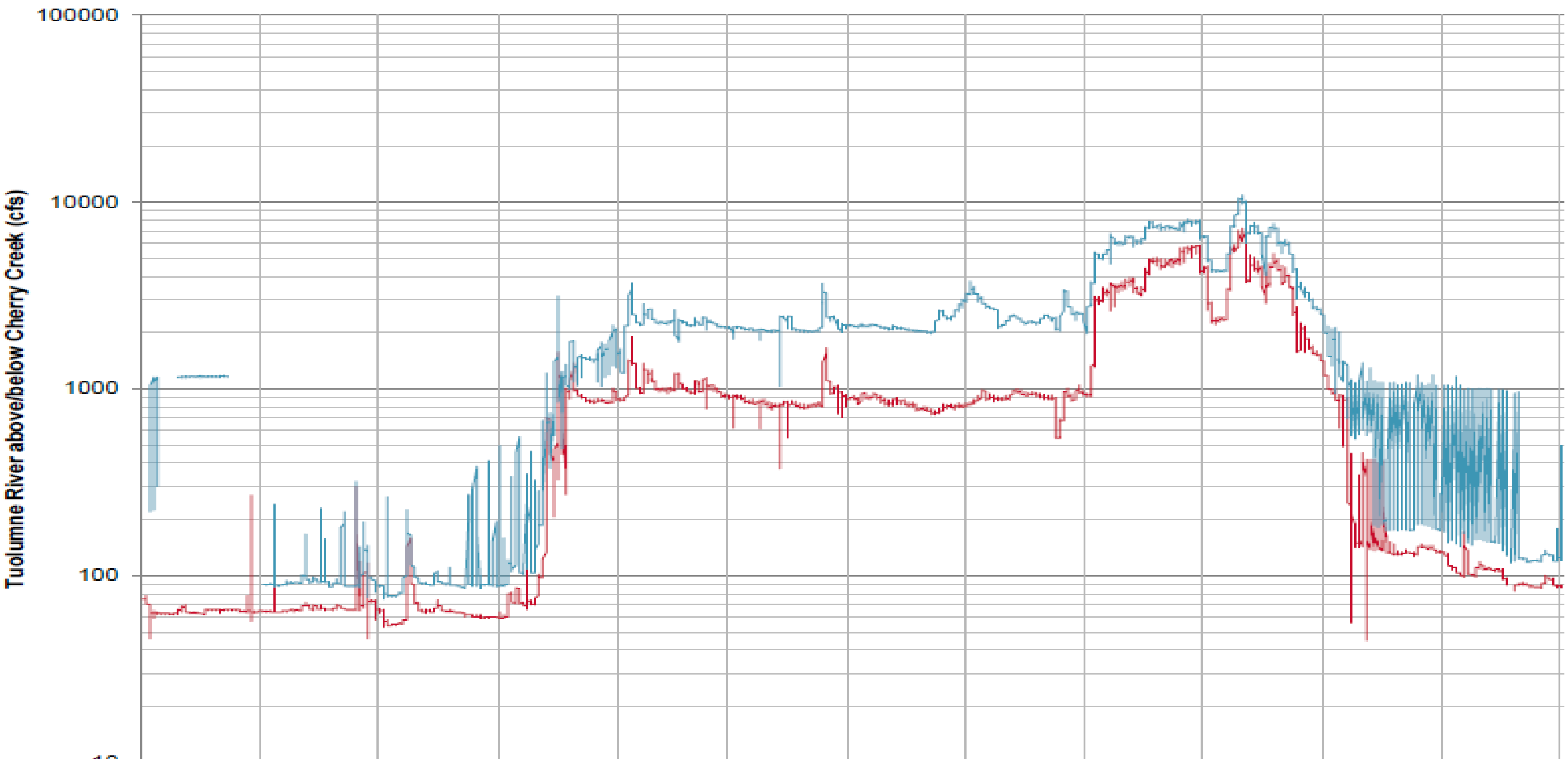
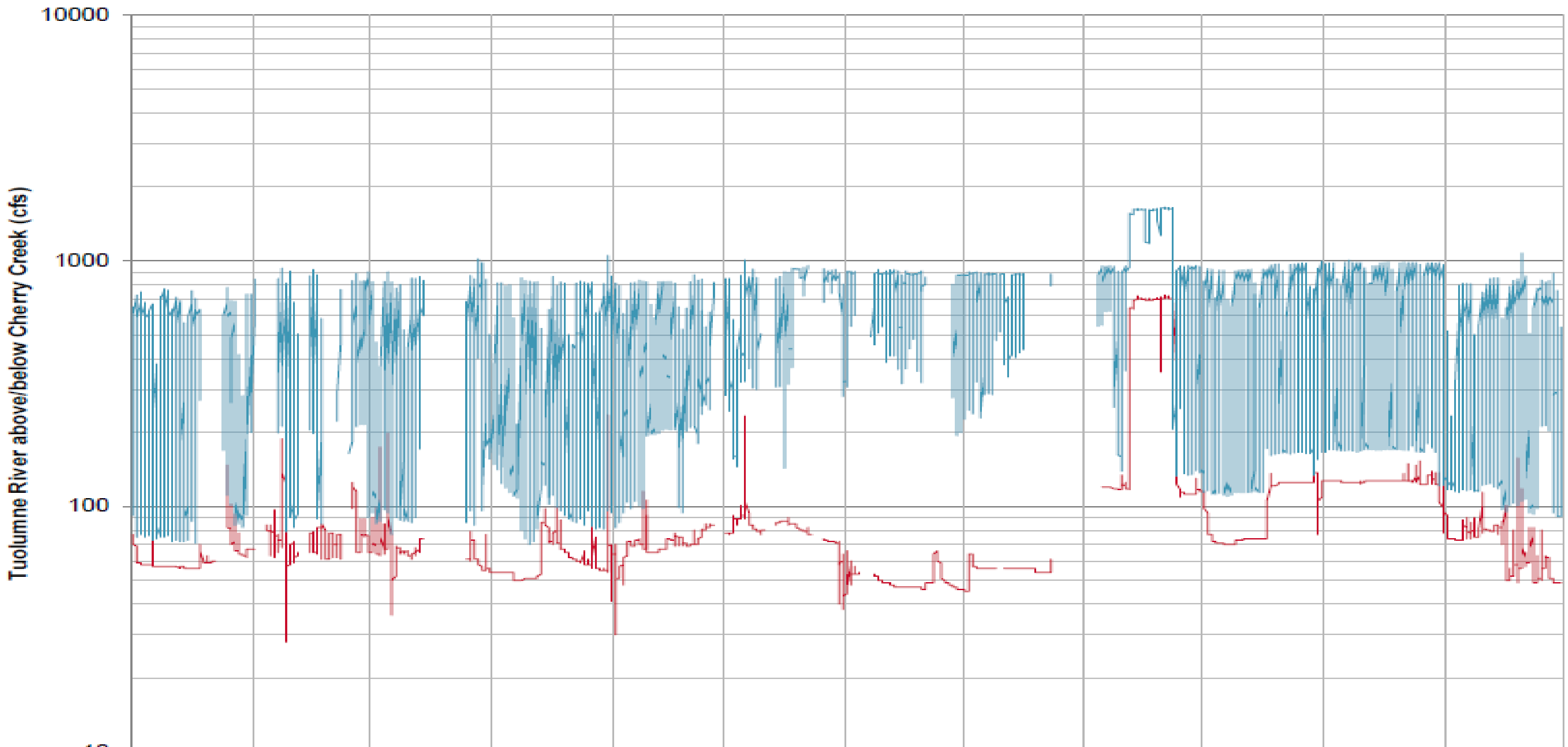
Mainstem TR Hydrology – Wet Year (WY 1998)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Above	4,001AF	4,085 AF	3,961AF	34,560 AF	57,717 AF	53,619 AF	49,670 AF	55,435 AF	242,666 AF	218,828 AF	18,939 AF	5,736 AF
Below	32,936 AF	5,936 AF	6,625 AF	58,303 AF	128,050 AF	133,769 AF	133,505 AF	156,443 AF	389,723 AF	335,667 AF	51,260 AF	17,580 AF

Water Year 1998 - 749,215 AF Above and 1,449,797 AF Below Cherry Creek

Mainstem TR Hydrology – Dry Year (WY 1990)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Above	3,515 AF	3,180 AF	2,713 AF	3,794 AF	3,589 AF	3,825 AF	2,647 AF	2,414 AF	19,020 AF	5,944 AF	7,734 AF	4,053 AF
Below	20,756 AF	16,088 AF	18,995 AF	27,515 AF	23,193 AF	30,834 AF	26,708 AF	20,286 AF	54,756 AF	34,719 AF	37,040 AF	28,241AF

Water Year 1990 - 62,428 AF Above and 339,133 AF Below Cherry Creek

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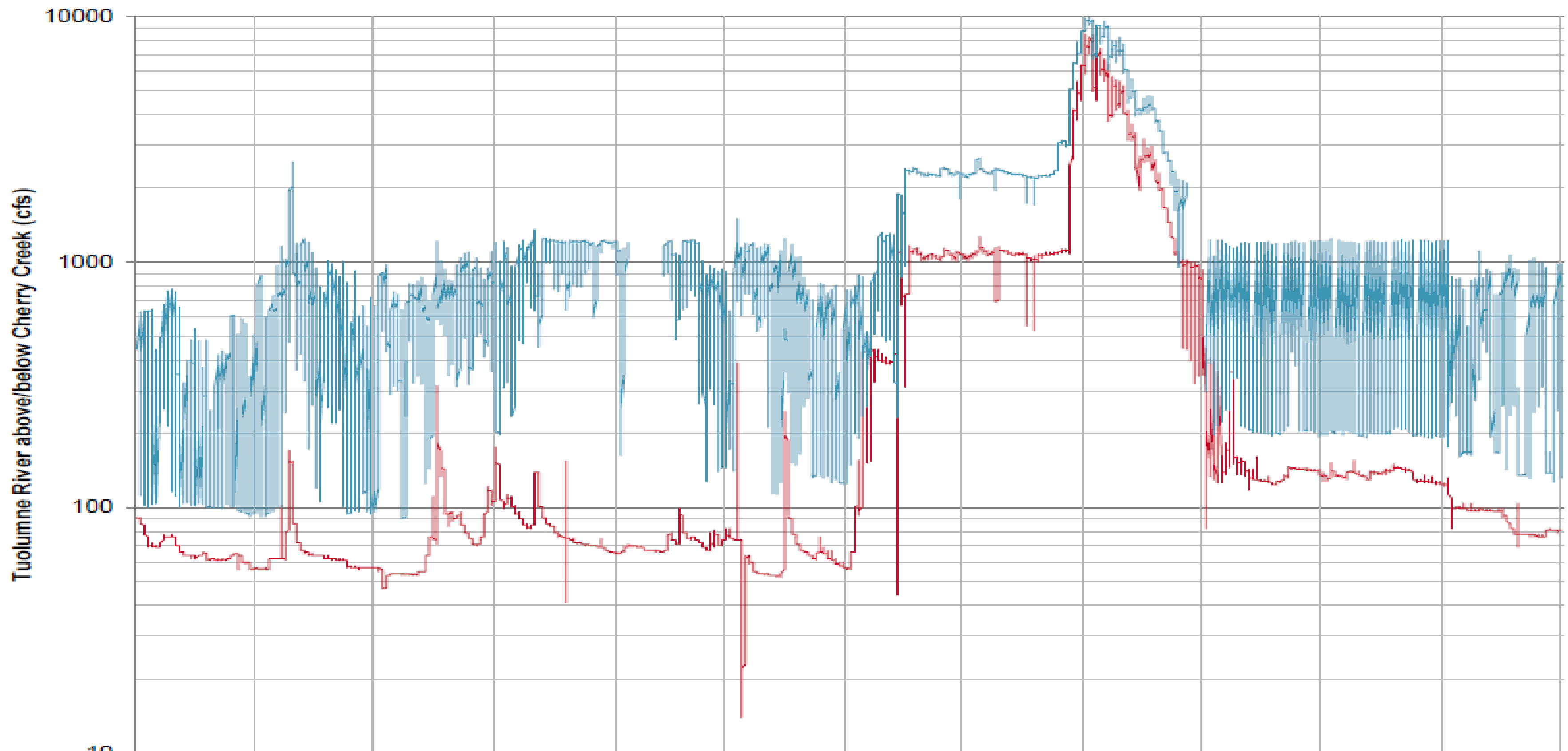
Mainstem TR Hydrology – Normal Year (WY 2003)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Above	4,081 AF	3,911 AF	4,878 AF	5,171 AF	3,978 AF	4,117 AF	42,832 AF	97,516 AF	190,194 AF	9,694 AF	8,329 AF	5,355 AF
Below	22,125 AF	39,352 AF	41,473 AF	63,332 AF	33,095 AF	42,842 AF	94,437 AF	189,684 AF	264,308 AF	32,092 AF	28,804 AF	32,047 AF

Water Year 2003 - 380,056 AF Above and 883,592 AF Below Cherry Creek

CCSF Minimum Flow Regimes

1982 Streamflow Stipulation for Eleanor Creek below Lake Eleanor Dam

Month	Minimum Flow (cfs)	
	Pumping	Not Pumping
Jan	5	5
Feb	5	5
Mar	10	5
April 1 - 14	10	5
April 15 - 30	20	5
May	20	5
June	20	5
July	20	15.5
Aug	20	15.5
Sept 1 - 15	20	15.5
Sept 16 - 30	10	15.5
Oct	-	5
Nov	5	5
Dec	5	5

1950 Streamflow Stipulation for Cherry Creek below Cherrry Valley Dam

Month	Minimum Flow (cfs)
Jan	5
Feb	5
Mar	5
April	5
May	5
June	5
July	15.5
Aug	15.5
Sept	15.5
Oct	5
Nov	5
Dec	5

1985 Streamflow Stipulation for the Tuolumne River below O'Shaughnessy Dam

Month	Minimum Flow (cfs)				
	A (60%)	A (60%)	B(32%)	B (32%)	C (8%)
Jan	50	114	40	104	35
Feb	60	124	50	114	35
Mar	60	124	50	114	35
April	75	139	65	129	35
May	100	164	80	144	50
June	125	189	110	174	75
July	125	189	110	174	75
Aug	125	189	110	174	75
Sep 1 - 15	100	164	80	144	75
Sep 16 - 30	80	144	65	129	50
Oct	60	124	50	114	35
Nov	60	124	50	114	35
Dec	50	114	40	104	35

Source: RMC Water and Environment and McBain & Trush, Inc. 2007.

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Anadromous Fish Species Being Considered For Reintroduction

Species of Interest

Steelhead ☑

Spring-run Chinook ☑

Fall-run Chinook ?

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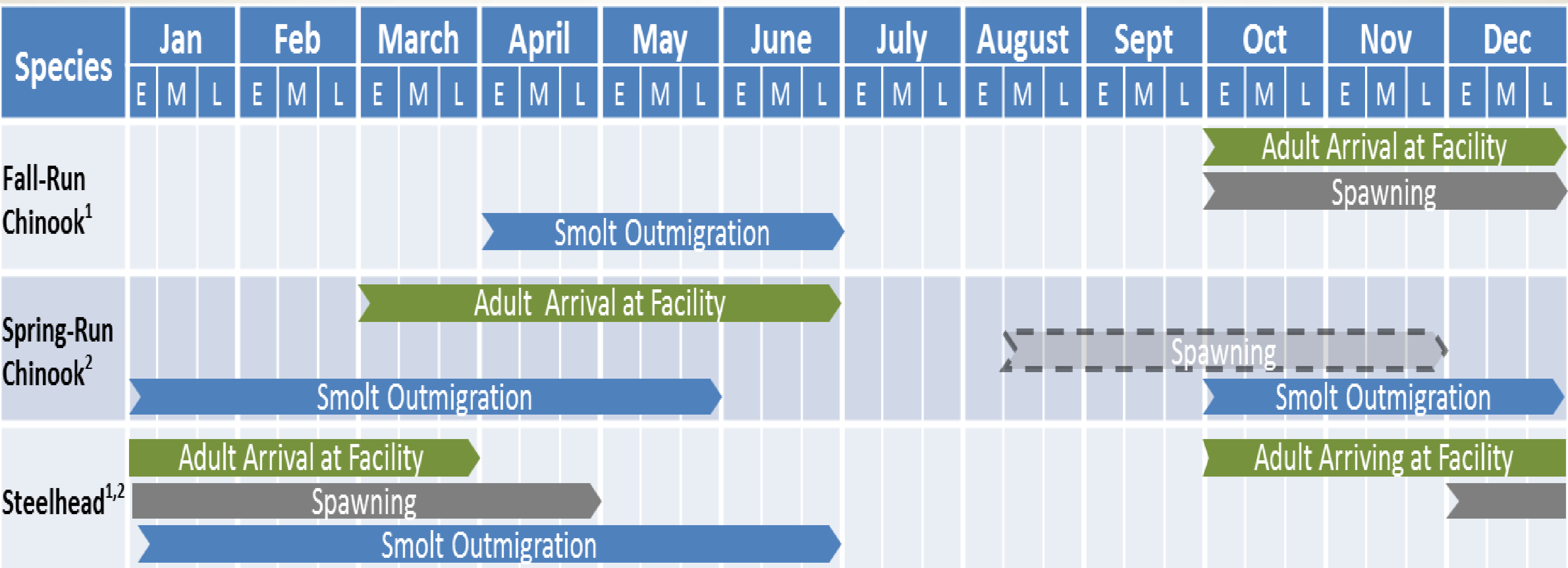
Species of Interest
Anticipated Life History Timing



[1] TID/MID 2013b.
[2] BOR et al. 2013 and NMFS 2014

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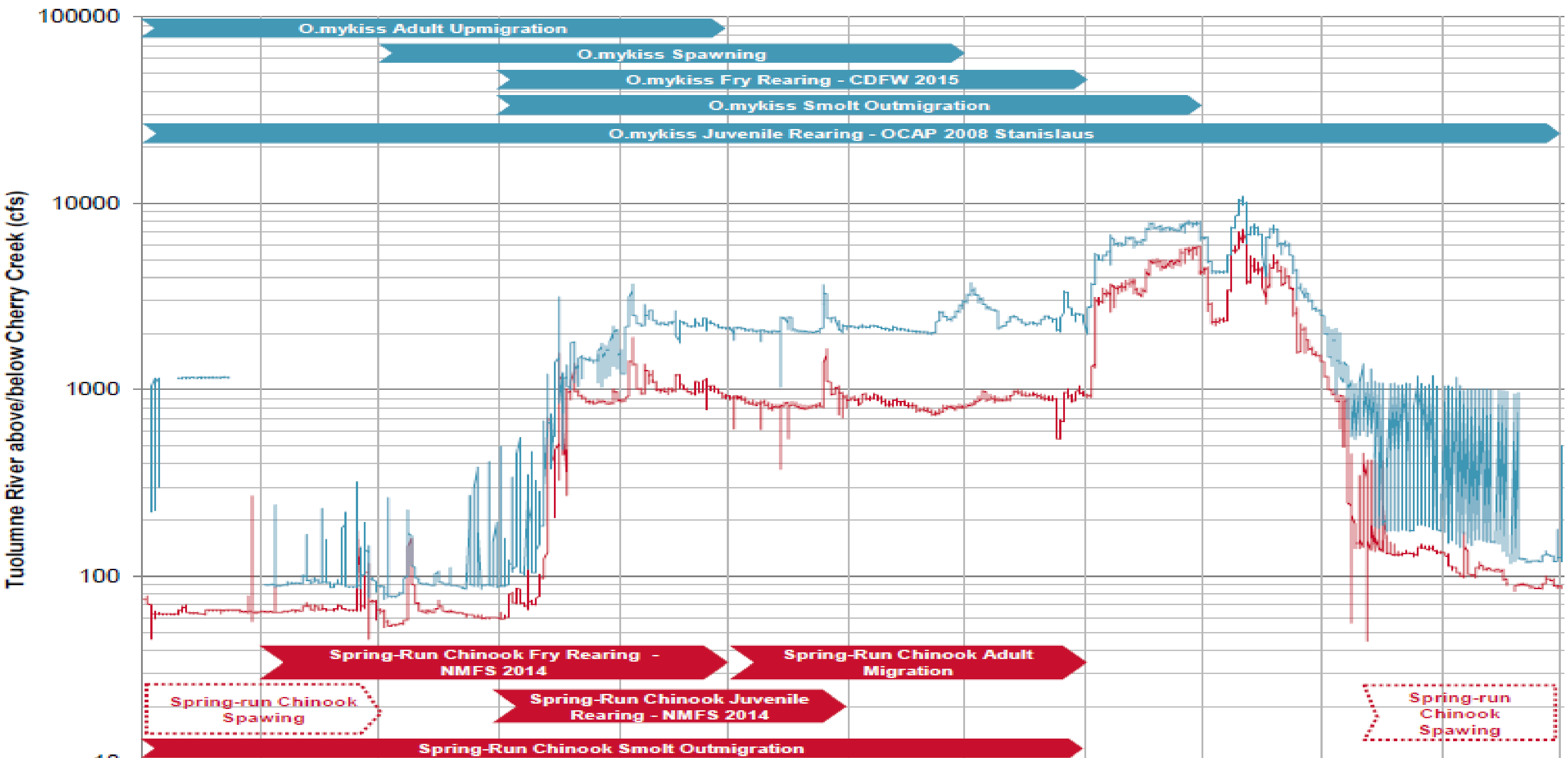
TR Abv/Bel Cherry Creek – Wet WY (WY 1998)



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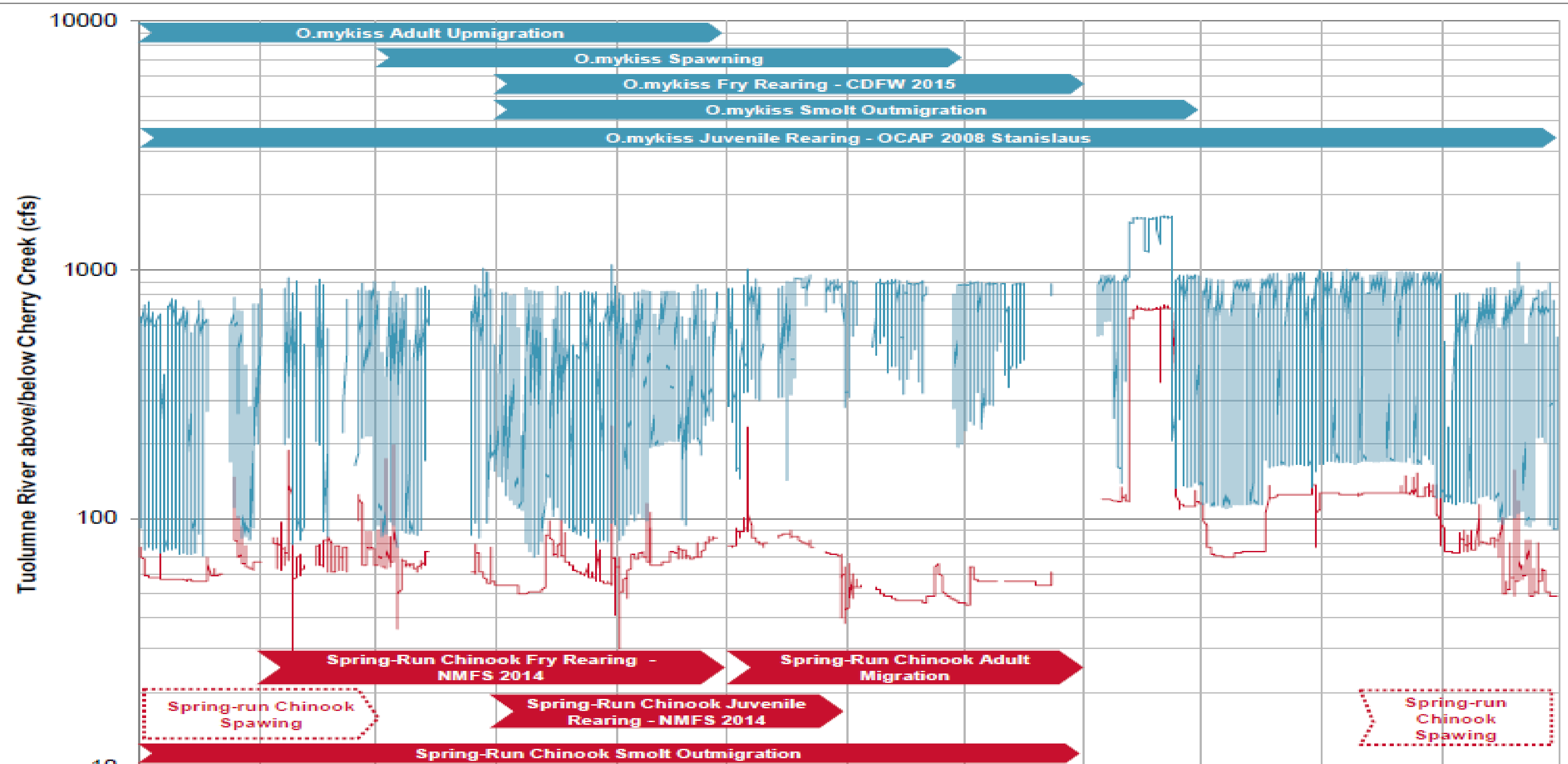

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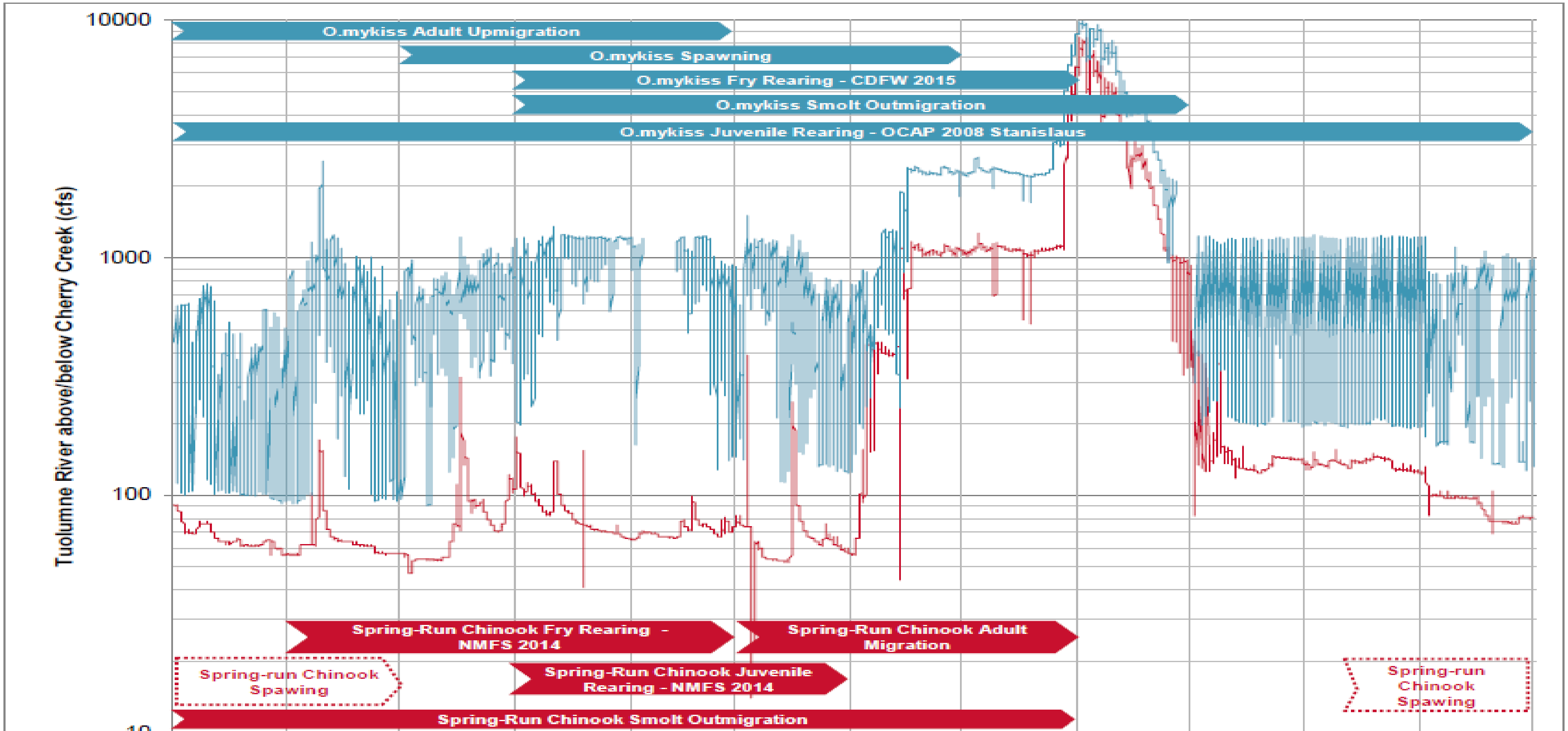

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Water Year 2003 - 380,056 AF Above and 883,592 AF Below Cherry Creek

Upper Tuolumne River Studies

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Goals of Upper Tuolumne River Studies

Upper River Barriers Study	Water Temp. Monitoring and Modeling	Anadromous Fish Habitat Reconnaissance

• Determine potential limits of anadromy by identifying physical features classified as total barriers on TR mainstem and tribs upstream of Don Pedro Project Boundary	• Use existing data and collect additional data (as necessary) to characterize thermal regimes of upper TR and tribs from Early Intake to above DP Reservoir
	• Develop and test a computer model to simulate existing thermal conditions in TR from below Early Intake to above DP Reservoir
		• Reconnaissance level investigation of habitat suitability for anadromous fish
		  • TR (downstream of Meral's Pool), S.F. Tuolumne River, Clavey River
		• Habitat elements for consideration
		  • Holding pools (mainstem)
		  • Spawning gravel (tributaries)
		  • Habitat unit diversity
		  • Summer thermal conditions
		  • Stranding potential (mainstem)

Upper River Barriers Study

- Observed via watercraft on August 2 – 4 and observed by foot on August 5 – 6 and October 26 – 27
- Surveys conducted on mainstem TR (downstream of Lumsden Falls and upstream of Cherry Creek confluence), South Fork TR, Clavey River, and Cherry Creek
- Each observed during lower flow of about 350 cfs and two-unit Holm powerhouse flow of about 1,000 cfs
- More information available in ISR

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Temp. Monitoring and Modeling Study

Summary of 2015 Activities

- Existing data through 2014 compiled and evaluated
- 2015 monitoring locations for additional data identified
- Loggers deployed in spring 2015 and downloaded fall 2015
- QA/QC of 2015 field data is near completion
- Additional data will be presented in ISR

Anadromous Fish Habitat Reconnaissance

- Habitat reconnaissance conducted in concert with barriers work in similar locations and reaches
- Habitat elements for consideration
  - Holding pools (mainstem)
  - Spawning gravel (tributaries)
  - Habitat unit diversity
  - Summer thermal conditions
  - Stranding potential (mainstem)
- Preliminary observations downstream of barriers suggest limited habitat in tributaries
- Additional mainstem habitat information (e.g. thermal regime, flow regime, spawning gravel, holding pools) is needed to evaluate suitability for anadromous salmonids

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Next Steps For Upper Tuolumne River Studies

Upper River Barriers Study	Water Temp. Monitoring and Modeling	Anadromous Fish Habitat Reconnaissance

• Complete remaining initial field surveys on North Fork and Tuolumne River mainstem between Lumsden and Cherry Creek Confluence (RM 97.3 to 104.0)
• Perform more detailed assessment of barriers identified in 2015.
	• Coordinate with barrier study team to identify potential limits to upstream migration
	• Confirm life history presence/absence in space and time through study area
	• Characterize temperature on a reach-by-reach basis
	  • Field data
	  • Models
		• Select studies for 2016 calendar year

Benthic Macroinvertebrates

Benthic Macroinvertebrates

- Data Availability
  - Numerous BMI samples were collected in study reach for Ponderosa Project
  - A limited number of samples were analyzed

- Preliminary Results (from McBain & Trush 2007)
  - "Species diversity (richness) downstream of Early Intake to Wards Ferry was moderate overall but low when compared to sites above Early Intake in the tributaries to the mainstem, probably due to hypolimnial releases from Holm PH"
  - "Plecoptera (stoneflies) and Elmidea (riffle beetles) were notably absent from the samples in the Lumsden Reach, which could be an indicator of environmental stress"
  - BMI "abundance was low at all sites in the reach"

Other Water Uses/ Affected Resources/ Potential Impacts

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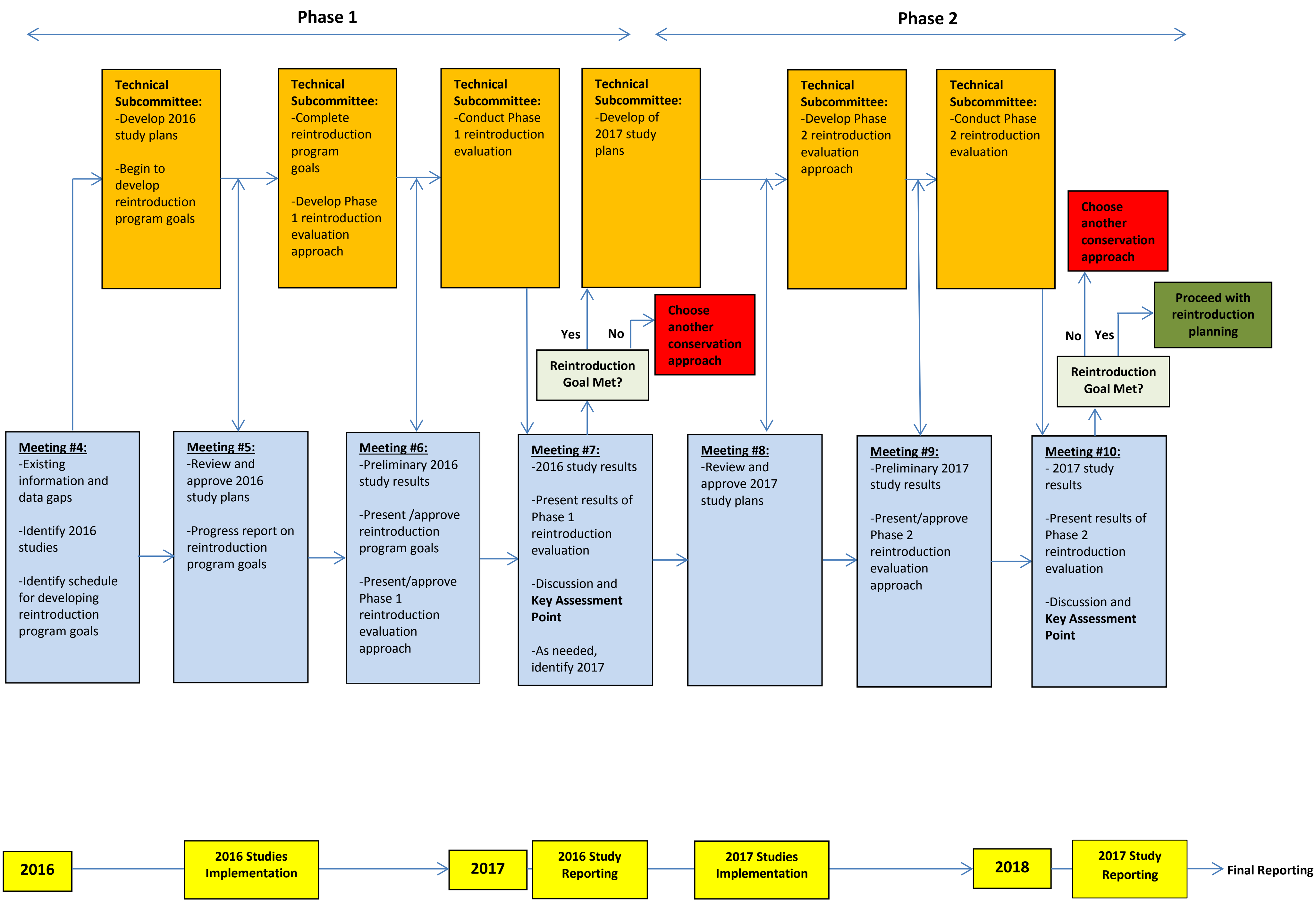
Other Water Uses/ Affected Resources/ Potential Impacts

Environmental Issues		Regulatory Issues
• Impacts caused by or to other fish species: river and reservoir predator abundance (rainbow trout; pikeminnow; smallmouth bass); Clavey River Wild Trout and Heritage Trout designation; competition for spawning habitat; interbreeding resident/ anadromous *O. mykiss*; interbreeding stocked Chinook and introduced Chinook; • Impacts to/effects of Don Pedro stocking of salmonids (kokanee; Chinook; coho; rainbows)	• *O. mykiss* genetic considerations • Impacts caused by or to whitewater boating • Impacts caused by or to recreational fishing • Fishing regulations in affected reaches and Don Pedro Reservoir • Effects on watershed forest harvest practices • Juvenile mortality in lower Tuolumne River	• Designations under ESA • USFS whitewater boating annual permits (need ESA protection – each year?, BiOps, NEPA compliance) • USFS Forest Plan changes due to introduction of listed species • BLM Mngt Plan changes • W&S River designation compatibility • Installation of passage facilities in W&S reaches? • CCSF operations – need ESA authorization and "take" permits?

Upper Tuolumne River Reintroduction/Fish Passage Assessment Framework – Flow Chart



La Grange Hydroelectric Project Licensing
Upper Tuolumne River Reintroduction Assessment Framework
Proposed Meetings/Schedule 2016-2017

DRAFT Programmatic Process Steps and Goals by Year
2016 (Phase 1):

- Share and assess existing information relevant to assessing reintroduction in the upper Tuolumne River (includes past studies/information, ongoing studies related to licensing, and agency-led studies).
- Identify data gaps/additional information needs and scope priority studies in 2016 to address data gaps. 2016 studies constitute Phase 1 of the assessment framework with a focus on preliminary biological/ecological, regulatory, and other uses/user impact information needs.
- Conduct 2016 studies.
- Develop reintroduction program goal (i.e., criteria for success) in order to evaluate reintroduction (in combination with available/collected information).
- Develop Phase I reintroduction evaluation approach that addresses biological/ecological and regulatory areas (last quarter of 2016).

2017 (end Phase 1, begin Phase 2):

- Review and finalize 2016 study reporting and make information available for Phase I reintroduction evaluation.
- Conduct Phase I reintroduction evaluation using relevant program goal (developed in 2016) and existing/collected information. Collaborative discussion of evaluation results and whether reintroduction program goal can be met (i.e., key assessment point).
- If Phase I reintroduction evaluation results and subsequent discussions support proceeding forward with assessment framework, scope 2017 studies that constitute Phase 2 and are focused on additional biological/ecological information (as needed), re-engaging fish passage engineering design (using more accurate biological information), socio-economic and cost-benefit analysis, etc.).
- Reservoir Transit Study as identified in FERC's Study Plan Determination.
- Conduct 2017 studies.
- Develop Phase II reintroduction evaluation approach that addresses additional biological/ecological, engineering, and social and economic areas of consideration (last quarter of 2017).

2018:

- Review and finalize 2017 study reporting and make information available for Phase II reintroduction evaluation.
- Conduct Phase II reintroduction evaluation using relevant program goal (developed in 2016) and existing/collected information. Collaborative discussion of evaluation results and whether reintroduction program goal can be met (i.e., key assessment point).

2016 Phase 1 Schedule:

1. **Workshop 4 - January 27, 2016 (Wednesday): 9am to 12pm.**
    a. Objectives:
        i. Present and reach agreement upon framework and schedule (Phased approach including 2016 meetings).
        ii. Discuss and identify approach/schedule for developing goals of reintroduction program.
        iii. Summarize existing information and begin scoping potential 2016 studies that address key Phase 1 elements of assessment framework and can be used to assess reintroduction program success (goal).
        iv. Approve the use of a technical subcommittee as a means to implement technical tasks approved by the plenary group to minimize the numbers of workgroup meetings.
    b. Materials to be distributed in advance:
        i. Agenda
        ii. Draft Reintroduction Framework schedule and flow diagram
        iii. Studies list

2. **Workshop 5 – April 13 or 20, 2016**

a. Objectives:
    i. Review and approve 2016 study plans developed by technical subcommittee.
    ii. Progress report on task to develop reintroduction program goals.
b. Materials to be distributed in advance:
    i. 2016 study plans – for review/approval as identified from meeting 1
    ii. Reintroduction goal materials - TBD

3. May 2016 to November 2016 – Implementation of 2016 studies

a. No meetings planned until November during study implementation but could have a progress update via optional conference call, if desired.
b. June/July: complete development of reintroduction program goals.
c. July/August: begin technical subcommittee development of Phase I reintroduction evaluation approach.

4. Workshop 6 – November 17, 2016 (Thursday)

a. Objectives:
    i. 2016 study updates.
        1. Share preliminary information.
        2. Reporting schedule.
    ii. Present reintroduction program goal (completed in June/July 2016).
    iii. Present/approve Phase I reintroduction evaluation approach.
b. Materials to be distributed in advance:
    i. Agenda
    ii. TBD

2017 End Phase 1/Phase 2 Schedule: Detailed meeting schedule TBD; high level ideas for consideration below:

- 2016 study reporting will likely be final in first quarter of 2017 depending upon specific study scope and schedule.
- Priority in 1st quarter of 2017 is to conduct Phase I reintroduction evaluation to inform next steps of reintroduction assessment framework. – **Key Assessment Point.**
- If information shows that reintroduction goal can be met, 2017 Phase 2 studies would focus on additional biological/ecological information (if needed), and non-biological/ecological considerations such as socio-economics, impacts to other uses, etc. 2017 study scoping and study plan development would occur in the late first quarter/early second quarter of 2017.
- If reintroduction from a biological, ecological and regulatory perspective is supported, information could be available to re-engage in a more detailed concept-level fish passage engineering design process so this could occur in 2017.
- 2017 study updates.
- Development of a Phase 2 reintroduction evaluation approach to inform next key assessment point will be required toward the end of the year.

2018 – Detailed schedule TBD

- 2017 reporting completed.
- Complete Phase II reintroduction evaluation, second **Key Assessment Point** and final conclusion developed.

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

FISH PASSAGE FACILITIES ALTERNATIVES ASSESSMENT
TECHNICAL COMMITTEE CONFERENCE CALL

FEBRUARY 16, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Technical Committee Conference Call

Tuesday, February 16, 2016
11:00 am to 1:00 pm

Final Meeting Notes

Conference Call Attendees		
No.	**Name**	**Organization**
1	Jenna Borovansky	HDR, Inc., consultant to the Districts
2	Steve Boyd	Turlock Irrigation District
3	John Buckley	Central Sierra Environmental Resource Center
4	Larry Byrd	Modesto Irrigation District
5	Adrianne Carr	Bay Area Water Supply and Conservation Agency
6	Jesse Deason	HDR, Inc., consultant to the Districts
7	John Devine	HDR, Inc., consultant to the Districts
8	Greg Dias	Modesto Irrigation District
9	Art Godwin	Turlock Irrigation District
10	Chuck Hanson	Hanson Environmental, consultant to the Districts
11	Steve Holdeman	U.S. Forest Service
12	Zach Jackson	U.S. Fish and Wildlife Service
13	Bao Le	HDR, Inc., consultant to the Districts
14	Ellen Levin	City and County of San Francisco (CCSF)
15	Lonnie Moore	Citizen
16	Gretchen Murphy	California Department of Fish and Wildlife (CDFW)
17	Bill Paris	Modesto Irrigation District
18	Bill Sears	City and County of San Francisco (CCSF)
19	Chris Shutes	California Sportfishing Protecting Alliance
20	John Wooster	National Marine Fisheries Service (NMFS)
21	Ron Yoshiyama	City and County of San Francisco (CCSF)

On February 16, 2016, Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) hosted a Technical Committee conference call for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment and Upper Tuolumne River Fish Passage/Reintroduction Assessment Framework. This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting. Attachment A to this document includes the meeting agenda and read-ahead materials.

Meeting attendees introduced themselves. Mr. Le said there are two objectives for this conference call: (1) determine what studies will be completed in 2016 for the Upper Tuolumne River Fish Passage/Reintroduction Assessment Framework (Reintroduction Framework) and (2) begin discussing an approach for developing the reintroduction program goals.

Mr. Devine said one additional meeting objective is to discuss how this conference call and Workshop No. 4 (held on January 27) interface with the upcoming La Grange Project Initial Study Report (ISR) meeting (to be held on February 25) and the overall ISR process. Mr. Devine said the Districts will file a summary of the ISR meeting and then licensing participants will have an opportunity to comment on the meeting summary and request new studies and study modifications. The Districts will then have an opportunity to respond to those comments and then the Federal Energy Regulatory Commission (FERC) will make a determination on new studies and study modifications. Mr. Devine said part of the rationale of having Workshop No. 4 and this conference call prior to the ISR meeting was to allow time to come to a decision on what studies will be completed in 2016 so that this decision can be documented in the ISR meeting notes, which FERC will review.

Mr. Wooster asked if the Districts have been in communication with FERC about the Plenary Group's (individuals participating in the Reintroduction Framework) activities, given that FERC has not been participating in the Workshops. Mr. Devine said he recently had a call with Mr. Jim Hastreiter (FERC) and briefed Mr. Hastreiter on the Plenary Group's Workshops and recent decisions. Mr. Devine said he told Mr. Hastreiter the Plenary Group is trying to come to a decision on 2016 studies and, if a decision is made, the decision will be discussed at the ISR meeting. Mr. Devine said Mr. Hastreiter had no comment.

Mr. Wooster asked if the 2016 studies to be discussed today will be implemented within the licensing process or outside the licensing process, similar to the upper Tuolumne River studies the Districts are currently conducting voluntarily. Mr. Devine said he envisioned the latter because the 2016 studies will not be held to the licensing process criteria for new studies and conducting the studies outside the licensing process allows for more freedom to collaborate amongst the Plenary Group. Mr. Wooster said he agreed, but there may come a point in the licensing process where a due date arises and the 2016 study results are not yet available. Mr. Devine said that was a good point and it will be important for the Plenary Group to keep FERC informed of its progress and schedule.

Mr. Le reviewed the table of potential studies to inform the Reintroduction Framework (Studies Table). He said the Studies Table was developed by the Districts' technical team and studies included were identified as potential studies that could support reintroduction evaluation. Mr. Le stated that not every study in the Studies Table should or would be completed. As agreed to at the January 27, 2016 Workshop, implementation of the Reintroduction Framework would be phased. Mr. Le said Phase 1 would include completing the 2016 studies and comparing the 2016 study results with the reintroduction goals (also to be developed in 2016). If the study results suggest the reintroduction goals can be met, studies in 2017 (Phase 2) may be implemented.

Mr. Wooster provided an update on the genetics study being completed by NMFS. In 2015, 17 sites were sampled in the upper Tuolumne River for resident *O. mykiss*. A total of 634 samples were collected from those 17 sites. The National Oceanic and Atmospheric Administration (NOAA) Southwest Fisheries Science Center (NOAA Lab) processed the samples and is currently running the samples through algorithms. Mr. Wooster said the NOAA Lab is happy with the results so far. Mr. Wooster said the NOAA Lab will be presenting the results at a conference in June 2016, so he expected the study results will be available at that time. Mr. Wooster said the second year of sampling will take place this summer and will be informed by the first year of sampling. Samples will also be collected from the Merced River to both compare samples from the Merced River to the Tuolumne River samples and to inform a possible reintroduction program in the upper Merced River. NMFS also intends to collect samples from the lower Tuolumne River. Although NMFS received lower Tuolumne River samples from CDFW, these samples are somewhat older and NMFS is interested in collecting additional samples. The NOAA Lab will analyze the second-year samples over the winter 2016. A final report will be available by May 2017, and may be available as early as March 2017.

Mr. Wooster said NMFS has some funding for the second year of sampling, but most of the funding will be spent on the lab work, leaving little money for collecting the samples. Mr. Wooster said sample collection will rely heavily on volunteers and the National Park Service may help with sampling on the Merced River.

Mr. Devine asked what the NOAA Lab will present on at the June conference. Mr. Wooster said he did not know much about the June presentation, but he thinks the presentation will include analyses similar to analyses the NOAA Lab completed recently for the upper American River. Mr. Wooster said he did not think a final report had been released on the upper American River analyses.

Mr. Devine asked if Mr. Wooster had a sense of the scope of conclusions or recommendations that may be in the NOAA Lab's Tuolumne River genetics study report. Mr. Wooster said the study includes isolating genetic markers to determine whether there is a propensity toward anadromy and the study report will likely include this analysis. Mr. Wooster said he also expects the report will describe how the Tuolumne River samples might relate to samples from other nearby rivers and to samples from within the larger Central Valley, as well as to known hatchery strains (i.e., hatchery influence or introgression). Mr. Wooster said the report will likely not make recommendations on where to capture fish for broodstock.

Mr. Devine asked if NMFS has received the CDFW permits necessary for collecting samples on the lower Tuolumne River. Mr. Wooster said the NOAA Lab has received the necessary permits. However, due to time and funding constraints, at this time there is not an active plan to sample the lower Tuolumne River. Mr. Wooster said it would be great if individuals volunteered to help collect samples.

Mr. Wooster gave an update on an action item from Workshop No. 4, which was for NMFS to provide an abstract for the climate change study they proposed for consideration. Mr. Wooster said the study would assess the likely effects of climate change on the Tuolumne River. Mr. Wooster said he had been in communication with Ms. Andrea Ray at the NOAA Center for Dynamics in Colorado about producing an abstract for this study but so far an abstract has not been developed. Mr. Wooster said many climate change models predict changes in snow pack and water supply for the region including the Tuolumne River, and these changes would likely influence environmental conditions over the new license period. Mr. Wooster said he anticipated developing an abstract for a risk assessment approach with Ms. Ray, but that this approach would not be specific to the Tuolumne River. Instead, the abstract would describe the methodology and approach for completing a climate change study that could apply more broadly to any FERC licensing proceeding. Meeting attendees decided to table future discussions of a climate change study until an abstract is available for review.

Mr. Wooster asked if the Districts or CCSF have conducted climate change analyses and if these climate change analyses can be translated to flow or temperature impacts for use in this effort. There were no responses. Mr. Moore asked if the Districts or CCSF have ongoing studies related to the drought that could relate to climate change. Mr. Devine said a climate change study was proposed during the Don Pedro Project relicensing process, but FERC did not require the Districts to complete the study. Mr. Devine said the Districts have not completed any work during the Don Pedro Project relicensing process related to climate change.

Mr. Moore asked about the ability to model changes to the Don Pedro Project's releases and operations. Mr. Devine said the Districts produced several models (e.g., an operations model, reservoir model, lower river model, fish models) that can be used to run different outflow scenarios. The Districts provided training on how to use these models and the models are available for use by the public. Mr. Devine said he is unsure how helpful the models would be for modeling climate change impacts because the models do not include the necessary climatological inputs.

Mr. Shutes asked if CCSF has studies looking at climate change and predicting future water availability and surface runoff patterns. Ms. Levin said CCSF has done some basic sensitivity analysis of the effect of changing temperatures on inflow to the Hetch Hetchy Project Reservoir, but the analysis is dated and does not look at water supply. Ms. Levin said CCSF has a study plan that includes more downscaled work, but CCSF is unlikely to take the analysis further and the analysis will not be used to inform decision-making. Mr. Wooster asked if information on the scenarios is available. Ms. Levin said the work was not completed due to insufficient funding and CCSF will revisit the study if funding becomes available.

Mr. Shutes asked if CCSF has a temperature model for the CCSF reservoirs. Mr. Sears said CCSF has a stream temperature model of O'Shaughnessy Dam to Early Intake that was produced by Mr. Mike Deas as part of the Upper Tuolumne River Ecosystem Program (UTREP). Also as part of UTREP, McBain & Trush produced a water storage versus outflow temperature model. Mr. Sears said that is the extent of CCSF's temperature work.

Mr. Shutes asked what the NMFS habitat analysis entails. Mr. Le said the study includes collecting hyperspectral LiDAR data and some ground-truthing. Mr. Le said one of the primary reasons the Districts propose to conduct a separate habitat study is that results from the NMFS study will not be available until late summer, and when the results do become available it may be that additional habitat work including further ground-truthing is necessary. Logistically, it may be extremely challenging to complete any additional fieldwork in the fall, which would require that this study then be conducted in 2017. With regards to the overall Reintroduction Framework schedule, delaying a habitat study to 2017 is of concern to the Districts. Mr. Le said the Technical Committee has already agreed on the importance of having the habitat work completed in 2016 as part of Phase 1, therefore the Districts are interested in doing a habitat study to complement the work being completed by NMFS. Mr. Wooster agreed with Mr. Le's characterization of the NMFS study and said he expects the habitat typing data to be available in August or possibly the end of September. Mr. Devine also agreed with Mr. Le and said the habitat data is essential information. Mr. Devine said the Districts have researched the type of hyperspectral work being used in the NMFS study and reported that the experts the Districts consulted with believe the hyperspectral technique is somewhat experimental. Mr. Wooster asked what would be the scope of the Districts' habitat study since his primary concern is that this study might be duplicative as opposed to complementary to NMFS' effort. Mr. Devine said the scope is not yet determined and the Districts are open to discussing this during development of the study plan.

Mr. Le suggested that as a first step, the Districts develop a study plan for the habitat study in collaboration with the Technical Committee. Mr. Moore agreed. Mr. Wooster disagreed and said from his perspective the money would be better spent collecting data where no data is currently being collected. Mr. Wooster said the NMFS study is a 100 percent census of the study area and the data resolution is on par with data collected in the field. Mr. Devine said part of the Districts' concern with relying on the NMFS data is that a study plan or any other detailed information of NMFS's work is unavailable. Mr. Devine said the NMFS study LiDAR report had only one page about the spectral analysis and did not include anything about accuracy or penetration. Mr. Devine said the Districts are hopeful the NMFS study will produce solid information.

Mr. Wooster clarified that the NMFS study is using hyperspectral LiDAR to assess grain size for sediment out of the water. Mr. Wooster said images were taken in the field to conduct pebble counts. There has been good agreement between the hyperspectral data and the calibration data. Mr. Wooster said he does not have any other written descriptions of the hyperspectral work than what he has previously provided to the Districts.

Mr. Shutes asked for how the spawning gravel study in the Studies Table might overlap with the habitat typing work. Mr. Le said in general a spawning gravel study can be completed as part of a habitat characterization study, but given the importance of the spawning gravel study to the overall evaluation of reintroduction, the Districts decided to propose it as a separate study. Mr. Le said at Workshop No. 4, Mr. Wooster agreed with keeping the spawning gravel study separate. Mr. Wooster said the NMFS habitat study is primarily looking at bar features at 150 cfs in the mainstem and additional work in the tributaries would be helpful.

Mr. Shutes asked which study or studies NMFS would prefer be completed instead of the Districts' habitat study. Mr. Wooster said he believes the benthic macro-invertebrate (BMI) study is a high priority study and goes hand-in-hand with the habitat typing work and the spawning gravel work. Mr. Wooster said the reservoir transit study should also be a priority and he believes the cost estimate provided by the Districts is low, based on a conversation he had with a NMFS engineer about the study. Mr. Wooster said he will get additional details about why it appears the reservoir transit study cost estimate is low and provide these details to the Technical Committee.

Mr. Le said the Districts at this time are not proposing to undertake a detailed BMI study in 2016. Mr. Le stated that from an ecological feasibility perspective, Phase 1 is designed to focus on physical habitat. If the 2016 study results suggest adequate habitat is available, limiting factor studies, such as the BMI study, could possibly be conducted in 2017 even within the current FERC schedule. Mr. Wooster believes understanding the availability of food (i.e., the BMI study) is just as important as understanding the availability of habitat and spawning gravel and thermal suitability, all of which are being studied in 2016. Mr. Shutes said he agrees the BMI study is a high priority study. Mr. Shutes said conducting the study in 2016 would provide the opportunity to conduct additional sampling in 2017, if 2016 results appear anomalous. Mr. Shutes said it would be helpful to determine upfront which riffles the BMI sampling would focus on. Mr. Shutes believes the study could be done for reasonable cost and noted that on the Feather River, they used high resolution aerial imagery to identify eight or nine riffles from which to sample BMI that effectively informed productivity. Mr. Wooster said from an economies-of-scale perspective, it may make sense to collect the BMI data at the same time as the other 2016 fieldwork. Mr. Devine said the Districts will consider today's discussion about the BMI study, explore alternatives, and will provide feedback on whether they have an interest in conducting this study in 2016.

Mr. Le summarized study decisions made thus far on the call. The Districts will develop a habitat typing study plan and discussions will continue on whether or not the Districts should conduct this study. The Technical Committee agreed the spawning gravel study should be conducted. The Districts will give further consideration to whether or not the BMI study should be completed in 2016. Mr. Le described the regulatory evaluation and socioeconomic scoping studies and asked if anyone on the phone objected to conducting these studies in 2016. There were no responses.

Mr. Devine described the hatchery practices review. Mr. Devine said there have been reports of a self-sustaining kokanee population in Don Pedro Reservoir and anecdotal evidence of self-sustaining populations of resident Chinook and rainbow trout, both of which have been stocked in the past. Mr. Devine said these populations may hamper the successful reintroduction of spring-run Chinook and/or steelhead. Ms. Murphy said a recent paper by Moyle and others mentioned the existence of juvenile Chinook in Don Pedro Reservoir. Ms. Murphy said she would send the paper to Rose Staples (HDR) for distribution to the group. Mr. Devine said the subject of hatchery practices is likely to come up in the future and that it seems advantageous to start collecting the information now. Mr. Wooster agreed that information on hatchery practices would be useful to have and, especially given the relatively low cost of completing the study, there is value in beginning the study this year. Mr. Le said he will revise the Studies Table to have a "p" for the hatchery practices review.

Mr. Shutes asked if any thought had been given to the risk of a reintroduction program introducing pathogens into the upper watershed. Mr. Shutes said it would be helpful to determine whether or not this is something to be concerned about. Mr. Le agreed and said that collecting information on disease profiles can be incorporated into the hatchery practices review. Mr. Devine also agreed.

Mr. Le asked if others have thoughts or input on 2016 studies. There were no responses.

Mr. Devine said the Districts have spoken with their technical team about whether or not it is prudent to consider fall-run Chinook in these studies. Mr. Devine said there are several reasons not to include fall-run Chinook:

1. Fall-run Chinook are not included in the NMFS Recovery Plan. If one of the main reasons for the reintroduction program is to advance the Recovery Plan, then the Reintroduction Framework should only consider species in the Recovery Plan (i.e., spring-run Chinook and steelhead).
2. There are concerns about the effects of stress from non-volitional passage on fall-run Chinook. CDFW previously expressed concern over the amount of stress placed on fall-run Chinook from passing Dennett Dam.
3. There may be adverse interactions between fall-run and spring-run Chinook, such as increased competition. Maintaining genetic separateness is also a concern.
4. The risk of predation in the lower Tuolumne River to outmigrating smolts is a significant concern.
5. Plenty of habitat for fall-run Chinook already exists in the lower Tuolumne River.
6. Passing fall-run Chinook to the upper river may create a population sink.

Mr. Wooster said the issue of whether or not to consider fall-run Chinook in the Reintroduction Framework was discussed by the fish agencies over several months. Mr. Wooster said the issues Mr. Devine raised are reasonable and Mr. Wooster does not have the answers. However, there are many unknowns with reintroducing spring-run Chinook and steelhead and we are still moving forward with those species so it does not seem unreasonable to continue to consider fall-run Chinook. Mr. Devine said the Districts would like meeting attendees to reconsider their position on including fall-run Chinook.

Mr. Le said that with regard to the objective of developing an approach for developing reintroduction program goals, the Districts propose a separate subcommittee be formed. Mr. Le said this Reintroduction Goals Subcommittee would be smaller than the Technical Committee and would develop goals independently from the information collected by 2016 study program. The Technical Committee agreed to form a Reintroduction Goals Subcommittee. Mr. Devine said all are welcome to participate and those who are interested should email Rose Staples (HDR) at Rose.Staples@hdrinc.com.

Mr. Le said the next steps for the Technical Committee are to develop draft study plans, with the goal of discussing these study plans on a conference call in mid-March, ahead of the next Plenary Group meeting (to be held on April 13) where approval of final study plans would be an objective. The Districts will send around a Doodle poll for the date of the next Technical Committee call. Mr. Le said the Districts will prepare notes from this meeting and send these around to the group.

ACTION ITEMS

1. The Districts will prepare a habitat typing study plan in collaboration with the Technical Committee.
2. Mr. Wooster will provide additional details about why it appears the reservoir transit study cost estimate is low.
3. The Districts will consider today's discussion about the BMI study and will provide feedback to the Technical Committee.
4. Ms. Murphy will send to Ms. Staples the paper by Moyle and others mentioning the existence of juvenile Chinook in Don Pedro Reservoir. Ms. Staples will send this paper to the Technical Committee (complete).
5. Mr. Le will revise the Studies Table to state the upstream hatchery practices study is a suggested study (complete).

6. The Districts will send around a Doodle poll for the date of the next Technical Committee call (complete; the next Technical Committee call will be on March 18 from 10:00 am to 12:00 pm Pacific).
7. The Districts will prepare notes from this meeting (complete).

Technical Committee Conference Call
February 16, 2016

Meeting Notes

ATTACHMENT A

La Grange Hydroelectric Project
Reintroduction/Fish Passage Assessment Framework
Technical Subcommittee Conference Call

Tuesday, February 16, 11:00 am to 1:00 pm
Conference Line: 1-866-583-7984; Passcode: 814-0607

Meeting Objectives:

1. Identify and decide on 2016 studies for the Upper Tuolumne River Reintroduction/Fish Passage Assessment Framework (Reintroduction Framework).
2. Prepare schedule for study plan development of identified 2016 studies.
3. Identify and decide on a schedule for the development of reintroduction program goals.

TIME	TOPIC
11:00 am – 11:10 am	Introduction of Participants (All) Review Agenda and Meeting Objectives (Districts)
11:10 am – 12:20 pm	2016 Studies to Support Reintroduction Framework (All) a. General studies list b. Discuss feedback/comments from Workshop #4 c. Updates on studies in progress d. Discuss and decide: - 2016 studies -Study plan development schedule for 2016 studies
12:20 pm – 12:50 pm	Reintroduction Program Goals to Support Reintroduction Framework (All) a. Purpose of development of program goals (i.e., metrics for success) in the Reintroduction Framework b. Relationship to Recovery Plan c. Discuss and decide: - Development schedule - Participants
12:50 pm – 1:00 pm	Next Steps (All) a. Schedule next call and agenda topics (e.g., review 2016 draft study plans, etc.) b. Action items

Potential Studies to Inform Reintroduction Assessment Framework For Discussion and Review by Technical Subcommittee

Framework Category	Studies	On-going and Potential Studies for 2016[1]	Cost Estimate	Schedule for Draft Report
Ecological	Limiting Factors Analysis and Carrying Capacity		$340,000	December 2017
Ecological	Reservoir Transit Study		$500,000	
Ecological	Interactions with Existing Aquatic Communities		$250,000	
Ecological	Source Population Assessment		NMFS lead?	
Ecological	Method of Colonization		$60,000	
Ecological	Genetics Assessment of Existing and Source Populations (NMFS has study on-going)	X	NMFS lead	April 2017
Ecological	Climate Change Assessment (proposed by NMFS)		NMFS lead?	
Biological	Habitat Typing and Characterization[2]	P	$240,000	Nov/Dec 2016
Biological	Upstream Migration Barriers	X	$220,000	Nov/Dec 2016
Biological	Instream Flow – Habitat Assessment: PHABSIM		$300,000[3]	
Biological	Water Temperature Monitoring and Modeling	X	$350,000	Nov/Dec 2016
Biological	Spawning Gravel Study	P	$140,000	Nov/Dec 2016
Biological	Macroinvertebrate Study		$220,000	
Biological	Swim Tunnel Study of Upper River *O. mykiss*		$450,000	
Economic, Regulatory, and Other Key Considerations	Regulatory Evaluation of Reintroduction (ESA Status, BLM/USFS Management Plans, Wild and Scenic, etc)	P	$50,000	October 2016
Economic, Regulatory, and Other Key Considerations	Socioeconomic Scoping and Issues Identification/ Preliminary Evaluation of Impacts on Tuolumne River Uses/Users	P	$50,000	October 2016
Economic, Regulatory, and Other Key Considerations	Hatchery Practices Review, including current Don Pedro related practices.		$50,000	

Draft Study Abstracts

Limiting Factors Analysis and Carrying Capacity

A limiting factors analysis (LFA) is a useful tool to identify and fill information gaps related to physical and biological factors controlling population dynamics of one or more target species. This type of analysis has been used extensively in California and the Pacific Northwest to identify habitat conditions, ecological interactions, and other factors that constrain salmonid population production potential. The LFA proposed herein would test hypotheses regarding potential factors that that could limit the ability of the upper Tuolumne River to support viable populations of reintroduced Chinook salmon and O. mykiss. The data analyzed and synthesized as part of a LFA can also include an analysis of carrying capacity, to determine the number of individuals of each freshwater life stage that can be supported by the available habitat. The results of a LFA provide valuable insight into possible effects of current or historical riverine habitat

[1] X = Ongoing study; P = Proposed additional 2016 study for consideration by collaborative group

[2] Habitat typing and characterization study proposal does not explicitly include habitat components being collected by NMFS; however, the NMFS data should be discussed in overall Assessment Framework.

[3] The geographic scope and amount of available information needs to be confirmed to refine scope and cost estimate.

conditions on salmonid populations (or reintroduced populations), allowing managers evaluate reintroduction potential, focus future management activities, help prioritize actions, and/or refine the current understanding of limitations of the ecosystem.

Reservoir Transit Study

As detailed in FERC's study plan determination, if the fish passage facilities assessment indicate that the most feasible concept alternative for fish passage would involve either upstream or downstream passage through the project reservoirs (i.e., La Grange or Don Pedro reservoirs), a study would be required to evaluate the technical and biological feasibility of upstream (adults) or downstream (juvenile) movement of anadromous fish (as appropriate) through the project's reservoirs. Until feasible concept alternatives have been selected, the scope of this study cannot be accurately identified.

Interactions with Existing Aquatic Communities

Evaluating potential interactions with existing species in the target area is a factor that can impact reintroduction success. This constraint includes predatory and competitive interactions with other species and populations. Often times, habitat in target areas have changed from historic conditions. Consequently, aquatic communities present in target reintroduction areas may be comprised of non-native species or native invaders that have filled these available niches. Furthermore, intraspecific competition is possible if a population of the target species is already present in the target reach (i.e., *O. mykiss*). This assessment would identify the potential interactions of target reintroduction species with the existing aquatic community in the target reach and characterize the potential risks/benefits to the reintroduction program.

Source Population Assessment

Consideration of genetic and ecological characteristics of a source population is important to assessing the probability of a successful reintroduction. Ecological factors such as life history, morphological, and behavioral traits compatible with the target area will increase the probability of a successful reintroduction. Source populations that are genetically similar to the historic population may also maximize the benefits and reduce the risks of reintroduction. This assessment would identify factors that should be considered when identifying viable source populations, potential sources, associated pros and cons of each, and constraints of utilizing each source, if any.

Method of Colonization Assessment

Colonization approaches (i.e., natural, transplants, and hatchery releases) differ in the effects on the parameters that are used to assess the success or failure of a reintroduction. Method of colonization also has implications for the infrastructure and operations needed to support a reintroduction program. As such, identifying early in the process the lowest-risk strategy for colonization will be a critical component of assessing risks, constraints, and benefits of any reintroduction program.

Genetics Assessment of Existing and Source Populations

NMFS is conducting a study of the upper river *O. mykiss* fishery genetics. Request a schedule and information update for the group.

Climate Change Assessment

At the January 27th, 2016 Upper Tuolumne River Reintroduction Assessment Framework Workshop #4, NMFS requested that a climate change assessment be added to this potential studies list. An action item was noted at this workshop for NMFS to develop an abstract.

Habitat Typing and Characterization

Habitat mapping quantifies the type, amount, and location of river habitat types available to reintroduced anadromous salmonids of all life stages. Habitat mapping would be conducted in the field and remotely using standardized methodologies. The frequency and area of each habitat type (e.g., pool, riffle, run) would be tabulated and where potential holding pools for spring-run salmon occur, the size, depth, and vertical thermal profile of the pools will be measured to determine possible holding capacity, stratification of the pools (if any), and thermal suitability. Additional (remote) mapping tasks will include assessments of channel gradient, width, habitat areas, etc. This baseline information provides the template for many other evaluations and is critical for assessing the feasibility of reintroduction. For example, data on habitat type, area, and distribution are required to assess potential Chinook salmon and steelhead adult holding capacity, spawning habitat potential, and juvenile rearing capacity.

Upstream Migration Barriers

Little information exists to reliably assess the current quantity and quality of suitable habitat for the adult, egg, fry and juvenile life stages of anadromous salmonid species that may be considered for reintroduction in the Upper Tuolumne River watershed (i.e., above the Don Pedro Project). Prior to assessing the quality/suitability of habitat for target species, an assessment of barriers (both complete and partial) to upstream anadromous salmonid migration must first be conducted to identify the quantity of habitat that is accessible. This assessment would utilize relevant prior studies, desktop analyses, and field surveys to characterize and document the physical structure of barriers in the mainstem Tuloumne River and its tributaries upstream of the Don Pedro Project Boundary. Note that this study was requested by NMFS but per FERC's determination, was not required to be conducted by the Districts as part of the La Grange licensing process. However, to more fully support licensing participants in their development of information to supplement fish passage and reintroduction assessments, and to foster collaboration among all parties, the Districts have opted to conduct an upstream migration barriers assessment.

Instream Flow – Habitat Assessment: PHABSIM

Hydraulic models such as the Physical Habitat Simulation (PHABSIM) system are widely used and accepted tools used to produce quantitative estimates of the amount (quantity and quality) of habitat available to fish at a range of stream flows. Using measured physical channel characteristics for representative habitat types or reaches, PHABSIM modeling incorporates habitat suitability relationships for the target fish species and life stage to produce estimates of weighted usable area (WUA) in relation to stream flow. Results of PHABSIM modeling can be combined with data from habitat mapping and water temperature modeling to provide estimates of habitat availability and suitability for target species and associated life stages throughout the project area at a range of flows. Additionally, the analysis would include an evaluation of the effect of fluctuating flows on habitat value, due to the frequent peaking operations in the upper Tuolumne River. This could be evaluated by comparing habitat values on a small time-step using the high and low flows within the fluctuation range. Water temperature data would also be overlaid with the PHABSIM results to evaluate how the total amount of habitat is affected by thermal rather than physical habitat conditions.

Water Temperature Monitoring and Modeling

The assessment of suitable habitat quality for the adult, egg, fry and juvenile life stages of anadromous salmonid species that may be considered for reintroduction in the Upper Tuolumne River watershed (i.e., above the Don Pedro Project) is dependent upon both physical and thermal characteristics. This study would use existing and additional data to characterize the thermal regimes of the upper Tuolumne River and tributaries from the Don Pedro Project Boundary to CCSF's Early Intake to characterize locations where temperatures may be suitable for anadromous salmonid species considered for reintroduction. The study would include the development of a computer model to simulate existing thermal conditions in the study area. Note that this study was requested by NMFS but per FERC's determination, was not required to be conducted by the Districts as part of the La Grange licensing process. However, to more fully support licensing participants in their development of information to supplement fish passage and reintroduction assessments, and to foster collaboration among all parties, the Districts have opted to conduct an upstream migration barriers assessment.

Spawning Gravel Study

Spawning gravel mapping quantifies the amount, location, and suitability of gravel available for spawning by reintroduced anadromous salmonids. In a confined, high gradient river channel dominated by large substrates (boulder, cobble, bedrock) like the upper Tuolumne River, spawning gravel distribution is typically patchy and overall abundance may be low. Initial evaluation of aerial photographs and an on-river reconnaissance survey indicate this is may be the case in portions of the Tuolumne River between Wards Ferry and Early Intake. Because successful spawning and fry production are dependent on the abundance and suitability of accessible spawning gravel, spawning gravel mapping is a critical component for assessing the feasibility of reintroduction. This information is a key part of any evaluation of the factors likely to limit production and viability of an existing or reintroduced salmonid population (i.e., a limiting factors or carrying capacity analysis).

Macroinvertebrate Study

Drifting and benthic macroinvertebrates (BMI) are the primary food source for rearing salmonids in fresh water habitats. Growth of juvenile anadromous salmonids during their freshwater rearing period is critical for their survival during outmigration and ocean phases, as well as to the overall viability of the population. Studies have shown a strong relationship between the size at which juvenile salmon and steelhead migrate to the ocean and the probability that they return to fresh water to spawn. Macroinvertebrate sampling provides a measure of food availability during this important life history period. Information on macroinvertebrate prey resource availability is therefore a key component of any evaluation of the factors likely to limit production and viability of an existing or reintroduced salmonid population (i.e., a limiting factors analysis).

Swim Tunnel Study of Upper River O. mykiss

Thermal acclimation among fish species dates back to the 1940's and since 2001, thermal adaptation at the population level and among a wide variety of fish species has been convincingly supported in the peer-reviewed scientific literature. Included in this evidence base are salmon and trout species. The objective of this study would be to determine the thermal performance of the subadult *O. mykiss* population inhabiting the upper Tuolumne River to assess any local adjustments in thermal performance. The study would test the hypothesis that the *O.mykiss* population in the Upper Tuolumne River (i.e., above the Don Pedro Project Reservoir) is locally adjusted to relatively warm thermal conditions that may exist during the summer. Results of the study would be used to support habitat suitability and temperature modeling assessments.

Hatchery Practices Review, including current Don Pedro related practices

Assessing historic and current hatchery practices in the upper Tuolumne River will be necessary to evaluate potential risks to reintroduction. Risks include but are not limited to evolutionary (homogenization or reduced fitness), ecological (competition, predation, etc.) and disease issues. Results of the review will identify past and current hatchery practices in the reintroduction area as well as connected areas (i.e., Don Pedro Reservoir), potential risks of past/present hatchery programs to a reintroduction program, and recommendations to address identified risks.

Regulatory Evaluation of Reintroduction

The Upper Tuolumne River watershed spans several land management agencies' jurisdictions and there are management plans and regulations in place based on established resource management objectives (e.g., Wild and Scenic Management Plan, Forest Plan, BLM Management Plan). The compatibility of the potential reintroduction of *O.mykiss* and/or spring run Chinook will be evaluated relative to these current management objectives. The potential reintroduction of Endangered Species Act (ESA) listed species may overlay additional management objectives and a new regulatory framework in the upper Tuolumne River. This evaluation will include compiling and reviewing all relevant and potentially relevant existing management plans for the upper Tuolumne River and the Don Pedro Reservoir. In addition, applicable recovery plans and ESA regulations and potential population status classifications for the reintroduced species will be summarized. Responsible resource management agencies will be contacted to determine the most recent guidance documents for the study area.

Socioeconomic Scoping and Issue Identification/Preliminary Evaluation of Impacts on Tuolumne River Uses/Users

Current management of the Don Pedro Reservoir and upper Tuolumne River supports a wide range of resources, uses, and users. The upper watershed includes the Tuolumne Wild & Scenic River segment managed for several outstanding resource values and is utilized by commercial and private recreational boaters. Other uses include the City and County of San Francisco's Hetch Hetchy Project operations, private timber practices, and a recreational fishery. Don Pedro Reservoir has an active house boating and recreational fishery; county government and businesses rely upon the economic activities supported by the upper watershed. This evaluation will conduct a comprehensive survey of uses in the upper watershed and identify potential issues for consideration in the reintroduction assessment. A literature survey and review of existing information from the Don Pedro Recreation Agency, county and federal land management agencies and other sources will be conducted. Surveys and/or focus groups will be used to verify and expand upon available information on the multiple existing uses of the watershed that could be impacted by a fish reintroduction program.

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

FISH PASSAGE FACILITIES ALTERNATIVES ASSESSMENT
TECHNICAL COMMITTEE CONFERENCE CALL

MARCH 18, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project
Reintroduction Assessment Framework
Technical Committee Conference Call

Friday, March 18, 10:00 am to 12:00 pm
Conference Line: 1-866-583-7984; Passcode: 230-0743

Meeting Objectives:

1. Review and discuss 2016 study plans for the Upper Tuolumne River Reintroduction Assessment Framework (Reintroduction Framework).
2. Identify schedule for study plan finalization in advance of April 13, 2016 Plenary Group meeting.
3. Discuss next steps on Reintroduction Program Goals subgroup.

TIME	TOPIC
10:00 am – 10:15 am	Introduction of Participants (All) Review Agenda and Meeting Objectives (Districts) Review Action Items from Last Call (All)
10:15 am – 11:30 am	2016 Study Plans to Support Reintroduction Framework (All) a. Present and discuss study plans b. Identify schedule for study plan finalization (for presentation at April 13, 2016 Plenary Group meeting)
11:30 am – 11:50 am	Reintroduction Program Goals to Support Reintroduction Framework (All) a. Purpose of developing program goals (i.e., metrics for success) in the Reintroduction Framework Assessment b. Relationship to Recovery Plan c. Update: - Schedule - Participants - Next steps
11:50 am – 12:00 pm	Next Steps (All) a. Schedule next call and agenda topics b. Action items from this call

La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Technical Committee Conference Call

Friday, March 18, 2016
10:00 am to 12:00 pm

Final Meeting Notes

Conference Call Attendees		
No.	**Name**	**Organization**
1	Leigh Bartoo	U.S. Fish and Wildlife Service
2	Jenna Borovansky	HDR, consultant to the Districts
3	Steve Boyd	Turlock Irrigation District
4	Paul Bratovich	HDR, consultant to the Districts
5	Adrianne Carr	Bay Area Water Supply and Conservation Agency
6	Jesse Deason	HDR, consultant to the Districts
7	John Devine	HDR, consultant to the Districts
8	Art Godwin	Turlock Irrigation District
9	Jason Guignard	FishBio, consultant to the Districts
10	Tom Holley	National Marine Fisheries Service
11	Zach Jackson	U.S. Fish and Wildlife Service
12	Patrick Koepele	Tuolumne River Trust
13	Ellen Levin	City and County of San Francisco
14	Lonnie Moore	Citizen
15	Marco Moreno	Latino Community Roundtable
16	Gretchen Murphy	California Department of Fish and Wildlife
17	Bill Paris	Modesto Irrigation District
18	Bill Sears	City and County of San Francisco
19	Jay Stallman	Stillwater Sciences, consultant to the Districts
20	Cory Warnock	HDR, consultant to the Districts
21	Scott Wilcox	Stillwater Sciences, consultant to the Districts
22	Alison Willy	U.S. Fish and Wildlife Service
23	John Wooster	National Marine Fisheries Service
24	Ron Yoshiyama	City and County of San Francisco

On March 18, 2016, Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) hosted a Technical Committee conference call for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment and Upper Tuolumne River Fish Reintroduction Assessment Framework (Framework). This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting. Attachment A to this document includes the meeting agenda and draft study plans.

Mr. John Devine (HDR, consultant to the Districts) provided background on why the Technical Committee was formed. Mr. Devine said at Workshop No. 4 (held on January 27, 2016; meeting notes and materials are available on the La Grange Project licensing website here), the Plenary Group (i.e., all Framework participants) agreed to form a Technical Committee to try to come to agreement on what studies would be completed in support of implementing the Framework. On the first Technical Committee conference call (held on February 16, 2016; draft meeting notes and materials available here), the Technical Committee agreed to draft study plans for several studies to be conducted in 2016. The

Districts drafted five study plans and on March 16, 2016, sent these study plans to the Technical Committee for review and comment.

Mr. Devine said the objective of today's meeting is to discuss each study plan with the Technical Committee. The Districts hope that providing an overview of each study plan will help expedite the Technical Committee's study plan review. Mr. Devine said a second objective of this call is to discuss the schedule for reviewing the study plans and, if necessary, schedule another conference call prior to the study plan comment due date, to allow individuals an opportunity to ask questions or get clarification on the study plans before comments are due.

Mr. Devine reviewed the status of the action items from the February 16 Technical Committee call. All action items from that call are complete except for one; Mr. John Wooster (National Marine Fisheries Service [NMFS]) will provide additional details about why it appears the reservoir transit study cost estimate provided by the Districts appears to be low.

Mr. Jay Stallman (Stillwater Sciences, consultant to the Districts) summarized his professional background and reviewed the goals, study area, and methodology for the Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study (Spawning Gravel Study). Mr. Tom Holley (NMFS) said Chinook salmon currently exist in Don Pedro Reservoir and these fish swim upstream to spawn. Mr. Holley asked if there is existing information on where those fish spawn and said he believes snorkel studies may have been performed in the area where Chinook spawn. Mr. Devine said he has also heard that resident Chinook salmon may exist in Don Pedro Reservoir, as well as Kokannee salmon, but he is unaware of any documented observations. Mr. Holley said he believes the California Department of Fish and Wildlife (CDFW) completed snorkel surveys in the Lumsden reach and documented adult Chinook salmon during those surveys. Ms. Gretchen Murphy (CDFW) said she is unaware of snorkel surveys being done in that reach. Mr. Patrick Koepele (Tuolumne River Trust) said Mr. Steve Holdeman (U.S. Forest Service) may have information on the presence of Chinook salmon in that reach of the river. Mr. Devine said the Districts will contact Mr. Holdeman about information the U.S. Forest Service may have relevant to resident Chinook salmon or other reservoir species using the upper Tuolumne River.

Mr. Jason Guignard (FishBio, consultant to the Districts) summarized his professional background and reviewed the goals, study area, and methodology for the Upper Tuolumne River Habitat Mapping and Macroinvertebrate Assessment (Habitat Mapping Study). Mr. Guignard noted that the Habitat Mapping Study Plan and Spawning Gravel Study Plan were developed in close coordination as both studies will be completed on the same rafting trips.

Mr. Lonnie Moore (citizen) asked if the Habitat Mapping Study will collect data on both drifting macroinvertebrates and benthic macroinvertebrates. Mr. Guignard confirmed the study will collect data about both types of macroinvertebrates.

Mr. Wooster said significant stage changes will likely occur during the Habitat Mapping Study fieldwork. He asked how the study will accommodate for those stage changes. Mr. Guignard said the flow schedule is not yet available for when the fieldwork will be completed. At this point, the study team is planning to complete the fieldwork at the end of the summer and/or early fall, when low flows and less flow fluctuation is anticipated. Mr. Guignard said the study team is cognizant that peaking flows may make it more difficult to collect detailed habitat mapping data.

Mr. Wooster asked if the study team will use depth sounders to collect water depth information and how the study team will account for daily flow fluctuations when water depths are measured. Mr. Guignard said depth sounders will be used. As much as possible, the study team is intending to collect data in each reach during off-peak, low flows conditions, not at on-peak flow conditions. Mr. Guignard said the study team is still determining whether the logistics associated with this approach is realistic. Mr. Wilcox (Stillwater Sciences, consultant to the Districts) said fluctuations in flow will likely not impact depth measurements at deep pools because any fluctuations in flow will likely be a small percentage of the total pool depth. Mr. Wooster said fluctuations of two or three feet could create significant variability regarding depth measurements at shallow pools. Mr. Devine said the study team is still working out the logistics and will aim to collect data during non-peaking flows. Mr. Devine reiterated that the intent of the study is to collect data during base flow conditions. Mr. Devine said the study team will be very careful to document field and flow conditions when data is collected.

Mr. Wooster asked if the Districts can provide the model number and other specifications for the depth finders that will be used. Mr. Wooster said in his experience, the amount of fine sediment in the water seems to impact a depth finder's performance. Mr. Guignard said he does not know the model numbers or specifications offhand. Mr. Guignard said several different models will likely be used during the fieldwork. Mr. Guignard said he has experience using each model and in his previous fieldwork, each model performed well, even in the presence of fine sediment. Mr. Guignard said a stadia rod will be used to measure depths where possible and depth finders will only be used for deep pools where the stadia rod is too short. Mr. Wooster asked if a depth finder was used during the 2015 mesohabitat data collection. Mr. Wilcox said a depth finder was used for the 2015 data collection and the depth finder provided consistent measurements. Mr. Devine asked if Mr. Wooster has recommendations on what depth sounders should be used, or avoided. Mr. Wooster said he did not have specific recommendations. Mr. Wooster said depending on the hydrograph at the time of data collection, sediment from the Rim Fire may or may not create turbidity and affect the depth sounder readings, and this is something that should be considered. Mr. Devine agreed. Mr. Wilcox said turbidity was not a problem during the 2015 data collection, but that likely had to do with the dry water year. Conditions may be different for the 2016 data collection.

Mr. Wooster asked if the Districts will provide additional information on the mesohabitat mapping that was completed last summer, as part of the Upper River Barriers Study. Mr. Wilcox said the Upper River Barriers Study researchers opportunistically collected data on gravel, large woody debris, and pool depth. This data collection was unrelated to the Upper River Barriers Study and was thus not included in the Upper River Barriers Study Progress Report. Mr. Devine said the mesohabitat data is currently being summarized and will be provided to licensing participants when the summary is complete. Mr. Wooster said receiving the summary soon would be helpful for informing NMFS's comments on the study plans. Mr. Wilcox said the data can be made available, but cautioned the data may not be ready for scientific analysis. Once the data undergoes necessary internal reviews, it can be made available to the public.

Mr. Moore asked if the Habitat Mapping Study will include surveys of the riparian habitat. Mr. Wilcox said the study will only look at stream habitat. Mr. Moore said there are a number of studies recognizing the benefit of riparian habitat to salmon and steelhead and asked if a study can be done on the riparian habitat in the lower Tuolumne River and upper Tuolumne River. Mr. Devine said a riparian study of the lower Tuolumne River was completed for the Don Pedro relicensing and he will send out a link to the study report. Mr. Devine said a study of the riparian habitat in the upper river is not planned, but collecting general observations about riparian habitat could be added to one of the studies being completed. Mr. Guignard noted the Habitat Mapping Study Plan includes documenting the percent total canopy, which is the amount of riparian habitat that is shading the river. Mr. Wilcox said there is not much riparian shading in the upper river.

Ms. Borovansky (HDR) reviewed the goals, study area, and methodology for the Hatchery and Stocking Practices Review. Ms. Borovansky said the study plan includes research into the disease profiles of hatchery stocks, per discussions on the February 16 Technical Committee call.

Ms. Borovansky reviewed the goals, study area, and methodology for the Regulatory Context Study. Ms. Borovansky requested that meeting attendees submit ideas for additional plans that should be reviewed as part of this study. Mr. Bill Sears (City and County of San Francisco) requested that the Stanislaus National Forest Wild and Scenic River Plan be added to the list of plans to be reviewed. Mr. Sears said he can provide a copy of the plan if the Districts do not already have a copy.

Ms. Borovansky reviewed the goals, study area, and methodology for the Socioeconomic Scoping Study. Mr. Wooster asked if the objective of the study is to only develop a list of activities that could potentially be affected by fish passage and reintroduction, and not to assess how these activities may be affected. Ms. Borovansky confirmed Mr. Wooster is correct. Ms. Borovansky said the study is a scoping exercise to identify existing uses and activities. Once conceptual fish passage alternatives are available, the study team can begin to assess how uses and activities may be affected. Mr. Moore asked if the study team would consider expanding the study area to include the lower Tuolumne River. Mr. Devine agreed the lower river may be impacted by fish passage. He said the Hatchery and Stocking Practices Review Study Plan, Regulatory Context Study Plan, and Socioeconomic Scoping Study Plan will be reviewed, and revised if necessary, to adequately consider effects to the lower river.

Mr. Devine reviewed the schedule. The Districts are hoping to receive any comments on the study plans by March 29. The Districts will address any comments received and provide revised versions of the study plans to the Plenary Group ahead of Workshop No. 5, scheduled for April 13. Mr. Devine suggested the Technical Committee may like to have another conference call between now and March 29, perhaps on March 24, to allow individuals an opportunity to ask questions or get clarification on the study plans prior to March 29. Mr. Devine said individuals are welcome to submit questions ahead of the March 29 deadline, and study leads would do their best to quickly provide answers. All questions should be sent to Ms. Rose Staples (HDR) (rose.staples@hdrinc.com).

Mr. Wooster said given that the deadline for comments on the La Grange Initial Study Report (ISR) is April 4, it will be nearly impossible for him to provide comments on the study plans by the March 29 deadline and he likely will not have time to participate on a call on March 24. Mr. Wooster said a call the week of April 4 would work much better for his schedule. Mr. Koepele said it will be difficult for him to make the March 29 study plan comment deadline, given the April 4 deadline for ISR comments. Mr. Devine said the Districts will convene on the schedule and get back to the Technical Committee.

Mr. Wooster asked if future fish passage engineering feasibility meetings will be separate from the Plenary Group meetings. Mr. Devine said the Districts do not envision separate meetings for fish passage engineering feasibility and any technical items that arise can likely be handled by the Technical Committee or via individual communications.

Mr. Devine discussed the importance of having reintroduction program goals and how the results of the 2016 studies will be measured against those goals. Mr. Devine said the Reintroduction Goals Subcommittee (Goals Subcommittee) will take the lead on developing reintroduction program goals. Mr. Devine said eight people have volunteered to participate on the Goals Subcommittee and, based on the results of a Doodle poll, the first Goals Subcommittee call will be on Friday, April 1, from 10:00 am to 12:00 pm.

Mr. Devine said no agency personnel volunteered to participate on the Goals Subcommittee and asked what is preventing agency personnel from participating. Mr. Wooster said his schedule is already full and he does not have time to participate in another committee or on a call on April 1. Mr. Devine asked if moving the meeting until after April 4 would allow Mr. Wooster to participate. Mr. Wooster said he would likely be able to participate if the meeting is after April 4. Ms. Gretchen Murphy (CDFW) said she does not have time to participate in the Goals Subcommittee given her upcoming field season. Ms.

Alison Willy (U.S. Fish and Wildlife Service) said she is also too busy to participate. Mr. Devine said it may be that at the first Goals Subcommittee meeting on April 1, a rough schedule is developed and then the broader group is canvased to determine the date for the second meeting. Mr. Wooster said he may be able to attend the second meeting or, if he is unable to attend, he can provide his comments after the meeting.

Mr. Devine reviewed action items from today's call and said the Districts will send out meeting notes.

Meeting adjourned.

ACTION ITEMS

1. Incomplete action item from February 16 Technical Committee call: Mr. Wooster will provide additional details about why it appears the reservoir transit study cost estimate provided by the Districts appears to be low.

2. Mr. Sears will provide a copy of the Stanislaus Forest Wild and Scenic River Plan. (complete)

3. Mr. Devine will send to the Technical Committee the snorkel survey report provided by Mr. Holley. (complete)

4. The Districts will contact Mr. Steve Holdeman (U.S. Forest Service) about information the U.S. Forest Service may have relevant to resident Chinook salmon or other reservoir species using the upper Tuolumne River.

5. The Habitat Practices Study Plan, Regulatory Context Study Plan, and Socioeconomic Study Plan will be revised to consider effects on the lower Tuolumne River (as well as Don Pedro Reservoir and the upper Tuolumne River).

6. HDR will send out a link to the Lower Tuolumne River Riparian Information and Synthesis Study Report (W&AR-19). (Rose to complete on 3/22)

7. The Habitat Mapping Study Plan will be revised to include completing general observations of riparian habitat, in addition to the percent total canopy which is already included in the study plan.

8. Given scheduling constraints discussed at the meeting, the Districts will revisit the current schedule including the March 29 due date for comments on the study plans and will report back to the Technical Committee. (complete)

9. The Districts will provide results from the 2015 habitat data collection work. This should be completed, with QA/QC done, by mid-April.

10. The Districts will provide notes from today's meeting. (complete)

DRAFT STUDY PLAN

**TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT**

**LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581**

Upper Tuolumne River Habitat Mapping and Macroinvertebrate Assessment

March 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Upper Tuolumne River Habitat Mapping and Macroinvertebrate Assessment is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to characterize habitat distribution, abundance, and quality in the upper Tuolumne River.

2.0 STUDY AREA

The study area will include the mainstem of the upper Tuolumne River from the upstream limit of the Don Pedro Project (approximately RM 81) to Early Intake (approximately RM 105).

3.0 STUDY GOALS

The primary goal of this study is to provide information on habitat distribution, abundance, and quality in the upper Tuolumne River. This information will inform evaluations in the Framework and is critical for assessing the feasibility of anadromous salmonid reintroduction, estimating potential population size and developing engineering alternatives for the upper Tuolumne River. Specific objectives include:

- document the number, size and distribution of mesohabitats available in the upper Tuolumne River;
- collect detailed data on habitat attributes in representative reaches of the upper Tuolumne River;

- documenting potential pool holding habitat for over-summering adult Chinook salmon; and
- collect drift and substrate samples of macroinvertebrates (salmonid prey organisms).

4.0 STUDY METHODS

For this assessment, habitat mapping will quantify the type, amount, and location of habitat types available to potentially reintroduced anadromous salmonids during their riverine life stages (adult holding/spawning, incubation and rearing). Habitat mapping will be conducted in the field and remotely using standardized methodologies. The frequency and area of each habitat type (e.g., pool, riffle, run) will be tabulated and where potential holding pools for adult Chinook occur, the size and depth of the pools will be measured to determine possible holding capacity. Additional mapping tasks will include assessments of channel gradient, width, habitat areas, etc.

Habitat mapping will consist of mapping all mesohabitat units between Early Intake (RM 105) and the upstream limit of the Don Pedro Project (approximately RM 81), and collecting detailed habitat data in a sub-set of the mapped mesohabitat units.

4.1 Task 1. Mesohabitat Mapping

Reconnaissance level mapping in the summer of 2015 consisted of mesohabitat classifications (Table 1.0) for portions of the reach between Lumsden (Merals Pool at RM 96) and approximately RM 81. In 2016, habitat mapping will be extended up to Early Intake (RM 105), and gaps in mapping between RM 96 and approximately RM 81 will be comprehensively assessed to obtain a more complete dataset. Habitat units will be identified visually by a boat-based survey crew and mapped on pre-existing high-resolution color aerial photographs. Boundaries of mesohabitat units will also be geo-referenced in the field with a handheld GPS unit.

Table 1.0 Mesohabitat mapping units and criteria for the mainstem Tuolumne River.

Mesohabitat types	Definitions/ Criteria
Deep Pool	>6 ft max depth
Shallow Pool	<6 ft max depth
Glide/ Pool tail	Typically in the downstream portion of a pool with negative bed slope where converging flow approaches the riffle crest. Wide, shallow, flat bottom with little to no surface agitation. Substrate type is typically smaller than riffle, but coarser than pool and often provides best salmonid spawning habitat.
Run	Long, smoothly flowing reaches, flat or concave bottom, and deeper than riffles with less surface agitation. Higher velocities than pools.
Boulder Garden/Pocket Water	Moderate to low gradient riffles, runs, and glides with numerous large boulders/obstructions that create scour pockets and eddies with near zero velocity. Often no clear thalweg present due to multiple flow paths.
Cascade/ Chute	>10% gradient, and with air entrainment (particularly in cascades), very large boulders and/or bedrock. Consisting of alternating small waterfalls and can have shallow pools in middle and margin of channel at low flows.
High Gradient Riffle	>4% gradient. Substrate is usually large boulder and bedrock (>24")
Low Gradient Riffle	<4% gradient. Substrate is usually small boulder and large cobble(6-24")
Side Channel	Contains < 20% of total flow. Connected at top and bottom to main channel at low flow.
Backwater	Low to zero velocities. Only connected to main channel from one end.

Mapped habitats will be digitized and added to the project GIS layer for mapping, as well as for quantitative and spatial analysis. Color maps will be created to depict the type and location of habitats throughout the study area and in relation to important features such as tributaries, potential passage barriers, access points, and water temperature monitoring locations. The frequency and area of each habitat type (e.g., pool, riffle, run) will also be tabulated.

4.2 Task 2. Habitat Inventory Mapping

Additional (remote) mapping tasks will include assessments of channel gradient, width, habitat areas, etc. following the CDFW Level III habitat typing methodology (CDFG 2010). Methods will be similar to habitat typing conducted in the lower Tuolumne River (TID/MID 2013). Sampling units selected for detailed habitat measurements will encompass approximately 10 to 20 percent of the study reach, as recommended in CDFG (2010). The habitat typing field effort will consist of a team of three biologists surveying the river by raft. The study area will be divided into seven sampling reaches, based on length of river rafted daily (two reaches from Early Intake to Lumsden and five reaches from Lumsden to Wards Ferry). Within each individual sampling reach, a one mile section will be randomly selected for habitat typing. Prior to the field assessment, the team will use maps and existing aerial photographs to delineate the specific reaches to be surveyed.

A suite of measurements consistent with the Level III CDFW criteria (Table 2.0) will be made within each mesohabitat type along each of the selected one-mile reaches. Data will be recorded on standardized datasheets to ensure all data are collected in a consistent manner. A photograph of each and GPS coordinates will be recorded at the bottom of each habitat unit. Unit length and width will be measured with a laser range finder. Depths will be measured using a stadia rod or handheld depth finder. Large woody debris (LWD) count will include a count of LWD pieces with a diameter greater than one foot and a length between six and twenty feet, as well as pieces greater than twenty feet in length, within the bankfull width. Percent total canopy will be measured using a spherical densiometer at the upstream end of each habitat unit in the center of the wetted channel. The remaining habitat parameters including substrate composition, substrate embeddedness, shelter complexity, and bank composition types will be visually estimated. Within each sampling reach, stream gradient will also be measured using a clinometer over a distance of at least 20 bankfull channel widths. In addition, the size and depth of each pool will be collected throughout the study reach to help quantify the amount of potential Chinook salmon adult holding habitat.

Table 2.0 List of data collected as part of Level III CDFW habitat mapping.

Data	Description
Form Number	Sequential numbering
Date	Date of survey
Stream Name	As identified on USGS (U.S. Geological Survey) quadrangle
Legal	Township, Range, and Section
Surveyors	Names of surveyors
Latitude/Longitude	Degrees, Minutes, Seconds from a handheld GPS
Quadrant	7.5 USGS quadrangle where survey occurred
Reach	Reach name or river mile range
Habitat Unit Number	The habitat unit identification number
Time	Recorded for each new data sheet start time
Water Temperature	Recorded to nearest degree Celsius
Air Temperature	Recorded to nearest degree Celsius
Flow Measurement	Available from USGS monitoring stations
Mean Length	Measurement in feet of habitat unit
Mean Width	Measurement in feet of habitat unit wetted width
Mean Depth	Measurement in feet of habitat unit
Maximum Depth	Measurement in feet of habitat unit
Depth Pool Tail Crest	Maximum thalweg depth at pool tail crest in feet

Data	Description
Pool Tail Embeddedness	Percentage in 25% interval ranges
Pool Tail Substrate	Dominant substrate: silt, sand, gravel, small cobble, large cobble, boulder, bedrock
Large Woody Debris Count	Count of LWD within wetted width and within bankfull width
Shelter Value	Assigned categorical value: 0 (none), 1 (low), 2 (medium), or 3 (high) according to complexity of the shelter.
Percent Unit Covered	Percent of the unit occupied
Substrate Composition	Composed of dominant and subdominant substrate: silt, sand, gravel, small cobble, large cobble, boulder, bedrock
Percent Exposed Substrate	Percent of substrate above water
Percent Total Canopy	Percent of canopy covering the stream
Percent Hardwood Trees	Percent of canopy composed of hardwood trees
Percent Coniferous Trees	Percent of canopy composed of coniferous trees

Results to be reported include the following:

- Ground-mapped habitat units
  - Total number of habitat units, by type
  - Total length of habitat units, by type
  - Number of habitat units (frequency)
  - Average width of habitat units, by type
  - Number and relative frequency of dominant instream cover types
  - Reach summary data (e.g., average bankfull width and depth, LWD density (within wetted and bankfull))
- Pool holding habitat
  - Total number of pools identified as potential holding habitat (and the criteria of determination)
  - Average and maximum pool depth
  - Percentage of pools with ≥ 5% cover
  - Map showing the suitable holding pools in each 1-mile sampled reach of the upper Tuolumne River
- Tributary mapping data and reconnaissance level mainstem Upper Tuolumne River habitat data collected in 2015

4.3 Task 3. Macroinvertebrate Assessment

If time and logistics allow as the final field schedule is developed, a macroinvertebrate assessment will be conducted following the methods outlined below.

4.3.1 Study Goals

Drifting and benthic macroinvertebrates typically comprise the primary food source for rearing salmonids in fresh water habitats (Allan 1978, Fausch 1984, Harvey and Railsback 2014). Information on macroinvertebrate prey resource availability is a component of an evaluation of the factors affecting production and viability of an existing or introduced salmonid population. The density and taxonomic composition of drifting macroinvertebrates can provide a relative measure of food availability for drift-feeding salmonids. To provide a relative measure of food availability for salmonids within the water column, a literature search of similar streams and macroinvertebrate studies in the region (Sierra foothill region) will be conducted. Substrate sampling for benthic macroinvertebrates will provide data that can be used in a standardized bioassessment approach to evaluate the potential for physical habitat impairment. The objectives of the macroinvertebrate assessment are to:

- collect and analyze macroinvertebrate drift samples to determine whether the taxonomic composition and density of drift is consistent with other regional systems currently supporting healthy salmonid populations; and
- collect and analyze benthic macroinvertebrate samples from the substrate to develop metrics for bioassessment and comparison with similar streams and data sets.

4.3.2 Study Methods

4.3.2.1 Sampling Site Selection

The study area for macroinvertebrate sampling within the upper mainstem of the Tuolumne River is from RM 81 to Lumsden Bridge (RM 98). The location and number of sampling sites and sampling frequency will represent the seasonal variability of macroinvertebrate populations and related seasonal variability of food resources for stream-dwelling salmonids during the primary salmonid rearing and growth period (spring-fall), as well as the variability of physical habitat characteristics in each study reach.

<u>Number of sites</u>
Depending on opportunities encountered during stream habitat mapping, drift and benthic macroinvertebrate samples will be collected at five sites, equating to approximately one site per 3.5 river miles.

<u>Locations</u>
Drift sampling will occur in the vicinity of Lumsden and at four additional downstream locations corresponding to locations selected for overnight camping during each five-day (four-night) rafting trip. Drift samples will be collected in riffle or run habitats selected opportunistically in the vicinity of overnight camping locations along each study reach. At each overnight camping location, drift sampling locations will be selected based on suitable depth, velocity, substrate, and accessibility/safety considerations, with two sites per location and two replicates (net placements) per site.

Benthic macroinvertebrate sampling will occur at suitable riffles initially identified in the office using aerial photographs and verified in the field. One composite sample will be collected daily from a suitable riffle or combination of suitable fast-water habitat types during the five-day raft-based sampling.

<u>Sample timing and frequency</u>
Macroinvertebrate sampling will be conducted daily during the five-day raft-based sampling effort. Drift sampling in late summer (September) will characterize food resources available to rearing juvenile anadromous salmonids prior to overwintering. Spring sampling may also occur if scheduling allows in conjunction with other field efforts. In many temperate streams, aquatic macroinvertebrate diversity and abundance peak during spring and summer and are reduced in late summer and fall. Peak feeding and growth by rearing salmonids occur when prey availability and water temperatures are relatively high, maximizing net energy gain (Rundio and Lindley 2008, Stillwater Sciences 2007, Wurtsbaugh and Davis 1977). Exact sampling dates for this study may be adjusted within the general seasonal period to coincide with other sampling efforts in order to maximize efficiency and accommodate river flow levels. However, macroinvertebrate sampling should not occur during periods of very high flows or when river discharge is changing rapidly due to safety and access concerns and the potential effects of flow fluctuations on invertebrate drift (Brittain and Eikland 1988).

Drift sampling will begin each afternoon by 1700 hours and proceed until approximately 2000 hours. This sample timing is intended to collect drifting macroinvertebrates during the daily period when feeding activity is often greatest for juvenile Chinook salmon and trout (Sagar and Glova 1988, Johnson 2008) and to avoid pre-dawn and post-dusk peaks in drifting macroinvertebrates that may not be available to drift-feeding salmonids at low light levels. The timing and duration of drift sampling can be adjusted if needed to accommodate rafting safety concerns or logistical constraints. All drift sampling should occur during the peak afternoon-evening feeding period and have the same start and end time.

The timing of the benthic macroinvertebrate sampling is not seasonally dependent, but will be coincident with the drift sampling effort to maximize efficiency and reduce the amount of field sampling time required for the study. Benthic macroinvertebrate samples will be collected once per day during the raft-based sampling effort, typically during mid-day or as determined by the location of suitable sampling riffles and logistics of the habitat mapping study.

4.3.2.2 Sampling Protocols

Invertebrate drift sampling

Drift samples will be collected using stationary nets with rigid rectangular openings and tapered, nylon mesh bags with a collection jar fitted at the downstream end – similar to drift nets used by other researchers (Brittain and Eikeland 1988), including the 1987–1988 drift studies in the lower Tuolumne River (Stillwater Sciences 2010). All drift nets will be identical, with a mesh size small enough to capture small invertebrates such as immature chironomids that may be important salmonid prey, while also large enough to minimize clogging (e.g., 250–500 μ). There is no standard mesh size for drift nets, with mesh size instead chosen according to study objectives, and to represent a compromise between filtration efficiency and clogging (Svendsen et al. 2004).

At each sampling location two transects will be selected perpendicular to the river and two drift nets will be placed at each transect: one near shore and one in the thalweg or as close to the thalweg as water depth and velocity will safely allow. Each drift net will be anchored in the water column using steel (e.g., rebar stakes or fence posts) driven into the stream bed, with the bottom of the net at least 10 cm above the river bottom and the top of the net at least 4–5 cm above the water surface. This vertical net placement ensures capture of terrestrial-origin organisms originating from outside the stream (Leung et al. 2009), which may be an important diet component for anadromous salmonids (Tiffan et al. 2014, Leung et al. 2009, Rundio and Lindley 2008) while avoiding capture of organisms crawling on the substrate. Because drift composition is not uniform across the channel (Waters 1969), placement of near-shore and mid-channel drift nets allows sampling of each portion of the channel to represent potential differences in taxonomic composition, origin (aquatic vs. terrestrial), density, or other factors. During sampling, the drift nets will be attended by one or more field crew members to monitor for approaching rafts or other safety hazards. If needed, field personnel will verbally warn rafters of the potential hazard and assist rafts in avoiding the nets.

Drift nets will be deployed for three hours each day (1700–2000 hours). The width and depth of the submerged portion of each net will be measured upon installation to calculate the effective net area (i.e., the area being sampled). Water velocity will be measured at the midpoint of each net mouth immediately after net installation, at the midpoint of sampling (after 1.5 hours), and immediately before retrieving the net. The three velocity values will be used to calculate the average water velocity at the mouth of each net during sampling, and the average velocity will be multiplied by the sampled area to determine the total volume of water passing through each net during the sampling event. Because net clogging during sampling can gradually reduce the velocity of water passing through the net, an average of several water velocities measured over the course of sampling provides a more accurate measure of volume than a single velocity measure.

After removing each drift net from the water, the contents will be carefully washed to the end of the net and into the collection bottle using river water. The bottle will then be removed and all contents will be transferred to a sample container, labeled, and preserved with 95% ethanol for later processing.

<u>Benthic sampling</u>

Benthic sampling will be conducted using a modified version of the targeted riffle composite (TRC) method described in the California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment Standard Operating Procedure (Ode 2007). The TRC has been widely used in California by state and federal water resource agencies, is consistent with the methods of EPA's Environmental Monitoring and Assessment Program (EMAP) (Peck et al. 2006), and has been adopted as the standard riffle protocol for bioassessment in California (Ode 2007). A similar methodology, the former California Stream Bioassessment Protocol (CSBP) and later the California Monitoring and Assessment Program (CMAP), produced comparable results and was used for the Districts' benthic macroinvertebrate sampling program in the lower Tuolumne River from 2001–2005 and from 2007–2009 (Stillwater Sciences 2010). The SWAMP TRC method was recently used to collect benthic macroinvertebrate samples in the upper Merced River as part of the Merced River Alliance Biological Monitoring and Assessment project (Stillwater Sciences 2008).

Due to site access constraints and non-wadeability in most habitat types, a modified version of the SWAMP protocol will be used to select riffles or other suitable fast-water habitat types for TRC sampling. Whereas the SWAMP protocol specifies that habitats (riffles or other fast-water habitats) for TRC sampling should be selected randomly from a pre-established reach 250 meters in length, riffles sampled for this study will instead be selected randomly from among all potentially wadeable riffles that are accessed during the habitat mapping study and were initially identified in the office by examining high-resolution color aerial photographs of the study reaches. During field sampling, the field crew will carry a set of the aerial photographs with potential sampling riffles identified, to enable identification of alternative sampling riffles if needed. Using the office-based method, a total of five riffles will be selected for sampling. Riffles selected for sampling will be spaced sufficiently to enable sampling of an average of one riffle per day during the five-day raft-based field effort.

In the field, riffles initially selected for benthic sampling will be evaluated individually as they are encountered during the rafting trip to determine whether substrate, depth, and velocity are suitable for sampling, and if they can be sampled safely. A riffle will be deemed suitable if it has enough gravel or cobble substrate to allow collection of up to eight non-overlapping benthic samples in areas that can be safely accessed on foot by a two-person field crew (i.e., depth and velocity do not prohibit safe access and sampling). If a riffle initially chosen for TRC sampling is unsuitable, the crew will proceed to the next suitable riffle. Ideally, a total of five riffles or other fast-water habitats will be sampled in the study reach using the TRC method. At each riffle selected for TRC sampling, physical habitat and water chemistry data will be collected following the SWAMP protocol for the "basic" level of effort (Ode 2007). These data include GPS coordinates and photographs of the site, water temperature, pH, dissolved oxygen, specific conductance, channel width, riparian canopy cover, bank stability, and channel gradient.

The TRC approach specifies collection of benthic samples at eight riffles within each 250 meter sampling reach (Ode 2007). However, preliminary examination of aerial photographs indicates that the riffles in the upper Tuolumne River are relatively infrequent and widely spaced, thus selection of a 250 meter sampling reach containing multiple riffles will likely be infeasible. A modified approach will therefore be used, which will entail collection of eight benthic samples per riffle. If additional suitable riffles or other suitable fast-water habitat types (e.g., run or pool tail) are located in close proximity to a riffle that has been selected for TRC sampling and can be safely accessed on foot, the required eight samples will be collected at locations distributed randomly among the suitable habitats. Sampling locations in each riffle or combination of fast-water habitat types at each site will be selected randomly using a digital stopwatch or random number chart, as described in Ode (2007). Samples will be collected using a standard D-frame kick net with 500-µ mesh. At each sampling location, a 0.09 m^2 (1 ft^2) area of bottom substrate will be sampled immediately upstream of the net following methods described in Ode (2007). All eight samples collected at each site (riffle or combination of fast-water habitats) will be combined into a single composite sample for the site, preserved in 95% ethanol, and labeled for laboratory processing.

4.3.2.3 Analysis and Reporting

All macroinvertebrate samples will be processed in the laboratory following standardized methods and the data will be entered into a database. Processing will enumerate and identify organisms to the taxonomic level necessary to calculate commonly reported biological metrics (numerical attributes of biotic assemblages) for each sample site from the benthic samples (i.e., TRC samples) and identify the diversity and abundance of primary salmonid prey items in the drift. Benthic macroinvertebrate metrics may include those calculated for benthic macroinvertebrate samples collected in the lower Tuolumne River from 2000–2005 and 2007–2009 (Stillwater Sciences 2010). Laboratory analysis of drift samples will also include length measurement of individual organisms, to allow calculation of biomass at a later date, if desired, to provide a relative measure of energy content and available fish food resources. Results will be included in a technical report that evaluates the adequacy of the macroinvertebrate prey resources to support healthy populations of juvenile anadromous salmonids, as indicated by comparison of the taxonomic composition and relative abundance (drift density) of the upper Tuolumne River macroinvertebrate drift samples with drift samples from other salmonid streams.

5.0 STUDY SCHEDULE

The study will be completed during the summer and fall of 2016; a detailed field schedule will be developed in conjunction with other field studies.

6.0 REFERENCES

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DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Hatchery and Stocking Practices Review

March 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Hatchery and Stocking Practices Review is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to inform an evaluation of the potential for hatchery stocking practices to affect Chinook salmon and steelhead that may be introduced into the upper Tuolumne River above the Don Pedro Project.

2.0 STUDY AREA

The study area for this desktop literature review will encompass the upper Tuolumne River basin, including Don Pedro Reservoir and the mainstem Tuolumne River, and associated tributaries (North Fork Tuolumne River, Clavey River, Cherry Creek, etc.), to the extent that information is available regarding historical or current hatchery and stocking practices.

3.0 STUDY GOALS

The overall goal of this study is to assess historical and current hatchery stocking practices in the upper Tuolumne River basin and identify potential interaction of stocking activities with the reintroduction of anadromous salmonids to the reach of the Tuolumne River between the upstream end of the Don Pedro Project and the City and County of San Francisco's Early Intake. Specific objectives of this study are listed below:

- identify the species, source hatcheries and their stocking practices in the area, and time periods of fish that were historically stocked in the upper Tuolumne River, tributaries to the upper Tuolumne River, and in Don Pedro Reservoir;
- identify stocking location and seasonal timing of stocking for species currently stocked (and that may be stocked in the future) in the upper Tuolumne River, tributaries to the upper Tuolumne River, and in Don Pedro Reservoir;
- identify and describe self-sustaining potamodromous populations (species of fish that migrate [upstream or downstream] exclusively in freshwater) originating from previously stocked species, their life history characteristics, and population characteristics, as available;
- identify available information on documented incidents of disease in hatchery stocks and in the upper Tuolumne River basin;
- describe life histories of stocked species, as well as their spatial and temporal migrations and distributions to identify the potential to interact with reintroduced anadromous salmonids;
- describe potential spatial and temporal overlap of stocked species and lifestages with potentially-reintroduced species and lifestages (i.e., steelhead and spring-run Chinook salmon) in the upper Tuolumne River; and
- identify potential effects of historical and existing/future hatchery and stocking practices on efforts to reintroduce anadromous salmonids to the upper Tuolumne River.

4.0 STUDY METHODS

A desktop literature review will be conducted and is expected to include review of agency technical memoranda, fish stocking data, fish health information, journal articles, and websites to identify and describe historical, current and future fish hatchery and stocking practices in the upper Tuolumne River Basin. Agencies and organizations involved with fish hatchery and stocking activities will be contacted to gather additional information on historical and existing fish stocking activities in the study area, including the Don Pedro Recreation Agency and California Department of Fish and Wildlife.

Based on the information collected regarding historical and current/future stocking practices, existing hatchery operations, life histories of stocked fish species, and literature on interactions between stocked fish species and anadromous salmonids, potential effects of hatchery and stocking practices to an anadromous salmonid reintroduction effort will be described and evaluated. Potential risks associated with hatchery and stocking practices to an anadromous salmonid reintroduction program will be identified and described.

5.0 STUDY SCHEDULE

The anticipated schedule is to conduct the desktop literature review and contact agency staff from May to July 2016. A draft report will be provided to the Technical Committee in November and a final report will be included in the February 2017 Updated Study Report.

6.0 REFERENCES

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 2016. Fish Passage Facilities Alternatives Assessment Progress Report. Prepared by HDR, Inc. Appendix to La Grange Hydroelectric Project Initial Study Report. February 2016.

DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Regulatory Context for Reintroduction

March 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Regulatory Context for Reintroduction review is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to evaluate federal, state, and local regulatory issues that may be associated with the reintroduction of Chinook salmon and steelhead into the upper Tuolumne River above the Don Pedro Project.

2.0 STUDY AREA

The study area will encompass the upper Tuolumne River basin, including Don Pedro Reservoir and the mainstem Tuolumne River, and associated tributaries (North Fork Tuolumne River, Clavey River, Cherry Creek, etc.), and surrounding public and private land.

3.0 STUDY GOALS

This regulatory review will evaluate federal, state, and local regulatory issues associated with the potential introduction of listed and protected fish species into the Tuolumne River upstream of the Don Pedro Project. The upper Tuolumne River basin spans the jurisdictions of several federal land management agencies (United States Forest Service [USFS], Bureau of Land Management [BLM], and National Park Service [NPS]). Current activities related to fisheries management (stocking, setting of fishing areas, seasons, limits, and catch quotas) are the responsibility of the State of California. With the potential introduction of protected anadromous salmonids, regulatory requirements related to such laws as the Endangered Species Act, Magnuson-Stevens Fishery Conservation and Management Act, Clean Water Act, National Environmental Protection Act, the Federal Land Policy and Management Act, and California Environmental Quality Act may become relevant to activities occurring in the study area. The goals of this study are to:

- identify applicable existing legal precedent, regulatory guidance and resource management plans in the study area;
- identify additional regulatory guidance and rules that may apply to or affect the reintroduction of spring-run Chinook and/or steelhead; and
- identify and define potential federal, state, and local regulatory issues associated with the potential fish passage/reintroduction program.

4.0 STUDY METHODS

The introduction of new species into the upper river may affect current uses and regulatory requirements/restrictions. A comprehensive understanding of the regulatory aspects of introducing federal- and state-listed species to the upper Tuolumne River watershed is necessary. For purposes of this evaluation, the regulatory context is defined as legal precedent, rules, regulations and guidelines in land and species management that may apply to land and species management in the study area.

State and federal resource management agencies will be contacted to confirm all relevant guidance documents and supporting materials are identified. A summary of regulations and authorities applicable and potentially applicable to activities in the watershed will be completed. This study report will include a matrix of species and land management goals, responsible authorities, and applicable laws and regulations relevant to current and future proposed activities in the watershed. An initial list of documents to be reviewed is provided below and will be expanded as necessary based on consultation with licensing participants.

- Recovery Plan for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead (National Marine Fisheries Service 2014)
- Sierra Nevada Forest and Community Initiative (SNFCI) Action Plan (Sierra Nevada Conservancy 2014)
- The State of the Sierra Nevada's Forests (Sierra Nevada Conservancy 2014)
- Tuolumne Wild and Scenic River Comprehensive Management Plan and supporting documents (NPS 2014)
- Sierra Nevada Forest Plan and Amendments (USFS 2004, 2013)
- Stanislaus National Forest Plan Direction (USFS 2010)
- Sierra Resource Management Plan (BLM 2008)
- Steelhead Restoration and Management Plan for California (California Department of Fish and Game 1996)
- Tuolumne County General Plan (Tuolumne County 1996)
- Red Hills Management Plan (BLM 1985)

5.0 STUDY SCHEDULE

The anticipated schedule is to gather relevant plans and consult licensing participants and agencies from May through July 2016. A draft report will be provided to the Technical Committee in November 2016 with a final report included in the February 2017 Updated Study Report.

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DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Socioeconomic Scoping Study

March 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Socioeconomic Scoping Study is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to evaluate the potential socioeconomic effects of reintroducing Chinook salmon and steelhead into the upper Tuolumne River above the Don Pedro Project.

2.0 STUDY GOALS

The goal of this study is to develop a comprehensive description of the human environment, activities, and current uses of the resources and facilities in the study area that may be impacted by constructing and/or operating fish passage facilities and the introduction of anadromous fish upstream of the Don Pedro Project.

3.0 STUDY METHODS

Socioeconomic considerations are identified as a key element in assessing whether potential reintroduction methods could be successful (Andersen et al. 2014). Current management of the Don Pedro Reservoir and upper Tuolumne River supports a wide range of resources, uses, and users. The upper watershed includes the Tuolumne Wild & Scenic River segment managed for several outstanding resource values and is utilized by commercial and private recreational boaters. Other uses of the watershed include the City and County of San Francisco's operation of the Hetch Hetchy Project, private timber practices, and a recreational fishery. Don Pedro Reservoir provides numerous recreational activities, including house boating and a popular recreational fishery. County government and businesses benefit from the economic activities supported by the upper watershed.

As part of this study, a comprehensive survey of uses in the upper watershed will be conducted and potential issues will be identified for consideration in the reintroduction assessment. A literature survey and review of existing information from the Don Pedro Recreation Agency, county and federal land management agencies, and other sources will be conducted. Surveys and/or focus groups will be used to verify and expand upon available information related to existing uses of the watershed that could be impacted by a fish reintroduction program. The information collected in this study is designed to support and expand upon the socioeconomic considerations identified in the Framework, such as recreation impacts (e.g., river recreation, reservoir recreation, recreational fishing) and impacts on private resources (e.g., timber resources, private landowners), and will be considered in any socioeconomic evaluation done once reintroduction and fish passage options are further developed.

4.0 STUDY SCHEDULE

The anticipated schedule is the study team will gather available literature and consult licensing participants and agencies from April to July 2016. The literature review and data gathering will be completed over the summer, with a draft report issued to the Technical Committee by October 2016. The final report will be included in the February 2017 Updated Study Report.

5.0 REFERENCES

Anderson, J. H. et al. 2014. Planning Pacific Salmon and Steelhead Reintroductions Aimed at Long-Term Viability and Recovery. North American Journal of Fisheries Management, 34:1, 72-93.

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DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study

March 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to characterize the distribution, quantity, and quality of suitable Chinook salmon and steelhead spawning gravel in the upper Tuolumne River.

2.0 STUDY AREA

The study area for mapping Chinook salmon and steelhead spawning gravel in the upper Tuolumne River includes the approximately 24-mile reach from the upstream limit of the Don Pedro Project (approximately RM 81) to Early Intake (approximately RM 105).

3.0 STUDY GOALS

Successful Chinook salmon and steelhead spawning and fry production are dependent on the abundance and quality of suitable spawning gravel. Information on the amount, distribution, and quality of spawning gravel are critical components in estimating habitat carrying capacity and assessing limiting factors. Limited information is available to describe the distribution, quantity, and quality of spawning gravel in the upper Tuolumne River. The goal of this study is to characterize the distribution, quantity, and quality of suitable Chinook salmon and steelhead spawning gravel in the upper Tuolumne River.

The study objectives are:

- map the distribution of potentially suitable spawning gravel available for Chinook salmon and steelhead in the upper Tuolumne River;
- assess the quality of potentially suitable spawning gravel based on gravel size characteristics, sorting, angularity, embeddedness, substrate depth, and permeability measured in a representative sample of gravel patches; and
- quantify the amount of suitable spawning gravel in the reach between RM 81 and RM 105.

Study results will help inform the feasibility of introducing Chinook salmon and steelhead into the upper Tuolumne River.

4.0 STUDY METHODS

4.1 Spawning Gravel Mapping

Probable locations of gravel patches will initially be delineated in a Geographic Information System (GIS) using the best available aerial photography. This desktop mapping step will inform field staff as to the approximate distribution of gravel deposits and the most efficient logistical process for locating and mapping those deposits in the field. Field mapping criteria and protocols will be consistent with studies in the lower Tuolumne River (TID/MID 1992, 2013), and will be refined following this initial desktop analysis, as needed.

Potentially suitable spawning gravel patches will then be delineated in the field on map tiles from high resolution orthorectified aerial imagery (e.g., 8-13-2007 photography and mapbook). A laser range finder will be used to measure the approximate dimensions of each gravel patch, if necessary to support the delineation of patch areas on field tiles. Each patch will be assigned a unique ID. Field delineation of potentially suitable spawning gravel patches will be performed by a two-person crew using whitewater raft support to access the study reach. The crew will stop frequently to locate and investigate preliminary gravel polygons obtained from desktop mapping and any other deposits that appear to meet the mapping criteria. Inflatable kayaks may also be used to navigate unwadable areas requiring investigation. To the extent feasible, mapping will be performed during low or off-peak flow conditions to optimize visibility of potentially suitable spawning gravels. Supplemental access to limited portions of the study reach are available at vehicle road crossings and by foot, depending on terrain and river flow.

4.1.1 Gravel Particle Size Criteria

Species-specific spawning gravel size criteria that will be used to delineate potentially suitable spawning gravel for Chinook salmon and steelhead in the upper Tuolumne River study reach are summarized in Table 1.0. These particle size criteria, based on D_{50} reported in the literature, may be refined in coordination with the Technical Committee prior to the field effort. Chinook salmon typically spawn in substrates with a D_{50} of 11–78 mm (0.42–3.0 in) (Platts et al. 1979, as cited in Kondolf and Wolman 1993, Chambers et al. 1954, 1955, as cited in Kondolf and Wolman 1993). Steelhead typically spawn in substrates with a D_{50} of 10–46 mm (0.4–1.8 in.) (Barnhart 1991, Kondolf and Wolman 1993). Wolman (1954) pebble counts will be conducted in selected areas to calibrate visual estimates of grain size parameters using methods developed by Bunte and Abt (2001). Patches with substantially different surface particle size characteristics will be delineated separately.

4.1.2 Minimum Gravel Patch Size Criteria

Minimum patch size criteria for mapping potentially suitable spawning gravel will be determined prior to the field effort based on (1) a combination of the minimum area required for a spawning Chinook salmon or steelhead pair and (2) the scale and resolution of available imagery used as a base for field mapping tiles. The minimum spawning area generally identified for Chinook salmon is approximately 12 m^2 (Healy 1991, Bjorn and Reiser 1991, Ward and Kier 1999). Steelhead typically defend a redd only during the period of active spawning, and therefore the area required for a spawning steelhead pair is approximately equal to the disturbed area of the redd. The average area encompassed by a steelhead redd is 4.4–5.4 m^2 (47–58 ft^2) (Bjornn and Reiser 1991; Orcutt et al. 1968). For mapping purposes, we assume a minimum patch size of approximately 6 m^2 is required for a steelhead pair to build and defend a redd. The minimum mappable size of potentially suitable spawning gravel patches based on the scale and resolution of available imagery will be evaluated during the desktop gravel mapping step described above.

Table 1.0 Summary of potential spawning gravel mapping criteria for Chinook salmon and steelhead in the upper Tuolumne River.

Species	Gravel D_{50} mm (in.)	Minimum Patch Size Required for Spawning, m^2 (ft^2)	References
Chinook salmon	10–78 (0.4–3)	12 (130)	Platts et al. 1979, Chambers et al. 1954, 1955, all as cited in Kondolf and Wolman 1993; Healy 1991, Bjorn and Reiser 1991, Ward and Kier 1999
Steelhead	10–46 (0.4–2)	6 (65)	Barnhart 1991, Kondolf and Wolman 1993, Bjornn and Reiser 1991, Orcutt et al. 1968

Note: D_{50} – diameter of particle (in millimeters) at which 50 percent of the sample is smaller (*e.g.*, median).

4.2 Spawning Gravel Quality

In addition to the particle size and patch size criteria described above, characteristics informing spawning habitat quality will be collected for each patch. These will include additional gravel particle size parameters (e.g., D_{16}, D_{84}); characterization of particle sorting, angularity, and embeddedness; and an estimate of the average substrate depth (where feasible).

4.2.1 Field Observations of Gravel Quality

Sorting describes the homogeneity of surficial particles within a patch. Spawning salmonids prefer substrates that are relatively well sorted. The degree of sorting will be visually estimated using the comparison chart in Compton (1985). Angular grains tend to pack more tightly than rounded particles and are more likely to slow intragravel flow. More loosely packed and rounded particles also increase a fish's ability to dislodge the substrate during redd construction. The degree of particle angularity within a patch will be visually estimated based on the comparison chart in Powers (1989). Substrate embeddedness describes the presence of fine sediment in the gravel interstices. Substrate embeddedness is measured by selecting a random sample of coarse surface particles within the patch and measuring the percent of the particle that is surrounded or buried by fine sediment (fines and sands <2 mm). This would be conducted concurrent with pebble count procedures. The substrate depth required for redd construction and egg deposition likely depends on the size of the spawning female and on particle size characteristics, as well as flow depth and velocity. Chinook salmon egg pocket depths range from 8 to 51 cm (3 to 20 in), with an average of 22 cm (8.5 in) (Burner 1951). Steelhead egg pocket depths range from 15 to 28 cm (6 to 11 in), with an average of 21 cm (8.4 in) (Briggs 1953).

4.2.2 *Gravel Permeability*

Gravel permeability will be collected to characterize incubation conditions and estimate predicted survival-to-emergence. The quality of spawning gravel will be assessed by measuring streambed permeability at select patches following the methods of Barnard and McBain (1994). Gravel inflow rate (ml/sec), which is an index of intragravel permeability (cm/hr), will be measured using a steel standpipe adapted from the Terhune Mark VI standpipe design (Terhume 1958; Barnard and McBain 1994). At select gravel patches, the standpipe will be driven into the gravel to an approximate depth of 30 cm (12 inches) using a protective end cap and sledge hammer. A battery powered peristaltic pump (e.g., IP Masterflex brand pump or equivalent) will be used to create a 2.5 cm head differential in the standpipe and the rate at which water is drawn from the pipe will be measured (Barnard and McBain 1994). While maintaining this constant pressure head, water will be drawn through the perforations in the standpipe buried in the gravel, and a stopwatch will be used to measure the time required to collect a volume of water.

Gravel permeability can be highly variable within and between patches in a reach. Therefore, a sampling plan will be developed based on the results of the spawning gravel mapping effort. The sampling plan will outline an approach and provide field protocols for characterizing the permeability of potential spawning patches throughout the study reach. The approach will generally rely on assigning patches to a morphologic unit (e.g., pool tail) and sampling from consistently similar positions within a morphologic unit. Sampling will occur in the morphological unit(s) that are best exhibit the effects of fine sediment supply on spawning gravel quality and that have the highest potential value to spawning Chinook and steelhead. Permeability sampling results may be stratified by subreach, as appropriate. Desktop and field-based mapping of potentially suitable spawning gravel patches will inform an appropriate system for delineating morphological units, appropriate permeability sampling locations within those units, and appropriate delineation of any subreaches.

4.2.3 *Gravel Quality Ranking*

When a gravel patch is deemed ‘‘usable’’ based upon initial measurements associated with particle size criteria, a qualitative ranking of overall suitability from 1 (poor) to 10 (good) will be assigned to each patch based on an overall assessment of the following physical characteristics (substrate particle size, sorting, angularity, embeddedness, gravel depth, permeability, and patch location and size). A separate ranking will be assigned for Chinook salmon and steelhead. Although reliable rankings rely heavily on the professional judgment and personal experience of the survey participants, this ranking will allow comparison of patch quality. Rankings will be summarized as follows: 1–3= low suitability, 4–7= medium suitability, and 8–10= high suitability.

4.3 Data Processing and Analysis

Potentially suitable spawning gravel patches delineated on field tiles will be digitized using GIS, and area estimates for each patch will be calculated. The quantity and quality of potentially suitable spawning gravel patches will be summarized in tabular format.

Results to be reported include the following:

- shapefiles with polygons of potentially suitable spawning gravel patches and associated patch attributes;

- a database of attributes for each mapped gravel patch (i.e., measured and/or estimated particle size parameters, sorting, angularity, embeddedness, estimated mean depth [where feasible], associated channel morphological feature, and quality score);
- mean, minimum and maximum gravel inflow rates (ml/sec) as an index of intragravel permeability (cm/hr) for each sample site, presented by river mile location; and
- derived mean permeability (cm/hr) by river mile.

5.0 STUDY SCHEDULE

The anticipated schedule is to conduct the initial office-based analysis in May-June 2016, with subsequent field surveys in August/September 2016 for gravel mapping and gravel quality assessments. Mapping of potentially suitable spawning gravel will occur over two separate five-day field trips. Permeability sampling will occur over one three-day field trip to be conducted after the gravel mapping is completed. A draft report will be provided to the Technical Committee in November 2016 with a final report to be included in the February 2017 Updated Study Report.

6.0 REFERENCES

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LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

FISH PASSAGE FACILITIES ALTERNATIVES ASSESSMENT
REINTRODUCTION GOALS SUBCOMMITTEE CONFERENCE CALL

APRIL 13, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project
Reintroduction Assessment Framework
Reintroduction Goals Subcommittee Conference Call

Wednesday, April 13, 10:00 am to 12:00 pm
Conference Line: 1-866-583-7984; Passcode: 8140607

Meeting Objectives:

1. Review and confirm the purpose of the Reintroduction Goals Subcommittee.
2. Present and discuss examples of reintroduction assessment goal(s) development.
3. Discuss development of reintroduction assessment goal(s) relevant to the Tuolumne River Reintroduction Assessment Framework.
4. Identify next steps on Reintroduction Goals Subcommittee.

TIME	TOPIC
10:00 am – 10:15 am	Introduction of Participants (All) Review Agenda and Meeting Objectives (Districts)
10:15 am – 10:45 am	Reintroduction Assessment Framework – Development of Program Goals. Why Is It Important? What Purpose Does it Serve? (All) a. Planning Pacific Salmon and Steelhead Reintroductions Aimed at Long-Term Viability and Recovery, Andersen et al. b. NMFS Recovery Plan
10:45 am – 11:15 am	Development of Reintroduction Goals - Examples a. Yuba River (Paul Bratovich) b. San Joaquin River (Chuck Hanson)
11:15 am – 11:50 am	Process for Developing Tuolumne River Reintroduction Goals (all) a. Part 1: Narrative goal(s) statement b. Par 2: Quantitative metrics
11:50 am – 12:00 pm	Next Steps (All) a. Schedule next call and agenda topics b. Action items from this call

La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Reintroduction Goals Subcommittee Conference Call

Wednesday, April 13, 2016
10:00 am to 12:00 pm

Final Meeting Notes

Conference Call Attendees		
No.	**Name**	**Organization**
1	Leigh Bartoo	U.S. Fish and Wildlife Service
2	Steve Boyd	Turlock Irrigation District
3	Anna Brathwaite	Modesto Irrigation District
4	Paul Bratovich	HDR, consultant to the Districts
5	Jesse Deason	HDR, consultant to the Districts
6	John Devine	HDR, consultant to the Districts
7	Greg Dias	Modesto Irrigation District
8	Steve Edmondson	National Marine Fisheries Service
9	Art Godwin	Turlock Irrigation District
10	Chuck Hanson	Hanson Environmental, consultant to the Districts
11	Patrick Koepele	Tuolumne River Trust
12	Bao Le	HDR, consultant to the Districts
13	Ellen Levin	City and County of San Francisco
14	Bill Paris	Modesto Irrigation District
15	Bill Sears	City and County of San Francisco
16	Chris Shutes	California Sportfishing Protection Alliance
17	John Wooster	National Marine Fisheries Service
18	Ron Yoshiyama	City and County of San Francisco

On April 13, 2016, Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) hosted a Reintroduction Goals Subcommittee conference call for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment and Upper Tuolumne River Fish Reintroduction Assessment Framework (Framework). This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting. Attachment A to this document includes the meeting agenda and meeting read ahead materials.

Mr. Bao Le (HDR, consultant to the Districts) said there are two primary components of Framework implementation: (1) collecting site-specific technical, regulatory and socioeconomic information, and (2) assessing that information in the context of the goals for reintroduction in order to evaluate reintroduction feasibility. Mr. Le reviewed the timeline for developing reintroduction goals, noting that goals are needed by the fall of 2016. Mr. Le said this meeting is intended to initiate discussions about developing goals. On today's call meeting attendees will discuss why setting goals is important, potential sources of information for developing goals, and specific examples of goals at other Central Valley reintroduction programs. Mr. Le said if there is time, attendees may begin to discuss what goals might look like for the Tuolumne River.

Mr. Steve Edmondson (National Marine Fisheries Service [NMFS]) said HDR may be able to provide examples of other reintroduction programs the company has worked on that have used a decision matrix similar to the Framework. Mr. Le said he will inquire within HDR as to whether there are examples applicable to the Tuolumne River. Mr. John Devine (HDR) said NMFS may also have worked on projects, perhaps projects in the Pacific Northwest, which could serve as examples relevant to the effort here. Mr. Edmondson said he is not familiar with any projects that are using a decision framework, like this process. Mr. Edmondson noted there will be a workshop with fish passage experts, both from federal agencies and the private sector, to discuss designing fish passage at high head dams. Mr. Le said he encourages anyone with knowledge of projects that may be applicable to this project to provide information they think might be useful. Later in the meeting, Mr. Edmonson said he had sent an email query out to other NMFS offices about the use of a framework in other reintroduction programs, and none of the individuals who responded to his email were aware of a process similar to the Framework being used elsewhere.

Mr. Le said he thinks Anderson et al. (2014; included in Attachment A) provides a sound basis for evaluating the feasibility of a reintroduction program for the Tuolumne River. In particular, the paper describes the importance of assessing a reintroduction program's potential benefits, risks, and constraints. While the focus is often on achieving success, a reintroduction program must also manage risk associated with the effort and be cognizant of working within the program's constraints. Mr. Le encouraged meeting attendees to read the paper and provide feedback.

Mr. Le said he believes the paper is particularly relevant for the Tuolumne River because the paper approaches reintroduction planning from the perspective of recovery of salmonid species listed under the Endangered Species Act (ESA), which is also the driving motivation behind the NMFS Recovery Plan (2014; available online here). The NMFS Recovery Plan lists the upper Tuolumne River as a candidate reach for steelhead and spring-run Chinook. Mr. Le said the Recovery Plan seems like an obvious source of information to explore to inform the development of reintroduction goals. Mr. Le asked if meeting attendees had any thoughts about the Recovery Plan and using that document as a source of information for helping to craft reintroduction goals and objectives for the Tuolumne River. No one responded. Mr. Le requested that meeting attendees review the Recovery Plan and provide feedback on whether the Recovery Plan is relevant to developing reintroduction goals on the Tuolumne River.

Mr. Paul Bratovich (HDR) provided a summary of the reintroduction program on the Yuba River. Mr. Bratovich noted that several individuals on this call, including Mr. Steve Edmondson (NMFS), Mr. Chris Shutes (California Sportfishing Protecting Alliance), and Mr. John Wooster (NMFS) have participated in the reintroduction program for the Yuba River. Mr. Bratovich said the reintroduction initiative on the Yuba River has evolved over several years. Most recently, goals and objectives were agreed to in a concept plan, which accompanied the settlement term sheet. Mr. Bratovich said the goals and objectives of a reintroduction program are much different from fish passage facility operational performance criteria, and that the two must not be confused. Mr. Bratovich said there are a number of ways in which reintroduction goals may be structured. Mr. Bratovich said the NMFS Recovery Plan has a section about recovery goals and population goals. However, these goals are structured differently than goals being developed for the Stanislaus River. Goals for the Yuba River are structured differently than both goals in the NMFS Recovery Plan and goals for the Stanislaus River.

Mr. Bratovich said one possible route is to create numeric goals and objectives, such as the number of individuals needed for a viable population. "Viability" is defined in the NMFS Recovery Plan by numeric criteria and extinction risk, but "viability" would still need to be defined as it pertains to the potential river and project. Mr. Bratovich said a "simpler criteria" that has been identified by Lindley may also be used. These criteria have four parameters: abundance, productivity, spatial structure, and diversity.

Mr. Bratovich said one issue to consider when developing reintroduction goals is in-basin versus out-of-basin effects. For example, a reintroduction program with a goal tied to a species population metric such as the number of returning adults will be assuming responsibility for out-of-basin and/or non-project effects, such as predation, ocean conditions, sportfishing and commercial fishing. One approach to defining goals that can remove out-of-basin and non-project effects is to define goals based on the number of individuals at various life stages that can be supported by managing suitable habitat.

Mr. Bratovich said the Yuba River concept plan reintroduction goals are based on providing suitable habitat to support a low extinction risk, as interpreted by the simpler criteria from Lindley and others. In particular, the goals specify a number of individuals in terms of habitat, and do not assume responsibility for numbers of returning adults. Mr. Bratovich noted the project is currently in settlement negotiations.

Dr. Chuck Hanson (Hanson Environmental, consultant to the Districts) gave a summary of the reintroduction program on the San Joaquin River. Dr. Hanson said talks of reintroduction on the San Joaquin River first began in 1988 when the National Resources Defense Council sued the U.S. Bureau of Reclamation (Reclamation). After many years of litigation and many environmental studies, the parties settled in 2006. The settlement agreement had several components. In particular, the settlement agreement: (1) recommended that several projects be implemented in order to successfully re-establish spring-run Chinook; (2) provided goals for re-establishing a self-sustaining naturally reproducing population of spring-run Chinook downstream of Friant Dam, and (3) formed a Technical Advisory Committee to provide advice on what needed to be done for the program to be successful.

Dr. Hanson said one of the first tasks of the new program was to compile into a single document all the existing environmental information about the reach identified for reintroduction, so that existing conditions and problem areas could be identified. With the data compilation in hand, the Technical Advisory Committee determined that reintroduction would focus on spring-run Chinook, and a secondary focus would be on fall-run Chinook.

Dr. Hanson said in October 2007, a document entitled *Recommendations on Restoring Spring-Run Chinook to the San Joaquin River* was released. The document recommended that the reintroduction strategy be compatible with existing conditions, such as the carrying capacity of the spawning gravel and existing water temperatures. The program should be responsive to natural selection processes. The "build it and they will come" approach was eliminated from consideration because it was likely there were not enough strays to make the program feasible. The program should aim to create a founding population with life history characteristics that match the anticipated environmental conditions. The founding population should also exhibit broad genetic diversity. Genetic diversity was important for fostering natural selection and thus creating a population that was genetically suited to conditions in the San Joaquin. The document also recommended the founding population be demographically diverse, with broad life history expression for juvenile rearing, with the goal that adults would return at multiple age classes, thus building resiliency.

Dr. Hanson said given there had been no Chinook present in the system for over 50 years, it was decided that the San Joaquin River reintroduction program would be best implemented through four phases: (1) Reintroduction Period; (2) Interim Period (during this period, infrastructure would be constructed and begin operating); (3) Population Growth Period (during this period, escapement and reproduction would take place); and (4) Maintenance Period (this is the long-term period of program operation). Dr. Hanson said at the beginning of the process, the number of returning adults was selected as the metric that best reflected whether the program was accomplishing its objective (i.e., to produce a self-sustaining, naturally reproducing population). The Reintroduction Period focused on achieving a five-year running average escapement of at least 2,500 fish, with a minimum escapement of 500 fish.

Dr. Hanson said the team looked at multiple life stage strategies for the founding population to mimic populations that had been established previously in northern California. The team looked into collecting eggs, fry, and juveniles from Deer Creek and Mill Creek, but there were political sensitivities to that approach. The team, which included NMFS, USFWS, and Reclamation, among others, determined a politically feasible strategy was to build a conservation hatchery. A conservation hatchery would increase the number of juveniles available for use by the program and would be helpful in low water years. To minimize impacts to natural populations, the conservation hatchery would use surplus fish from the Feather River Hatchery.

Dr. Hanson said currently the team has permits to import eggs and fry from the Feather River. CDFW started the conservation hatchery with fall-run Chinook. Currently, CDFW is applying what has been learned from raising the fall-run Chinook and is shifting the hatchery operations to spring-run Chinook. Dr. Hanson said the program is currently introducing spring-run into the system and trapping and hauling fall-run Chinook. The program monitors reproduction, fry emergence, juvenile migration, abundance of juveniles, and survival by reach, among other metrics. The program is also currently addressing multiple problems that have arisen unexpectedly, including seepage, impacts to agricultural and other water users, levy instability, and predation issues. Due to predation, the program is not producing as many juveniles as was previously anticipated.

Dr. Hanson said the program estimated adult escapement based on an analysis of the limiting factors. The analysis provided a useful framework, but it now must be applied to site-specific factors. The team is realizing that original projections for how long it would take to implement the project were overly optimistic, in part due to interdisciplinary issues that were not anticipated. Dr. Hanson said he will send Mr. Le documents related to the reintroduction approach. Dr. Hanson said he sees many parallels between the Yuba River and Tuolumne River in terms of establishing a successful reintroduction program.

Mr. Le noted that for the programs on the Yuba River and San Joaquin River, the summaries provided by Mr. Bratovich and Dr. Hanson describe a phase of the program where the decision to reintroduce fish had already been made. However, for the Tuolumne River, NMFS has stated in a previous workshop that a decision to reintroduce fish has still not yet been made. Mr. Le asked whether in either of the processes, there was a phase of the process that focused on evaluating reintroduction feasibility toward a "go/no go" decision. Both Mr. Bratovich and Dr. Hanson noted that reintroduction programs were identified from settlement discussions and a structured evaluation framework such as that proposed for the Tuolumne River had not been implemented. Mr. Bratovich said many millions of dollars were previously spent collecting information on the Yuba River, and all that information was available to inform the reintroduction planning process. Dr. Hanson said preliminary discussions for the San Joaquin focused on what it would take to meet the requirements suggested by the limiting factor analysis. Mr. Le said it appears the process on the San Joaquin was driven by limiting factors such as thermal suitability and carrying capacity, and not independently by goals. Mr. Le noted this is different from what this group is trying to do on the Tuolumne River, which is to collect the information in parallel but independent of developing the reintroduction program goals and success criteria, and then evaluate the information and criteria hand-in-hand to evaluate whether the goals can be met (i.e., feasibility) prior to considering implementation. Mr. Le stated that careful planning and evaluation was a valuable point he took from review of the Anderson et al. (2014) since the authors had noted that in their review of the salmonid reintroduction literature, there remain large uncertainties in the success of reintroduction in establishing self-sustaining populations, particularly for programs employing active colonization strategies.

Mr. Wooster asked Dr. Hanson to highlight a few of the parallels between the situation on the San Joaquin River and the situation on the Tuolumne River. Dr. Hanson said both rivers are in the southern geographic range of the target species, and both rivers share similar hydrologic and temperature concerns. In addition, habitat features such as the availability of spawning gravel are also problematic. Dr. Hanson noted too that both rivers exhibit poor survival of juvenile outmigrants.

Mr. Yoshiyama said he believes that the genetics of spring-run and fall-run on the Feather River cannot be genetically distinguished from one another. Mr. Yoshiyama said he sees the Feather River Chinook population as a gradation of life history timings and forms, with very early migrants that would be classified as spring-run and later fish that would be classified as fall-run. Mr. Yoshiyama said that this gradation would have repercussions for the Tuolumne River. Mr. Yoshiyama asked if the group here is more interested in achieving life history diversity, as opposed to achieving a true spring-run life history. Mr. Yoshiyama said it may make it easier to achieve a spring-run life history on the Tuolumne River if genetic mixing between fall-run and spring-run is not a concern. Dr. Hanson confirmed that the Feather River spring-run do not have unique genetics. Instead, the fish are a blend. Dr. Hanson noted that on the San Joaquin River, the team had to move away from a focus on maintaining genetic diversity to a focus on life history.

Mr. Le noted that on the San Joaquin, prior to the decision to move away from fall-run, the initial program was going to use fall-run as surrogates and then move to spring-run. Mr. Le asked what consideration had been given to how to separate out the two sets of fish, given that their life histories overlap both temporally and spatially. Dr. Hanson said consideration had been given to how flows or mechanical intervention could be used to separate the two runs. Dr. Hanson said genetic testing is currently underway to better understand the issue Dr. Yoshiyama raised.

Mr. Devine asked Mr. Bratovich to describe how the Framework was developed. Mr. Bratovich said he was unaware of examples where a similar reintroduction framework had been used. However, all the components of the Framework are issues that have been addressed at other projects and/or were issues Anderson et al. (2014) recommended be addressed. Mr. Bratovich said the Framework is simply a visual representation of those components. Mr. Devine said the Framework was an attempt to systematically bring together, organize, and sequence all the biological and ecological criteria, regulatory issues, and engineering considerations. Mr. Devine said one takeaway from Anderson et al. (2014) is that failing to approach reintroduction in a systematic way often leads to problems down the road. Mr. Devine discussed the importance of having a site-specific framework that reflects the specific issues of the watershed.

Dr. Yoshiyama said one item of note in Anderson et al. (2014) is that in order to assess the success of a reintroduction program, fish generations must be monitored for several decades. Dr. Yoshiyama said this group must also consider what indicators should be monitored in order to assess whether the program is failing or has failed. Mr. Le agreed that monitoring is a key component of evaluating a program, and that he thinks it will be necessary to include an adaptive component that provides an opportunity for a programmatic course correction. Mr. Le said his takeaway from Anderson et al. (2014) is that the first step in a reintroduction program is first determining whether the program is worth doing.

Mr. Shutes said it is a good idea in the beginning to identify front-end decisions that could have dramatic consequences for the success or failure of the program. For example, if the goal is to reintroduce fall-run on the San Joaquin, and there isn't enough water to get the fall-run to move to suitable habitat, it does not necessarily mean the program is doomed to fail, only that the limiting factor must be identified.

Mr. Le summarized issues discussed by Mr. Bratovich and Dr. Hanson that may be considered while developing reintroduction goals and objectives for the Tuolumne River. Mr. Le asked if others have thoughts about what would be realistic goals for this program. There was no response. Mr. Le asked if others thought the goals should be tied to habitat availability, escapement, and/or the NMFS Recovery Plan. Mr. Le added that there did not seem like a reason to pursue reintroduction if the end goal is not to support delisting the species. Mr. Shutes said in addition to the approach of tying goals to habitat, he believes the goals should apply to a defined geographic area, so that metrics are not based on out-of-basin factors beyond the control of the program and program proponents. An example would be a goal based on juveniles per spawner. Mr. Shutes said he recommended that each meeting attendee or entity sketch out a short high-level narrative goals proposal to be shared with the rest of the Reintroduction Goals Subcommittee. With those ideas in hand, the group can begin to consider something more quantitative. Mr. Shutes noted that objectives considered for the Yuba River may be helpful to reference and attendees might also consider how goals for the Tuolumne River might relate to the NMFS Recovery Plan criteria. Mr. Le suggested each Subcommittee member or entity send HDR a short bulleted list with thoughts on goals for a Tuolumne River reintroduction program and how success might be defined. The bulleted list could be a narrative/qualitative or quantitative. HDR will combined the lists and circulate the compilation for discussion on the next subcommittee call.

Mr. Edmondson asked if there is a reason why the group is not moving forward with the engineering feasibility portion of the study. Mr. Edmondson said he does not believe this exercise in setting goals is something that needs to happen in a step-wise manner, and he wondered how long this process will continue without moving forward with the engineering feasibility. Mr. Devine said the biological criteria must be known in order to develop reliable cost estimates and accurate facility designs that are the correct size and layout and that operate at the correct times. Mr. Devine said designing facilities without this basic information is akin to asking a builder to design a house without knowing how many people will live in it. The builder can design a house, but the design and cost estimate will be meaningless because the design was not based on solid information. Mr. Devine said it is not good practice to guess what the biological criteria are that will inform the design. Mr. Devine said the Districts asked for input on the biological criteria in Technical Memorandum No. 1, and the Districts are open to having a meeting to discuss in detail what biological criteria are needed for the design. Mr. Devine said differences in expected performance standards for the facilities, biological criteria, and percent efficiencies would result in the design of very different facilities.

Ms. Ellen Levin (City and County of San Francisco) asked how NMFS would go about building a fish passage facility without first knowing the goals of the facility. Mr. Edmondson said NMFS has contracted for fish passage engineering studies for the Merced River and the Yuba River. Mr. Edmondson said these studies use the NMFS fish passage design document, which is currently being updated, and provides the basic information on what is needed to design a facility. Mr. Edmondson said NMFS would look to expectations and performance criteria at state-of-the-art fish passage facilities to determine these factors for the Tuolumne River study. Mr. Edmondson said he believes the conceptual engineering feasibility can move forward in parallel with this effort to develop goals, and does not need to be in sequence. Mr. Edmonson said his concern is delay to the schedule, and in order to keep costs down the schedule should move forward as efficiently as possible.

Ms. Levin said she agreed this process must be done right. Ms. Levin said it is very unclear what the reintroduction goals should be and what it is that this program is trying to accomplish. Ms. Levin said without those goals, it is unknown how the design can move forward. Ms. Levin said that while a generic fish passage facility can be designed, without first knowing the goals of the facility the design could be at completely the wrong scale. Ms. Levin said if state-of-the-art is what NMFS wants, a state-of-the-art facility could be what is designed, but the end results may be incredibly expensive and completely overdesigned. Ms. Levin said the better approach would be to first determine what facilities are needed. Mr. Edmondson reiterated that he believes the conceptual engineering feasibility can move forward based on information provided in the NMFS design criteria. One can decide to build a house on a lot without first knowing what color the curtains will be. Mr. Edmondson said the NMFS design criteria provides guidance on layout sizing and performance elements. Mr. Edmondson said he is taken aback to hear that engineers who design fish passage for a living are unable to move forward with the engineering. Mr. Edmondson said he would be happy to put pen to paper and provide the biological information requested in TM No. 1.

Mr. Shutes said a middle ground between no definition and complete definition is to use ranges for these types of data. In some cases, it may be instructive to see what cost differences result when assuming a range, such as the costs to build a facility that accommodates 2,000 fish compared to facility designed to accommodate 10,000 fish. Mr. Shutes said he thinks it reasonable for meeting attendees to provide some initial thoughts and ideas. Mr. Shutes said these initial thoughts would not be commitments, but just general ideas. Mr. Shutes said perhaps the group could sit down and have a conversation about these numbers so that the engineering can move forward. Mr. Shutes said he agrees that planning for a range will provide a result with wide error bars. However, planning for a range will provide a sense of the scale of facility anticipated here. Mr. Shutes said he believes it is appropriate for the development of the goals and objectives to take place in parallel with engineering at the scale NMFS is referring to.

Mr. Devine said the Districts can move forward with the engineering using a range, but the range must be based on sound information. Mr. Devine said the Districts welcome feedback on biological criteria that is based on solid science. Mr. Edmondson asked what level of engineering will be completed for the facility designs. Mr. Devine said this is a conceptual engineering study, but the engineering must still be based in fact, otherwise the results are guaranteed to be wrong. Mr. Devine questioned why money should be spent to estimate something when the estimate is based on guesses.

Mr. Le noted there are examples of fish passage projects in the Pacific Northwest that moved forward with designing conceptual-level facilities, but in those cases there were existing runs and habitat suitability data to base the designs on. Mr. Le said similar information for the Tuolumne River does not exist. Two of the target species do not currently exist in the river. Mr. Le said the carrying capacity work NMFS is completing (available in October 2016) and work the Districts will be completing this summer will be very helpful for informing the design process. Mr. Le said he agrees with Mr. Devine and Mr. Shutes that a separate call may be needed to help move this forward. Mr. Le said the Districts will take on an action item to move this forward.

Mr. Le asked if meeting attendees are amendable to providing their initial thoughts about reintroduction goals and ideas. The ideas could be narrative/qualitative or quantitative, and need not be longer than one page. Mr. Le said the ideas would be considered as draft conceptual ideas, the purpose of which would be to stimulate conversation, and would be considered and discussed without attribution. Mr. Le said HDR will consolidate the ideas and circulate the compiled document. Mr. Le asked if two weeks is enough time to provide these initial thoughts.

Mr. Edmondson proposed that instead of meeting attendees providing their ideas, HDR create a proposal and allow meeting attendees to comment on that proposal. Mr. Devine said that is a possibility. Mr. Dias said getting feedback from meeting attendees on the proposal would be important. Mr. Le asked if Mr. Edmonson proposed this alternative because two weeks is an insufficient amount of time to draft ideas. Mr. Edmondson said he thinks it will be more efficient for HDR to draft a proposal and allow others to provide their comments. Mr. Edmondson said this approach is similar to how these documents are typically created in a FERC proceeding. In such proceedings, a contractor develops the product and stakeholders provide comments on that product. Mr. Edmondson said he thinks the one-pagers could all come out very differently, and since much of that variety won't be reflected in the final product, it would not be a good use of time. Mr. Devine said the Districts will consider Mr. Edmondson's suggestion and provide feedback. Mr. Edmondson said that would be acceptable.

Mr. Le said the Districts will send out notes from this meeting.

Meeting adjourned.

ACTION ITEMS

1. Mr. Le will inquire within HDR as to whether there are examples of other reintroduction programs that have used a decision matrix similar to the Framework and that are applicable to the Tuolumne River.
2. Dr. Hanson will send Mr. Le documents related to the approach to reintroduction on the San Joaquin River. The Districts will provide these documents to the Reintroduction Goals Subcommittee. (complete)
3. Mr. Edmondson will put pen to paper and provide the biological basis the engineering needs to make progress as outlined in TM No. 1.
4. The Districts will facilitate a future meeting to discuss the biological criteria necessary to move forward the engineering study.
5. The Districts will consider and provide feedback on Mr. Edmondson's suggestion that the Districts provide a one-pager about goals, and circulate this one pager for comment, instead of individual attendees and entities providing their own one-pagers.
6. The Districts will send out meeting notes. (complete)

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Planning Pacific Salmon and Steelhead Reintroductions Aimed at Long-Term Viability and Recovery

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ARTICLE

Planning Pacific Salmon and Steelhead Reintroductions Aimed at Long-Term Viability and Recovery

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Abstract
Local extirpations of Pacific salmon *Oncorhynchus* spp. and steelhead *O. mykiss*, often due to dams and other stream barriers, are common throughout the western United States. Reestablishing salmonid populations in areas they historically occupied has substantial potential to assist conservation efforts, but best practices for reintroduction are not well established. In this paper, we present a framework for planning reintroductions designed to promote the recovery of salmonids listed under the Endangered Species Act. Before implementing a plan, managers should first describe the benefits, risks, and constraints of a proposed reintroduction. We define benefits as specific biological improvements towards recovery objectives. Risks are the potential negative outcomes of reintroductions that could worsen conservation status rather than improve it. Constraints are biological factors that will determine whether the reintroduction successfully establishes a self-sustaining population. We provide guidance for selecting a recolonization strategy (natural colonization, transplanting, or hatchery releases), a source population, and a method for providing passage that will maximize the probability of conservation benefit while minimizing risks. Monitoring is necessary to determine whether the reintroduction successfully achieved the benefits and to evaluate the impacts on nontarget

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species or populations. Many of the benefits, especially diversity and the evolution of locally adapted population segments, are likely to accrue over decadal time scales. Thus, we view reintroduction as a long-term approach to enhancing viability. Finally, our review of published salmonid reintroduction case studies suggests that large uncertainties remain in the success of reintroduction in establishing self-sustaining populations, particularly for programs employing active methods.

Reintroducing species to areas from which they have been extirpated is a common and sometimes successful approach to conserving biodiversity. Indeed, reintroductions played a prominent role in some of the most spectacular success stories in conservation, including species that have recovered from the brink of extinction such as the Arabian oryx *Oryx leucoryx* (Spalton et al. 1999) and alpine ibex *Capra ibex ibex* (Stüwe and Nievergelt 1991). However, despite considerable cost and effort, reintroduction efforts often fail to establish self-sustaining populations (Wolf et al. 1996; Fischer and Lindenmayer 2000). A recent proliferation of reintroduction literature suggests that scientifically based management principles can improve the efficacy of these efforts (Seddon et al. 2007; Armstrong and Seddon 2008).

Conceptually, reintroductions offer an enormous potential to benefit the conservation of Pacific salmon *Oncorhynchus* spp. and steelhead *O. mykiss* (anadromous Rainbow Trout). For many anadromous salmonid populations, the primary cause of local extirpation is easily identified: obstructed access to suitable spawning and rearing habitats due to dams or other stream blockages. Large barriers are responsible for extirpation from nearly 45% of the habitat historically occupied by Pacific salmon and steelhead in the western contiguous United States (McClure et al. 2008a). Numerous smaller structures, such as irrigation diversion dams and culverts, also limit access to anadromous salmonid habitat (Gibson et al. 2005). Impassable dams are only one cause of declining salmonid populations and local extirpations (NRC 1996), but they are widespread. The removal or circumvention of dams and other barriers, therefore, provides many opportunities for the reestablishment of natural populations of Pacific salmon.

Despite the potential benefits of reintroduction, regional recovery planners must grapple with a variety of challenges in selecting and implementing such projects. Which populations should be prioritized for reintroduction? What methods should be used to reintroduce anadromous salmonids? How should managers evaluate whether efforts have been successful? Although previous authors have provided general guidelines for fish reintroductions (Williams et al. 1988; Minckley 1995; George et al. 2009; Dunham et al. 2011), the unique biology and management of Pacific salmon and steelhead merit special consideration.

In this paper, we provide recommendations for planning reintroductions of anadromous salmonids, focusing primarily on Pacific salmon and steelhead. Our guidelines are intended to help resource managers design reintroduction programs that contribute to the recovery of Pacific salmon and steelhead listed under the U.S. Endangered Species Act (ESA) by establishing or expanding self-sustaining natural populations. Thus, we present recommendations couched in the terminology, scientific concepts, and broad conservation objectives guiding ongoing salmonid recovery efforts under the ESA (McElhany et al. 2000). The International Union for the Conservation of Nature (IUCN 1998) defined reintroduction as "an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated." Using this broad definition, we consider a suite of management approaches to reintroduction, including passive strategies, such as barrier removal followed by natural colonization, and active strategies, such as transplanting or hatchery releases.

Reintroductions alter patterns of connectivity among populations. We therefore first develop a metapopulation framework to describe the ecological processes governing population connectivity and their evolutionary consequences. We then broadly overview a set of planning concepts (benefits, risks, and constraints) to help guide scoping efforts and determine if a proposed reintroduction has conservation merit. Next, we describe methods of executing reintroductions that increase the likelihood of achieving benefits while overcoming constraints and reducing risks, including a review of examples in which these methods have been employed. Finally, monitoring is essential to assess whether the effort was successful and, if not, how the program should be modified. Throughout, we focus on biological issues, acknowledging that a socioeconomic cost-benefit analysis will be crucial for policy decisions regarding large-scale restoration projects.

A METAPOPULATION PERSPECTIVE

A regional, landscape perspective is important for effective salmonid recovery (ISAB 2011). We therefore present our recommendations within a metapopulation conceptual framework. A metapopulation is a collection of spatially structured populations inhabiting discrete habitat patches, with dispersal between patches providing some level of connectivity between populations (Hanski and Gilpin 1997). Reintroductions intentionally alter connectivity among populations, so it is important to consider the consequences of such actions on the demography, ecology, and evolution of the metapopulation at large.

The metapopulation concept is readily applied to anadromous salmonids (Schtickzelle and Quinn 2007) and especially the case of population colonization. Pacific salmon have a strong tendency to return to their natal stream but also "stray" and breed in nonnatal streams (Hendry et al. 2004), providing the interpopulation dispersal characteristic of metapopulations. Dispersal, combined with variation in population growth rate, can lead to source–sink dynamics whereby populations with net demographic deficits (i.e., "sinks") are supported by immigration from populations with net demographic excesses (i.e., "sources") (Pulliam 1988). For colonizing Pacific salmon, source population dynamics will, in large part, determine the rate of numerical and spatial expansion (Pess et al. 2012).

Salmonid metapopulations might adopt a variety of different structural configurations depending on the spatial arrangement of habitat, heterogeneity in habitat quality among patches, and connectivity between populations (Schtickzelle and Quinn 2007; Fullerton et al. 2011). Metapopulation structure is useful to conceptualize the potential outcomes of reintroductions (Figure 1). Furthermore, an assessment of metapopulation structure might inform reintroduction methods. For example, a reintroduction that expands an existing population (Figure 1A) or establishes a new well-connected population (Figure 1B) might achieve success through passive natural colonization, whereas active methods might be required for more isolated reintroduction sites (Figure 1C).

Metapopulation structure, and the degree of connectivity among populations, also affects the evolution of locally adapted traits. Spatially structured populations experiencing different selection regimes within a heterogeneous landscape will tend to evolve traits advantageous in each environment, a process that is counterbalanced by connectivity between populations, which tends to homogenize gene pools (Barton and Whitlock 1997). Local adaptation is a fundamental aspect of salmonid population structure (Taylor 1991; Fraser et al. 2011). Furthermore, life history diversity exhibited by locally adapted populations buffers salmonid species against environmental variation, increasing stability and resilience (Greene et al. 2010; Schindler et al. 2010) while reducing extinction risk (Moore et al. 2010).

Increasing population connectivity, an implicit goal of all reintroduction programs, can have both positive and negative consequences on species viability. Some level of connectivity is beneficial because it can lead to the colonization of new habitat (Pess et al. 2012), demographically rescue extant populations experiencing periods of low productivity or abundance (Pulliam 1988), and provide new genetic material essential for fitness in populations suffering from fragmentation (Tallmon et al. 2004). However, excessive connectivity can have negative consequences such as genetic homogenization (Williamson and May 2005) and demographic synchrony (Liebhold et al. 2004), both of which would tend to reduce resilience.

For administering listing and recovery of Pacific salmon under the ESA, the National Marine Fisheries Service (NMFS) uses an explicitly defined population structure. For vertebrates,

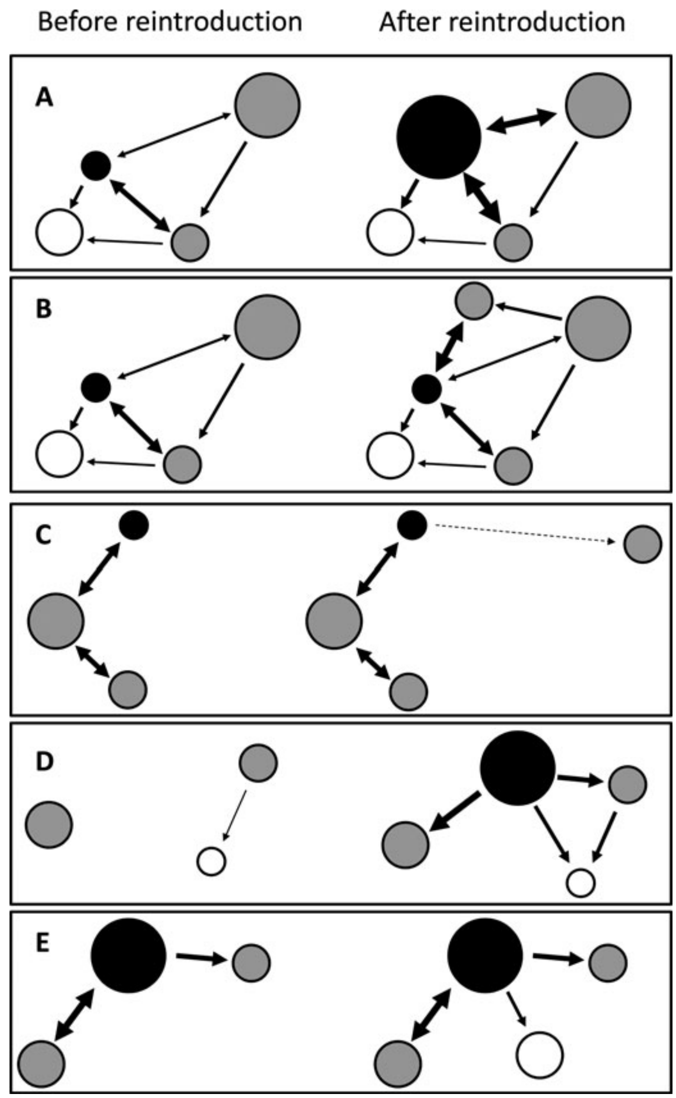

FIGURE 1. Possible effects of reintroduction on metapopulation structure are as follows: **(A)** increase the abundance of the existing population, **(B)** establish a new, independent population well connected to the metapopulation, **(C)** establish a new, independent population isolated from the other populations, **(D)** establish a new, independent mainland population in a historic mainland–island metapopulation, and **(E)** establish a new, independent sink population in a historic mainland–island metapopulation. In these diagrams, the size of the circle represents habitat capacity, the shade represents population density (darker shades are more dense), the thickness of the arrows represents the magnitude of connectivity, and the dashed lines indicate intermittent connectivity. These scenarios are not intended to represent all possible outcomes.

the ESA allows listing of Distinct Population Segments (DPSs), subspecies, or entire species. For Pacific salmon, the NMFS has defined a DPS to be an Evolutionary Significant Unit (ESU), which is a population or group of populations that is both substantially reproductively isolated from other populations and represents an important component of the evolutionary legacy of the species (Waples 1991). For steelhead, the NMFS uses the joint NMFS–U.S. Fish and Wildlife Service DPS definition

(NMFS 2006). We refer to both Pacific salmon ESUs and steelhead DPSs as ESUs in this paper for consistency and brevity. Similar to metapopulations, most Pacific salmon ESUs contain multiple independent populations that interact through dispersal (e.g., Myers et al. 2006; Ruckelshaus et al. 2006). Furthermore, metapopulation concepts are explicitly considered in the criteria used to evaluate the viability of Pacific salmon and steelhead ESUs and the populations within them (McElhany et al. 2000).

PLANNING CONCEPTS: BENEFITS, RISKS, AND CONSTRAINTS

Before implementing a reintroduction, it is essential to comprehensively consider the potential outcomes. Poorly planned reintroduction efforts might waste resources that would be better invested in other conservation approaches or, worse, impair the viability of an extant population. In evaluating a potential reintroduction, there are three primary concepts to consider: the benefits if the reintroduction is successful, the risks of causing biological harm to extant populations, and the constraints that might prevent population establishment. Weighing the potential benefits against the risks and constraints will help determine whether or not to implement a proposed reintroduction (Figure 2).

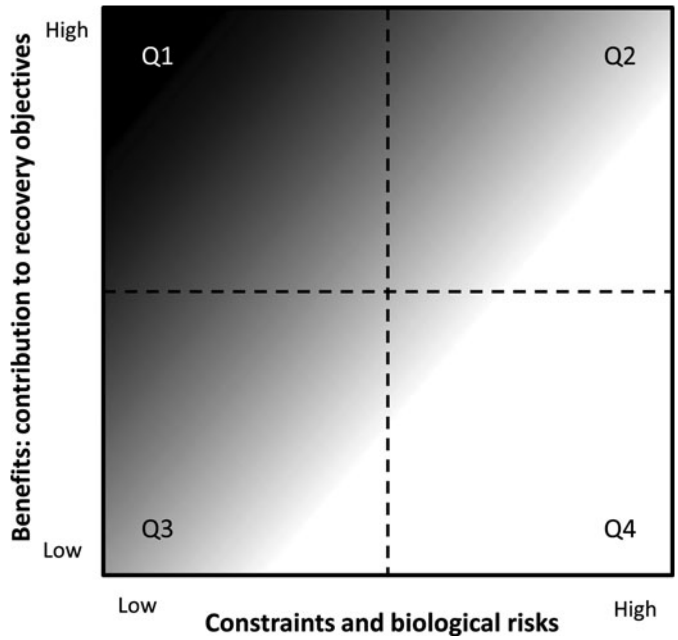

FIGURE 2. Framework for gauging the net benefit of reintroduction options, with darker colors representing a higher likelihood of contributing to conservation and recovery goals. In each case, the benefits are weighed against the constraints and risks of the project. In quadrant 1 (Q1), the benefits are high and the overall constraints and risks are low, providing the best opportunity for reintroduction to effectively contribute to the recovery objectives. Quadrant 2 (Q2) also has a high potential benefit, but either the difficulty in implementation or the risk of a negative outcome makes projects in this region less attractive. Both quadrants 3 (Q3) and 4 (Q4) have relatively low benefits; some in quadrant 3 may be selected owing to the low risk and ease of execution, whereas those in quadrant 4 will generally be avoided.

Benefits

Due to our focus on ESA-listed salmonids, we assess benefits with the same criteria used to evaluate recovery under the ESA. The biological viability of salmonid ESUs and the populations within them is dependent upon four characteristics: abundance, productivity, spatial structure, and diversity (McElhany et al. 2000). We use these same attributes for evaluating the potential benefits of a reintroduction that successfully establishes a self-sustaining population (Table 1). Abundance, productivity, and spatial structure (i.e., connectivity) are variables in metapoulation models useful for guiding salmonid management (Cooper and Mangel 1999; Fullerton et al. 2011; Pess et al. 2012), and diversity promotes resilience at a broad, regional (hence metapopulation) scale (Moore et al. 2010; Schindler et al. 2010).

Numerical increases in abundance and productivity are perhaps the most obvious benefits afforded by reintroductions.

TABLE 1. Potential benefits of a successful reintroduction.

Type	Definition	Potential benefit afforded by reintroduction
Abundance	Total number of naturally spawned fish in a population or ESU	Increase the carrying capacity of an existing population or establish a new, discrete, demographically independent population
Productivity	Numerical ratio of recruits in generation t to the spawners that produced them in generation $t - 1$	Increase average vital rates (e.g., reproductive success, survival) of an extant population or ESU by reestablishing occupancy of high quality habitat
Spatial structure	Geographic arrangement of fish across the landscape and connectivity of populations linked by dispersal	Reduce isolation of extant populations, thereby restoring natural patterns of dispersal and connectivity within the metapopulation
Diversity	Variation in morphological, behavioral, and genetic traits within a population or ESU	Reestablish occupancy of habitats that are rare or underrepresented within the extant distribution, thereby promoting ecological and evolutionary processes responsible for local adaptation and diverse life histories

Increased abundance has several beneficial consequences, including shielding a population from extinction due to stochastic variability (Lande 1993), minimizing genetic processes that can reduce fitness in small populations (Allendorf and Luikart 2007), exceeding thresholds for depensatory density-dependent processes (Liermann and Hilborn 2001), and providing marine-derived nutrient subsidies to aquatic and riparian ecosystems (Gende et al. 2002). Status evaluations of ESA-listed Pacific salmon and steelhead populations focus on numerical productivity (Ford 2011), or population growth rate as it is known in the ecological literature, so recruits per spawner is also an important variable to consider. Reintroductions can have either positive or negative impacts on the productivity of a given population or ESU, depending on the quality of the new habitat and survival through migration and ocean rearing. In general, a reintroduction resulting in a "sink" has far less value for long-term viability than a reintroduction yielding a self-sustaining population. Indeed, reintroduction to a sink would result in a net loss if the animals would have been more productive in their natal habitat. However, in highly connected metapopulations, sinks may increase the stability of the entire system by promoting higher abundance in source populations (Foppen et al. 2000).

Reintroductions that reduce the isolation of formerly connected extant populations will benefit spatial structure (Figure 1). In practice, this can be estimated as the extent to which a newly established population would reduce gaps between spawning areas or populations that were not historically separated. Given the spatial arrangement, models of dispersal, and estimates of habitat capacity, reintroduction could target areas that might have a significant role in metapopulation connectivity and serve as sources supporting less productive populations (Figure 1D; Fullerton et al. 2011; Pess et al. 2012). In addition, at the ESU scale, dispersion of populations across the landscape helps reduce vulnerability to catastrophic events (Good et al. 2008), so increasing spatial complexity via successful reintroduction will reduce ESU extinction risk.

Reintroductions can enhance salmonid diversity through a variety of mechanisms. Dams often selectively block access to certain habitat types, particularly snowmelt-dominated headwater streams (Beechie et al. 2006; McClure et al. 2008a). Therefore, reintroductions into habitats that are rare or underrepresented within the extant species distribution may promote unique local adaptations and life history traits. Barrier removal may provide seaward access for populations of facultatively migratory species (e.g., *O. mykiss*) that historically had anadromous components (Brenkman et al. 2008b). Reintroductions to large watersheds with multiple tributaries and subbasins also offer opportunities to enhance diversity through the evolution of population substructure and local adaptation to distinct spawning areas. In general, a reintroduction that establishes a new locally adapted population will provide a greater benefit to diversity than one that expands an existing population (Figure 1A, 1B).

Outlining the time frame required to achieve reintroduction benefits will help set expectations and establish benchmarks for monitoring. Some reintroductions may provide immediate benefits within a generation or two, but those requiring adaptation to new habitat will likely take decades. If an implemented project suffers initial setbacks and lacks a scientifically based timeline of expectations, it might be unnecessarily abandoned or altered before it has a chance to succeed. In general, reintroduction can provide benefits to viability characteristics that change on ecological time scales (abundance, productivity, and spatial structure) faster than benefits to diversity, which will accumulate over generations as a reintroduced population becomes demographically independent and evolves in response to local selective pressures. Salmonids have developed population structure within 20 years of introduction to new environments (Ayllon et al. 2006); evidence that such divergence is adaptive has been found after 50–100 years (Hendry et al. 2000; Quinn et al. 2001; Koskinen et al. 2002).

Moreover, in some cases adaptive evolution might be necessary to observe significant increases in abundance. Indeed, there is often a time lag from the initial introduction of an invading species to population growth that might be explained by evolutionary processes required to increase population fitness (Sakai et al. 2001). Dams have altered the evolution of traits such as adult spawn timing, embryonic development rate, and juvenile migration strategies (Angilletta et al. 2008; Williams et al. 2008), so some level of adaptive evolution may be necessary to overcome this "Darwinian debt" if reintroduction includes restoration of the natural flow regime (Waples et al. 2007b).

Risks

We define risks as unintended or undesirable negative consequences for nontarget species or nontarget populations of the reintroduced species (Table 2). Minimizing those risks is important if a reintroduction is to have a positive overall conservation effect (George et al. 2009). Here we outline the concepts underlying four categories of risk: evolutionary, demographic, ecological, and disease. More details on minimizing them are provided below in the Executing a Reintroduction section.

In terms of evolutionary risks, reintroduction could result in genetic homogenization, reduced fitness, or both. Transfers of fish between basins and large-scale hatchery releases, historically common practice throughout the Pacific Northwest, have eroded population structure that is essential for the local adaptation and hence fitness of salmonid populations (Williamson and May 2005; Eldridge and Naish 2007; McClure et al. 2008b). Hatchery fish often have lower fitness than wild fish when both groups breed sympatrically (Araki et al. 2008). Thus, although hatchery releases may provide short-term demographic benefits, they may compromise fitness in the long term, thereby limiting the probability of recovery (Bowlby and Gibson 2011). In many cases, populations or spawning areas near the reintroduction site are of conservation concern. Fish

TABLE 2. Summary of the major reintroduction risks, defined as unintended or undesirable negative consequences for nontarget species, nontarget populations, spawning areas, or life history types of the reintroduced species.

Type	Description	Methods of minimizing risk
Evolutionary	Homogenized population structure and reduced fitness within reintroduction site and adjacent areas	Avoid geographically and genetically distant source populations; opt for natural colonization rather than hatchery releases or transplanting; design passage facilities to minimize straying to adjacent areas
Demographic	Depletion of source population via removal of adults or gametes for reintroduction	Ensure that source population can sustain removal for multiple successive years or opt for natural colonization rather than hatchery releases or transplanting
Ecological	Invasion by nonnative species and suppression of preexisting native species within reintroduction site	Design passage facilities with selective access; avoid hatchery releases that alter density-dependent ecological interactions
Disease	Spread of pathogens	Establish baseline disease levels prior to reintroduction; screen individuals for pathogens prior to release

released into the reintroduction site, and their offspring, may not return there as adults, so fitness reductions and the erosion of population structure of the wild populations in adjacent spawning areas are potential consequences of excessive straying.

Reintroductions also pose demographic risks because the removal of individuals from the source population may harm its viability. If reintroduced fish experience poor reproductive success, the new habitat may become a sink that depletes an extant population but fails to provide the benefit of a newly established self-sustaining population. Transplanting or collecting broodstock from wild populations will exacerbate this risk, but it applies in concept to natural colonization as well. Ensuring that the population donating colonists has a net demographic excess (i.e., it is a true "source" in metapopulation source–sink dynamics) will help reduce demographic risks.

Nonnative fishes present a serious conservation threat to salmonids in the Pacific Northwest (Sanderson et al. 2009) and may invade the reintroduction site following barrier removal (Fausch et al. 2009). Invasion might not only reduce the likelihood of reintroduction success but also threaten preexisting native species. A careful examination of the likelihood of nonnative dispersal into the new habitat entails identifying any proximate populations of nonnative fishes and evaluating habitat suitability above the barrier. It is also important to consider whether reintroduction might suppress preexisting native species (which might be threatened or endangered themselves) through competition or predation. The few empirical assessments of reintroduction impacts have found little effect on preexisting native species (Pearsons and Temple 2007; Buehrens 2011).

Finally, reintroductions have potential to spread disease (Viggers et al. 1993). Colonists may serve as vectors of disease spread within the species they are intended to benefit, thereby hindering conservation efforts (Walker et al. 2008), or transmit pathogens to other species or resident life history types currently occupying the target site. Hatchery fish in particular, due to the crowded conditions in which they are typically reared, may act as vectors of disease transfer to wild populations (reviewed in Naish et al. 2008). Reintroduced animals might also be vulnerable to endemic pathogen strains within new habitat, and this could decrease the likelihood of successful population establishment if the effect is severe. Establishing a baseline of pathogen densities within the area prior to reintroduction will permit monitoring of disease during reintroduction (Brenkman et al. 2008a), and screening captively reared or transplanted animals prior to release will minimize the risk of spreading disease. Both are important components of reintroduction.

Constraints

We define a constraint as a factor limiting the ability of colonists to establish a self-sustaining population (Table 3). In some cases, an extirpated area may have a high potential to benefit long-term recovery, but current conditions do not support a reintroduction. Evaluating whether the original causes of the extirpation have been adequately ameliorated is an important step in determining whether a site is "reintroduction ready" (IUCN 1998). Importantly, more than one factor may have led to the original extirpation, and in many cases determining a logical sequence of restoring functioning conditions will be an important component of the reintroduction effort. Here, we describe the primary constraints affecting the ability of colonists to reach the reintroduction site, their reproductive success, and the survival of their offspring.

In many cases, migration barriers are the most obvious constraint to the reestablishment of a natural population. Evaluating the best methods for providing passage at barriers is heavily dependent on engineering and social considerations such as the geological setting, human benefits derived from the barrier, and expense. Furthermore, many river systems with reintroduction opportunities have more than one blockage to anadromous

TABLE 3. Summary of constraints to reintroductions, defined as factors that might limit the ability of colonists to establish a self-sustaining population.

Type	Description	Required action
Barriers	Engineering issues; prioritization among multiple blockages in a watershed or region	Removal or circumvention
Habitat quality	Poor habitat quality will limit reproductive success of colonists and survival of their offspring	Restoration prior to reintroduction
Migratory and ocean survival	Poor survival along migration corridor and during ocean residence	Improve survival through downstream dams; estuary restoration; wait for favorable ocean conditions or scale expectations to match poor ocean conditions
Harvest	Reduces number of potential colonists and survival of their offspring	Reduce fishing pressure on potential source population(s) during colonization
Interactions with other species and populations	Competition and predation from native and nonnative species	Suppress predator population or transport fish during migration to avoid predators
Changing conditions	Climate and land-use change will alter geographic patterns of habitat suitability	Prioritize reintroductions that enhance diversity, are likely to serve as refuges in a warming climate, or are located in river networks whose high connectivity will allow species distributions to shift in response to climate change

passage, requiring prioritization among multiple removal or circumvention options.

The quality of habitat in the reintroduction site will have a large effect on colonist productivity. In gauging habitat quality within an area targeted for reintroduction, planners should consider the requirements of all life phases. Spatially explicit models incorporating known fish–habitat relationships (e.g., Scheuerell et al. 2006; Burnett et al. 2007; Pess et al. 2008) can help identify potentially productive streams; determining the anthropogenic degradation of habitats can draw on the many efforts (largely expert opinion) to identify degraded habitat (e.g., subbasin or recovery plans). Where habitat quality is low due to anthropogenic disturbance, habitat restoration may be necessary for successful reintroduction and premature efforts to put fish into degraded habitat may simply be a waste of resources. For example, liming of rivers affected by acidification (Hesthagen and Larsen 2003) and reducing pollution (Perrier et al. 2010; Kesler et al. 2011) were necessary components of reestablishing Atlantic Salmon *Salmo salar* runs in Europe. When restoration is necessary, process-based restoration will maximize the long-term sustainability of habitat improvements (Beechie et al. 2010).

Interactions with existing species in the target area could influence the likelihood of a successful reintroduction. Dams that block salmonid habitat often create the warm, lentic reservoirs preferred by nonnative fishes (e.g., Channel Catfish *Ictalurus punctatus*, Smallmouth Bass *Micropterus dolomieu*, Yellow Perch *Perca flavescens*, and Walleye *Sander vitreus)* and "native invaders" (e.g., Northern Pikeminnow *Ptychocheilus oregonensis*), species that consume a considerable quantity of salmonids (Sanderson et al. 2009; Carey et al. 2012). Competition and predation from preexisting species might not be confined to reservoirs or degraded habitats. Nonnative Brook Trout *Salvelinus fontinalis*, for example, have invaded relatively pristine, free-flowing streams throughout the Pacific Northwest (Sanderson et al. 2009) and may have suppressed populations of ESA-listed Chinook Salmon *O. tshawytscha* (Levin et al. 2002). Slimy Sculpin *Cottus cognatus*, a native generalist predator, reduced the recruitment success of reintroduced Atlantic Salmon (Ward et al. 2008).

Due to climate forcing (Mantua et al. 2010) and alterations in land use (Bilby and Mollot 2008), salmonid habitat quality is likely to change over the time required for a reintroduction to result in a self-sustaining population. Thus, the likely future condition of the reintroduction site is an important consideration in reintroduction planning efforts. Climate and land-use models can inform restoration opportunities (Battin et al. 2007; Lohse et al. 2008) but have been applied to relatively few watersheds. In the absence of large-scale predictive models, two qualitative guidelines for reintroductions warrant consideration. First, dams selectively block access to certain habitat types (Beechie et al. 2006; McClure et al. 2008b), suggesting that reintroduction to mountain headwater reaches with higher elevations and cooler temperatures may provide refuges in a warming climate. Second, maintaining a diversity of habitat types will buffer against uncertainty in the response of salmonid populations to climate change (Schindler et al. 2008), suggesting that reintroduction should target habitats that are unique, rare, or underrepresented in the current species distribution.

High mortality during migration and ocean rearing due to impaired migratory corridor, poor ocean conditions, or harvest pressure may limit reintroduction success. Passage through

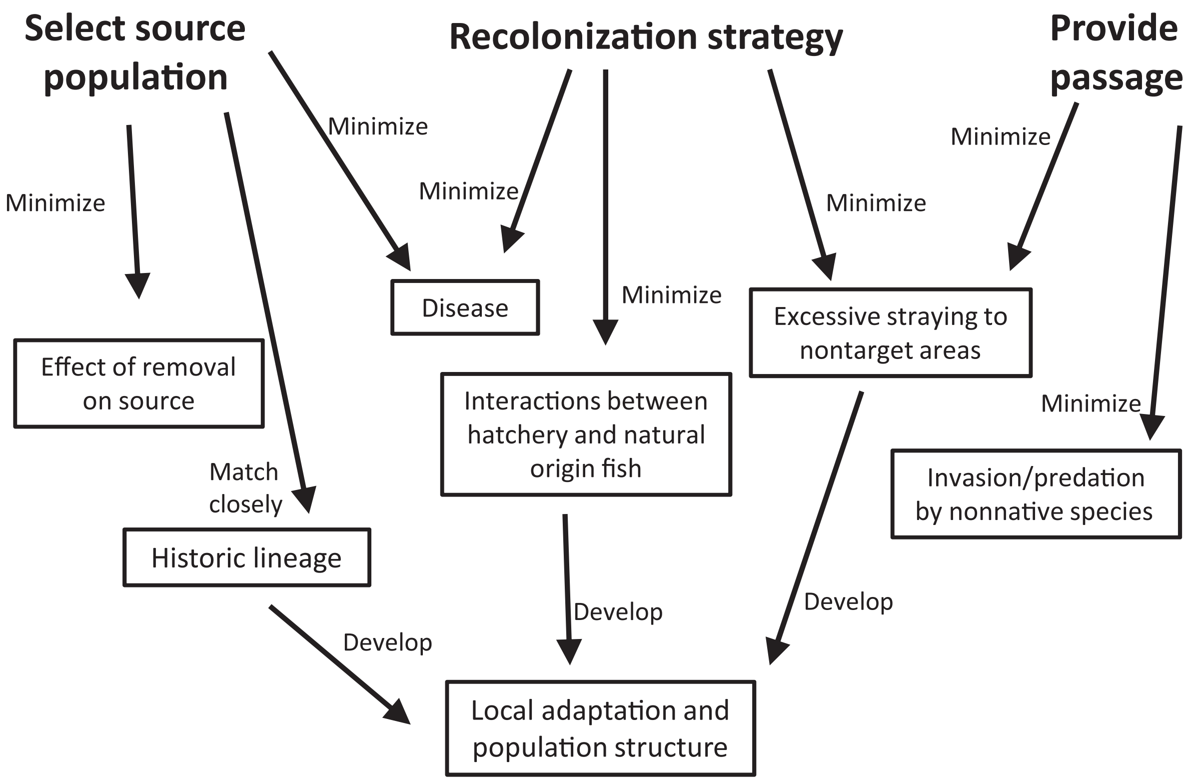

FIGURE 3. Minimizing biological risks in reintroduction planning. Biological risks are unintended negative consequences that may harm nontarget species, other populations, spawning areas, or life history types of the reintroduced species.

downstream dams, for example, may reduce the migratory survival of juveniles, either directly or through delayed effects that manifest in subsequent life stages (Budy et al. 2002; Schaller and Petrosky 2007). Dams may also cause the delay and eventual failure of upstream-migrating adults (Caudill et al. 2007). It is possible to improve survival through dams, even large ones (Ferguson et al. 2007), and this may be an essential action prior to reintroduction. Marine survival patterns are also a major determinant of salmonid population productivity. Ocean survival responds to long-term climatic processes such as the Pacific Decadal Oscillation (Mantua et al. 1997), as well as short-term processes such as interannual variation in sea surface temperature, marine upwelling, and river conditions experienced during migration (Mueter et al. 2005; Scheuerell and Williams 2005; Scheuerell et al. 2009; Petrosky and Schaller 2010). As our ability to identify favorable ocean and river conditions improves (e.g., Burke et al. 2013), there may be opportunities to time reintroduction efforts to favorable conditions. Harvest rates vary among ESUs and in some cases may limit recolonization potential. Fishing quotas set on aggregate stocks may constrain the ability to selectively reduce harvest rates on individual colonizing populations and their sources.

EXECUTING A REINTRODUCTION: COLONIZATION, SOURCE POPULATION, AND PASSAGE

In this section, we discuss the strategies for recolonization, the choice of a source population, and, in the case of reintroductions involving barriers, the techniques used to provide passage. Decisions related to these three execution elements will largely determine reintroduction risks (Figure 3). We define the colonization strategy as the mechanism of fish movement into the reintroduction site; it can be either passive (natural colonization) or active (transplanting or hatchery releases). We suggest that it is important to consider the colonization strategy and source population as two separate planning decisions. For example, even in cases where a hatchery stock is the source, it may be possible to reduce evolutionary risks by allowing hatchery adults to colonize naturally rather than planting hatchery-produced juveniles.

Colonization Strategy

The three basic types of colonization strategies are natural, transplant, and hatchery release. Importantly, these approaches differ in the effects on the viability parameters that will ultimately be used to judge the success or failure of a reintroduction. In general, natural colonization is the lowest-risk approach because it minimizes the interruption of natural biological processes. Transplanting and hatchery releases can immediately place fish in the reintroduction site, but tend to increase the risks associated with reintroduction relative to natural colonization. Fortunately, active reintroduction strategies will be most necessary for isolated reintroduction sites (e.g., Figure 1C), the very situations where evolutionary risks of straying to neighboring extant populations are the lowest. In general, a precautionary

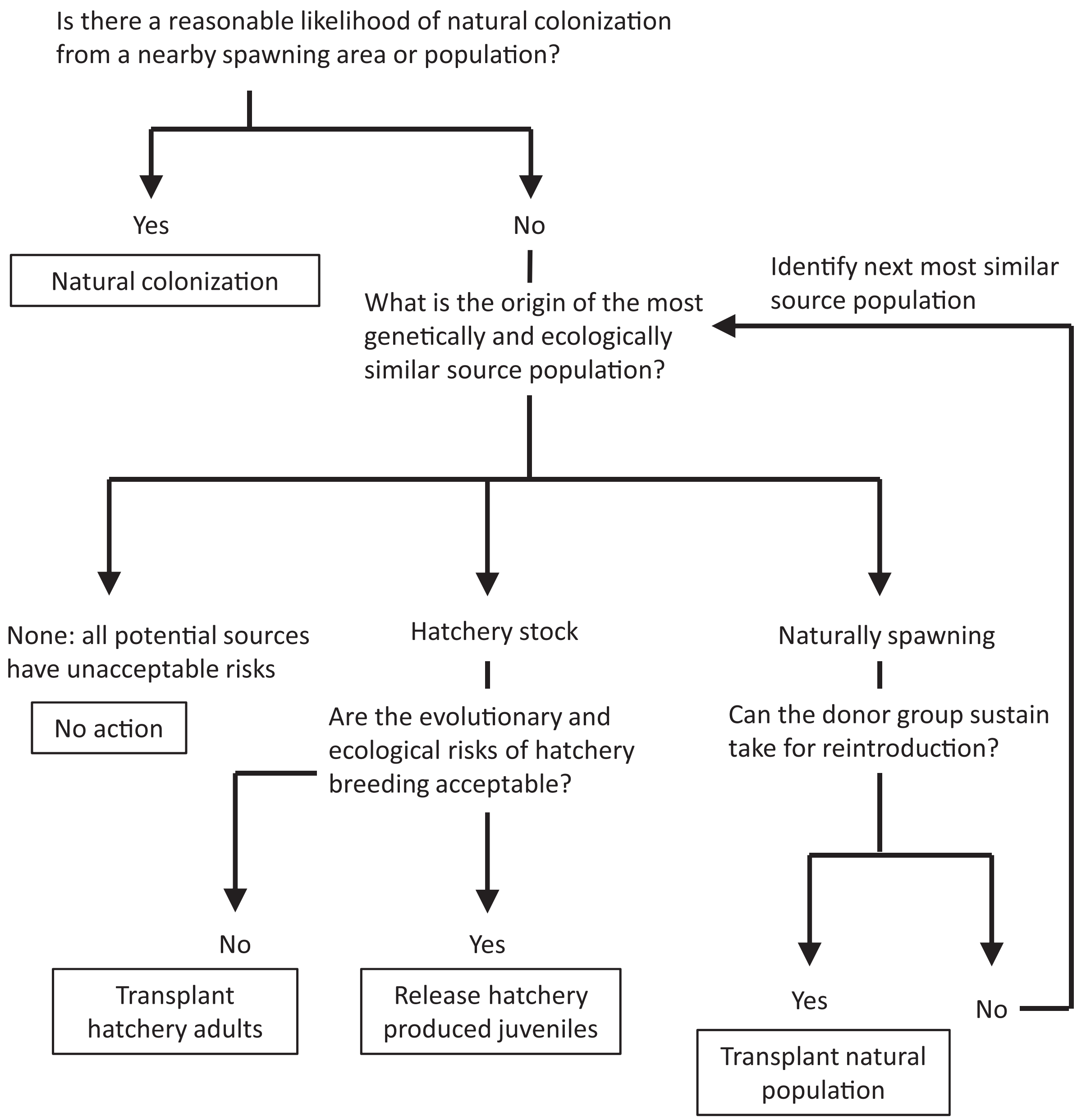

FIGURE 4. Decision framework for selecting a low-risk colonization strategy and source population. This diagram does not encompass every possibility but is intended to highlight the key decisions affecting reintroduction risks. Boxes indicate decision endpoints.

approach, outlined in Figure 4, adopts the lowest risk colonization strategy that has a reasonable chance of promoting long-term improvement in population and ESU viability.

What is the minimum number of fish necessary to establish a self-sustaining population? This is a crucial question applicable to all three colonization strategies whenever the goal is to establish a new population (e.g., Figures 1B–1E). On one hand, depensatory processes (Allee effects) may depress productivity at low densities through a variety of mechanisms (Courchamp et al. 1999; Liermann and Hilborn 2001) and, if the effect is severe, prevent population establishment following reintroduction (Deredec and Courchamp 2007). On the other hand, reintroduced species, particularly those with an extensive stream-rearing juvenile phase, may be released from density-dependent processes during colonization and enjoy high survival due to the lack of competition (Pess et al. 2011). Although the ultimate result will depend heavily on the constraints (Table 3), the choice of colonization strategy will have a strong influence on the number of fish that reach the reintroduction site. Here, we outline the benefits and risks of each colonization strategy, providing empirical examples if they are available.

Natural colonization.—Pacific salmon can rapidly exploit newly accessible habitat through natural colonization, which we define as volitional dispersal into a reintroduction site without human-assisted transport. Following construction of a fishway circumventing an anthropogenic blockage, Pink Salmon *O. gorbuscha* naturally dispersed upstream and established self-sustaining populations in multiple subbasins of the Fraser River, British Columbia, within a decade (Pess et al. 2012). Chinook Salmon and Coho Salmon *O. kisutch* immediately colonized habitat made accessible by modification of a dam on the Cedar River, Washington (Kiffney et al. 2009; Burton et al. 2013), and both species produced a significant number of returning adult offspring that bypassed the dam in the next generation (Anderson et al. 2010; Anderson et al. 2013a). In this system, extensive dispersal by juvenile Coho Salmon, including immigration into a tributary where survival was relatively high, contributed to colonization success (Pess et al. 2011; Anderson et al. 2013b). Steelhead and fluvial Rainbow Trout accessed Beaver Creek, Washington, in the very first season after barrier removal (Weigel et al. 2013). Atlantic Salmon naturally colonized rivers in Estonia, Norway, England, and France following improvements in water quality (Hesthagen and Larsen 2003; Perrier et al. 2010; Griffiths et al. 2011; Kesler et al. 2011), and some of these examples resulted from long-distance dispersal. Dam removal promoted natural colonization of the Upper Salmon River, New Brunswick, by Atlantic Salmon, though this population later crashed to near zero abundance for unknown reasons (Fraser et al. 2007).

In some cases, increasing water releases from dams has promoted natural colonization. In the Bridge River, British Columbia, Coho Salmon, Chinook Salmon, and steelhead were observed immediately following restoration of flow to a 4-km reach that had been dewatered for decades (Decker et al. 2008). Experimental water releases from dams on the Alouette and Coquitlam rivers, British Columbia, led to the reappearance of Sockeye Salmon *O. nerka* after 90 years of extirpation, and genetic and otolith analysis confirmed that the anadromous adults were the offspring of resident kokanee (lacustrine Sockeye Salmon) (Godbout et al. 2011).

Natural disturbances and circumvention of natural barriers provide additional examples of natural colonization. Steelhead recolonized the Toutle River, Washington, to relatively high densities 7 years after a catastrophic destruction following the eruption of Mount Saint Helens (Bisson et al. 2005). Natural colonization tends to proceed more slowly (e.g., decades) in initially barren glacial emergent streams, as evidenced by rates of Coho Salmon and Pink Salmon colonization in Glacier Bay, Alaska (Milner and Bailey 1989; Milner et al. 2008). Several salmonid species rapidly colonized Margaret Creek, Alaska, following construction of a fish ladder at a falls, although the Coho Salmon and Sockeye Salmon populations were supplemented by hatchery releases (Bryant et al. 1999).

Establishing a self-sustaining population via natural colonization is contingent on a reasonable likelihood of natural dispersal into the new habitat. The probability of colonization, in turn, is determined by metapopulation attributes such as the location of the potential source population, abundance of the source population, and stray rate (i.e., connectivity) as a function of distance (Pess et al. 2012). Despite these observations, it is difficult to predict precise colonization rates following barrier removal. Most examples of natural colonization by Pacific salmon in Table 4 had nearby, relatively robust source populations, but colonization rates of isolated reintroduction sites are likely to be much lower. Furthermore, one might predict colonization rate to vary by species, but there are few multispecies comparisons to guide expectations (Table 4). In this situation, habitat preferences and life history patterns offer a means to make species-specific predictions (Pess et al. 2008).

Natural colonization minimizes anthropogenic disturbance to biological processes during population establishment and expansion. Natural colonization provides the greatest opportunity for the evolution of locally adapted traits through natural selection on individuals that disperse into the new habitat, sexual selection during reproduction of the initial colonists, and natural selection on their offspring. In many cases, evolution resulting from the novel selection pressures during colonization may increase population fitness and the likelihood of establishment (Kinnison and Hairston 2007). In the Cedar River, Washington, strong selection on the breeding date and body size of Chinook Salmon and Coho Salmon colonists emphasized the importance of natural and sexual selection in promoting local adaptation during reintroduction (Anderson et al. 2010, 2013a).

Transplanting adults.—In areas that are isolated or distant from extant populations, long-distance dispersal from extant populations may be unlikely. In these cases, transplanting can ensure that an adequate number of adult fish reach the reintroduction site. Under this strategy, adult fish are trapped at one location then transported to the reintroduction site, where they are released to breed naturally. Here, we describe the process and consequences of transplanting from both hatchery and wild sources.

Although stock transfers have been common for Pacific salmon, there are relatively few examples in which only adults were released (Withler 1982). In programs that combined transplanted adults with hatchery releases (e.g., Burger et al. 2000; Spies et al. 2007), it is difficult to isolate the effects of each strategy. In a reintroduction or supplementation context, transplants often involve surplus hatchery adults. For example, hatchery-origin spring Chinook Salmon were transplanted to Shitike Creek, Oregon because the habitat was considered underseeded 15 years after dam removal and produced a significant fraction of the juveniles captured the following spring (Baumsteiger et al. 2008). Atlantic Salmon that had spent their entire lives in captivity successfully spawned following release into Wilmot Creek, Ontario (Scott et al. 2005b). Transplanting adults is frequently used to circumvent large dams and reservoirs in a "trap and haul" strategy (Table 5), and we discuss this approach further in the Providing Passage section below.

TABLE 4. Examples of anadromous salmonid reintroductions from the published literature.

Location	Date initiated	Species	Colonization strategy	Passage provision	References
Fraser River, British Columbia	1947	Pink Salmon	Natural colonization	Fishway	Pess et al. 2012
Clearwater River, Idaho	1960	Chinook Salmon	Hatchery juveniles	Dam removal	Narum et al. 2007
Upper Salmon River, New Brunswick	Mid-1960s	Atlantic Salmon	Natural recolonization	Dam removal	Fraser et al. 2007
Connecticut River, Connecticut, Massachusetts, Vermont, and New Hampshire	1967	Atlantic Salmon	Hatchery juveniles	Fishways	Gephard and McMenemy 2004; Ward et al. 2008
River Thames, England	1975	Atlantic Salmon	Natural colonization and hatchery juveniles	None	Griffiths et al. 2011
Rivers Rhine, Ems, Weser, and Elbe, Germany	1978	Atlantic Salmon	Hatchery juveniles	Primarily fishways	Monnerjahn 2011; Schneider 2011
Point Wolfe River, New Brunswick	1982	Atlantic Salmon	Hatchery juveniles	Dam removal	Fraser et al. 2007
Sawtooth Valley lakes, Idaho	1993	Sockeye Salmon	Hatchery juveniles	None	Griswold et al. 2011; Kalinowski et al. 2012
Middle Fork Willamette River, Oregon	1993	Chinook Salmon	Transplanted adults	Trap and haul	Keefer et al. 2010, 2011
Various Norwegian rivers	Mid-1990s	Atlantic Salmon	Natural colonization and hatchery juveniles[a]	None	Hesthagen and Larsen 2003
Seine River, France	Mid-1990s	Atlantic Salmon	Natural colonization	None	Perrier et al. 2010
River Selja, Estonia	Mid-1990s	Atlantic Salmon	Natural colonization and hatchery juveniles[b]	None	Väsemagi et al. 2001
Bridge River, British Columbia	2000	Chinook Salmon, Coho Salmon, steelhead	Natural colonization	Increased water releases from dam	Decker et al. 2008
Wilmot Creek, Ontario	2000	Atlantic Salmon	Transplanted adults	None	Scott et al. 2005a, 2005b
Salmon River, New York	2000	Atlantic Salmon	Hatchery juveniles	None	Coghlan and Ringer 2004
Shitike Creek, Oregon	2002	Chinook Salmon	Transplanted adults	Dam removal	Baumsteiger et al. 2008
Cedar River, Washington	2003	Chinook Salmon, Coho Salmon	Natural colonization	Fishway	Kiffney et al. 2009; Anderson et al. 2010, 2013a, 2013b; Pess et al. 2011; Burton et al. 2013
Various Lake Ontario tributaries, New York	2003	Atlantic Salmon	Hatchery juveniles	None	Coghlan et al. 2007

TABLE 4. Continued.

Location	Date initiated	Species	Colonization strategy	Passage provision	References
Alouette and Coquitlam rivers, British Columbia	2005	Sockeye Salmon	Natural colonization	Increased water releases from dams	Godbout et al. 2011
River Purtse, Estonia	2005	Atlantic Salmon	Natural colonization and hatchery juveniles[c]	None	Kesler et al. 2011
Beaver Creek, Washington	2005	Steelhead	Natural colonization	Fishways	Weigel et al. 2013

[a]Colonization strategy varied by river.
[b]Genetic analysis indicates that natural dispersal, not hatchery releases, were primarily responsible for colonization.
[c]Hatchery releases commenced after natural colonization was observed.

Conceptually, transplanting allows for natural patterns of natural and sexual selection within the new habitat and thus has many of the benefits of natural colonization. The offspring of any adults that successfully spawn will spend the entire freshwater phase, from embryonic incubation to the smolt migration, within the reintroduction site. Compared with hatchery releases, this will increase their exposure to natal odors and local geomorphic, hydrologic, and biotic conditions, all of which are likely to promote local adaptation. However, transplanting introduces artificial selection of the individuals that reach the reintroduction site. In some cases, natural selection during migration could be important for the evolution of traits (i.e., body morphology or energy reserves) that are advantageous for a particular migration route (i.e., long or steep) (Quinn et al. 2001). Thus, considering the run timing, size, and other phenotypic traits of individuals selected for transplantation is an important component of minimizing the negative, unintended consequences of transplanting.

The number and frequency of transplants is an important consideration. Reintroductions with many individuals are more likely to be successful (Wolf et al. 1996; Fischer and Lindenmayer 2000), but with few salmonid examples, it is difficult to provide precise guidance on the number to transplant. Metapopulation structure might provide guidance, as reintroduction sites isolated from the regional metapopulation are unlikely to receive large numbers of natural colonists and, therefore, will require a greater number of transplanted fish than those connected to potential source populations. Williams et al. (1988) observed that 50 individuals (25 males and 25 females, annually) is the absolute minimum for establishing a hatchery population in a controlled setting, so transplanting to a dynamic river environment will certainly require a greater number of fish. Some fraction of transplanted adults may die prior to spawning (Keefer et al. 2010) or depart the release site because they fail to detect natal odors (Blair and Quinn 1991). Continuing transplants for a full generation and into a second generation provides additional reproductive potential and new genetic material that may reduce the impact of a genetic bottleneck (e.g., Hedrick and Fredrickson 2010). In addition, selecting the highest quality habitat within the reintroduction site for the release site may increase the reproductive success of the colonists.

We suggest that reintroduction should maximize the total number of fish transplanted while minimizing the risks (Table 2), which are likely to increase as the number of fish transplanted increases. Given the same total number of transplanted fish, risks might be reduced by releasing a small number of fish each year for many years rather than many fish for a short period. The release strategy will affect density-dependent processes, which in turn will affect both the performance of the reintroduced species and the ecological risks of reintroduction. For example, it may be possible to reduce density-dependent processes by dispersing colonists among several release sites (Einum et al. 2008). With few empirical examples, the outcomes of these risks are difficult to precisely predict a priori, highlighting the importance of a well-designed monitoring program.

Hatchery releases.—The third colonization strategy is a hatchery reintroduction that stocks artificially propagated juvenile fish or eggs within the reintroduction site. There are a number of examples of reintroductions releasing hatchery-produced juveniles (Table 4). In the Clearwater River, Idaho, out-of-basin stocks were used to reintroduce ocean- and stream-type Chinook Salmon; these hatchery populations are now sustained by returns to the Clearwater River, and the naturally produced juveniles of the two run types are genetically distinct (Narum et al. 2007). Hatchery releases of Atlantic Salmon reintroduced to the Connecticut River (flowing through Connecticut, Massachusetts, Vermont, and New Hampshire) are also sustained by local returns (Gephard and McMenemy 2004). However, abundances in the Connecticut River and in other reintroduced New England populations have continued to decline despite heavy stocking, and there is very little natural spawning because most returning adults are bred in captivity (Wagner and Sweka 2011). A captive broodstock hatchery program has played an essential role in the persistence of Snake River Sockeye Salmon, which reached critically low abundances in the mid-1990s (Griswold

TABLE 5. Examples of proposed, ongoing, or relatively recent reintroduction programs for Pacific salmon, steelhead, and Bull Trout *Salvelinus confluentus*.

River basin	Species	Comments on execution
Elwha River, Washington	Chinook Salmon, steelhead, Coho Salmon, Pink Salmon, Chum Salmon *O. keta*, Sockeye Salmon, Bull Trout	Removal of Elwha and Glines Canyon dams; for some species, adults trapped within lower Elwha River relocated above former dam site
Umbrella Creek and Big River, Ozette Lake, Washington	Sockeye Salmon	Hatchery releases for both locations; some natural colonization of Big River prior to hatchery releases
Cowlitz River, Washington	Chinook Salmon, Coho Salmon, steelhead	Hatchery releases, trap and haul above Mayfield, Mossyrock, and Cowlitz Falls dams
Clackamas River, Oregon	Bull Trout	Transplanted juvenile and adult fish from Metolius River
North Santiam River, Oregon	Chinook Salmon, steelhead	Trap and haul adults above Big Cliff and Detroit dams
South Santiam River, Oregon	Chinook Salmon, steelhead	Trap and haul adults above Foster and Green Peter dams
Calapooia River, Oregon	Chinook Salmon, steelhead	Removal of Brownsville, Sodom, and Shearer dams
McKenzie River, Oregon	Chinook Salmon	Trap and haul adults above Cougar and Trail Bridge dams
White Salmon River, Washington	Chinook Salmon, steelhead, Coho Salmon	Removal of Condit Dam
Hood River, Oregon	Chinook Salmon	Removal of Powerdale Dam; hatchery releases derived from neighboring Deschutes River
Deschutes River, Oregon	Chinook Salmon, steelhead, Sockeye Salmon	Hatchery releases for Chinook Salmon and steelhead; passage for adults and juveniles around Reregulation, Pelton, and Round Butte dams
Umatilla River, Oregon	Chinook Salmon, Coho Salmon	Hatchery releases
Yakima River, Washington	Sockeye Salmon, Coho Salmon	Sockeye Salmon: adults captured at Priest Rapids Dam transplanted above Cle Elum Dam; Coho Salmon: hatchery releases
Wenatchee River, Washington	Coho Salmon	Hatchery releases
Methow River, Washington	Coho Salmon	Hatchery releases
Okanogan River, Washington	Chinook Salmon, Sockeye Salmon	Hatchery releases for both species; passage above McIntyre Dam for Sockeye Salmon
Walla Walla River, Washington	Chinook Salmon	Hatchery releases
Lookingglass Creek, Oregon	Chinook Salmon	Hatchery releases derived from nearby Catherine Creek
Big Sheep Creek, Oregon	Chinook Salmon	Transplant surplus hatchery adults captured in adjacent Imnaha River
Pine Creek, Oregon	Chinook Salmon, steelhead	Transplant surplus hatchery adults captured at Hells Canyon Dam
Klamath River, California and Oregon	Chinook Salmon, Coho Salmon, steelhead	Proposed removal of Iron Gate, Copco 1, Copco 2, and J.C. Boyle dams
San Joaquin River, California	Chinook Salmon	Proposed under San Joaquin River Restoration Settlement Act

et al. 2011). Although this population is demographically dependent on the hatchery, abundance has grown substantially in recent years and progress has been made towards the reestablishment of natural reproduction. The hatchery has retained approximately 95% of the genetic diversity present in the founders of the captive broodstock program (Kalinowski et al. 2012).

There are also examples of hatchery reintroductions, mainly of Atlantic Salmon, that have failed, or that have had insufficient time, to generate persistent returns of hatchery fish. Despite decades of stocking nonlocal Atlantic Salmon on the Thames River, most adult Atlantic Salmon observed recently have dispersed naturally from nearby river systems (Griffiths et al. 2011). Although some Atlantic Salmon returned to Point Wolfe Creek, New Brunswick, following 4 years of hatchery releases, the population subsequently crashed, similar to neighboring populations in the inner Bay of Fundy (Fraser et al. 2007). Atlantic Salmon have been reintroduced to several rivers in Germany, but these populations are still demographically reliant on importing nonlocal eggs and fry despite some observations of natural spawning (Monnerjahn 2011). Finally, the initial phase of

Atlantic Salmon reintroduction to tributaries of Lake Ontario in New York State has focused on experimental testing of various release strategies and sites in an effort to maximize survival (Coghlan and Ringler 2004; Coghlan et al. 2007).

Overall, despite initial successes in establishing hatchery populations in some systems, we found no clear-cut examples in which a reintroduction employing hatchery releases yielded a self-sustaining naturalized population. Importantly, even the most successful programs to date continue to release hatchery fish, so it is largely uncertain whether any natural spawning would persist without supplementation. It is worth noting, however, that hatchery releases have been used to introduce self-sustaining salmonid populations to new locations not previously inhabited by the species in question. Out-of-basin hatchery releases established multiple self-sustaining populations of Sockeye Salmon in Lake Washington, Washington, but it is uncertain whether these areas historically supported anadromous fish (Gustafson et al. 1997; Spies et al. 2007). Other examples include Sockeye Salmon in Frazer Lake, Alaska (Burger et al. 2000), Pink Salmon in the Great Lakes (Kwain 1987), and Chinook Salmon in New Zealand (Quinn et al. 2001). Collectively, these results suggest that it is possible to establish runs of anadromous fish through hatchery releases, and perhaps failed reintroduction efforts did not adequately solve the problems that caused extirpation in the first place (i.e., constraints).

Employed in a conservation setting, hatcheries generally aim to reduce the early life mortality that occurs in the egg incubation and juvenile-rearing phase relative to that of natural spawning (Waples et al. 2007a). Thus hatchery releases have the potential to approach juvenile-rearing carrying capacities faster than the other two approaches, and this may ultimately lead to a greater number of adults returning to the reintroduction site within a generation or two of reintroduction. In addition, hatchery releases may provide opportunities to test the effectiveness of new passage facilities without risking wild fish from a low-abundance source population.

However, even if managed properly, hatchery releases pose significant evolutionary and ecological risks. Domestication selection, or adaptation to a captive-breeding environment, can reduce the fitness of animals released into the wild (Frankham 2008) as well as the fitness of the wild component of a supplemented population (Ford 2002). Indeed, hatchery fish often have lower reproductive success than naturally spawned fish when both groups breed sympatrically in the wild (Araki et al. 2008), and domestication selection, which can occur in a single generation, seems a likely mechanism (Christie et al. 2012; Ford et al. 2012). Large-scale hatchery programs tend to erode population structure more than small ones (Eldridge and Naish 2007), so the risk of genetic homogenization is likely to be proportional to the number of fish released. In terms of ecological risks, hatchery releases could induce density-dependent processes that would limit the growth, survival, and other vital rates of naturally produced fish (Buhle et al. 2009; Kostow 2009).

These risks apply not only to the incipient population within the reintroduction site but also to any nearby extant populations. Hatchery reintroduction programs should therefore aim to minimize straying to proximate extant populations. Acclimating juvenile hatchery fish in the target area prior to release may improve the precision of homing (Dittman et al. 2010). Hatchery fish released into a reintroduction site may also interact ecologically with juvenile wild fish originating from proximate spawning areas in downstream rearing habitats, potentially competing for limited resources. The specific breeding protocols and rearing practices will influence the severity of these ecological and evolutionary effects, but some level of risk is unavoidable.

An important consideration for hatchery reintroductions is the length of time over which supplementation is planned. Evolutionary and ecological risks will tend to increase with the duration and magnitude of hatchery releases. A precautionary model would aim for a brief release of one to two generations, followed by cessation for at least a similar time frame, accompanied by a monitoring program to track performance. Such a pulsed release would provide the initial demographic boost to establish a population in an area unlikely to be colonized naturally and subsequently permit natural and sexual selection to shape local adaptation and the expression of natural diversity patterns. In the event that more than a generation or two of supplementation is needed to rebuild the run, specifying a timeline for phasing out releases in a detailed plan prior to reintroduction will help prevent hatchery efforts from becoming institutionalized. Abundance targets for naturally spawned fish would indicate when the incipient population has sufficient reproductive potential without supplementation. Contingencies for short-term environmental trends would permit flexibility in the timeline should poor migratory or ocean survival delay population establishment.

Choice of Source Population

Source populations with life history, morphological, and behavioral traits compatible with the target area will increase the probability of successful reintroduction. Anadromous salmonids are frequently adapted to local environmental conditions (Taylor 1991; Fraser et al. 2011), and so some source populations may be more successful than others during colonization. For example, following circumvention of a natural barrier, multiple populations of Sockeye Salmon were introduced to Fraser Lake, Alaska, and each preferentially colonized the habitats most similar to the source (Burger et al. 2000). Reintroductions employing transplants or hatchery releases must explicitly choose a source population; evaluating potential sources of natural colonization will help predict patterns of population expansion (Pess et al. 2008) and interpret reintroduction results (Burton et al. 2013). We suggest that reintroduction planners consider the genetic and ecological characteristics of potential source populations.

In general, selecting a source genetically similar to the historic population that inhabited the reintroduction site would maximize the benefits and reduce the risks of a reintroduction. Matching the genetic lineage of the extirpated population or spawning area as closely as possible helps ensure that following a successful reintroduction, regional population structure would accurately represent natural patterns of evolutionary diversity and thus contribute to long-term ESU viability. The evolutionary risks of straying to adjacent populations during reintroduction will be reduced if the source is genetically similar to these populations. In practice, genetic analysis may not be possible, so one might assume an isolation-by-distance model (e.g., Matala et al. 2011) and use the distance along the river corridor between the reintroduction site and source as a coarse guide for comparing options. Regardless of the specific criteria, ESUs were designated to comprise lineages with a distinct evolutionary legacy (Waples 1991), so reintroductions using sources with out-of-ESU ancestry would rarely, if ever, be expected to provide clear conservation benefits to an ESU.

Ecological considerations should focus on the morphological and behavioral traits of the source population and whether they are well suited for the reintroduction site. One approach is to assume that similar habitats promote the evolution of similar traits and evaluate metrics such as elevation, precipitation, and hydrologic patterns or composite indices such as the U.S. Environmental Protection Agency's ecoregions. However, sometimes genetic and ecological patterns will be in conflict. Some coastal rivers, for example, contain both fall- and spring-run Chinook Salmon populations, which are more genetically similar to each other than to other populations of the same run type in different major rivers (Waples et al. 2004). In these cases, selecting a source population will involve some degree of compromise.

Potential source populations affected by hatchery production require special consideration. Three main factors will determine the ecological and genetic suitability of a hatchery stock. The first is its origin. Stocks that were founded with individuals collected near the reintroduction site, preferably within the same basin, present less evolutionary risk than more distantly related stocks. Many of the most widespread hatchery stocks are mixed-lineage, composite-origin stocks with significant contributions from several populations, sometimes from separate ESUs (Busby et al. 1996; Myers et al. 1998). Although these stocks are probably the most available, and hence logistically practicable for reintroductions, they also pose much greater evolutionary risks than locally derived stocks. A second consideration is the current breeding protocol. Programs that operate under an integrated model by consistently incorporating wild or naturally spawned broodstock (without posing demographic risks to that population) will reduce (but not eliminate) domestication selection compared with segregated programs (Mobrand et al. 2005). A final consideration is the number of generations that the stock has been artificially propagated. Domestication selection accumulates over time, making populations that have been artificially propagated for many generations less similar to their wild counterparts than stocks that have been in captivity for few generations (Araki et al. 2008; Frankham 2008). In some cases, a hatchery stock directly derived from native fish that inhabited the reintroduction site may retain the only genetic legacy of the extirpated population and may be desirable for that reason.

What are the options if there is an unacceptable demographic risk of depleting the most attractive source population? In some cases, managers must either wait for the most appropriate stock to recover to levels that could sustain removal or select a less desirable stock that can immediately provide sufficient donors. This is a difficult trade-off, especially if recovery of depleted potential source populations is uncertain or is expected to take several generations even under optimistic scenarios. When removal does occur, monitoring should track the source population abundance during reintroduction to ensure that it remains healthy. If a single population cannot sustain removal for reintroduction, it may be possible to combine individuals from several sources. From a genetic perspective, this could have either positive or negative consequences. On one hand, mixing sources could benefit the genetic diversity of the colonist group, but on the other, it could lower fitness via outbreeding depression (Huff et al. 2010).

Finally, for facultatively migratory species, the presence of resident conspecifics may provide additional reproductive potential and serve as a source population. For example, resident Rainbow Trout frequently spawn with anadromous steelhead (McMillan et al. 2007; Pearsons et al. 2007). In fact, *O. mykiss* often exhibit partial anadromy in which a single, panmictic, interbreeding population contains both resident and migratory individuals (McPhee et al. 2007; Heath et al. 2008). Resident populations isolated by dams may retain significant anadromous ancestry and the physiological traits of smoltification (Clemento et al. 2009; Godbout et al. 2011; Holecek et al. 2012). However, if selection against anadromy has occurred in the resident population, it is also possible that secondary contact with reintroduced anadromous fish might decrease the rate of anadromy in the combined population. Life history models (Satterthwaite et al. 2009, 2010) offer one method of predicting the complicated interactions between resident fish and reintroduced anadromous populations. Regardless, we suggest that promoting the persistence and reproductive contribution of resident fish directly descended from formerly anadromous populations inhabiting the reintroduction site will ultimately contribute to local adaptation, diversity, and long-term viability.

Providing Passage

Providing passage is relevant to all reintroductions involving barriers regardless of the colonization strategy or the choice of source population. This must include passage for adults migrating upstream to spawning grounds as well as juveniles migrating downstream towards the ocean. Plans for passage can be categorized as either volitional or active transport (i.e., trap and haul).

Under volitional passage, a barrier is modified or removed such that fish arrive at the site under their own power, swimming through or around and eventually past the former blockage. Primary examples include culvert replacements, dam removals, engineered step-pools, fish ladders, increased releases from upstream dams, and screened bypass facilities for juveniles. Volitional fish passage facilities have advantages over more managed methods because they operate constantly, require little if any handling, are less stressful to the fish, are mechanically less likely to break, and are less costly to maintain and operate. A primary biological consideration is the degree to which passage structures reduce juvenile and adult migrant survival relative to a free-flowing river. Unnaturally high mortality imposed by passage at barriers will have to be compensated for elsewhere in the lifecycle to maintain a self-sustaining population. Furthermore, depending on the design, water velocity and gradient may restrict passage to certain species or size-classes, reducing the diversity of the incipient population. If poorly designed, passage facilities could increase the risk of straying into nontarget populations or spawning areas.

Barrier or dam removal is a special case of volitional passage that will provide substantial ecological benefits beyond salmonid recovery. Dam removal can repair riverine ecosystem processes, such as natural flow regime, sediment and wood transport, and nutrient cycling, that create and maintain habitat for many plants and animals (Poff and Hart 2002; Roni et al. 2008). The rehabilitation of these processes, especially where they have been substantially altered, will certainly provide long-term benefits for the Pacific salmon and steelhead populations targeted for reintroduction. However, in the short term, dam removal is a disturbance that may increase turbidity and deposit fine sediment downstream or mobilize toxic-laden materials (Stanley and Doyle 2003). Therefore, it is an approach most appropriate for enhancing long-term viability rather than rapid increases in abundance, and these "side effects" are important considerations for the planning process. Several recent dam removals (Table 5) provide important opportunities to study the salmonid response to dam removal.

In some cases, it may be possible to incorporate selective access into a volitional passage strategy. This would involve a weir, gate, or trap such that fish are handled prior to upstream passage. Such structures increase operation and maintenance costs and may adversely affect adults due to increased handling. However, they also allow managers to exclude fish that could undermine reintroduction objectives. For example, excluding the homogenizing influence of hatchery colonists may benefit diversity and excluding nonnative fish would reduce the ecological risks of reintroduction. Such structures would also assist research and monitoring because they would permit precise counts and measurements of fish.

Active transport, sometimes called trap and haul, is most appropriate for situations in which volitional passage is not logistically, technically, or biologically possible. Large dams, especially several occurring in sequence, are more likely to require trap and haul than small structures due to engineering and socioeconomic constraints. Particularly for juveniles, impoundments may present challenges that cannot be overcome with volitional passage, such as low water velocity that disrupts fish migration, predators that reduce survival below acceptable levels, or downstream passage routes that cannot be engineered to be safe and effective. Selection or exclusion of particular groups of fish will be fundamentally simple. Passage via trap and haul is similar in concept to a transplanting colonization strategy and thus has many of the same benefits, risks, and consequences.

Trap and haul, often combined with hatchery releases, is employed in several ongoing large-scale reintroduction efforts (Table 5). These examples will provide crucial case studies to evaluate the success and refine the methods of reintroducing Pacific salmon and steelhead above large, high-head dams. Research on the Middle Fork Willamette River, Oregon, has found significant prespawn mortality related to poor condition of spring Chinook Salmon adults prior to release and warm temperatures encountered in the migration corridor (Keefer et al. 2010). In addition, juvenile mortality at dams was high and deep-water passage routes severely restricted passage in the spring, when Chinook Salmon would ordinarily migrate downstream but reservoirs were filling rapidly (Keefer et al. 2011).

Despite few published examples, we suspect that at high-head dams, transporting adults upstream is much easier (and less expensive) than providing safe, efficient downstream passage for their offspring. Juvenile fish will be vulnerable to size-selective predation in reservoirs (Poe et al. 1991; Fritts and Pearsons 2006) and dam passage mortality unless they are collected and routed around these hazards. Survival rates will vary by species, life stage, and timing of migration but are likely to depend on the efficiency of juvenile collection methods and the design of engineered bypasses at dams. In some cases, successful reintroduction will require a mechanistic understanding of dam passage mortality, but this is difficult to predict generally and varies substantially by dam. For example, some studies have found greater mortality in small fish (Ferguson et al. 2007) while others found greater mortality in large fish (Keefer et al. 2011). Consequently, detailed studies of route-specific juvenile mortality rates are likely to be an essential component of reintroductions involving active transport (Keefer et al. 2011).

Execution Overview

One thing is clear—each case will be unique, and reintroduction planners will face trade-offs between the benefits and risks in selecting a colonization strategy, choosing a source population, and providing passage. These options need not be mutually exclusive, as a carefully planned reintroduction program may decide to use multiple colonization strategies. A precautionary model would initially adopt a low-risk approach and monitor its success, thereby permitting a scientific evaluation of whether higher-risk strategies are necessary. For active reintroduction strategies, planners could view an initially small release as a pilot study to assess reintroduction benefits and risks prior to full implementation.

Our review of the salmonid reintroduction literature (e.g., Table 4) suggests that there are large uncertainties in the success of reintroduction in establishing self-sustaining populations, particularly for programs employing active colonization strategies. Despite the increased risks of methods such as transplanting adults and hatchery releases, we found no direct evidence that these approaches have established a demographically independent, self-sustaining natural population. It is possible that situations in which active methods have been employed are inherently more difficult, but a lack of rigorous scientific evaluation precludes us from describing the benefits, risks, and constraints more explicitly or quantitatively. We strongly encourage managers of reintroduction efforts to disseminate results so that we may build on lessons learned in planning future programs.

MONITORING

Monitoring is an essential component of any reintroduction program (Williams et al. 1988; IUCN 1998; George et al. 2009), permitting an assessment of whether or not the reintroduction was successful. Monitoring before, during, and after the reintroduction provides information on both the target and neighboring populations that is needed to evaluate modifications to the program execution in an adaptive management feedback loop. In addition, monitoring provides the data that is essential for the effective planning of future programs.

We suggest that the monitoring program focus on the benefits, risks, and constraints likely to have a large impact on the success of the project. First, in order to quantify the benefits and determine if the goals have been achieved, unambiguously stating project objectives at the outset will help identify specific monitoring metrics (Tear et al. 2005). Second, for reintroductions in which the initial planning efforts identified some risks (Table 2), there must be monitoring in order to determine whether the benefits outweighed the risks. Third, monitoring constraints will promote a mechanistic understanding of why a reintroduction succeeded or failed. Even where barriers block migration, other factors may have contributed to extirpation. Consequently, although some biological constraints (Table 3) may have been addressed prior to reintroduction, others may persist that will limit project success. Identifying factors that limit survival and reproductive success will provide insight towards alternative reintroduction strategies that might lessen a negative impact. The specific monitoring methods will vary depending on the benefits, risks, and constraints of the reintroduction effort; Roni (2005), Johnson et al. (2007), and Schwartz (2007) provide guidance on establishing a robust monitoring program.

It is difficult to provide general criteria on whether a reintroduction effort has succeeded or failed because every situation is likely to be different. However, writing a detailed reintroduction plan, including specific viability targets or benchmarks, is a crucial component of project implementation. This will simplify interpretation of monitoring data, clarify any need for adaptive management during the program, and prevent the institutionalization of actions (e.g., hatchery releases) that impose risk to nontarget populations or spawning areas. In deriving targets and benchmarks, the reintroduction plan should explicitly consider patterns in annual abundance, productivity, and survival of comparable populations. We strongly urge all entities conducting or planning reintroductions to write a publicly available implementation plan that includes robust monitoring because it is essential to a scientifically rigorous reintroduction effort and will improve our ability to effectively conserve species in the future.

CONCLUSIONS

We have based our approach to planning, executing, and monitoring reintroductions upon the broad conservation goals and scientific principles guiding the recovery of ESA-listed Pacific salmon and steelhead populations. We acknowledge that there are other possible goals for reintroductions, including providing harvest opportunities, which might lead to different approaches than those described here. Although our recommendations are specifically designed for ESA recovery, more generally they are intended to promote the natural demographic, ecological, and evolutionary processes essential to the conservation benefit of all reintroductions, regardless of formal listing status. Even in cases where ESA recovery is not the primary goal, the concepts discussed here will help evaluate the overall conservation value of a reintroduction (Figure 5).

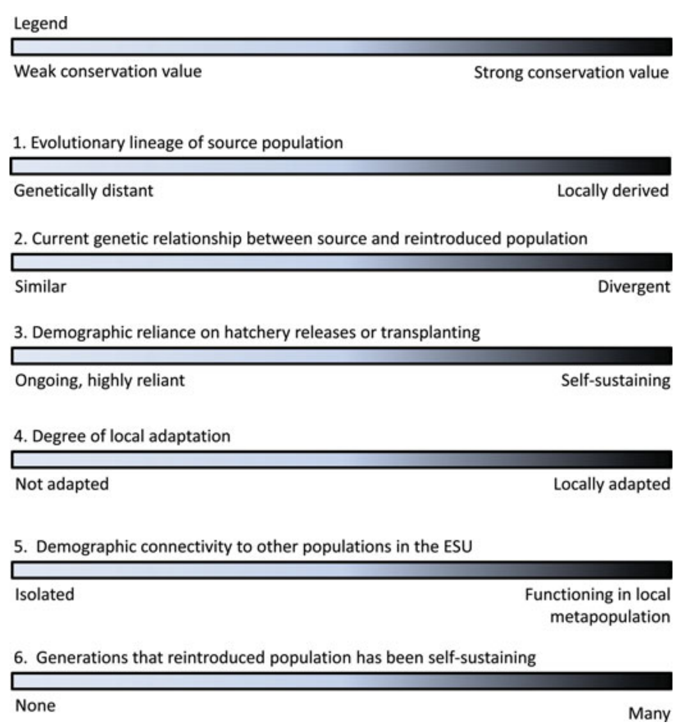

FIGURE 5. Factors to consider in evaluating the conservation value of reintroductions. Each bar is intended to represent a gradient of outcomes in between the extremes described at either end. The extent to which natural demographic, ecological, and evolutionary processes operate uninterrupted will strongly influence the overall conservation value of a reintroduction.

Despite the number of salmonid reintroductions (e.g., Tables 4 and 5), the science of reestablishing previously extirpated salmonid populations is still in its infancy. We found few direct assessments of reintroduction benefits, risks, and constraints, forcing us to provide general, qualitative rather than specific, quantitative recommendations. If reintroduction is to become a successful recovery tool, it is essential that monitoring and dissemination of results become standard practice in nearly every program. Rigorous scientific evaluation is particularly important for projects at large dams or those using active colonization strategies because they face the highest constraints and greatest risks.

The number and scale of Pacific salmon and steelhead extirpations suggest that reintroduction offers great potential to advance salmon recovery. However, complicated trade-offs, challenging obstacles, and uncertainty over the ultimate result confront reintroduction planners. Combined with the multiple generations probably required to achieve potential benefits, this suggests that reintroduction will rarely be a quick fix for improving the status of an ESU or population at immediate risk of extinction. It is also important to remember that reintroduction is only one management option. In some cases, reintroduction may be essential for the conservation of a particular life history type or evolutionary lineage. In other cases, management strategies designed to improve the reproductive success, survival, and productivity of extant populations might offer a better return on the investment dollar than reintroduction. We suggest that evaluating the potential benefits, risks, and constraints is necessary to weigh reintroduction against other management options and ensure that reintroductions contribute to long-term population and ESU viability.

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LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

FISH PASSAGE FACILITIES ALTERNATIVES ASSESSMENT
TECHNICAL COMMITTEE CONFERENCE CALL

APRIL 18, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Technical Committee Conference Call

Monday, April 18, 2016
11:00 am to 12:00 pm

Final Meeting Notes

Conference Call Attendees		
No.	**Name**	**Organization**
1	Alison Boucher	Tuolumne River Conservancy
2	Steve Boyd	Turlock Irrigation District
3	Anna Brathwaite	Modesto Irrigation District
4	Larry Byrd	Modesto Irrigation District
5	Jarvis Caldwell	HDR, consultant to the Districts
6	Jesse Deason	HDR, consultant to the Districts
7	John Devine	HDR, consultant to the Districts
8	Greg Dias	Modesto Irrigation District
9	Jason Guignard	FISHBIO, consultant to the Districts
10	Chuck Hanson	Hanson Environmental, consultant to the Districts
11	Bao Le	HDR, consultant to the Districts
12	Lonnie Moore	Citizen
13	Gretchen Murphy	California Department of Fish and Wildlife
14	Bill Sears	City and County of San Francisco
15	Chris Shutes	California Sportfishing Protection Alliance
16	Niccola Ulibarri	Stanford University
17	Scott Wilcox	Stillwater Sciences, consultant to the Districts
18	John Wooster	National Marine Fisheries Service
19	Ron Yoshiyama	City and County of San Francisco

On April 18, 2016, Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) hosted a Technical Committee conference call for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment and Upper Tuolumne River Fish Reintroduction Assessment Framework (Framework). This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting.

Mr. Bao Le (HDR, consultant to the Districts) noted the deadline for Technical Committee comments on the study plans has been extended from April 22 to April 29. The Districts will revise the study plans based on comments received and will provide revised study plans to the Technical Committee for final comments. Mr. Le said the Districts plan to send final study plans to the Plenary Group ahead of Workshop No. 5, which is scheduled for May 19.

Mr. Le provided an overview of the draft study plans discussed on the March 18 Technical Committee call. Mr. Le noted that last week, the Districts sent the draft Upper Tuolumne River Instream Flow Study Plan to the Technical Committee for review and comment. Mr. Le said the lead for this study, Mr. Jarvis Caldwell (HDR), will be providing a summary of this study plan on today's call. In addition, the study leads for the other draft study plans are also on this call and available to answer any questions attendees may have on those studies.

Mr. Caldwell reviewed the goals, study area, and methodology for the Upper Tuolumne River Instream Flow Study (Instream Flow Study). Mr. John Wooster (National Marine Fisheries Service) asked if the fieldwork for this study will be completed in tandem with the fieldwork for the Upper Tuolumne River Habitat Mapping and Macroinvertebrate Assessment (Habitat Mapping Study), or if the Habitat Mapping Study will be completed first. Mr. Caldwell said the Districts plan to complete the Habitat Mapping Study first and use information collected from that study to inform study site selection for the Instream Flow Study.

Mr. Wooster asked if the Instream Flow Study will be completed in 2016. Mr. Caldwell said the study will be completed in the fall of 2016. Mr. Wooster asked if, given that schedule, the necessary flows will be available. Mr. Wooster noted that higher flows associated with rafting are generally unavailable after Labor Day. Mr. Caldwell said based on the hydrology he has reviewed, standard operations upstream of the study reach provide a range of flows on a daily basis. Mr. Caldwell said that during the five or seven days at an Instream Flow Study site, he expects the study team will be able to capture a range of flows. Mr. Caldwell noted the study team is still working out the fieldwork logistics.

Mr. Wooster said the Instream Flow Study Plan states there will be two or three study sites, but it is unclear whether that means two or three sites per river reach or two or three sites for the entire study. Mr. Caldwell said there will be two or three sites identified between Lumsden Falls and the upstream end of the Don Pedro Project.

Mr. Larry Byrd (Modesto Irrigation District) asked if there is particular reason why the study cannot be completed before Labor Day, when higher flows are available. Mr. Caldwell said it is important that the Habitat Mapping Study first be completed, as information from that study is required to help select study sites for the Instream Flow Study. Mr. Caldwell said a range of flows at each site is necessary to calibrate the model. Mr. Caldwell reiterated that the study team is still working on the schedule logistics. Mr. Byrd asked when the study site locations will be determined. Mr. Le responded that the study team had been waiting for the summer flow schedule to be released in order to finalize the summer fieldwork schedule. Mr. Le said the study team anticipates fieldwork for the Habitat Mapping Study and the Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study (Spawning Gravel Study) will be completed in late June or early July, in time to compile the results for consideration in the Instream Flow Study.

Mr. Chris Shutes (California Sportfishing Protection Alliance) said the Middle Fork American River Project relicensing instream flow model provided output in a series of tables that depicted how habitat changed from one flow to another. Mr. Shutes asked if the Districts' two dimensional (2D) model (i.e., River 2D) will be able to capture changes in habitat during flow fluctuations. Mr. Caldwell said he is familiar with the analysis Mr. Shutes is referring to, and in that project, model output was depicted using effective habitat tables, which are also known as wedge tables. Mr. Caldwell said at the site level, these tables provide some indication of how total habitat suitability (i.e., WUA) for a specific life stage changes from one flow to another, which may be important for understanding how general habitat changes with flow. Mr. Caldwell said such tables, however, do not help explain or show where the habitat goes in the river with changes in flow. This may be more important for non-mobile life stages (e.g., spawning/incubation) than for mobile life stages (e.g., fry and juvenile). Mr. Caldwell said for this study, time series analysis will be completed that will use GIS to show habitat over a range of flows. This analysis is more spatial and visual than what is provided by wedge tables.

Mr. Shutes asked for an explanation why holding habitat will not be modeled. Mr. Caldwell confirmed the study plan states holding habitat will not be modeled. Mr. Caldwell said one reason holding habitat will not be modeled is that habitat suitability criteria for holding habitat are not available. Another reason is that the Habitat Mapping Study will already be evaluating pools from the perspective of habitat holding. Mr. Caldwell said habitat generated by River 2D may be used to look at variables such as depth and velocity, but habitat suitability criteria will not be used. Mr. Caldwell noted that the ongoing Upper Tuolumne River Basin Temperature Monitoring and Modeling Study is analyzing temperature, which is a driving variable in habitat suitability. Mr. Scott Wilcox (Stillwater Sciences, consultant to the Districts) said regarding spring-run Chinook holding habitat, that particular habitat is not well-suited for modeling because the habitat is specific pools, which are better characterized by taking depth and temperature measurements at those specific locations.

Mr. Shutes requested that the Districts send out the habitat suitability criteria used for spring-run Chinook on the McCloud. Mr. Wilcox said he will send out that information.

Mr. Wooster said the study plan states that habitat suitability criteria for spring-run Chinook on the McCloud were developed for the reintroduction program. Mr. Wooster said that is not quite accurate. The study was implemented as part of the relicensing proceeding at the request of the State Water Resources Control Board (SWRCB), and not at the request of the Interagency Fish Passage Steering Committee, which was the entity working on the reintroduction program. Mr. Wooster said the study plan states the Interagency Fish Passage Steering Committee stemmed from the NMFS Recovery Plan, and this is also inaccurate. Mr. Caldwell said he will revise the study plan to clarify this. Mr. Wilcox said the SWRCB requested the study on behalf of the SWRCB as well as other agencies, including NMFS, because NMFS had stated reintroduction on the McCloud was imminent. Mr. Wilcox said regardless of how the study came about, the criteria developed by the study are relevant to this effort for the Tuolumne River. Mr. Wooster agreed the study is relevant, and he only sought to clarify how the study came about.

Mr. Wooster said that if specific flow releases are arranged as part of this study, it would be helpful for NMFS to be kept informed as those flows may have implications for NMFS fieldwork. Mr. Devine said the Districts will not be arranging specific flow releases for the Instream Flow Study and that planning for field work will be under conditions dictated by CCSF's flow schedule at the time of study implementation. However, Mr. Devine stated in order to ensure the field program for the study occurs under appropriate flow conditions, the Districts would remain in close coordination with CCSF to better understand what the likely flow schedule will be in the late summer and fall and will keep licensing participants informed of what they find out.

Mr. Le reviewed the schedule for finalizing the study plans. Mr. Le said Technical Committee comments on the study plans are due by April 29. The study leads will revise the study plans based on comments received and the Districts will provide revised drafts to the Technical Committee on May 3. Final Technical Committee comments on the study plans will be due on May 6. The Districts anticipate sending final study plans to the Plenary Group on May 10. At Workshop No. 5, which will take place on May 19, an objective will be to get approval from the Plenary Group on the study plans in time to begin implementing the studies this summer.

Mr. Le said the Districts will provide notes from this meeting.

Meeting adjourned.

ACTION ITEMS

1. The Districts will send out the habitat suitability criteria used for spring-run Chinook on the McCloud River. (complete)

2. Mr. Caldwell will revise the Instream Flow Study Plan to clarify how the McCloud River habitat suitability study came about and that the Interagency Fish Passage Steering Committee was not a result of the NMFS Recovery Plan. (complete)

DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Upper Tuolumne River Instream Flow Study

March 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Upper Tuolumne River Instream Flow Study is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to evaluate existing aquatic habitat and provide quantifiable metrics of aquatic habitat suitability in the upper Tuolumne River.

2.0 STUDY AREA

The study area for the Instream Flow Study is the main stem of the Tuolumne River extending from the upstream end of the Don Pedro Project (RM 81 +/-) to Early Intake (RM 105).

3.0 STUDY GOALS

The goals of this study are (1) to model existing aquatic habitat for spring-run and fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (O. *mykiss*); (2) to evaluate the existing aquatic habitat over a representative range of observed water years and operations of the City and County of San Francisco's Holm powerhouse; and (3) to provide quantifiable metrics of aquatic habitat suitability in the context of potential reintroduction of Chinook salmon and steelhead.

4.0 STUDY METHODS

The following instream flow study methods are consistent with normal and customary 2-dimensional (2D) instream flow methodologies, and will provide data that are comparable to data collected and used at other salmonid-bearing streams and rivers in California and elsewhere.

The study will be performed in five steps: (1) reach and site selection; (2) field data collection; (3) hydraulic modeling; (4) aquatic habitat modeling; and (5) report preparation. Each of these steps is described below.

Step 1 – Reach and Site Selection

The establishment of study reaches and the location of a study site within each reach will be based on five primary sources of information: (1) upper Tuolumne River geomorphology; (2) watershed hydrology; (3) habitat mapping study results; (4) spawning gravel mapping study results; and (5) existing aerial imagery. Based on current information, it is expected that two or three study sites will be selected throughout the study area.

Reach segmentation in the study area will be based on geomorphic characteristics (e.g., gradient, channel width, substrate composition) and hydrologic contributions (e.g., accretion, percent contribution to overall streamflow from tributaries, effects of hydropower peaking). Based on these characteristics and results from detailed mesohabitat mapping and gravel surveys, one or more study sites will be selected in each reach. Lastly, study site selection will focus on selecting both low gradient mesohabitats (pool, run and low gradient riffle) and likely short high gradient transition mesohabitats (e.g., high gradient riffle, cascade).

Study sites will be selected of a sufficient size and habitat composition to adequately characterize, and be indicative of, the range of habitat attributes (e.g., spawning, rearing and holding) documented through previous and concurrent field data gathering efforts conducted as part of the Framework. The final length of each site will be dependent on the geomorphic characteristics and lengths of mesohabitats contained within the selected study location. The number and types of mesohabitats selected will also depend on the length and variability of mapped units in the vicinity.

While study sites will initially be developed using field and aerial imagery data sources, final site selection may also be influenced by (1) proximity to camping locations, an important logistical consideration in this remote river canyon, and (2) safety considerations, which are influenced by gradient, channel configuration, hydraulic conditions, and availability of downstream recovery/safety zones.

Step 2 – Field Data Collection

Given the remoteness and limited access to the upper Tuolumne River, field data collection at each site will be completed in one continuous five to seven day period. It is anticipated that most of the out-of-water topography will be developed using airborne Light Detection and Ranging (LiDAR) data collected by NMFS in 2015 along the upper Tuolumne River. Before use, the LiDAR data will be evaluated by a remote sensing expert for quality and study utility.

Additional topographic data will be collected using a variety of methods depending on site conditions. Initially, LiDAR coverage will be evaluated and used to describe the majority of each study site not submerged at the time of the data collection. The remaining in-water and out-of-water topographic data collection will be completed utilizing a number of survey techniques. Given the steep nature of the canyon, standard Real Time Kinematic (RTK) Global Positioning System (GPS) survey will likely not be practical. Therefore, the primary survey instruments used will be Robotic Total Stations (RTS), surveyed into a RTK GPS network. The RTS units will be used for topographic surveys conducted on foot and for single beam bathymetric surveys conducted to collect unwadable in-channel topography. Depending on river conditions and safety considerations during each survey, a variety of manned and unmanned craft may be used for bathymetric data collection. Field staff will record all relevant survey information into predefined survey log sheets throughout each survey day.

After each data collection period, the RTK static GPS data files collected by the base station will be submitted to the National Oceanic and Atmospheric Administration's (NOAA) Online Positioning User Service (OPUS). OPUS returns a position corrected and mapped into the high accuracy National Spatial Reference System (NSRS). Using Trimble Business Center software, the OPUS-corrected position will then used to correct the network of RTS collected points from each survey instrument.

Habitat modeling for certain lifestages will require that substrate classification be consistent with habitat suitability criteria (HSC). Once final HSC are defined for this study, substrate classification tables and codes will be developed for use in the field. Similarly, and if applicable, cover types will correspond to cover codes defined in HSC selected for each species.

Prior to field work, detailed substrate information from the *Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study* will be reviewed and, as appropriate, used for field reference. Additionally, if aerial photos are of suitable resolution, preliminary substrate polygons will be digitized throughout each model domain. In the field, crews will use an iPad loaded with aerial photos and GIS mapping software to either validate and refine the desktop delineation or develop substrate polygons and cover features throughout each study site.

Water surface elevations (WSE), discharges, and calibration depths and velocities will be collected throughout each study site at two calibration flows. The final measured flows will ultimately depend on the hydropower peaking operations and the duration of stable flows observed at each study site. Flow stability for data collection and modeling purposes is defined as a 'steady' discharge that results in minimal fluctuation in stage (e.g., no more than +/- 0.05 ft) for a long enough duration to measure discharge, WSEs, depths and velocities throughout the study site. It is anticipated that target flows will range from approximately 200 cfs to 1,200 cfs but will be dictated by upstream hydropeaking operations during each survey period. Based on these targets, hydraulic-habitat relationships modeled in each study site will extend from approximately 50 cfs to 2,000 cfs. The final range will be determined by the overall quality of site specific rating curves and model performance.

WSE's will be surveyed using a RTS in approximately 50 locations throughout the wetted channel for each calibration flow. In addition, spatially referenced depth and velocity validation data will be collected in at approximately 50 locations by an acoustic Doppler current profiler (ADCP) or manual velocity meter depending on location and hydraulic condition. Spot velocities depths and WSE measurements will span the entire longitudinal profile of model site.

Study site discharge measurements will be made using a combination of manual velocity meters and an ADCP mounted on an OceanSciences™ trimaran or similar vessel. ADCP measurements will follow standard USGS procedures (Mueller and Wagner 2009) for measuring discharge.

On-site rating curves will be developed using a combination of stage and discharge measurements and stage recording pressure transducers. At a minimum, three stage and discharge measurements will be made at each site. To supplement these data, stage recorders, which also record temperature, will be deployed at the top and bottom of the each study site to passively record stage over the data collection period. Stage recorders may also be deployed at various locations throughout the site to monitor the rate of stage change at specific mesohabitats. To relate WSE to discharge, the WSE will be measured directly above each installed logger at the time of deployment and again when the units are retrieved. A barometric pressure transducer will also be installed at the site to compensate for changes in atmospheric pressure. For validation purposes, WSEs will be measured during calibration flow surveys in the vicinity of each recorder. In addition to providing stage data for rating curve development, stage and temperature data from the recorders will be used to inform habitat and peaking analyses, discussed in Step 5 below.

Study site photographs will be collected to document site conditions during each survey. A representative collection of site photos, arranged by calibration survey flow will provided in a report attachment.

Step 3 – Hydraulic Modeling

Surface and Mesh Development

Hydraulic modeling for the study site will use River2D (Steffler and Blackburn 2002). The River2D model uses the finite element method to solve the basic equations of vertically averaged 2D flow incorporating mass and momentum conservation in the two horizontal dimensions (Steffler and Blackburn 2002).

The main input parameters for the River2D model include channel surface topography, bed roughness (in the form of an effective roughness height), and upstream and downstream hydraulic boundary conditions (i.e., water levels and discharge). Accurate topography is the primary variable that allows for the development of a well calibrated model.

Topographic surfaces will be constructed by combining the total station survey data, RTS and RTK GPS standard survey data, bathymetric data, and the LiDAR ground return data. In order to increase the definition in areas of topographic gradient and variability, breaklines will be defined within the topographic surface. Breaklines enforce the topographic surface to 'snap' to the entire length of the line and are used to define features with large vertical gradient changes, such as cascades, toe of slopes, and boulders.

Before entering the data into the River2D model, topographic data from the site will be reviewed for errors in ArcMap and ArcScene. Triangulated Irregular Networks (TINs) will be developed to visualize the data in two and three dimensions

Mesh development will follow procedures outlined in the R2D_Mesh User's Manual (Waddle and Steffler 2002). When building a computational mesh, it is important to optimize for computational performance without sacrificing mesh quality. Using the topographic surface nodes to define the mesh is not recommended as the computational requirements for such a model exceed the limits of the software and currently available computer hardware. Instead, a low density uniform mesh is developed and then refined using a variety of techniques.

As recommended by the R2D_Mesh User's Manual, a balance between mesh density and computational burden will be addressed in part by applying a procedure called 'wet refinement' which places nodes at the centroid of each mesh element. This process ensures the appropriate mesh density in wetted areas only, while limiting mesh density in dry areas.

Another method used to refine the mesh is to review mesh-generated elevation contours as compared to bed elevation contours at an interval of 0.82-foot with a goal of close contour approximation. Since the topographic points and mesh nodes are not in the same location, the contours will not be exactly the same. Therefore, to increase contour agreement, additional nodes may be added in topographically complex areas. To achieve the appropriate mesh density over all simulation flows, the mesh will be iteratively refined in the context of the full range of possible wetted areas.

A third method used to refine the mesh will be to identify large elevation differences between topographic data points and the interpolated elevation of each mesh triangle. Most often, large elevation differences exist in areas of high gradient (e.g., cascade) or significant localized topographic relief (e.g., cliff or vertical bank). Mesh triangles that exceed a 0.82-ft difference threshold are highlighted yellow in the mesh development software and further refined until the difference is no longer detected.

QI is a mesh quality index where a value of 1.0 represents a mesh comprised of perfect equilateral triangles. The goal minimum triangle quality index (QI) for each computational mesh is 0.15. Low QI values (i.e., <0.10) do not necessarily compromise model quality, but will increase computational run times. Tools in the mesh development software are used to improve geometry to achieve the minimum goal QI value.

One initial base mesh used for model calibration will be used for all simulation runs. However, it will be necessary to make small changes if model run time errors (i.e., eddy shedding velocity oscillation, extremely high velocity, or Froude number) occur.

Model Calibration

Model parameters such as bed roughness (Ks, in the form of an effective roughness height), substrate transmissivity (tr) and eddy viscosity can be adjusted during model calibration to reflect field conditions. A stage-wise approach with target criteria for model performance will be used to guide calibration. The specific stages and criteria are discussed below.

For the initial hydraulic model, hydraulic calibration tests will be conducted using the target calibration flows of 200 cfs and 1,200 cfs. Bed roughness (Ks) and transmissivity (tr) will be varied as necessary to match observed WSEs and wetted area. As part of normal calibration, Ks and tr values are incrementally adjusted through an integrative sensitivity analysis until modeled WSEs calibrate well to observed WSEs. In addition to the WSE comparisons, velocity and depth predictions will be compared to field measured data to evaluate changes made to Ks.

The term “Ks” is scientific notation for bed roughness factor (in meters) and the term refers to gradation of material in the river. Compared to traditional one-dimensional models, where many two-dimensional effects are abstracted into the resistance factor, the 2D resistance term accounts only for the direct bed shear (Steffler and Blackburn 2002). Ks is iteratively varied as necessary to match observed water surface elevations using the default transmissivity of tr = 0.1. In general, the initial Ks value entered is 1-3 times the grain size documented during field data collection. Multiple regional Ks values (i.e., heterogeneous substrate material and/or large elevation changes) may be selected for each study site based on model performance.

Groundwater transmissivity (tr) is a user-defined variable which corresponds to groundwater flow and the relationship to surface flow. The default value is 0.1 which ensures that groundwater discharge is negligible. Because subsurface flow through gravel or cobble may be present at the study site, it may be necessary to modify the default value of tr to aid in the wetting and drying function throughout the model domain.

The target criterion for mean error in WSE between simulated versus observed data is, to a large extent, based on the accuracy of the survey equipment used to measure WSE. It is also important to recognize the influence of highly heterogeneous or high gradient topography (e.g., cascades and high gradient riffles) habitats on differences between field data and model data. Given the expected range of site characteristics in the upper Tuolumne River an average of 0.10 ft difference between simulated and observed WSE will be targeted.

Similarly, no specific target calibration criteria exist for velocity or depth parameters as these variables are greatly influenced by the differences in topographic detail between the field conditions, initial bed file detail, and the final bed detail resulting from the interpolated mesh. Using professional judgment and standard industry practice, velocity and depth variables are reviewed for reasonableness and significant errors in depth (i.e., > 0.33 ft mean error) and velocity (i.e., > 0.5 fps mean error) are evaluated. For all sets of model calibration variables, the correlation coefficient (r) and the coefficient of determination (r2) (i.e., percent of variance in an indicator variable explained by a factor and the measure of the proportion of variance of model results, respectively) will be calculated. In general, coefficients greater than 0.7 are expected while coefficient of determination values for velocity magnitude are expected to be within a range of 0.4 and 0.8 (Pasternack 2011).

Flow field velocity vectors (i.e., the direction and magnitude) are used to evaluate velocity prediction reasonableness during the calibration process but are otherwise not incorporated into the statistical review process.

Model convergence for a given hydraulic simulation is achieved and accepted when the inflow (Qin) equals outflow (Qout) and the solution change is nominal. Solution change is the relative change in the solution variable over the last time step. Specific criteria thresholds do not exist for these parameters and are largely based on the magnitude of the simulation discharge and the professional judgment of the modeler. The target solution change goal will be 0.0001. This target value is consistent with recommendations made in the River2D User’s Manual (Steffler and Blackburn 2002).

Step 4 – Aquatic Habitat Modeling

Habitat Suitability Criteria

HSC define the range of microhabitat variables that are suitable for a particular species and lifestage of interest. HSC provide the biological criteria input to the River2D model which combines the physical habitat data and the habitat suitability criteria into a site-wide habitat suitability index (i.e., Weighted Usable Area or WUA) over a range of simulation flows. Variables typically defined with HSC include depth, velocity, instream cover and bottom substrate. HSC values range from 0.0 to 1.0, indicating habitat conditions that are unsuitable to optimal, respectively. WUA is defined as the sum of stream surface area within a nodal area model domain or stream reach, weighted by multiplying area by habitat suitability variables, most often velocity, depth, and substrate or cover, which range from 0.0 to 1.0 each.

Spring-run Chinook salmon HSC information compiled for the McCloud River, a tributary of the Sacramento River, will be used for habitat modeling. The HSC were recently developed for use in a PHABSIM study related to the Interagency Fish Passage Steering Committee’s draft recovery plan (NMFS 2009) for reintroduction of Chinook salmon upstream of Shasta Lake. The PHABSIM study was conducted for PG&E’s McCloud Pit Hydroelectric Project (FERC No. 2106) (PG&E 2012). Using the best available HSC information and professional judgment, composite curves were developed for spawning, fry and juvenile lifestages. Holding HSC were not developed in the process. Holding habitat will be evaluated in the *Upper Tuolumne River Habitat Mapping and Macroinvertebrate Assessment*. Model results from this study may, however, inform the suitability of holding habitat. Spring-run periodicity information will rely upon information provided in Technical Memorandum No. 1 (TID/MID 2015).

Steelhead and fall-run Chinook salmon HSC information developed for the lower Tuolumne River instream flow study (Stillwater Sciences 2013) will be used to model habitat suitability in this study. Spawning and juvenile lifestages will be modeled. The Districts note that the lower Tuolumne River HSC may require some modification to appropriately be used in the upper Tuolumne River channel. Modifications to HSC will be made by a regional HSC expert familiar with the proposed curves and any changes will be thoroughly documented in the final report. Periodicity information for these species will rely upon information provided in Technical Memorandum No. 1 (TID/MID 2015).

Model Simulation

Approximately 18 discharges will be simulated for each study site resulting in an expected flow range of 50 cfs to 2,000 cfs. Habitat suitability and WUA for all fish species and lifestages will be calculated for each simulation flow. In order to calculate habitat suitability, four data inputs are required: a fish preference file (i.e., HSC), a channel index, depth, and velocity. A fish preference file is loaded into River2D as a text file. Depth and velocity values are provided from the model once a simulation has converged and is at a steady state. Channel index files are a River2D model file equivalent to a substrate and/or cover map of the entire study site. Substrate may only be applicable to the spawning lifestages and possibly fry/juvenile lifestages (as a cover component) but will depend on the HSC used.

For this study, the habitat suitability calculation will use the standard triple product function which multiplies depth, velocity, and channel index suitability together at each model node. Channel index interpolation will be defined using discrete node selection (i.e., nearest node rather than a continuous linear interpolation of the channel index values from surrounding nodes). Discrete node selection is typically applied to substrate classifications such that the original substrate code value is maintained. If cover codes are defined for the proposed HSC, continuous interpolation will be applied to cover indices where a gradient of cover may be best described by the interpolation function.

Hydropeaking Analysis – Habitat Persistence

It is of particular importance to evaluate and understand the potential effect of hydropeaking operations on the habitat utilized by various lifestages of aquatic organisms. For example, an area with suitable depth, velocity and substrate for spawning adults at one flow may become unsuitable as flows rise or recede over a large range of hydropeaking operations. At some point, if redds were developed at a high flow, they may become dewatered at lower flows. Similarly, it is important to understand the spatial and temporal distribution of habitat for fry and juvenile salmonids. Suitable rearing habitat at one flow may quickly become unsuitable and shift in location when flows rapidly increase or decrease. These analyses are often termed habitat effectiveness, or habitat persistence. These terms relate to the temporal and spatial change in habitat suitability and distribution under changing flow conditions.

Within each model domain, regions of special interest (e.g., spawning gravel patches) will be identified. The areas of interest (AOI) will be areas that could provide suitable spawning and rearing habitat under a range of flow conditions. Polygons representing the AOI regions will be digitized in ArcGIS in order to extract data from model nodes in the computational mesh.

Relying on information generated from each of the model simulation runs, model parameters such as suitability, WSE, velocity and depth will be extracted at each model node such that changes in each parameter, per unit discharge, can be calculated and evaluated. These analyses will be conducted using Geographic Information System (GIS) and spreadsheet tools.

Effects on aquatic habitat from daily changes in power plant operation will be modeled for time periods specified by species and lifestage periodicity and will be initially conducted at 15-minute to 1-hr time intervals using data collected at each site by stage recorders. Additional longer duration analyses will focus on weekly or monthly time steps and rely on hydrologic time series data from representative water years (e.g., dry, normal and wet). Results for the selected AOI regions in each model domain will be reported in both tabular and spatial form.

Step 5 – Reporting

A detailed technical memorandum will be provided that includes the following sections: (1) Study Goals and Objectives; (2) Methods; (3) Results; (4) Discussion; and (5) Description of Variances from the study plan, if any. A number of report attachments will include, but not be limited to, additional data such as representative site photographs and, habitat suitability maps. Models and interactive spreadsheets will be made available on CD.

5.0 STUDY SCHEDULE

Final study sites will be selected once data from habitat mapping and spawning gravel surveys are completed and data evaluated. Field data collection is anticipated to commence in the fall of 2016. Hydraulic and habitat modeling and associated analyses will be conducted in the fall of 2016 and winter of 2017. A progress report will be included in the February 2017 Updated Study Report.

6.0 REFERENCES

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LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

FISH PASSAGE FACILITIES ALTERNATIVES ASSESSMENT
WORKSHOP NO. 5

MAY 19, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project
Reintroduction/Fish Passage Assessment Framework
Plenary Group - Meeting No. 5

Thursday, May 19, 10:00 am to 12:00 pm
MID Office, 1231 11th Street, Modesto, California
Conference Line: 1-866-583-7984; Passcode: 814-0607
Join Lync Meeting: https://meet.hdrinc.com/jenna.borovansky/3D64F0F5

Meeting Objectives:

1. Discuss and seek approval of the field studies planned for 2016.
2. Progress update on the Reintroduction Goals Subcommittee activities.
3. Introduce development of temperature criteria.

TIME	TOPIC
10:00 am – 10:10 am	Introduction of Participants (All)
10:10 am – 10:30 am	Opening Remarks (All) Review Agenda and Meeting Objectives (All) Overview of Activities (since the January 27, 2016, Workshop No. 4) (Districts/All)
10:30 am – 11:15 am	Reintroduction Assessment Framework 2016 Study Program (All) Summary and Discussion of the following 2016 studies: a. Habitat Mapping and Macroinvertebrate Assessment b. Spawning Gravel Mapping Study c. Instream Flow Study d. Regulatory Context for Reintroduction Assessment e. Socioeconomic Scoping Study f. Hatchery and Stocking Practices Review
11:15 am – 11:30 am	Reintroduction Goals Subcommittee – Progress Update (All)
11:30 am – 11:50 am	Water Temperature Criteria (All) a. Introductory discussion – collaborative development of suitable criteria
11:50 am – 12:00 pm	Next Steps (All) a. Schedule for Workshop No. 6 b. Action items

La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Workshop No. 5
Modesto Irrigation District
1231 11th Street, Modesto, California

Thursday, May 19, 2016
10:00 am to 12:00 pm

Final Meeting Notes

On May 19, 2016, Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) hosted Workshop No. 5 for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment and Upper Tuolumne River Fish Reintroduction Assessment Framework (Framework). This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting. Attachment A to this document includes a list of attendees, the meeting agenda, and study plans distributed by the Districts on May 10.

Mr. Bao Le (HDR, consultant to the Districts) said today's meeting is the fifth Workshop of this process and the second Workshop in 2016. Workshop No. 4, held on January 27, 2016 (meeting notes are available on the La Grange Project Licensing Website here), focused on the two primary drivers of the Framework, which are to (1) develop a study program to collect information about the upper Tuolumne River relevant to a possible reintroduction program and (2) develop the goals of the reintroduction program. As described in the Framework, later this year an analysis will be conducted to evaluate whether, based on the results of the study program, it is feasible to meet the goals for reintroduction.

Mr. Le said at Workshop No. 4, meeting attendees decided to form a Technical Committee to take the lead on developing the study program. The Technical Committee has since developed several study plans and later in the meeting, each study lead will provide a brief overview of his or her study. The objective of this discussion is to reach consensus on moving forward with implementing the studies. Later in this meeting, a brief update will be provided on the progress made developing reintroduction program goals. Finally, the need for understanding what water temperature criteria should be used, and how this group may collaboratively develop these criteria, will be discussed. Mr. Le asked if there are any questions. There were none.

Mr. Le summarized progress made by the Technical Committee since Workshop No. 4. On February 16, the Technical Committee met to identify a preliminary list of studies that may be implemented to support the Framework. That list was refined and on March 16, the Districts sent draft study plans to the Technical Committee for review and comment (the Districts sent the draft Upper Tuolumne River Instream Flow Study Plan to the Technical Committee on April 12). On March 18 and April 18, the Technical Committee met by conference call to discuss the draft study plans (March 18 notes are available here, April 18 notes are available here). Based on feedback received from the Technical Committee, the Districts revised the study plans. These revised study plans were forwarded to the Technical Committee on May 4. No additional comments were received and on May 10, the Districts sent the study plans to the Plenary Group. Mr. Le said the Districts anticipate fieldwork will start in mid-July, and would like to get consent from the Plenary Group to proceed with the studies. Mr. Le noted that meeting notices and draft study plans were sent out via email by Ms. Rose Staples (HDR); any attendees who have not been receiving these emails should contact Ms. Staples at Rose.Staples@hdrinc.com.

Mr. John Buckley (Central Sierra Environmental Resource Center) said one of the questions raised at a previous meeting was whether Chinook salmon currently exist in the upper Tuolumne River. Mr. Buckley asked if that question has been answered or if information on that topic has been provided to the Plenary Group. Mr. Buckley asked if it would be possible to study the genetics of Chinook that may exist in that reach of the river. Mr. Le said there have been discussions about stocking practices in Don Pedro Reservoir and whether these practices have resulted in a landlocked Chinook population. Ms. Gretchen Murphy (California Department of Fish and Wildlife [CDFW]) added that there is some anecdotal evidence about the possible existence of a landlocked Chinook population in Don Pedro Reservoir. This evidence is documented in Perales et al. 2015, a copy of which Ms. Murphy provided to this group in February (available online here). Mr. Le said the Districts had an action item from the March 18 Technical Committee meeting to contact Mr. Steve Holdeman (U.S. Forest Service [USFS]) about data the USFS may have regarding Chinook in Don Pedro Reservoir or in the upper Tuolumne River. The Districts sent an inquiry to Mr. Holdeman, who replied that he is aware of several anecdotal observations of Chinook in this reach, but he did not know of any formal studies or data that are available. Mr. Le said the Hatchery and Stocking Practices Review will help us better understand the effects of past and current stocking practices. Mr. Buckley said determining whether or not salmon are already present in the upper Tuolumne River seems like an important piece of information to have before significant resources are spent on studies. Mr. Buckley said the NGOs previously shared anecdotal evidence that salmon in Don Pedro Reservoir moved upstream to spawn. Mr. Ron Yoshiyama (consultant to City and County of San Francisco [CCSF]) said that past records indicate that fall-run Chinook have been stocked in Don Pedro Reservoir. These records provide annual stocking statistics. Mr. Yoshiyama said the paper described by Ms. Murphy states that Chinook have been found upstream of Don Pedro Reservoir. Mr. Yoshiyama said he is also aware of anecdotal observations of Chinook by Dr. Moyle and his graduate students, and that it would be possible to request more information about these observations from Dr. Moyle.

Mr. Peter Drekmeier (Tuolumne River Trust) asked if historical records are available about the existence of *O. mykiss* in the upper Tuolumne River. Mr. Le said he is aware of a report from the 1980s that notes the existence of *O. mykiss* in the Clavey River. Mr. Le said the Hatchery and Stocking Practices Review aims to provide additional information about this topic.

Mr. Jason Guignard (FISHBIO, consultant to the Districts) reviewed the goals, study area, methodology, and schedule for the Upper Tuolumne River Habitat Mapping and Macroinvertebrate Assessment. Mr. Guignard noted that originally the study team planned to begin the fieldwork in June, but given the snow pack this year, the study team will instead begin fieldwork in mid-July. Mr. Guignard said the study team plans to use the peaking flows to raft between sites and will collect the data during the low flow following each pulse.

Mr. John Wooster (National Marine Fisheries Service [NMFS]) asked how many sites will be sampled for macroinvertebrates. Mr. Guignard said drifting and benthic macroinvertebrates will be collected at seven sites. Mr. Guignard said that although the actual habitat units have not yet been identified, the study team plans to collect samples at a suitable habitat unit nearby to where the study team will camp each night.

Mr. Larry Byrd (Modesto Irrigation Districts [MID]) asked how it is known whether a fish is natural or introduced. Mr. Le said the only way to determine where a fish comes from is by looking at its genetics. Mr. Le noted that genetics testing is not part of the Districts' studies to be completed in 2016 but that NMFS is conducting a genetics study in the upper reach.

Ms. Dana Ferreira (Office of U.S. Congressman Jeff Denham) asked if Mr. Wooster would provide an update on both the genetics study and the habitat and carrying capacity study being completed by NMFS. For the genetics study, Mr. Wooster said 700 *O. mykiss* samples were collected last summer in the upper Tuolumne River basin. Those samples have been processed and analyzed by the National Oceanic and

Atmospheric Administration Southwest Fisheries Science Center. NMFS will be completing a second round of sampling this year with a focus on higher elevation sites in the upper Tuolumne River and upper Merced River. NMFS aims to collect another 700 samples during this round of sampling. These new samples will be processed this winter, and a final report should be available in the spring of 2017.

Mr. Wooster said he has not seen any results or conclusions from the analysis completed on the 2015 samples. Mr. Wooster said he thinks part of the goal of collecting additional samples this year is to try to understand the variability and relationships between samples collected at higher elevation locations, which, in terms of reintroduction, are not hydrologically connected. NMFS is trying to understand what is native to this stretch of the river. The study has compared the 2015 samples to known hatchery strains. Mr. Wooster said based on the results so far, there does not appear to be a strong relationship between the samples collected in 2015 and known hatchery strains. Mr. Yoshiyama asked if Mr. Wooster can provide more details about what hatchery strains the samples were compared to. Mr. Yoshiyama asked if the 2015 samples were compared to samples of Central Valley hatchery strains, California hatchery strains, or a broader suite of west coast hatchery strains, given that an evaluation of genetic origin is important and should be robust. Mr. Wooster said he did not know the answer to that question. Mr. Wooster said the 2015 paper by Pearce and Garza (available online here) about Central Valley *O. mykiss* contains a genetic tree diagram, and he thinks the hatchery strains included on that diagram may be the strains that were used in the comparison.

Mr. Wooster said *O. mykiss* samples were also collected from the Clavey River. Samples were collected at river miles 8 and 16. Mr. Wooster estimated that about 100 samples in total were collected from these two sites.

Mr. Wooster said the NMFS Upper Tuolumne Habitat and Carrying Capacity Study (NMFS Carrying Capacity Study) is behind schedule. NMFS is still in the process of generating bathymetry from the hyperspectral imagery. This needs to be completed before habitat units can be generated. Once the habitat units are delineated, carrying capacity can be calculated. Mr. Wooster said NMFS hopes the development of bathymetry data will be completed soon.

Mr. Greg Dias (MID) said imagery from the NMFS Carrying Capacity Study will be very helpful for informing the Districts' 2016 fieldwork. Mr. Dias said given the Districts are on a tight schedule to complete these studies, the Districts would be interested in helping the NMFS Carrying Capacity Study move forward. Mr. Wooster said the current bottleneck in the study is running the algorithms to translate the photo data into depth data (i.e., hyperspectral data to bathymetry). Mr. Wooster said the individual who had been completing this work recently left the project, and now the work is on-hold until another individual with suitable training and expertise is found who can step in and resume this effort. Mr. Wooster noted that he is not directly involved with this work, but if the Districts are offering to provide programming assistance, he will relay the Districts' offer to the team working on this task. Mr. Dias confirmed the Districts are offering to make computer/GIS support available to help process the photos, if that would help keep the study on schedule. Mr. Wooster thanked Mr. Dias for his offer and said he will follow up with the appropriate individuals. Ms. Ferreira said it would be helpful if the Districts and NMFS can find a way to collaborate on these studies since they are complementary to the Districts' studies.

Mr. Jay Stallman (Stillwater Sciences, consultant to the Districts) reviewed the goals, study area, methodology, and schedule for the Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study. Mr. Buckley said on a recent field visit to Wards Ferry, he observed high amounts of fine sediment in the river. Mr. Buckley said the current high flows in the river are the first flows of this magnitude since the Rim Fire occurred, and these flows are washing down sediment produced by the fire. Mr. Buckley said this sediment has the potential to fill in gaps around the gravel, which could affect results from this study. Mr. Buckley asked if this is a concern, and if the team should consider conducting another round of study next year. Mr. Stallman said the point is well taken and this topic has been discussed by the study team. Mr. Stallman said he does not believe there will be an opportunity in 2017 to repeat this study, so the study team will need to do the best they can with this effort. Mr. Stallman said he believes the overall distribution of gravel deposits will not change significantly as a result of the recent sediment delivery, but the surface grain size distribution may be affected by fine sediment deposits in some locations. This will be a consideration as the study progresses. Mr. Wooster said in his previous fieldwork, he observed gravel completely buried by sediment. Mr. Stallman said the study team will be probing with a silvey rod, but will need to consider how to interpret gravel covered by fine sediment. Mr. John Devine (HDR) said the underlying question here is whether data collected this year is representative of other years and whether the data collected this year would have been significantly different if the Rim Fire had not occurred.

Mr. Drekmeier asked if anything relevant to this study had been learned from the recent pulse flow in the upper reach. Mr. Bill Sears (CCSF) said crews have not been in the field since the recent high flows. Mr. Sears said post-flood monitoring upstream of Early Intake is scheduled for July or August. This monitoring is part of the standard ongoing annual monitoring that is completed related to the Rim Fire and experimental releases from O'Shaughnessy Dam. Mr. Sears said he thinks next steps should be for the Districts to complete the 2016 work and at a future workshop the results can be discussed. Mr. Sears said that given these are the first flows of this magnitude and duration since 2011, it is unknown what may be happening on the river. Mr. Devine said it is known that a flood of this magnitude has the ability to mobilize sediment, but it is unknown how the sediment will be redeposited.

Mr. Wooster confirmed the NMFS LiDAR and hyperspectral data was flown after the Rim Fire, in late September and early October 2014. In August 2014, NMFS photographed gravel cobble bars using suspended cameras. Mr. Wooster said during that fieldwork, he observed sediment in the river, presumably from the fire. Mr. Wooster said he observed less sediment in the river during the NMFS 2015 fieldwork. Mr. Wooster said the photos from 2014 may be helpful, even though these photos were not taken prior to the fire. Mr. Dias agreed that the photos could be helpful for that purpose. Mr. Wooster said he will check on what documentation exists for the photos. Mr. Sears said CCSF has provided 2007 color aerial photos to the study team. Mr. Sears said photogrammetry associated with that 2007 flight was also developed.

Mr. Wooster said the study plan states the minimum patch size for *O. mykiss* is six square meters. Mr. Wooster said he thinks that six square meters is large compared to the minimum patch size used in previous studies completed by NMFS and the Districts, as well as studies completed on the McCloud River, which used a minimum patch size of two square meters. Mr. Wooster said that on similar studies, NMFS typically uses five square meters for a minimum patch size for Chinook and two square meters for a minimum patch size for steelhead. Mr. Stallman said the criteria were based on criteria used in studies previously completed on the Tuolumne River, McCloud River, and other rivers. Mr. Dirk Pedersen (Stillwater Sciences) said the study team felt that using a slightly larger minimum patch size than might appear in the literature would be helpful from a logistical standpoint. Given the resolution of the existing aerial photos, the study team was not confident a smaller patch size could be accurately mapped. Noting that the study plan currently assumes a 12 square meter patch size Chinook, Mr. Wooster asked if the study plan could be revised to instead assume a 6 square meter patch size for Chinook similar to for steelhead. Mr. Le said the Districts will consider this request.

Mr. Le asked if there were any concerns, besides those previously voiced, to the Districts moving forward with the study. There were no objections.

Mr. Jarvis Caldwell (HDR) reviewed the goals, study area, methodology, and schedule for the Upper Tuolumne River Instream Flow Study. Mr. Wooster asked about the projected cost of the study. Mr. Caldwell said given that the study team is still finalizing the fieldwork logistics, the budget has not yet been finalized. Mr. Devine said the budget can be provided once it is finalized.

Mr. Buckley asked if the model will be able to show how alternative future flows may help prevent dewatering caused by Holm peaking. Mr. Devine said the model will consider existing conditions only.

Mr. Le asked if there were any concerns with the Districts moving forward with the study. Mr. Wooster said it does not appear that the cost/benefit analysis warrants this study. Mr. Wooster said the study will likely be very expensive and there are documented shortcomings related to this type of study. Mr. Wooster said he thinks data on habitat availability at different stages and flow releases could be collected in a much more cost efficient manner. There were no other objections.

Ms. Jenna Borovansky (HDR) reviewed the goals, study area, methodology, and schedule for the Regulatory Context for Reintroduction. Mr. Buckley said whether or not salmon or steelhead currently exist in Don Pedro Reservoir and/or the upper river may have an effect on what regulations come into play. Ms. Borovansky said the study will consider applicable regulations in a broad context including if landlocked populations do exist or do not exist.

Ms. Borovansky reviewed the goals, study area, methodology, and schedule for the Socioeconomic Scoping Study. Mr. Drekmeier asked if the study will also consider the potential positive benefits of reintroduction such as a revived sport fishery. Ms. Borovansky said the study will consider current uses and how these uses may be affected, both positively and negatively, if fish are reintroduced. Ms. Jennifer Shipman (Manufacturer's Council of the Central Valley) asked if recreational boating activities on the reservoir would be considered since this is currently a significant activity. Ms. Borovansky said the boaters are a key stakeholder group for Don Pedro Reservoir. This study will include outreach to the boaters.

Mr. Don Swotman (citizen) said he has been very active on Don Pedro Reservoir and the Tuolumne River since the dam was built. As many as 4,000 families visit Don Pedro Reservoir on a summer weekend. Over 250 houseboats provide base income for the area year-round. The area also hosts several bass tournaments. Mr. Swotman said many millions of dollars are being spent on extremely detailed investigation and this money would be better spent elsewhere. Mr. Swotman questioned what is accomplished by taking water away from farmers as many acres are now fallow because water is being used for other purposes. Mr. Swotman said many of the houseboats must be removed, but it is unknown where they should be relocated or when a new marina will be built. Mr. Swotman said the focus should be on the global picture. It is not economically feasible to release 30 to 40 percent of water for fish when so few fish will be benefited.

Mr. Le reviewed the goals, study area, methodology, and schedule for the Hatchery and Stocking Practices Review. Mr. Le asked if there were any concerns with the Districts moving forward with the study. There were no objections.

Mr. Le thanked the Technical Committee members for taking time out of their busy schedules to participate. Mr. Le noted that participation is completely voluntary, and it takes a lot of effort and time to follow up on action items and review draft study plans. He said the Districts appreciate the Technical Committee's voluntary participation.

Mr. Le summarized progress made by the Reintroduction Goals Subcommittee. On April 13, the Reintroduction Goals Subcommittee, which includes the Districts and representatives from the agencies and NGOs, discussed the importance of developing goals for reintroduction and how such goals fit into the Framework. The Districts have an action item from that meeting to draft a preliminary reintroduction goals statement and circulate this to the Subcommittee, as the means for kicking off discussion. Mr. Le noted that as work began on this task, the Districts quickly realized it is extremely difficult to develop a concise goal in just one or two sentences that is representative of all participants' interests. Mr. Le said the Districts will aim to complete a draft goals statement in the next two weeks, and will send the draft out with a Doodle poll for future discussion.

Mr. Lonnie Moore (citizen) asked who is in charge of developing the goals statement. Mr. Le said Districts staff, HDR staff, and other consultants are working on developing this initial goals statement. Mr. Moore asked who is in charge of this process. Mr. Devine said he is the lead of the process, but he is not the decision maker. Mr. Dias added that he is the lead for Modesto Irrigation District and Mr. Steve Boyd is the lead for Turlock Irrigation District. Mr. Dias said the Districts welcome individuals to submit their ideas or comments on the goals. Mr. Dias said individuals are also welcome to submit their comments anonymously if they prefer. Mr. Devine said the Districts' initial draft of a goals statement is just the opening step to getting feedback. The Districts look forward to receiving comments from everyone.

Mr. Le asked if there are any objections to moving forward with the six studies presented for consideration. Ms. Ferreira and Ms. Shipman specifically asked for the representatives of NMFS and the U.S. Fish and Wildlife Service (USFWS) to indicate whether they object to the studies. Mr. Wooster said all the studies are supported by NMFS except for the Instream Flow Study. Mr. Zac Jackson (USFWS) said he has no concerns moving forward with the suite of studies.

Mr. Le said the Districts' Initial Study Report (ISR) contained several statements about temperature in the upper river. NMFS's ISR comment letter correctly noted that no temperature criteria as it relates to habitat suitability currently exist for the upper Tuolumne River. Mr. Le said that point was well taken by the Districts, and thus in their ISR comment response letter, the Districts stated it would be important that these criteria be developed through a collaborative process. Mr. Le asked if NMFS had ideas or thoughts about moving forward with developing temperature criteria related to the reintroduction program. Mr. Tom Holley (NMFS) said that a very similar effort was completed for the Yuba Salmon Forum, and that reviewing the results from that effort may be a good place to start. Mr. Le noted that Mr. Paul Bratovich (HDR) was central to the development of temperature criteria on the Yuba. He is also a team member on this process and would be well-qualified to develop a summary of Yuba temperature criteria. Mr. Le said the Districts will develop a document summarizing how water temperature criteria were developed for the Yuba River, as well as similar efforts at other Central Valley reintroduction programs if they exist. Mr. Holley said that seemed like a reasonable place to start. Mr. Devine said the Districts will also reach out to Mr. Peter Barnes at the State Water Resources Control Board to get his input on temperature criteria. Mr. Devine said once the information is collected, the Districts will send out a Doodle poll to schedule a meeting to discuss the information.

Meeting attendees discussed a date for the next Workshop. Meeting attendees agreed the next Workshop will be on Thursday, September 15, from 10:00 am to 12:00 pm. Ms. Rose Staples (HDR) will send out a save-the-date email. Mr. Le confirmed there are no meetings currently scheduled for the Technical Committee or Reintroduction Goals Subcommittee.

Meeting adjourned.

ACTION ITEMS

1. The Districts will contact Dr. Peter Moyle at UC Davis and ask for any data he and his classes have collected regarding Chinook salmon in Don Pedro Reservoir and in the Tuolumne River upstream of Don Pedro Reservoir.
2. Mr. Wooster will relay to the appropriate individuals the Districts' offer to assist on the NMFS Carrying Capacity Study. (complete)
3. Mr. Wooster will check on what documentation exists for the photos NMFS took in August 2014 of gravel cobble bars. (complete)
4. The Districts will consider NMFS' request to revise the Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study Plan to state that the minimum patch size for Chinook is 6 square meters (the study plan currently states the minimum patch size for Chinook is 12 square meters).
5. The Districts will provide to NMFS the final budget for the Upper Tuolumne River Instream Flow Study Plan.
6. The Districts will develop a document summarizing how water temperature criteria were developed for the Yuba River, as well as how criteria were developed at other reintroduction programs.
7. The Districts will reach out to Mr. Peter Barnes at the State Water Resources Control Board to get his input on water temperature criteria.
8. Ms. Rose Staples will send out a save-the-date email for Workshop No. 6, which is scheduled for Thursday, September 15, from 10:00 am to 12:00 pm. (complete)

WORKSHOP NO. 5
MAY 19, 2016

MEETING NOTES

ATTACHMENT A

Workshop No. 5 Meeting Attendees		
No.	**Name**	**Organization**
In Person Attendees		
1	Jenna Borovansky	HDR, consultant to the Districts
2	Steve Boyd	Turlock Irrigation District
3	Paul Bratovich	HDR, consultant to the Districts
4	Gavin Bruce	Stanislaus Business Alliance
5	John Buckley	Central Sierra Environmental Resource Center
6	Larry Byrd	Modesto Irrigation District
7	Paul Campbell	Modesto Irrigation District
8	Calvin Curtin	Turlock Irrigation District
9	John Devine	HDR, consultant to the Districts
10	Greg Dias	Modesto Irrigation District
11	Peter Drekmeier	Tuolumne River Trust
12	Leonard Van Elderen	Yosemite Farm Credit
13	Gordon Enas	Modesto Irrigation District
14	Dana Ferreira	Office of U.S. Congressman Jeff Denham
15	Art Godwin	Turlock Irrigation District
16	Kelsey Gowans	Modesto Irrigation District
17	Brenda Herbert	Office of State Senator Anthony Cannella
18	John Holland	Modesto Bee
19	Bao Le	HDR, consultant to the Districts
20	Lisa Mantarro	Office of State Assemblymember Adam Gray
21	Brandon McMillan	Turlock Irrigation District
22	Lacy Monier	Tuolumne River Trust
23	Lonnie Moore	Citizen
24	Marco Moreno	Latino Community Roundtable
25	Gretchen Murphy	California Department of Fish and Wildlife
26	Bill Paris	Modesto Irrigation District
27	Liz Peterson	Tuolumne County
28	Daniel Richardson	Tuolumne County
29	Greg Salyer	Modesto Irrigation District
30	Alfred A. Scuza	Yosemite Farm Credit
31	Jennifer Shipman	Manufacturer’s Council of the Central Valley
32	Don Swotman	Citizen
33	Jake Wenger	Modesto Irrigation District
34	Melissa Williams	Modesto Irrigation District
35	Samantha Wookey	Modesto Irrigation District
36	Ron Yoshiyama	City and County of San Francisco
37	Paul Zeek	Office of State Assemblymember Kristin Olsen
Conference Call Attendees		
38	Jarvis Caldwell	HDR, consultant to the Districts
39	Jesse Deason	HDR, consultant to the Districts
40	Jason Guignard	FISHBIO, consultant to the Districts
41	Tom Holley	National Marine Fisheries Service
42	Zac Jackson	U.S. Fish and Wildlife Service
43	Patrick Koepele	Tuolumne River Trust
44	Ellen Levin	City and County of San Francisco
45	Dirk Pedersen	Stillwater Sciences, consultant to the Districts
46	Bill Sears	City and County of San Francisco
47	Chris Shutes	California Sportfishing Protection Alliance
48	Jay Stallman	Stillwater Sciences, consultant to the Districts
49	John Wooster	National Marine Fisheries Service

REVISED DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Upper Tuolumne River Habitat Mapping and Macroinvertebrate Assessment

May 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Upper Tuolumne River Habitat Mapping and Macroinvertebrate Assessment is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to characterize habitat distribution, abundance, and quality in the upper Tuolumne River.

2.0 STUDY AREA

The study area will include the mainstem of the upper Tuolumne River from the upstream limit of the Don Pedro Project (approximately RM 81) to Early Intake (approximately RM 105).

3.0 STUDY GOALS

The primary goal of this study is to provide information on habitat distribution, abundance, and quality in the upper Tuolumne River. This information will inform evaluations in the Framework and is critical for assessing the feasibility of anadromous salmonid reintroduction, estimating potential population size and developing engineering alternatives for the upper Tuolumne River. Specific objectives include:

- documenting the number, size and distribution of mesohabitats available in the upper Tuolumne River;
- collecting detailed data on habitat attributes in representative reaches of the upper Tuolumne River;

- documenting potential pool holding habitat for over-summering adult Chinook salmon; and
- collecting drift and substrate samples of macroinvertebrates (salmonid prey organisms).

4.0 STUDY METHODS

For this assessment, habitat mapping will quantify the type, amount, and location of habitat types available to potentially reintroduced anadromous salmonids during their riverine life stages (adult holding/spawning, incubation and rearing). Habitat mapping will be conducted in the field and remotely using standardized methodologies. The frequency and area of each habitat type (e.g., pool, riffle, run) will be tabulated and where potential holding pools for adult Chinook occur, the size and depth of the pools will be measured to determine possible holding capacity. Additional mapping tasks will include assessments of channel gradient, width, habitat areas, etc.

Habitat mapping will consist of mapping all mesohabitat units between Early Intake (RM 105) and the upstream limit of the Don Pedro Project (approximately RM 81), and collecting detailed habitat data in a sub-set of the mapped mesohabitat units.

4.1 Task 1. Mesohabitat Mapping

Reconnaissance level mapping in the summer of 2015 consisted of mesohabitat classifications (Table 1.0) for portions of the reach between Lumsden (Merals Pool at RM 96) and approximately RM 81. In 2016, habitat mapping will be extended up to Early Intake (RM 105), and gaps in mapping between RM 96 and approximately RM 81 will be comprehensively assessed to obtain a more complete dataset. Habitat units will be identified visually by a boat-based survey crew and mapped on pre-existing high-resolution color aerial photographs. Boundaries of mesohabitat units will also be geo-referenced in the field with a handheld GPS unit.

Table 1.0 Mesohabitat mapping units and criteria for the mainstem Tuolumne River.

Mesohabitat types	Definitions/ Criteria
Deep Pool	>6 ft max depth
Shallow Pool	<6 ft max depth
Glide/ Pool tail	Typically in the downstream portion of a pool with negative bed slope where converging flow approaches the riffle crest. Wide, shallow, flat bottom with little to no surface agitation. Substrate type is typically smaller than riffle, but coarser than pool and often provides best salmonid spawning habitat.
Run	Long, smoothly flowing reaches, flat or concave bottom, and deeper than riffles with less surface agitation. Higher velocities than pools.
Boulder Garden/Pocket Water	Moderate to low gradient riffles, runs, and glides with numerous large boulders/obstructions that create scour pockets and eddies with near zero velocity. Often no clear thalweg present due to multiple flow paths.
Cascade/ Chute	>10% gradient, and with air entrainment (particularly in cascades), very large boulders and/or bedrock. Consisting of alternating small waterfalls and can have shallow pools in middle and margin of channel at low flows.
High Gradient Riffle	>4% gradient. Substrate is usually large boulder and bedrock (>24”)
Low Gradient Riffle	<4% gradient. Substrate is usually small boulder and large cobble(6-24”)
Side Channel	Contains < 20% of total flow. Connected at top and bottom to main channel at low flow.
Backwater	Low to zero velocities. Only connected to main channel from one end.

Mapped habitats will be digitized and added to the project GIS layer for mapping, as well as for quantitative and spatial analysis. Color maps will be created to depict the type and location of habitats throughout the study area and in relation to important features such as tributaries, potential passage barriers, access points, and water temperature monitoring locations. The frequency and area of each habitat type (e.g., pool, riffle, run) will also be tabulated.

4.2 Task 2. Habitat Inventory Mapping

Additional (remote) mapping tasks will include assessments of channel gradient, width, habitat areas, etc. following the CDFW Level III habitat typing methodology (CDFG 2010). Methods will be similar to habitat typing conducted in the lower Tuolumne River (TID/MID 2013). Sampling units selected for detailed habitat measurements will encompass approximately 10 to 20 percent of the study reach, as recommended in CDFG (2010). The habitat typing field effort will consist of a team of three biologists surveying the river by raft. The study area will be divided into seven sampling reaches, based on length of river rafted daily (two reaches from Early Intake to Lumsden and five reaches from Lumsden to Wards Ferry). Within each individual sampling reach, a one mile section will be randomly selected for habitat typing. Prior to the field assessment, the team will use maps and existing aerial photographs to delineate the specific reaches to be surveyed.

A suite of measurements consistent with the Level III CDFW criteria (Table 2.0) will be made within each mesohabitat type along each of the selected one-mile reaches. Data will be recorded on standardized datasheets to ensure all data are collected in a consistent manner. A photograph of each and GPS coordinates will be recorded at the bottom of each habitat unit. Unit length and width will be measured with a laser range finder. Depths will be measured using a stadia rod or handheld depth finder. Large woody debris (LWD) count will include a count of LWD pieces with a diameter greater than one foot and a length between six and twenty feet, as well as pieces greater than twenty feet in length, within the bankfull width. Percent total canopy will be measured using a spherical densiometer at the upstream end of each habitat unit in the center of the wetted channel, as well as general observations of riparian habitat. The remaining habitat parameters including substrate composition, substrate embeddedness, shelter complexity, and bank composition types will be visually estimated. Within each sampling reach, stream gradient will also be measured using a hand level over a distance of at least 20 bankfull channel widths. In addition, the size and depth of each pool will be collected throughout the study reach to help quantify the amount of potential Chinook salmon adult holding habitat.

Table 2.0 List of data collected as part of Level III CDFW habitat mapping.

Data	Description
Form Number	Sequential numbering
Date	Date of survey
Stream Name	As identified on USGS (U.S. Geological Survey) quadrangle
Legal	Township, Range, and Section
Surveyors	Names of surveyors
Latitude/Longitude	Degrees, Minutes, Seconds from a handheld GPS
Quadrant	7.5 USGS quadrangle where survey occurred
Reach	Reach name or river mile range
Habitat Unit Number	The habitat unit identification number
Time	Recorded for each new data sheet start time
Water Temperature	Recorded to nearest degree Celsius
Air Temperature	Recorded to nearest degree Celsius
Flow Measurement	Available from USGS monitoring stations
Mean Length	Measurement in feet of habitat unit
Mean Width	Measurement in feet of habitat unit wetted width
Mean Depth	Measurement in feet of habitat unit

Data	Description
Maximum Depth	Measurement in feet of habitat unit
Bankfull Width	Measurement in feet of channel width at bankfull discharge
Bankfull Depth	Averaged unit depth in feet at bankfull discharge
Depth Pool Tail Crest	Maximum thalweg depth at pool tail crest in feet
Pool Tail Embeddedness	Percentage in 25% interval ranges
Pool Tail Substrate	Dominant substrate: silt, sand, gravel, small cobble, large cobble, boulder, bedrock
Large Woody Debris Count	Count of LWD within wetted width and within bankfull width
Shelter Value	Assigned categorical value: 0 (none), 1 (low), 2 (medium), or 3 (high) according to complexity of the shelter.
Percent Unit Covered	Percent of the unit occupied
Substrate Composition	Composed of dominant and subdominant substrate: silt, sand, gravel, small cobble, large cobble, boulder, bedrock
Percent Exposed Substrate	Percent of substrate above water
Percent Total Canopy	Percent of canopy covering the stream
Percent Hardwood Trees	Percent of canopy composed of hardwood trees
Percent Coniferous Trees	Percent of canopy composed of coniferous trees

Results to be reported include the following:

- Ground-mapped habitat units
  - Total number of habitat units, by type
  - Total length of habitat units, by type
  - Number of habitat units (frequency)
  - Average width of habitat units, by type
  - Number and relative frequency of dominant instream cover types
  - Reach summary data (e.g., average bankfull width and depth, LWD density (within wetted and bankfull))
- Pool holding habitat
  - Total number of pools identified as potential holding habitat (and the criteria of determination)
  - Average and maximum pool depth
  - Percentage of pools with ≥ 5% cover
  - Map showing the suitable holding pools in each 1-mile sampled reach of the upper Tuolumne River
- Tributary mapping data and reconnaissance level mainstem Upper Tuolumne River habitat data collected in 2015

4.3 Task 3. Macroinvertebrate Assessment

If time and logistics allow as the final field schedule is developed, a macroinvertebrate assessment will be conducted following the methods outlined below.

4.3.1 Study Goals

Drifting and benthic macroinvertebrates typically comprise the primary food source for rearing salmonids in fresh water habitats (Allan 1978, Fausch 1984, Harvey and Railsback 2014). Information on macroinvertebrate prey resource availability is a component of an evaluation of the factors affecting production and viability of an existing or introduced salmonid population. The density and taxonomic composition of drifting macroinvertebrates can provide a relative measure of food availability for drift-feeding salmonids. To provide a relative measure of food availability for salmonids within the water column, a literature search of similar streams and macroinvertebrate studies in the region (Sierra foothill region) will be conducted. Substrate sampling for benthic macroinvertebrates will provide data that can be used in a standardized bioassessment approach to evaluate the potential for physical habitat impairment. The objectives of the macroinvertebrate assessment are to:

- collect and analyze macroinvertebrate drift samples to determine whether the taxonomic composition and density of drift is consistent with other regional systems currently supporting healthy salmonid populations; and
- collect and analyze benthic macroinvertebrate samples from the substrate to develop metrics for bioassessment and comparison with similar streams and data sets.

4.3.2 Study Methods

4.3.2.1 Sampling Site Selection

The study area for macroinvertebrate sampling within the upper mainstem of the Tuolumne River is from RM 81 to Early Intake (RM 105). The location and number of sampling sites and sampling frequency will represent the seasonal variability of macroinvertebrate populations and related seasonal variability of food resources for stream-dwelling salmonids during the primary salmonid rearing and growth period (spring-fall), as well as the variability of physical habitat characteristics in each study reach.

<u>Number of sites</u>
Depending on opportunities encountered during stream habitat mapping, drift and benthic macroinvertebrate samples will be collected at seven sites, equating to approximately one site per 3.5 river miles.

<u>Locations</u>
Drift sampling will occur at seven sites, based on length of river rafted daily (two sites from Early Intake to Lumsden and five sites from Lumsden to Wards Ferry) at sites selected near overnight camping locations during each rafting trip. Drift samples will be collected in riffle or run habitats and be selected based on suitable depth, velocity, substrate, and accessibility/safety considerations, with two sites per location and two replicates (net placements) per site.

Benthic macroinvertebrate sampling will occur at suitable riffles initially identified in the office using aerial photographs and verified in the field. One composite sample will be collected daily from a suitable riffle or combination of suitable fast-water habitat types during the seven-day raft-based sampling.

<u>Sample timing and frequency</u>
Macroinvertebrate sampling will be conducted daily during the raft-based habitat mapping effort. Drift sampling in early summer (June) will characterize food resources available to rearing juvenile anadromous salmonids. In many temperate streams, aquatic macroinvertebrate diversity and abundance peak during spring and summer and are reduced in late summer and fall. Peak feeding and growth by rearing salmonids occur when prey availability and water temperatures are relatively high, maximizing net energy gain (Rundio and Lindley 2008, Stillwater Sciences 2007, Wurtsbaugh and Davis 1977). Exact sampling dates for this study may be adjusted within the general seasonal period to coincide with other sampling efforts in order to maximize efficiency and accommodate river flow levels. However, macroinvertebrate sampling should not occur during periods of very high flows or when river discharge is changing rapidly due to safety and access concerns and the potential effects of flow fluctuations on invertebrate drift (Brittain and Eikland 1988).

Drift sampling will begin each afternoon by 1700 hours and proceed until approximately 2000 hours. This sample timing is intended to collect drifting macroinvertebrates during the daily period when feeding activity is often greatest for juvenile Chinook salmon and trout (Sagar and Glova 1988, Johnson 2008) and to avoid pre-dawn and post-dusk peaks in drifting macroinvertebrates that may not be available to drift-feeding salmonids at low light levels. The timing and duration of drift sampling can be adjusted if needed to accommodate rafting safety concerns or logistical constraints. All drift sampling should occur during the peak afternoon-evening feeding period and have the same start and end time.

The timing of the benthic macroinvertebrate sampling is not seasonally dependent, but will be coincident with the drift sampling effort to maximize efficiency and reduce the amount of field sampling time required for the study. Benthic macroinvertebrate samples will be collected once per day during the raft-based sampling effort, typically during mid-day or as determined by the location of suitable sampling riffles and logistics of the habitat mapping study.

4.3.2.2 Sampling Protocols

Invertebrate drift sampling

Drift samples will be collected using stationary nets with rigid rectangular openings and tapered, nylon mesh bags with a collection jar fitted at the downstream end – similar to drift nets used by other researchers (Brittain and Eikeland 1988), including the 1987–1988 drift studies in the lower Tuolumne River (Stillwater Sciences 2010). All drift nets will be identical, with a mesh size small enough to capture small invertebrates such as immature chironomids that may be important salmonid prey, while also large enough to minimize clogging (e.g., 250–500 μ). There is no standard mesh size for drift nets, with mesh size instead chosen according to study objectives, and to represent a compromise between filtration efficiency and clogging (Svendsen et al. 2004).

At each sampling location two transects will be selected perpendicular to the river and two drift nets will be placed at each transect: one near shore and one in the thalweg or as close to the thalweg as water depth and velocity will safely allow. Each drift net will be anchored in the water column using steel (e.g., rebar stakes or fence posts) driven into the stream bed, with the bottom of the net at least 10 cm above the river bottom and the top of the net at least 4–5 cm above the water surface. This vertical net placement ensures capture of terrestrial-origin organisms originating from outside the stream (Leung et al. 2009), which may be an important diet component for anadromous salmonids (Tiffan et al. 2014, Leung et al. 2009, Rundio and Lindley 2008) while avoiding capture of organisms crawling on the substrate. Because drift composition is not uniform across the channel (Waters 1969), placement of near-shore and mid-channel drift nets allows sampling of each portion of the channel to represent potential differences in taxonomic composition, origin (aquatic vs. terrestrial), density, or other factors. The safety of approaching rafts will be considered during the selection of transect locations, and each drift net will be clearly marked with a buoy. During sampling, the drift nets will be attended by one or more field crew members to monitor for approaching rafts or other safety hazards. If needed, field personnel will verbally warn rafters of the potential hazard and assist rafts in avoiding the nets.

Drift nets will be deployed for three hours each day (1700–2000 hours). The width and depth of the submerged portion of each net will be measured upon installation to calculate the effective net area (i.e., the area being sampled). Water velocity will be measured at the midpoint of each net mouth immediately after net installation, at the midpoint of sampling (after 1.5 hours), and immediately before retrieving the net. The three velocity values will be used to calculate the average water velocity at the mouth of each net during sampling, and the average velocity will be multiplied by the sampled area to determine the total volume of water passing through each net during the sampling event. Because net clogging during sampling can gradually reduce the velocity of water passing through the net, an average of several water velocities measured over the course of sampling provides a more accurate measure of volume than a single velocity measure.

After removing each drift net from the water, the contents will be carefully washed to the end of the net and into the collection bottle using river water. The bottle will then be removed and all contents will be transferred to a sample container, labeled, and preserved with 95% ethanol for later processing.

<u>Benthic sampling</u>
Benthic sampling will be conducted using a modified version of the targeted riffle composite (TRC) method described in the California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment Standard Operating Procedure (Ode 2007). The TRC has been widely used in California by state and federal water resource agencies, is consistent with the methods of EPA's Environmental Monitoring and Assessment Program (EMAP) (Peck et al. 2006), and has been adopted as the standard riffle protocol for bioassessment in California (Ode 2007). A similar methodology, the former California Stream Bioassessment Protocol (CSBP) and later the California Monitoring and Assessment Program (CMAP), produced comparable results and was used for the Districts' benthic macroinvertebrate sampling program in the lower Tuolumne River from 2001–2005 and from 2007–2009 (Stillwater Sciences 2010). The SWAMP TRC method was recently used to collect benthic macroinvertebrate samples in the upper Merced River as part of the Merced River Alliance Biological Monitoring and Assessment project (Stillwater Sciences 2008).

Due to site access constraints and non-wadeability in most habitat types, a modified version of the SWAMP protocol will be used to select riffles or other suitable fast-water habitat types for TRC sampling. Whereas the SWAMP protocol specifies that habitats (riffles or other fast-water habitats) for TRC sampling should be selected randomly from a pre-established reach 250 meters in length, riffles sampled for this study will instead be selected randomly from among all potentially wadeable riffles that are accessed during the habitat mapping study and were initially identified in the office by examining high-resolution color aerial photographs of the study reaches. During field sampling, the field crew will carry a set of the aerial photographs with potential sampling riffles identified, to enable identification of alternative sampling riffles if needed. Using the office-based method, a total of seven riffles will be selected for sampling. Riffles selected for sampling will be spaced sufficiently to enable sampling of an average of one riffle per day during the raft-based field effort.

In the field, riffles initially selected for benthic sampling will be evaluated individually as they are encountered during the rafting trip to determine whether substrate, depth, and velocity are suitable for sampling, and if they can be sampled safely. A riffle will be deemed suitable if it has enough gravel or cobble substrate to allow collection of up to eight non-overlapping benthic samples in areas that can be safely accessed on foot by a two-person field crew (i.e., depth and velocity do not prohibit safe access and sampling). If a riffle initially chosen for TRC sampling is unsuitable, the crew will proceed to the next suitable riffle. Ideally, a total of five riffles or other fast-water habitats will be sampled in the study reach using the TRC method. At each riffle selected for TRC sampling, physical habitat and water chemistry data will be collected following the SWAMP protocol for the "basic" level of effort (Ode 2007). These data include GPS coordinates and photographs of the site, water temperature, pH, dissolved oxygen, specific conductance, channel width, riparian canopy cover, bank stability, and channel gradient.

The TRC approach specifies collection of benthic samples at eight riffles within each 250 meter sampling reach (Ode 2007). However, preliminary examination of aerial photographs indicates that the riffles in the upper Tuolumne River are relatively infrequent and widely spaced, thus selection of a 250 meter sampling reach containing multiple riffles will likely be infeasible. A modified approach will therefore be used, which will entail collection of eight benthic samples per riffle. If additional suitable riffles or other suitable fast-water habitat types (e.g., run or pool tail) are located in close proximity to a riffle that has been selected for TRC sampling and can be safely accessed on foot, the required eight samples will be collected at locations distributed randomly among the suitable habitats. Sampling locations in each riffle or combination of fast-water habitat types at each site will be selected randomly using a digital stopwatch or random number chart, as described in Ode (2007). Samples will be collected using a standard D-frame kick net with 500-µ mesh. At each sampling location, a 0.09 m^2 (1 ft^2) area of bottom substrate will be sampled immediately upstream of the net following methods described in Ode (2007). All eight samples collected at each site (riffle or combination of fast-water habitats) will be combined into a single composite sample for the site, preserved in 95% ethanol, and labeled for laboratory processing.

4.3.2.3 Analysis and Reporting

All macroinvertebrate samples will be processed in the laboratory following standardized methods and the data will be entered into a database. Processing will enumerate and identify organisms to the taxonomic level necessary to calculate commonly reported biological metrics (numerical attributes of biotic assemblages) for each sample site from the benthic samples (i.e., TRC samples) and identify the diversity and abundance of primary salmonid prey items in the drift. Benthic macroinvertebrate metrics may include those calculated for benthic macroinvertebrate samples collected in the lower Tuolumne River from 2000–2005 and 2007–2009 (Stillwater Sciences 2010). Laboratory analysis of drift samples will also include length measurement of individual organisms, to allow calculation of biomass at a later date, if desired, to provide a relative measure of energy content and available fish food resources. Results will be included in a technical report that evaluates the adequacy of the macroinvertebrate prey resources to support healthy populations of juvenile anadromous salmonids, as indicated by comparison of the taxonomic composition and relative abundance (drift density) of the upper Tuolumne River macroinvertebrate drift samples with drift samples from other salmonid streams.

5.0 STUDY SCHEDULE

The study will be completed during the summer and fall of 2016; a detailed field schedule will be developed in conjunction with other field studies.

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REVISED DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Hatchery and Stocking Practices Review

May 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Hatchery and Stocking Practices Review is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to inform an evaluation of the potential for hatchery stocking practices to affect Chinook salmon and steelhead that may be introduced into the upper Tuolumne River above the Don Pedro Project.

2.0 STUDY AREA

The study area for this desktop literature review will encompass the Tuolumne River basin, including Don Pedro Reservoir and the mainstem Tuolumne River, and associated tributaries (North Fork Tuolumne River, Clavey River, Cherry Creek, etc.), to the extent that information is available regarding historical or current hatchery and stocking practices.

3.0 STUDY GOALS

The overall goal of this study is to assess historical and current hatchery stocking practices in the Tuolumne River basin and identify potential interaction of stocking activities with the reintroduction of anadromous salmonids to the reach of the Tuolumne River between the upstream end of the Don Pedro Project and the City and County of San Francisco’s Early Intake. Specific objectives of this study are listed below:

- identify the species, source hatcheries and their stocking practices in the area, and time periods of fish that were historically stocked in the Tuolumne River, tributaries to the Tuolumne River, and in Don Pedro Reservoir;
- identify stocking location and seasonal timing of stocking for species currently stocked (and that may be stocked in the future) in the Tuolumne River, tributaries to the Tuolumne River, and in Don Pedro Reservoir;
- identify and describe self-sustaining potamodromous populations (species of fish that migrate [upstream or downstream] exclusively in freshwater) originating from previously stocked species, their life history characteristics, and population characteristics, as available;
- identify available information on documented incidents of disease in hatchery stocks and in the Tuolumne River basin;
- describe life histories of stocked species, as well as their spatial and temporal migrations and distributions to identify the potential to interact with reintroduced anadromous salmonids;
- describe potential spatial and temporal overlap of stocked species and lifestages with potentially-reintroduced species and lifestages (i.e., steelhead and spring-run Chinook salmon) in the Tuolumne River; and
- identify potential effects of historical and existing/future hatchery and stocking practices on efforts to reintroduce anadromous salmonids to the Tuolumne River.

4.0 STUDY METHODS

A desktop literature review will be conducted and is expected to include review of agency technical memoranda, fish stocking data, fish health information, journal articles, and websites to identify and describe historical, current and future fish hatchery and stocking practices in the Tuolumne River Basin. Agencies and organizations involved with fish hatchery and stocking activities will be contacted to gather additional information on historical and existing fish stocking activities in the study area, including the Don Pedro Recreation Agency and California Department of Fish and Wildlife.

Based on the information collected regarding historical and current/future stocking practices, existing hatchery operations, life histories of stocked fish species, and literature on interactions between stocked fish species and anadromous salmonids, potential effects of hatchery and stocking practices to an anadromous salmonid reintroduction effort will be described and evaluated. Potential risks associated with hatchery and stocking practices to an anadromous salmonid reintroduction program will be identified and described.

5.0 STUDY SCHEDULE

The anticipated schedule is to conduct the desktop literature review and contact agency staff from May to July 2016. A draft report will be provided to the Technical Committee in November and a final report will be included in the February 2017 Updated Study Report.

6.0 REFERENCES

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 2016. Fish Passage Facilities Alternatives Assessment Progress Report. Prepared by HDR, Inc. Appendix to La Grange Hydroelectric Project Initial Study Report. February 2016.

REVISED DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Upper Tuolumne River Instream Flow Study

May 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Upper Tuolumne River Instream Flow Study is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to evaluate existing aquatic habitat and provide quantifiable metrics of aquatic habitat suitability in the upper Tuolumne River.

2.0 STUDY AREA

The study area for the Instream Flow Study is the main stem of the Tuolumne River extending from the upstream end of the Don Pedro Project (RM 81 +/-) to Early Intake (RM 105).

3.0 STUDY GOALS

The goals of this study are (1) to model existing aquatic habitat for spring-run and fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (O. *mykiss*); (2) to evaluate the existing aquatic habitat over a representative range of observed water years and operations of the City and County of San Francisco's Holm powerhouse; and (3) to provide quantifiable metrics of aquatic habitat suitability in the context of potential reintroduction of Chinook salmon and steelhead.

4.0 STUDY METHODS

The following instream flow study methods are consistent with normal and customary 2-dimensional (2D) instream flow methodologies, and will provide data that are comparable to data collected and used at other salmonid-bearing streams and rivers in California and elsewhere.

The study will be performed in five steps: (1) reach and site selection; (2) field data collection; (3) hydraulic modeling; (4) aquatic habitat modeling; and (5) report preparation. Each of these steps is described below.

Step 1 – Reach and Site Selection

The establishment of study reaches and the location of a study site within each reach will be based on five primary sources of information: (1) upper Tuolumne River geomorphology; (2) watershed hydrology; (3) habitat mapping study results; (4) spawning gravel mapping study results; and (5) existing aerial imagery. Based on current information, it is expected that two or three study sites will be selected throughout the study area.

Reach segmentation in the study area will be based on geomorphic characteristics (e.g., gradient, channel width, substrate composition) and hydrologic contributions (e.g., accretion, percent contribution to overall streamflow from tributaries, effects of hydropower peaking). Based on these characteristics and results from detailed mesohabitat mapping and gravel surveys, one or more study sites will be selected in each reach. Lastly, study site selection will focus on selecting both low gradient mesohabitats (pool, run and low gradient riffle) and likely short high gradient transition mesohabitats (e.g., high gradient riffle, cascade).

Study sites will be selected of a sufficient size and habitat composition to adequately characterize, and be indicative of, the range of habitat attributes (e.g., spawning, rearing and holding) documented through previous and concurrent field data gathering efforts conducted as part of the Framework. The final length of each site will be dependent on the geomorphic characteristics and lengths of mesohabitats contained within the selected study location. The number and types of mesohabitats selected will also depend on the length and variability of mapped units in the vicinity.

While study sites will initially be developed using field and aerial imagery data sources, final site selection may also be influenced by (1) proximity to camping locations, an important logistical consideration in this remote river canyon, and (2) safety considerations, which are influenced by gradient, channel configuration, hydraulic conditions, and availability of downstream recovery/safety zones.

Step 2 – Field Data Collection

Given the remoteness and limited access to the upper Tuolumne River, field data collection at each site will be completed in one continuous five to seven day period. It is anticipated that most of the out-of-water topography will be developed using airborne Light Detection and Ranging (LiDAR) data collected by NMFS in 2015 along the upper Tuolumne River. Before use, the LiDAR data will be evaluated by a remote sensing expert for quality and study utility.

Additional topographic data will be collected using a variety of methods depending on site conditions. Initially, LiDAR coverage will be evaluated and used to describe the majority of each study site not submerged at the time of the data collection. The remaining in-water and out-of-water topographic data collection will be completed utilizing a number of survey techniques. Given the steep nature of the canyon, standard Real Time Kinematic (RTK) Global Positioning System (GPS) survey will likely not be practical. Therefore, the primary survey instruments used will be Robotic Total Stations (RTS), surveyed into a RTK GPS network. The RTS units will be used for topographic surveys conducted on foot and for single beam bathymetric surveys conducted to collect unwadable in-channel topography. Depending on river conditions and safety considerations during each survey, a variety of manned and unmanned craft may be used for bathymetric data collection. Field staff will record all relevant survey information into predefined survey log sheets throughout each survey day.

After each data collection period, the RTK static GPS data files collected by the base station will be submitted to the National Oceanic and Atmospheric Administration's (NOAA) Online Positioning User Service (OPUS). OPUS returns a position corrected and mapped into the high accuracy National Spatial Reference System (NSRS). Using Trimble Business Center software, the OPUS-corrected position will then used to correct the network of RTS collected points from each survey instrument.

Habitat modeling for certain lifestages will require that substrate classification be consistent with habitat suitability criteria (HSC). Once final HSC are defined for this study, substrate classification tables and codes will be developed for use in the field. Similarly, and if applicable, cover types will correspond to cover codes defined in HSC selected for each species.

Prior to field work, detailed substrate information from the *Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study* will be reviewed and, as appropriate, used for field reference. Additionally, if aerial photos are of suitable resolution, preliminary substrate polygons will be digitized throughout each model domain. In the field, crews will use an iPad loaded with aerial photos and GIS mapping software to either validate and refine the desktop delineation or develop substrate polygons and cover features throughout each study site.

Water surface elevations (WSE), discharges, and calibration depths and velocities will be collected throughout each study site at two calibration flows. The final measured flows will ultimately depend on the hydropower peaking operations and the duration of stable flows observed at each study site. Flow stability for data collection and modeling purposes is defined as a 'steady' discharge that results in minimal fluctuation in stage (e.g., no more than +/- 0.05 ft) for a long enough duration to measure discharge, WSEs, depths and velocities throughout the study site. It is anticipated that target flows will range from approximately 200 cfs to 1,200 cfs but will be dictated by upstream hydropeaking operations during each survey period. Based on these targets, hydraulic-habitat relationships modeled in each study site will extend from approximately 50 cfs to 2,000 cfs. The final range will be determined by the overall quality of site specific rating curves and model performance.

WSE's will be surveyed using a RTS in approximately 50 locations throughout the wetted channel for each calibration flow. In addition, spatially referenced depth and velocity validation data will be collected in at approximately 50 locations by an acoustic Doppler current profiler (ADCP) or manual velocity meter depending on location and hydraulic condition. Spot velocities depths and WSE measurements will span the entire longitudinal profile of model site.

Study site discharge measurements will be made using a combination of manual velocity meters and an ADCP mounted on an OceanSciences™ trimaran or similar vessel. ADCP measurements will follow standard USGS procedures (Mueller and Wagner 2009) for measuring discharge.

On-site rating curves will be developed using a combination of stage and discharge measurements and stage recording pressure transducers. At a minimum, three stage and discharge measurements will be made at each site. To supplement these data, stage recorders, which also record temperature, will be deployed at the top and bottom of the each study site to passively record stage over the data collection period. Stage recorders may also be deployed at various locations throughout the site to monitor the rate of stage change at specific mesohabitats. To relate WSE to discharge, the WSE will be measured directly above each installed logger at the time of deployment and again when the units are retrieved. A barometric pressure transducer will also be installed at the site to compensate for changes in atmospheric pressure. For validation purposes, WSEs will be measured during calibration flow surveys in the vicinity of each recorder. In addition to providing stage data for rating curve development, stage and temperature data from the recorders will be used to inform habitat and peaking analyses, discussed in Step 5 below.

Study site photographs will be collected to document site conditions during each survey. A representative collection of site photos, arranged by calibration survey flow will provided in a report attachment.

Step 3 – Hydraulic Modeling

Surface and Mesh Development

Hydraulic modeling for the study site will use River2D (Steffler and Blackburn 2002). The River2D model uses the finite element method to solve the basic equations of vertically averaged 2D flow incorporating mass and momentum conservation in the two horizontal dimensions (Steffler and Blackburn 2002).

The main input parameters for the River2D model include channel surface topography, bed roughness (in the form of an effective roughness height), and upstream and downstream hydraulic boundary conditions (i.e., water levels and discharge). Accurate topography is the primary variable that allows for the development of a well calibrated model.

Topographic surfaces will be constructed by combining the total station survey data, RTS and RTK GPS standard survey data, bathymetric data, and the LiDAR ground return data. In order to increase the definition in areas of topographic gradient and variability, breaklines will be defined within the topographic surface. Breaklines enforce the topographic surface to 'snap' to the entire length of the line and are used to define features with large vertical gradient changes, such as cascades, toe of slopes, and boulders.

Before entering the data into the River2D model, topographic data from the site will be reviewed for errors in ArcMap and ArcScene. Triangulated Irregular Networks (TINs) will be developed to visualize the data in two and three dimensions

Mesh development will follow procedures outlined in the R2D_Mesh User's Manual (Waddle and Steffler 2002). When building a computational mesh, it is important to optimize for computational performance without sacrificing mesh quality. Using the topographic surface nodes to define the mesh is not recommended as the computational requirements for such a model exceed the limits of the software and currently available computer hardware. Instead, a low density uniform mesh is developed and then refined using a variety of techniques.

As recommended by the R2D_Mesh User's Manual, a balance between mesh density and computational burden will be addressed in part by applying a procedure called 'wet refinement' which places nodes at the centroid of each mesh element. This process ensures the appropriate mesh density in wetted areas only, while limiting mesh density in dry areas.

Another method used to refine the mesh is to review mesh-generated elevation contours as compared to bed elevation contours at an interval of 0.82-foot with a goal of close contour approximation. Since the topographic points and mesh nodes are not in the same location, the contours will not be exactly the same. Therefore, to increase contour agreement, additional nodes may be added in topographically complex areas. To achieve the appropriate mesh density over all simulation flows, the mesh will be iteratively refined in the context of the full range of possible wetted areas.

A third method used to refine the mesh will be to identify large elevation differences between topographic data points and the interpolated elevation of each mesh triangle. Most often, large elevation differences exist in areas of high gradient (e.g., cascade) or significant localized topographic relief (e.g., cliff or vertical bank). Mesh triangles that exceed a 0.82-ft difference threshold are highlighted yellow in the mesh development software and further refined until the difference is no longer detected.

QI is a mesh quality index where a value of 1.0 represents a mesh comprised of perfect equilateral triangles. The goal minimum triangle quality index (QI) for each computational mesh is 0.15. Low QI values (i.e., <0.10) do not necessarily compromise model quality, but will increase computational run times. Tools in the mesh development software are used to improve geometry to achieve the minimum goal QI value.

One initial base mesh used for model calibration will be used for all simulation runs. However, it will be necessary to make small changes if model run time errors (i.e., eddy shedding velocity oscillation, extremely high velocity, or Froude number) occur.

Model Calibration

Model parameters such as bed roughness (Ks, in the form of an effective roughness height), substrate transmissivity (tr) and eddy viscosity can be adjusted during model calibration to reflect field conditions. A stage-wise approach with target criteria for model performance will be used to guide calibration. The specific stages and criteria are discussed below.

For the initial hydraulic model, hydraulic calibration tests will be conducted using the target calibration flows of 200 cfs and 1,200 cfs. Bed roughness (Ks) and transmissivity (tr) will be varied as necessary to match observed WSEs and wetted area. As part of normal calibration, Ks and tr values are incrementally adjusted through an integrative sensitivity analysis until modeled WSEs calibrate well to observed WSEs. In addition to the WSE comparisons, velocity and depth predictions will be compared to field measured data to evaluate changes made to Ks.

The term “Ks” is scientific notation for bed roughness factor (in meters) and the term refers to gradation of material in the river. Compared to traditional one-dimensional models, where many two-dimensional effects are abstracted into the resistance factor, the 2D resistance term accounts only for the direct bed shear (Steffler and Blackburn 2002). Ks is iteratively varied as necessary to match observed water surface elevations using the default transmissivity of tr = 0.1. In general, the initial Ks value entered is 1-3 times the grain size documented during field data collection. Multiple regional Ks values (i.e., heterogeneous substrate material and/or large elevation changes) may be selected for each study site based on model performance.

Groundwater transmissivity (tr) is a user-defined variable which corresponds to groundwater flow and the relationship to surface flow. The default value is 0.1 which ensures that groundwater discharge is negligible. Because subsurface flow through gravel or cobble may be present at the study site, it may be necessary to modify the default value of tr to aid in the wetting and drying function throughout the model domain.

The target criterion for mean error in WSE between simulated versus observed data is, to a large extent, based on the accuracy of the survey equipment used to measure WSE. It is also important to recognize the influence of highly heterogeneous or high gradient topography (e.g., cascades and high gradient riffles) habitats on differences between field data and model data. Given the expected range of site characteristics in the upper Tuolumne River an average of 0.10 ft difference between simulated and observed WSE will be targeted.

Similarly, no specific target calibration criteria exist for velocity or depth parameters as these variables are greatly influenced by the differences in topographic detail between the field conditions, initial bed file detail, and the final bed detail resulting from the interpolated mesh. Using professional judgment and standard industry practice, velocity and depth variables are reviewed for reasonableness and significant errors in depth (i.e., > 0.33 ft mean error) and velocity (i.e., > 0.5 fps mean error) are evaluated. For all sets of model calibration variables, the correlation coefficient (r) and the coefficient of determination (r2) (i.e., percent of variance in an indicator variable explained by a factor and the measure of the proportion of variance of model results, respectively) will be calculated. In general, coefficients greater than 0.7 are expected while coefficient of determination values for velocity magnitude are expected to be within a range of 0.4 and 0.8 (Pasternack 2011).

Flow field velocity vectors (i.e., the direction and magnitude) are used to evaluate velocity prediction reasonableness during the calibration process but are otherwise not incorporated into the statistical review process.

Model convergence for a given hydraulic simulation is achieved and accepted when the inflow (Qin) equals outflow (Qout) and the solution change is nominal. Solution change is the relative change in the solution variable over the last time step. Specific criteria thresholds do not exist for these parameters and are largely based on the magnitude of the simulation discharge and the professional judgment of the modeler. The target solution change goal will be 0.0001. This target value is consistent with recommendations made in the River2D User's Manual (Steffler and Blackburn 2002).

Step 4 – Aquatic Habitat Modeling

Habitat Suitability Criteria

HSC define the range of microhabitat variables that are suitable for a particular species and lifestage of interest. HSC provide the biological criteria input to the River2D model which combines the physical habitat data and the habitat suitability criteria into a site-wide habitat suitability index (i.e., Weighted Usable Area or WUA) over a range of simulation flows. Variables typically defined with HSC include depth, velocity, instream cover and bottom substrate. HSC values range from 0.0 to 1.0, indicating habitat conditions that are unsuitable to optimal, respectively. WUA is defined as the sum of stream surface area within a nodal area model domain or stream reach, weighted by multiplying area by habitat suitability variables, most often velocity, depth, and substrate or cover, which range from 0.0 to 1.0 each.

Spring-run Chinook salmon HSC information compiled for the McCloud River, a tributary of the Sacramento River, will be used for habitat modeling. The HSC were recently developed for use in a PHABSIM study assessing potential habitat availability related to the reintroduction of Chinook salmon upstream of Shasta Lake (PG&E 2011). The PHABSIM study was conducted for PG&E's McCloud Pit Hydroelectric Project (FERC No. 2106) (PG&E 2012). Using the best available HSC information and professional judgment, composite curves were developed for spawning, fry and juvenile lifestages. Holding HSC were not developed in the process. Holding habitat will be evaluated in the *Upper Tuolumne River Habitat Mapping and Macroinvertebrate Assessment.* Model results from this study may, however, inform the suitability of holding habitat. Spring-run periodicity information will rely upon information provided in Technical Memorandum No. 1 (TID/MID 2015).

Steelhead and fall-run Chinook salmon HSC information developed for the lower Tuolumne River instream flow study (Stillwater Sciences 2013) will be used to model habitat suitability in this study. Spawning and juvenile lifestages will be modeled. The Districts note that the lower Tuolumne River HSC may require some modification to appropriately be used in the upper Tuolumne River channel. Modifications to HSC will be made by a regional HSC expert familiar with the proposed curves and any changes will be thoroughly documented in the final report. Periodicity information for these species will rely upon information provided in Technical Memorandum No. 1 (TID/MID 2015).

Model Simulation

Approximately 18 discharges will be simulated for each study site resulting in an expected flow range of 50 cfs to 2,000 cfs. Habitat suitability and WUA for all fish species and lifestages will be calculated for each simulation flow. In order to calculate habitat suitability, four data inputs are required: a fish preference file (i.e., HSC), a channel index, depth, and velocity. A fish preference file is loaded into River2D as a text file. Depth and velocity values are provided from the model once a simulation has converged and is at a steady state. Channel index files are a River2D model file equivalent to a substrate and/or cover map of the entire study site. Substrate may only be applicable to the spawning lifestages and possibly fry/juvenile lifestages (as a cover component) but will depend on the HSC used.

For this study, the habitat suitability calculation will use the standard triple product function which multiplies depth, velocity, and channel index suitability together at each model node. Channel index interpolation will be defined using discrete node selection (i.e., nearest node rather than a continuous linear interpolation of the channel index values from surrounding nodes). Discrete node selection is typically applied to substrate classifications such that the original substrate code value is maintained. If cover codes are defined for the proposed HSC, continuous interpolation will be applied to cover indices where a gradient of cover may be best described by the interpolation function.

Hydropeaking Analysis – Habitat Persistence

It is of particular importance to evaluate and understand the potential effect of hydropeaking operations on the habitat utilized by various lifestages of aquatic organisms. For example, an area with suitable depth, velocity and substrate for spawning adults at one flow may become unsuitable as flows rise or recede over a large range of hydropeaking operations. At some point, if redds were developed at a high flow, they may become dewatered at lower flows. Similarly, it is important to understand the spatial and temporal distribution of habitat for fry and juvenile salmonids. Suitable rearing habitat at one flow may quickly become unsuitable and shift in location when flows rapidly increase or decrease. These analyses are often termed habitat effectiveness, or habitat persistence. These terms relate to the temporal and spatial change in habitat suitability and distribution under changing flow conditions.

Within each model domain, regions of special interest (e.g., spawning gravel patches) will be identified. The areas of interest (AOI) will be areas that could provide suitable spawning and rearing habitat under a range of flow conditions. Polygons representing the AOI regions will be digitized in ArcGIS in order to extract data from model nodes in the computational mesh.

Relying on information generated from each of the model simulation runs, model parameters such as suitability, WSE, velocity and depth will be extracted at each model node such that changes in each parameter, per unit discharge, can be calculated and evaluated. These analyses will be conducted using Geographic Information System (GIS) and spreadsheet tools.

Effects on aquatic habitat from daily changes in power plant operation will be modeled for time periods specified by species and lifestage periodicity and will be initially conducted at 15-minute to 1-hr time intervals using data collected at each site by stage recorders. Additional longer duration analyses will focus on weekly or monthly time steps and rely on hydrologic time series data from representative water years (e.g., dry, normal and wet). Results for the selected AOI regions in each model domain will be reported in both tabular and spatial form.

Step 5 – Reporting

A detailed technical memorandum will be provided that includes the following sections: (1) Study Goals and Objectives; (2) Methods; (3) Results; (4) Discussion; and (5) Description of Variances from the study plan, if any. A number of report attachments will include, but not be limited to, additional data such as representative site photographs and, habitat suitability maps. Models and interactive spreadsheets will be made available on CD.

5.0 STUDY SCHEDULE

Final study sites will be selected once data from habitat mapping and spawning gravel surveys are completed and data evaluated. Field data collection is anticipated to commence in the fall of 2016. Hydraulic and habitat modeling and associated analyses will be conducted in the fall of 2016 and winter of 2017. A progress report will be included in the February 2017 Updated Study Report.

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REVISED DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Regulatory Context for Reintroduction

May 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Regulatory Context for Reintroduction review is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to evaluate federal, state, and local regulatory issues that may be associated with the reintroduction of Chinook salmon and steelhead into the upper Tuolumne River above the Don Pedro Project.

2.0 STUDY AREA

The study area will encompass the Tuolumne River basin, including Don Pedro Reservoir and the mainstem Tuolumne River, associated tributaries (North Fork Tuolumne River, Clavey River, Cherry Creek, etc.), and surrounding public and private land.

3.0 STUDY GOALS

This regulatory review will evaluate federal, state, and local regulatory issues associated with the potential introduction of fall-run and spring-run Chinook (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) into the upper Tuolumne River. The upper Tuolumne River basin spans the jurisdictions of several federal land management agencies (United States Forest Service [USFS], Bureau of Land Management [BLM], and National Park Service [NPS]), while the lower Tuolumne River basin is primarily state and private land. Current activities related to fisheries management (stocking, setting of fishing areas, seasons, limits, and catch quotas) are the responsibility of the State of California. With the potential introduction of protected anadromous salmonids (i.e., spring-run Chinook and steelhead), regulatory requirements related to such laws as the Endangered Species Act, Magnuson-Stevens Fishery Conservation and Management Act, Clean Water Act, National Environmental Protection Act, the Federal Land Policy and Management Act, and California Environmental Quality Act may become relevant to activities occurring in the study area. The goals of this study are to:

- identify applicable existing legal precedent, regulatory guidance and resource management plans in the study area;
- identify additional regulatory guidance and rules that may apply to or affect the reintroduction of Chinook and/or steelhead; and
- identify and define potential federal, state, and local regulatory issues associated with the potential fish passage/reintroduction program.

4.0 STUDY METHODS

The introduction of new species into the upper river may affect current uses and regulatory requirements/restrictions throughout the basin. A comprehensive understanding of the regulatory aspects of introducing federal- and state-listed species to the Tuolumne River watershed is necessary. For purposes of this evaluation, the regulatory context is defined as legal precedent, rules, regulations and guidelines in land and species management that may apply to land and species management in the study area.

State and federal resource management agencies will be contacted to confirm all relevant guidance documents and supporting materials are identified. A summary of regulations and authorities applicable and potentially applicable to activities in the watershed will be completed. This study report will include a matrix of species and land management goals, responsible authorities, and applicable laws and regulations relevant to current and future proposed reintroduction or fish passage activities in the watershed. An initial list of documents to be reviewed is provided below and will be expanded as necessary based on consultation with licensing participants.

- Recovery Plan for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead (National Marine Fisheries Service 2014)
- Sierra Nevada Forest and Community Initiative (SNFCI) Action Plan (Sierra Nevada Conservancy 2014)
- The State of the Sierra Nevada's Forests (Sierra Nevada Conservancy 2014)
- Tuolumne Wild and Scenic River Comprehensive Management Plan and supporting documents (NPS 2014)
- Sierra Nevada Forest Plan and Amendments (USFS 2004, 2013)
- Stanislaus National Forest Plan Direction (USFS 2010)
- Sierra Resource Management Plan (BLM 2008)
- Steelhead Restoration and Management Plan for California (California Department of Fish and Game 1996)
- Tuolumne County General Plan (Tuolumne County 1996)
- Tuolumne Wild and Scenic River Management Plan (USFS 1998)
- Red Hills Management Plan (BLM 1985)

5.0 STUDY SCHEDULE

The anticipated schedule is to gather relevant plans and consult licensing participants and agencies from May through July 2016. A draft report will be provided to the Technical Committee in November 2016 with a final report included in the February 2017 Updated Study Report.

6.0 REFERENCES

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REVISED DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Socioeconomic Scoping Study

May 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Socioeconomic Scoping Study is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to evaluate the potential socioeconomic effects of reintroducing Chinook salmon and steelhead into the upper Tuolumne River above the Don Pedro Project.

2.0 STUDY AREA

The study area will encompass the upper and lower Tuolumne River basin, including Don Pedro Reservoir and the mainstem Tuolumne River, associated tributaries (North Fork Tuolumne River, Clavey River, Cherry Creek, etc.), and surrounding public and private land.

3.0 STUDY GOALS

The goal of this study is to develop a comprehensive description of the human environment, activities, and current uses of the resources and facilities in the study area that may be impacted by constructing and/or operating fish passage facilities and the introduction of anadromous fish.

4.0 STUDY METHODS

Socioeconomic considerations are identified as a key element in assessing whether potential reintroduction methods could be successful (Andersen et al. 2014). Current management of the Don Pedro Reservoir and Tuolumne River supports a wide range of resources, uses, and users. The upper watershed includes the Tuolumne Wild & Scenic River segment managed for several outstanding resource values and is utilized by commercial and private recreational boaters. Other uses in the watershed include the City and County of San Francisco's operation of the Hetch Hetchy Project, private timber practices, water supply, flood control, state recreation areas, private land, and a recreational fishery. Don Pedro Reservoir provides numerous recreational activities, including house boating and a popular recreational fishery. County government and businesses benefit from the economic activities supported by the activities in the watershed.

As part of this study, a comprehensive survey of uses in the Tuolumne River watershed will be conducted and potential issues will be identified for consideration in the reintroduction assessment. A literature survey and review of existing information from the Don Pedro Recreation Agency, county and federal land management agencies, and other sources will be conducted. Surveys and/or focus groups will be used to verify and expand upon available information related to existing uses of the watershed that could be impacted by a fish reintroduction program. The information collected in this study is designed to support and expand upon the socioeconomic considerations identified in the Framework, such as recreation impacts (e.g., river recreation, reservoir recreation, recreational fishing) and impacts on private resources (e.g., timber resources, private landowners, agricultural water supply), and will be considered in any socioeconomic evaluation done once reintroduction and fish passage options are further developed.

5.0 STUDY SCHEDULE

The anticipated schedule is the study team will gather available literature and consult licensing participants and agencies from April to July 2016. The literature review and data gathering will be completed over the summer, with a draft report issued to the Technical Committee by November 2016. The final report will be included in the February 2017 Updated Study Report.

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REVISED DRAFT STUDY PLAN

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study

May 2016

1.0 BACKGROUND

As part of the La Grange Hydroelectric Project licensing proceeding, the Districts are undertaking the Fish Passage Facilities Alternatives Assessment (Fish Passage Assessment), the goal of which is to identify and develop concept-level alternatives for upstream and downstream passage of Chinook salmon and steelhead at the La Grange and Don Pedro dams. In September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design for the Fish Passage Assessment. In November 2015, licensing participants adopted a plan to implement the Upper Tuolumne River Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne River (TID/MID 2016). As part of implementing the Framework, a number of environmental studies are planned.

The Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study is one of several studies to be implemented in 2016 in support of the Framework. Information collected during this study will be used to characterize the distribution, quantity, and quality of suitable Chinook salmon and steelhead spawning gravel in the upper Tuolumne River.

2.0 STUDY AREA

The study area for mapping Chinook salmon and steelhead spawning gravel in the upper Tuolumne River includes the approximately 24-mile reach from the upstream limit of the Don Pedro Project (approximately RM 81) to Early Intake (approximately RM 105).

3.0 STUDY GOALS

Successful Chinook salmon and steelhead spawning and fry production are dependent on the abundance and quality of suitable spawning gravel. Information on the amount, distribution, and quality of spawning gravel are critical components in estimating habitat carrying capacity and assessing limiting factors. Limited information is available to describe the distribution, quantity, and quality of spawning gravel in the upper Tuolumne River. The goal of this study is to characterize the distribution, quantity, and quality of suitable Chinook salmon and steelhead spawning gravel in the upper Tuolumne River.

The study objectives are:

- map the distribution of potentially suitable spawning gravel available for Chinook salmon and steelhead in the upper Tuolumne River;
- quantify the amount of suitable spawning gravel in the reach between RM 81 and RM 105; and
- assess the quality of potentially suitable spawning gravel based on gravel size characteristics, sorting, angularity, embeddedness, substrate depth, and permeability measured in a representative sample of gravel patches.

Study results will help inform the feasibility of introducing Chinook salmon and steelhead into the upper Tuolumne River.

4.0 STUDY METHODS

4.1 Spawning Gravel Mapping

Probable locations of gravel patches will initially be delineated in a Geographic Information System (GIS) using recent LIDAR, the best available aerial photography, and other existing information from prior mapping efforts and studies. This desktop mapping step will inform field staff as to the approximate distribution of gravel deposits and the most efficient logistical process for locating and mapping those deposits in the field. Field mapping criteria and protocols will be consistent with studies in the lower Tuolumne River (TID/MID 1992, 2013), and will be refined following this initial desktop analysis, as needed.

Potentially suitable spawning gravel patches will then be delineated in the field on map tiles from high resolution orthorectified aerial imagery (e.g., 8-13-2007 photography and mapbook). A laser range finder will be used to measure the approximate dimensions of each gravel patch, if necessary to support the delineation of patch areas on field tiles. Each patch will be assigned a unique ID. Field delineation of potentially suitable spawning gravel patches will be performed by a two-person crew using whitewater raft support to access the study reach. The crew will stop frequently to locate and investigate preliminary gravel polygons obtained from desktop mapping and any other deposits that appear to meet the mapping criteria. Inflatable kayaks may also be used to navigate unwadable areas requiring investigation. To the extent feasible, mapping will be performed during low or off-peak flow conditions to optimize visibility of potentially suitable spawning gravels. Supplemental access to limited portions of the study reach are available at vehicle road crossings and by foot, depending on terrain and river flow.

4.1.1 Gravel Particle Size Criteria

Species-specific particle size criteria that will be used to delineate potentially suitable spawning gravel for Chinook salmon and steelhead in the upper Tuolumne River study reach are summarized in Table 1.0. Patches with substantially different surface particle size characteristics will be separately delineated. Chinook salmon typically spawn in substrates with a D_{50} of 11–78 mm (0.42–3.0 in) (Platts et al. 1979, as cited in Kondolf and Wolman 1993, Chambers et al. 1954, 1955, as cited in Kondolf and Wolman 1993). Steelhead typically spawn in substrates with a D_{50} of 10–46 mm (0.4–1.8 in.) (Barnhart 1991, Kondolf and Wolman 1993). Wolman (1954) pebble counts will be conducted in selected areas to calibrate visual estimates of grain size parameters using methods developed by Bunte and Abt (2001). These preliminary particle size criteria, based on D_{50} reported in the literature, may be refined in coordination with the Technical Committee prior to the field effort.

4.1.2 Minimum Gravel Patch Size Criteria

Minimum patch size criteria for mapping potentially suitable spawning gravel will be determined prior to the field effort based on a combination of (1) the minimum area required for a spawning Chinook salmon or steelhead pair and (2) the scale and resolution of available imagery used as a base for field mapping tiles. The minimum spawning area generally identified for Chinook salmon is approximately 12 m^2 (Healy 1991, Bjorn and Reiser 1991, Ward and Kier 1999). Steelhead typically defend a redd only during the period of active spawning, and therefore the area required for a spawning steelhead pair is approximately equal to the disturbed area of the redd. . For mapping purposes, we will initially assume that a minimum patch size of approximately 6 m^2 is required for a steelhead pair to build and defend a redd (Bjornn and Reiser 1991; Orcutt et al. 1968). Preliminary minimum patch size criteria for mapping potentially suitable spawning gravel will be refined prior to field mapping based on review of available spawning patch information from the lower Tuolumne River and other relevant Central Valley river systems.

Table 1.0 Preliminary particle size and minimum patch size criteria for mapping potential spawning gravel for Chinook salmon and steelhead in the upper Tuolumne River.

Species	Gravel D_{50} mm (in.)	Minimum Patch Size Required for Spawning, m^2 (ft^2)	References
Chinook salmon	10–78 (0.4–3)	12 (130)	Platts et al. 1979, Chambers et al. 1954, 1955, all as cited in Kondolf and Wolman 1993; Healy 1991, Bjorn and Reiser 1991, Ward and Kier 1999
Steelhead	10–46 (0.4–2)	6 (65)	Barnhart 1991, Kondolf and Wolman 1993, Bjornn and Reiser 1991, Orcutt et al. 1968

Note: D_{50} – diameter of particle (in millimeters) at which 50 percent of the sample is smaller (*e.g.*, median).

4.2 Spawning Gravel Quality

In addition to the particle size and minimum patch size criteria described above, measurements and observations of the quality of gravel patches will be collected in the field to inform spawning habitat quality. These will include additional gravel particle size parameters (e.g., D_{16}, D_{84}); characterization of particle sorting, angularity, and embeddedness; an estimate of the average substrate depth (where feasible); and measurements of permeability.

4.2.1 Field Observations of Gravel Quality

Sorting describes the homogeneity of surficial particles within a patch. Spawning salmonids prefer substrates that are relatively well sorted. The degree of sorting will be visually estimated using the comparison chart in Compton (1985). Angular grains tend to pack more tightly than rounded particles and are more likely to slow intragravel flow. More loosely packed and rounded particles also increase a fish's ability to dislodge the substrate during redd construction. The degree of particle angularity within a patch will be visually estimated based on the comparison chart in Powers (1989). Substrate embeddedness describes the presence of fine sediment in the gravel interstices. Substrate embeddedness is measured by selecting a random sample of coarse surface particles within the patch and measuring the percent of the particle that is surrounded or buried by fine sediment (fines and sands <2 mm) (Burns and Edwards 1985). Embeddedness measurements will be conducted concurrent with pebble counts and/or during permeability sampling. The substrate depth required for redd construction and egg deposition likely depends on the size of the spawning female and on particle size characteristics, as well as flow depth and velocity. Chinook salmon egg pocket depths range from 8 to 51 cm (3 to 20 in), with an average of 22 cm (8.5 in) (Burner 1951). Steelhead egg pocket depths range from 15 to 28 cm (6 to 11 in), with an average of 21 cm (8.4 in) (Briggs 1953). Substrate depth will be estimated from exposure of bedrock and boulder framework and by probing with a Silvey rod.

4.2.2 Gravel Permeability

Gravel permeability will be collected to characterize incubation conditions and estimate predicted survival-to-emergence. The quality of spawning gravel will be assessed by measuring streambed permeability at select patches following the methods of Barnard and McBain (1994). Gravel inflow rate (ml/sec), which is an index of intragravel permeability (cm/hr), will be measured using a steel standpipe adapted from the Terhune Mark VI standpipe design (Terhume 1958; Barnard and McBain 1994). At select gravel patches, the standpipe will be driven into the gravel to an approximate depth of 30 cm (12 inches) using a protective end cap and sledge hammer. A battery powered peristaltic pump (e.g., IP Masterflex brand pump or equivalent) will be used to create a 2.5 cm head differential in the standpipe and the rate at which water is drawn from the pipe will be measured. While maintaining this constant pressure head, water will be drawn through the perforations in the standpipe buried in the gravel, and a stopwatch will be used to measure the time required to collect a volume of water.

Gravel permeability can be highly variable within and between patches in a reach. Therefore, a sampling plan will be developed based on the results of the spawning gravel mapping effort. The sampling plan will outline an approach and provide field protocols for characterizing the permeability of potential spawning patches throughout the study reach. The approach will generally rely on assigning patches to a morphologic unit (e.g., pool tail) and sampling from consistently similar positions within a morphologic unit. Sampling will occur in the morphological unit(s) that best exhibit the effects of fine sediment supply on spawning gravel quality and that have the highest potential value to spawning Chinook and steelhead. Permeability sampling results may be stratified by subreach, as appropriate. Desktop and field-based mapping of potentially suitable spawning gravel patches will inform an appropriate system for delineating morphological units, appropriate permeability sampling locations within those units, and appropriate delineation of any subreaches useful in extrapolating permeability sampling results.

4.2.3 Gravel Quality Ranking

When a gravel patch is identified as potentially suitable based on minimum area and particle size criteria, a qualitative ranking of overall suitability from 1 (poor) to 10 (good) will be assigned to the patch based on an overall assessment of the following physical characteristics (substrate particle size, sorting, angularity, embeddedness, gravel depth, permeability, and patch location and size). A separate ranking will be assigned for spawning gravel patches potentially suitable for Chinook salmon and steelhead. Although reliable rankings rely heavily on the professional judgment and personal experience of the survey participants, this ranking will allow comparison of patch quality. Rankings will be summarized as follows: 1–3= low suitability, 4–7= medium suitability, and 8–10= high suitability.

4.3 Data Processing and Analysis

Potentially suitable spawning gravel patches delineated on field tiles will be digitized using GIS, and area estimates for each patch will be calculated. The quantity and quality of potentially suitable spawning gravel patches will be summarized in tabular format.

Results to be reported include the following:

- shapefiles with polygons of potentially suitable spawning gravel patches and associated patch attributes;
- a database of attributes for each mapped gravel patch (i.e., measured and/or estimated particle size parameters, sorting, angularity, embeddedness, estimated mean depth [where feasible], associated channel morphological feature, and quality score);
- mean, minimum and maximum gravel inflow rates (ml/sec) as an index of intragravel permeability (cm/hr) for each sample site, presented by river mile location; and
- derived mean permeability (cm/hr) by river mile.

5.0 STUDY SCHEDULE

The anticipated schedule is to conduct the initial office-based analysis in May-June 2016, with subsequent field surveys in August/September 2016 for gravel mapping and gravel quality assessments. Mapping of potentially suitable spawning gravel will occur over two separate five-day field trips. Permeability sampling will occur over one three-day field trip to be conducted after the gravel mapping is completed. A draft report will be provided to the Technical Committee in November 2016 with a final report to be included in the February 2017 Updated Study Report.

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LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

FISH PASSAGE FACILITIES ALTERNATIVES ASSESSMENT
WATER TEMPERATURE SUBCOMMITTEE CONFERENCE CALL

SEPTEMBER 15, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Water Temperature Criteria Subcommittee Conference Call

Thursday, September 15, 2016
1:00 pm to 3:00 pm

Final Meeting Notes

Meeting Attendees		
No.	**Name**	**Organization**
1	Allison Boucher	Tuolumne River Conservancy
2	Steve Boyd	Turlock Irrigation District
3	Paul Bratovich	HDR, consultant to the Districts
4	Jean Castillo	National Marine Fisheries Service
5	Greg Dias	Modesto Irrigation District
6	Jesse Deason	HDR, consultant to the Districts
7	John Devine	HDR, consultant to the Districts
8	Art Godwin	Turlock Irrigation District
9	Andy Gordus	California Department of Fish and Wildlife, Fresno
10	Chuck Hanson	Hanson Environmental, consultant to the Districts
11	Jonathan Knapp	City and County of San Francisco
12	Patrick Koepele	Tuolumne River Trust
13	Bao Le	HDR, consultant to the Districts
14	Ellen Levin	City and County of San Francisco
15	Lonnie Moore	Private citizen
16	Gretchen Murphey	California Department of Fish and Wildlife
17	Bill Paris	Modesto Irrigation District
18	Bill Sears	City and County of San Francisco
19	Chris Shutes	California Sportfishing Protection Alliance
20	Ron Yoshiyama	City and County of San Francisco

On September 15, 2016, Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) hosted the first Water Temperature Criteria Subcommittee (Temperature Subcommittee) conference call for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment and Upper Tuolumne River Fish Reintroduction Assessment Framework. This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting. Attachment A to this document provides meeting materials.

Mr. Bao Le (HDR, consultant to the Districts) welcomed meeting attendees. Mr. Le said meeting materials for this call are available on the La Grange Project licensing website. There are three documents: (1) meeting agenda, (2) Temperature Subcommittee draft process and schedule, and (3) water temperature criteria matrix. Mr. Le said the process and schedule document is meant to provide a draft description of the purpose of the Temperature Subcommittee and what the Temperature Subcommittee will accomplish. Mr. Le said the water temperature criteria matrix is the result of an action item the Districts had from Workshop No. 5, held on May 19, 2016, to develop a document summarizing what water temperature criteria were developed for the Yuba River, as well as what criteria were developed for other potentially relevant programs in the Central Valley.

Mr. Le reviewed the meeting agenda and the meeting objectives. Mr. Le asked if there are any questions. There were none.

Mr. Paul Bratovich (HDR) reviewed the draft process and schedule document. Mr. Bratovich said evaluating thermal habitat suitability is a fundamental component in determining the feasibility of a reintroduction program, especially for anadromous salmonids. Mr. Bratovich added that evaluating water thermal habitat suitability could be considered as an appropriate initial step in evaluating physical habitat suitability or availability because if habitat is not thermally suitable then it will not be suitable from other habitat perspectives. Mr. Bratovich said the process and schedule document briefly discusses why the Temperature Subcommittee was formed and the purpose of the group. The document also describes what work the Temperature Subcommittee will accomplish and provides an implementation schedule. By December 2016, the goal is to have a technical document that evaluates thermal habitat suitability for reintroduction purposes. Mr. Bratovich noted there is a lot to accomplish in a relatively short amount of time.

Mr. Bratovich said the Temperature Subcommittee needs to establish the purpose of the proposed activities. The purpose could be as simple as establishing the technical basis for evaluating temperature regimes in different reaches of the Tuolumne River. Mr. Bratovich said drilling down to specific objectives will help frame exactly what the Temperature Subcommittee will do and how it will be done. To evaluate thermal habitat suitability, the Temperature Subcommittee must first confirm target species being considered for reintroduction, life stage periodicities, what river reaches should be considered, and at what times temperature criteria are applicable.

Mr. Le said some work has already been done to establish an area of consideration and target species and life stage periodicities. Fieldwork for the Upper Tuolumne River Basin Fish Migration Barriers Study is nearing completion and total barriers have been identified in some of the tributaries and could be used to help identify evaluation reaches. Mr. Le said relevant information on proposed species and some life stage periodicity information is also available in the Fish Passage Facilities Assessment Technical Memorandum (TM) No. 1 (available here on the La Grange Project licensing website). Mr. Le noted that although this document was provided to licensing participants for review in fall 2015 and identified additional relevant information needs, the Districts have not received any feedback on TM No. 1.

Mr. Bratovich said he has been involved in several processes similar to this one, and in these other processes it had been very helpful at the beginning of the process to produce a glossary of terms. Mr. Bratovich said terms related to thermal habitat suitability, such as "optimal", are often interpreted to mean different things by different individuals. A glossary of terms helps ensure all members of the team are speaking the same language. Mr. Le said the Districts will develop a glossary of terms.

Mr. Bratovich said that after the purpose of the Temperature Subcommittee is established, the next step is to undertake a comprehensive literature review. Mr. Bratovich said some comprehensive reviews of information in the Central Valley have already been completed. There is a lot of information available in the Central Valley as well as in the rest of California and the Pacific Northwest. Mr. Bratovich said a literature review completed by the Yuba Salmon Forum (YSF) contains over 100 references and this literature review would be a good basis to start this effort. This group will also want to include site-specific data, if available, for the Tuolumne River as well.

Mr. Bratovich said once the literature review is completed, the next step is to turn the information collected into a suite of water temperature index values that indicate suitability for reintroduction purposes by such variables as species, run, and life stage. Once water temperature index values are created, the Temperature Subcommittee will need to determine what metrics will be used. There are many different types of metrics, such as maximum weekly average temperature (MWAT) and seven day average daily maximum (7DADM). The literature review will produce a number of different options to support further discussion. Once the Temperature Subcommittee decides on a metric, thermal habitat suitability will be evaluated using data produced by the Upper Tuolumne River Basin Water Temperature Monitoring and Modeling Study.

Mr. Le asked if anyone would like to share additional thoughts regarding the purpose of the Temperature Subcommittee or the overview document. Mr. Chris Shutes (California Sportfishing Protection Alliance) said a lot of the activities proposed for the Temperature Subcommittee were addressed previously in the YSF process. Mr. Shutes said many individuals on this conference call participated in that process. Mr. Shutes noted that the YSF had a lot of stakeholder buy-in. Mr. Bratovich agreed with this point. Mr. Shutes suggested that the document prepared for the YSF entitled *Water Temperature Considerations for Yuba River Basin Anadromous Salmonid Reintroduction Evaluations* be distributed to the Temperature Subcommittee for review. The Temperature Subcommittee can determine how much can be adapted for this process. We can also walk through how YSF decisions were made and why, and this may help the process for the Tuolumne River move along quicker and be more cost-effective. Mr. Le said that is a good point and part of the rationale for including Mr. Bratovich in this process was his YSF experience. Mr. Le said the Districts see the YSF serving as a foundation for the work to be done here and using the available information from that process seems prudent as a means to avoid "reinventing the wheel".

Mr. Le asked if there are any questions about the overall process or the suite of objectives. There were none.

Mr. Le said the implementation schedule laid out in the overview document is fairly aggressive. The goal is to complete all objectives by the end of 2016. The end product will be a technical document summarizing the findings.

Mr. Le said the Districts had an action item from Workshop No. 5 to summarize water temperature criteria from other processes in the Central Valley. This information is summarized in the water temperature criteria matrix. Mr. Le noted that based on the four or five processes summarized in the matrix, there is quite a bit of variation among watersheds regarding criteria, metrics, and compliance. Mr. Le added that the matrix is not intended to be an endorsement by the Districts of any one process in particular. Dr. Chuck Hanson (Hanson Environmental, consultant to the Districts) added that the purpose of the matrix is to facilitate discussion and provide a central source of information. The matrix summarizes information available in technical reports and various other sources related to water temperature criteria on the American River, Feather River, San Joaquin River, Shasta River, and Yuba River developed for FERC processes, State Board processes, and other processes. The document also summarizes EPA (2003) criteria to provide context for federal river-specific criteria. Dr. Hanson said the matrix is a living document that can serve as a cornerstone to help define temperature criteria from a suitability perspective as well as a sub-optimal perspective.

Mr. Le asked if there are any comments about the matrix and if individuals know of additional rivers or reaches to add to matrix. He also asked if individuals think the matrix is informative. Ms. Jean Castillo (National Marine Fisheries Service [NMFS]) said she thinks the matrix is very informative, especially since she is new to the area. Ms. Castillo said she thinks a glossary of terms is a great idea. She added that a list of acronyms would also be helpful. Mr. Le said the Districts will prepare an acronym list in addition to a glossary of terms.

Mr. Le asked the individuals on the call to review the matrix. He said the Districts welcome any comments, thoughts, or additions to the document. Mr. Le reiterated that the matrix is a living document.

Regarding the literature review, Mr. Le said information collected by previous review efforts will serve as a valuable starting place. It is now time to get feedback on what management agency literature and documents must still be reviewed. Mr. Bratovich added that basin-specific information must also be reviewed.

Mr. Le said the objective of the next Temperature Subcommittee call will be to present and discuss the results from the literature review. Prior to the next call, Mr. Le asked that members of the Temperature Subcommittee provide any information they think is relevant to the literature review, whether or not it may have already been reviewed as part of the YSF literature review. Mr. Le said any information should be sent to Ms. Rose Staples (HDR) at rose.staples@hdrinc.com.

Mr. Le said there is also a need to establish the species of interest. At this time, fall-run Chinook, spring-run Chinook, and steelhead are being considered the target species of interest. However, Mr. Le noted that the Districts are skeptical about whether fall-run Chinook should still be considered a species of interest. At this time, the Districts will keep fall-run Chinook as part of the evaluation but wanted to make this point about their concerns. The Districts welcome feedback on this topic. Ms. Castillo said she will check back with her NMFS colleagues about this. Ms. Gretchen Murphey (California Department of Fish and Wildlife [CDFW]) asked what species are being considered by the Reintroduction Goals Subcommittee. Mr. Le said until further feedback is received, the Reintroduction Goals Subcommittee is considering all three as species of interest. Mr. Lonnie Moore (private citizen) said he recently filed a paper on the FERC docket related to this topic. The paper summarizes historical information and previous studies about the historical presence of fall-run Chinook, spring-run Chinook, and steelhead in the Tuolumne River.

Mr. Le asked if there are any comments or questions about the literature review. There were none.

Ms. Murphey asked if an updated Don Pedro Project Swim Tunnel Study Report has been released. Mr. John Devine (HDR) said an updated study report was recently filed with FERC and should be appearing in the FERC docket soon. He said he would be happy to send a link to Ms. Murphey if she is unable to find it. [*On September 20, 2016, Mr. Devine emailed Ms. Murphey to explain he had been mistaken and an updated Swim Tunnel Study Report had not been filed with FERC. Mr. Devine said on September 6, 2016, the Districts received comments on the January 2015 draft Swim Tunnel Study Report from CDFW. The Districts will file the final report once the Districts respond to and address CDFW's comments.*]

Mr. Le said the Districts would like to have the next Temperature Subcommittee call in mid-October. Between now and the next call, Temperature Subcommittee members will plan to provide information to add to the literature review and the Districts will develop an acronym list and glossary of terms in addition to updating the body of literature relevant to temperature suitability criteria. Mr. Le requested that feedback on the literature review be provided to Ms. Staples by Friday, September 23.

Meeting attendees discussed dates for the next Temperature Subcommittee call. Mr. Le said the Districts will send out a Doodle poll for October 11, 12, 14, 17 and 18. The Districts will also send out notes from today's call.

Ms. Castillo requested that Mr. Le send her a copy of TM. No.1. Mr. Le said he will send this.

Dr. Ron Yoshiyama (City and County of San Francisco) requested that the year be added to future meeting agendas and meeting notes. Mr. Le said the year will be added to future meeting documents.

ACTION ITEMS

1. The Districts will distribute *Water Temperature Considerations for Yuba River Basin Anadromous Salmonid Reintroduction Evaluations* to the Temperature Subcommittee for review.

2. The Districts will prepare a glossary of terms.

3. The Districts will prepare an acronym list.

4. Ms. Castillo said she will check back with her NMFS colleagues about species for consideration.

5. Temperature Subcommittee members will provide feedback on information that should be considered as part of updating the existing YSF literature review by Friday, September 23.

6. The Districts will send out a Doodle poll for the next Temperature Subcommittee call. (complete)

7. The Districts will send out meeting notes. (complete)

8. Mr. Le will send Ms. Castillo a copy of TM No. 1. (complete)

9. The Districts will add the year to future meeting documents.

La Grange Hydroelectric Project
Reintroduction Assessment Framework
Water Temperature Criteria Subcommittee Conference Call

Thursday, September 15, 1:00 pm to 3:00 pm
Conference Line: 1-866-583-7984; Passcode: 814-0607

Meeting Objectives:

1. Review and discuss Water Temperature Criteria Subcommittee Overview.
2. Develop subcommittee "purpose" statement, specific objectives and confirm subcommittee schedule.
3. Review and discuss Water Temperature Criteria Matrix for select Central Valley reintroduction/fish passage programs (Districts' action item).
4. Discuss available existing information and identify scope for additional water temperature literature review.

TIME	TOPIC
10:00 am – 10:15 am	Introduction of Participants (All) Review Agenda and Meeting Objectives (Districts)
10:15 am – 10:45 am	Water Temperature Criteria Subcommittee (All) a. Why is it important? (Districts) b. Discuss Subcommittee Overview Document (Bao Le/Paul Bratovich)
10:45 am – 11:15 am	Water Temperature Criteria Subcommittee (All) a. Develop Purpose Statement and Objectives (Paul Bratovich) b. Confirm Schedule (Bao Le)
11:15 am – 11:50 am	Temperature Criteria Matrix and Literature Review Discussion (All) a. Temperature Criteria Matrix (Chuck Hanson) b. Existing Information and Additional Need for a Literature Review (Paul Bratovich)
11:50 am – 12:00 pm	Next Steps (All) a. Schedule next call and agenda topics b. Action items from this call

La Grange Hydroelectric Project Licensing (FERC No. 14581)
Upper Tuolumne River Reintroduction Assessment Framework
Water Temperature Subcommittee – Draft Process and Schedule

<u>Overview and Subcommittee Purpose</u>

Water temperature considerations are a primary component of assessing any potential anadromous salmonid reintroduction effort. As such, the Upper Tuolumne River Reintroduction Assessment Framework Plenary Group has established a water temperature subcommittee to begin investigating water temperature considerations pertinent to anadromous salmonid reintroduction opportunities in the accessible reaches of the Tuolumne River upstream of Don Pedro Reservoir (Upper Tuolumne River).

The subcommittee, working in collaboration, is anticipated to address a suite of specific tasks related to the investigation of water temperature considerations, including the following:

- Establish the purpose ("charter") for the water temperature subcommittee.
- Evaluate the need for and if appropriate, conduct a comprehensive literature review of lifestage-specific water temperature relationships for target species of interest (TBD by the subcommittee).
- Identify a suite of water temperature index (WTI) values representing summarization of the literature review.
- Select water temperature criteria for each species-specific lifestage for reintroduction evaluation in the Upper Tuolumne River.
- Identify the water temperature evaluation methodological approach including metrics and application to monitoring and/or modeling data.
- Conduct species and lifestage-specific water temperature evaluations.
- Prepare a technical document reporting the results for all of the above objectives.

Subcommittee Purpose

An initial step in the process will be to establish the purpose for the subcommittee. Once a purpose has been established, detailed subcommittee objectives will also be identified

Comprehensive Literature Review and Water Temperature Index Values

For each species under consideration, an evaluation will be conducted to determine whether a comprehensive review of available literature to identify lifestage-specific water temperature index values is appropriate. For species requiring a literature review, this information may be used in the evaluation of thermally suitable habitat for reintroduction of anadromous salmonids in the Upper Tuolumne River. The thermal requirements of anadromous salmonids, in particular Chinook salmon and steelhead, have been extensively studied in California and elsewhere. The literature review will draw upon regional research, and if available, site specific information to inform the selection of WTI values to be used in the subcommittee's evaluation of the water temperature-related reintroduction potential in the reaches of the Upper Tuolumne River. Other considerations regarding thermal suitability may also be considered such as local adaptation, genetics, and information on potential source populations of target species.

Criteria Selection

In order to support a subsequent evaluation of thermally suitable habitat for selected target species in the Upper Tuolumne River, the subcommittee will collaboratively need to identify, define, and select appropriate water temperature criteria (e.g., WTIs, metric(s), lifestages, temporal distributions, etc.) based upon the available information resulting from the literature review and relevant site-specific information from Tuolumne River studies, if available.

Selecting and Implementing an Evaluation Approach

For the evaluation of thermally suitable habitat for potential reintroduction of anadromous salmonids into the upper Tuolumne River Basin, it is anticipated that water temperature modeling and/or monitoring will be applied for a comparison among selected rivers and reaches in the Basin. Concurrent with subcommittee activities, the Upper Tuolumne River Temperature Monitoring and Modeling Study is being implemented in support of the La Grange Hydroelectric Project licensing. Because this study has been approved by licensing participants, including those participating on the subcommittee, it is proposed that the model being developed as part of this study be used to support the thermally suitable habitat evaluation.

Reporting

As noted above, results of subcommittee activities will be summarized in a technical document. The technical document will undergo subcommittee review and be provided to the Upper Tuolumne River Reintroduction Assessment Framework Plenary Group when complete.

<u>Implementation Schedule</u>

It is envisioned that the aforementioned water temperature considerations will be addressed by the subcommittee through a series of subcommittee meetings corresponding to a schedule for the completion of key steps. At each step of the way (i.e., each meeting) the objective is to obtain agreement/acceptance of the topic addressed. A schedule is as follows:

- September 15, 2016
    - Convene subcommittee and develop “purpose” statement and objectives.
    - Review available, existing information and identify scope for additional literature review of lifestage-specific water temperature relationships.
    - Confirm subcommittee schedule.
- Early October 2016
    - Present/discuss results of literature review.
    - Identify a suite of WTI values representing a summarization of the literature review.
- Mid- to late October 2016
    - Select water temperature criteria for each species-specific lifestage for reintroduction evaluation.
        - Existing water temperature guidelines/standards.
        - Site-specific WTIs.
- November 2016

- Identify the water temperature evaluation methodological approach.
  - Water temperature metrics.
  - Metrics application to water temperature model and/or monitoring data.
- Conduct species and lifestage-specific evaluations.
- Prepare draft technical document reporting the results for all of the above objectives.

- December 2016
  - Prepare a final technical document.

Water Temperature Criteria for Select California Central Valley River Systems

Project	Species	Life Stage	Water Temperature	Timeframe	Location	Metric	Source(s)	Notes
Lower American River	Steelhead	Juvenile (rearing)	65°F or less (at the Watt Avenue Bridge) If analysis during the formulation of the Temperature Plan indicates that meeting a 65ºF water temperature target will prematurely exhaust the available cold water in Folsom Reservoir, the target water temperature in the summer may be increased by 1ºF increments up to 68ºF	May 15 – October 31	Watt Avenue Bridge	Daily average temperature (DAT)	Water Forum 2006 Water Forum 2007 NMFS 2009, as amended 2011, Biological Opinion	
	Fall-run Chinook	Adult (spawning) Egg (incubation)	60°F or less 56°F or less	As early in October as possible As early in November as possible	Hazel Avenue Hazel Avenue			
Lower Feather	Spring-run Chinook and steelhead	Not identified	56°F	January - April	Robinson Riffle	Daily mean	SWRCB 2010	
			56-63°F [1]	May 1-15				
			63°F	May 16 - August				
			63-58°F [2]	September 1-8				
			58°F	September 9-30				
			56°F	October - December				
San Joaquin	Fall-run Chinook and steelhead	Adult	64°F	September	Above Merced	7-day average of the daily maximum water temperature (7DADM)	CALFED 2009	Per modeling report (CALFED 2009): "It should be emphasized that the stakeholders agreed that the Panel criteria should only serve as a means for comparing simulated alternatives and should not be construed as an agreed upon criteria in establishing temperature policy in the basin. "
		Egg (incubation)	55°F	October - December	Above Merced			
		Juvenile (rearing)	61°F	January – April 15	Above Tuolumne Above Stanislaus (first two weeks of April)			
		Smolt	57°F	April 16 - May	Above Stanislaus			
		Juvenile (rearing)	61°F	June - August	Above Stanislaus (first week of June) Mossdale (2nd week of June – third week of July) Vernalis (forth week of July – August)			

[1] Indicates a period of transition from the first temperature to the second temperature.
[2] Indicates a period of transition from the first temperature to the second temperature.

Project	Species	Life Stage	Water Temperature	Timeframe	Location	Metric	Source(s)	Notes
Shasta	Winter-run Chinook	Egg/Alvin	56°F or less	May 15 – September 30	Between Balls Ferry and Bend Bridge	Daily average temperature (DAT)	BOR 2016 NMFS 2016	Scenarios identified to manage water to 55°F or less (7DADM) through the winter run spawning area.
	Spring-run Chinook	Egg/Alvin	56°F or less	October				
Yuba	Steelhead	Adult (migration)	64°F[3] / 68°F[4]	August – March	Smartsville, Daguerre Point Dam, Marysville	Maximum weekly average temperature (MWAT) Average daily water temperature (ADT) and monthly exceedance distributions	River Management Team (RMT) 2013 Bratovich et al. 2012	
		Adult (holding)	61°F / 65°F	August – March	Smartsville, Daguerre Point Dam, Marysville			
		Adult (spawning)	54°F / 57°F	January – April	Smartsville and Daguerre Point Dam			
		Egg (incubation)	54°F / 57°F	January – May	Smartsville and Daguerre Point Dam			
		Juvenile (rearing and downstream movement)	65°F / 68°F	Year-round	Daguerre Point Dam and Marysville			
		Smolt (emigration)	52°F / 55°F	October – April 15	Daguerre Point Dam and Marysville			
	Spring-run Chinook	Adult (immigration)	64°F / 68°F	April – September	Smartsville, Daguerre Point Dam, Marysville			
		Adult (holding)	61°F / 65°F	April – September	Smartsville, Daguerre Point Dam, Marysville			
		Adult (spawning)	56°F / 58°F	September – October 15	Smartsville			
		Egg (incubation)	56°F / 58°F	September – December	Smartsville			
		Juvenile (rearing and downstream movement)	61°F / 65°F	Year-round	Daguerre Point Dam, Marysville			
		Smolt (emigration)	63°F / 68°F	October – May 15	Daguerre Point Dam, Marysville			
	Fall-run Chinook	Adult (immigration and staging)	64°F / 68°F	July – December	Daguerre Point Dam and Marysville			
		Adult (spawning)	56°F / 58°F	October – December	Smartsville and Daguerre Point Dam			
		Egg (incubation)	56°F / 58°F	October – March	Smartsville and Daguerre Point Dam			
		Juvenile (rearing and downstream movement)	61°F / 65°F	December 15 – June	Daguerre Point Dam and Marysville			

[3] Upper optimum water temperature index (WTI).
[4] Upper tolerance WTI.

Project	Species	Life Stage	Water Temperature	Timeframe	Location	Metric	Source(s)	Notes
EPA	Salmon and trout	Adult (migration)	<64°F <68°F generally in lower part of river basins that likely reach temp naturally, if there are cold-water refugia	Unspecified (species specific)	NA	7DADM	EPA 2003	Note: source is EPA Region 10 Guidance for Pacific Northwest state and Tribal Temperature Water Quality Standards.
	Salmon and trout	Adult (spawning) Egg (incubation) Fry (emergence)	<55°F	Unspecified (species specific)	NA			
	Salmon	Juvenile (rearing)	<61°F	"Early year"	Mid- to upper river basin			"Core" juvenile rearing
	Salmon	Smolt	<59°F	Unspecified (species specific)	NA			
	Steelhead	Smolt	<57°F	Unspecified (species specific)	NA			
	Salmon and steelhead	Juvenile (rearing)	<64°F	"Late year"	Lower river basin			"Non-Core" juvenile rearing

Sources:

CALFED. 2009. San Joaquin River Basin, Water Temperature Modeling and Analysis. October 2009.

EPA (U.S. Environmental Protection Agency). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. April.

NMFS (National Marine Fisheries Service). 2016. Sacramento River Temperature Management Plan concurrence letter. June 28, 2016.

SWRCB (State Water Resources Control Board). 2010. Water Quality Certification for Feather River, FERC Project No. 2100. Order 2010-0016.

SWRCB. 2016. Sacramento River Temperature Management Plan approval letter. July 8, 2016.

Water Forum. 2006. Lower American River Flow Management Standard. July 31, 2006.

Water Forum. 2007. Summary of the Lower American River Flow Management Standard. January 2007.

Yuba Accord River Management Team. 2013. Yuba Accord Monitoring and Evaluation Program. Draft Interim Report. April 2013

Bratovich et al. 2012. Water Temperature Considerations for Yuba River Basin Anadromous Salmonid Reintroduction Evaluations. October 2012.

References:

Boles, G. L., S. M. Turek, C. C. Maxwell, and D. M. McGill. 1988. Water Temperature Effects on Chinook Salmon (*Oncorhynchus Tshawytscha*) With Emphasis on the Sacramento River: A Literature Review. California Department of Water Resources.

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Myrick, C.A. and J.J. Cech. 2001. Temperature effects on Chinook salmon and steelhead: A review focusing on California's Central Valley populations. Department of Wildlife, Fish, and Conservation Biology, University of California. Davis.

Myrick, C.A. and J.J. Cech, Jr. 2004. Temperature effects on juvenile anadromous salmonids in California's Central Valley: What don't we know? Reviews in Fish Biology and Fisheries 14: 113-123.

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NMFS. 2009. Biological Opinion for the Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP).

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

FISH PASSAGE FACILITIES ALTERNATIVES ASSESSMENT
WATER TEMPERATURE SUBCOMMITTEE CONFERENCE CALL

OCTOBER 14, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Water Temperature Criteria Subcommittee Conference Call

Friday, October 14, 2016
1:00 pm to 3:00 pm

Final Meeting Notes

Meeting Attendees		
No.	**Name**	**Organization**
1	Steve Boyd	Turlock Irrigation District
2	Paul Bratovich	HDR Inc., consultant to the Districts
3	Jean Castillo	National Marine Fisheries Service
4	Jesse Deason	HDR Inc., consultant to the Districts
5	John Devine	HDR Inc., consultant to the Districts
6	Greg Dias	Modesto Irrigation District
7	Tim Heyne	California Department of Fish and Wildlife
8	Bao Le	HDR Inc., consultant to the Districts
9	Ellen Levin	City and County of San Francisco
10	Lonnie Moore*	Private citizen
11	Gretchen Murphey	California Department of Fish and Wildlife
12	Bill Paris	Modesto Irrigation District
13	Bill Sears	City and County of San Francisco
14	Chris Shutes	California Sportfishing Protection Alliance
15	John Wooster	National Marine Fisheries Service
16	Ron Yoshiyama	City and County of San Francisco

* Joined call about 15 minutes late.

On October 14, 2016, Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) hosted the second Water Temperature Criteria Subcommittee (Temperature Subcommittee) conference call for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment and Upper Tuolumne River Fish Reintroduction Assessment Framework (Framework). This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting. Attachment A to this document provides meeting materials.

Mr. Bao Le (HDR, consultant to the Districts) welcomed meeting attendees. Mr. Le said the purpose of the Temperature Subcommittee is to establish a technical basis for evaluating thermal suitability for the purposes of the Framework. As background, Mr. Le said the Upper Tuolumne River Basin Fish Migration Barriers Study Progress Report included several statements about thermal suitability in the upper Tuolumne River. In the agency's comments on the report, the National Marine Fisheries Service (NMFS) stated that such statements were premature. Given that no thermal suitability criteria had yet been decided on by licensing participants, the Districts agreed with NMFS's comments that statements about thermal suitability were premature. Subsequently, the topic of thermal suitability criteria was discussed by the Plenary Group. As part of implementing the Framework, the Plenary Group decided to create the Temperature Subcommittee.

Mr. Le summarized discussions at the September 15 Temperature Subcommittee call. Mr. Le said on the call, licensing participants discussed the temperature criteria matrix prepared by the Districts. Mr. Le said the water temperature criteria matrix was the result of an action item the Districts had from Workshop No. 5 to develop a document summarizing what water temperature values were developed for the Yuba River, as well as what information were developed for other potentially relevant programs in the Central Valley. Mr. Le said at the September 15 conference call, licensing participants decided the best path forward was to first update the literature review completed by the Yuba Salmon Forum (YSF). The literature review would be updated to include results from recent studies as well as site-specific information about the Tuolumne River. Mr. Le said on the first Temperature Subcommittee call, the Districts requested that any feedback on what information or data should be added to update the YSF literature review be provided by September 23. Mr. Le said no feedback was received.

Mr. Bratovich (HDR) said the YSF completed a comprehensive literature review of Central Valley temperature experiments and field observations. Mr. Bratovich said the literature review contains over 100 references and that many of the individuals on this call participated in the YSF. Mr. Bratovich noted that where data needed to be augmented, the review extended to information collected in the Pacific Northwest. Based on the information collected, the YSF developed water temperature index values for each life stage of spring-run Chinook and steelhead. Ultimately, the YSF identified upper optimal and upper tolerable index values for each life stage. Maximum weekly average temperature (MWAT) was used as the metric.

Mr. Le said the Districts have updated the YSF literature review, and this draft was provided to licensing participants yesterday. The foundation of the document is Appendix A of "Water Temperature Considerations for Yuba River Basin Anadromous Salmonid Reintroduction Evaluations" (Bratovich et al. 2012). Additional information has been added, including site-specific information about the Tuolumne River collected as part of the Don Pedro Project relicensing proceeding and data collected for the temperature criteria matrix (provided to Temperature Subcommittee members prior to the September 15 call).

Mr. Bill Sears (City and County of San Francisco) asked what is the difference between "water temperature criteria" and "index values". Mr. Bratovich said there is a lot of phraseology that can influence how data may be interpreted or understood. Some literature references water temperature "guidelines". EPA (2003) refers to both "criteria" and "guidelines". Mr. Bratovich said "index values" is a term used to reference specific water temperature values that are indicative of a specific physiological response. Mr. Bratovich said some of the references collected in the YSF literature review use Celsius while others use Fahrenheit. Some references provided values to a tenth of a degree while others used whole integers. Mr. Bratovich said YSF chose whole-integer "values of consideration" for evaluating thermal suitability.

Ms. Gretchen Murphey (California Department of Fish and Wildlife) requested that the Literature Review Summary provide values in Celsius as well as Fahrenheit. Mr. Le said future iterations of the document will provide values in both Celsius and Fahrenheit.

Mr. Le said the YSF literature review identified life stage specific temperature information by species (i.e., steelhead and Chinook) although fall-run and spring-run Chinook values were grouped together. Mr. Bratovich noted that separate holding values for spring-run Chinook were also established.

Mr. Le asked if anyone on the call has looked at the updated literature review. Ms. Murphey said she reviewed part of the document. Mr. Chris Shutes (California Sportfishing Protection Alliance) said he also reviewed part of the document.

Mr. Shutes noted that the the Swim Tunnel Study Report is included in the updated literature review. Mr. Shutes said he is trying to understand how that study is relevant to thinking about reintroduction. Mr. Shutes asked how the Districts see the study as being relevant for the purposes of evaluating reintroduction in the upper Tuolumne River. Mr. Le said the Don Pedro Project relicensing studies included several studies that seemed natural to include in the updated literature review, including the Swim Tunnel Study and the two fish model studies, W&AR-06 and W&AR-10. Mr. Le said in general, studies were added to the literature review if they provided site-specific data. Once the literature review is complete, the next step would be to discuss what implications these studies may have for reintroduction. Mr. John Devine (HDR) added that site-specific data on the thermal tolerance of juvenile *O. mykiss* seemed appropriate regarding possible relevance to temperature benchmarks on the Tuolumne River.

Mr. Shutes asked if the Districts would like comments on what still should be added to the literature review or comments on the relevance and usefulness of the studies included in the literature review for evaluating reintroduction. Mr. Le stated that although comments were due on September 23 and none were received, comments are still welcome. Mr. Le said at a minimum, individuals should provide any key studies or data or other relevant information that may be missing from the literature review. Comments on how specific studies included in the literature review may or may not be relevant to considering reintroduction would also be valuable.

Meeting attendees discussed when comments on the updated literature review should be provided. Comments are due to Ms. Rose Staples (HDR) at rose.staples@hdrinc.com by November 1, 2016.

Mr. Shutes said the Literature Review Summary is currently in the form of a narrative, with the temperature values sprinkled throughout. In the YSF Planning Document, the numbers were displayed in tables. It may be useful to display the numbers in both a narrative form and in tables. Ms. Jean Castillo (National Marine Fisheries Service [NMFS]) agreed that a table would be helpful. Mr. John Wooster (NMFS) asked what would be the difference between the table prepared for the first Temperature Subcommittee call and this new table. Mr. Le replied that the matrix discussed on the first call summarized temperature values identified in several Central Valley reintroduction or salmon management programs. This new table would display numbers pulled from the literature review, which would also include the numbers from the matrix.

Mr. Le said the narrative provides a lot of helpful background on the nature and context of the studies. However, a table summarizing relevant numbers could be added to the narrative section of each life stage. Meeting attendees agreed with this approach.

Mr. Wooster asked if there is a central location where the references are stored. Mr. Le and Mr. Bratovich confirmed copies of all the references are available. Mr. Wooster asked if copies of all the references, or select references, can be shared with the group. Mr. Le said he can provide any references that may be of interest, if folks first send him a list of the references they would like to review. Mr. Wooster said he would provide a list of the references he would like.

Mr. Le said the next Temperature Subcommittee call will be in early- or mid-November to discuss what water temperature index values should be used and to start establishing a technical basis for evaluating thermal suitability. Meeting attendees discussed the date for the next Temperature Subcommittee call. Mr. Le said he will send out a Doodle poll with possible meeting dates. Mr. Le said prior to the next call, the Districts will provide an updated literature review and responses to any comments received on the updated literature review.

Mr. Le asked if there were any comments on the glossary of terms. Ms. Castillo said the glossary was helpful. Mr. Le asked meeting attendees to review the glossary of terms and provide comments on what additional terms should be added by November 1, 2016.

ACTION ITEMS

1. Future iterations of the literature review summary will provide values in both Celsius and Fahrenheit.

2. Licensing participants will provide comments on the updated literature review and glossary of terms to Ms. Rose Staples at rose.staples@hdrinc.com by November 1, 2016.

3. The Districts will update the literature review narrative to include tables at the end of each life stage section that summarize the relevant temperature values identified in the associated subsection.

4. Mr. Wooster will send Ms. Rose Staples a list of references that he would like to review and Ms. Rose Staples will send him those references.

5. Mr. Le will send out a Doodle poll with possible meeting dates. (complete)

6. Prior to the next Temperature Subcommittee call, the Districts will send out an updated literature review and responses to any comments received on the updated literature review.

7. The Districts will send out meeting notes from this call. (complete)

La Grange Hydroelectric Project
Reintroduction Assessment Framework
Water Temperature Criteria Subcommittee Conference Call

Friday, October 14, 2016, 1:00 pm to 3:00 pm

Conference Line: 1-866-583-7984; Passcode: 8140607

Meeting Objectives:

1. Review and discuss water temperature literature review summary, glossary of terms/acronym list (Districts' action item).
2. Discuss potential water temperature index (WTI) values that may be relevant to the Upper Tuolumne River Reintroduction Assessment Framework.
3. Discuss next steps and schedule for WTI selection.

TIME	TOPIC
1:00 pm – 1:15 pm	Introduction of Participants (All) Review Agenda and Meeting Objectives (Districts)
1:15 pm – 2:45 pm	Water Temperature Literature Review Summary, Glossary of Terms/Acronym List (All) a. Summary of documents (Districts) b. Subcommittee discussion and relevance to selection of WTI values (All)
2:45 pm – 3:00 pm	Next Steps (All) a. Schedule next call and agenda topics b. Action items from this call

UPPER TUOLUMNE RIVER REINTRODUCTION ASSESSMENT FRAMEWORK WATER TEMPERATURE CRITERIA SUBCOMMITTEE

LIFESTAGE-SPECIFIC WATER TEMPERATURE BIOLOGICAL EFFECTS AND INDEX TEMPERATURE VALUES

Literature Review Summary

INTRODUCTION

The La Grange Hydroelectric Project (La Grange Project), owned and operated by the Turlock Irrigation District and Modesto Irrigation District (TID/MID), is currently undergoing the Federal Energy Regulatory Commission (FERC) Integrated Licensing Process. As part of this process, the Districts are implementing a FERC-approved Fish Passage Facilities Alternatives Assessment which consists of developing general design criteria and design considerations applicable to upstream and downstream fish passage facilities at the La Grange Project. Design criteria and considerations include such items as site-specific physical and operational parameters; applicable regulatory requirements; National Marine Fisheries Service (NMFS),U.S. Fish and Wildlife Service (USFWS), and California Department of Fish and Wildlife (CDFW) biological and engineering design criteria; site-specific biological/habitat information relevant to the sizing and configuration of facilities; and any other information gaps that may affect siting, sizing, general design parameters, capital cost, and operating requirements of potential fish passage facilities.

To make certain that detailed, site-specific information is available to support and adequately inform decisions regarding fish reintroduction and fish passage, TID, MID, and licensing participants came to a consensus on the need for and utility of an Upper Tuolumne River Reintroduction Assessment Framework (Framework). The Framework is intended to provide a comprehensive, collaborative, and transparent approach for evaluating the full range of potential issues associated with the future reintroduction of anadromous fish to the upper Tuolumne River. In addition to considering aspects of the technical feasibility of building and operating fish passage facilities, the Framework considers the interrelated issues of ecological feasibility, biological constraints, economics, regulatory implications, and other considerations of reintroduction. Elements of the Framework are interconnected, with fish passage construction and operational requirements needing to properly reflect biological constraints, ecological considerations, and economic cost:benefit assessments.

Water temperature considerations are a primary component of assessing any potential anadromous salmonid reintroduction effort. In support of the Framework, the Districts and licensing participants established a Water Temperature Criteria Subcommittee to begin investigating water temperature considerations pertinent to anadromous salmonid reintroduction opportunities in the accessible reaches of the Tuolumne River upstream of Don Pedro Reservoir (upper Tuolumne River). On September 15, 2016, the Districts hosted the first conference call for the Water Temperature Criteria Subcommittee (draft meeting notes from this call were distributed on October 3 for a 30-day comment period). On the conference call, attendees discussed the need for a comprehensive literature review of regional and site-specific information to inform the selection of water temperature index values to be used in an evaluation of the water temperature-related reintroduction potential in the reaches of the upper Tuolumne River. Meeting attendees agreed that the literature review performed for the Yuba Salmon Forum (Appendix A; Bratovich et al. 2012) to support the anadromous salmonid reintroduction assessment in this watershed coupled with site-specific temperature studies or data for the Tuolumne River, if available, would be a good basis for this effort. The following represents and updated literature review summary and is provided to the Water Temperature Criteria Subcommittee to support selection of water temperature index values for the Framework.

STEELHEAD LIFESTAGE-SPECIFIC WATER TEMPERATURE INDEX VALUES

Adult Immigration and Holding

Water temperatures can control the timing of adult spawning migrations and can affect the viability of eggs in holding females. Yuba County Water Agency (YCWA) *et al.* (2007) suggests that few studies have been published examining the effects of water temperature on either steelhead immigration or steelhead holding, and none of the available studies were recent (Bruin and Waldsdorf 1975; McCullough *et al.* 2001). The available studies suggest that adverse effects occur to immigrating and holding steelhead at water temperatures exceeding the mid 50°F range, and that immigration will be delayed if water temperatures approach approximately 70°F. Water temperature index values of 52°F, 56°F, 61°F, 65°F and 70°F were chosen because they provide a gradation of potential water temperature effects, and the available literature provided the strongest support for these values.

Because of the paucity of literature pertaining to steelhead adult immigration and holding, an evenly spaced range of water temperature index values could not be achieved. We also used some pertinent information related to other salmonids (e.g., Chinook salmon). 52°F was selected as a water temperature index value because it has been referred to as a "recommended" (Reclamation 2003), "preferred" (McEwan and Jackson 1996; NMFS 2000; NMFS 2002), and "optimum" (Reclamation 1997a) water temperature for steelhead adult immigration. Increasing levels of thermal stress to this life stage may reportedly occur above the 52°F water temperature index value. 56°F was selected as a water temperature index value because 56°F represents a water temperature above which adverse effects to migratory and holding steelhead begin to arise (Bruin and Waldsdorf 1975; Leitritz and Lewis 1980; McCullough *et al.* 2001; Smith *et al.* 1983). 50-59°F is referred to as the "preferred" range of water temperatures for California summer steelhead holding (Moyle *et al.* 1995). Whereas, water temperatures greater than 61°F may result in "chronic high stress" of holding Central Valley winter- run steelhead (USFWS 1995a). 65°F was selected as a water temperature index value because steelhead (and fall-run Chinook salmon) encounter potentially stressful temperatures between 64.4-73.4°F (Richter and Kolmes 2005). Additionally, over 93% of steelhead detections occurred in the 65.3-71.6°F range, although this may be above the temperature for optimal immigration (Salinger and Anderson 2006) and/or may modify migration timing due to holding in coldwater refugia (High *et al.* 2006). 70°F was selected as the highest water temperature index value because the literature suggests that water temperatures near and above 70.0°F may result in a thermal barrier to adult steelhead migrating upstream (McCullough *et al.* 2001) and are water temperatures referred to as "stressful" to upstream migrating steelhead in the Columbia River (Lantz 1971 as cited in Beschta et al 1987). Further, Coutant (1972) found that the upper incipient lethal temperature (UILT) for adult steelhead was 69.8°F and temperatures between 73-75°F are described as "lethal" to holding adult steelhead in Moyle (2002).

As part of the Framework, TID and MID, in collaboration with stakeholders developed a table of established water temperature criteria from select salmon and steelhead programs in the Central Valley (Temperature Criteria Matrix; presented at the September 15, 2016 Water Temperature

Subcommittee conference call). The table was developed to support the Framework's Water Temperature Criteria Subcommittee whose purpose is to establish a technical basis to evaluate water temperature regimes for target anadromous salmonid reintroduction into the Tuolumne River upstream of Don Pedro Reservoir. For steelhead adult immigration, the Temperature Criteria Matrix identified 64°F in for the San Joaquin (CALFED 2009) and 64°F (Upper Optimum Value) and 68°F (Upper Tolerable Value) for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012). For steelhead adult holding, the Temperature Criteria Matrix identified 61°F (Upper Optimum Value) and 65°F (Upper Tolerable Value) for the Yuba Reintroduction Assessment (Bratovich et al. 2012).

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) identifies 64°F (7DADM) for "salmon and trout" migration.

<u>Spawning and Embryo Incubation</u>

Relatively few studies have been published directly addressing the effects of water temperature on steelhead spawning and embryo incubation (Redding and Schreck 1979; Rombough 1988). Because anadromous steelhead and non-anadromous rainbow trout are genetically and physiologically similar, studies on non-anadromous rainbow trout also were considered in the development of water temperature index values for steelhead spawning and embryo incubation (Moyle 2002; McEwan 2001). From the available literature, water temperatures in the low 50°F range appear to support high embryo survival, with substantial mortality to steelhead eggs reportedly occurring at water temperatures in the high 50°F range and above. Water temperatures in the 45-50°F range have been referred to as the "optimum" for spawning steelhead (FERC 1993).

Water temperature index values of 46°F, 52°F, 54°F, 57°F, and 60°F were selected for two reasons. First, the available literature provided the strongest support for water temperature index values at or near 46°F, 52°F, 54°F, 57°F, and 60°F. Second, the index values reflect a gradation of potential water temperature effects ranging between optimal to lethal conditions for steelhead spawning and embryo incubation. Some literature suggests water temperatures ≤ 50°F are when steelhead spawn (Orcutt *et al.* 1968) and/or are optimal for steelhead spawning and embryo survival (FERC 1993; Myrick and Cech 2001; Timoshina 1972) and temperatures between 39-52°F are "preferred" by spawning steelhead (IEP Steelhead Project Work Team (no date); McEwan and Jackson 1996), a larger body of literature suggests optimal conditions occur at water temperatures ≤ 52°F (Humpesch 1985; NMFS 2000; NMFS 2001a; NMFS 2002; Reclamation 1997b; SWRCB 2003; USFWS 1995b). Further, water temperatures between 48-52°F were referred to as "optimal" (FERC 1993; McEwan and Jackson 1996; NMFS 2000) and "preferred" (Bell 1986) for steelhead embryo incubation. Therefore, 52°F was selected as the lowest water temperature index value. Increasing levels of thermal stress to the steelhead spawning and embryo incubation life stage may reportedly occur above the 52°F water temperature index value.

54°F was selected as the next index value, because although most of the studies conducted at or near 54.0°F report high survival and normal development (Kamler and Kato 1983; Redding and Schreck 1979; Rombough 1988), some evidence suggests that symptoms of thermal stress arise at or near 54.0°F (Humpesch 1985; Timoshina 1972). Thus, water temperatures near 54°F may represent an inflection point between properly functioning water temperature conditions, and conditions that cause negative effects to steelhead spawning and embryo incubation. Further, water temperatures greater than 55°F were referred to as "stressful" for incubating steelhead embryos (FERC 1993). 57°F was selected as an index value because embryonic mortality increases sharply and development becomes retarded at incubation temperatures greater than or equal to 57.0°F. Velsen (1987) provided a compilation of data on rainbow trout and steelhead embryo mortality to 50% hatch under incubation temperatures ranging from 33.8°F to 60.8°F that demonstrated a two-fold increase in mortality for embryos incubated at 57.2°F, compared to embryos incubated at 53.6°F. In a laboratory study using gametes from Big Qualicum River, Vancouver Island, steelhead mortality increased to 15% at a constant temperature of 59.0°F, compared to less than 4% mortality at constant temperatures of 42.8°F, 48.2°F, and 53.6°F (Rombough 1988). Also, alevins hatching at 59.0°F were considerably smaller and appeared less well developed than those incubated at the lower temperature treatments. From fertilization to 50% hatch, Big Qualicum River steelhead had 93% mortality at 60.8°F, 7.7% mortality at 57.2°F, and 1% mortality at 47.3°F and 39.2°F (Velsen 1987). Myrick and Cech (2001) similarly described water temperatures >59°F as "lethal" to incubating steelhead embryos, although FERC (1993) suggested that water temperatures exceeding 68°F were "stressful" to spawning steelhead and "lethal" when greater than 72°F.

As part of the Don Pedro Hydroelectric Project FERC relicensing process, the TID and MID conducted an *O. mykiss* Population Study (TID/MID 2014) for the Lower Tuolumne River below La Grange Diversion Dam. The goal of the study is to provide a quantitative population model to investigate the relative influences of various factors on the lifestage specific production of *O. mykiss in* the Tuolumne River including water temperature effects on population response for specific in-river lifestages. The study noted that although no literature information could be identified regarding upper temperature limits for spawning initiation, maximum temperature limits for spawning are assumed to be on the order of 15°C (59°F) inferred from egg mortality thresholds for resident *O. mykiss* (Velsen 1987) as well as steelhead (Rombough 1988). Similarly, for egg incubation, the model allowed for a broad range of flow and water temperature conditions using the completed model, an initial acute mortality threshold of 15°C (59°F) was included based upon a literature review by Myrick and Cech (2001).

For steelhead spawning and embryo incubation in the Yuba River, the Framework Temperature Criteria Matrix identified 54°F and 57°F for Upper Optimum and Upper Tolerable values, respectively (Bratovich *et al.* 2012).

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) identifies 55°F (7DADM) for "salmon and trout" spawning and egg incubation.

<u>Juvenile Rearing & Downstream Movement</u>

Water temperature index values were developed to evaluate the combined steelhead rearing (fry and juvenile) and juvenile downstream movement lifestages. Some steelhead may rear in freshwater for up to three years before emigrating as yearling+ smolts, whereas other individuals move downstream shortly after emergence as post- emergent fry, or rear in the river for several months and move downstream as juveniles without exhibiting the ontogenetic characteristics of smolts . Presumably, these individuals continue to rear and grow in downstream areas (e.g., lower Feather River, Sacramento River, and Upper Delta) and undergo the smoltification process prior to entry into saline environments. Thus, fry and juvenile rearing occur concurrently with post-emergent fry and juvenile downstream movement and are assessed in this Technical Memorandum using the fry and juvenile rearing water temperature index values.

The growth, survival, and successful smoltification of juvenile steelhead are controlled largely by water temperature. The duration of freshwater residence for juvenile steelhead is long relative to that of Chinook salmon, making the juvenile life stage of steelhead more susceptible to the influences of water temperature, particularly during the over-summer rearing period. Central Valley juvenile steelhead have high growth rates at water temperatures in the mid 60°F range, but reportedly require lower water temperatures to successfully undergo the transformation to the smolt stage.

Water temperature index values of 63°F, 65°F, 68°F, 72°F, and 75°F were selected to represent a gradation of potential water temperature effects ranging between optimal to lethal conditions for steelhead juvenile rearing. The lowest water temperature index value of 63°F was established because Myrick and Cech (2001) describe 63°F as the “preferred” water temperature for wild juvenile steelhead, whereas “preferred” water temperatures for juvenile hatchery steelhead reportedly range between 64-66°F. 65°F was also identified as a water temperature index value because NMFS (2000; 2002a) reported 65°F as the upper limit preferred for growth and development of Sacramento and American River juvenile steelhead. Also, 65°F was found to be within the optimum water temperature range for juvenile growth (i.e., 59-66°F) (Myrick and Cech 2001), and supported high growth of Nimbus strain juvenile steelhead (Cech and Myrick 1999).

Increasing levels of thermal stress to this life stage may reportedly occur above the 65°F water temperature index value. For example, Kaya *et al.* (1977) reported that the upper avoidance water temperature for juvenile rainbow trout was measured at 68°F to 71.6°F. Cherry *et al.* (1977) observed an upper preference water temperature near 68.0°F for juvenile rainbow trout, duplicating the upper preferred limit for juvenile steelhead observed in Cech and Myrick (1999) and FERC (1993). Empirical adult *O. mykiss* population data from the North Yuba, Middle Yuba, South Yuba, Middle Fork American, and Rubicon rivers were collected in 2007-2009 were plotted against temperature (Figure 4 of Bratovich et al. 2012). The temperature used was the 8^{th} largest average daily temperature during the summer (i.e., up to seven days had higher daily average temperatures). The data show a population density break at about 68.0°F. Although smaller population densities occurred at higher temperatures, the largest population densities occurred at temperatures near 68.0°F or less. In addition growth for a 200 mm juvenile *O. mykiss* versus temperature for three food levels (percent of maximum consumption = 30%, 50%, and 70%) was evaluated. The average empirically derived percent of maximum consumption in an adjacent watershed (Middle Fork American Fork River) was 50% (Hanson *et al.* 1997). Positive growth only occurs up to approximately 68°F. Because of the literature describing 68.0°F as both an upper preferred and an avoidance limit for juvenile *O. mykiss*, and because of the empirical fish population data and bioenergetics growth data, 68°F was established as a upper tolerable water temperature index value.

A water temperature index value of 72°F was established because symptoms of thermal stress in juvenile steelhead have been reported to arise at water temperatures approaching 72°F. For example, physiological stress to juvenile steelhead in Northern California streams was demonstrated by increased gill flare rates, decreased foraging activity, and increased agonistic activity as stream temperatures rose above 71.6°F (Nielsen *et al.* 1994). Also, 72°F was selected as a water temperature index value because 71.6°F has been reported as an upper avoidance water temperature (Kaya *et al.* 1977) and an upper thermal tolerance water temperature (Ebersole *et al.* 2001) for juvenile rainbow trout. The highest water temperature index value of 75°F was established because NMFS and EPA report that direct mortality to rearing juvenile steelhead results when stream temperatures reach 75.0°F (EPA 2002; NMFS 2001b). Water temperatures >77°F have been referred to as "lethal" to juvenile steelhead (FERC 1993; Myrick and Cech 2001). The UILT for juvenile rainbow trout, based on numerous studies, is between 75-79°F (Sullivan *et al.* 2000; McCullough 2001).

A swim tunnel study conducted on the Lower Tuolumne River (TID/MID 2016) generated high quality field data on the physiological performance of Tuolumne River *O. mykiss* acutely exposed to a temperature range of 13 to 25°C. The data indicated that wild juvenile *O. mykiss* represents an exception to the expected based on the 7DADM criterion for juvenile rearing set out by EPA (2003b) for Pacific Northwest *O. mykiss*. The study recommended that a conservative upper aerobic performance limit of 71.6°F, instead of 64.4°F (EPA), be considered in re-determining a 7DADM for this population.

The Lower Tuolumne River *O. mykiss* Population Study (TID/MID 2014) identified the upper incipient lethal temperature (UILT) for *O. mykiss* juveniles has been estimated at 22.8–25.9ºC (73–79°F) (Threader and Houston 1983). In the model, an initial mortality threshold of 25°C (77°F) daily average temperature was selected for *O. mykiss* juveniles. Note also that both fry rearing and resident adult rearing lifestages of *O. mykiss* also had UILT values of 77°F to support the model.

For steelhead juvenile rearing, the Temperature Criteria Matrix identified 65°F for the Lower American River (Water Forum 2007); 61°F for the San Joaquin (CALFED 2009); and 65°F (Upper Optimum Value) and 68°F (Upper Tolerable Value) for the Yuba (Bratovich *et al.* 2012).

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) identifies 64°F (7DADM) for "salmon and steelhead" juvenile rearing.

<u>Yearling + Smolt Emigration</u>

Laboratory data suggest that smoltification, and therefore successful emigration of steelhead smolts, is directly controlled by water temperature (Adams *et al.* 1975). Water temperature index values of 52°F and 55°F were selected to evaluate the steelhead smolt emigration life stage, because most literature on water temperature effects on steelhead smolting suggest that water temperatures less than 52°F (Adams *et al.*1975; Myrick and Cech 2001; Rich 1987a) or less than 55°F (EPA 2003a; McCullough *et al.* 2001; Wedemeyer *et al.* 1980; Zaugg and Wagner 1973) are required for successful smoltification to occur. (Adams *et al.* 1973) tested the effect of water temperature (43.7°F, 50.0°F, 59.0°F or 68.0°F) on the increase of gill microsomal Na^{+}-, K^{+}-stimulated ATPase activity associated with parr-smolt transformation in steelhead and found a two-fold increase in Na^{+}-, K^{+}-ATPase at 43.7 and 50.0°C, but no increase at 59.0°F or 68.0°F . In a subsequent study, the highest water temperature where a parr-smolt transformation occurred was at 52.3°F (Adams *et al.* 1975). The results of Adams *et al.* (1975) were reviewed in Myrick and Cech (2001) and Rich (1987b), which both recommended that water temperatures below 52.3°F are required to successfully complete the parr-smolt transformation. Further, Myrick and Cech (2001) suggest that water temperatures between 43-50°F are the "physiologically optimal" temperatures required during the parr-smolt transformation and necessary to maximize saltwater survival. The 52°F water temperature index value established for the steelhead smolt emigration life stage is the index value generally reported in the literature as the upper limit of the water temperature range that provides successful smolt transformation thermal conditions. Increasing levels of thermal stress to this life stage may reportedly occur above the 52°F water temperature index value.

Zaugg and Wagner (1973) examined the influence of water temperature on gill ATPase activity related to parr-smolt transformation and migration in steelhead. They found ATPase activity was decreased and migration reduced when juveniles were exposed to water temperatures of 55.4°F or greater. In a technical document prepared by the EPA to provide temperature water quality standards for the protection of Northwest native salmon and trout, water temperatures less than or equal to 54.5°F were recommended for emigrating juvenile steelhead (EPA 2003b). Water temperatures are considered "unsuitable" for steelhead smolts at >59°F (Myrick and Cech 2001) and "lethal" at 77°F (FERC 1993).

The Lower Tuolumne River *O. mykiss* Population Study (TID/MID 2014) identified an initial UILT mortality threshold of 77°F daily average temperature for *O. mykiss* smolts on the basis of literature reviews by Myrick and Cech (2001).

For steelhead smolt emigration, the Temperature Criteria Matrix identified 57°F for the San Joaquin (CALFED 2009) and 52°F (Upper Optimum Value) and 55°F (Upper Tolerable Value) for the Yuba (Bratovich *et al.* 2012).

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) identifies 57°F (7DADM) for steelhead smolt.

CHINOOK SALMON LIFESTAGE-SPECIFIC WATER TEMPERATURE INDEX VALUES

It has been suggested that separate water temperatures standards should be developed for each run-type of Chinook salmon. For example, McCullough (1999) states that spring-run Chinook salmon immigrate in spring and spawn in 3rd to 5th order streams and, therefore, face different migration and adult holding temperature regimes than do summer- or fall-run Chinook salmon, which spawn in streams of 5th order or greater . However, to meet the objectives of the current literature review, run-types are not separated because: (1) there is a paucity of literature specific to each life stage of each run-type; (2) there is an insufficient amount of data available in the literature suggesting that Chinook salmon run-types respond to water temperatures differently; (3) the water temperature index (WTI) values derived from all the literature pertaining to Chinook salmon for a particular life stage will be sufficiently protective of that life stage for each run-type; and (4) all run- types overlap in timing of adult immigration and holding and in some cases are not easily distinguished (Healey 1991).

Adult Immigration and Holding

The adult immigration and adult holding life stages are evaluated together, because it is difficult to determine the thermal regime that Chinook salmon have been exposed to in the river prior to spawning and in order to be sufficiently protective of pre-spawning fish, water temperatures that provide high adult survival and high egg viability must be available throughout the entire pre-spawning freshwater period. Although studies examining the effects of thermal stress on immigrating Chinook salmon are generally lacking, it has been demonstrated that thermal stress during the upstream spawning migration of sockeye salmon negatively affected the secretion of hormones controlling sexual maturation causing numerous reproductive impairment problems (McCullough *et al.* 2001).

The water temperature index values reflect a gradation of potential water temperature effects that range between those reported as "optimal" to those reported as "lethal" for adult Chinook salmon during upstream spawning migrations and holding. The water temperature index values established for the Chinook salmon adult immigration and holding lifestage are 61°F, 65°F, and 68°F. Although 56°F is referenced in the literature frequently as the upper "optimal" water temperature limit for upstream migration and holding, the references are not foundational studies and often are inappropriate citations. For example, Boles *et al.* (1988), Marine (1992), and NMFS (1997b) all cite Hinze (1959) in support of recommendations for a water temperature of 56°F for adult Chinook salmon immigration. However, Hinze (1959) is a study examining the effects of water temperature on incubating Chinook salmon eggs in the American River Basin. Further, water temperatures between 38-56°F are considered to represent the "observed range" for upstream migrating spring-run Chinook salmon (Bell 1986).

The lowest water temperature index value established was 61°F, because in the NMFS biological opinion for the proposed operation of the Central Valley Project (CVP) and State Water Project (SWP), 59°F to 60°F is reported as…"*The upper limit of the optimal temperature range for adults holding while eggs are maturing*" (NMFS 2000). Also, NMFS (1997b) states…"*Generally, the maximum temperature of adults holding, while eggs are maturing, is about 59°F to 60°F*" …and… "*Acceptable range for adults migrating upstream range from 57°F to 67°F*." Oregon Department of Environmental Quality (ODEQ; 1995) reports that "*…many of the diseases that commonly affect Chinook become highly infectious and virulent above 60°F*." Study summaries in EPA (2003a) indicate disease risk is high at 62.6°F. Additionally, Ward and Kier (1999) designated temperatures <60.8°F as an "optimum" water temperature threshold for holding Battle Creek spring-run Chinook salmon. EPA (2003a) chose a holding value of 61°F (7DADM) based on laboratory data various assumptions regarding diel temperature fluctuations. 61°F is also a holding temperature index value for steelhead (see above). The 61°F water temperature index value established for the Chinook salmon adult immigration and holding life stage is the index value generally reported in the literature as the upper limit of the optimal range, and is within the reported acceptable range. Increasing levels of thermal stress to this life stage may reportedly occur above the 61°F water temperature index value.

An index value of 65°F was established because Berman (1990) suggests effects of thermal stress to pre-spawning adults are evident at water temperatures near 65°F. Berman (1990) conducted a laboratory study to determine if pre-spawning water temperatures experienced by adult Chinook salmon influenced reproductive success, and found evidence suggesting latent embryonic abnormalities associated with water temperature exposure to pre-spawning adults that ranged from 63.5°F to 66.2°F. Ward *et al.* (2003; 2004) identified an extended period of average daily temperatures above 67°F during July as measured at the Quartz Bowl that preceded the onset of significant pre-spawn mortalities. During 2002, temperatures exceeded 67°F a total of 16 days with a maximum of 20.8°C on July 12. During 2003, temperatures exceed 67°F a total of 11 days with a maximum of 20.9°C on July 23. However during other years when there were minimal pre-spawn mortalities, maximum daily average water temperature at Quartz Bowl never exceeded 67°F more than an few days (Ward *et al.* 2004; Ward *et al.* 2006; McReynolds *et al*. 2007; McReynolds and Garman 2008). During each of the years when Chinook salmon temperature mortality was not observed at Butte Creek (2001, 2004-2007), on average, daily temperature did not exceed 65.8°F for more than 7 days (Figure 6 of Bratovich et al. 2012). Tracy McReynolds (Pers. Comm. October 2011) indicated that an upper tolerable holding temperature of 65°F was reasonable based on her experience.

An index value of 68°F was established because the Butte Creek data and the literature suggests that thermal stress at water temperatures greater than 68°F is pronounced, and severe adverse effects to immigrating and holding pre-spawning adults, including mortality, can be expected (Berman 1990; Marine 1997; NMFS 1997b; Ward *et al*. 2004).

Water temperatures between 70-77°F are reported as the range of maximum temperatures for holding pool conditions used by spring-run Chinook salmon in the Sacramento-San Joaquin system (Moyle *et al*. 1995). Migration blockage occurs for Chinook salmon at temperatures from 70-71+°F (McCollough 1999; McCullough *et al*. 2001; EPA 2003b). Strange (2010) found that the mean average body temperature during the first week of Chinook salmon migration on the Klamath River was 71.4°F. The UILT for Chinook salmon jacks is 69.8-71.6°F (McCullough 1999). The upper limit for spring-run Chinook salmon holding in Deer Creek is reportedly 80.6°F, at which point temperatures exceeding this value become "lethal" (Cramer and Hammack 1952, as cited in Moyle *et al.* 1995). As a result of the potential effects to immigrating and holding adult Chinook salmon that reportedly occur at water temperatures greater than or equal to 68°F, index values higher than 68°F were not established.

For Chinook adult immigration, the Framework Temperature Criteria Matrix identified 64°F (Upper Optimum Value) and 68°F (Upper Tolerable Value) for the Yuba River (Bratovich et al. 2012). For Chinook adult holding, the Framework Temperature Criteria Matrix identified 61°F

(Upper Optimum Value) and 65°F (Upper Tolerable Value) for the Yuba River (Bratovich *et al.* 2012).

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) identifies 64°F (7DADM) for "salmon and trout" adult migration.

Spawning and Embryo Incubation

The adult spawning and embryo (i.e., eggs and alevins) incubation life stage includes redd construction, egg deposition, and embryo incubation. Potential effects to the adult spawning and embryo incubation life stages are evaluated together using one set of water temperature index values because it is difficult to separate the effects of water temperature between lifestages that are closely linked temporally, especially considering that studies describing how water temperature affects embryonic survival and development have included a pre-spawning or spawning adult component in the reporting of water temperature experiments conducted on fertilized eggs (Marine 1992; McCullough 1999; Seymour 1956).

The water temperature index values selected for the Chinook salmon spawning and embryo incubation life stages are 56°F, 58°F, 60°F, and 62°F. Anomalously, FERC (1993) refers to 50°F as the "optimum" water temperature for spawning and incubating Chinook salmon. Additionally, for the adult spawning lifestage, FERC (1993) reports "stressful" and "lethal" water temperatures occurring at >60°F and >70°F, respectively, whereas for incubating Chinook salmon embryos, water temperatures are considered to be "stressful" at <56°F or "lethal" at >60°F. Much literature suggests that water temperatures must be less than or equal to 56°F for maximum survival of Chinook salmon embryos (i.e., eggs and alevins) during spawning and incubation. NMFS (1993b) reported that optimum water temperatures for egg development are between 43°F and 56°F. Similarly, Myrick and Cech (2001) reported the highest egg survival rates occur between water temperatures of 39-54°F. Reclamation (unpublished work) reports that water temperatures less than 56°F results in a natural rate of mortality for fertilized Chinook salmon eggs. Bell (1986) recommends water temperatures ranging between 42-57°F for spawning Chinook salmon, and water temperatures between 41-58°F for incubating embryos. USFWS (1995a) reported a water temperature range of 41.0°F to 56.0°F for maximum survival of eggs and yolk-sac larvae in the Central Valley of California. The preferred water temperature range for Chinook salmon egg incubation in the Sacramento River was suggested as 42.0°F to 56.0°F (NMFS 1997a). Alevin mortality is reportedly significantly higher when Chinook salmon embryos are incubated at water temperatures above 56°F (USFWS 1999). NMFS (2002a) reported 56.0°F as the upper limit of suitable water temperatures for spring-run Chinook salmon spawning in the Sacramento River. The 56°F water temperature index value established for the Chinook salmon spawning and embryo incubation life stage is the index value generally reported in the literature as the upper limit of the optimal range for egg development and the upper limit of the range reported to provide maximum survival of eggs and yolk-sac larvae in the Central Valley of California. Increasing levels of thermal stress to this life stage may reportedly occur above the 56°F water temperature index value.

High survival of Chinook salmon embryos also has been suggested to occur at incubation temperatures at or near 58.0°F. For example, (Reclamation Unpublished Work) reported that the natural rate of mortality for alevins occurs at 58°F or less. Combs (1957) concluded constant incubation temperatures between 42.5°F and 57.5°F resulted in normal development of Chinook salmon eggs, and NMFS (2002a) suggests 53.0°F to 58.0°F is the preferred water temperature range for Chinook salmon eggs and fry. Johnson (1953) found consistently higher Chinook salmon egg losses resulted at water temperatures above 60.0°F than at lower temperatures. In order to protect late incubating Chinook salmon embryos and newly emerged fry NMFS (1993a) has determined a water temperature criterion of less than or equal to 60.0°F be maintained in the Sacramento River from Keswick Dam to Bend Bridge from October 1 to October 31. Seymour (1956) provides evidence that 100% mortality occurs to late incubating Chinook salmon embryos when held at a constant water temperature greater than or equal to 60.0°F. For Chinook salmon eggs incubated at constant temperatures, mortality increases rapidly at temperatures greater than about 59-60°F (see data plots in Myrick and Cech 2001). Olsen and Foster (1957), however, found high survival of Chinook salmon eggs and fry (89.6%) when incubation temperatures started at 60.9°F and declined naturally for the Columbia River (about 7°F/month). Geist *et al.* (2006) found high (93.8%) Chinook salmon incubation survival through emergence for naturally declining temperatures (0.36°F/day) starting as high as 61.7°F; however, a significant reduction in survival occurred above this temperature.

The literature largely agrees that 100% mortality will result to Chinook salmon embryos incubated at water temperatures greater than or equal to 62.0°F (Hinze 1959; Myrick and Cech 2003; Seymour 1956; USFWS 1999). Approximately 80% or greater mortality of eggs incubated at constant temperatures of 63°F or greater (see data plots in Myrick and Cech 2001). Olsen and Foster (1957) found high mortality of Chinook salmon eggs and fry (79%) when incubation temperatures started at 65.2°F and declined naturally for the Columbia River (about 7°F / month). Geist *et al.* (2006) found low Chinook salmon incubation survival (1.7%) for naturally declining temperatures (0.36°F/day) when temperatures started at 62.6°F

As part of the Don Pedro Hydroelectric Project FERC relicensing process, the TID and MID developed a Chinook Salmon Population Model Study (TID/MID 2013) for the Lower Tuolumne River below La Grange Diversion Dam. The goal of the study is to provide a quantitative population model to investigate the relative influences of various factors on the lifestage specific production of Chinook salmon in the Tuolumne River including water temperature effects on population response for specific in-river lifestages. The Chinook Salmon Population Model (TID/MID 2013) established an initial estimate of 60.4°F as the upper limit for initiation of spawning (Groves and Chandler 1999); also interpreted as the temperature at which spawning habitat will be considered usable by spawners. To address the egg and alevin lifestages, the model established an initial acute egg/alevin mortality threshold of 58°F (TID/MID 2013).

For Chinook spawning and incubation, the Framework Temperature Criteria Matrix identified 60°F or less (as early in October as possible) and 56°F or less (as early in November as possible) for Lower American River fall-run Chinook (Water Forum 2007); 64°F (spawning) and 55°F (incubation) for San Joaquin fall-run Chinook (CALFED 2009); 56°F for Shasta River winter and spring-run Chinook (SWRCB 2016); and 54°F (Upper Optimum Value) and 57°F (Upper Tolerable Value) in the Yuba (Bratovich et al. 2012).

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality

Standards (EPA 2003b) identifies 55°F (7DADM) for “salmon and trout” spawning, egg incubation, and fry emergence.

Juvenile Rearing and Downstream Movement

Water temperature index values were identified for the combined spring-run Chinook salmon rearing (fry and juvenile) and juvenile downstream movement lifestages, for the reasons previously described regarding steelhead. Fry and juvenile rearing occur concurrently with post-emergent fry and juvenile downstream movement, and are assessed in this Technical Memorandum using the fry and juvenile rearing water temperature index values.

The water temperature index values of 60°F, 65°F, 68°F, 70°F and 75°F were identified for the spring-run Chinook salmon juvenile rearing and downstream movement lifestage . The lowest index value of 60°F was chosen because regulatory documents as well as several source studies, including ones recently conducted on Central Valley Chinook salmon fry and juveniles report 60°F as an optimal water temperature for growth (Banks *et al.* 1971; Brett *et al.* 1982; Marine 1997; NMFS 1997b; NMFS 2000; NMFS 2001a; NMFS 2002; Rich 1987b). Water temperatures below 60°F also have been reported as providing conditions optimal for fry and fingerling growth, but were not selected as index values, because the studies were conducted on fish from outside of the Central Valley (Brett 1952; Seymour 1956). Studies conducted using local fish may be particularly important because *Oncorhynchus* species show considerable variation in morphology, behavior, and physiology along latitudinal gradients (Myrick 1998; Taylor 1990b; Taylor 1990a). More specifically, it has been suggested that salmonid populations in the Central Valley prefer higher water temperatures than those from more northern latitudes (Myrick and Cech 2000).

The 60°F water temperature index value established for the Chinook salmon juvenile rearing and downstream movement life stage is the index value generally reported in the literature as the upper limit of the optimal range for fry and juvenile growth and the upper limit of the preferred range for growth and development of spring-run Chinook salmon fry and fingerlings. FERC (1993) referred to 58°F as an “optimum” water temperature for juvenile Chinook salmon in the American River. NMFS (2002a) identified 60°F as the “preferred” water temperature for juvenile spring-run Chinook salmon in the Central Valley. Increasing levels of thermal stress to this life stage may reportedly occur above the 60°F water temperature index value.

The index value of 65°F was selected because it represents an intermediate value between 64.0°F and 66.2°F, at which both adverse and beneficial effects to juvenile salmonids have been reported to occur. For example, at temperatures approaching and beyond 65°F, sub-lethal effects associated with increased incidence of disease reportedly become severe for juvenile Chinook salmon (EPA 2003a; Johnson and Brice 1953; Ordal and Pacha 1963; Rich 1987a). Conversely, numerous studies report that temperatures between 64.0°F and 66.2°F provide conditions ranging from suitable to optimal for juvenile Chinook salmon growth (Brett *et al.* 1982; Cech and Myrick 1999; Clarke and Shelbourn 1985; EPA 2003a; Myrick and Cech 2001; NMFS 2002; USFWS 1995b). Maximum growth of juvenile fall-run Chinook salmon has been reported to occur in the American River at water temperatures between 56-59°F (Rich 1987b) and in Nimbus Hatchery spring-run Chinook salmon at 66°F (Cech and Myrick 1999).

Growth for a 100 mm juvenile Chinook salmon versus temperature for three food levels (percent of maximum consumption = 30%, 50%, and 70%) was evaluated. The average percent of maximum consumption in an adjacent watershed (Middle Fork American Fork River) for O. mykiss was 50% (Hanson et al. 1997). Positive growth only occurs up to approximately 64°F for food levels expected in the wild (e.g., 50% maximum consumption).

A water temperature index value of 68°F was selected because, at water temperatures above 68°F, sub-lethal effects become severe such as reductions in appetite and growth of juveniles (Marine 1997; Rich 1987a; Zedonis and Newcomb 1997). Chronic stress associated with water temperature can be expected when conditions reach the index value of 70°F. For example, growth becomes drastically reduced at temperatures close to 70.0°F and has been reported to be completely prohibited at 70.5°F (Brett *et al.* 1982; Marine 1997). 75°F was chosen as the highest water temperature index value because high levels of direct mortality to juvenile Chinook salmon reportedly result at this water temperature (Cech and Myrick 1999; Hanson 1991; Myrick and Cech 2001; Rich 1987b). Other studies have suggested higher upper lethal water temperature levels (Brett 1952; Orsi 1971), but 75°F was chosen because it was derived from experiments using Central Valley Chinook salmon and it is a more rigorous index value representing a more protective upper lethal water temperature level. Furthermore, the lethal level determined in Rich (1987b) was derived using slow rates of water temperature change and, thus, is ecologically relevant. The juvenile Chinook Salmon UILT based on numerous studies is 75-77°F (Sullivan *et al.* 2000; McCullough *et al.* 2001; Myrick and Cech 2001).

Based upon information reviewed for Chinook salmon juvenile mortality (Brett 1952; Orsi 1971), the Chinook Salmon Population Model (TID/MID 2013) established an initial UILT mortality threshold of 77°F for Chinook salmon juveniles as a daily average water temperature. Note that the model also selected this same value for fry mortality.

For Chinook juvenile rearing, the Framework Temperature Criteria Matrix identified 61°F for the San Joaquin (CALFED 2009) and 61°F (Upper Optimum Value) and 65°F (Upper Tolerable Value) for both fall and spring-run Chinook in the Yuba River (Bratovich *et al.* 2012).

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) identifies 61°F (early year) and 64°F (late year) for salmon juvenile rearing based upon a 7DADM.

<u>Yearling + Smolt Emigration</u>

Juvenile Chinook salmon that exhibit extended rearing in the lower Yuba River are assumed to undergo the smoltification process and volitionally emigrate from the river as yearling+ individuals . Water temperature index values of 63°F, 68°F and 72°F were selected for the spring-run Chinook yearling+ emigration lifestage.

A water temperature index value of 63°F was selected because water temperatures at or below this value allow for successful transformation to the smolt stage, and water temperatures above this value may result in impaired smoltification indices, inhibition of smolt development, and decreased survival and successful smoltification of juvenile spring-run Chinook salmon . Laboratory experiments suggest that water temperatures at or below 62.6°F provide conditions that allow for successful transformation to the smolt stage (Clarke and Shelbourn 1985; Marine 1997; Zedonis and Newcomb 1997). 62.6°F was rounded and used to support an index value of 63°F. Indirect evidence from tagging studies suggests that the survival of fall-run Chinook salmon smolts decreases with increasing water temperatures between 59°F and 75°F in the Sacramento-San Joaquin Delta (Kjelson and Brandes 1989). A water temperature index value of 68°F was selected because water temperatures above 68°F prohibit successful smoltification (Marine 1997; Rich 1987a; Zedonis and Newcomb 1997). Support for an index value of 72°F is provided from a study conducted by (Baker *et al.* 1995) in which a statistical model is presented that treats survival of Chinook salmon smolts fitted with coded wire tags in the Sacramento River as a logistic function of water temperature. Using data obtained from mark-recapture surveys, the statistical model suggests a 95% confidence interval for the upper incipient lethal water temperature for Chinook salmon smolts as 71.5°F to 75.4°F.

Based upon information reviewed for Chinook salmon juvenile mortality (Brett 1952), the Chinook Salmon Population Model (TID/MID 2013) established an initial mortality threshold of 77°F for Chinook salmon smolts as a daily average water temperature.

For Chinook smolt migration, the Framework Temperature Criteria Matrix identified 57°F for the San Joaquin (CALFED 2009) and 63°F (Upper Optimum Value) and 68°F (Upper Tolerable Value) for both fall and spring-run Chinook in the Yuba River (Bratovich et al. 2012).

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) identifies 59°F (7DADM) for salmon smolt.

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Upper Tuolumne River Reintroduction Assessment Framework
Water Temperature Criteria Subcommittee
Water Temperature Evaluation
Glossary of Terms

Acute temperature criteria – water temperature identified as being in the **acute temperature zone** for a particular species/lifestage.

Acute temperature exposure – water temperature exposure that is less than 7 days and results in 50% mortality.

Acute temperature zone – zone where acute water temperature exposure occurs with potential for rapid mortality; **zone of resistance**.

Average daily temperature (ADT) – average of temperatures in a 24-hour period.

Chronic temperature criteria – water temperature identified as being in the **chronic temperature zone** for a particular species/lifestage.

Chronic temperature exposure – water temperature exposure that is long-term or $\geq$ 7 days and results in 50% mortality.

Chronic temperature zone – zone where chronic water temperature exposure occurs with no or reduced growth and reproduction and increased mortality; **zone of tolerance**.

Critical thermal maximum – very short duration (minutes) mortality after acute temperature exposure.

Diel temperature – temperature over 24-hour period.

Diurnal temperature – temperature fluctuations between high and low or day and night of the same day.

Lifestage periodicity – season/dates corresponding to a specific lifestage (e.g. spring-run Chinook salmon spawning); identified through study of a particular watershed.

Maximum weekly average temperature (MWAT) – the highest value calculated for all possible 7-day periods over a given time period (e.g. season or lifestage) and generally used to summarize instream water temperature variation occurring on daily or seasonal basis for evaluation of chronic water temperature impacts; found by calculating mathematical mean of multiple, equally spaced, daily water temperatures over a 7-day consecutive period.

Optimum temperature range – zone of temperatures where fish growth, reproduction, and behavior is not appreciably affected by temperature.

Seven (7)-day moving average temperature (7DMA) – “smoothed” average of temperatures over a period of time using moving seven day subsets.

Seven(7)-day moving average daily maximum temperature (7DMADM) – "smoothed" water temperature metric describing the maximum 7-day average of the daily maxima; calculated by adding the daily maximum temperatures recorded at a site on seven consecutive days and dividing by seven, uses moving seven day subsets.

Seven (7)-day average daily maximum temperature (7DADM) – water temperature metric describing the maximum 7-day average of the daily maxima; calculated by adding the daily maximum temperatures recorded at a site on seven consecutive days and dividing by seven.

Upper incipient lethal temperature (UILT) – boundary between lower end of **acute temperature exposure** range and upper end of **chronic temperature exposure** range; where 50% mortality occurs after 7 days (If a shorter duration is used, temperatures will be correspondingly higher).

Upper optimal WTI (UOWTI) – temperatures where physiological processes (growth, disease resistance, normal development of embryos) are not stressed by temperature; **optimal temperature range** identified for specific lifestage.

Upper tolerance WTI (UTWTI) – temperature identified as the boundary between sustained (chronic) tolerance and no tolerance; boundary between **zone of tolerance** and **zone of resistance** identified for a specific lifestage.

Use designation – category applied to a waterbody that determines which **water quality standards (WQS)** will be enforced.

Volitional migration – upstream or downstream migration occurring when anadromous fish are physiologically ready.

Water quality standards (WQS) – specified concentrations/values of various water quality parameters not to be exceeded as established by the U.S. Environmental Protection Agency (EPA) and/or state for beneficial uses such as aquatic life and drinking water.

Water temperature index (WTI) – description of water temperatures that are optimal and/or tolerated by an aquatic species; developed empirically through laboratory and field studies.

Water temperature exceedance curves – used to identify probabilities/duration of time that lifestage-specific **WTI** values would be exceeded over a given time.

Water temperature metrics – provide index of temperature over a period of time (e.g. **MWAT**, **7DADM**).

Water year type – describes amount of precipitation received during water year (e.g. critically dry to wet).

Zone of resistance – water temperature zone between the **UILT** (7 days) and **critical thermal maximum**.

Zone of tolerance – water temperature zone that fish can tolerate that is below the **UILT** and above the **optimal temperature** range, but at higher end temperatures may not thrive and may have modified behavior.

Water Temperature Considerations for Yuba River Basin Anadromous Salmonid Reintroduction Evaluations

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1 INTRODUCTION

The Yuba Salmon Forum (YSF) is a multi-stakeholder group addressing the opportunities for reintroducing anadromous salmonids (i.e., spring-run Chinook salmon and steelhead) in the Upper Yuba River Basin upstream of Englebright Dam.

The YSF stakeholder group is comprised of representatives from National Marine Fisheries Service (NMFS), U.S. Forest Service (USFS), California Department of Fish and Game (CDFG), the Yuba County Water Agency (YCWA), Placer County Water Agency (PCWA) and a group of the non-governmental organizations (NGOs) including Trout Unlimited, American Rivers, The Bay Institute, Sierra Club, California Sport Fishing Protection Alliance, and South Yuba River Citizens League. The YSF is comprised of a Plenary Group and a Technical Working Group (TWG). The purpose of the TWG is to address technical issues associated with anadromous salmonid reintroduction. One of the technical issues addressed by the TWG includes water temperature considerations for the reintroduction of anadromous salmonids into the Upper Yuba River Basin.

2 TECHNICAL MEMORANDUM PURPOSE AND OBJECTIVES

The overall purpose of this Technical Memorandum is to establish the technical basis to evaluate water temperature regimes for spring-run Chinook salmon and steelhead reintroduction in the various rivers and reaches of the Upper Yuba River Basin (North Yuba River upstream of New Bullards Bar Reservoir, North Yuba River downstream of New Bullards Bar Dam to the high water mark of Englebright Reservoir, Middle Yuba River, and South Yuba River) **(Figure 1)**.

Specific objectives are to: (1) conduct a comprehensive literature review of lifestage-specific water temperature relationships; (2) identify a suite of water temperature index (WTI) values representing a summarization of the literature review; (3) select water temperature criteria for each species-specific lifestage for reintroduction evaluation; and (4) identify the water temperature evaluation methodological approach (water temperature metrics and metric application to water temperature monitoring and/or modeling data).

NMFS commented (NOAA Memorandum dated January 18, 2012) on the November 2011 version of this technical memorandum, stating that it should demonstrate the need for new criteria in consideration of criteria previously developed by Stillwater Sciences (2006). In summary, this technical memorandum differs from Stillwater Sciences (2006) in some lifestage periodicities (e.g., spring-run Chinook salmon spawning (Sep – mid Nov vs. Sep – Oct), and embryo incubation (Sep – Feb vs. late Sep – Jan). Notably, Stillwater Sciences (2006) assumed that juvenile spring-run Chinook salmon in the Upper Yuba River Basin *"…would not typically over-summer due to excessively high summer water temperatures*." By contrast, this technical memorandum assumes that juvenile rearing in the Upper Yuba River Basin could occur year-round. In addition, this technical memorandum identifies spring-run Chinook salmon smolt emigration potentially occurring from November through mid-May, whereas Stillwater Sciences (2006) did not identify spring-run Chinook salmon smolt emigration as a lifestage to be addressed. Similarly, Stillwater Sciences (2006) did not identify smolt emigration as a steelhead lifestage to be addressed. In addition to lifestage periodicities, this technical memorandum identifies upper optimum and upper tolerance water temperature index values to be used in the evaluation of water temperature suitability for reintroduction of spring-run Chinook salmon and steelhead into the Upper Yuba River Basin, whereas Stillwater Sciences (2006) identified optimal, suboptimal, and chronic-to-acute stress water temperature index values. These categories are not directly comparable, and the actual values also differ between the two reports.

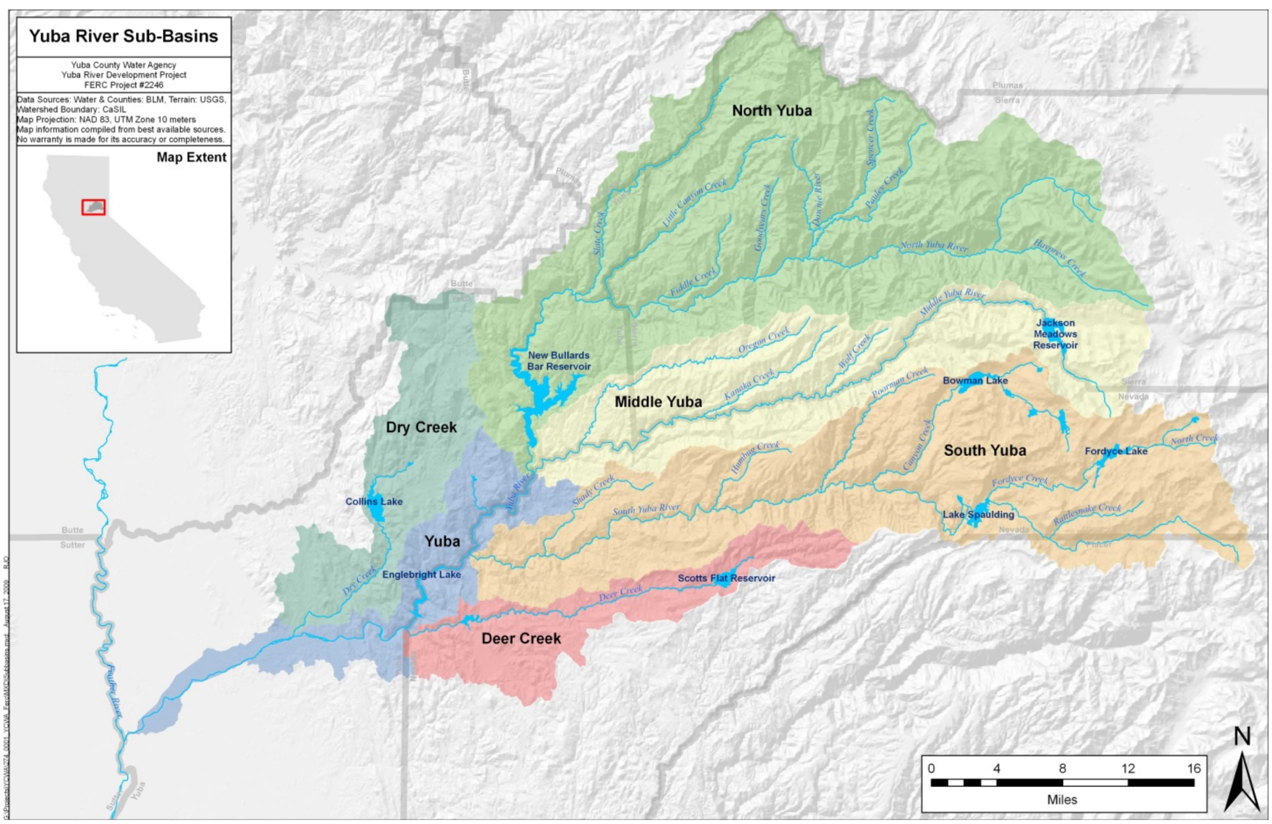


Figure 1. Sub-basins of the Yuba River Basin (source: Yuba County Water Agency 2010).

3 LIFESTAGE PERIODICITIES OF ANADROMOUS SALMONIDS

Lifestage-specific water temperature considerations for spring-run Chinook salmon and steelhead were addressed by the TWG in the evaluation of anadromous reintroduction in the Upper Yuba River Basin. A review of previously conducted studies, as well as recent and currently ongoing data collection activities by the Yuba Accord Monitoring and Evaluation Program (M&E Program) in the lower Yuba River was conducted to identify species- and lifestage-specific temporal periodicities for water temperature considerations. The TWG agreed on the spring-run Chinook salmon and steelhead lifestage periodicities presented in **Table 1** for reintroduction consideration in the Upper Yuba River Basin during a meeting held May 20, 2011. However, it was noted that these periodicities reflect existing conditions in the lower Yuba River, and that lifestage periodicities may change in response to local adaptation over time. It was further noted that although some lifestages may occur concurrently, the periodicities presented in Table 1 reflect specific consideration for water temperature evaluation for reintroduction. For example, spring-run Chinook salmon holding continues to occur during September, even though spawning activity begins during that month.

Table 1. Lifestage-Specific Periodicities for Spring-run Chinook Salmon and Steelhead in the Lower Yuba River.

Lifestage	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Spring-Run Chinook Salmon																								
Adult Immig. & Holding							■	■	■	■	■	■	■	■	■	■								
Spawning																	■	■	■	■	■			
Embryo Incubation	■	■	■	■													■	■	■	■	■	■	■	■
Juv. Rearing & Outmig.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Yearling+ Smolt Emig.	■	■	■	■	■	■	■	■	■												■	■	■	■
Steelhead																								
Adult Immig. & Holding	■	■	■	■	■	■									■	■	■	■	■	■	■	■	■	■
Spawning	■	■	■	■	■	■	■	■																
Embryo Incubation	■	■	■	■	■	■	■	■	■	■														
Juv. Rearing & Outmig.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Yearling+ Smolt Emig.	■	■	■	■	■	■	■												■	■	■	■	■	■

4 LITERATURE REVIEW OF WATER TEMPERATURE RELATIONSHIPS FOR STEELHEAD AND CHINOOK SALMON

A comprehensive review and compilation of available literature was conducted to identify the range of acceptable water temperatures for reintroduction evaluation of Chinook salmon and steelhead, by lifestage, in the Upper Yuba River Basin. The thermal requirements of Chinook salmon and steelhead have been extensively studied in California and elsewhere. The literature review informed the selection of a range of WTI values to be used in the TWG's evaluation of the water temperature-related reintroduction potential in the Upper Yuba River Basin. The information presented herein is largely based on information provided in Appendix E2 to the Public Draft EIR/EIS for the Yuba Accord (YCWA *et al.* 2007), Appendix B (Stillwater Sciences 2006) to the Upper Yuba River Studies Program (UYRSP) Technical Report (DWR 2007), and the Yuba Accord River Management Team Water Temperature Objectives Technical Memorandum (RMT 2010).

WTI values were identified from laboratory experiments and field studies that examined how water temperature affects Central Valley Chinook salmon and steelhead. WTI values were also identified from regulatory documents such as biological opinions from NMFS. Results of the literature review are presented in **Appendix A**. Specific temperature index values were then selected by the TWG to evaluate temperature-related reintroduction potential in the Upper Yuba River Basin.

Studies on fish from outside the Central Valley were used to establish WTI values when local studies were unavailable. To avoid unwarranted specificity, only whole integers were selected as WTI values. In some cases, whole integer WTI values were partially derived from literature results that varied from the index value by several tenths of a degree. For example, Combs and Burrows (1957) reported that constant incubation temperatures up to 57.5°F resulted in normal development of Chinook salmon eggs, and their report was referenced as support for a rounded[1] WTI value of 58°F.

The WTI values presented herein represent a gradation of potential biological effects from optimal to lethal water temperatures for each lifestage. Literature on salmonid water temperature requirements generally reports water temperature thresholds using various descriptive terms including "optimal", "preferred", "suitable", "suboptimal", "tolerable", "stressful – chronic and acute", "sublethal", "incipient lethal", and "lethal". Water temperature effects on salmonids are often discussed in terms of "lethal" and "sublethal" effects, and depend on the both the magnitude and the duration of exposure (Sullivan *et al.* 2000), as well as acclimation water temperature. Exposure to adverse water temperatures can result in adverse effects on the biological functions, feeding activity, lifestage timing, growth, reproduction, competitive interactions, susceptibility to disease, growth and development and ultimately probability of survival (McCullough 1999).

[1] Rounding for the purposes of selecting index values is appropriate because the daily variation of experimental treatment temperatures is often high. For example, temperature treatments in Marine (1997) consisted of control (55.4°F to 60.8°F), intermediate (62.6°F to 68.0°F) and extreme (69.8°F to 75.2°F) treatments that varied daily by several degrees.

There are inherent limitations associated with the development and application of WTI values. Some of the limitations are summarized by McEwan (2001). Namely, that WTI values serve as general guidelines, originally developed by researchers on specific streams or under laboratory conditions. Also, research under controlled laboratory conditions does not take into account ecological considerations associated with water temperature regimes, such as predation risk, inter- and intra-specific competition, long-term survival and local adaptation.

5 LIFESTAGE-SPECIFIC WATER TEMPERATURE INDEX VALUES

Lifestage-specific WTI summary tables derived from the literature review are provided for steelhead and Chinook salmon: (1) adult immigration and holding; (2) spawning and embryo incubation; (3) juvenile rearing and downstream movement; and (4) yearling + smolt emigration in **Tables 2 - 9** (see below). A written discussion of the literature used to create the summary tables is provided in Appendix A. A short discussion of acute versus chronic temperature tolerance also is provided.

5.1 Steelhead and Chinook Salmon Acute Versus Chronic Temperature Tolerance (Juveniles and Adults)

Lifestage-specific WTI values (Sections 5.2 and 5.3 below) were based on long-term (≥ 7 days) chronic temperature exposure rather than acute temperature exposure (< 7 days). The boundary between the upper end of the chronic exposure range and the lower end of the acute exposure range is typically measured as the upper incipient lethal temperature (UILT) where 50% mortality occurs after 7 days (Elliott 1981)[2].

The UILT for both juvenile steelhead and Chinook salmon is very similar and is between 75-79°F (24-26°C) depending on the study (McCullough 1999; Sullivan et al. 2000; McCullough et al. 2001). The UILT for adult steelhead and Chinook salmon is 70-72°F (21-22°C) (Coutant 1970; Becker 1973; McCullough et al. 2001), which is much lower than that for juveniles and is approximately the same temperature that has been identified as an upstream migration barrier for Chinook salmon (McCullough 1999).

Acute temperature response (< 7 days) is strongly dependent on duration of exposure. **Figure 2** shows some example acute exposure relationships for juvenile salmonids. The hourly (60 minute) acute temperature is 5.4 – 9.0°F (3-5°C) higher than the 7-day (10,000 minute) chronic temperature. Because the acute temperature for juvenile salmonids, approximately 82.4°F (28.4°C) is relatively high, it rarely becomes a factor affecting

[2] Note that some authors have measured the UILT using shorter duration exposure than 7 days (e.g., 1,000 mins or 24 hrs). UILT values based on a shorter duration exposure than 7 days will be higher than the UILT values based on a 7 day exposure.

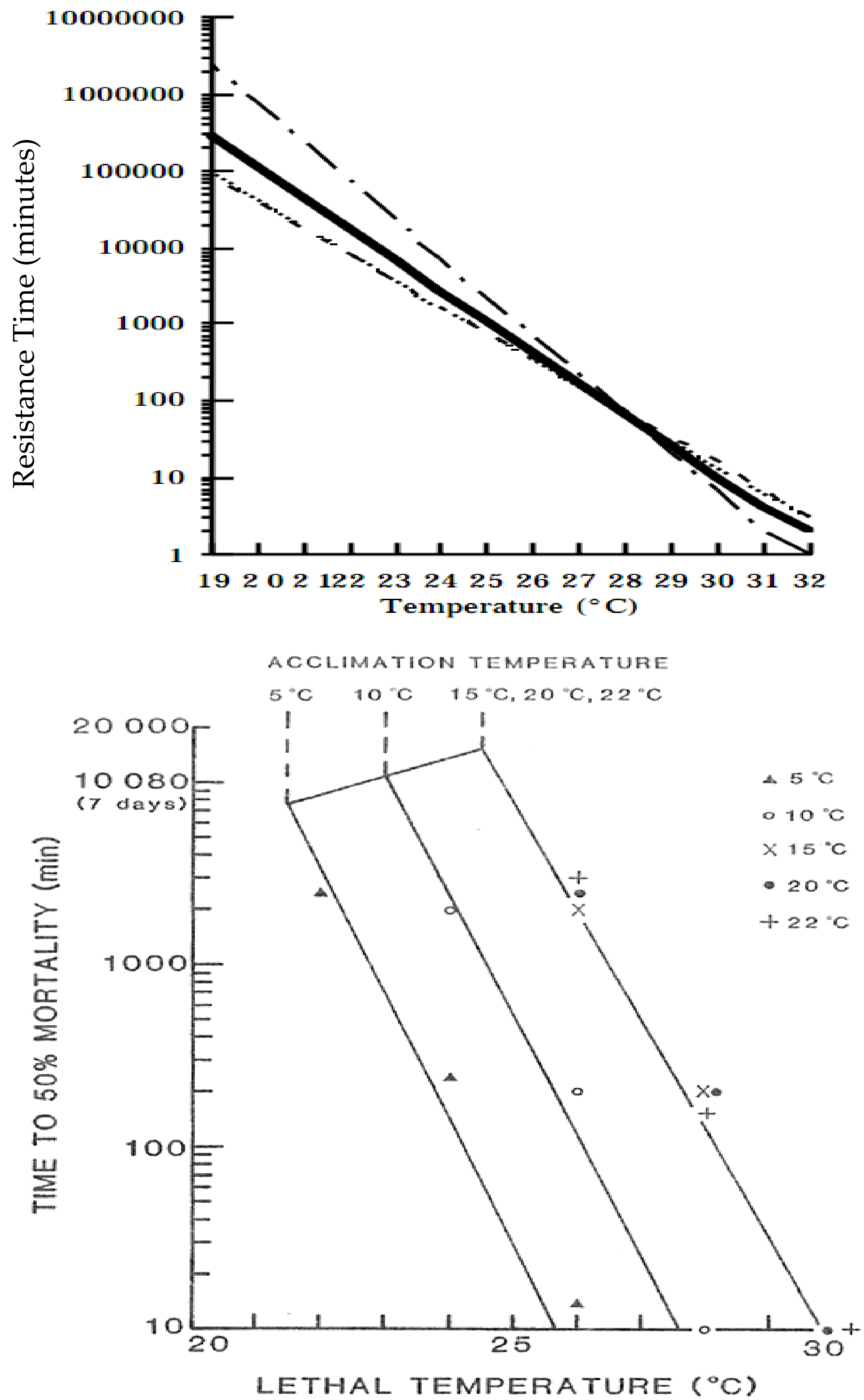


Figure 2. Relationship Between the Time (Minutes) to Mortality and the Lethal Temperature for Rainbow Trout (Top) (Bidgood 1969) and Brown Trout (Bottom) (Elliott 1981). Note the Effect of Acclimation Temperature in the Bottom Figure.

survival in natural streams (Sullivan et al. 2000). However, the acute temperature for adult salmonids is lower – it could become a survival factor particularly for adult spring-run Chinook salmon holding through the summer.

The temperature range between the UILT (7 days) and very short duration mortality (minutes) (e.g., critical thermal maximum) is called the zone of resistance. Below the UILT is a zone of tolerance where fish can tolerate the temperature for an extended period of time (> 7 days). At the higher temperatures in the tolerance zone fish may not feed, grow, or reproduce and they may have modified behavior (e.g., holding in temperature refugia locations). An important point to note is that the effects of water temperature are associated with duration of exposure and, depending upon the actual water temperature value, short duration exposure to relatively high temperatures may not result in sustained adverse effects if temperatures quickly decrease to non-impactive levels.

At lower temperatures in the tolerance zone, denoted "tolerable" in this report, growth and/or reproduction occur, but are reduced from optimal due to temperature effects. The zone of temperature where fish processes (growth, reproduction, behavior) are not affected appreciably by temperature is denoted as the "optimum" temperature range in this report (**Figure 3**).

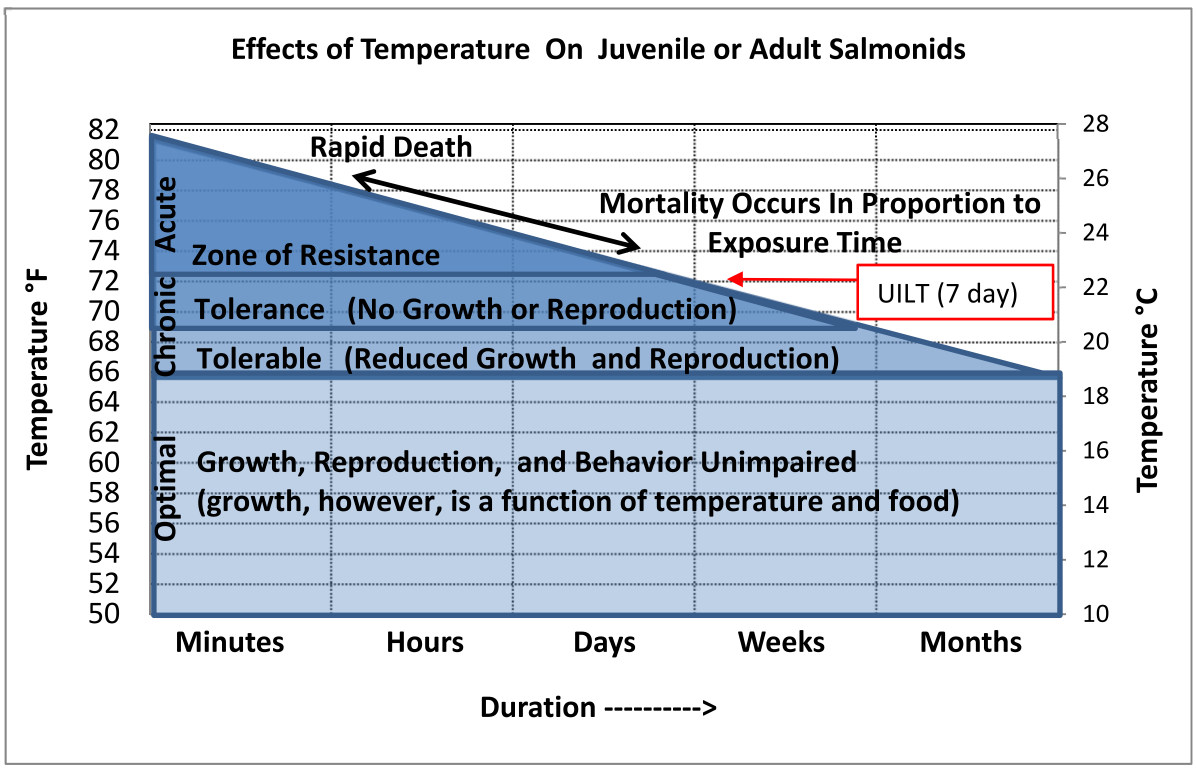


Figure 3. Illustration of Acute, Chronic, and Optimum Temperature Zones.

5.2 Steelhead Lifestage-specific Water Temperature Index Values

5.2.1 Adult Immigration and Holding

Table 2. Steelhead Adult Immigration and Holding Water Temperature Index Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
52°F	Preferred range for adult steelhead immigration of 46.0°F to 52.0°F (NMFS 2000; NMFS 2001a; SWRCB 2003). Optimum range for adult steelhead immigration of 46.0°F to 52.1°F (Reclamation 1997a). Recommended adult steelhead immigration temperature range of 46.0°F to 52.0°F (Reclamation 2003).
56°F	To produce rainbow trout eggs of good quality, brood fish must be held at water temperatures not exceeding 56.0°F (Leitritz and Lewis 1980). Rainbow trout brood fish must be held at water temperatures not exceeding 56°F for a period of 2 to 6 months before spawning to produce eggs of good quality (Bruin and Waldsdorf 1975). Holding migratory fish at constant water temperatures above 55.4°F to 60.1°F may impede spawning success (McCullough *et al.* 2001).
61°F	Water temperatures greater than 61°F may result in "chronic high stress" of holding Central Valley winter-run steelhead (USFWS 1995a). Preferred range of water temperature for holding Caliifornia summer steelhead occurs between 50-59°F (Moyle 1995).
64°F	Steelhead (and fall-run Chinook salmon) encounter potentially stressful temperatures between 64.4-73.4°F (Richter and Kolmes 2005). Over 93% of steelhead detections occurred in the 65.3-71.6°F, although this may be above the temperature for optimal immigration (Salinger and Anderson 2006).
70°F	Migration barriers have frequently been reported for pacific salmonids when water temperatures reach 69.8°F to 71.6°F (McCullough *et al.* 2001). Snake River adult steelhead immigration was blocked when water temperatures reached 69.8 (McCullough *et al.* 2001). A water temperature of 68°F was found to drop egg fertility in vivo to 5 percent after 4.5 days (McCullough *et al.* 2001). The UILT for adult steelhead was determined to be 69.8°F (Coutant 1972).

5.2.2 Spawning and Embryo Incubation

Table 3. Steelhead Spawning and Embryo Incubation Water Temperature Index Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
46°F	Orcutt et al. (1968) reported that steelhead spawning in late spring in the Clearwater and Salmon Rivers, Idaho, occurred at temperatures between 35.6 and 46.4°F.
52°F	Rainbow trout from Mattighofen (Austria) had highest egg survival at 52.0°F compared to 45.0°F, 59.4°F, and 66.0°F (Humpesch 1985). Water temperatures from 48.0°F to 52.0°F are suitable for steelhead incubation and emergence in the American River and Clear Creek (NMFS 2000; NMFS 2001a; NMFS 2002a). Optimum water temperature range of 46.0°F to 52.0°F for steelhead spawning in the Central Valley (USFWS 1995b). Optimum water temperature range of 46.0°F to 52.1°F for steelhead spawning and 48.0°F to 52.1°F for steelhead egg incubation (Reclamation 1997a). Upper limit of preferred water temperature of 52.0°F for steelhead spawning and egg incubation (SWRCB 2003).
54°F	Big Qualicum River steelhead eggs had 96.6 percent survival to hatch at 53.6°F (Rombough 1988). Highest survival from fertilization to hatch for *Salmo gairdneri* incubated at 53.6°F (Kamler and Kato 1983). Emergent fry were larger when North Santiam River (Oregon) winter steelhead eggs were incubated at 53.6°F than at 60.8°F (Redding and Schreck 1979). The upper optimal water temperature regime based on constant or acclimation water temperatures necessary to achieve full protection of steelhead is 51.8°F to 53.6°F (EPA 2001). From fertilization to hatch, rainbow trout eggs and larvae had 47.3 percent mortality (Timoshina 1972). Survival of rainbow trout eggs declined at water temperatures between 52.0 and 59.4°F (Humpesch 1985). The optimal constant incubation water temperature for steelhead occurs below 53.6°F (McCullough *et al.* 2001).

Index Value	Supporting Literature
57°F	From fertilization to 50 percent hatch, Big Qualicum River steelhead had 93 percent mortality at 60.8°F, 7.7 percent mortality at 57.2°F, and 1 percent mortality at 47.3°F and 39.2°F (Velsen 1987). A sharp decrease in survival was observed for rainbow trout embryos incubated above 57.2°F (Kamler and Kato 1983).
60°F	Water temperatures >59°F are described as "lethal" to incubating steelhead embryos (Myrick and Cech 2001), From fertilization to 50 percent hatch, Big Qualicum River steelhead had 93 percent mortality at 60.8°F, 7.7 percent mortality at 57.2°F, and 1 percent mortality at 47.3°F and 39.2°F (Velsen 1987). From fertilization to 50 percent hatch, rainbow trout eggs from Ontario Provincial Normendale Hatchery had 56 percent survival when incubated at 59.0°F (Kwain 1975).

5.2.3 Juvenile Rearing and Downstream Movement

Table 4. Steelhead Juvenile Rearing and Downstream Movement Water Temperature Index Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
63°F	Preferred water temperature for wild juvenile steelhead is reportedly 63°F, whereas preferred water temperatures for juvenile hatchery steelhead reportedly range between 64-66°F. Myrick and Cech (2001)
65°F	Upper limit of 65°F preferred for growth and development of Sacramento River and American River juvenile steelhead (NMFS 2002a). Nimbus juvenile steelhead growth showed an increasing trend with water temperature to 66.2°F, irrespective of ration level or rearing temperature (Cech and Myrick 1999). The final preferred water temperature for rainbow fingerlings was between 66.2 and 68°F (Cherry *et al.* 1977). Nimbus juvenile steelhead preferred water temperatures between 62.6°F and 68.0°F (Cech and Myrick 1999). Rainbow trout fingerlings preferred or selected water temperatures in the 62.6°F to 68.0°F range (McCauley and Pond 1971).
68°F	Nimbus juvenile steelhead preferred water temperatures between 62.6°F and 68.0°F (Cech and Myrick 1999). The final preferred water temperature for rainbow trout fingerlings was between 66.2°F and 68°F (Cherry *et al.* 1977). Rainbow trout fingerlings preferred or selected water temperatures in the 62.6°F to 68.0°F range (McCauley and Pond 1971). The upper avoidance water temperature for juvenile rainbow trout was measured at 68°F to 71.6°F (Kaya et al. 1977). FERC (1993) referred to 68°F as "stressful" to juvenile steelhead. Empirical fish population and water temperature data in the North Yuba, Middle Yuba, South Yuba, Middle Fork American, and Rubicon Rivers (**Figure 4**) indicate a sharp reduction in O. *mykiss* population densities when temperatures exceed 68°F for greater than one week. Bioenergetics modeling of growth based on consumption (P value = 0.5) in the Middle Fork American River watershed (adjacent watershed) indicates that growth likely does not occur above 68°F (**Figure 5**).
72°F	Increased physiological stress, increased agonistic activity, and a decrease in forage activity in juvenile steelhead occur after ambient stream temperatures exceed 71.6°F (Nielsen *et al.* 1994). The upper avoidance water temperature for juvenile rainbow trout was measured at 68°F to 71.6°F (Kaya *et al.* 1977). Estimates of upper thermal tolerance or avoidance limits for juvenile rainbow trout (at maximum ration) ranged from 71.6°F to 79.9°F (Ebersole *et al.* 2001).
75°F	The maximum weekly average water temperature for survival of juvenile and adult rainbow trout is 75.2°F (EPA 2002). Rearing steelhead juveniles have an upper lethal limit of 75.0°F (NMFS 2001a). Estimates of upper thermal tolerance or avoidance limits for juvenile rainbow trout (at maximum ration) ranged from 71.6 to 79.9°F (Ebersole *et al.* 2001). The UILT for juvenile rainbow trout, based on numerous studies, is between 75-79°F (Sullivan et al. 2000; McCullough 2001).

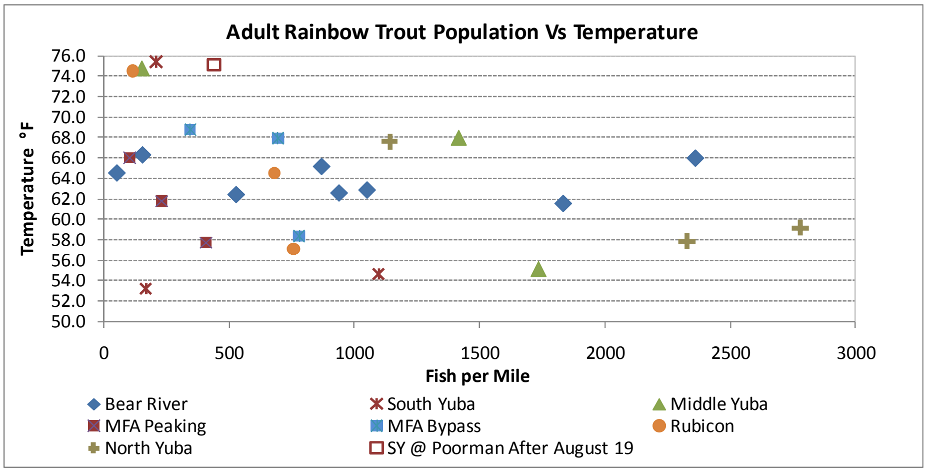
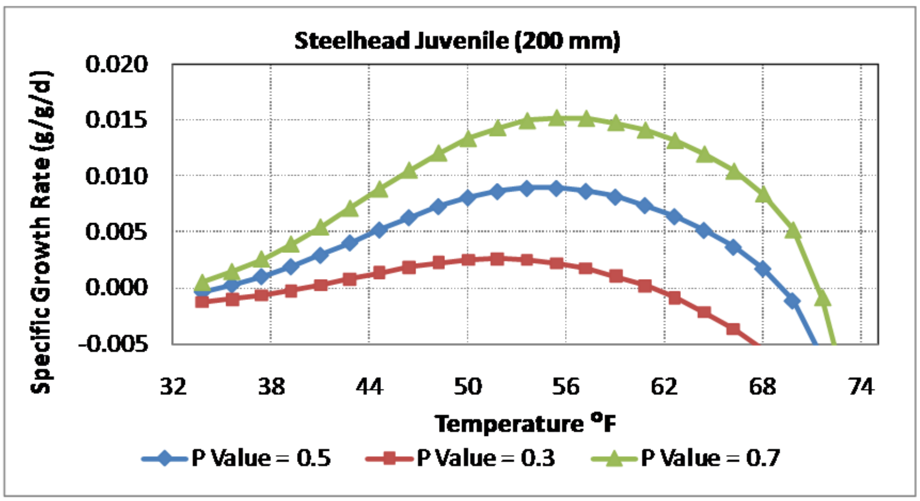


Figure 4. Empirical Adult Fish Population Data in the Middle Fork American and Yuba River Rivers Compared to the Maximum Temperature Exceeded Less Than 7 Days.



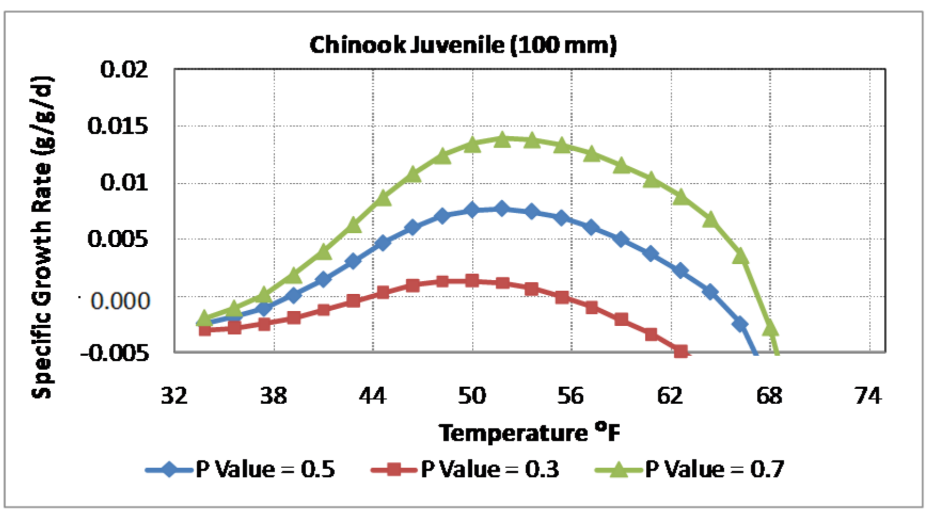


Figure 5. Bioenergetics Growth Rate Modeling For Steelhead and Chinook Salmon Juveniles Over a Range of Temperatures.

5.2.4 Yearling + Smolt Emigration

Table 5. Steelhead Smolt Emigration Water Temperature Index Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
52°F	Steelhead successfully smolt at water temperatures in the 43.7°F to 52.3°F range (Myrick and Cech 2001). Steelhead undergo the smolt transformation when reared in water temperatures below 52.3°F, but not at higher water temperatures (Adams *et al.* 1975). Optimum water temperature range for successful smoltification in young steelhead is 44.0°F to 52.3°F (Rich 1987a).
55°F	ATPase activity was decreased and migration reduced for steelhead at water temperatures greater than or equal to 55.4°F (Zaugg and Wagner 1973). Water temperatures should be below 55.4°F at least 60 days prior to release of hatchery steelhead to prevent premature smolting and desmoltification (Wedemeyer *et al.* 1980). In winter steelhead, a temperature of 54.1°F is nearly the upper limit for smolting (McCullough *et al.* 2001; Zaugg and Wagner 1973). Water temperatures less than or equal to 54.5°F are suitable for emigrating juvenile steelhead (EPA 2003b). Water temperatures greater than 55°F prevent increases in ATPase activity in steelhead juveniles (Hoar 1988). Water temperatures greater than 56°F do not permit smoltification in summer steelhead (Zaugg *et al.* 1972)
59°F	Yearling steelhead held at 43.7°F and transferred to 59°F had a substantial reduction in gill ATPase activity, indicating that physiological changes associated with smoltification were reversed (Wedemeyer *et al.* 1980).

5.3 Chinook Salmon Lifestage-Specific Water Temperature Index Values

5.3.1 Adult Immigration and Holding

Table 6. Chinook Salmon Adult Immigration and Holding Water Temperature Index Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
60°F	Maximum water temperature for adults holding, while eggs are maturing, is approximately 59°F to 60°F (NMFS 1997b). Acceptable water temperatures for adults migrating upstream range from 57°F to 67°F (NMFS 1997b). Upper limit of the optimal water temperature range for adults holding while eggs are maturing is 59°F to 60°F (NMFS 2000). Many of the diseases that commonly affect Chinook salmon become highly infectious and virulent above 60°F (ODEQ 1995). Mature females subjected to prolonged exposure to water temperatures above 60°F have poor survival rates and produce less viable eggs than females exposed to lower water temperatures (USFWS 1995b). Ward and Kier (1999) designated temperatures <60.8°F as an "optimum" water temperature threshold for holding Battle Creek spring-run Chinook salmon.
65°F	Acceptable range for adults migrating upstream is from 57°F to 67°F (NMFS 1997b). Disease risk becomes high at water temperatures above 64.4°F (EPA 2003b). Latent embryonic mortalities and abnormalities associated with water temperature exposure to pre-spawning adults occur at 63.5°F to 66.2°F (Berman 1990). During each of the years when Chinook salmon temperature mortality was not observed at Butte Creek (2001, 2004-2007), on average, daily temperature did not exceed 65.8°F for more than 7 days (**Figure 6**).
68°F	Acceptable range for adults migrating upstream range from 57°F to 67°F (NMFS 1997b). For chronic exposures, an incipient upper lethal water temperature limit for pre-spawning adult salmon probably falls within the range of 62.6°F to 68.0°F (Marine 1992). Spring-run Chinook salmon embryos from adults held at 63.5°F to 66.2°F had greater numbers of pre-hatch mortalities and developmental abnormalities than embryos from adults held at 57.2°F to 59.9°F (Berman 1990). Water temperatures of 68°F resulted in nearly 100 percent mortality of Chinook salmon during columnaris outbreaks (Ordal and Pacha 1963). In Butte Creek a period of average daily temperatures above 67°F (11-16 days) preceded the onset of significant pre-spawn mortalities. In

	years when 67°F was exceeded only a few days, pre-spawn mortality was minimal (Ward et al. 2004). Adult Chinook salmon migration rates through the lower Columbia River were slowed significantly when water temperatures exceeded 68°F (Goniea et al. 2006).
70°F	Migration blockage occurs for Chinook salmon at temperatures from 70-71+°F (McCollough 1999; McCullough *et al.* 2001; EPA 2003b). Strange (2010) found that the mean average body temperature during the first week of Chinook salmon migration on the Klamath River was 71.4°F. The UILT for Chinook salmon jacks is 69.8-71.6°F (McCullough 1999).

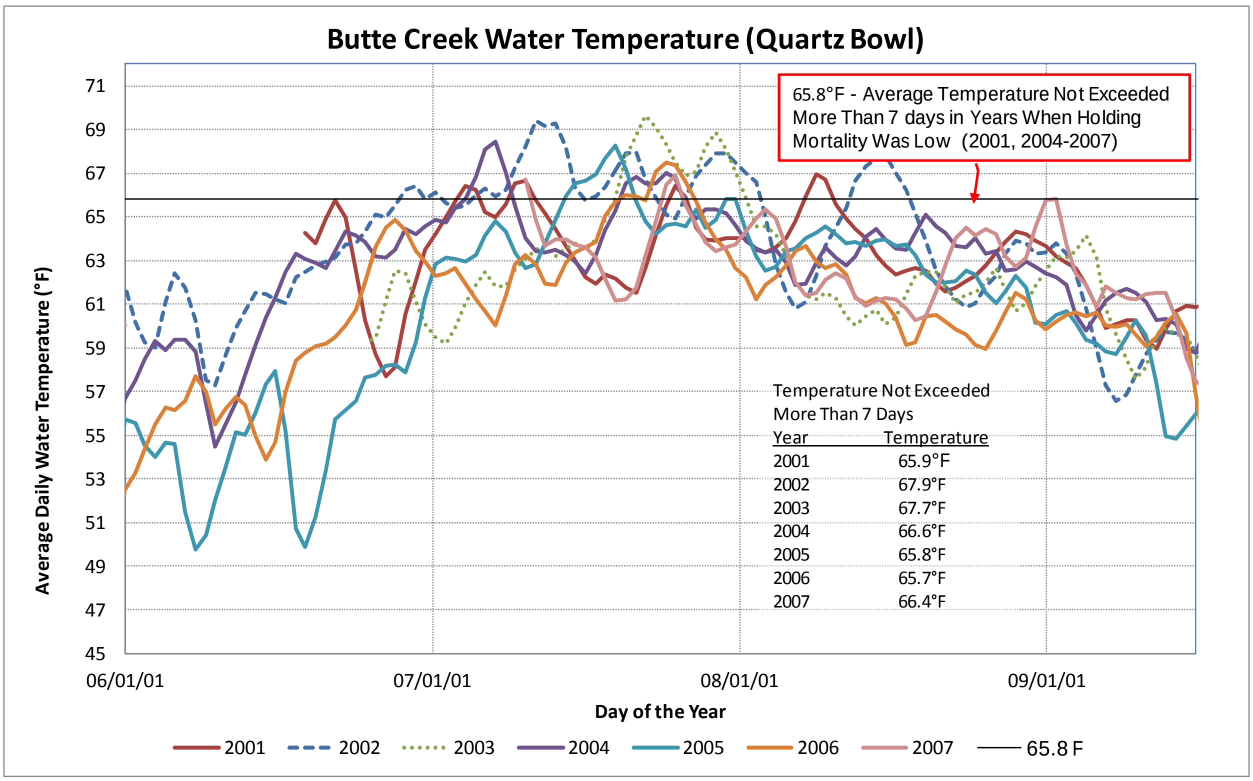


Figure 6. Water Temperature in Butte Creek at Quartz Bowl (2001-2007).

5.3.2 Spawning and Embryo Incubation

Table 7. Chinook Salmon Spawning and Embryo Incubation Water Temperature Index Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
56°F	Less than 56°F results in a natural rate of mortality for fertilized Chinook salmon eggs (Reclamation Unpublished Work). Optimum water temperatures for egg development are between 43°F and 56°F (NMFS 1993b). Upper value of the water temperature range (i.e., 41.0°F to 56.0°F) suggested for maximum survival of eggs and yolk-sac larvae in the Central Valley of California (USFWS 1995b). Upper value of the range (i.e., 42.0°F to 56.0°F) given for the preferred water temperature for Chinook salmon egg incubation in the Sacramento River (NMFS 1997a). Incubation temperatures above 56°F result in significantly higher alevin mortality (USFWS 1999). 56.0°F is the upper limit of suitable water temperatures for spring-run Chinook salmon spawning in the Sacramento River (NMFS 2002a). Water temperatures averaged 56.5°F during the week of fall-run Chinook salmon spawning initiation on the Snake River (Groves and Chandler 1999).
58°F	Upper value of the range given for preferred water temperatures (i.e., 53.0°F to 58.0°F) for eggs and fry (NMFS 2002a). Constant egg incubation temperatures between 42.5°F and 57.5°F resulted in normal development (Combs and Burrows 1957). The natural rate of mortality for alevins occurs at 58°F or less (Reclamation Unpublished Work).
60°F	100 percent mortality can occur to late incubating Chinook salmon embryos (yolk-sac stage) if temperatures are 60°F or greater (Seymour 1956). An October 1 to October 31 water temperature criterion of less than or equal to 60°F in the Sacramento River from Keswick Dam to Bend Bridge has been determined for protection of late incubating larvae and newly emerged fry (NMFS 1993b). Mean weekly water temperature at first observed Chinook salmon spawning in the Columbia River was 59.5°F (Dauble and Watson 1997). Consistently higher egg losses resulted at water temperatures above 60.0°F than at lower temperatures (Johnson and Brice 1953). For Chinook Salmon eggs incubated at constant temperatures, mortality increases rapidly at temperatures greater than about 59-60°F (see data plots in Myrick and Cech 2001). Olsen and Foster (1957) found high survival of Chinook salmon eggs and fry (89.6%) when incubation temperatures started at 60.9°F and declined naturally for the Columbia River (about 7°F / month). Geist et al. (2006) found high (93.8%) Chinook salmon incubation survival through emergence for naturally declining temperatures (0.36°F/day) starting as high as 61.7°F; however, a significant reduction in survival occurred above this temperature.
62°F	100 percent mortality of fertilized Chinook salmon eggs after 12 days at 62°F (Reclamation Unpublished Work). Incubation temperatures of 62ºF to 64°F appear to be the physiological limit for embryo development resulting in 80 to 100 percent mortality prior to emergence (USFWS 1999). 100 percent loss of eggs incubated at water temperatures above 62°F (Hinze 1959). 100 percent mortality occurs during yolk-sac stage when embryos are incubated at 62.5°F (Seymour 1956). Approximately 80% or greater mortality of eggs incubated at constant temperatures of 63°F or greater (see data plots in Myrick and Cech 2001). Olsen and Foster (1957) found high mortality of Chinook salmon eggs and fry (79%) when incubation temperatures started at 65.2°F and declined naturally for the Columbia River (about 7°F / month). Geist et al. (2006) found low Chinook salmon incubation survival (1.7%) for naturally declining temperatures (0.36°F/day) when temperatures started at 62.6°F.

5.3.3 Juvenile Rearing and Downstream Movement

Table 8. Chinook Salmon Juvenile Rearing and Downstream Movement Water Temperature Index Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
60°F	Optimum water temperature for Chinook salmon fry growth is between 55.0°F and 60°F (Seymour 1956). Water temperature range that produced optimum growth in juvenile Chinook salmon was between 54.0°F and 60.0°F (Rich 1987b). Water temperature criterion of less than or equal to 60.0°F for the protection of Sacramento River winter-run Chinook salmon from Keswick Dam to Bend Bridge (NMFS 1993b). Upper optimal water temperature limit of 61°F for Sacramento River fall-run Chinook salmon juvenile rearing (Marine 1997; Marine and Cech 2004). Upper water temperature limit of 60.0°F preferred for growth and development of spring-run Chinook salmon fry and fingerlings (NMFS 2000; NMFS 2002a). To protect salmon fry and juvenile Chinook salmon in the upper Sacramento River, daily average water temperatures should not exceed 60°F after September 30 (NMFS 1997b). A water temperature of 60°F appeared closest to the optimum for growth of fingerlings (Banks *et al.* 1971). Optimum growth of Nechako River Chinook salmon juveniles would occur at 59°F at a feeding level that is 60 percent of that required to satiate them (Brett *et al.* 1982). In a laboratory study, juvenile fall-run Chinook salmon from the Sacramento River reared in water temperatures between 70°F and 75°F experienced significantly decreased growth rates, and increased predation vulnerability compared with juveniles reared between 55°F and 61°F (Marine 1997; Marine and Cech 2004).
65°F	Water temperatures between 45°F to 65°F are preferred for growth and development of fry and juvenile spring-run Chinook salmon in the Feather River (NMFS 2002a). Recommended summer maximum water temperature of 64.4°F for migration and non-core rearing (EPA 2003b). Water temperatures greater than 64.0°F are considered not "properly functioning" by NMFS in Amendment 14 to the Pacific Coast Salmon Plan (NMFS 1995). Fatal infection rates caused by *C. columnaris* are high at temperatures greater than or equal to 64.0°F (EPA 2001). Disease mortalities diminish at water temperatures below 65.0°F (Ordal and Pacha 1963). Fingerling Chinook salmon reared in water greater than 65.0°F contracted *C. columnaris* and exhibited high mortality (Johnson and Brice 1953). Water temperatures greater than 64.9°F identified as being stressful in the Columbia River Ecosystem (Independent Scientific Group 1996). Juvenile Chinook salmon have an optimum temperature for growth that appears to occur at about 66.2°F (Brett *et al.* 1982). Juvenile Chinook salmon reached a growth maximum at 66.2°F (Cech and Myrick 1999). Optimal range for Chinook salmon survival and growth from 53.0°F to 64.0°F (USFWS 1995b). Survival of Central Valley juvenile Chinook salmon declines at temperatures greater than 64.4°F (Myrick and Cech 2001). Increased incidence of disease, reduced appetite, and reduced growth rates at 66.2±1.4 °F (Rich 1987b). Bioenergetics modeling of growth based on consumption of rainbow trout (P value = 0.5) in the Middle Fork American River watershed (adjacent watershed) indicates that growth likely does not occur above about 65°F (Figure 5)
68°F	Sacramento River juvenile Chinook salmon reared at water temperatures greater than or equal to 68.0°F suffer reductions in appetite and growth (Marine 1997; Marine and Cech 2004). Significant reductions in growth rates may occur when chronic elevated temperatures exceed 68°F (Marine 1997; Marine and Cech 2004). Juvenile spring-run Chinook salmon were not found in areas having mean weekly water temperatures between 67.1°F and 71.6°F (Burck *et al.* 1980; Zedonis and Newcomb 1997). Results from a study on wild spring-run Chinook salmon in the John Day River system indicate that juvenile fish were not found in areas having mean weekly water temperatures between 67.1°F and 72.9°F (McCullough 1999; Zedonis and Newcomb 1997).
70°F	No growth at all would occur for Nechako River juvenile Chinook salmon at 70.5°F (Brett *et al.* 1982; Zedonis and Newcomb 1997). Juvenile spring-run Chinook salmon were not found in areas having mean weekly water temperatures between 67.1°F and 71.6°F (Burck *et al.* 1980; Zedonis and Newcomb 1997). Results from a study on wild spring-run Chinook salmon in the John Day River system indicate that juvenile fish were not found in areas having mean weekly water temperatures between 67.1°F and 72.9°F (McCullough 1999; Zedonis and Newcomb 1997). Increased incidence of disease, hyperactivity, reduced appetite, and reduced growth rates at 69.8 ±1.8 °F (Rich 1987b). In a laboratory study, juvenile fall-run Chinook salmon from the Sacramento River reared in water temperatures between 70°F and 75°F experienced significantly decreased growth rates and increased predation vulnerability compared with juveniles reared between 55°F and 61°F (Marine 1997; Marine and Cech 2004).

75°F	For juvenile Chinook salmon in the lower American River fed maximum rations under laboratory conditions, 75.2°F was determined to be 100 percent lethal due to hyperactivity and disease (Rich 1987b; Zedonis and Newcomb 1997). Lethal temperature threshold for fall-run juvenile Chinook salmon between 74.3 and 76.1°F (McCullough 1999). In a laboratory study, juvenile fall-run Chinook salmon from the Sacramento River reared in water temperatures between 70°F and 75°F experienced significantly decreased growth rates, and increased predation vulnerability compared with juveniles reared between 55°F and 61°F (Marine 1997; Marine and Cech 2004). The juvenile Chinook Salmon UILT based on numerous studies is 75-77°F (Sullivan et al. 2000; McCullough et al. 2001; Myrick and Cech 2001)

5.3.4 Yearling + Smolt Emigration

Table 9. Chinook Salmon Yearling + Smolt Emigration Water Temperature Index Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
63°F	Acceleration and inhibition of Sacramento River Chinook salmon smolt development reportedly may occur at water temperatures above 63°F (Marine 1997; Marine and Cech 2004). Laboratory evidence suggest that survival and smoltification become compromised at water temperatures above 62.6°F (Zedonis and Newcomb 1997). Juvenile Chinook salmon growth was highest at 62.6°F (Clarke and Shelbourn 1985).
68°F	Significant inhibition of gill sodium ATPase activity and associated reductions of hyposmoregulatory capacity, and significant reductions in growth rates, may occur when chronic elevated temperatures exceed 68°F (Marine 1997; Marine and Cech 2004). Water temperatures supporting smoltification of fall-run Chinook salmon range between 50°F to 68°F, the colder temperatures represent more optimal conditions (50°F to 62.6°F), and the warmer conditions (62.6°F to 68°F) represent marginal conditions (Zedonis and Newcomb 1997).
72°F	In a laboratory study, juvenile fall-run Chinook salmon from the Sacramento River reared in water temperatures between 70°F and 75°F experienced significantly decreased growth rates, impaired smoltification indices, and increased predation vulnerability compared with juveniles reared between 55°F and 61°F (Marine 1997; Marine and Cech 2004). Indirect evidence from tagging studies suggests that the survival of fall-run Chinook salmon smolts decreases with increasing water temperatures between 59°F and 75°F in the Sacramento-San Joaquin Delta (Kjelson and Brandes 1989).

5.4 Upstream Migration Behavioral Effects Due to River Temperature Gradients

If volitional upstream passage was provided past Englebright Reservoir (e.g., ladder, dam removal), the potential exists for upstream migrating adult salmonids to have to volitionally pass through significant water temperature differentials from the Lower Yuba River into the South or Middle Yuba rivers (Upper Yuba River) due to cold water releases from New Bullards Bar Reservoir into the Yuba River (via Colgate Powerhouse). **Figure 7** shows an example of water temperature in the Yuba River below Colgate Powerhouse and the South and Middle Fork Yuba rivers near their confluence with the Yuba River. It is possible to modify the temperature differentials by selective withdrawal of water from New Bullards Bar Reservoir (Colgate Powerhouse temperature) or by modifying flows in the South or Middle Yuba rivers; nevertheless, the temperature differentials could be large. For example, during the May-June migration period for spring-run Chinook salmon or the late summer/fall migration period for steelhead, Middle and South Yuba river temperatures are much warmer than the downstream Yuba River temperatures (e.g., > 7°F or > 4°C).

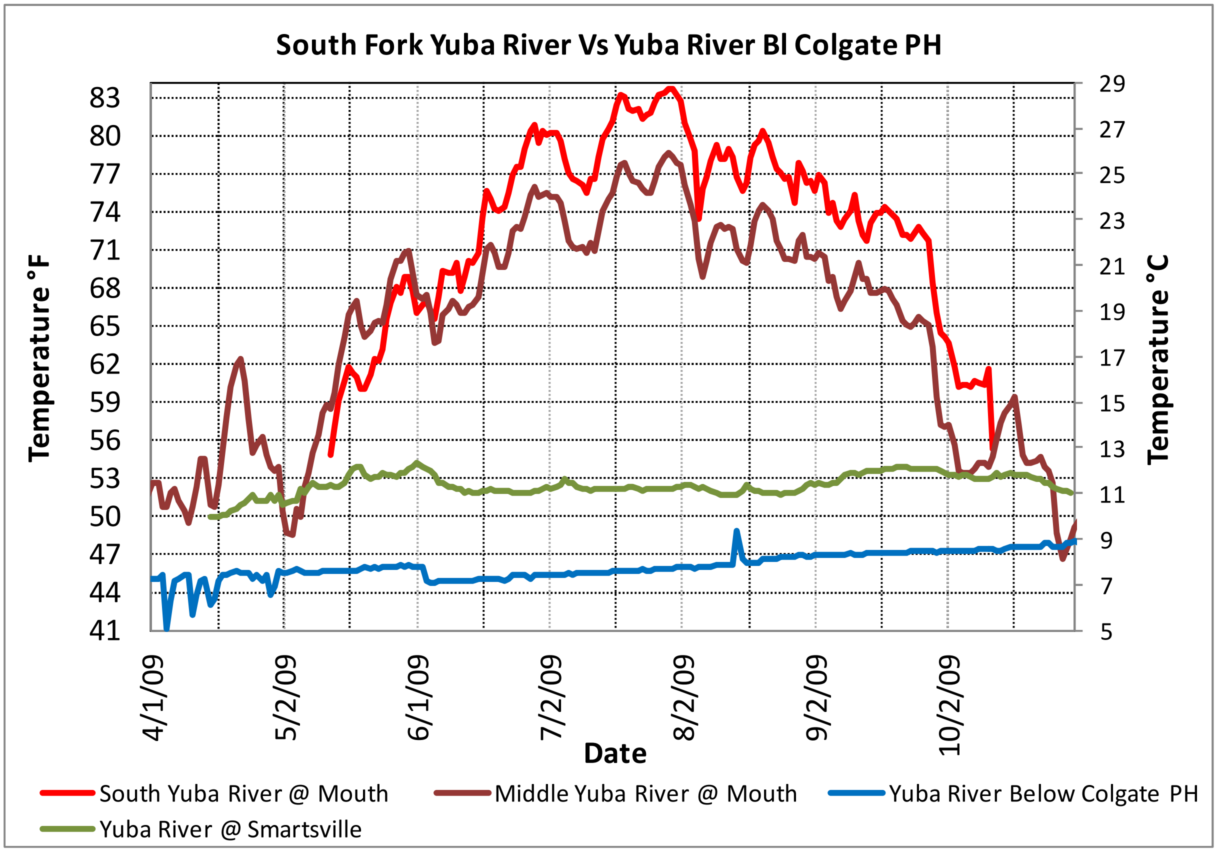


Figure 7. Water Temperature Differentials Between the South and Middle Yuba Rivers, and the Yuba River Below Colgate and at Smartsville.

To date, we have only identified limited information in the literature regarding the effect of temperature differentials on volitional upstream migration of Chinook salmon or steelhead. Typically, as fish migrate upstream in rivers the water temperature becomes cooler. Migrating fish may move from cooler ocean/estuary temperatures (Strange 2010) into warmer river temperatures, but as fish move upstream in rivers, the temperature typically gets cooler. In the case of migration from the Yuba River to the South and Middle Yuba rivers, fish could be faced with moving in a reverse temperature gradient from cooler downstream water, into warmer upstream water.

In the Columbia River both migrating Chinook salmon and steelhead use coolwater tributaries as thermal refugia during warm summer conditions. Staging in coolwater tributaries significantly slows and affects the migratory behavior of the fish (High et al.

2006; Goniea et al. 2006). Also temperature differentials at Columbia River ladders (e.g., colder water at the entrance to the ladder versus warmer water in the ladder), even relatively small temperature differentials, can slow migration rates through the ladders. Caudill et al. (2005) found that few fish passed the ladders when temperature differentials were > 7°F (> 4°C) and that passage times increased with increased temperature differential (e.g., > 2°F).

In the Snake River/Clearwater River system a somewhat analogous temperature situation exists compared to that which may occur in the Yuba River system. During the summer (July-August) cold water is released from Dworshak Reservoir on the North Fork Clearwater River into the Clearwater River. As a result, the Clearwater River becomes colder than the Snake River where they meet near Lewiston, Idaho. Spring-run Chinook salmon are generally not affected because by July, most spring-run Chinook salmon moving up the Clearwater River are already past the mouth of the North Fork Clearwater River, and are up close to or in their higher elevation natal streams getting ready to spawn. It does appear, however, that some later returning spring-run Chinook salmon do hold longer than they would have normally, near or in the North Fork Clearwater River, because of the colder water coming out of Dworshak Reservoir. As a result, there is spawning activity that occurs in the lower North Fork Clearwater River (it is possible that some of these fish may be hatchery fish shunted off from entering Dworshak Hatchery).

The cooling effect of Dworshak Reservoir releases to the Clearwater River does modify the behavior of returning steelhead and fall-run Chinook salmon at the confluence with the Snake River. The cooler water in the Clearwater River draws fish destined for the Snake River into the Clearwater River and they hold in the mouth of the Clearwater River until the Snake River cools down (Personal Communication, Bill Arnsberg, Nez Perce Tribal Biologist).

Our recommendation is that additional literature and data should be obtained and summarized regarding the effect of water temperature differentials on volitional migration (if such information exists). In addition, based on the limited information available, a temperature differential of 7°F (4°C) should precautionarily be viewed as a potential thermal barrier to adult upstream migration. It is possible that even lower temperature differentials (< 7°F) could result in migrating fish holding downstream and not migrating, or significantly delaying migration.

6 TEMPORAL TEMPERATURE PATTERNS RELATED TO WATER TEMPERATURE INDEX VALUES AND METRICS

Typical water temperature patterns in the Yuba River system exhibit a week or two of high temperatures and a much broader range of temperatures that are lower. For example, **Figure 8** shows historical water temperature in the section of the Middle Yuba River near Wolf Creek in 2008. This site is used below to briefly discuss temporal temperature patterns and their relationship to critical WTI values and some typical water temperature metrics used in the literature to summarize water temperature.

Historical daily average water temperatures at the Middle Yuba River site were near the temperature that has been observed to cause mortality to Chinook Salmon in Butte Creek (e.g., 67°F or greater) (Ward et al. 2004). Most of the summer, daily average water temperatures at the Middle Yuba River site were at or below 67°F, but there were a couple of weeks that the average daily water temperature exceeded 67°F (similar to conditions that caused mortality in Butte Creek). Maximum daily water temperatures at the site during much of the summer were near the 7-day UILT[3] for Chinook salmon adults of 69.8-71.6°F (McCullough 1999). However, the duration of time within a day that the water temperature was near the 7-day UILT was short and is not available from the plot nor from typical maximum temperature metrics (see below).

Some typical temperature metrics are shown on Figure 8. The 7-day moving average temperature (7DMA) also exceeded 67°F for the same two time periods that the average daily temperature exceeded 67°F. The maximum weekly average temperature (MWAT) (average of the daily mean temperature of the 7 warmest days) occurred in mid-July and was 67.9°F. The maximum daily temperatures, 7-day moving average daily maximum (7DMADM), were about 4°F greater than the mean daily temperature during the warmest months, and the 7-day average daily maximum temperature (7DADM) occurred at the same time as the MWAT (67.9 °F versus 71.7°F).

Historically in Butte Creek, when average daily water temperature was 67°F for more than about a week (11 and 16 days in 2002 and 2003, respectively) significant adult Chinook salmon mortality occurred. However, if water temperature exceeded 67°F for a relatively short number of days (e.g., < 7 days), significant mortality did not occur (Ward et al. 2004).

An analogous approach for analyzing the Yuba River water temperatures could be used. This could be done by using WTI values, where exceeding the WTI temperature criteria for less than 7 days would not be expected to affect each lifestage, but exceeding the WTI for more than 7 days would be detrimental.

[3] Note, however, the UILT is 7 continuous days exposure and is not comparable to a daily maximum temperature.

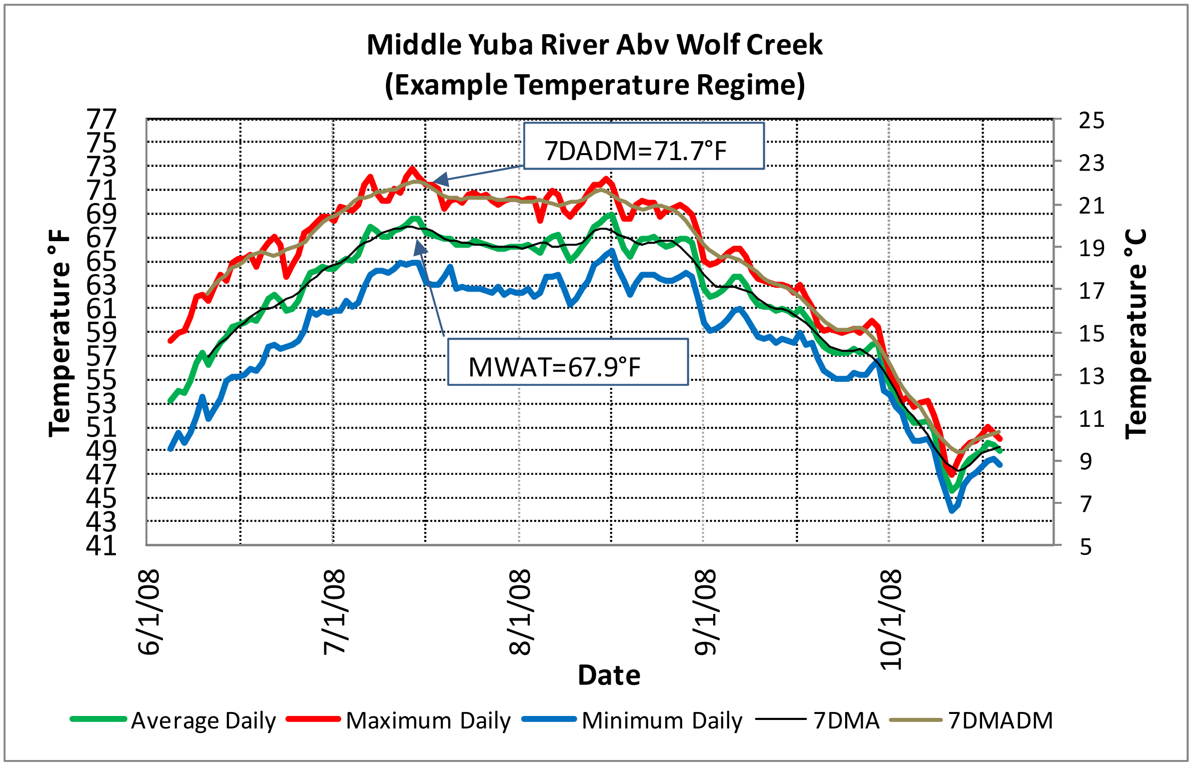


Figure 8. Middle Fork Yuba River Water Temperature Including 7 Day Moving Averages of the Average Daily Temperature and the Maximum Daily Temperature. Also Included Are the Maximum Weekly Average Temperature (MWAT) and the 7 Day Average Daily Maximum Temperature (7DADM).

Quantifying the number of average daily water temperature values that exceed a WTI threshold would be a direct approach to quantifying habitat suitability. The MWAT and/or the moving average (7DMA) identify a maximum average weekly water temperature value, but do not indicate the duration of time that this occurred. Similarly, if acute temperature was a concern, the individual water temperature measurements (e.g., hourly) could be used to identify the number of hours (duration) that a maximum WTI value was exceeded (e.g., tally the number of days and hours). Conversely, the 7DADM and/or the moving average (7DMADM) identify a maximum average weekly maximum temperature value, but do not indicate the duration of time that it occurred.

7 SPECIES- AND LIFESTAGE-SPECIFIC WATER TEMPERATURE RANGE ACCEPTABLE FOR REINTRODUCTION EVALUATION

The goal of the temperature analysis is twofold: (1) to identify the high temperature WTI value(s) that clearly demarcate the spatial/temperature boundary between where steelhead and Chinook salmon lifestages can and cannot exist (even though temperature is a stressor) (upper tolerable WTI); and (2) to determine within the "can exist" boundary, if there is a core area where they can thrive without temperature as a stressor (upper optimal WTI). The upper tolerable temperature represents the upper boundary of the range of acceptable water temperatures for reintroduction evaluation. It represents a water temperature at which fish can survive indefinitely, without experiencing substantial detrimental effects to physiological and biological functions such that survival occurs, but growth and reproduction success are reduced below optimal. The upper optimal temperature represents the upper boundary of the optimum range and represents a temperature below which growth, reproduction, and/or behavior are not affected by temperature. Below, we discuss: (1) existing regulatory water temperature standards or guidelines that could be used as index values; and (2) specific water temperature index values that have been derived based on the literature review in this report.

7.1 Existing Water Temperature Standards/Guidelines

Several different water temperature standards are used currently by states for salmonids (e.g., California, Oregon, and Washington water temperature standards). California's Basin Plan is largely based on not altering the temperature of intrastate waters unless alterations can be shown to not have an effect on beneficial uses for cold freshwater habitat, migration, and/or spawning (**Table 10**). The beneficial uses of the Yuba River are listed in **Table 11**. Specific temperature criteria for species/lifestages are not identified in the Basin Plan nor are there specific temperature objectives for the Yuba River system. However, for the Sacramento River, seasonal temperature criteria have been developed (Table 10). These temperature objectives, while not directly applicable to the Yuba River, give an indication of temperature objectives that have been set for anadromous fish in the basin.

Table 10. Basin Plan Temperature Standards Including Specific Standards for the Sacramento River.

Temperature

The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses.

Temperature objectives for COLD interstate waters, WARM interstate waters, and Enclosed Bays and Estuaries are as specified in the *Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays of California* including any revisions. There are also temperature objectives for the Delta in the State Water Board's May 1991 *Water Quality Control Plan for Salinity*.

At no time or place shall the temperature of COLD or WARM intrastate waters be increased more than 5°F above natural receiving water temperature. Temperature changes due to controllable factors shall be limited for the water bodies specified as described in Table III-4. To the extent of any conflict with the above, the more stringent objective applies.

In determining compliance with the water quality objectives for temperature, appropriate averaging periods may be applied provided that beneficial uses will be fully protected.

TABLE III-4
SPECIFIC TEMPERATURE OBJECTIVES

DATES	APPLICABLE WATER BODY
From 1 December to 15 March, the maximum temperature shall be 55°F. From 16 March to 15 April, the maximum temperature shall be 60°F. From 16 April to 15 May, the maximum temperature shall be 65°F. From 16 May to 15 October, the maximum temperature shall be 70°F. From 16 October to 15 November, the maximum temperature shall be 65°F. From 16 November to 30 November, the maximum temperature shall be 60°F.	Sacramento River from its source to Box Canyon Reservoir (9); Sacramento River from Box Canyon Dam to Shasta Lake (11)
The temperature in the epilimnion shall be less than or equal to 75°F or mean daily ambient air temperature, whichever is greater.	Lake Siskiyou (10)
The temperature shall not be elevated above 56°F in the reach from Keswick Dam to Hamilton City nor above 68°F in the reach from Hamilton City to the I Street Bridge during periods when temperature increases will be detrimental to the fishery.	Sacramento River from Shasta Dam to I Street Bridge (13, 30)

Table 11. Basin Plan Beneficial Uses for the Yuba River.

TABLE II-1

SURFACE WATER BODIES AND BENEFICIAL USES

	SURFACE WATER BODIES (1)			AGRI-CULTURE		INDUSTRY			RECREATION			FRESHWATER HABITAT (2)		MIGRATION		SPAWNING			
			MUN	AGR		PROC	IND	POW	REC-1		REC-2	WARM	COLD	MIGR		SPWN		WILD	NAV
		HYDRO UNIT NUMBER	MUNICIPAL AND DOMESTIC SUPPLY	IRRIGATION	STOCK WATERING	PROCESS	SERVICE SUPPLY	POWER	CONTACT	CANOEING AND RAFTING (1)	OTHER NONCONTACT	WARM	COLD	WARM (3)	COLD (4)	WARM (3)	COLD (4)	WILDLIFE HABITAT	NAVIGATION
	YUBA RIVER																		
41	SOURCES TO ENGLEBRIGHT RESERVOIR	517.	E	E	E			E	E	E	E		E				E	E	
42	ENGLEBRIGHT DAM TO FEATHER RIVER	515.3		E	E			E	E	E	E	E	E	E	E	E	E	E	

LEGEND
E = EXISTING BENEFICIAL USES
P = POTENTIAL BENEFICIAL USES
L = EXISTING LIMITED BENEFICIAL USE

The EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) provides water temperature recommendations regarding coldwater salmonid uses and numeric criteria to protect those uses for the following:

Salmonid Uses	Criteria
Salmon/trout core juvenile rearing	61°F (16°C) 7DADM
Salmon/trout migration plus non-core juvenile rearing	64°F (18°C) 7DADM
Salmon/trout migration	68°F (20°C) 7DADM
Salmon/trout spawning, egg incubation, and fry emergence	55°F (13°C) 7DADM
Steelhead smoltification	57°F (14°C) 7DADM

These temperature criteria are developed for summer water temperatures, except for the spawning and smolting lifestages which occur earlier in the year. The criteria are intended to represent the upper end of the optimal temperature range for each lifestage. It is important to note that the criteria are based on 7DADM (daily maximum temperatures), while the data used to generate the criteria were primarily based on daily average or continuous temperature field/laboratory data sets (**Table 12**). Several general assumptions were applied by EPA (2003b) to the data to make a connection between 7DADM temperature and the field/laboratory data (Section 8.1).

Table 12. EPA (2003b) Laboratory and Field Data Summary for Generating Water Temperature Criteria.

Life Stage	Temperature Consideration	Temperature & Unit	Reference
Spawning and Egg Incubation	*Temp. Range at which Spawning is Most Frequently Observed in the Field	4 - 14°C (daily avg)	Issue Paper 1; pp 17-18 Issue Paper 5; p 81
	* Egg Incubation Studies - Results in Good Survival -Optimal Range	4 - 12°C (constant) 6 - 10°C (constant)	Issue Paper 5; p 16
	*Reduced Viability of Gametes in Holding Adults	> 13°C (constant)	Issue Paper 5; pp 16 and 75
Juvenile Rearing	*Lethal Temp. (1 Week Exposure)	23 - 26°C (constant)	Issue Paper 5; pp 12, 14 (Table 4), 17, and 83-84
	*Optimal Growth - unlimited food - limited food	13 - 20°C (constant) 10 - 16°C (constant)	Issue Paper 5; pp 3-6 (Table 1), and 38-56
	*Rearing Preference Temp. in Lab and Field Studies	10 - 17°C (constant) < 18°C (7DADM)	Issue Paper 1; p 4 (Table 2). Welsh et al. 2001.
	*Impairment to Smoltification	12 - 15°C (constant)	Issue Paper 5; pp 7 and 57-65 Issue Paper 5; pp 7 and 57-65
	*Impairment to Steelhead Smoltification	> 12°C (constant)	
	*Disease Risk (lab studies) -High - Elevated - Minimized	> 18 - 20°C (constant) 14 - 17°C (constant) 12 - 13°C (constant)	Issue Paper 4, pp 12 - 23
Adult Migration	*Lethal Temp. (1 Week Exposure)	21- 22°C (constant)	Issue Paper 5; pp 17, 83 - 87
	*Migration Blockage and Migration Delay	21 - 22°C (average)	Issue Paper 5; pp 9, 10, 72-74. Issue Paper 1; pp 15 - 16
	*Disease Risk (lab studies) - High - Elevated - Minimized	> 18 - 20°C (constant) 14 - 17°C (constant) 12- 13°C (constant)	Issue Paper 4; pp 12 - 23
	*Adult Swimming Performance - Reduced - Optimal	> 20°C (constant) 15 - 19°C (constant)	Issue Paper 5; pp 8, 9, 13, 65 - 71
	* Overall Reduction in Migration Fitness due to Cumulative Stresses	> 17-18°C (prolonged exposures)	Issue Paper 5; p 74

In addition to the numeric temperature criteria, there are a number of other factors (e.g., site specific issues, background temperatures) that EPA (2003b) considered in recommending coldwater salmonid uses and water quality standards (WQS) to protect those uses. These factors and the EPA's recommended approach for establishing WQS are described in EPA (2003b).

EPA (2003b) recognized that salmonids will use waters that are warmer than their optimal thermal range and further recognizes that some portions of rivers and streams naturally (i.e., absent human impacts) were warmer than the salmonid optimal range. They also recognized that some streams have unique diurnal temperature patterns, which may necessitate modified WQS. To account for these issues, the EPA identified three alternate salmonid temperature standard approaches. These include identifying the natural background temperature of the water body, creating site-specific temperature criteria, and/or identifying that a criterion is "unattainable" and altering the use designation to a use designation that has a criterion that is obtainable.

The EPA's water temperature recommendations are intended to assist States and Tribes to adopt temperature WQS that the EPA can approve consistent with its obligations under the Clean Water Act and the Endangered Species Act. States and Tribes that adopt temperature WQS consistent with these recommendations can expect an expedited review by EPA and the Services, subject to new data and information that might be available to during that review (EPA 2003b). In some cases, the criteria seem to be conservative and may exclude habitat that is currently used and/or demonstrably usable by salmonid lifestages. Section 8.1 has a brief discussion of issues related to the EPA (2003b) numerical criteria based on 7DADM temperatures and the needs of the Yuba Salmon Forum.

7.2 Site Specific Water Temperature Index Values

In addition to the EPA (2003b) numeric temperature criteria (Section 7.1) it also seems appropriate to develop Yuba Salmon Forum water temperature index values that are specific to the purposes of the Yuba Salmon Forum and the Yuba River. Below, for each species/lifestage, we provide: (1) an upper tolerance WTI (UTWTI) that identifies the sustained (chronic) tolerance/no tolerance boundary; and (2) the upper optimal WTI (UOWTI) where physiological processes (growth, disease resistance, normal development of embryos) are not stressed by temperature.

The lifestage-specific WTI values are not intended to represent significance thresholds, but instead provide criteria to evaluate reintroduction of anadromous salmonids. Moreover, as suggested by DWR (2007), the use of temperature "boundaries" has inherent drawbacks associated with the often indistinguishable effects at the upper and lower ends of an identified range and attributing undue specificity to values slightly exceeding an identified range. Nonetheless, WTI values, as defined, are used for evaluation of water temperature considerations regarding the reintroduction of steelhead (**Table 13**) and spring-run Chinook salmon (**Table 14**) in the Upper Yuba River Basin.

7.2.1 Steelhead

Table 13. Lifestage-Specific Upper Optimal Water Temperature Index (UOWTI) Values and Upper Tolerance Water Temperature Index (UTWTI) Values Identified as Defining the Range of Acceptable Water Temperatures for Evaluation of the Reintroduction of Steelhead in the Upper Yuba River Basin.

Lifestage	Upper Optimum WTI[1]	Upper Tolerance WTI[1]	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Adult Migration	64°F	68°F	■■	■■	■■	□□	□□	□□	□□	■■	■■	■■	■■	■■
Adult Holding	61°F	65°F	■■	■■	■■	□□	□□	□□	□□	■■	■■	■■	■■	■■
Spawning	54°F	57°F	■■	■■	■■	■■	□□	□□	□□	□□	□□	□□	□□	□□
Embryo Incubation	54°F	57°F	■■	■■	■■	■■	■■	□□	□□	□□	□□	□□	□□	□□
Juv. Rearing & Downstream Mvmt.	65°F	68°F	■■	■■	■■	■■	■■	■■	■■	■■	■■	■■	■■	■■
Smolt Emigration	52°F	55°F	■■	■■	■■	■□	□□	□□	□□	□□	□□	■■	■■	■■

[1] The WTI values are to be applied to the water temperature metrics recommended in Section 8, below.

7.2.2 Spring-run Chinook Salmon

Table 14. Lifestage-Specific Upper Optimal Water Temperature Index (UOWTI) Values and Upper Tolerance Water Temperature Index (UTWTI) Values Identified as Defining the Upper Acceptable Water Temperatures for Evaluation of the Reintroduction of Spring-Run Chinook Salmon in the Upper Yuba River Basin.

Lifestage	Upper Optimum WTI[1]	Upper Tolerance WTI[1]	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Adult Migration	64°F	68°F	□□	□□	□□	■■	■■	■■	■■	■■	□□	□□	□□	□□
Adult Holding	61°F	65°F	□□	□□	□□	■■	■■	■■	■■	■■	□□	□□	□□	□□
Spawning	56°F	58°F	□□	□□	□□	□□	□□	□□	□□	□□	■■	■■	■□	□□
Embryo Incubation	56°F	58°F	■■	■■	□□	□□	□□	□□	□□	□□	■■	■■	■■	■■
Juv. Rearing & Downstream Mvmt.	61°F	65°F	■■	■■	■■	■■	■■	■■	■■	■■	■■	■■	■■	■■
Smolt Emigration	63°F	68°F	■■	■■	■■	■■	■■	□□	□□	□□	□□	■■	■■	■■

[1] The WTI values are to be applied to the water temperature metrics recommended in Section 8, below.

8 WATER TEMPERATURE METRICS

Water temperature metrics (e.g., MWAT, 7DADM) are typically designed to provide a reproducible index of temperature over a period of time that can be used in combination with temperature standards (numeric criteria values) to determine if a water temperature body is impaired. Water temperature metrics are by definition an index of the complete temperature time series. As such, they do not completely represent the temperature time series nor are they always the most accurate way to represent the biological response of various lifestages. Water temperature metrics for potential application to the Yuba Salmon Forum specific criteria (UOWTI and UTWTI) are described below.

8.1 7DADM

The EPA (2003a) recommends the 7DADM (maximum 7-day average of the daily maxima) as a water temperature metric for all of the numeric criteria that is applied to a specific species and lifestage. The 7DADM is similar to the maximum weekly average temperature metric that was previously used by the EPA for its national temperature criteria recommendations (EPA 1977). However, in 2003, the EPA initiated use of the 7DADM metric "because it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day."

A 7DADM value is calculated by adding the daily maximum temperatures recorded at a site on seven consecutive days and dividing by seven. Thus, it reflects an average of daily maximum temperatures that fish are exposed to over a week-long period. EPA (2003b) states that because this metric "is oriented to daily maximum temperatures, it can be used to protect against acute effects, such as lethality and migration blockage conditions." This statement illustrates two shortcomings of the EPA (2003a) use of the 7DADM metric. The 7DADM: (1) includes no duration information, which is critical to understanding acute (zone of resistance) temperature analysis – rather, it is an index of maximum temperature that occurs for a short time each day and, most importantly; (2) the numeric criteria that are identified by EPA (2003b) are not acute criteria nor derived from acute criteria data, but are chronic temperature criteria.

The EPA (2003b) numeric criteria were derived from chronic field or laboratory studies (e.g., > 7 day continuous or average daily temperatures), including the migratory blockage data (see Section 5.1; Table 12). A couple of simple examples illustrate this concept. The EPA (2003b) juvenile core rearing criteria is 61°F 7DADM and is the same temperature value as the upper optimal growth temperature under limited food (Table 12, 16°C), but the optimal growth temperature was derived from constant temperature laboratory studies. This temperature is much lower than the temperature where acute temperature affects occur. The UILT (7 day) from literature studies is 72 - 79°F (e.g., Table 12) and for shorter duration exposure is even much higher 80 - 88°F (e.g., see Table TT2 in Myrick and Cech 2001). Another example is the migration criteria. The migration blockage source data is based on observations in natural rivers, and is based on daily average or weekly field temperatures (70 – 72°F) (Table 12; McCullough 1999).

A daily maximum temperature equivalent of this temperature (70°F) is approximately 75°F [4], but the EPA (2003b) 7DADM numeric criterion for migration was set at 68°F.

EPA (2003b) states that the 7DADM metric can also can be used to protect against sub-lethal or chronic effects (e.g., temperature effects on growth, disease, smoltification, and competition), but the resultant cumulative thermal exposure fish experience over the course of a week or more needs to be considered when selecting a 7DADM value to protect against these effects. The EPA's general conclusion from studies on fluctuating water temperature regimes (which is what fish generally experience in rivers) is that fluctuating temperatures increase juvenile growth rates when mean temperatures are colder than the optimal growth temperature derived from constant temperature studies, but will reduce growth when the mean temperature exceeds the optimal growth temperature (see Issues Paper 5, pages 51-56). When the mean temperature is above the optimal growth temperature, the "mid-point" temperature between the mean and the maximum is the "equivalent" constant temperature. This "equivalent" constant temperature then can be directly compared to laboratory studies done at constant temperatures. For example, a river with a 7DADM value of 64°F and a 58°F weekly mean temperature (i.e., diurnal variation of ± 5.4°F) will be roughly equivalent to a constant laboratory study temperature of 61.7°F (mid-point between 58°F and 65°F). Thus, both maximum and mean temperatures are important when determining a 7DADM value that is protective against sub-lethal/chronic temperature effects.

To account for using the 7DADM metric based on constant temperature laboratory data, EPA (2003a) assumed an average diel temperature difference between the mean and daily maximum temperature of 5.4°F, although the EPA appears to have decreased the temperature in the laboratory data down by 2.7°F (equivalently added 2.7°F to the criteria). It is completely unclear, however, if or how EPA then also accounted for the fact that 7DADM temperature is on average also 5.4°F greater than the average daily temperature (i.e., was this accounted for or not).

It also is unclear if the "midpoint of the maximum and average temperature" correction was applied for all lifestages. If so, this would be inappropriate based on the data available. The "midpoint" correction literature is only applicable to juvenile growth. There is no evidence presented that it is applicable to other lifestages. Also, the juvenile growth "midpoint" temperature correction is somewhat mis-represented in EPA (2003b). The main study relied on by EPA (2003b) is Hokanson et al. (1977), and that study states that the difference in growth between constant and diel fluctuating temperatures was 39% (1.5°C in a ±3.8C fluctuating range) of the difference between the

[4] Maximum daily temperatures are typically 5.4°F higher than average daily temperature (EPA 2003b).

average and maximum temperature (not 50% or the midpoint) and, perhaps more importantly, most of the studies reviewed by EPA indicate that growth in constant temperature was essentially equivalent to growth in fluctuating temperatures. Elliott (1975), for example, found that a growth model developed from constant temperature experimental data predicted brown trout growth in daily fluctuating temperature environments accurately when the mean daily value of the fluctuating temperature was used as input to the growth model.

For the evaluation of potential water temperature-related impacts associated with the reintroduction of anadromous salmonids into the Upper Yuba River Basin, 7DADM values could be calculated for species-specific lifestage periods on an annual basis over the simulation or empirical data period, and the occurrences when that 7DADM values exceed the EPA (2003b) numeric values could be compared among rivers/reaches in the Upper Yuba River Basin.

8.2 ADT

The average daily temperature (ADT) should be considered for application to the Yuba Salmon Forum specific criteria (WTI values) because nearly all of the data in the literature review were either based on ADT or on continuous temperature (also see Table 12). For juvenile growth, the data from Hokanson et al. (1977) can be directly applied to the constant temperature data to provide a correction, if deemed appropriate. The average daily temperature also can be used to determine the number of days (duration) that a WTI is exceeded, and duration of exceedance can be compared among specific geographic areas.

8.3 MWAT

The Maximum Weekly Average Temperature (MWAT) is a metric used by the California RWQCB that is commonly applied to water temperature numeric objectives. Generally, the MWAT serves as a summary measurement of instream water temperature variation that may occur on a daily or seasonal basis, and is used to evaluate chronic (sub-lethal) water temperature impacts (SWRCB website).

The MWAT is found by calculating the mathematical mean of multiple, equally spaced, daily water temperatures over a 7-day consecutive period. The MWAT is defined as the highest value calculated for all possible 7-day periods over a given time period, which usually extends over the summer or is commensurate to the duration of a salmonid lifestage. In order to determine whether the maximum weekly temperature standard is attained, the mathematical mean of multiple, equally spaced, daily temperatures over a seven-day consecutive period is compared to the criterion.

For the evaluation of acceptable water temperature-related reintroduction potential associated with spring-run Chinook salmon and steelhead in the Upper Yuba River Basin, MWAT values should be calculated for species-specific lifestage periods, on an annual basis over the monitoring or simulation period, and the probability that MWAT values exceed specified water temperature index values will be compared among rivers/reaches in the Upper Yuba River Basin.

The use of a single temperature measurement such as MWAT is convenient from a monitoring and regulatory standpoint, but oversimplifies the complex interactions between water temperature regimes and fish health which are affected by the duration of peak and daily average temperatures. Therefore, for the evaluation of acceptable water temperature-related reintroduction potential associated with spring-run Chinook salmon and steelhead in the Upper Yuba River Basin, it is recommended that both the MWAT, and ADT lifestage-specific exceedance durations, be compared with the UOWTI and UTWTI values.

8.4 7DMAVG

The 7-day moving average of maximum daily temperature (7DMAVG) serves as the basis for instream water temperature standards, including those of the Oregon Department of Environmental Quality (ODEQ). The reason for using the 7DMAVG is to decrease the effect of a single peak temperature on data interpretation. Aquatic organisms are affected more by exposure to high temperature over an extended period than to a single exceedance of the criteria. The ODEQ recognizes that not only summer maximum temperatures are of importance to aquatic biota. The intent is to protect the temperature regime through the year. Built into the ODEQ 7DMAVG standard is the assumption that if stream and riparian conditions are managed such that they meet the summer maximum criteria, those same conditions will protect the temperature regime of the stream through the year.

The 7DMAVG standard is based not on directly lethal temperatures (usually above 70°F), but on sub-lethal effects, which are numerous. Sub-lethal effects can lead to death indirectly, or they may reduce the ability of the fish to successfully reproduce and for their offspring to survive and grow. These sub-lethal effects include an increase in the incidence of disease, an inability to spawn, a reduced survival rate of eggs, a reduced growth and survival rate of juveniles, increased competition for limited habitat and food, reduced ability to compete with other species that are better adapted to higher temperatures (many of these are introduced species) and other adverse effects. Sub-lethal effects of temperature on salmonids occur gradually as stream temperatures increase.

In California, the 7DMAVG has been applied in effectiveness monitoring protocols (e.g. 2006 Green Diamond Resource Company Aquatic Habitat Conservation Plan/Candidate Conservation Agreement and Assurances) and other monitoring efforts (e.g., Upper Yuba River Studies Program 2006 Upper Yuba River Water Temperature Criteria for Chinook salmon and Steelhead). However, for the evaluation of water temperature-related reintroduction potential associated with spring-run Chinook salmon and steelhead in the Upper Yuba River Basin, 7DMAVG is not recommended as a metric.

9 WATER TEMPERATURE EVALUATION CONSIDERATIONS

For the evaluation of water temperatures acceptable for reintroduction of salmonids in the Upper Yuba River Basin, it is anticipated that water temperature modeling and/or monitoring will be applied for a comparison among rivers and reaches in the Upper Yuba River Basin. In addition to the application of the criteria and metrics as described in the preceding sections, it may be appropriate to consider other specific evaluation methodologies.

9.1 Water Year Type

Model output and/or monitoring data could be summarized by water year type. Comparisons of the water temperature-related potential among rivers and reaches in the Upper Yuba River Basin could include water year types. This would help identify reaches/lengths of river that would be suitable in all conditions (e.g., critically dry to wet years) as well as the lengths of river that would be suitable under more favorable conditions (e.g., wet water year types only).

9.2 Water Temperature Exceedance Curves

Model output and/or monitoring data also could be summarized by the calculation of water temperature exceedance curves, by month, occurring over the period of evaluation for each of the rivers and reaches. Exceedance curves are particularly useful for examining the probability of occurrence/duration of water temperatures. The evaluation approach could specifically evaluate the probabilities/duration of time that each of the identified lifestage-specific water temperature index values would be exceeded over the period of evaluation. Comparisons of the water temperature-related potential among rivers and reaches in the Upper Yuba River Basin could be made by presentation of monthly cumulative water temperature exceedance distribution probabilities (using average daily water temperatures) relative to specified water temperature index values corresponding to the appropriate months for each lifestage of spring-run Chinook salmon and steelhead.

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APPENDIX A

LIFESTAGE-SPECIFIC WATER TEMPERATURE BIOLOGICAL EFFECTS AND INDEX TEMPERATURE VALUES

STEELHEAD LIFESTAGE-SPECIFIC WATER TEMPERATURE INDEX VALUES

Adult Immigration and Holding

Water temperatures can control the timing of adult spawning migrations and can affect the viability of eggs in holding females. YCWA et al. (2007) suggests that few studies have been published examining the effects of water temperature on either steelhead immigration or steelhead holding, and none of the available studies were recent (Bruin and Waldsdorf 1975; McCullough *et al.* 2001). The available studies suggest that adverse effects occur to immigrating and holding steelhead at water temperatures exceeding the mid 50°F range, and that immigration will be delayed if water temperatures approach approximately 70°F (**Table 2**). Water temperature index values of 52°F, 56°F, 61°F, 65°F and 70°F were chosen because they provide a gradation of potential water temperature effects, and the available literature provided the strongest support for these values.

Because of the paucity of literature pertaining to steelhead adult immigration and holding, an evenly spaced range of water temperature index values could not be achieved. We also used some pertinent information related to other salmonids (e.g., Chinook salmon). 52°F was selected as a water temperature index value because it has been referred to as a "recommended" (Reclamation 2003), "preferred" (McEwan and Jackson 1996; NMFS 2000; NMFS 2002a), and "optimum" (Reclamation 1997a) water temperature for steelhead adult immigration. Increasing levels of thermal stress to this life stage may reportedly occur above the 52°F water temperature index value. 56°F was selected as a water temperature index value because 56°F represents a water temperature above which adverse effects to migratory and holding steelhead begin to arise (Bruin and Waldsdorf 1975; Leitritz and Lewis 1980; McCullough *et al.* 2001; Smith *et al.* 1983). 50-59°F is referred to as the "preferred" range of water temperatures for California summer steelhead holding (Moyle 1995). Whereas, water temperatures greater than 61°F may result in "chronic high stress" of holding Central Valley winter-run steelhead (USFWS 1995). 65°F was selected as a water temperature index value because steelhead (and fall-run Chinook salmon) encounter potentially stressful temperatures between 64.4-73.4°F (Richter and Kolmes 2005). Additionally, over 93% of steelhead detections occurred in the 65.3-71.6°F range, although this may be above the temperature for optimal immigration (Salinger and Anderson 2006) and/or may modify migration timing due to holding in coldwater refugia (High et al. 2006). 70°F was selected as the highest water temperature index value because the literature suggests that water temperatures near and above 70.0°F may result in a thermal barrier to adult steelhead migrating upstream (McCullough *et al.* 2001) and are water temperatures referred to as "stressful" to upstream migrating steelhead in the Columbia River (Lantz

1971 as cited in Beschta et al 1987). Further, Coutant (1972) found that the UILT for adult steelhead was 69.8°F and temperatures between 73-75°F are described as "lethal" to holding adult steelhead in Moyle (2002).

Spawning and Embryo Incubation

Relatively few studies have been published directly addressing the effects of water temperature on steelhead spawning and embryo incubation (Redding and Schreck 1979; Rombough 1988). Because anadromous steelhead and non-anadromous rainbow trout are genetically and physiologically similar, studies on non-anadromous rainbow trout also were considered in the development of water temperature index values for steelhead spawning and embryo incubation (Moyle 2002; McEwan 2001). From the available literature, water temperatures in the low 50°F range appear to support high embryo survival, with substantial mortality to steelhead eggs reportedly occurring at water temperatures in the high 50°F range and above (**Table 3**). Water temperatures in the 45-50°F range have been referred to as the "optimum" for spawning steelhead (FERC 1993).

Water temperature index values of 46°F , 52°F, 54°F, 57°F, and 60°F were selected for two reasons. First, the available literature provided the strongest support for water temperature index values at or near 46°F, 52°F, 54°F, 57°F, and 60°F. Second, the index values reflect a gradation of potential water temperature effects ranging between optimal to lethal conditions for steelhead spawning and embryo incubation. Some literature suggests water temperatures ≤ 50°F are when steelhead spawn (Orcutt et al. 1968) and/or are optimal for steelhead spawning and embryo survival (FERC 1993; Myrick and Cech 2001; Timoshina 1972) and temperatures between 39-52°F are "preferred" by spawning steelhead (IEP Steelhead Project Work Team (no date); McEwan and Jackson 1996), a larger body of literature suggests optimal conditions occur at water temperatures ≤ 52°F (Humpesch 1985; NMFS 2000; NMFS 2001a; NMFS 2002a; Reclamation 1997b; SWRCB 2003; USFWS 1995a). Further, water temperatures between 48-52°F were referred to as "optimal" (FERC 1993; McEwan and Jackson 1996; NMFS 2000) and "preferred" (Bell 1986) for steelhead embryo incubation. Therefore, 52°F was selected as the lowest water temperature index value. Increasing levels of thermal stress to the steelhead spawning and embryo incubation life stage may reportedly occur above the 52°F water temperature index value.

54°F was selected as the next index value, because although most of the studies conducted at or near 54.0°F report high survival and normal development (Kamler and Kato 1983; Redding and Schreck 1979; Rombough 1988), some evidence suggests that symptoms of thermal stress arise at or near 54.0°F (Humpesch 1985; Timoshina 1972). Thus, water temperatures near 54°F may represent an inflection point between properly functioning water temperature conditions, and conditions that cause negative effects to steelhead spawning and embryo incubation. Further, water temperatures greater than 55°F were referred to as "stressful" for incubating steelhead embryos (FERC 1993). 57°F was selected as an index value because embryonic mortality increases sharply and development becomes retarded at incubation temperatures greater than or equal to 57.0°F. Velsen (1987) provided a compilation of data on rainbow trout and steelhead embryo mortality to 50% hatch under incubation temperatures ranging from 33.8°F to 60.8°F that demonstrated a two-fold increase in mortality for embryos incubated at 57.2°F, compared to embryos incubated at 53.6°F. In a laboratory study using gametes from Big Qualicum River, Vancouver Island, steelhead mortality increased to 15% at a constant temperature of 59.0°F, compared to less than 4% mortality at constant temperatures of 42.8°F, 48.2°F, and 53.6°F (Rombough 1988). Also, alevins hatching at 59.0°F were considerably smaller and appeared less well developed than those incubated at the lower temperature treatments. From fertilization to 50% hatch, Big Qualicum River steelhead had 93% mortality at 60.8°F, 7.7% mortality at 57.2°F, and 1% mortality at 47.3°F and 39.2°F (Velsen 1987). Myrick and Cech (2001) similarly described water temperatures >59°F as "lethal" to incubating steelhead embryos, although FERC (1993) suggested that water temperatures exceeding 68°F were "stressful" to spawning steelhead and "lethal" when greater than 72°F.

Juvenile Rearing & Downstream Movement

Water temperature index values were developed to evaluate the combined steelhead rearing (fry and juvenile) and juvenile downstream movement lifestages. Some steelhead may rear in freshwater for up to three years before emigrating as yearling+ smolts, whereas other individuals move downstream shortly after emergence as post-emergent fry, or rear in the river for several months and move downstream as juveniles without exhibiting the ontogenetic characteristics of smolts. Presumably, these individuals continue to rear and grow in downstream areas (e.g., lower Feather River, Sacramento River, and Upper Delta) and undergo the smoltification process prior to entry into saline environments. Thus, fry and juvenile rearing occur concurrently with post-emergent fry and juvenile downstream movement and are assessed in this Technical Memorandum using the fry and juvenile rearing water temperature index values.

The growth, survival, and successful smoltification of juvenile steelhead are controlled largely by water temperature. The duration of freshwater residence for juvenile steelhead is long relative to that of Chinook salmon, making the juvenile life stage of steelhead more susceptible to the influences of water temperature, particularly during the over-summer rearing period. Central Valley juvenile steelhead have high growth rates at water temperatures in the mid 60°F range, but reportedly require lower water temperatures to successfully undergo the transformation to the smolt stage.

Water temperature index values of 63°F, 65°F, 68°F, 72°F, and 75°F were selected to represent a gradation of potential water temperature effects ranging between optimal to lethal conditions for steelhead juvenile rearing (Table 4). The lowest water temperature index value of 63°F was established because Myrick and Cech (2001) describe 63°F as the "preferred" water temperature for wild juvenile steelhead, whereas "preferred" water temperatures for juvenile hatchery steelhead reportedly range between 64-66°F. 65°F was also identified as a water temperature index value because NMFS (2000; 2002a) reported 65°F as the upper limit preferred for growth and development of Sacramento and American River juvenile steelhead. Also, 65°F was found to be within the optimum water temperature range for juvenile growth (i.e., 59-66°F) (Myrick and Cech 2001), and supported high growth of Nimbus strain juvenile steelhead (Cech and Myrick 1999).

Increasing levels of thermal stress to this life stage may reportedly occur above the 65°F water temperature index value. For example, Kaya *et al.* (1977) reported that the upper avoidance water temperature for juvenile rainbow trout was measured at 68°F to 71.6°F. Cherry *et al.* (1977) observed an upper preference water temperature near 68.0°F for juvenile rainbow trout, duplicating the upper preferred limit for juvenile steelhead observed in Cech and Myrick (1999) and FERC (1993). Empirical adult *O. mykiss* population data from the North Yuba, Middle Yuba, South Yuba, Middle Fork American, and Rubicon rivers collected in 2007-2009 are plotted against temperature in Figure 4. The temperature used was the 8th largest average daily temperature during the summer (i.e., up to seven days had higher daily average temperatures). The data show a population density break at about 68.0°F. Although smaller population densities occurred at higher temperatures, the largest population densities occurred at temperatures near 68.0°F or less. In addition Figure 5 shows growth for a 200 mm juvenile O. mykiss versus temperature for three food levels (percent of maximum consumption = 30%, 50%, and 70%). The average empirically derived percent of maximum consumption in an adjacent watershed (Middle Fork American Fork River) was 50% (Hanson et al. 1997). Positive growth only occurs up to approximately 68°F. Because of the literature describing 68.0°F as both an upper preferred and an avoidance limit for juvenile *Oncorhynchus mykiss*, and because of the empirical fish population data and bioenergetics growth data, 68°F was established as a upper tolerable water temperature index value.

A water temperature index value of 72°F was established because symptoms of thermal stress in juvenile steelhead have been reported to arise at water temperatures approaching 72°F. For example, physiological stress to juvenile steelhead in Northern

California streams was demonstrated by increased gill flare rates, decreased foraging activity, and increased agonistic activity as stream temperatures rose above 71.6°F (Nielsen *et al.* 1994). Also, 72°F was selected as a water temperature index value because 71.6°F has been reported as an upper avoidance water temperature (Kaya *et al.* 1977) and an upper thermal tolerance water temperature (Ebersole *et al.* 2001) for juvenile rainbow trout. The highest water temperature index value of 75°F was established because NMFS and EPA report that direct mortality to rearing juvenile steelhead results when stream temperatures reach 75.0°F (EPA 2002; NMFS 2001b). Water temperatures >77°F have been referred to as "lethal" to juvenile steelhead (FERC 1993; Myrick and Cech 2001). The UILT for juvenile rainbow trout, based on numerous studies, is between 75-79°F (Sullivan et al. 2000; McCullough 2001).

Yearling + Smolt Emigration

Laboratory data suggest that smoltification, and therefore successful emigration of steelhead smolts, is directly controlled by water temperature (Adams *et al.* 1975) (**Table 5**). Water temperature index values of 52°F and 55°F were selected to evaluate the steelhead smolt emigration life stage, because most literature on water temperature effects on steelhead smolting suggest that water temperatures less than 52°F (Adams *et al.* 1975; Myrick and Cech 2001; Rich 1987a) or less than 55°F (EPA 2003a; McCullough *et al.* 2001; Wedemeyer *et al.* 1980; Zaugg and Wagner 1973) are required for successful smoltification to occur. (Adams *et al.* 1973) tested the effect of water temperature (43.7°F, 50.0°F, 59.0°F or 68.0°F) on the increase of gill microsomal Na^+-, K^+-stimulated ATPase activity associated with parr-smolt transformation in steelhead and found a two-fold increase in Na^+-, K^+-ATPase at 43.7 and 50.0°C, but no increase at 59.0°F or 68.0°F. In a subsequent study, the highest water temperature where a parr-smolt transformation occurred was at 52.3°F (Adams *et al.* 1975). The results of Adams *et al.* (1975) were reviewed in Myrick and Cech (2001) and Rich (1987b), which both recommended that water temperatures below 52.3°F are required to successfully complete the parr-smolt transformation. Further, Myrick and Cech (2001) suggest that water temperatures between 43-50°F are the "physiologically optimal" temperatures required during the parr-smolt transformation and necessary to maximize saltwater survival. The 52°F water temperature index value established for the steelhead smolt emigration life stage is the index value generally reported in the literature as the upper limit of the water temperature range that provides successful smolt transformation thermal conditions. Increasing levels of thermal stress to this life stage may reportedly occur above the 52°F water temperature index value.

Zaugg and Wagner (1973) examined the influence of water temperature on gill ATPase activity related to parr-smolt transformation and migration in steelhead. They found ATPase activity was decreased and migration reduced when juveniles were exposed to water temperatures of 55.4°F or greater. In a technical document prepared by the EPA to provide temperature water quality standards for the protection of Northwest native salmon and trout, water temperatures less than or equal to 54.5°F were recommended for emigrating juvenile steelhead (EPA 2003b). Water temperatures are considered "unsuitable" for steelhead smolts at >59°F (Myrick and Cech 2001) and "lethal" at 77°F (FERC 1993).

CHINOOK SALMON LIFESTAGE-SPECIFIC WATER TEMPERATURE INDEX VALUES

It has been suggested that separate water temperatures standards should be developed for each run-type of Chinook salmon. For example, McCullough (1999) states that spring-run Chinook salmon immigrate in spring and spawn in 3rd to 5th order streams and, therefore, face different migration and adult holding temperature regimes than do summer- or fall-run Chinook salmon, which spawn in streams of 5th order or greater. However, to meet the objectives of the current literature review, run-types are not separated because: (1) there is a paucity of literature specific to each life stage of each run-type; (2) there is an insufficient amount of data available in the literature suggesting that Chinook salmon run-types respond to water temperatures differently; (3) the WTI values derived from all the literature pertaining to Chinook salmon for a particular life stage will be sufficiently protective of that life stage for each run-type; and (4) all run-types overlap in timing of adult immigration and holding and in some cases are not easily distinguished (Healey 1991). Nonetheless, water temperature relationships for each lifestage of spring-run Chinook salmon available in the literature are emphasized in the consideration and identification of WTI values for evaluation of reintroduction of spring-run Chinook salmon in the Upper Yuba River Basin.

Adult Immigration and Holding

The adult immigration and adult holding life stages are evaluated together, because it is difficult to determine the thermal regime that Chinook salmon have been exposed to in the river prior to spawning and in order to be sufficiently protective of pre-spawning fish, water temperatures that provide high adult survival and high egg viability must be available throughout the entire pre-spawning freshwater period. Although studies examining the effects of thermal stress on immigrating Chinook salmon are generally lacking, it has been demonstrated that thermal stress during the upstream spawning migration of sockeye salmon negatively affected the secretion of hormones controlling sexual maturation causing numerous reproductive impairment problems (McCullough *et al.* 2001).

The water temperature index values reflect a gradation of potential water temperature effects that range between those reported as "optimal" to those reported as "lethal" for adult Chinook salmon during upstream spawning migrations and holding. The water temperature index values established for the Chinook salmon adult immigration and holding lifestage are 61°F, 65°F, and 68°F (**Table 6**). Although 56°F is referenced in the literature frequently as the upper "optimal" water temperature limit for upstream migration and holding, the references are not foundational studies and often are inappropriate citations. For example, Boles *et al.* (1988), Marine (1992), and NMFS (1997b) all cite Hinze (1959) in support of recommendations for a water temperature of 56°F for adult Chinook salmon immigration. However, Hinze (1959) is a study examining the effects of water temperature on incubating Chinook salmon eggs in the American River Basin. Further, water temperatures between 38-56°F are considered to represent the "observed range" for upstream migrating spring-run Chinook salmon (Bell 1986).

The lowest water temperature index value established was 61°F, because in the NMFS biological opinion for the proposed operation of the Central Valley Project (CVP) and State Water Project (SWP), 59°F to 60°F is reported as…"*The upper limit of the optimal temperature range for adults holding while eggs are maturing*" (NMFS 2000). Also, NMFS (1997b) states…"*Generally, the maximum temperature of adults holding, while eggs are maturing, is about 59°F to 60°F*" …and… "*Acceptable range for adults migrating upstream range from 57°F to 67°F*." ODEQ (1995) reports that "…*many of the diseases that commonly affect Chinook become highly infectious and virulent above 60°F*." Study summaries in EPA (2003) indicate disease risk is high at 62.6°F. Additionally, Ward and Kier (1999) designated temperatures <60.8°F as an "optimum" water temperature threshold for holding Battle Creek spring-run Chinook salmon. EPA (2003) chose a holding value of 61°F (7DADM) based on laboratory data various assumptions regarding diel temperature fluctuations. 61°F is also a holding temperature index value for steelhead (see above). The 61°F water temperature index value established for the Chinook salmon adult immigration and holding life stage is the index value generally reported in the literature as the upper limit of the optimal range, and is within the reported acceptable range. Increasing levels of thermal stress to this life stage may reportedly occur above the 61°F water temperature index value.

An index value of 65°F was established because Berman (1990) suggests effects of thermal stress to pre-spawning adults are evident at water temperatures near 65°F. Berman (1990) conducted a laboratory study to determine if pre-spawning water temperatures experienced by adult Chinook salmon influenced reproductive success, and found evidence suggesting latent embryonic abnormalities associated with water temperature exposure to pre-spawning adults that ranged from 63.5°F to 66.2°F. Ward et al. (2003; 2004) identified an extended period of average daily temperatures above 67°F during July as measured at the Quartz Bowl that preceded the onset of significant pre-spawn mortalities. During 2002, temperatures exceeded 67°F a total of 16 days with a maximum of 20.8°C on July 12. During 2003, temperatures exceed 67°F a total of 11 days with a maximum of 20.9°C on July 23. However during other years when there were minimal pre-spawn mortalities, maximum daily average water temperature at Quartz Bowl never exceeded 67°F more than an few days (Ward et al. 2004; Ward et al. 2006; Ward et al. 2007; McReynolds and Garman 2008; McReynolds and Garman 2010). During each of the years when Chinook salmon temperature mortality was not observed at Butte Creek (2001, 2004-2007), on average, daily temperature did not exceed 65.8°F for more than 7 days (Figure 6). Tracy McReynolds (Pers. Comm. October 2011) indicated that an upper tolerable holding temperature of 65°F was reasonable based on her experience.

An index value of 68°F was established because the Butte Creek data and the literature suggests that thermal stress at water temperatures greater than 68°F is pronounced, and severe adverse effects to immigrating and holding pre-spawning adults, including mortality, can be expected (Berman 1990; Marine 1997; NMFS 1997b; Ward et al. 2004).

Water temperatures between 70-77°F are reported as the range of maximum temperatures for holding pool conditions used by spring-run Chinook salmon in the Sacramento-San Joaquin system (Moyle et al. 1995). Migration blockage occurs for Chinook salmon at temperatures from 70-71+°F (McCollough 1999; McCullough et al. 2001; EPA 2003b). Strange (2010) found that the mean average body temperature during the first week of Chinook salmon migration on the Klamath River was 71.4°F. The UILT for Chinook salmon jacks is 69.8-71.6°F (McCullough 1999). The upper limit for spring-run Chinook salmon holding in Deer Creek is reportedly 80.6°F, at which point temperatures exceeding this value become "lethal" (Cramer and Hammack (1952), as cited in Moyle et al. (1995). As a result of the potential effects to immigrating and holding adult Chinook salmon that reportedly occur at water temperatures greater than or equal to 68°F, index values higher than 68°F were not established.

Spawning and Embryo Incubation

The adult spawning and embryo (i.e., eggs and alevins) incubation life stage includes redd construction, egg deposition, and embryo incubation. Potential effects to the adult spawning and embryo incubation life stages are evaluated together using one set of water temperature index values because it is difficult to separate the effects of water temperature between lifestages that are closely linked temporally, especially considering that studies describing how water temperature affects embryonic survival and development have included a pre-spawning or spawning adult component in the reporting of water temperature experiments conducted on fertilized eggs (Marine 1992; McCullough 1999; Seymour 1956).

The water temperature index values selected for the Chinook salmon spawning and embryo incubation life stages are 56°F, 58°F, 60°F, and 62°F (**Table 7**). Anomalously, FERC (1993) refers to 50°F as the "optimum" water temperature for spawning and incubating Chinook salmon. Additionally, for the adult spawning lifestage, FERC (1993) reports "stressful" and "lethal" water temperatures occuring at >60°F and >70°F, respectively, whereas for incubating Chinook salmon embryos, water temperatures are considered to be "stressful" at <56°F or "lethal" at >60°F. Much literature suggests that water temperatures must be less than or equal to 56°F for maximum survival of Chinook salmon embryos (i.e., eggs and alevins) during spawning and incubation. NMFS (1993b) reported that optimum water temperatures for egg development are between 43°F and 56°F. Similarly, Myrick and Cech (2001) reported the highest egg survival rates occur between water temperatures of 39-54°F. Reclamation (unpublished work) reports that water temperatures less than 56°F results in a natural rate of mortality for fertilized Chinook salmon eggs. Bell (1986) recommends water temperatures ranging between 42-57°F for spawning Chinook salmon, and water temperatures between 41-58°F for incubating embryos. USFWS (1995a) reported a water temperature range of 41.0°F to 56.0°F for maximum survival of eggs and yolk-sac larvae in the Central Valley of California. The preferred water temperature range for Chinook salmon egg incubation in the Sacramento River was suggested as 42.0°F to 56.0°F (NMFS 1997a). Alevin mortality is reportedly significantly higher when Chinook salmon embryos are incubated at water temperatures above 56°F (USFWS 1999). NMFS (2002a) reported 56.0°F as the upper limit of suitable water temperatures for spring-run Chinook salmon spawning in the Sacramento River. The 56°F water temperature index value established for the Chinook salmon spawning and embryo incubation life stage is the index value generally reported in the literature as the upper limit of the optimal range for egg development and the upper limit of the range reported to provide maximum survival of eggs and yolk-sac larvae in the Central Valley of California. Increasing levels of thermal stress to this life stage may reportedly occur above the 56°F water temperature index value.

High survival of Chinook salmon embryos also has been suggested to occur at incubation temperatures at or near 58.0°F. For example, (Reclamation Unpublished Work) reported that the natural rate of mortality for alevins occurs at 58°F or less. Combs (1957) concluded constant incubation temperatures between 42.5°F and 57.5°F resulted in normal development of Chinook salmon eggs, and NMFS (2002a) suggests 53.0°F to 58.0°F is the preferred water temperature range for Chinook salmon eggs and fry.

Johnson (1953) found consistently higher Chinook salmon egg losses resulted at water temperatures above 60.0°F than at lower temperatures. In order to protect late incubating Chinook salmon embryos and newly emerged fry NMFS (1993a) has determined a water temperature criterion of less than or equal to 60.0°F be maintained in the Sacramento River from Keswick Dam to Bend Bridge from October 1 to October 31. Seymour (1956) provides evidence that 100% mortality occurs to late incubating Chinook salmon embryos when held at a constant water temperature greater than or equal to 60.0°F. For Chinook salmon eggs incubated at constant temperatures, mortality increases rapidly at temperatures greater than about 59-60°F (see data plots in Myrick and Cech 2001). Olsen and Foster (1957), however, found high survival of Chinook salmon eggs and fry (89.6%) when incubation temperatures started at 60.9°F and declined naturally for the Columbia River (about 7°F / month). Geist et al. (2006) found high (93.8%) Chinook salmon incubation survival through emergence for naturally declining temperatures (0.36°F/day) starting as high as 61.7°F; however, a significant reduction in survival occurred above this temperature.

The literature largely agrees that 100% mortality will result to Chinook salmon embryos incubated at water temperatures greater than or equal to 62.0°F (Hinze 1959; Myrick and Cech 2003; Seymour 1956; USFWS 1999). Approximately 80% or greater mortality of eggs incubated at constant temperatures of 63°F or greater (see data plots in Myrick and Cech 2001). Olsen and Foster (1957) found high mortality of Chinook salmon eggs and fry (79%) when incubation temperatures started at 65.2°F and declined naturally for the Columbia River (about 7°F / month). Geist et al. (2006) found low Chinook salmon incubation survival (1.7%) for naturally declining temperatures (0.36°F/day) when temperatures started at 62.6°F

Juvenile Rearing & Downstream Movement

Water temperature index values were identified for the combined spring-run Chinook salmon rearing (fry and juvenile) and juvenile downstream movement lifestages, for the reasons previously described regarding steelhead. Fry and juvenile rearing occur concurrently with post-emergent fry and juvenile downstream movement, and are assessed in this Technical Memorandum using the fry and juvenile rearing water temperature index values.

The water temperature index values of 60°F, 65°F, 68°F, 70°F and 75°F were identified for the spring-run Chinook salmon juvenile rearing and downstream movement lifestage. The lowest index value of 60°F was chosen because regulatory documents as well as several source studies, including ones recently conducted on Central Valley Chinook salmon fry and juveniles report 60°F as an optimal water temperature for growth (Banks *et al.* 1971; Brett *et al.* 1982; Marine 1997; NMFS 1997b; NMFS 2000;

NMFS 2001a; NMFS 2002a; Rich 1987b) (**Table 8**). Water temperatures below 60°F also have been reported as providing conditions optimal for fry and fingerling growth, but were not selected as index values, because the studies were conducted on fish from outside of the Central Valley (Brett 1952; Seymour 1956). Studies conducted using local fish may be particularly important because *Oncorhynchus* species show considerable variation in morphology, behavior, and physiology along latitudinal gradients (Myrick 1998; Taylor 1990b; Taylor 1990a). More specifically, it has been suggested that salmonid populations in the Central Valley prefer higher water temperatures than those from more northern latitudes (Myrick and Cech 2000).

The 60°F water temperature index value established for the Chinook salmon juvenile rearing and downstream movement life stage is the index value generally reported in the literature as the upper limit of the optimal range for fry and juvenile growth and the upper limit of the preferred range for growth and development of spring-run Chinook salmon fry and fingerlings. FERC (1993) referred to 58°F as an "optimum" water temperature for juvenile Chinook salmon in the American River. NMFS (2002a) identified 60°F as the "preferred" water temperature for juvenile spring-run Chinook salmon in the Central Valley. Increasing levels of thermal stress to this life stage may reportedly occur above the 60°F water temperature index value.

The index value of 65°F was selected because it represents an intermediate value between 64.0°F and 66.2°F, at which both adverse and beneficial effects to juvenile salmonids have been reported to occur. For example, at temperatures approaching and beyond 65°F, sub-lethal effects associated with increased incidence of disease reportedly become severe for juvenile Chinook salmon (EPA 2003a; Johnson and Brice 1953; Ordal and Pacha 1963; Rich 1987a). Conversely, numerous studies report that temperatures between 64.0°F and 66.2°F provide conditions ranging from suitable to optimal for juvenile Chinook salmon growth (Brett *et al.* 1982; Cech and Myrick 1999; Clarke and Shelbourn 1985; EPA 2003a; Myrick and Cech 2001; NMFS 2002a; USFWS 1995a). Maximum growth of juvenile fall-run Chinook salmon has been reported to occur in the American River at water temperatures between 56-59°F (Rich 1987) and in Nimbus Hatchery spring-run Chinook salmon at 66°F (Cech and Myrick 1999). Figure 5 shows growth for a 100 mm juvenile Chinook salmon versus temperature for three food levels (percent of maximum consumption = 30%, 50%, and 70%). The average percent of maximum consumption in an adjacent watershed (Middle Fork American Fork River) for O. *mykiss* was 50% (Hanson et al. 1997). Positive growth only occurs up to approximately 64°F for food levels expected in the wild (e.g., 50% maximum consumption).

A water temperature index value of 68°F was selected because, at water temperatures above 68°F, sub-lethal effects become severe such as reductions in appetite and growth of juveniles (Marine 1997; Rich 1987a; Zedonis and Newcomb 1997). Chronic stress associated with water temperature can be expected when conditions reach the index value of 70°F. For example, growth becomes drastically reduced at temperatures close to 70.0°F and has been reported to be completely prohibited at 70.5°F (Brett *et al.* 1982; Marine 1997). 75°F was chosen as the highest water temperature index value because high levels of direct mortality to juvenile Chinook salmon reportedly result at this water temperature (Cech and Myrick 1999; Hanson 1991; Myrick and Cech 2001; Rich 1987b). Other studies have suggested higher upper lethal water temperature levels (Brett 1952; Orsi 1971), but 75°F was chosen because it was derived from experiments using Central Valley Chinook salmon and it is a more rigorous index value representing a more protective upper lethal water temperature level. Furthermore, the lethal level determined in Rich (1987b) was derived using slow rates of water temperature change and, thus, is ecologically relevant. The juvenile Chinook Salmon UILT based on numerous studies is 75-77°F (Sullivan et al. 2000; McCullough et al. 2001; Myrick and Cech 2001)

Yearling + Smolt Emigration

Juvenile Chinook salmon that exhibit extended rearing in the lower Yuba River are assumed to undergo the smoltification process and volitionally emigrate from the river as yearling+ individuals. Water temperature index values of 63°F, 68°F and 72°F were selected for the spring-run Chinook yearling+ emigration lifestage (**Table 9)**.

A water temperature index value of 63°F was selected because water temperatures at or below this value allow for successful transformation to the smolt stage, and water temperatures above this value may result in impaired smoltification indices, inhibition of smolt development, and decreased survival and successful smoltification of juvenile spring-run Chinook salmon. Laboratory experiments suggest that water temperatures at or below 62.6°F provide conditions that allow for successful transformation to the smolt stage (Clarke and Shelbourn 1985; Marine 1997; Zedonis and Newcomb 1997). 62.6°F was rounded and used to support an index value of 63°F. Indirect evidence from tagging studies suggests that the survival of fall-run Chinook salmon smolts decreases with increasing water temperatures between 59°F and 75°F in the Sacramento-San Joaquin Delta (Kjelson and Brandes 1989). A water temperature index value of 68°F was selected because water temperatures above 68°F prohibit successful smoltification (Marine 1997; Rich 1987a; Zedonis and Newcomb 1997). Support for an index value of 72°F is provided from a study conducted by (Baker *et al.* 1995) in which a statistical model is presented that treats survival of Chinook salmon smolts fitted with coded wire tags in the Sacramento River as a logistic function of water temperature. Using data obtained from mark-recapture surveys, the statistical model suggests a 95% confidence interval for the upper incipient lethal water temperature for Chinook salmon smolts as 71.5°F to 75.4°F.

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

FISH PASSAGE FACILITIES ALTERNATIVES ASSESSMENT
REINTRODUCTION GOALS SUBCOMMITTEE CONFERENCE CALL

OCTOBER 20, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Reintroduction Goals Subcommittee Conference Call

Thursday, October 20, 2016
1:00 pm to 3:00 pm

Final Meeting Notes

Meeting Attendees		
No.	**Name**	**Organization**
1	Allison Boucher	Friends of the Tuolumne
2	Steve Boyd	Turlock Irrigation District
3	Jean Castillo	National Marine Fisheries Service
4	Jesse Deason	HDR, consultant to the Districts
5	John Devine	HDR, consultant to the Districts
6	Chuck Hanson	Hanson Environmental, consultant to the Districts
7	Patrick Koepele	Tuolumne River Trust
8	Bao Le	HDR, consultant to the Districts
9	Lonnie Moore	Private citizen
10	Gretchen Murphey	California Department of Fish and Wildlife
11	Bill Paris	Modesto Irrigation District
12	John Wooster	National Marine Fisheries Service
13	Ron Yoshiyama	City and County of San Francisco

On October 20, 2016, Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) hosted the second Reintroduction Goals Subcommittee (Goals Subcommittee) conference call for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment and Upper Tuolumne River Fish Reintroduction Assessment Framework (Framework). This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting. Attachment A to this document provides meeting materials.

Mr. Bao Le (HDR, consultant to the Districts) welcomed meeting attendees. Mr. Le said the purpose of the Goals Subcommittee is to establish the overall purpose of the reintroduction program. Mr. Le summarized discussions at the first Goals Subcommittee call, held on April 13, 2016, noting that the call included a lot of discussion about developing a narrative goals statement. After the call, HDR staff, with some reluctance, took an action item to develop an initial draft statement that would serve as a starting point for collaboratively identifying the goal of the reintroduction program or how program success would be defined. Mr. Le said having a defined goal is an important part of the Framework. Currently, the National Marine Fisheries Service (NMFS) and the Districts are collecting information on the upper Tuolumne River to help understand such factors as habitat availability, thermal suitability, and migration barriers. Mr. Le said in order to evaluate the feasibility of a reintroduction action, these data must be evaluated against a defined reintroduction goal(s).

Mr. Le reviewed the meeting agenda and asked if there are any questions about the agenda or the purpose of the meeting. Mr. Wooster noted that Mr. Le said the purpose of the Goals Subcommittee is to develop a statement for the reintroduction "program". Mr. Wooster said he considers a reintroduction "program" to be something that is currently being implemented, whereas this group is evaluating the potential for reintroduction and various other issues that spun out of the FERC-approved Fish Passage Facilities Alternatives Assessment. Mr. Wooster said he believes using the word "program" is little confusing and seems premature. Mr. Le said use of the word "program" is not meant to imply anything specific. Mr. Le said NMFS likely has ideas on what they think success would look like regarding reintroducing fish into the upper Tuolumne River. Mr. Le said he thinks the question is basic; if there is a potential action to put fish into the upper Tuolumne River that are not there currently, what is the objective of this action and how will we know if it is successful? Mr. Le said using the word "program" is not meant to imply there is currently a program in place or that it is known exactly what such a program might entail. Mr. Wooster said he agreed with Mr. Le's description, but he thinks we should look for a different term to use that suggests that we are currently at the evaluation stage. Dr. Ron Yoshiyama (City and County of San Francisco) suggested using the term "reintroduction concept goals". Mr. Lonnie Moore (private citizen) suggested using the phrase "reintroduction goals" instead of "program goals". Mr. Le noted that the word "program" is only used in the agenda, and it is not used in the draft goals statement. Mr. Wooster said he is in favor of the phrase "reintroduction goals". Mr. Le said the term "reintroduction goals" will be used going forward.

Mr. Le said part of today's meeting will be spent discussing why having a goal is important. Mr. Le said on the first Goals Subcommittee call, the Districts introduced literature from state and federal agencies in the Pacific Northwest about the need for sound planning related to reintroduction. Anderson et al. (2014) focused on ESA-listed salmonids and is particularly pertinent to our discussions here. A key message from Anderson et al. (2014) is that best practices for reintroduction are not well established. Given the significance of an action like introducing a species, whether the species is new to the reach or one that was previously extirpated, a significant amount of planning is necessary and should include consideration of the benefits, risks, and constraints of the action. Mr. Le said Anderson et al. (2014) supports having the types of discussions this group is having, and knowing in advance the biological goals of the program.

Mr. Le said in addition to Anderson et al. (2014), another important document to consider is the Framework prepared by Mr. Paul Bratovich (HDR). The Framework considers such important components as the goals and objectives of the reintroduction, ecological considerations, biological constraints, regulatory and socioeconomic considerations, and engineering constraints.

Mr. Le said the NMFS Recovery Plan is another important guiding document to help develop and inform a reintroduction goal. Mr. Le said it would be helpful to hear from Mr. Wooster (NMFS) and Ms. Castillo (NMFS) on what NMFS would consider the goal to be. Mr. Le said the goal could be quantitative or qualitative.

Mr. Le asked if individuals on the call knew of other relevant documents to consider. Mr. Le asked if there were any comments or questions. There were none.

Mr. Wooster said regarding the Temperature Subcommittee, he was unable to locate the final version of Bratovich et al. (2012), and requested that Mr. Le send him a copy. Mr. Le said he will do that.

Mr. Le said Ms. Rose Staples (HDR) previously emailed out to this group a draft goals statement. HDR developed this statement in response to an action item from the first Goals Subcommittee call. Mr. Le apologized for the delay in sending out the draft goals statement. He noted that developing the statement was much harder than had been anticipated, given that there are many different and complex issues at play and a diverse group of interests. Mr. Le said the statement is not meant to be attributable to any stakeholder and was intended to serve as a starting point for collaborative discussions to further development of a statement.

Mr. Le reviewed the statement and noted that the statement intended to represent the diversity of potential interests that had been discussed previously. For example, the "identify and evaluate" language in the statement is meant to indicate that may be several reintroduction options to choose from and that currently we are in the early stages of planning which requires that all options be evaluated. Mr. Le said though we may not all agree on the results of the evaluation, it is important that the evaluation is based on solid information that everyone agrees to. The language “reasonable efforts which may enhance and assist” is meant to acknowledge that for any approach, cost and cost/benefit is an important consideration. Mr. Le said it is well known that a reintroduction program can be very expensive, and Anderson et al. (2014) identified cost, and more specifically socioeconomics, as a component to consider. Mr. Le said the final part of the statement, “in the recovery of ESA listed salmonids in the Central Valley”, relates to the NMFS Recovery Plan for listed species, and tying the goal to recovery and establishing a distinct population. Mr. Le asked for thoughts or comments on the draft goals statement.

Mr. Wooster said the phrase “in the Central Valley” is potentially too broad for what this group is trying to accomplish. Mr. Wooster said the NMFS Recovery Plan breaks up the Central Valley into sub-regions, each of which has separate recovery goals. Mr. Wooster said an example is the South Central Valley region (which includes the Tuolumne River). The NMFS Recovery Plan states the goal for this region is two populations each of steelhead and spring-run Chinook salmon. This goal is at odds with what we would try for on the Tuolumne River, which would be one population of steelhead and one population of spring-run Chinook (i.e., you could not attain more than one population for each listed species). Mr. Wooster said he did not understand why the statement does not focus on the Tuolumne River, since that is what this group is focusing on. Mr. Le said Mr. Wooster brought up a good point about how the NMFS Recovery Plan contains different goals by sub-region. Mr. Le said the rationale behind “in the Central Valley” was to provide geographic relevance. Mr. John Devine (HDR) said that when the statement was being discussed internally, it seemed important to tie the statement more broadly back to the recovery of ESA listed species for the Central Valley. Mr. Le noted that establishing a population of a listed species on the Tuolumne River would not automatically mean meeting the recovery objectives; therefore, it seemed best to frame the statement in the context of the Central Valley, which seemed to be the appropriate geographic scope as it related to ESA recovery. Mr. Wooster said based on this discussion, he better understands the rationale behind using Central Valley in the statement. Mr. Wooster said the actions may be specific to the Tuolumne River, but the goals statement speaks to how the results would apply to the greater region as it relates to recovery. Mr. Le said he agrees with Mr. Wooster’s characterization and that the statement is meant to capture the geographic scope of recovery.

Mr. Wooster said the larger group has been discussing actions to benefit fall-run Chinook, which are not ESA listed. Mr. Wooster asked how consideration of fall-run Chinook fits into this goals statement. Mr. Le said that is a good point, and the statement would need to be modified to included fall-run Chinook, given that fall-run Chinook is not ESA listed. Mr. Wooster said he does not have a suggestion of how to modify the statement, but he agrees it should be modified to include fall-run Chinook. Mr. Patrick Koepele suggested naming the three species under consideration directly in the goals statement. For example, “assist in the recovery of Central Valley steelhead, Central Valley spring-run Chinooks salmon, and fall-run Chinook salmon in the southern Central Valley”. Mr. Le said the word “recovery” is used specifically in the context of ESA, so it should not be applied to fall-run Chinook. To include fall-run Chinook, we may need to add an additional sentence to the goals statement. Mr. Le said regarding Mr. Wooster’s earlier point about the goals in the Recovery Plan, given that fall-run Chinook are not included in the Recovery Plan, it may make sense to have an independent discussion of how to define goals for fall-run Chinook. To determine goals for fall-run Chinook, we may need to look beyond the Recovery Plan. Dr. Yoshiyama suggested revising the statement to use the phrase “at-risk salmonids”. This language would work for all three species given that fall-run Chinook is a candidate species. Dr. Yoshiyama said corollary statements could be added that are specific to each species. Mr. Le said it would be helpful to get additional feedback on the statement and Dr. Yoshiyama’s suggestion of corollary statements is an option worth considering. Mr. Le stated corollary statements could be quantitative or narrative. Mr. Le also asked the group whether additional information or literature may be helpful to developing these statements.

Mr. Devine said regarding the internal discussions that took place to draft the goals statement, some individuals thought numeric measurements should be part of the goal. However, HDR couldn't decide what those numbers should be. That is the genesis behind the "identify and evaluate" language in the statement. The reasoning behind that language was the term "evaluate" implies a quantitative goal or metric, without having to pinpoint a specific quantitative goal. Mr. Devine noted that identifying quantitative goals seems important.

Dr. Yoshiyama agreed that there needs to be a quantitative component in this discussion. Dr. Yoshiyama said he thinks there is a difference between a quantitative goal and a quantitative metric or benchmark. One does not necessarily need a quantitative goal to have a quantitative metric. We can proceed without a quantitative goal, and just do as much as we can to foster steelhead or spring-run Chinook, and then use a quantitative metric or benchmark to assess our progress. That way, we can avoid painting ourselves into a corner where the goal may be unattainable. Mr. Devine said the Districts believe it would be inappropriate to invest a considerable amount of money into a reintroduction program without knowing how success is defined and when it can be achieved. Mr. Devine said the Districts believe the only way to move forward without a defined goal is to do so by starting small and building incrementally based on certain benchmarks. Dr. Yoshiyama said he agreed with Mr. Devine and it is important to ask that if the goal was a certain number of fish, what would it take to achieve that target. Dr. Yoshiyama said that wouldn't necessarily mean setting a goal, but instead setting a target or strawman, and then determining what it would take to establish that return such as what ocean survival would be needed and how many smolts and spawners would be needed. With this approach, we can figure out what the costs would be, and this would be an extremely important part of that, but without having a final goal set in stone.

Mr. Devine said he thinks that the target does eventually need to tie back to recovery, especially when talking about listed species. Regarding the southern Central Valley targets, Mr. Devine asked what would be a sufficient number of fish to achieve recovery.

Mr. Le said that HDR prepared the draft statement, but the HDR staff are not experts in the NMFS Recovery Plan or the overall management of salmonids of the Central Valley. Mr. Le said it is important that individuals like Mr. Wooster, Ms. Castillo, and Ms. Murphey, as well as other agency staff with jurisdiction, provide guidance and leadership as this group revises and adds to the goals statement. If we decide the goals will be tied to recovery, we might look to the Recovery Plan or other documents to tease out numbers related to viability or distinct populations.

Mr. Wooster said establishing quantitative goals for steelhead is a much different exercise than establishing quantitative goal for spring-run Chinook. Regarding spring-run Chinook, Lindley (2007) is a good place to start to determine what constitutes a viable population. Mr. Wooster said from there, he would turn to additional staff at NMFS for guidance, specifically Mr. Brian Ellrott, who is the NMFS Recovery Coordinator, and Mr. John Ambrose, who is the NMFS Reintroduction Coordinator. Mr. Wooster said there may be some value to having them participate in a call, or the next call, with this group. Mr. Devine said that would be very helpful.

Mr. Devine said Mr. Wooster had mentioned earlier about the Recovery Plan having goals to establish an "independent and viable" population, and Mr. Devine said that perhaps the goals could tie in to what is meant by "independent and viable". Mr. Wooster said Lindley (2007) is often what NMFS uses to quantify what would be an independent and viable population. Mr. Wooster said Lindley (2007) is a starting point. Mr. Wooster said looking at the Tuolumne River scale, there are two questions to consider: (1) what kind of independent population can be made on the Tuolumne River and (2) how would that independent population relate to the distinct population segment (DPS) or evolutionarily significant unit (ESU). Mr. Wooster said when NMFS is completing a jeopardy analysis, the agency looks at what is happening on the river and how that relates to the ESU. Mr. Le asked Mr. Wooster to send him Lindley (2007), and Mr. Wooster said he would do that.

Mr. Le asked Mr. Wooster to elaborate on the differences between defining quantitative objectives for spring-run Chinook and defining quantitative objectives for steelhead. Mr. Wooster said regarding quantitative metrics, one can plan on regular intervals of Chinook. Returns of Chinook may be traced back to a single cohort, and the population trends are on three-year averages. With steelhead, there is no guarantee of when or if an individual will smolt, which makes the species more difficult to measure than Chinook. Mr. Wooster said we may be able to look to the Pacific Northwest for examples of how to quantify goals for steelhead. Or, we may need to instead consider habitat metrics, such as how much suitable habitat exists, perhaps by life stage. Mr. Wooster said Dr. Yoshiyama made some good points about estimating outmigrant survival based on different scenarios.

Regarding how steelhead life history is considered in the NMFS Recovery Plan, Mr. Le asked if NMFS considers numbers of resident fish. Mr. Wooster said resident population numbers are not considered from a recovery standpoint, but they are something that NMFS is aware of. Mr. Wooster said a large increase in the resident population would not trigger any changes to the listing for steelhead. Mr. Le said this appears to be similar to how bull trout are treated in the Pacific Northwest, as the bull trout ESA listing seeks to protect the migratory form of the species and does not consider resident bull trout in listing status. Mr. Wooster said he is not very familiar with bull trout, but it sounds like a similar situation. Mr. Wooster said Mr. Ellrott would be a good person to ask about the finer details of how steelhead life history is considered in the NMFS Recovery Plan, given that he was the primary author.

Mr. Le asked if there are any other initial thoughts or input on the draft statement. Mr. Le said participation by Mr. Ellrott and/or Mr. Ambrose may be helpful, and asked that Mr. Wooster reach out to these two individuals to determine their interest and availability in participating. Mr. Wooster said Mr. Ellrott would be good to include now, but Mr. Ambrose usually gets involved in these types of processes once they are further developed.

Mr. Le asked if there are any other initial thoughts on the statement. There were none.

Mr. Le said it is important that the goals statement be developed in a collaborative way, and that individuals take some time to review the statement and provide feedback. Mr. Le asked that individuals provide modifications or additions to the statement, corollary statements, quantitative goals, and/or potential sources of information that might help in developing the statement further. Feedback might also be a completely new statement, or input that the statement is headed in the wrong direction. Mr. Le asked that feedback be provided by Thursday, November 3. Mr. Le said all feedback received will be compiled, along with the feedback received today. We will discuss all the feedback on the next call.

Meeting attendees discussed dates for the new Goals Subcommittee call. Mr. Le said he will send out a Doodle poll.

Meeting adjourned.

ACTION ITEMS

1. Going forward, the phrase "reintroduction goals" will be used instead of "program goals".

2. Mr. Le will send Mr. Wooster a copy of Bratovich et al. (2012). (complete)

3. Mr. Wooster will send Mr. Le a copy of Lindley (2007). (complete)

4. Mr. Wooster will contact Mr. Ellrott and Mr. Ambrose about participating on the Goals Subcommittee.

5. Meeting attendees will provide feedback on the goals statement, as well as additional documents that may be helpful for drafting the goals statement, by Thursday, November 3, 2016 to Ms. Rose Staples at rose.staples@hdrinc.com.

6. HDR will compile and organize feedback received on the goals statement.

7. Mr. Le will send out a Doodle poll.

La Grange Hydroelectric Project
Reintroduction Assessment Framework
Reintroduction Goals Subcommittee Conference Call

Thursday, October 20, 2016, 1:00 pm to 3:00 pm
Conference Line: 1-866-583-7984; Passcode: 814-0607

Meeting Objectives:

1. Review and confirm the purpose of the Reintroduction Goals Subcommittee.
2. Review and discuss preliminary draft reintroduction goals statement.
3. Identify next steps on Reintroduction Goals Subcommittee.

TIME	TOPIC
1:00 pm – 1:15 pm	Introduction of Participants (All) Review Agenda and Meeting Objectives (Districts)
1:15 pm – 1:45 pm	Reintroduction Assessment Framework – Development of Program Goals. Why Is It Important? What Purpose Does it Serve? Potential sources to further inform goal development (All) a. Planning Pacific Salmon and Steelhead Reintroductions Aimed at Long-Term Viability and Recovery, Andersen et al. b. NMFS Recovery Plan c. Others?
1:45 pm – 2:45 pm	Tuolumne River Reintroduction Goals – preliminary draft narrative statement (All) – "*Identify and evaluate, in collaboration with stakeholders, reasonable efforts which may enhance and assist in the recovery of ESA listed salmonids in the Central Valley*." a. Brief background on draft narrative statement b. Discuss feedback/refinement from subcommittee members c. Need for quantitative metrics?
2:45 pm – 3:00 pm	Next Steps toward (All) a. Schedule next call and agenda topics Action items from this call

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

REINTRODUCTION ASSESSMENT FRAMEWORK
WATER TEMPERATURE SUBCOMMITTEE IN-PERSON MEETING

DECEMBER 1, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Water Temperature Subcommittee Meeting

Thursday, December 1, 2016
1:00 pm to 2:30 pm

Final Meeting Notes

Meeting Attendees		
No.	**Name**	**Organization**
1	Steve Boyd	Turlock Irrigation District
2	Paul Bratovich	HDR, consultant to the Districts
3	Jean Castillo	National Marine Fisheries Service
4	Calvin Curtin	Turlock Irrigation District
5	Jesse Deason	HDR, consultant to the Districts
6	John Devine*	HDR, consultant to the Districts
7	Greg Dias	Modesto Irrigation District
8	Nann Fangue*	U.C. Davis, consultant to the Districts
9	Dana Ferreira	Office of U.S. Congressman Jeff Denham
10	Mark Gard*	U.S. Fish and Wildlife Service
11	Art Godwin	Turlock Irrigation District
12	Andy Gordus	California Department of Fish and Wildlife
13	Chuck Hanson	Hanson Environmental, consultant to the Districts
14	Zac Jackson	U.S. Fish and Wildlife Service
15	Bill Ketscher	Private citizen
16	Patrick Koepele*	Tuolumne River Trust
17	Bao Le	HDR, consultant to the Districts
18	Ellen Levin*	City and County of San Francisco
19	Lonnie Moore	Private citizen
20	Marco Moreno	Latino Community Roundtable
21	Gretchen Murphey	California Department of Fish and Wildlife
22	Bill Paris	Modesto Irrigation District
23	Amanda Ransom	HDR, consultant to the Districts
24	Bill Sears*	City and County of San Francisco
25	Samantha Wookey	Modesto Irrigation District
26	John Wooster*	National Marine Fisheries Service
27	Ron Yoshiyama	City and County of San Francisco

* Attended by phone.

On December 1, 2016, Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) hosted the third Water Temperature Subcommittee (Temperature Subcommittee) meeting for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment and Upper Tuolumne River Fish Reintroduction Assessment Framework (Framework). This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting. Attachment A to this document provides meeting materials. After this meeting concluded, the Reintroduction Goals Subcommittee meeting began. Notes from the Reintroduction Goals Subcommittee meeting are available as a separate document.

Mr. Bao Le (HDR, consultant to the Districts) welcomed meeting attendees. Mr. Le summarized the discussions that occurred at the previous Temperature Subcommittee meeting held on October 14, 2016. At the last meeting, the Districts introduced the report on the literature review, which was largely based on the literature review completed for the Yuba Salmon Forum (i.e. Bratovich et al. 2012). The Tuolumne literature review also included site-specific information available for the Tuolumne River. Comments on the literature review were received, and the Districts then updated the literature review and glossary. Mr. Le reviewed the rest of the agenda and asked if there were any questions. There were none.

Mr. Le said comments on the literature review and glossary were received from the California Department of Fish and Wildlife (CDFW). The Districts reviewed and responded to those comments and revised the literature review and glossary of terms (glossary) based on the comments. The Districts' responses, the revised literature review, and the glossary were circulated prior to this meeting. Mr. Le said he does not think it would be efficient use of time to review each specific change to the documents in this meeting, but wanted to allow time in the meeting for individuals to provide comments or ask questions about the updated documents and/or response to comments. There were no comments or questions.

Mr. Le said there is quite a bit of terminology to get use to when it comes to evaluating thermal suitability and it is important that the subcommittee be in agreement on the definition of terms. Mr. Le said Mr. Paul Bratovich (HDR) will provide a presentation about thermal suitability terminology.

Mr. Bratovich said thermal suitability is a fundamental consideration in the reintroduction feasibility process. Thermal suitability is an important consideration because if habitat is not thermally suitable, other measurements of suitability (i.e., physical parameters) may not be relevant. At the first Temperature Subcommittee meeting, Mr. Le provided the Water Temperature Subcommittee – Draft Process and Schedule, which proposed the overall intent of and process for the Temperature Subcommittee. Since then, the literature review was completed and distributed. The literature review identified water temperature indices used at various other programs and projects. Mr. Bratovich said water temperature *metrics* are completely different from water temperature *indices*. Water temperature metrics are how the data is presented (e.g., daily average, weekly average, 7 day average daily maximum, etc.). Water temperature evaluation guidelines are a combination of water temperature indices (i.e., numerical value) and metrics for each species/life stage-specific period. Mr. Bratovich presented a conceptual graphic of the effect of temperature on juvenile and adult salmonids over varying lengths of time. Mr. Bratovich said the optimal zone means that water temperature does not impair any metabolic functions or life history mechanisms. In the chronic zone, the temperature could affect metabolic function or life history mechanisms but fish can still live indefinitely. In the acute zone of resistance, mortality may result in a matter of minutes. Dr. Andy Gordus (CDFW) requested that the graphic be added to the literature review. Mr. Le said the graphic will be added. Mr. Bratovich reviewed common terms used to describe thermal suitability and discussed different types of water temperature metrics that may be adopted for this process. Mr. Bratovich reviewed the water temperature indices identified during the literature review, noting that for each life stage, a number of different values are provided in the literature. Finally, Mr. Bratovich reviewed next steps for the Temperature Subcommittee, which include establishing water temperature evaluation guidelines and determining species/run-specific life stage periodicities and evaluation methodology.

Mr. Le asked if there are any questions or comments about the presentation. There were none. Mr. Le noted that the intent of this presentation is to get everyone on the same page about what is meant by thermal suitability and how relevant terms are defined to set up a discussion of what may be appropriate values and metrics to use.

Mr. Le said Mr. John Wooster (National Marine Fisheries Service [NMFS]) had provided some additional references for the literature review as well as a paper by Boughton et al. (2015), which was distributed ahead of this meeting. Mr. Le said Mr. Wooster characterized Boughton et al. (2015) as the approach the NMFS Science Center (Science Center) is likely to adopt when evaluating temperature suitability in the upper Tuolumne River. Mr. Wooster said in general, the Science Center will use an upper temperature range when it comes to suitable habitat, instead of just a single temperature. By modeling a range of temperatures, the Science Center can determine whether an area provides habitat on a given day. When looking at temperatures between 20°C and 25°C, a dynamic situation occurs. Mr. Wooster said when evaluating temperatures in this range, the model considers how much of the day the temperature exceeds 20°C. This is considered a stress index. These results feed into a bioenergetics model, which takes into account such factors as pool stratification and cover. From there, habitat carrying capacity may be calculated. Mr. Wooster said Boughton et al. (2015) notes a range of temperatures are identified in the literature as "stressful", but not necessarily lethal, and the bioenergetics approach takes this into account. Mr. Wooster said the Science Center has used this approach to study steelhead in southern California as described in Boughton et al. (2015) and to study steelhead in the Bay area. A memo about this second study should be out soon. Mr. Wooster said the Science Center will take a similar approach to thermal suitability studies of spring-run Chinook, but with slightly different numbers.

Mr. Le asked Mr. Wooster to explain if the Science Center's approach considers such factors as available food and refugia in calculating carrying capacity. Mr. Wooster said the first step in the approach is to calculate the stress index, which is a function of degrees over 20°C and the duration of the temperature. Mr. Wooster said food availability and refugia are also considered in the analysis. Dr. Chuck Hanson (Hanson Environmental, consultant to the Districts) said Boughton et al. (2015) appeared to focus on the steelhead over-summering and rearing period. Dr. Hanson asked if the Science Center has expanded this approach to other life stages, such as spawning and incubation. Dr. Hanson also asked if the Science Center has applied this analysis to other species such as spring-run Chinook. Mr. Wooster said these questions generally fall outside his knowledge of the Science Center's activities. Mr. Wooster said the other draft paper he mentioned had applications for migration and spawning. The Science Center has applied this approach to spring-run Chinook in the Tuolumne River and Merced River, and is looking at both systems simultaneously. Mr. Wooster said he did not know about applying the approach to winter-run Chinook or other species. Dr. Hanson said he recently spoke to Dr. Hendrix and Dr. Lindley at the Science Center and they describe an approach to life cycle modeling that is similar to what Mr. Wooster just described. Dr. Hanson wondered if these two approaches were actually one and the same. Mr. Wooster speculated that these were likely the same process.

Mr. Le said a goal of the Temperature Subcommittee is to populate the life stage timing and temperature table. Mr. Le asked Mr. Wooster how this table might tie-in to what NMFS is considering for temperature objectives for evaluating reintroduction. Mr. Le asked if NMFS will be providing information on how the agency evaluates temperature. He also asked when additional analysis from the Science Center using this approach will be available to the Temperature Subcommittee. Mr. Wooster said the Science Center's work on all three life stages of *O. mykiss* will be described in the Russian River estuary paper, which is almost final. Mr. Wooster said the Science Center is currently working on the Tuolumne River and Merced River spring-run Chinook analyses, but he does not know a timeline for this work. Mr. Wooster said the Science Center's approach is somewhat different than taking the water temperature index approach, which is more of a binary approach. Mr. Le said it would be helpful to get input from the Science Center as this subcommittee moves forward on selecting an approach, indices, metrics, and determination on suitability.

Regarding Boughton et al. (2015), Mr. John Devine (HDR) asked if the temperatures selected under the thermal indices for temperature suitability are meant only to apply to the Santa Ynez River or will the Science Center apply these temperatures to other rivers too. Mr. Wooster said it is his understanding that the next study using this approach, which deals with the Russian River, used the same numbers as the Santa Ynez River study, but with some refinement. Mr. Wooster said he thinks both studies used data derived from a literature review, which included many of the same sources as the literature review completed by the Temperature Subcommittee. Mr. Bill Sears (City and County of San Francisco [CCSF]) asked if it would be possible to have the Science Center make a presentation to the Temperature Subcommittee about their approach. Mr. Wooster said a presentation is possible, but he had assumed the Temperature Subcommittee would want a presentation focused on study results, and not study approach. Mr. Wooster advised the Temperature Subcommittee should only plan to receive one presentation from the Science Center.

Mr. Le asked for the timeline for when results will become available for the Tuolumne River and Merced River work. Mr. Wooster said he is expecting to have a draft to review in March 2017. He said he will check in with the Science Center and find out if that schedule is still accurate. Mr. Wooster said that if a draft is available for his review in March, another month to six weeks of internal review would be necessary before the report would be finalized. Mr. Wooster said he expects to see a draft of the report for the Tuolumne River Genetics Study before March.

Mr. Devine asked if it is possible to match the temperatures used in Boughton et al. (2015) to the thermal suitability terms defined in Mr. Bratovich's presentation. For example, the Districts could try to determine how temperatures identified in Boughton et al. (2015) correspond to tolerable, optimum, acute, etc. Mr. Devine asked if the Districts made an attempt to match up temperatures to terms in an effort to connect these two concepts, would Mr. Wooster and/or the Science Center be able to review the results and provide feedback. Mr. Wooster said he would provide feedback.

Dr. Hanson asked Mr. Wooster to provide more details on how the Science Center uses the model output related to the stress index to demonstrate habitat suitability or carrying capacity. Mr. Wooster said he did not know much more than he already described. He noted that the technical memo in progress about the Russian River gives a lot more detail about the modeling approach. Mr. Wooster said Dr. Hanson's questions would be good ones to ask the Science Center when they come to present. Dr. Hanson said it would also be helpful to know more about whether the Science Center has had an opportunity to evaluate the model's predictions against actual results on other rivers. Dr. Hanson noted that the Santa Ynez Watershed is a highly stressed system, which may have implications for using the approach on other rivers. Mr. Wooster said these are all good questions for the Science Center.

Mr. Le asked at what scale the Science Center's approach may be applied. Mr. Le asked if the approach would be applied to the entire Tuolumne River as it relates to suitability and recovery. Mr. Wooster said the focus of the approach is to calculate carrying capacity, and not to calculate the amount of river that is optimal, suboptimal, etc. Mr. Wooster said the question is really how many fish can be supported in the upper river.

Ms. Dana Ferreira (U.S. Congressman Jeff Denham's office) asked if NMFS is proposing different temperatures for different reaches of the river. Mr. Wooster said NMFS is not proposing a temperature for the upper river. Mr. Wooster said there are different objectives for, and differences in how flows are regulated in, the lower river as compared to the upper river. Mr. Wooster said he does not have much ability to propose temperatures in the upper Tuolumne River. Mr. Devine said Ms. Ferreira's question may be better directed to CDFW. Mr. Devine said there are obvious differences between temperatures recommended in EPA (2003) and the temperatures used in the Science Center's approach. Mr. Wooster said the goal in the lower river is to design a protective flow regime for the fish that are already there, while in the upper river the goal is first to evaluate how many fish would survive or could be produced in the existing habitat, and what benefit may be gained to the population by putting fish in this reach. Mr. Devine said it seems that EPA (2003) temperatures recommend 18°C as a compliance or temperature benchmark for over-summering *O. mykiss*, and that if this temperature is exceeded, it is presumably harmful to fish.

Mr. Devine said the question here is if exceeding 18°C is very harmful to fish in the lower river, why wouldn't exceeding 18°C in the upper river also be harmful to the same fish. Mr. Wooster said the 20°C to 25°C stress index attempts to quantify how much harm occurs at these temperatures. Mr. Wooster said at one end of the stress index the habitat is totally unusable, while in the middle of the stress index habitat is sometimes usable.

Mr. Devine asked Dr. Gordus that if it is determined that fish do well at temperatures in the upper reach that are warmer than EPA (2003) recommended temperatures for below the dams, would CDFW consider changing the criteria for the reach below the dams to warmer temperatures. Ms. Gretchen Murphey (CDFW) and Dr. Gordus stated they did not have the authority to weigh in on that question.

Mr. Le asked if there were any additional thoughts or input about the temperature indices discussion. Mr. Bratovich said in reviewing Boughton et al. (2015), and understanding that the Science Center's approach looks at thermal suitability as a gradation of effects, it appears that the question then becomes what constitutes thermally suitable habitat. Mr. Bratovich said the Temperature Subcommittee will need to consider at what point in the gradation of effects is reintroduction feasible. Mr. Bratovich said this question gets to the overall goal of the reintroduction program, and how success is defined. Mr. Wooster said NMFS is looking at it from an entire life cycle perspective. For example, if there is negative growth, it is obvious there will not be a viable population. How much habitat is thermally suitable or not depends on the whole life cycle process.

Mr. Le said the temperature and periodicity timing table is broken out by life stage and species. The voluntary studies being completed by the Districts examine water temperature as well as barriers to migration and instream flows. Mr. Le said it seems that NMFS is trying to consider all these factors at once using one analysis, while individuals participating in the Framework process are looking at these factors as discreet pieces to first be considered individually. Mr. Wooster generally agreed with this characterization.

Dr. Hanson said a classic approach to the topic at hand is to first consider life stage. Normally you would first look at the suitability and distribution of spawning gravel, and then from there estimate redd size and the number of redds that can be supported. Then, you would look at temperature suitability to estimate how many would hatch. Thermal conditions for fry and juveniles would be examined. Making assumptions about emergence and growth, you can calculate how many days are needed for growth and then look to bioenergetics. Outmigration success must also be considered. From there, you can figure out how many fish might survive to adulthood. And then in Year 2, a certain percent of the fish return and using a set of assumptions the analysis continues. Mr. Wooster said the Science Center's approach considers all these factors. Mr. Le said thermal suitability is one of many filters to determine overall reintroduction suitability, and he is curious to better understand the Science Center's approach. Ms. Jean Castillo (NMFS) noted the approach described by Dr. Hanson would be fairly repetitive. Dr. Ron Yoshiyama (CCSF) said this is the general approach the Districts took in the population models built for the lower Tuolumne River.

Dr. Yoshiyama said there are two issues at play here. The first is representing the life cycle, which has already been done by the Districts' population models. The second is habitat suitability. Boughton et al. (2015) describes temperature suitability in the Santa Ynez River in conjunction with food availability. Various other factors appear to already be integrated into the approach. The approach for the Santa Ynez River is a simplified approach compared to what will be necessary for the Tuolumne River as the Santa Ynez approach does not include consideration of resident life history. Dr. Yoshiyama summarized other aspects of Boughton et al. (2015). Dr. Yoshiyama said additional details about the mechanisms behind the bioenergetics approach appear to be forthcoming in the upcoming manuscript mentioned by Mr. Wooster.

Mr. Devine asked Dr. Yoshiyama if Boughton et al. (2015) assumes that when a fish reaches a certain size, it will be anadromous. Dr. Yoshiyama said yes, and that a missing part of the story seems to be the consideration of those fish that reach that size but do not become anadromous. Dr. Yoshiyama said this group can look to analysis on other rivers to inform assumptions about residency and anadromy.

Mr. Le asked about the schedule for the Russian River memo. Mr. Wooster said he believes the memo is drafted and under review. He said he will check on the schedule. Mr. Le asked if the report for the Tuolumne River will includes further details about how carrying capacity is calculated. Mr. Wooster said the Science Center's approach to calculating carrying capacity was honed on the Santa Ynez and fine-tuned for the Russian River. The Russian River memo will include most of the details on methodology.

Mr. Devine said it appears one outcome of the Science Center's work is that NMFS will not be adopting EPA (2003) for salmonids in the upper Tuolumne River. Mr. Wooster said NMFS is only trying to determine how many fish can be produced in that stretch of the river.

Referring to Mr. Bratovich's presentation, Ms. Ferreira said his slides seem to indicate that 60°F to 65°F is optimal for all life stages, and that when 70°F is reached, the conditions are stressful. Mr. Bratovich said that is pretty much true except for spawning, which requires temperatures in the mid-50s. Ms. Ferreira asked if 20°C and 21°C is stressful, and the fish are already stressed from swimming upstream and trying to avoid predation, isn't more water needed in the river to cool it off. Mr. Bratovich said that topic is covered in Boughton et al. (2015). Ms. Ferreira said it is confusing trying to determine what "stressful" actually means and she asked if fish would die at 70°F or 71°F. Mr. Bratovich said Boughton et al. (2015) notes fish die at 24°C and 25°C. Mr. Bratovich questioned how to determine how much stress is too much stress and at what point elevated temperatures become so influential that the population over time will no longer be successful.

Ms. Ferreira asked why 70°F is even being discussed if the temperature is so stressful for fish. Mr. Lonnie Moore (public citizen) said at some points of the year, the stress that may result from higher temperatures may be mitigated by other factors, such as greater amounts of food. Therefore, it is important to consider these higher temperatures.

Ms. Ferreira asked if lower temperatures are generally better for fish. Ms. Murphey said in general lower temperatures are better. In the lower Tuolumne River, fish can generally move around to take advantage of different temperatures that exist in different reaches. The water is coolest in the upstream reaches near the dam. Dr. Yoshiyama said that as the water from the dam flows downstream, it becomes warmer and warmer. A certain amount of water must be released in order to keep the river cool enough for the fish to survive. That is why it is important to explore what higher temperatures mean in the upper river. Dr. Yoshiyama said it is the goal of this group to give some direction to a temperature boundary in the upper river. Ms. Ferreira asked if the studies being done will arrive at that temperature. Ms. Murphey said that would not be an outcome of the studies.

Mr. Le said it is concerning that EPA (2003) may be applied in the lower river but in the upper river more lenient criteria is being considered. Mr. Le asked if lenient criteria are used to justify building fish passage, and fish passage is ultimately built, will the lenient criteria be kept going forward or will more conservative criteria then be implemented. Ms. Murphey said the difference between the upper and lower reaches is that there are no mechanisms for changing the flow in the upper river, while mechanisms do exist for changing flow in the lower river. Mr. Le said the question still exists how these temperature considerations inform whether or not to reintroduce fish. Mr. Le said it seems like more conservative parameters should be considered. Mr. Zac Jackson (US Fish and Wildlife Service) said one way to look at it is that there are 1,000 widgets of habitat and we want to see how many widgets can support fish. Maybe just one widget can support fish, but enough fish can be supported by that one widget that it appears the population can be viable. That doesn't necessarily mean that fish should or should not be introduced. Mr. Le said if water temperature indices are used to assess the widgets, and then fish passage is built, will those same water temperature indices be what is required in the future. Mr. Le said it seems as though any analysis should start with the conservative protective criteria. Mr. Jackson said he understands these are two different approaches, and that if more protective temperatures were implemented, that might change the amount of habitat that is available. Mr. Wooster said NMFS' approach does not say whether a temperature is good or bad, only if it is "stressful" and, based on other factors, how stressful it is. Mr. Wooster said it is known that there are stressful temperatures in the upper river, but there are also areas that are not as stressful. Given that there are both stressful and not stressful areas, NMFS is trying to determine how many fish the reach can support. Mr. Wooster said if fish are reintroduced, temperatures in the upper reach would not be managed. Mr. Devine said that would mean managing the same fish under different temperature regimes. Mr. Devine asked why the agencies would ask the Districts to put more water downstream if it had already been determined that the same population is viable under stressful conditions? Mr. Wooster said the potential benefit of reintroducing fish upstream is potential water savings downstream.

The meeting concluded. After a short break, the Reintroduction Goals Subcommittee meeting began.

Action Items

1. The Districts will add the effects of temperature on juvenile or adult salmonids graphic to the water temperature literature review and literature review summary.

2. Given that the NMFS Science Center may only want to give one presentation to the Temperature Subcommittee, the Temperature Subcommittee will consider the timing of when to request a presentation.

3. The Districts will try to match up the temperature numbers presented in Boughton et al. (2015) with the water temperature definitions provided on slide 5 of Mr. Bratovich's presentation. The Districts will provide their findings to the Temperature Subcommittee and NMFS for feedback. NMFS will provide feedback.

4. Mr. Wooster will provide a schedule for when the Russian River memo will be available for review.

5. Mr. Wooster will provide a schedule for when the Tuolumne and Merced Habitat and Carrying Capacity and Genetics study reports will be available for review.

La Grange Hydroelectric Project
Reintroduction Assessment Framework
Water Temperature/Reintroduction Goals Subcommittees – In-person Meeting

Thursday, December 1, 2016, 1:00 pm to 4:00 pm

Modesto Irrigation District, 1231 11th St., Modesto, CA 95354
Conference Line: 1-866-583-7984; Passcode: 814-0607

Meeting Objectives:

1. Review and discuss updated water temperature literature review summary, glossary of terms/acronym list based upon comments received.
2. Presentation and discussion on relevant temperature terms.
3. Discuss water temperature indices (WTI) when considering anadromous fish reintroduction in the Upper Tuolumne River.
4. Discuss next steps and schedule for WTI selection.
5. Review, discuss and modify draft narrative reintroduction goals statement.
6. Discuss next steps and schedule for finalizing a reintroduction goals statement.

TIME	TOPIC
1:00 pm – 1:10 pm	Introduction of Participants (All) Review Agenda and Meeting Objectives (Districts)
1:10 pm – 2:30 pm	Water Temperature Subcommittee Topics (All) a. Updated Literature Review Summary and Acronym List– comments received (Districts) b. Presentation and discussion on relevant temperature terms (Districts) c. Subcommittee discussion of potential WTI values (All) - NMFS Input
2:30 pm – 3:50 pm	Reintroduction Goals Subcommittee Topics (All) a. Additional discussion on current draft narrative reintroduction goals statement (All) b. Subcommittee discussion of further development of draft narrative goal statement (All) - Additional corollary statements? - Quantitative input (Lindley 2007)?
3:50 pm – 4:00 pm	Next Steps (All) a. Schedule next call and agenda topics b. Action items from this call

Upper Tuolumne River Reintroduction Assessment Framework
Water Temperature Subcommittee
Water Temperature Evaluation
Glossary of Terms

Acute temperature – water temperature identified as being in the **zone of resistance** for a particular species/lifestage. The lower boundary of the acute temperature response range is represented by the **upper incipient lethal temperature**.

Acute temperature exposure – water temperature exposure that is less than 7 days and results in 50% mortality.

Acute temperature zone – zone where acute water temperature exposure occurs with potential for rapid mortality; **zone of resistance**.

Average daily temperature (ADT) – average of temperatures in a 24-hour period.

Chronic temperature – water temperature identified as being in the **temperature tolerance zone** for a particular species/lifestage. The lower boundary of the temperature tolerance zone is represented by the upper optimal temperature.

Chronic temperature exposure – water temperature exposure that is long-term (≥ 7 days).

Chronic temperature zone – zone where chronic water temperature exposure occurs with reduced (or no) growth and reproduction, and increased mortality.

Critical thermal maximum – very short duration (minutes) mortality after acute temperature exposure.

Diel temperature – temperature over 24-hour period.

Diurnal temperature – temperature fluctuations between high and low or day and night of the same day.

Lifestage periodicity – season/dates corresponding to a specific lifestage (e.g. spring-run Chinook salmon spawning); identified through study of a particular watershed.

Maximum weekly average temperature (MWAT) – the highest value calculated for all possible 7-day periods over a given time period (e.g. season or lifestage) and generally used to summarize instream water temperature variation occurring on daily or seasonal basis for evaluation of chronic water temperature impacts; found by calculating mathematical mean of multiple, equally spaced, daily water temperatures over a 7-day consecutive period.

Optimal temperature range – zone of temperatures where physiological processes (growth, reproduction, disease resistance) and behavior are not stressed by temperature.

Seven (7)-day moving average temperature (7DMA) – water temperature metric describing the running 7-day average of average daily water temperatures; calculated by adding the daily average temperatures recorded at a site on seven consecutive days and dividing by seven uses consecutive seven day subsets.

Seven (7)-day moving average daily maximum temperature (7DMADM) – water temperature metric describing the running 7-day average of the daily maxima; calculated by adding the daily maximum temperatures recorded at a site on seven consecutive days and dividing by seven, uses consecutive seven day subsets.

Seven (7)-day average daily maximum temperature (7DADM) – water temperature metric describing the maximum 7-day average of the daily maxima; calculated by adding the daily maximum temperatures recorded at a site on seven consecutive days and dividing by seven.

Upper incipient lethal temperature (UILT) – boundary between lower end of **acute temperature exposure** range and upper end of **chronic temperature exposure** range, at which 50% mortality occurs after 7 days.Upper optimal WTI (UOWTI) – the upper boundary of the optimal temperature range where physiological processes (growth, reproduction, disease resistance) and behavior are not stressed by temperature; **optimal temperature range** identified for specific lifestage.Upper tolerance WTI (UTWTI) – the water temperature at which fish can survive indefinitely, without experiencing substantial detrimental effects to physiological and biological functions such that survival occurs, but growth and reproduction success are reduced below optimal.

Use designation – category applied to a waterbody that determines which **water quality standards (WQS)** will be enforced.

Volitional migration – active behavior of upstream or downstream migration occurring when anadromous fish are physiologically ready.

Water quality standards (WQS) – specified concentrations/values of various water quality parameters not to be exceeded as established by the U.S. Environmental Protection Agency (EPA) and/or state for beneficial uses such as aquatic life and drinking water.

Water temperature index (WTI) values – values representing a gradation of potential water temperature effects ranging between optimal to lethal conditions by species and lifestage; developed empirically through laboratory and field studies.

Water temperature exceedance curves – used to identify probabilities/duration of time that lifestage-specific **WTI** values would be exceeded over a given time.

Water temperature metrics – provide index of temperature over a period of time (e.g. **MWAT**, **7DADM**).

Water year type – describes amount of precipitation received during water year (e.g. critically dry to wet).

Zone of resistance – water temperature zone between the **UILT** (7 days) and **critical thermal maximum**.

Zone of tolerance – water temperature zone that fish can tolerate that is below the **UILT** and above the **optimal temperature** range, but at the higher end of the range individuals may not thrive and may exhibit modified behavior.

UPPER TUOLUMNE RIVER REINTRODUCTION ASSESSMENT FRAMEWORK
WATER TEMPERATURE SUBCOMMITTEE

LIFESTAGE-SPECIFIC WATER TEMPERATURE BIOLOGICAL EFFECTS AND INDEX TEMPERATURE VALUES

Literature Review Summary

INTRODUCTION

The La Grange Hydroelectric Project (La Grange Project), owned and operated by the Turlock Irrigation District and Modesto Irrigation District (TID/MID, or the Districts), is currently undergoing the Federal Energy Regulatory Commission (FERC) Integrated Licensing Process. As part of this process, the Districts are implementing a FERC-approved Fish Passage Facilities Alternatives Assessment which consists of developing general design criteria and design considerations applicable to upstream and downstream fish passage facilities at the La Grange Project. Design criteria and considerations include items such as: site-specific physical and operational parameters; applicable regulatory requirements; National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and California Department of Fish and Wildlife (CDFW) biological and engineering design criteria; site-specific biological/habitat information relevant to the sizing and configuration of facilities; and any other information gaps that may affect siting, sizing, general design parameters, capital cost, and operating requirements of potential fish passage facilities.

To make certain that detailed, site-specific information is available to support and adequately inform decisions regarding fish reintroduction and fish passage, TID, MID, and licensing participants came to a consensus on the need for and utility of an Upper Tuolumne River Reintroduction Assessment Framework (Framework). The Framework is intended to provide a comprehensive, collaborative, and transparent approach for evaluating the full range of potential issues associated with the future reintroduction of anadromous salmonids to the upper Tuolumne River. In addition to considering aspects of the technical feasibility of building and operating fish passage facilities, the Framework considers the interrelated issues of ecological feasibility, biological constraints, economics, regulatory implications, and other considerations of reintroduction. Elements of the Framework are interconnected, with fish passage construction and operational requirements needing to properly reflect biological constraints, ecological considerations, and economic cost-benefit assessments.

Water temperature considerations are a primary component of assessing any potential anadromous salmonid reintroduction effort. In support of the Framework, the Districts and licensing participants established a Water Temperature Subcommittee to begin investigating water temperature considerations pertinent to anadromous salmonid reintroduction opportunities in the accessible reaches of the Tuolumne River upstream of Don Pedro Reservoir (upper Tuolumne River). On September 15, 2016, the Districts hosted the first conference call for the Water Temperature Subcommittee (draft meeting notes from this call were distributed on October 3 for a 30-day comment period). On the conference call, attendees discussed the need for a comprehensive literature review of regional and site-specific information to inform the selection of water temperature index (WTI) values to be used in an evaluation of the water temperature-related reintroduction potential in the reaches of the upper Tuolumne River. Meeting attendees agreed that the literature review performed for the Yuba Salmon Forum (Appendix A; Bratovich *et al.* 2012) to support the anadromous salmonid reintroduction assessment in this watershed coupled with site-specific temperature studies or data for the Tuolumne River, if available, would be a good basis for this effort. The following represents and updated literature review summary and is provided to the Water Temperature Subcommittee to support selection of water temperature index values for the Framework.

STEELHEAD LIFESTAGE-SPECIFIC WATER TEMPERATURE INDEX VALUES

Adult Immigration and Holding

Water temperatures can control the timing of adult spawning migrations and can affect the viability of eggs in holding females. Yuba County Water Agency (YCWA) *et al.* (2007) suggests that few studies have been published examining the effects of water temperature on either steelhead immigration or steelhead holding, and none of the available studies were recent (Bruin and Waldsdorf 1975; McCullough *et al.* 2001). The available studies suggest that adverse effects occur to immigrating and holding steelhead at water temperatures exceeding the mid-50°F range, and that immigration will be delayed if water temperatures approach approximately 70°F (Table 1). WTI values of 52°F, 56°F, 61°F, 64°F, 65°F, 68°F and 70°F were identified because they provide a gradation of potential water temperature effects, and the available literature provided the strongest support for these values.

Because of the paucity of literature pertaining to steelhead adult immigration and holding, an evenly spaced range of WTI values could not be achieved. 52°F was identified as a WTI value because it has been referred to as a "recommended" (Reclamation 2003), "preferred" (McEwan and Jackson 1996; NMFS 2000; NMFS 2002), and "optimum" (Reclamation 1997a) water temperature for steelhead adult immigration. Increasing levels of thermal stress to this lifestage may reportedly occur above the 52°F WTI value. 56°F was identified as a WTI value because 56°F represents a water temperature above which adverse effects to migratory and holding steelhead begin to arise (Bruin and Waldsdorf 1975; Leitritz and Lewis 1980; McCullough *et al.* 2001; Smith *et al.* 1983). 50-59°F is referred to as the "preferred" range of water temperatures for California summer steelhead holding (Moyle *et al.* 1995). Water temperatures greater than 61°F may result in "chronic high stress" of holding Central Valley winter-run steelhead (USFWS 1995a). A water temperature of 64°F (7DADM) was identified as the value for steelhead adult lifestage for the San Joaquin River (CALFED 2009) and as the Upper Optimum Value for steelhead adult migration (MWAT) for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 64°F (7DADM) for "salmon and trout" migration (EPA 2003b). 65°F was identified as a WTI value because steelhead (and fall-run Chinook salmon) encounter potentially stressful temperatures between 64.4-73.4°F (Richter and Kolmes 2005). Additionally, over 93% of steelhead detections occurred in the 65.3-71.6°F range, although this may be above the temperature for optimal immigration (Salinger and Anderson 2006) and/or may modify migration timing due to holding in coldwater refugia (High *et al.* 2006). A water temperature of 68°F (MWAT) was identified as the Upper Tolerable Value for steelhead adult migration for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012). A water temperature of 68°F was found to drop egg fertility in vivo to 5% after 4.5 days (McCullough *et al*. 2001). Additionally, empirical adult *O. mykiss* population data from the North Yuba, Middle Yuba, South Yuba, Middle Fork American, and Rubicon rivers were collected in 2007-2009 were plotted against temperature (Figure 4 of Bratovich *et al*. 2012). The data show a population density break at about 68°F. Although smaller population densities occurred at higher temperatures, the largest population densities occurred at temperatures near 68.0°F or less. 70°F was identified as the highest WTI value because the literature suggests that water temperatures near and above 70.0°F may result in a thermal barrier to adult steelhead migrating upstream (McCullough *et al.* 2001) and are water temperatures referred to as "stressful" to upstream migrating steelhead in the Columbia River (Lantz 1971 as cited in Beschta *et al.* 1987). Further, Coutant (1972) found that the upper incipient lethal temperature (UILT) for adult steelhead was 69.8°F and temperatures between 73-75°F are described as "lethal" to holding adult steelhead in Moyle (2002).

As part of the Framework, TID and MID, in collaboration with stakeholders developed a table of WTI values from select salmon and steelhead programs in the Central Valley (Temperature Criteria Matrix; presented at the September 15, 2016 Water Temperature Subcommittee conference call). The table was developed to support the Framework's Water Temperature Subcommittee whose purpose is to establish a technical basis to evaluate water temperature regimes for target anadromous salmonid reintroduction into the Tuolumne River upstream of Don Pedro Reservoir. For steelhead adult immigration, the Temperature Criteria Matrix identified 64°F for the San Joaquin (CALFED 2009) and 64°F (Upper Optimum Value) and 68°F (Upper Tolerable Value) for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012). For steelhead adult holding, the Temperature Criteria Matrix identified 61°F (Upper Optimum Value) and 65°F (Upper Tolerable Value) for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).

Table 1. Steelhead Adult Immigration and Holding WTI Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
52°F (11.1°C)	Preferred range for adult steelhead immigration of 46.0°F to 52.0°F (NMFS 2000; NMFS 2001a; SWRCB 2003). Optimum range for adult steelhead immigration of 46.0°F to 52.1°F[1] (Reclamation 1997a). Recommended adult steelhead immigration temperature range of 46.0°F to 52.0°F (Reclamation 2003).
56°F (13.3°C)	To produce rainbow trout eggs of good quality, brood fish must be held at water temperatures not exceeding 56.0°F (Leitritz and Lewis 1980). Rainbow trout brood fish must be held at water temperatures not exceeding 56°F for a period of 2 to 6 months before spawning to produce eggs of good quality (Bruin and Waldsdorf 1975). Holding migratory fish at constant water temperatures above 55.4°F to 60.1°F may impede spawning success (McCullough *et al.* 2001).
61°F (16.1°C)	Water temperatures greater than 61°F may result in "chronic high stress" of holding Central Valley winter- run steelhead (USFWS 1995a). Preferred range of water temperature for holding California summer steelhead occurs between 50-59°F (Moyle 1995). A water temperature of 61°F was identified as the Upper Optimum Value for steelhead adult holding, MWAT, for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
64°F (17.8°C)	Steelhead (and fall-run Chinook salmon) encounter potentially stressful temperatures between 64.4-73.4°F (Richter and Kolmes 2005). Over 93% of steelhead detections occurred in the 65.3-71.6°F, although this may be above the temperature for optimal immigration (Salinger and Anderson 2006). A water temperature of 64°F was identified as the value for steelhead adult lifestage, 7DADM, for the San Joaquin River (CALFED 2009) and as the Upper Optimum Value for steelhead adult migration, MWAT, for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 64°F (7DADM) for "salmon and trout" migration (EPA 2003b).
65°F (18.3°C)	A water temperature of 65°F (MWAT) was identified as the Upper Tolerable Value for steelhead adult holding for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
68°F (20°C)	A water temperature of 68°F (MWAT) was identified as the Upper Tolerable Value for steelhead adult migration for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012). A water temperature of 68°F was found to drop egg fertility in vivo to 5% after 4.5 days (McCullough *et al.* 2001).
70°F (21.1°C)	Migration barriers have frequently been reported for pacific salmonids when water temperatures reach 69.8°F to 71.6°F (McCullough *et al.* 2001). Snake River adult steelhead immigration was blocked when water temperatures reached 69.8 (McCullough *et al.* 2001). The UILT for adult steelhead was determined to be 69.8°F (Coutant 1972).

<u>Spawning and Embryo Incubation</u>

Relatively few studies have been published directly addressing the effects of water temperature on steelhead spawning and embryo incubation (Redding and Schreck 1979; Rombough 1988). Because anadromous steelhead and non-anadromous rainbow trout are genetically and physiologically similar, studies on non-anadromous rainbow trout also were considered in the development of WTI values for steelhead spawning and embryo incubation (Moyle 2002; McEwan 2001). From the available literature, water temperatures in the low

[1] Similar to Bratovich *et al*. 2012, rounded whole integers were identified for index values to avoid unwarranted specificity.

50°F range appear to support high embryo survival, with substantial mortality to steelhead eggs reportedly occurring at water temperatures in the high 50°F range and above (Table 2). Water temperatures in the 45-50°F range have been referred to as the "optimum" for spawning steelhead (FERC 1993).

WTI values of 46°F, 52°F, 54°F, 55°F, 57°F, 59°F and 60°F were identified for two reasons. First, the available literature provided the strongest support for WTI values at or near these integers. Second, the index values reflect a gradation of potential water temperature effects ranging between optimal to lethal conditions for steelhead spawning and embryo incubation. Some literature suggests water temperatures ≤ 50°F are when steelhead spawn (Orcutt *et al.* 1968) and/or are optimal for steelhead spawning and embryo survival (FERC 1993; Myrick and Cech 2001; Timoshina 1972) and temperatures between 39-52°F are "preferred" by spawning steelhead (IEP Steelhead Project Work Team (no date); McEwan and Jackson 1996). Orcutt *et al.* (1968) reported that steelhead spawning in late spring in the Clearwater and Salmon Rivers, Idaho, occurred at temperatures between 35.6 and 46.4°F. A larger body of literature suggests optimal conditions occur at water temperatures ≤ 52°F (Humpesch 1985; NMFS 2000; NMFS 2001a; NMFS 2002; Reclamation 1997b; SWRCB 2003; USFWS 1995b). Further, water temperatures between 48-52°F were referred to as "optimal" (FERC 1993; McEwan and Jackson 1996; NMFS 2000) and "preferred" (Bell 1986) for steelhead embryo incubation. Therefore, 52°F was identified as the lowest WTI value. Increasing levels of thermal stress to the steelhead spawning and embryo incubation lifestage may reportedly occur above the 52°F WTI value.

54°F was identified as the next index value, because although most of the studies conducted at or near 54.0°F report high survival and normal development (Kamler and Kato 1983; Redding and Schreck 1979; Rombough 1988), some evidence suggests that symptoms of thermal stress arise at or near 54.0°F (Humpesch 1985; Timoshina 1972). Thus, water temperatures near 54°F may represent an inflection point between properly functioning water temperature conditions, and conditions that cause negative effects to steelhead spawning and embryo incubation. Further, water temperatures greater than 55°F were referred to as "stressful" for incubating steelhead embryos (FERC 1993). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 55°F (7DADM) for "salmon and trout" spawning and egg incubation (EPA 2003b). For steelhead spawning and embryo incubation in the Yuba River, the Framework Temperature Criteria Matrix identified 54°F and 57°F for Upper Optimum and Upper Tolerable values, respectively (Bratovich *et al.* 2012). 57°F was identified as an index value because embryonic mortality increases sharply and development becomes retarded at incubation temperatures greater than or equal to 57°F. Velsen (1987) provided a compilation of data on rainbow trout and steelhead embryo mortality to 50% hatch under incubation temperatures ranging from 33.8°F to 60.8°F that demonstrated a two-fold increase in mortality for embryos incubated at 57.2°F, compared to embryos incubated at 53.6°F.

In a laboratory study using gametes from Big Qualicum River, Vancouver Island, steelhead mortality increased to 15% at a constant temperature of 59.0°F, compared to less than 4% mortality at constant temperatures of 42.8°F, 48.2°F, and 53.6°F (Rombough 1988). Also, alevins hatching at 59°F were considerably smaller and appeared less well developed than those incubated at the lower temperature treatments. From fertilization to 50% hatch, rainbow trout eggs from Ontario Provincial Normendale Hatchery had 56% survival when incubated at 59.0°F (Kwain 1975).

As part of the Don Pedro Hydroelectric Project FERC relicensing process, the Districts conducted an *O. mykiss* Population Study (TID/MID 2014) for the Lower Tuolumne River below La Grange Diversion Dam. The goal of the study is to provide a quantitative population model to investigate the relative influences of various factors on the lifestage-specific production of *O. mykiss* in the Tuolumne River including water temperature effects on population response for specific in-river lifestages. The study noted that although no literature information could be identified regarding upper temperature limits for spawning initiation, maximum temperature limits for spawning are assumed to be on the order of 15°C (59°F) inferred from egg mortality thresholds for resident *O. mykiss* (Velsen 1987) as well as steelhead (Rombough 1988). Similarly, for egg incubation, the model allowed for a broad range of flow and water temperature conditions using the completed model, an initial acute mortality threshold of 15°C (59°F) was included based upon a literature review by Myrick and Cech (2001).

From fertilization to 50% hatch, Big Qualicum River steelhead had 93% mortality at 60.8°F, 7.7% mortality at 57.2°F, and 1% mortality at 47.3°F and 39.2°F (Velsen 1987). Myrick and Cech (2001) similarly described water temperatures >59°F as "lethal" to incubating steelhead embryos, although FERC (1993) suggested that water temperatures exceeding 68°F were "stressful" to spawning steelhead and "lethal" when greater than 72°F.

Table 2. Steelhead Spawning and Embryo Incubation WTI Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
46°F (7.8°C)	Orcutt *et al*. (1968) reported that steelhead spawning in late spring in the Clearwater and Salmon Rivers, Idaho, occurred at temperatures between 35.6 and 46.4°F.
52°F (11.1°C)	Rainbow trout from Mattighofen (Austria) had highest egg survival at 52.0°F compared to 45.0°F, 59.4°F, and 66.0°F (Humpesch 1985). Water temperatures from 48.0°F to 52.0°F are suitable for steelhead incubation and emergence in the American River and Clear Creek (NMFS 2000; NMFS 2001a; NMFS 2002a). Optimum water temperature range of 46.0°F to 52.0°F for steelhead spawning in the Central Valley (USFWS 1995b). Optimum water temperature range of 46.0°F to 52.1°F for steelhead spawning and 48.0°F to 52.1°F for steelhead egg incubation (Reclamation 1997a). Upper limit of preferred water temperature of 52.0°F for steelhead spawning and egg incubation (SWRCB 2003).
54°F (12.2°C)	Big Qualicum River steelhead eggs had 96.6% survival to hatch at 53.6°F (Rombough 1988). Highest survival from fertilization to hatch for *Salmo gairdneri* incubated at 53.6°F (Kamler and Kato 1983). Emergent fry were larger when North Santiam River (Oregon) winter steelhead eggs were incubated at 53.6°F than at 60.8°F (Redding and Schreck 1979). The upper optimal water temperature regime based on constant or acclimation water temperatures necessary to achieve full protection of steelhead is 51.8°F to 53.6°F (EPA 2001). From fertilization to hatch, rainbow trout eggs and larvae had 47.3% mortality (Timoshina 1972). Survival of rainbow trout eggs declined at water temperatures between 52.0 and 59.4°F (Humpesch 1985). The optimal constant incubation water temperature for steelhead occurs below 53.6°F (McCullough *et al*. 2001). A water temperature of 54°F (MWAT) was identified as the Upper Optimum Value for steelhead spawning and embryo incubation for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
55°F (12.8°C)	EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 55°F (7DADM) for "salmon and trout" spawning and egg incubation (EPA 2003b). Water temperatures greater than 55°F were referred to as "stressful" for incubating steelhead embryos (FERC 1993).
57°F (13.9°C)	From fertilization to 50% hatch, Big Qualicum River steelhead had 93% mortality at 60.8°F, 7.7% mortality at 57.2°F, and 1% mortality at 47.3°F and 39.2°F (Velsen 1987). A sharp decrease in survival was observed for rainbow trout embryos incubated above 57.2°F (Kamler and Kato 1983). A water temperature of 57°F (MWAT) was identified as the Upper Tolerable Value for steelhead spawning and embryo incubation for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
59°F (15°C)	Based on egg mortality thresholds for steelhead, maximum temperature limits for spawning are assumed to be 59°F (Rombaugh 1988 as cited in TID/MID 2014). A water temperature of 59°F was identified as the initial acute mortality threshold for steelhead egg incubation (Myrick and Cech 2001 as cited in TID/MID 2014). From fertilization to 50% hatch, rainbow trout eggs from Ontario Provincial Normendale Hatchery had 56% survival when incubated at 59.0°F (Kwain 1975).
60°F (15.6°C)	Water temperatures >59°F are described as "lethal" to incubating steelhead embryos (Myrick and Cech 2001), From fertilization to 50% hatch, Big Qualicum River steelhead had 93% mortality at 60.8°F, 7.7% mortality at 57.2°F, and 1% mortality at 47.3°F and 39.2°F (Velsen 1987).

Juvenile Rearing & Downstream Movement

Water temperature index values were developed to evaluate the combined steelhead rearing (fry and juvenile) and juvenile downstream movement lifestages. Some steelhead may rear in freshwater for up to three years before emigrating as yearling+ smolts, whereas other individuals move downstream shortly after emergence as post- emergent fry, or rear in the river for several months and move downstream as juveniles without exhibiting the ontogenetic characteristics of smolts. Presumably, these individuals continue to rear and grow in downstream areas and undergo the smoltification process prior to entry into saline environments. Thus, fry and juvenile rearing occur concurrently with post-emergent fry and juvenile downstream movement and are assessed in this Technical Memorandum using the fry and juvenile rearing WTI values.

The growth, survival, and successful smoltification of juvenile steelhead are controlled largely by water temperature. The duration of freshwater residence for juvenile steelhead is long relative to that of Chinook salmon, making the juvenile lifestage of steelhead more susceptible to the influences of water temperature, particularly during the over-summer rearing period. Central Valley juvenile steelhead have high growth rates at water temperatures in the mid-60°F range, but reportedly require lower water temperatures to successfully undergo the transformation to the smolt stage.

WTI values of 61°F, 63°F, 64°F, 65°F, 68°F, 72°F, 75°F, and 77°F were identified to represent a gradation of potential water temperature effects ranging between optimal to lethal conditions for steelhead juvenile rearing (Table 3). A water temperature of 61°F (7DADM) was identified as the value for steelhead juvenile rearing for the San Joaquin River (CALFED 2009). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) identifies 61°F (7DADM) for "salmon and trout" core juvenile rearing. The WTI value of 63°F was identified because Myrick and Cech (2001) describe 63°F as the "preferred" water temperature for wild juvenile steelhead, whereas "preferred" water temperatures for juvenile hatchery steelhead reportedly range between 64-66°F. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 64°F (7DADM) for "salmon and trout" juvenile rearing (EPA 2003b). 65°F was also identified as a WTI value because NMFS (2000; 2002a) reported 65°F as the upper limit preferred for growth and development of Sacramento and American River juvenile steelhead. Also, 65°F was found to be within the optimum water temperature range for juvenile growth (i.e., 59-66°F) (Myrick and Cech 2001), and supported high growth of Nimbus strain juvenile steelhead (Cech and Myrick 1999). Increasing levels of thermal stress to this life stage may reportedly occur above the 65°F WTI value.

Kaya *et al.* (1977) reported that the upper avoidance water temperature for juvenile rainbow trout was measured at 68°F to 71.6°F. Cherry *et al.* (1977) observed an upper preference water temperature near 68.0°F for juvenile rainbow trout, duplicating the upper preferred limit for juvenile steelhead observed in Cech and Myrick (1999) and FERC (1993). Growth for 200 mm juvenile *O. mykiss* versus temperature for three food levels (percent of maximum consumption = 30%, 50%, and 70%) was evaluated. The average empirically derived percent of maximum consumption in the Middle Fork American Fork River was 50% (Hanson *et al.* 1997). Positive growth only occurs up to approximately 68°F. Because of the literature describing 68°F as both an upper preferred and an avoidance limit for juvenile *O. mykiss*, and because of the empirical fish population data and bioenergetics growth data, 68°F was identified as an upper tolerable WTI value.

A WTI value of 72°F was identified because symptoms of thermal stress in juvenile steelhead have been reported to arise at water temperatures approaching 72°F. For example, physiological stress to juvenile steelhead in Northern California streams was demonstrated by increased gill flare rates, decreased foraging activity, and increased agonistic activity as stream temperatures rose above 71.6°F (Nielsen *et al.* 1994). Also, 72°F was identified as a WTI value because 71.6°F has been reported as an upper avoidance water temperature (Kaya *et al.* 1977) and an upper thermal tolerance water temperature (Ebersole *et al.* 2001) for juvenile rainbow trout. The WTI value of 75°F was identified because NMFS and EPA report that direct mortality to rearing juvenile steelhead results when stream temperatures reach 75°F (EPA 2002; NMFS 2001b). Water temperatures >77°F have been referred to as "lethal" to juvenile steelhead (FERC 1993; Myrick and Cech 2001). The UILT for juvenile rainbow trout, based on numerous studies, is between 75-79°F (Sullivan *et al.* 2000; McCullough 2001).

A swim tunnel study conducted on the Lower Tuolumne River (TID/MID 2016) generated high quality field data on the physiological performance of Tuolumne River *O. mykiss* acutely exposed to a temperature range of 13 to 25°C (55.4°F to 77°F). The data indicated that wild juvenile *O. mykiss* represents an exception to the expected based on the 7DADM criterion for juvenile rearing set out by EPA (2003b) for Pacific Northwest *O. mykiss*. The study recommended that a conservative upper aerobic performance limit of 71.6°F, instead of 64.4°F (EPA), be considered in re-determining a 7DADM for this population.

The Lower Tuolumne River *O. mykiss* Population Study (TID/MID 2014) identified the UILT for *O. mykiss* juveniles has been estimated at 22.8–25.9ºC (73–79°F) (Threader and Houston 1983). In the model, an initial mortality threshold of 25°C (77°F) daily average temperature was identified for *O. mykiss* juveniles. Note also that both fry rearing and resident adult rearing lifestages of *O. mykiss* also had UILT values of 77°F to support the model.

For steelhead juvenile rearing, the Temperature Criteria Matrix identified 65°F for the Lower American River (Water Forum 2007); 61°F for the San Joaquin (CALFED 2009); and 65°F (Upper Optimum Value) and 68°F (Upper Tolerable Value) for the Yuba River Basin (Bratovich *et al.* 2012).

Table 3. Steelhead Juvenile Rearing WTI Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
61°F (16.1°C)	A water temperature of 61°F (7DADM) was identified as the value for steelhead juvenile rearing for the San Joaquin River (CALFED 2009).
63°F (17.2°C)	Preferred water temperature for wild juvenile steelhead is reportedly 63°F, whereas preferred water temperatures for juvenile hatchery steelhead reportedly range between 64-66°F. Myrick and Cech (2001)
64°F (17.8°C)	EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 64°F (7DADM) for “salmon and trout” juvenile rearing (EPA 2003b).
65°F (18.3°C)	Upper limit of 65°F preferred for growth and development of Sacramento River and American River juvenile steelhead (NMFS 2002a). Nimbus juvenile steelhead growth showed an increasing trend with water temperature to 66.2°F, irrespective of ration level or rearing temperature (Cech and Myrick 1999). The final preferred water temperature for rainbow fingerlings was between 66.2 and 68°F (Cherry *et al.* 1977). Nimbus juvenile steelhead preferred water temperatures between 62.6°F and 68.0°F (Cech and Myrick 1999). Rainbow trout fingerlings preferred or identified water temperatures in the 62.6°F to 68.0°F range (McCauley and Pond 1971). A water temperature of 65°F (daily average temperature) was identified as the value for steelhead juvenile rearing for the Lower American River (Water Forum 2007). A water temperature of 65°F (MWAT) was identified as the Upper Optimum Value for steelhead juvenile rearing for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
68°F (20°C)	Nimbus juvenile steelhead preferred water temperatures between 62.6°F and 68.0°F (Cech and Myrick 1999). The final preferred water temperature for rainbow trout fingerlings was between 66.2°F and 68°F (Cherry *et al.* 1977). Rainbow trout fingerlings preferred or identified water temperatures in the 62.6°F to 68.0°F range (McCauley and Pond 1971). The upper avoidance water temperature for juvenile rainbow trout was measured at 68°F to 71.6°F (Kaya *et al*. 1977). FERC (1993) referred to 68°F as “stressful” to juvenile steelhead. Empirical fish population and water temperature data in the North Yuba, Middle Yuba, South Yuba, Middle Fork American, and Rubicon Rivers (Figure 4 of Bratovich *et al.* 2012) indicate a sharp reduction in O. *mykiss* population densities when temperatures exceed 68°F for greater than one week. Bioenergetics modeling of growth based on consumption (P value = 0.5) in the Middle Fork American River watershed (adjacent watershed) indicates that growth likely does not occur above 68°F (Figure 5 of Bratovich *et al.* 2012). A water temperature of 68°F (MWAT) was identified as the Upper Tolerable Value for steelhead juvenile rearing for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
72°F (22.2°C)	Increased physiological stress, increased agonistic activity, and a decrease in forage activity in juvenile steelhead occur after ambient stream temperatures exceed 71.6°F (Nielsen *et al.* 1994). The upper avoidance water temperature for juvenile rainbow trout was measured at 68°F to 71.6°F (Kaya *et al.* 1977). Estimates of upper thermal tolerance or avoidance limits for juvenile rainbow trout (at maximum ration) ranged from 71.6°F to 79.9°F (Ebersole *et al.* 2001). A swim tunnel study conducted on the Lower Tuolumne recommended a conservative upper aerobic performance limit of 71.6°F for steelhead juvenile rearing (TID/MID 2016).
75°F (23.9°C)	The maximum weekly average water temperature for survival of juvenile and adult rainbow trout is 75.2°F (EPA 2002). Rearing steelhead juveniles have an upper lethal limit of 75.0°F (NMFS 2001a). Estimates of upper thermal tolerance or avoidance limits for juvenile rainbow trout (at maximum ration) ranged from 71.6 to 79.9°F (Ebersole *et al.* 2001). The UILT for juvenile rainbow trout, based on numerous studies, is between 75-79°F (Sullivan *et al*. 2000; McCullough 2001).
77°F (25°C)	In the model associated with the Lower Tuolumne River *O. mykiss* Population Study (TID/MID 2014), an initial mortality threshold of 77°F daily average temperature was identified for *O. mykiss* juveniles.

Smolt Emigration

Laboratory data suggest that smoltification, and therefore successful emigration of steelhead smolts, is directly controlled by water temperature (Adams *et al.* 1975) (Table 4). WTI values of 52°F and 55°F were identified to evaluate the steelhead smolt emigration lifestage, because most literature on water temperature effects on steelhead smolting suggest that water temperatures less than 52°F (Adams *et al.*1975; Myrick and Cech 2001; Rich 1987a) or less than 55°F (EPA 2003a; McCullough *et al.* 2001; Wedemeyer *et al.* 1980; Zaugg and Wagner 1973) are required for successful smoltification to occur. Adams *et al.* (1973) tested the effect of water temperature (43.7°F, 50.0°F, 59.0°F or 68.0°F) on the increase of gill microsomal Na^+-, K^+-stimulated ATPase activity associated with parr-smolt transformation in steelhead and found a two-fold increase in Na^+-, K^+-ATPase at 43.7 and 50.0°F, but no increase at 59.0°F or 68.0°F. In a subsequent study, the highest water temperature where a parr-smolt transformation occurred was at 52.3°F (Adams *et al.* 1975). The results of Adams *et al.* (1975) were reviewed in Myrick and Cech (2001) and Rich (1987b), which both recommended that water temperatures below 52.3°F are required to successfully complete the parr-smolt transformation. Further, Myrick and Cech (2001) suggest that water temperatures between 43-50°F are the “physiologically optimal” temperatures required during the parr-smolt transformation and necessary to maximize saltwater survival. The 52°F WTI value identified for the steelhead smolt emigration lifestage is the index value generally reported in the literature as the upper limit of the water temperature range that provides successful smolt transformation thermal conditions. Increasing levels of thermal stress to this lifestage may reportedly occur above the 52°F WTI value.

Zaugg and Wagner (1973) examined the influence of water temperature on gill ATPase activity related to parr-smolt transformation and migration in steelhead. They found ATPase activity was decreased and migration reduced when juveniles were exposed to water temperatures of 55.4°F or greater. In a technical document prepared by the EPA to provide temperature water quality standards for the protection of Northwest native salmon and trout, water temperatures greater than 54.5°F were identified as an impairment to smoltification for juvenile steelhead (EPA 2003b). Water temperatures are considered “unsuitable” for steelhead smolts at >59°F (Myrick and Cech 2001) and “lethal” at 77°F (FERC 1993).

For steelhead smolt emigration, the Temperature Criteria Matrix identified 57°F for the San Joaquin (CALFED 2009) and 52°F (Upper Optimum Value) and 55°F (Upper Tolerable Value) for the Yuba River Basin (Bratovich *et al.* 2012). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) identifies 57°F (7DADM) for steelhead smoltification.

The Lower Tuolumne River *O. mykiss* Population Study (TID/MID 2014) identified an initial UILT mortality threshold of 77°F daily average temperature for *O. mykiss* smolts on the basis of literature reviews by Myrick and Cech (2001).

Table 4. Steelhead Smolt Emigration WTI Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
52°F (11.1°C)	Steelhead successfully smolt at water temperatures in the 43.7°F to 52.3°F range (Myrick and Cech 2001). Steelhead undergo the smolt transformation when reared in water temperatures below 52.3°F, but not at higher water temperatures (Adams *et al.* 1975). Optimum water temperature range for successful smoltification in young steelhead is 44.0°F to 52.3°F (Rich 1987a). A water temperature of 52°F (MWAT) was identified as the Upper Optimum Value for steelhead smolt emigration for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
55°F (12.8°C)	ATPase activity was decreased and migration reduced for steelhead at water temperatures greater than or equal to 55.4°F (Zaugg and Wagner 1973). Water temperatures should be below 55.4°F at least 60 days prior to release of hatchery steelhead to prevent premature smolting and desmoltification (Wedemeyer *et al.* 1980). In winter steelhead, a temperature of 54.1°F is nearly the upper limit for smolting (McCullough *et al.* 2001; Zaugg and Wagner 1973). Water temperatures less than or equal to 54.5°F are suitable for emigrating juvenile steelhead (EPA 2003b). Water temperatures greater than 55°F prevent increases in ATPase activity in steelhead juveniles (Hoar 1988). Water temperatures greater than 56°F do not permit smoltification in summer steelhead (Zaugg *et al.* 1972). A water temperature of 55°F (MWAT) was identified as the Upper Tolerable Value for steelhead smolt emigration for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
57°F (13.9°C)	A water temperature of 57°F (7DADM) was identified as the value for steelhead smolt emigration for the San Joaquin River (CALFED 2009). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 57°F (7DADM) for steelhead smoltification (EPA 2003b).
59°F (15°C)	Yearling steelhead held at 43.7°F and transferred to 59°F had a substantial reduction in gill ATPase activity, indicating that physiological changes associated with smoltification were reversed (Wedemeyer *et al.* 1980).
77°F (25°C)	A water temperature of 77°F (daily average temperature) was identified as UILT mortality threshold for *O. mykiss* smolts (Myrick and Cech 2001 as cited in TID/MID 2014).

CHINOOK SALMON LIFESTAGE-SPECIFIC WATER TEMPERATURE INDEX VALUES

It has been suggested that separate water temperatures standards should be developed for each run-type of Chinook salmon. For example, McCullough (1999) states that spring-run Chinook salmon immigrate in spring and spawn in 3rd to 5th order streams and, therefore, face different migration and adult holding temperature regimes than do summer- or fall-run Chinook salmon, which spawn in streams of 5th order or greater . However:(1) there is a general paucity of literature specific to each lifestage of each run-type; (2) there is an insufficient amount of data available in the literature suggesting that Chinook salmon run-types respond to water temperatures differently; (3) the WTI values derived from all the literature pertaining to Chinook salmon for a particular lifestage will be sufficiently protective of that lifestage for each run-type; and (4) all run- types overlap in timing of adult immigration and holding and in some cases are not easily distinguished (Healey 1991). Information distinctly applicable to spring-run or fall-run Chinook salmon is identified where run-specific information is available.

Adult Immigration and Holding

The adult immigration and staging lifestages for fall-run Chinook salmon are evaluated together, because they are believed to not spend significant amounts of time after immigrating and prior to spawning. The adult immigration and holding lifestages are evaluated separately for spring-run Chinook salmon, because of the potential extended duration of holding after immigrating and prior to spawning.

The WTI values reflect a gradation of potential water temperature effects that range between those reported as "optimal" to those reported as "lethal" for adult Chinook salmon during upstream spawning migrations and holding. The WTI values identified for the Chinook salmon adult immigration and holding lifestage are 60°F, 61°F, 64°F, 65°F, 68°F and 70°F (Table 5). Although 56°F is referenced in the literature frequently as the upper "optimal" water temperature limit for upstream migration and holding, the references are not foundational studies and often are inappropriate citations. For example, Boles *et al.* (1988), Marine (1992), and NMFS (1997b) all cite Hinze (1959) in support of recommendations for a water temperature of 56°F for adult Chinook salmon immigration. However, Hinze (1959) is a study examining the effects of water temperature on incubating Chinook salmon eggs in the American River Basin. Further, water temperatures between 38-56°F are considered to represent the "observed range" for upstream migrating spring-run Chinook salmon (Bell 1986).

The lowest WTI value identified was 60°F because in a previous NMFS biological opinion for the proposed operation of the Central Valley Project (CVP) and State Water Project (SWP), 59°F to 60°F is reported as…"*The upper limit of the optimal temperature range for adults holding while eggs are maturing*" (NMFS 2000). Also, NMFS (1997b) states…"*Generally, the maximum temperature of adults holding, while eggs are maturing, is about 59°F to 60°F*". Oregon Department of Environmental Quality (ODEQ; 1995) reports that "*…many of the diseases that commonly affect Chinook become highly infectious and virulent above 60°F*." Mature females subjected to prolonged exposure to water temperatures above 60°F have poor survival rates and produce less viable eggs than females exposed to lower water temperatures (USFWS 1995b).

Ward and Kier (1999) designated temperatures <60.8°F as an "optimum" water temperature threshold for holding Battle Creek spring-run Chinook salmon. EPA (2003a) chose a holding value of 61°F (7DADM) based on laboratory data various assumptions regarding diel temperature fluctuations. The 61°F WTI value identified for the Chinook salmon adult immigration and holding lifestage is the index value generally reported in the literature as the upper limit of the optimal range, and is within the reported acceptable range. Increasing levels of thermal stress to this lifestage may reportedly occur above the 61°F WTI value.

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (EPA 2003b) identifies 64°F (7DADM) for "salmon and trout" adult migration. A water temperature of 64°F (MWAT) was identified as the Upper Optimum Value for Chinook adult migration for the Yuba Reintroduction Assessment (Bratovich *et al*. 2012).

An index value of 65°F was identified because Berman (1990) suggests effects of thermal stress to pre-spawning adults are evident at water temperatures near 65°F. Berman (1990) conducted a laboratory study to determine if pre-spawning water temperatures experienced by adult Chinook salmon influenced reproductive success, and found evidence suggesting latent embryonic abnormalities associated with water temperature exposure to pre-spawning adults that ranged from 63.5°F to 66.2°F. During each of the years when Chinook salmon temperature mortality was not observed at Butte Creek (2001, 2004-2007), on average, daily temperature did not exceed 65.8°F for more than 7 days (Figure 6 of Bratovich *et al.* 2012). Tracy McReynolds (pers. comm. October 2011) suggested that an upper tolerable holding temperature of 65°F was reasonable. A water temperature of 65°F (MWAT) was identified as the Upper Tolerable Value for Chinook adult holding for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).

An index value of 68°F was identified because the Butte Creek data and the literature suggests that thermal stress at water temperatures greater than 68°F is pronounced, and severe adverse effects to immigrating and holding pre-spawning adults, including mortality, can be expected (Berman 1990; Marine 1997; NMFS 1997b; Ward *et al.* 2004).

Acceptable water temperatures for adults migrating upstream range from 57°F to 67°F (NMFS 1997b). For chronic exposures, an incipient upper lethal water temperature limit for pre-spawning adult salmon probably falls within the range of 62.6°F to 68°F (Marine 1992). Water temperatures of 68°F resulted in nearly 100% mortality of Chinook salmon during columnaris outbreaks (Ordal and Pacha 1963). Adult Chinook salmon migration rates through the lower Columbia River were slowed significantly when water temperatures exceeded 68°F (Goniea *et al.* 2006). A water temperature of 68°F (MWAT) was identified as the Upper Tolerable Value for Chinook adult migration for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).

Water temperatures between 70-77°F are reported as the range of maximum temperatures for holding pool conditions used by spring-run Chinook salmon in the Sacramento-San Joaquin system (Moyle *et al*. 1995). Migration blockage occurs for Chinook salmon at temperatures from 70-71+°F (McCollough 1999; McCullough *et al*. 2001; EPA 2003b). Strange (2010) found that the mean average body temperature during the first week of Chinook salmon migration on the Klamath River was 71.4°F. The UILT for Chinook salmon jacks is 69.8-71.6°F (McCullough 1999).

For spring-run Chinook salmon adult immigration, the Framework Temperature Criteria Matrix identified 64°F (Upper Optimum Value) and 68°F (Upper Tolerable Value) for the Yuba River Basin (Bratovich *et al*. 2012). For spring-run Chinook salmon adult holding, the Framework Temperature Criteria Matrix identified 61°F (Upper Optimum Value) and 65°F (Upper Tolerable Value) for the Yuba River Basin (Bratovich *et al.* 2012).

Table 5. Chinook Salmon Adult Immigration and Holding WTI Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
60°F (15.6°C)	Maximum water temperature for adults holding, while eggs are maturing, is approximately 59°F to 60°F (NMFS 1997b). Upper limit of the optimal water temperature range for adults holding while eggs are maturing is 59°F to 60°F (NMFS 2000). Many of the diseases that commonly affect Chinook salmon become highly infectious and virulent above 60°F (ODEQ 1995). Mature females subjected to prolonged exposure to water temperatures above 60°F have poor survival rates and produce less viable eggs than females exposed to lower water temperatures (USFWS 1995b).
61°F (16.1°C)	A water temperature of 61°F (MWAT) was identified as the Upper Optimum Value for Chinook adult holding for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012). Ward and Kier (1999) designated temperatures <60.8°F as an "optimum" water temperature threshold for holding Battle Creek spring-run Chinook salmon.
64°F (17.8°C)	A water temperature of 64°F (MWAT) was identified as the Upper Optimum Value for Chinook adult migration for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 64°F (7DADM) for "salmon and trout" adult migration (EPA 2003b).
65°F (18.3°C)	Acceptable range for adults migrating upstream is from 57°F to 67°F (NMFS 1997b). Disease risk becomes high at water temperatures above 64.4°F (EPA 2003b). Latent embryonic mortalities and abnormalities associated with water temperature exposure to pre-spawning adults occur at 63.5°F to 66.2°F (Berman 1990). During each of the years when Chinook salmon temperature mortality was not observed at Butte Creek (2001, 2004-2007), on average, daily temperature did not exceed 65.8°F for more than 7 days (Figure 6 of Bratovich *et al.* 2012). A water temperature of 65°F (MWAT) was identified as the Upper Tolerable Value for Chinook adult holding for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
68°F (20°C)	Acceptable water temperatures for adults migrating upstream range from 57°F to 67°F (NMFS 1997b). For chronic exposures, an incipient upper lethal water temperature limit for pre-spawning adult salmon probably falls within the range of 62.6°F to 68.0°F (Marine 1992). Water temperatures of 68°F resulted in nearly 100% mortality of Chinook salmon during columnaris outbreaks (Ordal and Pacha 1963). Adult Chinook salmon migration rates through the lower Columbia River were slowed significantly when water temperatures exceeded 68°F (Goniea *et al.* 2006). A water temperature of 68°F (MWAT) was identified as the Upper Tolerable Value for Chinook adult migration for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
70°F (21.1°C)	Migration blockage occurs for Chinook salmon at temperatures from 70-71+°F (McCollough 1999; McCullough *et al.* 2001; EPA 2003b). Strange (2010) found that the mean average body temperature during the first week of Chinook salmon migration on the Klamath River was 71.4°F. The UILT for Chinook salmon jacks is 69.8-71.6°F (McCullough 1999).

Spawning and Embryo Incubation

The adult spawning and embryo (i.e., eggs and alevins) incubation lifestages share one set of WTI values because spawning and embryonic survival and development typically are considered concurrently in the literature on the effects of water temperature. Spawning and incubation evaluations are conducted separately due to differences in their temporal distributions.

The WTI values identified for the Chinook salmon spawning and embryo incubation lifestages are 55°F, 56°F, 58°F, 60°F, and 62°F (Table 6). Anomalously, FERC (1993) refers to 50°F as the "optimum" water temperature for spawning and incubating Chinook salmon. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 55°F (7DADM) for "salmon and trout" spawning, egg incubation, and fry emergence (EPA 2003b). A water temperature of 55°F (7DADM) was identified as the value for Chinook incubation for the San Joaquin River fall-run Chinook salmon (CALFED 2009).

Additionally, for the adult spawning lifestage, FERC (1993) reports "stressful" and "lethal" water temperatures occurring at >60°F and >70°F, respectively, whereas for incubating Chinook salmon embryos, water temperatures are considered to be "stressful" at <56°F or "lethal" at >60°F. Much literature suggests that water temperatures must be less than or equal to 56°F for maximum survival of Chinook salmon embryos (i.e., eggs and alevins) during spawning and incubation. NMFS (1993b) reported that optimum water temperatures for egg development are between 43°F and 56°F. Similarly, Myrick and Cech (2001) reported the highest egg survival rates occur between water temperatures of 39-54°F. Reclamation (unpublished work) reports that water temperatures less than 56°F results in a natural rate of mortality for fertilized Chinook salmon eggs. Bell (1986) recommends water temperatures ranging between 42-57°F for spawning Chinook salmon, and water temperatures between 41-58°F for incubating embryos. USFWS (1995a) reported a water temperature range of 41°F to 56°F for maximum survival of eggs and yolk-sac larvae in the Central Valley of California. The preferred water temperature range for Chinook salmon egg incubation in the Sacramento River was suggested as 42°F to 56°F (NMFS 1997a). Alevin mortality is reportedly significantly higher when Chinook salmon embryos are incubated at water temperatures above 56°F (USFWS 1999). NMFS (2002a) reported 56°F as the upper limit of suitable water temperatures for spring-run Chinook salmon spawning in the Sacramento River. The 56°F WTI value identified for the Chinook salmon spawning and embryo incubation lifestage is the index value generally reported in the literature as the upper limit of the optimal range for egg development and the upper limit of the range reported to provide maximum survival of eggs and yolk-sac larvae in the Central Valley of California. Increasing levels of thermal stress to this lifestage may reportedly occur above the 56°F WTI value.

High survival of Chinook salmon embryos also has been suggested to occur at incubation temperatures at or near 58°F. For example, (Reclamation Unpublished Work) reported that the natural rate of mortality for alevins occurs at 58°F or less. Combs (1957) concluded constant incubation temperatures between 42.5°F and 57.5°F resulted in normal development of Chinook salmon eggs, and NMFS (2002a) suggests 53°F to 58°F is the preferred water temperature range for Chinook salmon eggs and fry. The model associated with the Chinook Salmon Population Model Study (TID/MID 2013), established an initial acute egg/alevin mortality threshold of 58°F. A water temperature of 58°F (MWAT) was identified as the Upper Tolerable Value for Chinook spawning and incubation for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).

Johnson (1953) found consistently higher Chinook salmon egg losses resulted at water temperatures above 60°F than at lower temperatures. In order to protect late incubating Chinook salmon embryos and newly emerged fry NMFS (1993a) determined that a water temperature criterion of less than or equal to 60°F be maintained in the Sacramento River from Keswick Dam to Bend Bridge from October 1 to October 31. Seymour (1956) provides evidence that

100% mortality occurs to late incubating Chinook salmon embryos when held at a constant water temperature greater than or equal to 60°F. For Chinook salmon eggs incubated at constant temperatures, mortality increases rapidly at temperatures greater than about 59-60°F (see data plots in Myrick and Cech 2001). Olsen and Foster (1957), however, found high survival of Chinook salmon eggs and fry (89.6%) when incubation temperatures started at 60.9°F and declined naturally for the Columbia River (about 7°F/month). The Chinook Salmon Population Model (TID/MID 2013) established an initial estimate of 60.4°F as the upper limit for initiation of spawning (Groves and Chandler 1999); also interpreted as the temperature at which spawning habitat will be considered usable by spawners.

The literature largely agrees that 100% mortality will result to Chinook salmon embryos incubated at water temperatures greater than or equal to about 62°F (Hinze 1959; Myrick and Cech 2003; Seymour 1956; USFWS 1999). Approximately 80% or greater mortality of eggs incubated at constant temperatures of 63°F or greater (see data plots in Myrick and Cech 2001). Geist *et al.* (2006) found low Chinook salmon incubation survival (1.7%) for naturally declining temperatures (0.36°F/day) when temperatures started at 62.6°F.

For Chinook salmon spawning and incubation, the Framework Temperature Criteria Matrix identified 60°F or less (as early in October as possible) and 56°F or less (as early in November as possible) as water temperature targets for lower American River fall-run Chinook salmon (Water Forum 2007); 64°F (spawning) and 55°F (incubation) for San Joaquin fall-run Chinook salmon (CALFED 2009); 56°F for Shasta River winter and spring-run Chinook salmon (SWRCB 2016); and 56°F (Upper Optimum Value) and 58°F (Upper Tolerable Value) in the Yuba River Basin (Bratovich *et al*. 2012).

Table 6. Chinook Salmon Spawning and Embryo Incubation WTI Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
55°F (12.8°C)	EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 55°F (7DADM) for "salmon and trout" spawning, egg incubation, and fry emergence (EPA 2003b). A water temperature of 55°F (7DADM) was identified as the value for Chinook incubation for the San Joaquin River fall-run Chinook salmon (CALFED 2009).
56°F (13.3°C)	Less than 56°F results in a natural rate of mortality for fertilized Chinook salmon eggs (Reclamation Unpublished Work). Optimum water temperatures for egg development are between 43°F and 56°F (NMFS 1993b). Upper value of the water temperature range (i.e., 41°F to 56°F) suggested for maximum survival of eggs and yolk-sac larvae in the Central Valley of California (USFWS 1995b). Upper value of the range (i.e., 42°F to 56°F) given for the preferred water temperature for Chinook salmon egg incubation in the Sacramento River (NMFS 1997a). Incubation temperatures above 56°F result in significantly higher alevin mortality (USFWS 1999). 56°F is the upper limit of suitable water temperatures for spring-run Chinook salmon spawning in the Sacramento River (NMFS 2002a). Water temperatures averaged 56.5°F during the week of fall-run Chinook salmon spawning initiation on the Snake River (Groves and Chandler 1999). A water temperature of 56°F or less (daily average temperature), as early in November as possible, was identified as the value for fall-run Chinook salmon spawning and incubation for the lower American River (Water Forum 2007). A water temperature of 56°F (daily average temperature) was identified as the value for Chinook spawning and incubation for the Shasta River winter- and spring-run Chinook (SWRCB 2016). A water temperature of 56°F (MWAT) was identified as the Upper Optimum Value for Chinook spawning and incubation for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).
58°F (14.4°C)	Upper value of the range given for preferred water temperatures (i.e., 53°F to 58°F) for eggs and fry (NMFS 2002a). Constant egg incubation temperatures between 42.5°F and 57.5°F resulted in normal development (Combs and Burrows 1957). The natural rate of mortality for alevins occurs at 58°F or less (Reclamation Unpublished Work). The model associated with the Chinook Salmon Population Model Study, established an initial acute egg/alevin mortality threshold of 58°F (TID/MID 2013). A water temperature of 58°F (MWAT) was identified as the Upper Tolerable Value for Chinook spawning and incubation for the Yuba Reintroduction Assessment (Bratovich *et al.* 2012).

Index Value	Supporting Literature
60°F (15.6°C)	100% mortality can occur to late incubating Chinook salmon embryos (yolk-sac stage) if temperatures are 60°F or greater (Seymour 1956). An October 1 to October 31 water temperature criterion of less than or equal to 60°F in the Sacramento River from Keswick Dam to Bend Bridge has been determined for protection of late incubating larvae and newly emerged fry (NMFS 1993b). Mean weekly water temperature at first observed Chinook salmon spawning in the Columbia River was 59.5°F (Dauble and Watson 1997). Consistently higher egg losses resulted at water temperatures above 60°F than at lower temperatures (Johnson and Brice 1953). For Chinook Salmon eggs incubated at constant temperatures, mortality increases rapidly at temperatures greater than about 59-60°F (see data plots in Myrick and Cech 2001). Olsen and Foster (1957) found high survival of Chinook salmon eggs and fry (89.6%) when incubation temperatures started at 60.9°F and declined naturally for the Columbia River (about 7°F/month). A water temperature of 60°F or less (daily average temperature), as early in October as possible, was identified as a target value for Chinook spawning and incubation for the lower American River fall-run Chinook (Water Forum 2007). The model associated with the Chinook Salmon Population Model Study (TID/MID 2013), established an initial estimate of 60.4°F as the upper limit for initiation of spawning (Groves and Chandler 1999).
62°F (16.7°C)	100% mortality of fertilized Chinook salmon eggs after 12 days at 62°F (Reclamation Unpublished Work). Incubation temperatures of 62°F to 64°F appear to be the physiological limit for embryo development resulting in 80 to 100% mortality prior to emergence (USFWS 1999). 100% loss of eggs incubated at water temperatures above 62°F (Hinze 1959). 100% mortality occurs during yolk-sac stage when embryos are incubated at 62.5°F (Seymour 1956). Approximately 80% or greater mortality of eggs incubated at constant temperatures of 63°F or greater (see data plots in Myrick and Cech 2001). Geist *et al*. (2006) found low Chinook salmon incubation survival (1.7%) for naturally declining temperatures (0.36°F/day) when temperatures started at 62.6°F.

Juvenile Rearing and Downstream Movement

WTI values were developed to evaluate the Chinook salmon rearing (fry and juvenile) and juvenile downstream movement lifestages. Some Chinook salmon juveniles, both fall-run and spring-run, move downstream shortly after emergence as post- emergent fry, or rear in the river for several months and move downstream as YOY juveniles without exhibiting the ontogenetic characteristics of smolts. Presumably, these individuals undergo the smoltification process prior to entry into saline environments. Thus, fry and juvenile rearing occur concurrently with post-emergent fry and juvenile downstream movement and are presented in this Technical Memorandum using the fry and juvenile rearing WTI values.

The WTI values of 60°F, 61°F, 64°F, 65°F, 68°F, 70°F,75°F, and 77°F were identified for the Chinook salmon juvenile rearing and downstream movement lifestage. The lowest index value of 60°F was identified because regulatory documents as well as several source studies, including ones conducted on Central Valley Chinook salmon fry and juveniles, report 60°F as an optimal water temperature for growth (Banks *et al.* 1971; Brett *et al.* 1982; Marine 1997; NMFS 1997b; NMFS 2000; NMFS 2001a; NMFS 2002; Rich 1987b) (Table 7). Water temperatures below 60°F also have been reported as providing conditions optimal for fry and fingerling growth, but were not identified as index values, because the studies were conducted on fish from outside of the Central Valley (Brett 1952; Seymour 1956). Studies conducted using local fish may be particularly important because *Oncorhynchus* species show considerable variation in morphology, behavior, and physiology along latitudinal gradients (Myrick 1998; Taylor 1990b; Taylor 1990a). More specifically, it has been suggested that salmonid populations in the Central Valley prefer higher water temperatures than those from more northern latitudes (Myrick and Cech 2000).

The 60°F WTI value identified for the Chinook salmon juvenile rearing and downstream movement lifestage is the index value generally reported in the literature as the upper limit of the optimal range for fry and juvenile growth and the upper limit of the preferred range for growth and development of spring-run Chinook salmon fry and fingerlings. NMFS (2002a) identified 60°F as the "preferred" water temperature for juvenile spring-run Chinook salmon in the Central Valley. Increasing levels of thermal stress to this lifestage may reportedly occur above the 60°F WTI value.

A water temperature of 61°F (7DADM) was identified as the value for Chinook juvenile rearing for the San Joaquin River (CALFED 2009). A water temperature of 61°F (MWAT) was identified as the Upper Optimum Value for Chinook juvenile rearing for the Yuba Reintroduction Assessment for both fall- and spring-run Chinook (Bratovich *et al.* 2012). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 61°F (7DADM; early year) for salmon juvenile rearing (EPA 2003b).

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 64°F (7DADM; late year) for salmon juvenile rearing (EPA 2003b). Recommended summer maximum water temperature of 64.4°F for migration and non-core rearing (EPA 2003b). Water temperatures greater than 64°F are considered not ″properly functioning" by NMFS in Amendment 14 to the Pacific Coast Salmon Plan (NMFS 1995). Fatal infection rates caused by *C. columnaris* are high at temperatures greater than or equal to 64°F (EPA 2001). Optimal range for Chinook salmon survival and growth from 53°F to 64°F (USFWS 1995b). Survival of Central Valley juvenile Chinook salmon declines at temperatures greater than 64.4°F (Myrick and Cech 2001).

The index value of 65°F was identified because it represents an intermediate value between 64°F and 66.2°F, at which both adverse and beneficial effects to juvenile salmonids have been reported to occur. For example, at temperatures approaching and beyond 65°F, sub-lethal effects associated with increased incidence of disease reportedly become severe for juvenile Chinook salmon (EPA 2003a; Johnson and Brice 1953; Ordal and Pacha 1963; Rich 1987a). Conversely, numerous studies report that temperatures between 64.0°F and 66.2°F provide conditions ranging from suitable to optimal for juvenile Chinook salmon growth (Brett *et al.* 1982; Cech and Myrick 1999; Clarke and Shelbourn 1985; EPA 2003a; Myrick and Cech 2001; NMFS 2002; USFWS 1995b). Maximum growth of juvenile fall-run Chinook salmon has been reported to occur in the American River at water temperatures between 56-59°F (Rich 1987b) and in Nimbus Hatchery spring-run Chinook salmon at 66°F (Cech and Myrick 1999). Bioenergetics modeling of growth based on consumption for 100 mm juvenile Chinook salmon in the Middle Fork American River watershed indicates that growth likely does not occur above about 65°F (Figure 5 of Bratovich *et al.* 2012). A water temperature of 65°F (MWAT) was identified as the Upper Tolerable Value for Chinook juvenile rearing for the Yuba Reintroduction

Assessment for both fall- and spring-run Chinook salmon (Bratovich *et al.* 2012).

A WTI value of 68°F was identified because, at water temperatures above 68°F, sub-lethal effects become severe such as reductions in appetite and growth of juveniles (Marine 1997; Rich 1987a; Zedonis and Newcomb 1997). Significant reductions in growth rates may occur when chronic elevated temperatures exceed 68°F (Marine 1997; Marine and Cech 2004). Juvenile spring-run Chinook salmon were not found in areas having mean weekly water temperatures between 67.1°F and 71.6°F (Burck *et al.* 1980; Zedonis and Newcomb 1997). Results from a study on wild spring-run Chinook salmon in the John Day River system indicate that juvenile fish were not found in areas having mean weekly water temperatures between 67.1°F and 72.9°F (McCullough 1999; Zedonis and Newcomb 1997).

Chronic stress associated with water temperature can be expected when conditions reach the index value of 70°F. For example, growth becomes drastically reduced at temperatures close to 70.0°F and has been reported to be completely prohibited at 70.5°F (Brett *et al.* 1982; Marine 1997). No growth at all would occur for Nechako River juvenile Chinook salmon at 70.5°F (Brett *et al.* 1982; Zedonis and Newcomb 1997). Juvenile spring-run Chinook salmon were not found in areas having mean weekly water temperatures between 67.1°F and 71.6°F (Burck *et al.* 1980; Zedonis and Newcomb 1997). Results from a study on wild spring-run Chinook salmon in the John Day River system indicate that juvenile fish were not found in areas having mean weekly water temperatures between 67.1°F and 72.9°F (McCullough 1999; Zedonis and Newcomb 1997). Increased incidence of disease, hyperactivity, reduced appetite, and reduced growth rates at 69.8 ± 1.8°F (Rich 1987b). In a laboratory study, juvenile fall-run Chinook salmon from the Sacramento River reared in water temperatures between 70°F and 75°F experienced significantly decreased growth rates and increased predation vulnerability compared with juveniles reared between 55°F and 61°F (Marine 1997; Marine and Cech 2004).

75°F was identified as a WTI value because high levels of direct mortality to juvenile Chinook salmon reportedly result at this water temperature (Cech and Myrick 1999; Hanson 1991; Myrick and Cech 2001; Rich 1987b). Other studies have suggested higher upper lethal water temperature levels (Brett 1952; Orsi 1971), but 75°F was identified because it was derived from experiments using Central Valley Chinook salmon and it is a more rigorous index value representing a more protective upper lethal water temperature level. Furthermore, the lethal level determined in Rich (1987b) was derived using slow rates of water temperature change and, thus, is ecologically relevant. The juvenile Chinook Salmon UILT based on numerous studies is 75-77°F (Sullivan *et al.* 2000; McCullough *et al.* 2001; Myrick and Cech 2001). Based upon information reviewed for Chinook salmon juvenile mortality (Brett 1952; Orsi 1971), the Chinook Salmon Population Model (TID/MID 2013) identified an initial UILT mortality threshold of 77°F for Chinook salmon juveniles as a daily average water temperature. Note that the model also identified this same value for fry mortality.

Table 7. Chinook Salmon Juvenile Rearing and Downstream Movement WTI Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
60°F (15.6°C)	Optimum water temperature for Chinook salmon fry growth is between 55°F and 60°F (Seymour 1956). Water temperature range that produced optimum growth in juvenile Chinook salmon was between 54°F and 60°F (Rich 1987b). Water temperature criterion of less than or equal to 60°F for the protection of Sacramento River winter-run Chinook salmon from Keswick Dam to Bend Bridge (NMFS 1993b). Upper optimal water temperature limit of 61°F for Sacramento River fall-run Chinook salmon juvenile rearing (Marine 1997; Marine and Cech 2004). Upper water temperature limit of 60°F preferred for growth and development of spring-run Chinook salmon fry and fingerlings (NMFS 2000; NMFS 2002a). To protect salmon fry and juvenile Chinook salmon in the upper Sacramento River, daily average water temperatures should not exceed 60°F after September 30 (NMFS 1997b). A water temperature of 60°F appeared closest to the optimum for growth of fingerlings (Banks *et al.* 1971). Optimum growth of Nechako River Chinook salmon juveniles would occur at 59°F at a feeding level that is 60% of that required to satiate them (Brett *et al.* 1982). In a laboratory study, juvenile fall-run Chinook salmon from the Sacramento River reared in water temperatures between 70°F and 75°F experienced significantly decreased growth rates, and increased predation vulnerability compared with juveniles reared between 55°F and 61°F (Marine 1997; Marine and Cech 2004).
61°F (16.1°C)	A water temperature of 61°F (7DADM) was identified as the value for Chinook juvenile rearing for the San Joaquin River (CALFED 2009). A water temperature of 61°F (MWAT) was identified as the Upper Optimum Value for Chinook juvenile rearing for the Yuba Reintroduction Assessment for both fall- and spring-run Chinook (Bratovich *et al.* 2012). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 61°F (7DADM; early year) for salmon juvenile rearing (EPA 2003b).
64°F (17.8°C)	EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 64°F (7DADM; late year) for salmon juvenile rearing (EPA 2003b). Recommended summer maximum water temperature of 64.4°F for migration and non-core rearing (EPA 2003b). Water temperatures greater than 64°F are considered not ″properly functioning" by NMFS in Amendment 14 to the Pacific Coast Salmon Plan (NMFS 1995). Fatal infection rates caused by *C. columnaris* are high at temperatures greater than or equal to 64°F (EPA 2001). Optimal range for Chinook salmon survival and growth from 53°F to 64°F (USFWS 1995b). Survival of Central Valley juvenile Chinook salmon declines at temperatures greater than 64.4°F (Myrick and Cech 2001).

Index Value	Supporting Literature
65°F (18.3°C)	Water temperatures between 45°F to 65°F are preferred for growth and development of fry and juvenile spring-run Chinook salmon in the Feather River (NMFS 2002a). Disease mortalities diminish at water temperatures below 65°F (Ordal and Pacha 1963). Fingerling Chinook salmon reared in water greater than 65°F contracted *C. columnaris* and exhibited high mortality (Johnson and Brice 1953). Water temperatures greater than 64.9°F identified as being stressful in the Columbia River Ecosystem (Independent Scientific Group 1996). Juvenile Chinook salmon have an optimum temperature for growth that appears to occur at about 66.2°F (Brett *et al.* 1982). Juvenile Chinook salmon reached a growth maximum at 66.2°F (Cech and Myrick 1999). Increased incidence of disease, reduced appetite, and reduced growth rates at 66.2 ± 1.4 °F (Rich 1987b). Bioenergetics modeling of growth based on consumption for 100 mm juvenile Chinook salmon in the Middle Fork American River watershed indicates that growth likely does not occur above about 65°F (Figure 5 of Bratovich *et al.* 2012). A water temperature of 65°F (MWAT) was identified as the Upper Tolerable Value for Chinook juvenile rearing for the Yuba Reintroduction Assessment for both fall- and spring-run Chinook salmon (Bratovich *et al.* 2012).
68°F (20°C)	Sacramento River juvenile Chinook salmon reared at water temperatures greater than or equal to 68°F suffer reductions in appetite and growth (Marine 1997; Marine and Cech 2004). Significant reductions in growth rates may occur when chronic elevated temperatures exceed 68°F (Marine 1997; Marine and Cech 2004). Juvenile spring-run Chinook salmon were not found in areas having mean weekly water temperatures between 67.1°F and 71.6°F (Burck *et al.* 1980; Zedonis and Newcomb 1997). Results from a study on wild spring-run Chinook salmon in the John Day River system indicate that juvenile fish were not found in areas having mean weekly water temperatures between 67.1°F and 72.9°F (McCullough 1999; Zedonis and Newcomb 1997).
70°F (21.1°C)	No growth at all would occur for Nechako River juvenile Chinook salmon at 70.5°F (Brett *et al.* 1982; Zedonis and Newcomb 1997). Juvenile spring-run Chinook salmon were not found in areas having mean weekly water temperatures between 67.1°F and 71.6°F (Burck *et al.* 1980; Zedonis and Newcomb 1997). Results from a study on wild spring-run Chinook salmon in the John Day River system indicate that juvenile fish were not found in areas having mean weekly water temperatures between 67.1°F and 72.9°F (McCullough 1999; Zedonis and Newcomb 1997). Increased incidence of disease, hyperactivity, reduced appetite, and reduced growth rates at 69.8 ±1.8 °F (Rich 1987b). In a laboratory study, juvenile fall-run Chinook salmon from the Sacramento River reared in water temperatures between 70°F and 75°F experienced significantly decreased growth rates and increased predation vulnerability compared with juveniles reared between 55°F and 61°F (Marine 1997; Marine and Cech 2004).
75°F (23.9°C)	For juvenile Chinook salmon in the lower American River fed maximum rations under laboratory conditions, 75.2°F was determined to be 100% lethal due to hyperactivity and disease (Rich 1987b; Zedonis and Newcomb 1997). Lethal temperature threshold for fall-run juvenile Chinook salmon between 74.3°F and 76.1°F (McCullough 1999). In a laboratory study, juvenile fall-run Chinook salmon from the Sacramento River reared in water temperatures between 70°F and 75°F experienced significantly decreased growth rates, and increased predation vulnerability compared with juveniles reared between 55°F and 61°F (Marine 1997; Marine and Cech 2004). The juvenile Chinook Salmon UILT based on numerous studies is 75-77°F (Sullivan *et al*. 2000; McCullough *et al.* 2001; Myrick and Cech 2001).
77°F (25°C)	The model associated with the Chinook Salmon Population Model Study, established an initial UILT mortality threshold of 77°F (daily average temperatures) for Chinook salmon fry and juveniles (Brett 1952 and Orsi 1971, as cited in TID/MID 2013).

Smolt Emigration

Juvenile Chinook salmon that exhibit extended rearing in a riverine environment are assumed to undergo the smoltification process and volitionally emigrate from the river as smolts. WTI values of 57°F, 59°F, 63°F, 68°F 72°F, and 77°F were identified for the Chinook salmon smolt emigration lifestage (Table 8).

A water temperature of 57°F (7DADM) was identified as the value for Chinook smolt migration for the San Joaquin River (CALFED 2009). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 59°F (7DADM; late year) for salmon smolts (EPA 2003b).

A WTI value of 63°F was identified because water temperatures at or below this value allow for successful transformation to the smolt stage, and water temperatures above this value may result in impaired smoltification indices, inhibition of smolt development, and decreased survival and successful smoltification of juvenile Chinook salmon. Laboratory experiments suggest that water temperatures at or below 62.6°F provide conditions that allow for successful transformation to the smolt stage (Clarke and Shelbourn 1985; Marine 1997; Zedonis and Newcomb 1997). 62.6°F was rounded and used to support an index value of 63°F. A water temperature of 63°F (MWAT) was identified as the Upper Optimum Value for Chinook smolt migration for the Yuba Reintroduction Assessment for both fall- and spring-run Chinook (Bratovich *et al.* 2012).

Indirect evidence from tagging studies suggests that the survival of fall-run Chinook salmon smolts decreases with increasing water temperatures between 59°F and 75°F in the Sacramento-San Joaquin Delta (Kjelson and Brandes 1989). A WTI value of 68°F was identified because water temperatures above 68°F prohibit successful smoltification (Marine 1997; Rich 1987a; Zedonis and Newcomb 1997). Significant inhibition of gill sodium ATPase activity and associated reductions of hyposmoregulatory capacity, and significant reductions in growth rates, may occur when chronic elevated temperatures exceed 68°F (Marine 1997; Marine and Cech 2004). Water temperatures supporting smoltification of fall-run Chinook salmon range between 50°F to 68°F, the colder temperatures represent more optimal conditions (50°F to 62.6°F), and the warmer conditions (62.6°F to 68°F) represent marginal conditions (Zedonis and Newcomb 1997). A water temperature of 68°F (MWAT) was identified as the Upper Tolerable Value for Chinook smolt migration for the Yuba Reintroduction Assessment for spring-run Chinook salmon (Bratovich *et al*. 2012).

Support for an index value of 72°F is provided from a study conducted by (Baker *et al.* 1995) in which a statistical model is presented that treats survival of Chinook salmon smolts fitted with coded wire tags in the Sacramento River as a logistic function of water temperature. Using data obtained from mark-recapture surveys, the statistical model suggests a 95% confidence interval for the upper incipient lethal water temperature for Chinook salmon smolts as 71.5°F to 75.4°F. In a laboratory study, juvenile fall-run Chinook salmon from the Sacramento River reared in water temperatures between 70°F and 75°F experienced significantly decreased growth rates, impaired smoltification indices, and increased predation vulnerability compared with juveniles reared between 55°F and 61°F (Marine 1997; Marine and Cech 2004).

Indirect evidence from tagging studies suggests that the survival of fall-run Chinook salmon smolts decreases with increasing water temperatures between 59°F and 75°F in the Sacramento-San Joaquin Delta (Kjelson and Brandes 1989).

Based upon information reviewed for Chinook salmon juvenile mortality (Brett 1952), the Chinook Salmon Population Model (TID/MID 2013) identified an initial mortality threshold of 77°F for Chinook salmon smolts as a daily average water temperature.

Table 8. Chinook Salmon Smolt Emigration WTI Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
57°F (13.9°C)	A water temperature of 57°F (7DADM) was identified as the value for Chinook smolt migration for the San Joaquin River (CALFED 2009).
59°F (15°C)	EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards identifies 59°F (7DADM; late year) for salmon smolts (EPA 2003b).
63°F (17.2°C)	Acceleration and inhibition of Sacramento River Chinook salmon smolt development reportedly may occur at water temperatures above 63°F (Marine 1997; Marine and Cech 2004). Laboratory evidence suggest that survival and smoltification become compromised at water temperatures above 62.6°F (Zedonis and Newcomb 1997). Juvenile Chinook salmon growth was highest at 62.6°F (Clarke and Shelbourn 1985). A water temperature of 63°F (MWAT) was identified as the Upper Optimum Value for Chinook smolt migration for the Yuba Reintroduction Assessment for both fall- and spring-run Chinook (Bratovich *et al.* 2012).
68°F (20°C)	Significant inhibition of gill sodium ATPase activity and associated reductions of hyposmoregulatory capacity, and significant reductions in growth rates, may occur when chronic elevated temperatures exceed 68°F (Marine 1997; Marine and Cech 2004). Water temperatures supporting smoltification of fall-run Chinook salmon range between 50°F to 68°F, the colder temperatures represent more optimal conditions (50°F to 62.6°F), and the warmer conditions (62.6°F to 68°F) represent marginal conditions (Zedonis and Newcomb 1997). A water temperature of 68°F (MWAT) was identified as the Upper Tolerable Value for Chinook smolt migration for the Yuba Reintroduction Assessment for both fall- and spring-run Chinook (Bratovich *et al.* 2012).
72°F (22.2°C)	In a laboratory study, juvenile fall-run Chinook salmon from the Sacramento River reared in water temperatures between 70°F and 75°F experienced significantly decreased growth rates, impaired smoltification indices, and increased predation vulnerability compared with juveniles reared between 55°F and 61°F (Marine 1997; Marine and Cech 2004). Indirect evidence from tagging studies suggests that the survival of fall-run Chinook salmon smolts decreases with increasing water temperatures between 59°F and 75°F in the Sacramento-San Joaquin Delta (Kjelson and Brandes 1989).
77°F (25°C)	The model associated with the Chinook Salmon Population Model Study, established an initial mortality threshold of 77°F (daily average temperatures) for Chinook salmon smolts (Brett 1952 as cited in TID/MID 2013).

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<u>TID/MID Response to Comments on the Water Temperature Literature Review</u>

Comment No.	Organization / Source	Comment	Response
1.	CDFW 11/3/16 email	It would be helpful to include in the Glossary of Terms definitions for both **acute** and **chronic** especially in terms to timeframes and implications.	Acute and chronic terms in addition to other terms have been updated in The Glossary of Terms document.
2.	CDFW 11/3/16 email	The literature review contains temperatures in both English and Metric units which is confusing. In the interest of clarity and consistency with established scientific literature we request that all temperatures be available Celsius.	As noted in the introduction of the literature review, subcommittee members supported use of an already published review as the basis for this assessment (i.e., Appendix A of Bratovich et al. 2012). Much of the narrative text was cited "as-is" from the existing document. However, for each of the life history tables (which summarize the narrative text at the end of each life history stage section) included in the literature review, Metric units have been added in parentheses alongside English units. Not all scientific or technical documents report temperature in °C. For example, the SWRCB's recently released Substitute Environmental Document uses °F. For future reference, we will make every effort to report in °F in whole integers, with °C provided in parentheses.
3.	CDFW 11/3/16 email	Water Temperature Indices - The literature review is unclear as to the purpose of water temperature index values. It is stated that they provide a gradation of potential effects but there is no indication as to what the index values will be used for.	Water temperature index values will be used to evaluate potential thermal habitat suitability for anadromous salmonid reintroduction in the Tuolumne River Basin.

Comment No.	Organization / Source	Comment	Response
4.	CDFW 11/3/16 email	The inclusion of water temperature criteria for other rivers and the EPA is helpful for comparison but, clarification as to how the Upper Optimum Value and Upper Tolerable Value are applied in the Yuba River would be helpful.	The Yuba Salmon Forum (YSF) conducted a summary assessment of potential spring-run Chinook salmon and steelhead habitat in the Yuba River Basin to provide information for use in reviewing potential options that warrant further investigation regarding reintroduction into the North, Middle, and South Yuba rivers, as well as portions of the mainstem Yuba River. Evaluations conducted by the YSF (2013) emphasized water temperature habitat suitability determinations. These evaluations utilized water temperature index (WTI) values specific to each of the species' lifestages, and the time periods throughout the year during which they occur. The WTI values selected for evaluation corresponded to lifestage-specific Upper Optimum and Upper Tolerable WTI values. The maximum weekly average (daily) water temperature (MWAT) was the metric applied to water temperature monitoring and modeling data, for various years and water year types, to identify when and where WTI values were exceeded. The estimated location when MWAT exceeded the specified WTI value was then used to identify the number of river miles of thermally suitable habitat for a particular species/lifestage.
5.	CDFW 11/3/16 email	The inclusion of data obtained from the Lower Tuolumne River swim tunnel study is inappropriate. Results obtained during the study are based on an acute response to temperature which does little to inform a fish's response to a chronic condition. CDFW has provided extensive comments on this study to HDR Inc. in a letter dated August 31, 2016.	The researchers responsible for this study indicate that it is incorrect to classify the Swim Tunnel study as an investigation of acute response to water temperature. The comments provided by CDFW have been addressed and will be provided in the final study filed with FERC which is scheduled to occur the week of November 28, 2016. The study represents the only site-specific study of wild juvenile *O. mykiss* in the Tuolumne River and is important to consider.

Deason, Jesse

From: John Wooster - NOAA Federal <john.wooster@noaa.gov>
Sent: Monday, November 07, 2016 4:16 PM
To: Le, Bao
Cc: Deason, Jesse; Staples, Rose; Steve Edmondson; Jean Castillo - NOAA Federal
Subject: Re: Change in Due Date for Comments on the Temp Criteria Subcommittee Oct 14 Conf Call Draft Notes
Attachments: BoughtonEtAl2015.pdf

Bao:

I think an important component for the temperature sub-group is to understand how the NMFS Science Center will treat the topic of thermal suitability in modeling habitat capacity in their study of the Upper Tuolumne watershed. Their approach for O.mykiss is currently likely to follow the approach used in this 2015 Boughton et al. paper that I am attaching to this email – with emphasis on the *Thermal Indicators of habitat suitability* section on pdf page 263. The Science Center has another technical memo in draft form that provides greater detail for this approach and the rationale / data behind it– once that memo is finalized I can pass it along too. The spring-run Chinook approach for the Tuolumne is still under development, although likely to follow a similar mechanistic/bio-energetic approach but maybe some adjustment to the temperature thresholds.

In short, they will not be taking a relatively simplistic approach of selecting one temperature metric and deciding if a reach is "suitable" or "not". For O.mykiss, if a given day has a maximum temp >29C or average daily temp >25C then it is not suitable. Temperatures in the 21 to 25C range are considered stressful. What impacts those stressful temperatures have and whether the O.mykiss can utilize the habitat depends on several factors, including but not limited to: thermal refugia (e.g., stratified deep pools), food availability, growth potential, level of stress (e.g., function of the degrees above 20C and for how many hours), etc…

I also inquired about other useful references towards temperature and steelhead and the lab recommended these papers (in addition to the one I am attaching):

Rodnick, K. J., A. K. Gamperl, K. R. Lizars, M. T. Bennett, R. N. Rausch, and E. R. Keeley. 2004. Thermal tolerance and metabolic physiology among Redband Trout populations in southeastern Oregon. Journal of Fish Biology 64:310–335.

Sloat, M. R., and A. M. K. Osterback. 2013. Maximum stream temperature and the occurrence, abundance, and behavior of steelhead trout (Oncorhynchus mykiss) in a southern California stream. Canadian Journal of Fisheries and Aquatic Sciences 70:64–73.

Spina, A. P. 2007. Thermal ecology of juvenile steelhead in a warm-water environment. Environmental Biology of Fishes 80:23–34.

Zoellick, B. W. 1999. Stream temperatures and the elevational distribution of Redband Trout in southwestern Idaho. Great Basin Naturalist 59:136–143.

Regards,

John

On Mon, Oct 31, 2016 at 4:40 PM, Staples, Rose <Rose.Staples@hdrinc.com> wrote:

Please note correction in the date to provide comments on the draft meeting notes—it is Wednesday, November 30th. Thank you.

Temperature Criteria Subcommittee,

DRAFT NOTES from the October 14, 2016 Water Temperature Criteria Subcommittee call have been uploaded to the licensing website www.lagrange-licensing.com in the DOCUMENTS section and also as an attachment to the October 14, 2016 date on the website calendar.

Please provide any comments on the meeting notes by ~~Monday, November 28, 2016~~ Wednesday, November 30, 2016 to rose.staples@hdrinc.com. The Districts will incorporate any comments received and then post a final version of the meeting notes to the licensing website.

In addition, this email will be forwarded to the La Grange Project licensing email list stating that the draft meeting notes are available online.

If you have any difficulties locating and/or accessing the document, please let me know.

As a reminder, please provide any comments on the updated literature review and glossary of terms to rose.staples@hdrinc.com by November 1, 2016.

Thank you.

Rose Staples, CAP-OM, MOS

Executive Assistant

HDR

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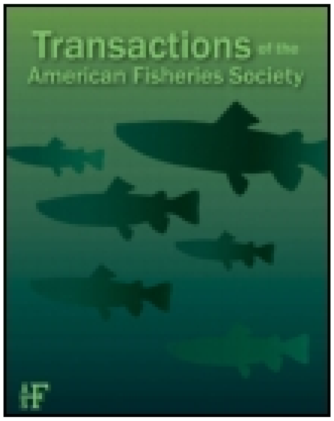

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Thermal Potential for Steelhead Life History Expression in a Southern California Alluvial River

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ARTICLE

Thermal Potential for Steelhead Life History Expression in a Southern California Alluvial River

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Abstract

Steelhead *Oncorhynchus mykiss* (anadromous Rainbow Trout) near the southern limit of the species' range commonly use shallow alluvial rivers for migration, spawning, and rearing. These rivers have been widely modified for water management, and an enduring question is whether their rehabilitation would create summer nursery habitat for steelhead. We used process-based models to evaluate the thermal potential for steelhead nursery habitat in the Santa Ynez River, California, a regulated alluvial river that currently supports few steelhead. We assessed (1) how well a calibrated model of river heat fluxes predicted summer temperature patterns for a warm year and an average year; (2) whether those patterns created thermal potential for the rapid growth that is characteristic of steelhead nursery habitat; and (3) whether manipulation of flows from an upstream dam significantly altered thermal potential. In the heat flux model, the root mean square error for 15-min temperatures was 1.51°C, about three times greater than that of the larger, deeper Sacramento River in northern California. Generally, the Santa Ynez River was thermally suitable but stressful for juvenile steelhead. Flow augmentation reduced the number of thermally stressful days only near the dam, but it reduced the intensity of thermal stress throughout the river. Daytime movement of steelhead into natural, thermally stratified pools would reduce stress intensity by similar levels. In this region, *O. mykiss* commonly pursue an anadromous (steelhead) life history by entering nursery habitat early in their first or second summer and rapidly growing to attain a threshold size for anadromy by fall. In the average year, the river was thermally suitable for the first-summer pathway under high food availability and for the second-summer pathway under medium food availability. The warm year also supported the second-summer pathway under high food availability. Currently, the Santa Ynez River's capacity to support these pathways does not appear to be limited by summer temperature, thus indicating a need to identify other limiting factors.

Steelhead *Oncorhynchus mykiss* (anadromous Rainbow Trout) in southern California near the southern limit of the species' native range historically migrated up wide, shallow alluvial rivers that drained arid mountain ranges (Figure 1). An enduring question is whether the summertime thermal patterns of these rivers constitute a fundamental control on

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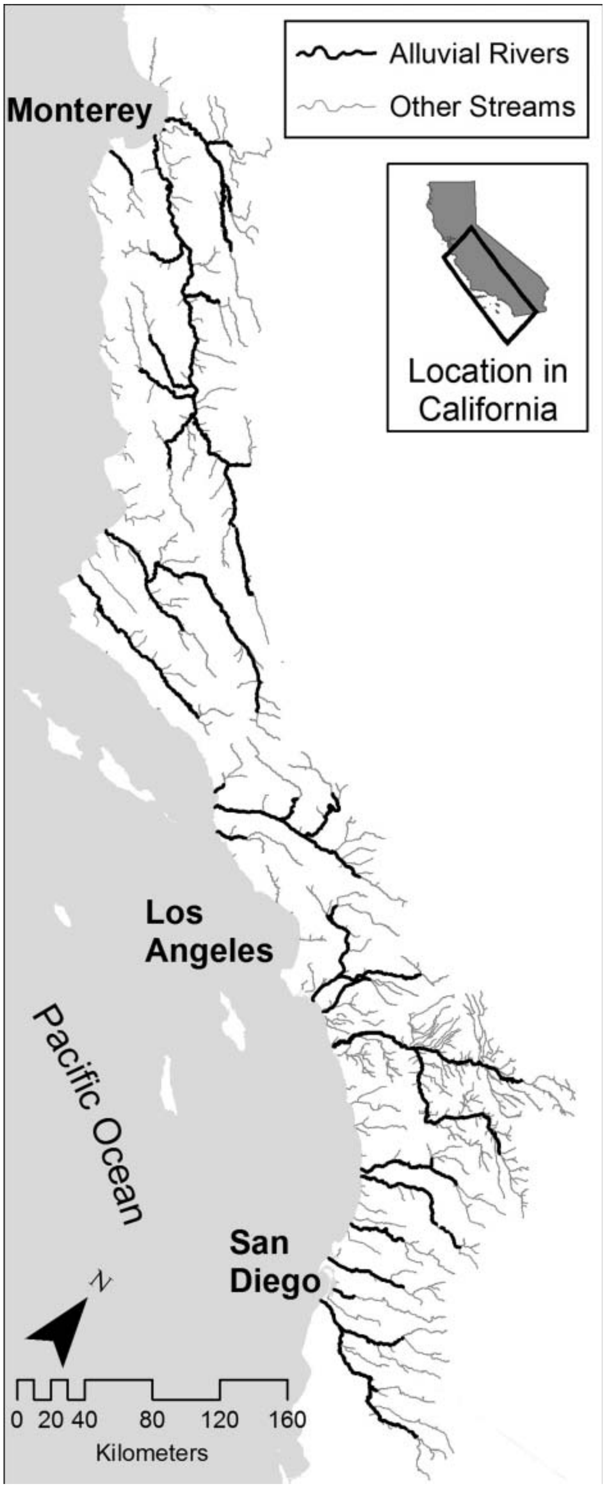

FIGURE 1. Coastal California alluvial rivers currently or formerly used by steelhead (anadromous *Oncorhynchus mykiss*) near the southern limit of the species' native range (Boughton et al. 2005). Steelhead historically used alluvial rivers as migration corridors to upland creek habitat and possibly as spawning and rearing habitat. The alluvial rivers that are highlighted here are channels with gradients less than 1% and upstream watershed areas greater than 500 km^2 within the shrub-dominated coastal mountain ranges south of Monterey Bay.

productivity and life history diversity of *O. mykiss* in this region. Southern California steelhead are currently scarce and considered highly endangered, in part due to widespread human impacts but also to challenging climatic conditions that may limit the rivers' suitability (Boughton et al. 2009). Better insight into thermal factors that limit steelhead has implications for recovery potential in the region and, more broadly, for the responses of other steelhead populations to the impacts of climate change on rivers (e.g., Mantua et al. 2010; Benjamin et al. 2013).

Steelhead are stressed by or excluded from water that is warmer than specific tolerance limits (Jobling 1981; Eaton et al. 1995; Werner et al. 2005; Kammerer and Heppell 2013a), which indirectly links their geographic distribution to summer climate via river temperature (Mohseni et al. 2003). Water temperature also sets an upper limit on the potential growth of juveniles (Wurtsbaugh and Davis 1977; Kammerer and Heppell 2013b, 2013a), with implications for the fitness and expression of anadromous and nonanadromous (resident) life histories (Mangel and Satterthwaite 2008; McMillan et al. 2012; Sogard et al. 2012; Benjamin et al. 2013). Numerous other ecological factors and human impacts also influence distribution, abundance, and life history expression in *O. mykiss* (Busby et al. 1996) but only within the bounds of a river's thermal potential for the species. Thus, if a given river habitat lacks the basic thermal potential to support the anadromous life history, then there is little scope for steelhead recovery, irrespective of other factors. We used this premise to assess the recovery potential of steelhead in an alluvial main-stem river in southern California.

Southern California *O. mykiss* populations historically expressed both anadromous (steelhead) and resident (Rainbow Trout) life histories. Anadromous life histories appear to depend on habitats that produce large smolts, which survive well in the ocean and are disproportionately represented in adult spawning migrations (Bond 2006). Such areas qualify as nursery habitat—defined as rearing habitats for which the contribution per unit area to the production of recruits to the adult population is greater than the contributions from other habitats where juveniles occur (Beck et al. 2001). Thus, steelhead nursery habitats constitute the subset of juvenile rearing habitats that generate high numbers of adult steelhead per unit area, and these nursery habitats are important for maintaining population size and persistence (Beck et al. 2001). Hayes et al. (2008) identified three pathways by which juvenile *O. mykiss* use nursery habitat in coastal California to achieve sizes that are suitable for anadromous life histories; each of the pathways involves the use of summer habitats that are capable of sustaining rapid growth (Figure 2). In the "first-summer" pathway, age-0 steelhead enter nursery habitat in early summer and grow rapidly. By fall, they reach a size that enables them to exhibit more typical growth during winter yet still successfully smolt the following spring at age 1. In the "second-summer" pathway and the much rarer "third-summer" pathway, age-0

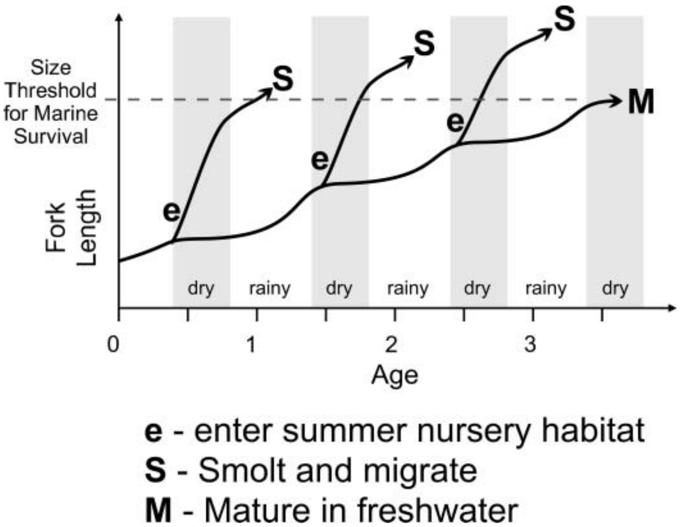

FIGURE 2. Conceptual model for *Oncorhynchus mykiss* life history pathways in stream systems of the California coast (adapted from Hayes et al. 2008; see also Bond 2006; Satterthwaite et al. 2009, 2012; and Beakes et al. 2010). Because marine survival is low for *O. mykiss* smaller than a certain size threshold (~150 mm FL), habitats only produce the anadromous life history form (steelhead) if the fish sustain rapid growth during the summer before smolting. Such habitats disproportionately contribute recruits to anadromous runs and thus fit the definition of steelhead nursery habitat (sensu Beck et al. 2001).

steelhead remain in upland creeks for 1 or 2 years, where they grow slowly until entering nursery habitat in their second or third summer and then smolting the following spring at age 2 or age 3. Some fish also follow a resident pathway, maturing in freshwater as Rainbow Trout (Hayes et al. 2012).

Growth potential is probably a central feature distinguishing steelhead nursery habitat from Rainbow Trout nursery habitat. This is because body size correlates strongly with fitness components, such as habitat-specific survival (Ward et al. 1989; Bond 2006; Evans et al. 2014; Thompson and Beauchamp 2014) and female fecundity (Shapovalov and Taft 1954), and such fitness components evolutionarily favor anadromy in some environments and freshwater residency in others (Satterthwaite et al. 2009, 2010). Thus, although life histories are partly under genetic control (Thrower and Joyce 2004; McPhee et al. 2007; Heath et al. 2008; Pearse et al. 2014), natural selection should favor a conditional life history strategy that uses body size as an internal cue for whether and when to switch from freshwater habitat to marine habitat (Mangel and Satterthwaite 2008; Satterthwaite et al. 2009; McMillan et al. 2012; Sloat et al. 2014). At the same time, the growth and body size necessary to cue the switch are expected to (1) differ for males and females (Sloat et al. 2014); (2) vary regionally as a function of local survival in both the marine and freshwater environments; and (3) depend on the maximum attainable body size (asymptotic body size) in the two environments (Satterthwaite et al. 2010). For simplicity, we focus here on female life histories under the assumption that limits on anadromous production are more closely tied to female fecundity than to male fecundity. For some salmonid species in some environments, very rapid growth and large attainable body sizes for females in freshwater appear to favor resident life histories (i.e., maturation in freshwater; Sloat et al. 2014). For *O. mykiss* in coastal California, the combination of survival schedules and very rapid growth that favors such a strategy has not yet been observed (Hayes et al. 2008). Instead, rapid growth appears to evolutionarily favor an anadromous life history, whereas moderate growth apparently favors a resident life history (Satterthwaite et al. 2009). Feeding experiments suggest that the physiological "decision" to forsake a nonanadromous path and switch to marine habitats is made in the fall—after the summer growth period and before outmigration the next spring (Beakes et al. 2010). Thus, to a first approximation, a habitat's potential to generate the anadromous life history in coastal California simplifies to the potential to support survival and rapid growth of juvenile female *O. mykiss* during summer. In the context of thermal potential addressed here, survival will fail if temperatures become lethally warm, and rapid growth will fail if water temperatures are either too warm or too cool for the growth rate required to trigger smoltification and the switch to marine habitats.

The best-studied steelhead nursery habitats in the region are coastal estuaries (Bond 2006), which form dry-season lagoons that produce abundant large smolts. Coastal climate and inputs of marine wrack and invertebrates provide the appropriate combination of temperature and feeding opportunity for rapid growth, but the total productivity of estuaries is limited by their small spatial extent. Upland creek habitat is more widespread and supports abundant juvenile *O. mykiss* (e.g., Boughton et al. 2009). However, the channels must be well shaded to stay cool enough for the species (Boughton et al. 2012), whereas dense shade appears to limit instream primary productivity, creating a food-limited environment and low growth potential in summer (Hayes et al. 2008; Rundio and Lindley 2008; Sogard et al. 2009). Coastal estuaries are usually steelhead nurseries and upland creeks are usually not, but the nursery role of a third common habitat, alluvial rivers, remains an open question.

Lowland alluvial rivers, defined here as streams with low gradients ($<1\%$) and large upstream watersheds (>500 km^2), are numerous and widespread at the species' southern range limit in California (Figure 1); therefore, these systems could potentially produce large steelhead runs if they are capable of functioning as nursery habitat. In summer, alluvial rivers are wide, shallow, and sparsely shaded, making them vulnerable to heating but also typically allowing them to support substantial algal growth, which suggests a physical basis for a productive food web and the high feeding opportunities necessary for rapid growth of juvenile fish. Summer air temperatures in this region routinely exceed 30°C, but river temperatures are reduced to varying extents by cool onshore winds and fog from the ocean and by hydrological exchange with large aquifers. These physical influences on temperature are spatially heterogeneous (e.g., Alagona et al. 2012; Booth et al. 2013), and the degree to which they keep rivers in the thermal zone required for rapid growth—or even survival—of juvenile *O. mykiss* is unclear. Unfortunately, the potential role of lowland alluvial rivers as summer nursery habitat is ambiguous due to an incomplete historical record and the extensive negative impacts from water development, adjacent land uses, and nonnative species (Marchetti et al. 2004; Klose et al. 2012; Cooper et al. 2013).

We used process-based models of river temperature and fish response to evaluate whether a representative alluvial river in southern California has the thermal potential to support anadromous life history expression by the local population of *O. mykiss*. The Santa Ynez River serves as a useful case study because it has a historical record of occasional (and perhaps frequent) large steelhead runs (Alagona et al. 2012) and because the existing river and its human impacts are representative of many other rivers in the region (Kondolf et al. 2013). We focused our analysis on three questions: (1) Do summer temperature patterns in the main stem of the river create thermal potential for steelhead survival and a first-summer or second-summer life history strategy?; (2) How much does the manipulation of water releases from an upstream dam alter the thermal potential of the river?; and (3) How much do cold patches of water in thermally stratified pools increase the thermal potential of the river by reducing thermal stress on steelhead?

STUDY AREA

The Santa Ynez River flows west about 110 km from tributaries in the Transverse Ranges of California to the Pacific Ocean just north of Point Conception. The reach we modeled was the lower 65-km section below Bradbury Dam (Figure 3). Historical data suggest that steelhead runs once numbered in the tens of thousands in some years but were nearly nonexistent in other years (Alagona et al. 2012). Currently, anadromous *O. mykiss* are consistently rare despite the predominance of anadromous genotypes in the local population (Pearse et al. 2014, cf. Salsipuedes and Hilton creeks) and more than a decade of rehabilitation efforts (Robinson et al. 2009). Bradbury Dam impounds a large reservoir near the middle of the basin and blocks steelhead migration 70 km upstream of the

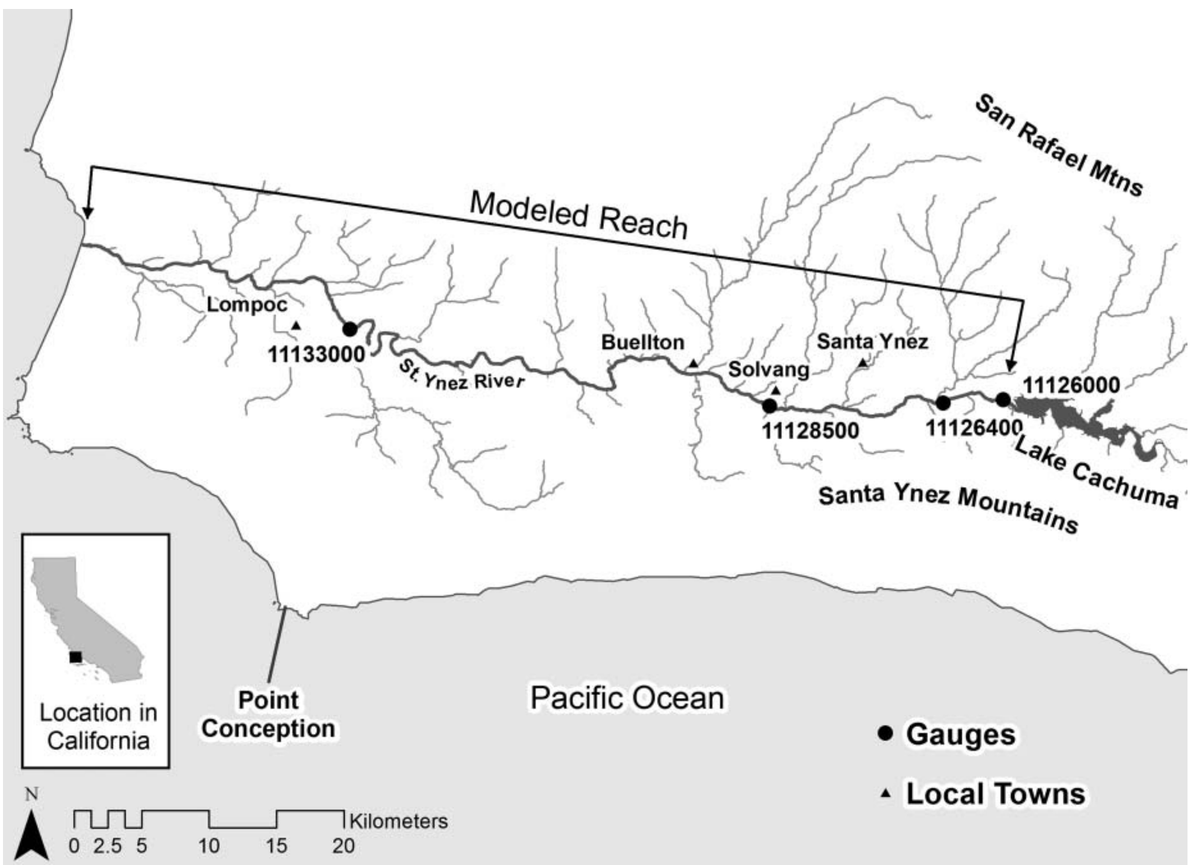

FIGURE 3. Map of the study area in the Santa Ynez River, showing landmarks and locations of stream gauges that recorded flow and temperature. U.S. Geological Survey (USGS) gauge 1112600 defined the upstream boundary conditions for the River Assessment for Forecasting Temperature model; USGS gauges 11126400, 11128500, and 11133000 were used to calibrate the parameters.

estuary; about two-thirds of the basin's spawning and rearing habitat are located upstream of the dam and are therefore inaccessible (Alagona et al. 2012). Genetically similar but nonanadromous *O. mykiss* occupy the stream network upstream of the dam (Clemento et al. 2009; Pearse et al. 2014). Summertime flows below the dam are managed for multiple objectives, including steelhead rearing and continuous replenishment of aquifers tapped by agriculture. Summer flows typically range between 0.3 and 1.0 m^3/s but may be temporarily ramped up as high as 4 m^3/s to replenish the downstream aquifers.

Between Bradbury Dam and the town of Solvang (Figure 3), the Santa Ynez River has a gravel bed with alternating pool–riffle sequences and a sparsely vegetated floodplain. The channel migrates laterally during infrequent flood events, thereby scouring pools, shaping gravel bars, and recruiting coarse woody debris via bank migration. Together, these processes produce physical habitat complexity that is characteristic of the habitats typically used by steelhead. This complexity includes a diversity of water depths and velocities; visual cover provided by instream wood, undercut banks, and overhanging vegetation; and gravel beds suitable for spawning. During years between floods, dense shrubby vegetation colonizes the active channel margins, and the riverbed develops thick algal mats. Further downstream from Solvang, the Santa Ynez River shifts to a sand-bedded channel with fewer pool–riffle sequences and more closely resembles a braided river. Important human impacts include managed flow regimes, high nitrogen loading from agricultural activities, and a profusion of exotic fish species. Juvenile and adult Largemouth Bass *Micropterus salmoides* are especially abundant, occurring in the tens of thousands throughout the lower river during summer (Robinson et al. 2009).

In summer, juvenile steelhead are common in a few small tributaries of the lower Santa Ynez River; in the river itself, however, they are rare and confined to small coldwater patches associated with thermally stratified pools or groundwater seeps (Robinson et al. 2009). Thermal stratification occurs at low flows, when water velocities are slow enough to allow poorly mixed layers of water at different temperatures to develop in well-shaded pools, or in areas where groundwater seeps up from the bed. Geomorphically, the river seems suitable for steelhead rearing, yet rearing is rare; therefore, the key questions (and the motivation for this study) are whether the lack of steelhead rearing can be attributed to thermal constraints and whether such constraints are more closely linked to dam releases or to prevailing weather.

METHODS

River temperature.—We estimated fine-grained temperature dynamics in the Santa Ynez River by using the River Assessment for Forecasting Temperature (RAFT) model (Pike et al. 2013). The RAFT model was previously developed for the Sacramento River, a large, cool California river with managed summer flows that typically range from 180 to 520 m^3/s—or about 200–1,500 times greater than typical summer flows in the Santa Ynez River. The much shallower Santa Ynez River provides a more challenging system to model because heat fluxes with the riverbed and atmosphere are potentially large relative to the thermal capacity of the river. Pike et al. (2013) described the RAFT model in detail; below, we summarize aspects that are relevant to the challenge of simulating thermal processes in the Santa Ynez River.

The RAFT model assimilates data on meteorology, flow, and river temperature to simulate hydrological and thermal processes at a temporal resolution of 15 min and a spatial resolution of 1 km. A one-dimensional hydrodynamic model simulates the advection and diffusion of heat longitudinally in the river, coupled to physical models of all upward and downward heat fluxes with the atmosphere and streambed, respectively. For the Sacramento River, RAFT accurately predicted (root mean square error [RMSE] $< 0.5°C$) the magnitude and timing of diel temperature fluctuations over entire summers, including thermal artifacts, such as the phase–antiphase pattern of downstream temperature below a dam releasing water of constant temperature (Pike et al. 2013). The model requires channel bathymetry as input, which in this study comprised topographic cross-sections spaced at ~50-m intervals, derived from aerial LiDAR and ground surveys of the Santa Ynez River. Other required input included gridded hourly meteorological data and a time series of measured hourly temperature and flow at the upstream boundary of the modeled reach (U.S. Geological Survey [USGS] gauge 1112600, about 5 km downstream of Bradbury Dam; see Figure 3).

The model runs in either a hindcast or forecast mode. Hindcasts simply assimilate temperature observations to spatiotemporally infer a past temperature field that is encompassed by the time span of the data. Forecasts predict future temperature time series based on constructed flow and temperature scenarios at the upstream boundary. We used hindcasts to calibrate RAFT and reconstruct temperature fields from the recent past, and we used forecasts to predict the effects of hypothetical water release scenarios.

Calibration of the model benefits from the assimilation of flow records that include both large and small flows, so we focused on two recent summers (2006 and 2010) with flows spanning a relatively broad range (0.3 to 5.0 m^3/s). Based on daily temperatures at the Lompoc gauge (USGS gauge 11133000), 2006 had the hottest summer of the last decade, with a mean summer water temperature of 21.41°C (range of summer means for the last decade = 19.46–21.41°C; calculated for June 1–October 1 of each year from 2003 to 2012). In contrast, 2010 had a nearly average summer, with a mean water temperature of 20.48°C (mean of summer means for the last decade = 20.56°C).

For each summer, the RAFT model was calibrated by adjusting several tunable parameters to achieve a best fit with 15-min water temperatures at three gauges downstream of

Bradbury Dam (USGS gauges 11126400, 11128500, and 11133000; Figure 3). Tunable parameters included the depth of the streambed (affecting the rate of bed heat conduction), the temperature of the deep groundwater reservoir (assumed to be constant over time), and coefficients for the rate of evaporative cooling relative to wind speed.

After calibration, we simulated alternative flow scenarios by using the same data used for hindcasts, altering only the flow. Seven scenarios of constant flow (0.14, 0.28, 0.71, 1.4, 2.8, 4.3, and 5.7 m^3/s [5, 10, 25, 50, 100, 150, and 200 ft^3/s]) were simulated for the dry season (May 1–October 1).

Thermal indicators of habitat suitability.—To evaluate how river temperature was likely to affect southern California steelhead, we developed a set of biological indicators. A review of the literature suggested that steelhead in various regions can persist in streams if short-term maximum temperatures remain below 30°C or perhaps 29°C (Zoellick 1999; Rodnick et al. 2004; Huff et al. 2005; Werner et al. 2005; Sloat and Osterback 2013), which is similar to laboratory estimates of the critical thermal maximum, a measure of short-term physiological tolerance for high temperature (Myrick and Cech 2004; Rodnick et al. 2004; Hasnain et al. 2013). However, at temperatures above 22–24°C, feeding and agonistic behaviors decline in frequency (Sloat and Osterback 2013), and the fish show signs of stress (Werner et al. 2005). Laboratory estimates of incipient lethal temperature (50% mortality after long exposure) vary across studies but average around 25°C. Steelhead start to concentrate in thermal refugia, if available, when temperatures exceed 21°C, and they almost completely retreat to refugia when temperatures are around 24°C (Nielsen et al. 1994; Ebersole et al. 2001; Baird and Krueger 2003; Sutton et al. 2007). Many southern California streams that support steelhead do not provide such refugia, and steelhead actively feed in the temperature range of 21–24°C, which is presumably stressful (Spina 2007; Sloat and Osterback 2013).

Based on this review, we define thermal indicators as follows. A day is "thermally suitable" if maximum daily temperature stays below 29°C *and* mean daily temperature stays below 25°C. However, a day is "thermally stressful" if temperature rises above 21°C at any time, with the daily stress intensity quantified as degree-hours above 21°C (i.e., for each day, $\Sigma[T_t - 21]\Delta t$).

Thermal growth potential.—We defined thermal growth potential as the maximum attainable growth of an individual fish, a function of the river's thermal regime and food availability. Thermal growth potential was estimated using the bioenergetics model for *O. mykiss* described by Railsback and Rose (1999), as modified by Satterthwaite et al. (2010) and Arriaza (2013). Individual growth arises from the difference between energy intake and energy expenditure (Rand et al. 1993; Railsback and Rose 1999; Satterthwaite et al. 2010), which are modeled as weight- and temperature-dependent functions for food consumption and respiration, respectively (see Arriaza [2013] for details). The functional form of the growth response to temperature is hump-shaped after Thornton and Lessem (1978) for coldwater species; the functional form was parameterized for California steelhead as in Railsback and Rose (1999). Expressions for maximum food intake and respiration costs in the basic model were modified by functions simulating the energy cost of activity and the difficulty of finding food in a wild habitat, in accordance with recommendations made by Andersen and Riis-Vestergaard (2004) and Bajer et al. (2004). Higher activity increases food consumption, but total energetic cost also increases. For simplicity, we assumed that fish choose a unique activity level that optimizes growth given all other parameters (Arriaza 2013). In the resulting model, the growth rate depends on fish size and food availability but generally peaks in the range of 15–17°C and becomes negative at temperatures above 22–24°C.

We applied the bioenergetics model to temperature output from RAFT scenarios in combination with assumptions about food availability. For *O. mykiss* in the Santa Ynez River (either in its current state or under hypothetical flow scenarios), the level of difficulty in finding food is unknown although presumably low, as judged from the great abundance of juvenile Largemouth Bass and other exotic fish in the river. For simplicity, we assumed that the difficulty of finding food over the summer was constant, and uncertainty was represented by simulating low, medium, and high food availability as drawn from parameter estimates for the same model when applied to two alluvial rivers in California's Central Valley over various years and seasons (Satterthwaite et al. 2010).

Nursery potential.—Growth potential was used to evaluate whether thermal patterns in the Santa Ynez River were sufficient to support either a first-summer or second-summer pathway to anadromy. Growth of age-0 and age-1 *O. mykiss* from June 1 to October 1 was simulated at daily time steps by using mean daily temperature from the RAFT scenarios. Weights of juveniles on June 1 were assumed to be 1.9 g for age-0 fish and 13.6 g for age-1 fish (D. Rundio, National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center, personal communication).

Thermal growth potential was judged to be sufficient for steelhead nursery habitat if fish had grown past a smolting criterion, defined as the minimum FL on October 1 associated with successful anadromy. In the spring, FLs greater than 150 mm are associated with successful anadromy (i.e., a high smolting rate and high marine survival; Ward et al. 1989; Bond 2006; Evans et al. 2014; Thompson and Beauchamp 2014). We examined two versions of the October 1 criterion to account for uncertainty. The "high" smolting criterion was an October 1 FL exceeding 150 mm, which makes the very conservative assumption that growth is negligible in the intervening winter. The "typical" smolting criterion was an October 1 FL greater than 100 mm; this criterion is more apt because it assumes that growth in the intervening winter is typical of upland creeks in the region, which would produce fish larger than the 150-mm threshold by the following spring (Satterthwaite et al. 2009).

Stratified pools.—To assess the extent to which thermally stratified pools might reduce thermal stress, we deployed vertical arrays of temperature loggers in five sections of the Santa Ynez River during summer 2011. Sites were chosen on the basis of accessibility and wide geographic distribution. Stratified pools have been observed in California rivers with large gravel bars, flow separation, extensive intergravel flow, groundwater seeps, and pools that are forced by large woody debris or boulders (Nielsen et al. 1994). Based largely on these findings, we selected pools within each section that possessed at least three geomorphic and hydrologic criteria indicating a high potential for stratification. We identified 16 such pools. In each pool, we positioned a fence post vertically at the deepest point (either by driving it into the substrate or placing it in a manufactured concrete base) and attached three Hobo pendant loggers (Onset Corporation) housed by gray plastic sunshields. One logger was placed 10 cm below the water's surface, another logger was placed against the streambed, and the third logger was deployed midway between the first two. The period of record was July 1–October 1, except for three loggers that were not deployed until the second week of July.

The pools were snorkel surveyed for the presence of steelhead in late summer (August 16–18). Standard methods (e.g., Boughton et al. 2009) were used for the survey, including visual assignment of fish to three general size-classes (<100, 100–200, or >200 mm FL). Such methods generally achieve per-fish observation probabilities around 0.70–0.85.

Complete data sets were recovered from 14 pools. In many cases, declining flows exposed the upper (surface) temperature logger; in the remaining cases, the records of the middle and surface loggers were nearly identical, so records from the middle logger were taken to represent the main flow. Pools were defined as stratified if they showed an absolute difference greater than 1°C between middle and bottom loggers for at least 5% of the period of record. Mean daily stress intensity was calculated for the middle and bottom logger positions in each pool.

RESULTS

Performance of the RAFT Model

Each RAFT hindcast produced 14,689 temperature predictions for the 153 d from midnight on May 1 to midnight on October 1. The RMSE of 15-min temperatures was 1.51°C in both years, with the RMSE of daily means being slightly smaller and the RMSE of daily maximums being slightly larger (Table 1). The RMSE broken down by USGS gauge and flow showed a negative relationship with flow but not consistently; the lower flows generally involved prediction error ranging from 1°C to 2°C. Thermal stress had an RMSE of 14.8 degree-hours in 2006 and 11.0 degree-hours in 2010, which were comparable in magnitude to the predicted daily stress itself (see below).

TABLE 1. Performance metrics for the River Assessment for Forecasting Temperature hindcasts estimated from three downstream temperature gauges in the Santa Ynez River, California (RMSE = root mean square error).

	RMSE		Bias	
Metric	2006	2010	2006	2010
15-min temperature (°C)	1.51	1.51	−0.04	0.30
Daily mean temperature (°C)	1.03	0.80	−0.04	0.30
Daily maximum temperature (°C)	1.70	2.00	−0.24	1.60

Mean biases in 15-min and daily temperatures were small (≤0.3°C; Table 1). The bias in maximum daily temperature was about five times larger than the bias in mean daily temperature for each year (Table 1). Bias as a function of flow tended to be hump-shaped, with a relatively small or negative bias at low and high flows and a positive bias at intermediate flows.

Thermal Suitability and Thermal Stress

The seven flow scenarios altered the mean daily river temperature relative to the temperature records of the recent past (Figure 4A, C). The lowest flow (0.14 m^3/s) raised temperature by as much as 1.25°C but only in the vicinity of Bradbury Dam; effects were less than 0.5°C further than 10 km from the dam and were negligible beyond 20 km from the dam. The highest flow (5.7 m^3/s) lowered temperature by as much as −2.6°C in 2006 and −1.6°C in 2010, with effects persisting further downstream (40–50 km); however, less extreme scenarios (1.4 m^3/s or less) always had negligible effects further than 20 km below the dam.

In contrast, the seven flow scenarios had larger and more extensive effects on mean maximum daily temperature (Figure 4B, D). The largest effects were close to the dam and ranged from +2.5°C to −4.6°C for the lowest and highest flow scenarios, respectively. However, effects ranging between about +0.8°C and −1.7°C persisted as far as 60 km from the dam, much further than the effects for mean daily temperature.

Based on the recent temperature data and based on the scenarios, no part of the river became thermally unsuitable for steelhead, with one small exception. In 2006, at the lowest flow (0.14 m^3/s), 3 km of the lower river became unsuitable for 1 d in late summer.

In general, nearly all summer days were thermally stressful throughout the entire river except for the area immediately below Bradbury Dam (Figure 5A, C). Higher water releases could expand this less-stressful zone downstream, but the highest release could only create a truly low-stress zone a few kilometers long just below the dam. However, dam releases had large effects on the intensity of stressful days, and these effects persisted much further downstream, especially for the three largest releases (Figure 5B, D).

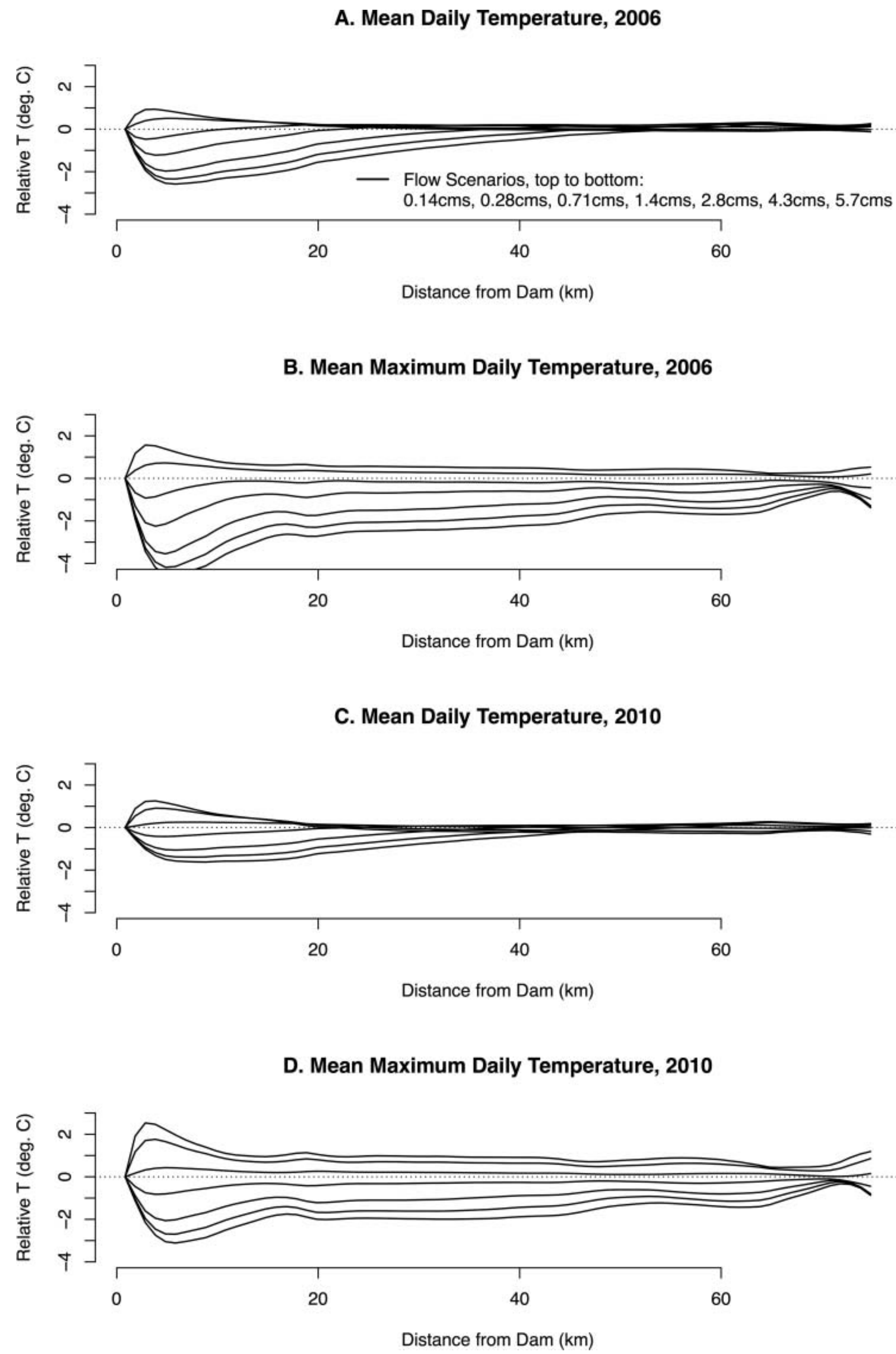

FIGURE 4. Effects of flow levels (simulated dam releases; cms = cubic meters per second) on temperatures (T) downstream of Bradbury Dam on the Santa Ynez River relative to the calibration scenario (hindcast temperature from actual flow releases occurring in 2006 and 2010). The mean of mean daily temperature and mean maximum daily temperature for the summer release season (May 1–October 1) are shown.

Nursery Potential

For clarity, nursery potential results from the various scenarios are reported in terms of relative final mass, calculated as the final mass of fish on October 1 divided by the corresponding final mass projected under the actual summer flows of 2006 and 2010.

Age-0 fish.—In 2010, the average year, medium to high food availability produced fish with masses greater than the

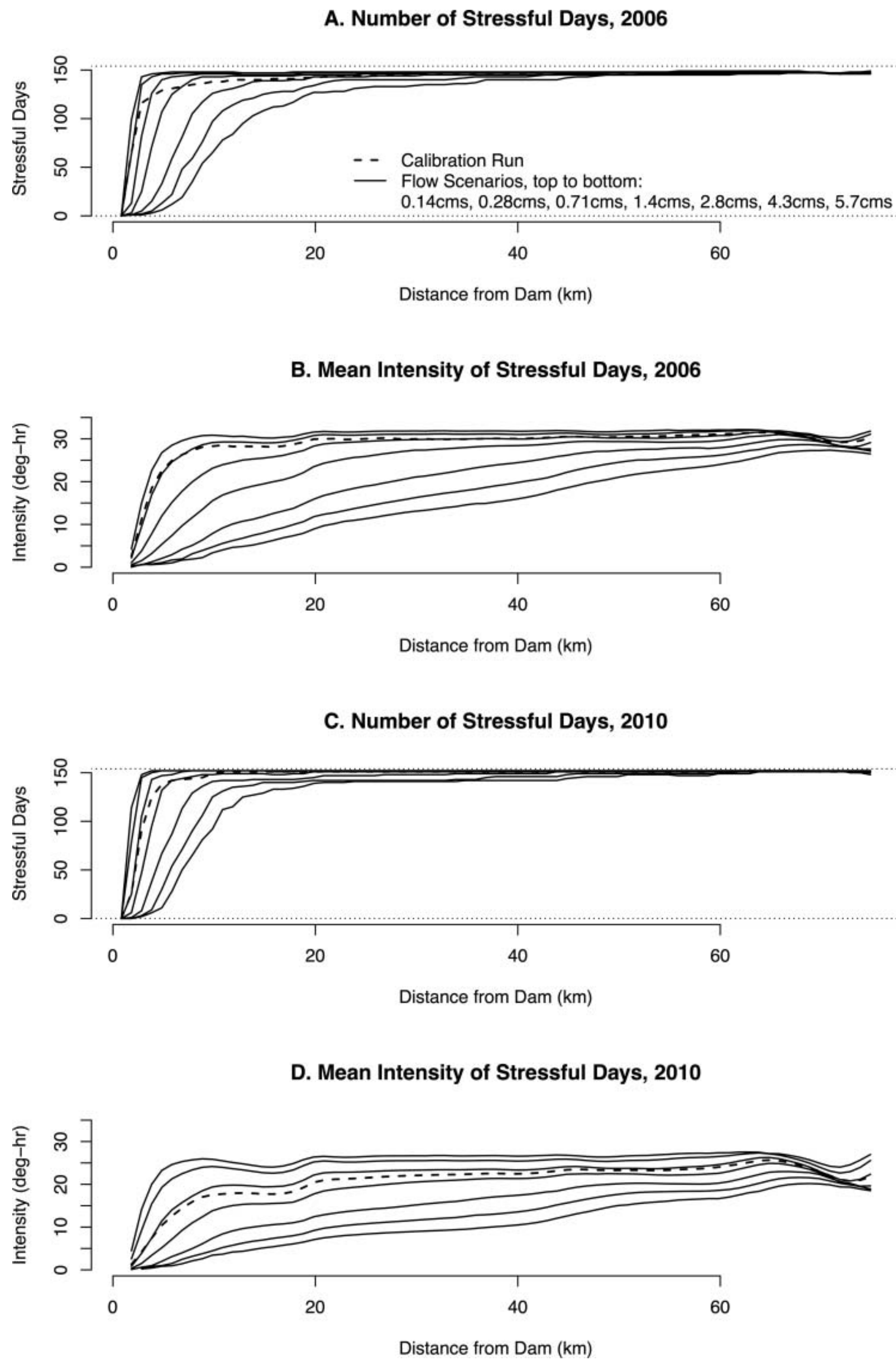

FIGURE 5. Number of days that were thermally stressful for steelhead and the mean stress intensity (degree-hours) under various simulated flow levels (cms = cubic meters per second) in the Santa Ynez River during the summer season (May 1–October 1).

typical smolting criterion throughout the entire river and regardless of flow scenario (Figure 6A, B). For other combinations (high food availability plus high smolting criterion; or low food availability plus typical smolting criterion), fish only reached smolting size near the dam (Figure 6A, C). The size of the potential nursery zone near the dam ranged from 3 to 20 km depending on the flow scenario examined (Figure 6A, C). If the high smolting criterion was used in combination with medium or low food availability, the first-summer pathway was not supported in any area of the river.

The year 2006, a hot year, had results similar to those for 2010 except that at intermediate food availability under the typical smolting criterion, the first-summer strategy was not supported throughout the entire river (Figure 6D). Instead, a nursery zone was present below the dam, and the size of the zone varied greatly (5–42 km) depending on the flow scenario. Very high flows (>4 m^3/s) were necessary to expand the nursery zone to a length greater than 20 km.

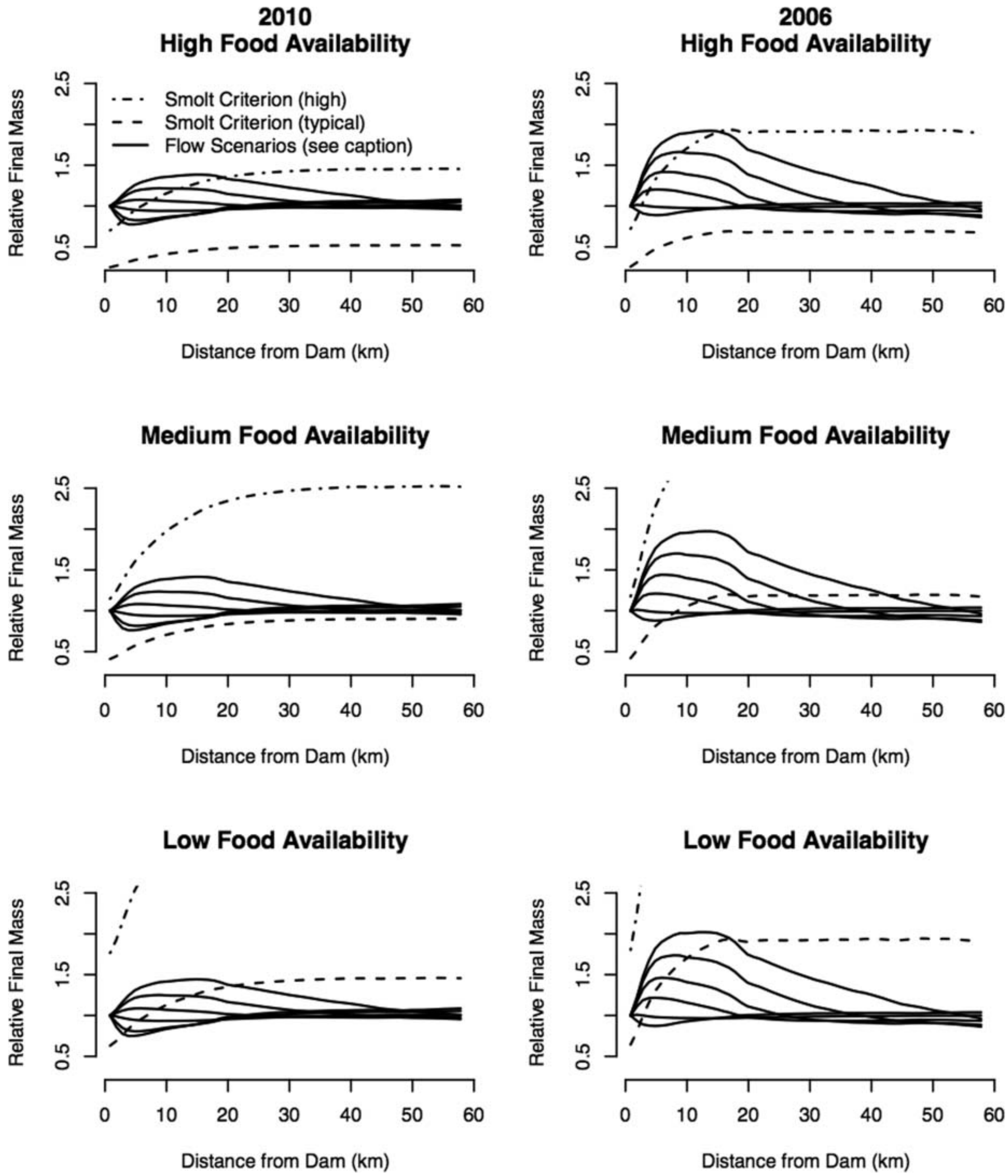

FIGURE 6. Relative final mass for age-0 steelhead on October 1 as modeled for various flow scenarios (solid lines), years (columns), and levels of food availability (rows) at locations downstream of Bradbury Dam on the Santa Ynez River. The "typical" smolt criterion describes the final mass on October 1 that is assumed necessary to trigger smolting and out-migration during the following spring, given typical winter growth conditions. The "high" smolt criterion conservatively assumes zero winter growth. Flow scenarios (lines from top to bottom) are 5.7, 4.3, 2.8, 1.4, 0.71, and 0.28 m^3/s.

Age-1 fish.—In 2010, the entire river could support the second-summer pathway under a typical smolting criterion, regardless of food availability (Figure 7A, C, E). Under the high smolting criterion, the area supporting the second-summer pathway was still the entire river if food availability was high (Figure 7A), but the area shrank to a flow-dependent zone near the dam if food availability was intermediate (Figure 7C). The year 2006 gave similar overall results except

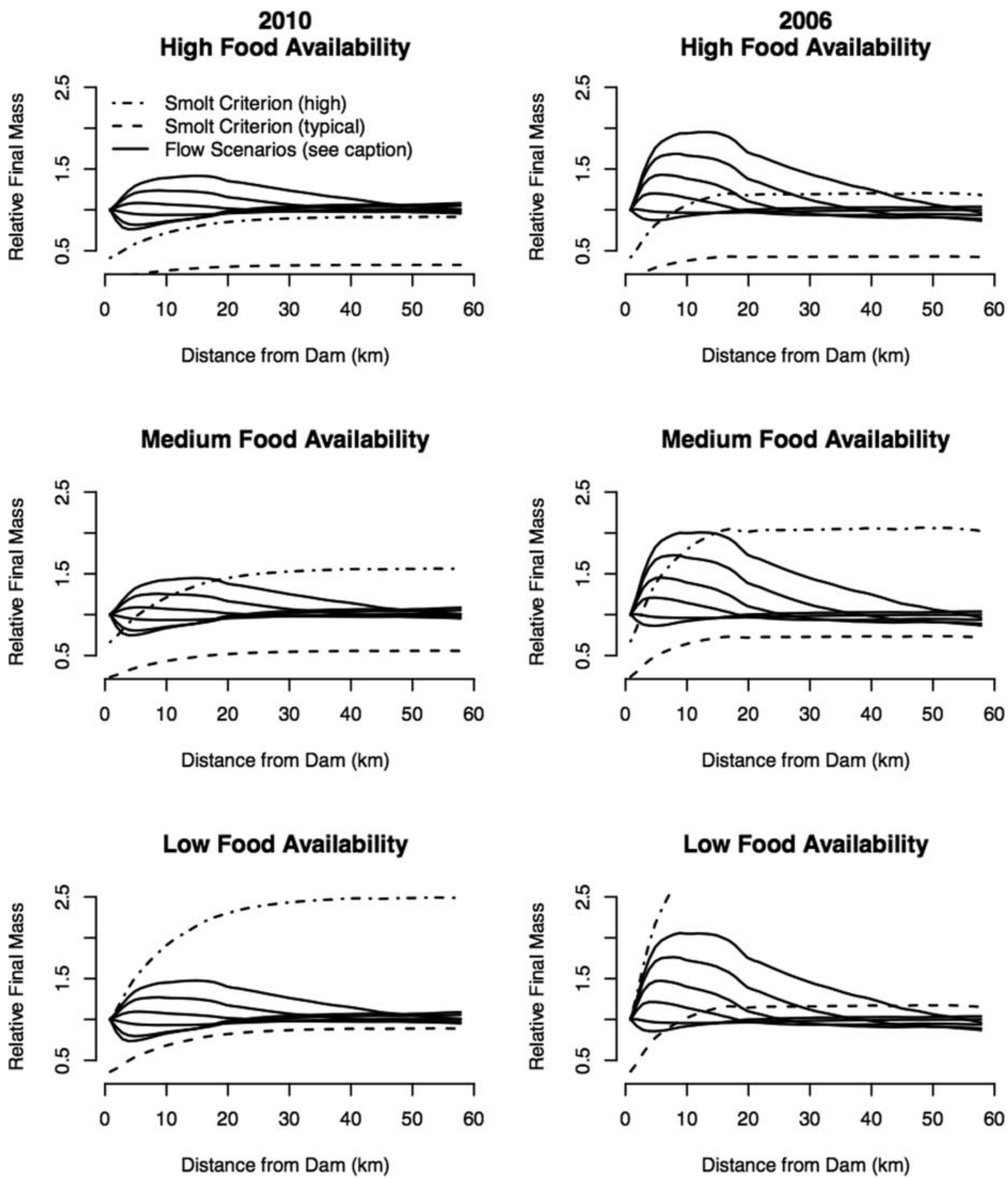

FIGURE 7. Relative final mass for age-1 steelhead on October 1 as modeled for various flow scenarios (solid lines), years (columns), and food availability (rows) at locations downstream of Bradbury Dam on the Santa Ynez River. The "typical" smolt criterion describes the final mass on October 1 that is assumed necessary to trigger smolting and out-migration during the following spring, given typical winter growth conditions. The "high" smolt criterion conservatively assumes zero winter growth. Flow scenarios (lines from top to bottom) are 5.7, 4.3, 2.8, 1.4, 0.71, and 0.28 m^3/s.

that reaches supporting a second-summer pathway shrank from the entire river to the zone below the dam for two scenarios: (1) high food availability plus the high smolting criterion (Figure 7B); and (2) low food availability plus the typical smolting criterion (Figure 7F). The size of the nursery zone generally ranged from 5 to 18 km depending on flow; however, for very high flows (>4 m^3/s), the zone could extend as far as 43 km downstream.

In no case did a flow scenario convert the entire river into potential nursery habitat—either the combination of year (meteorological conditions) and food availability produced riverwide nursery habitat or the flow scenarios created a nursery zone near the dam that disappeared downstream as the river reached thermal "quasi-equilibrium" with meteorological conditions. Only for flows greater than 4 m^3/s was the nursery zone ever longer than approximately 20 km.

Stratified Pools

Of the 14 pools that were successfully monitored, eight (~60%) were thermally stratified. Neither the bottom nor the main flow of any pool became thermally unsuitable for steelhead during the study, but water temperatures were often stressful. Mean daily stress intensity was consistently lower at the bottoms of stratified pools (Figure 8).

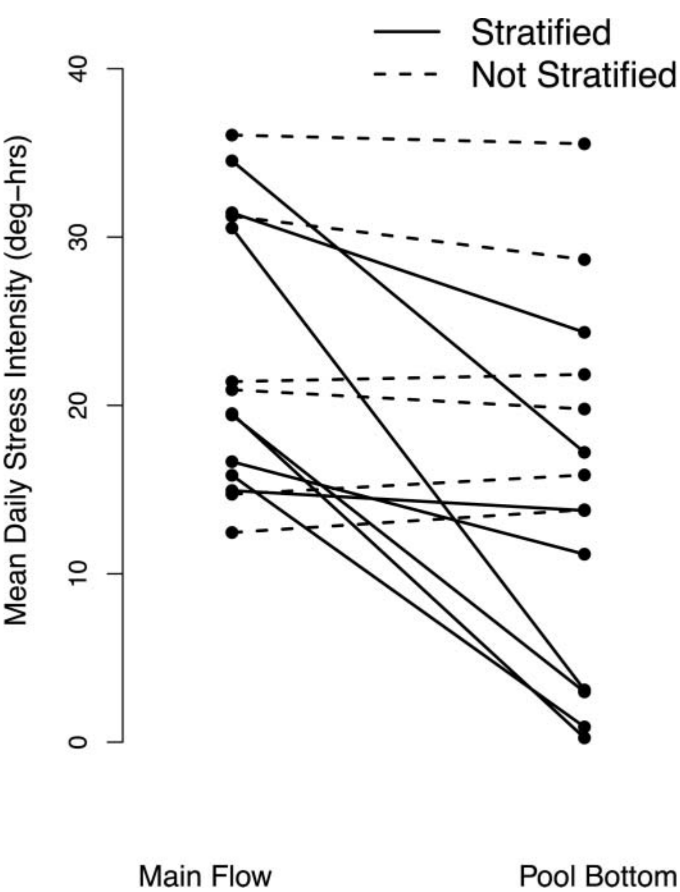

FIGURE 8. Mean daily intensity of thermal stress (degree-hours) for steelhead, as measured in the main flow and at the bottom of thermally stratified and unstratified pools in the Santa Ynez River during summer 2011.

Only five of the pools were thermally stratified on the day of their fish survey; of these pools, three harbored juvenile *O. mykiss*, whereas only one of the nine unstratified pools harbored *O. mykiss* (one-tailed z-test: $P = 0.027$).

DISCUSSION

Thermal Potential for Steelhead Life Histories

The simulations suggested that even during relatively hot summers, a coastal alluvial river in southern California was thermally suitable for juvenile steelhead. Nevertheless, nearly every summer day in both 2006 (the hot year) and 2010 (the average year) was thermally stressful throughout the Santa Ynez River, with stress intensity about 20% higher during 2006 than during 2010. Increasing the flow did not reduce the number of thermally stressful days except in an area just downstream of Bradbury Dam, but it did reduce the stress intensity throughout the entire river (Figure 5). Our data suggest that fish movement into stratified pools when temperatures exceed 21°C would tend to reduce stress intensity by an amount comparable to that achieved by increasing the flow (10–20 degree-hours/d; Figure 8). Presumably, this retreat to stratified pools would lower the rearing capacity for the river as a whole. However, juvenile steelhead appear to be able to use thermal refugia as a base from which to exploit the wider river during cool times of day (Brewitt and Danner 2014), so overall rearing capacity would be considerably larger than the pools themselves. Increasing the water releases from the dam might have additional benefits beyond stress reduction, such as increasing the river's capacity for first-summer life histories relative to second-summer life histories, thus supporting a greater life history diversity overall.

Predictions for potential steelhead nursery habitat can be summarized as follows. If the Santa Ynez River system supports typical winter growth, the second-summer pathway will be thermally available throughout the entire lower river but will be sensitive to climate if summer feeding opportunity is low. The first-summer pathway will also be thermally available but will become sensitive to climate when feeding opportunity is intermediate. In such situations, the pathways to anadromy can become thermally restricted to a tailwater zone below Bradbury Dam. On the other hand, if the river system produces neglible winter growth, then nursery habitat usually will be restricted to the tailwater or will be completely absent, depending on food availability.

In the simulations, flow scenarios did not determine whether the entire Santa Ynez River was nursery versus nonnursery habitat. Flow only altered the spatial extent of the tailwater zone when the river was otherwise physically unsuited to producing rapid growth of *O. mykiss*. Downstream of this zone, the river temperature became more equilibrated to local microclimate and riverbed conditions. Thus, temperature presumably became shaped much more by natural processes than by upstream dam releases and therefore was more similar to what would generally be considered an unimpaired thermal regime for this climate. In general, temperatures tended to stay above the range for maximum growth (15–17°C) but below the threshold for thermal exclusion (mean daily temperature <25°C, maximum temperature <29°C). Whether the river is thermally suitable for steelhead production (as opposed to producing *O. mykiss* that grow slowly and mature in freshwater) appears to depend more on annual weather than on flow, at least for the 2 years studied. This result accords with historical information for the late-19th and early 20th centuries, which suggests that annual runs of adult steelhead in the Santa Ynez River numbered in the thousands during some years and in the single digits during other years (Alagona et al. 2012).

Recent annual runs of steelhead in the Santa Ynez River have consistently stayed below approximately 10 fish since intensive monitoring began in the 1990s (Robinson et al. 2009). Our results suggest that water temperatures are not so high that they eliminate the potential for considerable smolt production; this indicates the existence of some other factor that keeps current steelhead production depressed relative to the production observed a century ago. Recent snorkel surveys conducted in the summer usually have found juvenile *O. mykiss* to be few and concentrated in stratified pools (Robinson et al. 2009), suggesting that very few fish currently pursue a first-summer or second-summer strategy in the lower main stem. The capacity for the second-summer pathway could also be limited by a lack of suitable upland creek habitat that can support successful spawning by anadromous *O. mykiss* and successful rearing of their progeny up to the second summer. Currently, most such habitat occurs upstream of the dam, where it is inaccessible to anadromous steelhead although commonly used by Rainbow Trout.

Exotic fish species almost certainly impact steelhead rearing in the Santa Ynez River. In particular, Largemouth Bass are quite abundant in the lower river (Robinson et al. 2009), occupy a thermal niche that broadly overlaps with the thermal niche of steelhead (Currie et al. 1998, 2004), and may both compete with and prey on juvenile steelhead (Hodgson et al. 1991; Christensen and Moore 2008, 2010; Braun and Walser 2011). Prior to the introduction of exotic fishes, southern California steelhead would have been the only medium-to-large bodied fish (>150 mm TL) feeding on invertebrates and other fishes in the Santa Ynez River and in nearby streams, where steelhead remain the only such fish and are observed to behave normally in water temperatures up to around 24°C (Spina 2007; Sloat and Osterback 2013). One explanation for the rarity of steelhead in the Santa Ynez River may be the competitive or predatory dominance of introduced fish (e.g., Largemouth Bass) that are adapted to the high end of the steelhead's thermal niche.

Shallow-River Heat Dynamics

Changing climate is generally expected to decrease summer flows relative to winter flows in western U.S. rivers that are occupied by Pacific salmonids; mechanisms include less water storage in deep soil, increased water demand by vegetation, greater surface evaporation, and especially the loss of snowpack (Mantua et al. 2010; Null et al. 2010). Although decreased summer flow affects heat fluxes by a variety of mechanisms, for simplicity these are often omitted from assessments (Mantua et al. 2010; Wenger et al. 2011; Benjamin et al. 2013). Instead, water temperature is assumed to track air temperature; this assumption relies on equilibrium assumptions that are only valid at relatively large flows and at a resolution of weekly (or coarser) average temperature (Bogan et al. 2003). Finer-grained temperature patterns, such as daily maximum temperature or degree-hours above some temperature threshold, are often biologically important but are poorly predicted by equilibrium assumptions. For example, Caissie et al. (2001) used statistical techniques to predict maximum daily creek temperature from air temperature and found that the empirical coefficient linking stream temperature and air temperature varied seasonally and was not independent of flow within seasons.

In general, subdaily temperature patterns should be sensitive to flow because for a given channel geometry and microclimate, flow establishes the scaling between heat fluxes and the thermal mass, or responsiveness, of the stream. Heat fluxes tend to scale to areas (surface area, streambed area, and cross-sectional area), whereas thermal mass, which describes the temperature response to a given flux, scales to water volume. In contrast to deep rivers, such as those fed by snowmelt, a wide, shallow river like the Santa Ynez River will have a cross-sectional area and volume that are quite small relative to horizontal surface areas; thus, longitudinal flux and thermal mass will be small relative to vertical energy fluxes. Longitudinal heat flux is reduced even further by slow water velocities in shallow rivers due to a greater effect of bed roughness. This situation would tend to decouple a shallow river from upstream conditions and raise the river's responsiveness to vertical heat exchange with the immediate riverbed and atmosphere. Since thermal mass acts as a sort of "smoother" on the temperature response, a RAFT hindcast for a shallow river such as the Santa Ynez River should involve greater error than a hindcast for a deeper river with a relatively high thermal mass; indeed, this is what we observed (RMSE = 1.5°C for the Santa Ynez River, whereas RMSE = 0.5°C for the Sacramento River; Pike et al. 2013).

Our results suggest that when the thermal mass of the water itself becomes small relative to vertical heat flux, the thermal mass of the riverbed becomes an important smoother of subdaily fluctuations. In the RAFT model, heat exchange between water and bed passively follows thermal gradients and thus reduces the temperature response to the diurnal fluctuations in atmospheric heat fluxes. When we conducted RAFT simulations with the streambed flux turned off (results not reported here), we found that this mechanism was essential to accurately hindcasting the temperatures of the lower Santa Ynez River. In our results, each doubling (or halving) of flow changed the maximum daily temperature by less than 1°C in most of the river (Figure 4), suggesting that a large amount of water must be released to add enough thermal mass to significantly augment what the riverbed already provides. In general, heat exchanges between rivers and their beds are often highly heterogeneous due to various mechanisms (Constantz 1998; Arscott et al. 2001; Arrigoni et al. 2008; Burkholder et al. 2008; Westhoff et al. 2010; Boughton et al. 2012). Anticipation of such heterogeneity may be important in identifying rivers with greater thermal resilience to the loss of summer flow, which is expected to result from climate change.

In our case study, changes in flow altered summer thermal habitat in the Santa Ynez River by two mechanisms: (1) the release of water that was out of thermal equilibrium with the local climate directly downstream of the dam; and (2) modulation of the mean depth—and thus thermal mass—of the entire river. Mechanism 1 produced a zone near the dam that functioned as a heat sink, with thermal properties that attenuated rapidly downstream, whereas mechanism 2 produced a heat buffer throughout the river. Steelhead indices that were sensitive to fine-grained fluctuations in temperature (e.g., stress intensity) responded to flow scenarios throughout the entire river (Figure 5). In contrast, the indices that integrated temperature effects over multiple days (e.g., potential growth) only responded strongly to flow scenarios within 20 km of Bradbury Dam (Figures 6, 7) or to extremely high-flow scenarios (>2.8 m^3/s [>100 ft^3/s]) that would probably not be characteristic of the river if the dam was absent. By decreasing upstream temperature, increasing mean depth, and raising water velocities, large enough summer releases from the dam might expand steelhead life history diversity in the Santa Ynez River, especially by enabling more steelhead to pursue a first-summer pathway, although it remains unclear whether this first-summer expression would be characteristic of the river in the absence of dams.

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	UOWTI	UTWTI	Incip Lethal WTI	Other WTI Values?	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fall-run Chinook Salmon																
Adult Upstream Migration																
Adult Spawning																
Egg Incubation and Fry Emergence																
In-River Rearing (Age 0+)																
Smolt Outmigration																
Spring-run Chinook Salmon																
Adult Upstream Migration																
Adult Holding																
Adult Spawning																
Egg Incubation and Fry Emergence																
Fry Rearing																
Juvenile Rearing and Downstream Movement																
Smolt Outmigration																
Steelhead																
Adult Upstream Migration																
Adult Spawning																
Egg Incubation and Fry Emergence																
Fry Rearing																
Juvenile Rearing and Downstream Movement																
Smolt Outmigration																

UOWTI = Upper Optimum Water Temperature Index
UTWTI = Upper Tolerance Water Temperature Index

November 2016

Thermal Suitability Considerations for Anadromous Salmonid Reintroduction

LA GRANGE HYDROELECTRIC PROJECT

FERC NO. 14581

December 1, 2016

Evaluating Thermal Habitat Suitability

- A fundamental component in determining the feasibility of a reintroduction program for anadromous salmonids.
- An initial step in evaluating physical habitat suitability and availability.
  - If habitat is not thermally suitable then it will not be suitable from other habitat perspectives.
- Purpose – To establish the technical basis to evaluate water temperature regimes for anadromous salmonid reintroduction into the Tuolumne River upstream of Don Pedro Reservoir.

Process Overview

- **Literature Review**
  - Conduct a comprehensive literature review of species/lifestage-specific water temperature relationships.
- **Water Temperature Indices**
  - Identify a suite of water temperature index (WTI) values representing a summarization of the literature review. A WTI value is an integer in a sequence characterizing thermally-related physiologic and behavioral responses.
- **Water Temperature Metrics**
  - Identify water temperature metrics and metric application to water temperature monitoring and/or modeling data. Water temperature metrics provide a reproducible measure of temperature over a period of time that can be used in combination with WTIs to determine thermal suitability.
- **Water Temperature Evaluation Guidelines**
  - Select water temperature guidelines (WTIs and metrics) for each species/lifestage-specific period for reintroduction evaluation.
- **Evaluation Methodology**
  - Identify water temperature evaluation methodological approach.

Literature Review

Water Temperature Effects

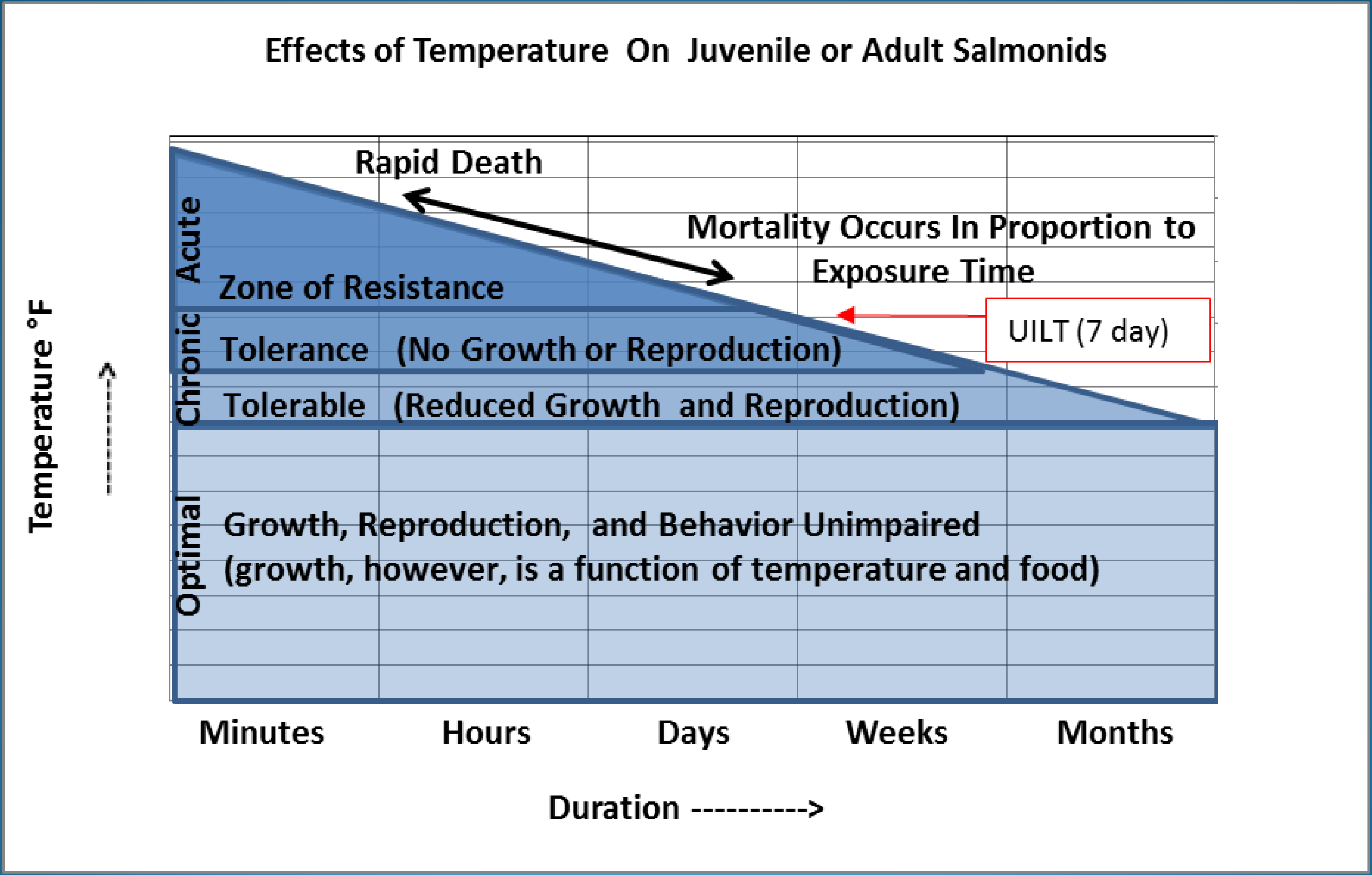

Illustration of Acute, Chronic, and Optimal Temperature Zones (adapted from Sullivan et al. 2000).

Water Temperature

LETHAL – temperatures at which direct mortality occurs.

X

Critical Thermal Maximum – Very short duration (minutes) mortality after acute temperature exposure.

Acute – Temperatures at which short-term exposure (<7days) results in rapid mortality. Mortality occurs in proportion to magnitude and duration of exposure.

Upper Incipient Lethal (UILT) – Boundary between lower end of acute temperature exposure range and upper end of chronic temperature exposure range. Temperature at which 50% mortality occurs after 7 days.

Sublethal – Temperatures that can result in indirect mortality, or that may reduce the survival and fitness of offspring. Associated with reduced disease resistance, reproductive success, juvenile growth and survival. Interference with physiological processes (e.g., metabolism, smoltification). Reduced competitive ability and altered behaviors (e.g., migration).

Suboptimal – Does not cause direct mortality, but may result in a higher probability of diminished success of a particular life stage due to sublethal effects (e.g., reduced fitness, viability, competitive ability or growth, and increased susceptibility to disease) .

Chronic – Long-term (> 7 days) exposure associated with reduced growth and reproduction. With increasing magnitude and duration of exposure, increasing potential for no growth and reproduction, and increased mortality.

Upper Tolerable (UT) – Upper boundary of the range of water temperatures at which fish can survive indefinitely, without experiencing substantial detrimental effects to physiological and biological functions such that survival occurs, but growth and reproduction success are reduced below optimal.

Upper Optimal (UO) – Upper boundary of the optimal temperature range where physiological processes (growth, reproduction, disease resistance) and behavior are not stressed by temperature.

OPTIMAL – temperatures at which physiological processes (growth, reproduction, disease resistance) and behavior are not stressed.

Water Temperature Metrics

- Designed to provide a reproducible index of water temperature over a period of time that can be used in combination with index values to determine habitat suitability for reintroduction.

- Metrics for potential application to the WTI values
  - ADT - Average Daily Temperature
  - 7DADM - Maximum of the Running 7-Day Average of the Daily Maxima for a specified time period
  - MWAT - Maximum of the Running Weekly (7-Day) Average Daily Temperature for a specified time period

Water Temperature Metrics

Average Daily Temperature

- Average daily temperature (ADT) could be considered for application because a majority of data in the literature review are based on ADT or continuous (constant) temperature.

- ADT can be used to determine the number of days (duration) that a water temperature index is exceeded, and duration of exceedance can be compared among specific geographic areas.

Water Temperature Metrics

Maximum 7-Day Average of the Daily Maxima

- The EPA (2003) recommends the maximum 7-day average of the daily maxima (7DADM)… "*because it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day*".

- 7DADM is calculated by summing the daily maximum temperatures at a site for 7 consecutive days and dividing by 7.

Water Temperature Metrics

Maximum Weekly Average Temperature

- Maximum Weekly Average (Daily) Temperature (MWAT) is a summary measurement of instream water temperature variation that may occur on a daily or seasonal basis, and is used to evaluate chronic (sub-lethal) water temperature impacts.

- MWAT is found by calculating the mathematical mean of multiple, equally spaced, daily water temperatures over a 7-day consecutive period. The MWAT is defined as the highest value calculated for all possible consecutive 7-day periods over a given time period.

Lifestage & Water Temperature Indices

Steelhead

Lifestage	WTI Identified in Literature Review	WTIs for Reintroduction Consideration
Adult Upstream Migration	52°F, 56°F, 61°F, 64°F, 65°F, 68°F, 70°F	?
Adult Spawning	46°F, 52°F, 54°F, 55°F, 57°F, 59°F, 60°F	?
Egg Incubation and Fry Emergence	46°F, 52°F, 54°F, 55°F, 57°F, 59°F, 60°F	?
Fry Rearing	61°F, 63°F, 64°F, 65°F, 68°F, 72°F, 75°F, 77°F	?
Juvenile Rearing and Downstream Movement	61°F, 63°F, 64°F, 65°F, 68°F, 72°F, 75°F, 77°F	?
Smolt Outmigration	52°F, 55°F, 57°F, 59°F, 77°F	?

Lifestage & Water Temperature Indices

Spring-run Chinook Salmon

Lifestage	WTIs Identified in Literature Review	WTIs for Reintroduction Consideration
Adult Upstream Migration	60°F, 61°F, 64°F, 65°F, 68°F, 70°F	?
Adult Holding	60°F, 61°F, 64°F, 65°F, 68°F, 70°F	?
Adult Spawning	55°F, 56°F, 58°F, 60°F, 62°F	?
Egg Incubation and Fry Emergence	55°F, 56°F, 58°F, 60°F, 62°F	?
Fry Rearing	60°F, 61°F, 64°F, 65°F, 68°F, 70°F, 75°F, 77°F	?
Juvenile Rearing & Downstream Movement	60°F, 61°F, 64°F, 65°F, 68°F, 70°F, 75°F, 77°F	?
Smolt Outmigration	57°F, 59°F, 63°F, 68°F 72°F, 77°F	?

Lifestage & Water Temperature Indices
Fall-run Chinook Salmon

Lifestage	WTI Identified in Literature Review	WTIs for Reintroduction Consideration
Adult Upstream Migration	60°F, 61°F, 64°F, 65°F, 68°F, 70°F	?
Adult Spawning	55°F, 56°F, 58°F, 60°F, 62°F	?
Egg Incubation and Fry Emergence	55°F, 56°F, 58°F, 60°F, 62°F	?
In-River Rearing (Age 0+)	60°F, 61°F, 64°F, 65°F, 68°F, 70°F, 75°F, 77°F	?
Smolt Outmigration	57°F, 59°F, 63°F, 68°F 72°F, 77°F	?

Process Overview

- **Literature Review**
  - **Conduct a comprehensive literature review of species/lifestage-specific water temperature relationships.**
- **Water Temperature Indices**
  - **Identify a suite of WTI values representing a summarization of the literature review.**
- **Water Temperature Metrics**
  - **Identify potential water temperature metrics for application to water temperature monitoring and/or modeling data.**
- **Water Temperature Evaluation Guidelines**
  - **Select water temperature guidelines (WTIs and metrics) for each species/lifestage-specific period for reintroduction evaluation.**
- **Determine Species/Run-Specific Lifestage Periodicities**
  - **Establish the time period associated with each lifestage.**
- **Evaluation Methodology**
  - **Compare temperature guidelines to monitored and/or modeled data.**
  - **Quantify the length of river with suitable species/run lifestage-specific water temperatures.**

Thermal Suitability Considerations for Anadromous Salmonid Reintroduction

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

December 1, 2016

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

REINTRODUCTION ASSESSMENT FRAMEWORK GOALS SUBCOMMITTEE IN-PERSON MEETING

DECEMBER 1, 2016

FINAL MEETING NOTES AND MATERIALS

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La Grange Hydroelectric Project Licensing (FERC No. 14581)
Fish Passage Facilities Alternatives Assessment
Reintroduction Goals Subcommittee Meeting

Thursday, December 1, 2016
2:30 pm to 4:00 pm

Final Meeting Notes

Meeting Attendees		
No.	**Name**	**Organization**
1	Steve Boyd	Turlock Irrigation District
2	Paul Bratovich	HDR, consultant to the Districts
3	Jean Castillo	National Marine Fisheries Service
4	Calvin Curtin	Turlock Irrigation District
5	Jesse Deason	HDR, consultant to the Districts
6	John Devine*	HDR, consultant to the Districts
7	Greg Dias	Modesto Irrigation District
8	Nann Fangue*	U.C. Davis, consultant to the Districts
9	Dana Ferreira	Office of U.S. Congressman Jeff Denham
10	Mark Gard*	U.S. Fish and Wildlife Service
11	Art Godwin	Turlock Irrigation District
12	Andy Gordus	California Department of Fish and Wildlife
13	Chuck Hanson	Hanson Environmental, consultant to the Districts
14	Zac Jackson	U.S. Fish and Wildlife Service
15	Bill Ketscher	Private citizen
16	Patrick Koepele*	Tuolumne River Trust
17	Bao Le	HDR, consultant to the Districts
18	Ellen Levin*	City and County of San Francisco
19	Lonnie Moore	Private citizen
20	Marco Moreno	Latino Community Roundtable
21	Gretchen Murphey	California Department of Fish and Wildlife
22	Bill Paris	Modesto Irrigation District
23	Amanda Ransom	HDR, consultant to the Districts
24	Bill Sears*	City and County of San Francisco
25	Samantha Wookey	Modesto Irrigation District
26	John Wooster*	National Marine Fisheries Service
27	Ron Yoshiyama	City and County of San Francisco

* Attended by phone.

On December 1, 2016, Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) hosted the third Reintroduction Goals Subcommittee (Goals Subcommittee) meeting for the La Grange Hydroelectric Project (La Grange Project) Fish Passage Facilities Alternatives Assessment and Upper Tuolumne River Fish Reintroduction Assessment Framework (Framework). This document summarizes discussions during the meeting. It is not intended to be a transcript of the meeting. Attachment A to this document provides meeting materials. This meeting began after the conclusion of the Water Temperature Subcommittee meeting, held earlier that day from 1:00 pm to 2:30 pm. Notes from the Water Temperature Subcommittee meeting are available as a separate document.

Mr. Bao Le (HDR) reviewed the background of why the Plenary Group formed the Goals Subcommittee. Mr. Le said in April 2016, the Districts were tasked with crafting a simple narrative goals statement to help begin discussions. The resulting statement is included in the agenda from the October 20, 2016, Goals Subcommittee meeting. [Narrative draft statement, as provided in the October 20, 2016 meeting agenda: "*Identify and evaluate, in collaboration with stakeholders, reasonable efforts which may enhance and assist in the recovery of ESA listed salmonids in the Central Valley"*.]

Mr. Le summarized discussions held during the October 20, 2016 meeting. He noted that since that meeting, the Districts have received no feedback on the draft goals statement. Given that no feedback was received, the Goals Subcommittee has made little progress since the October 20 meeting.

Mr. Le said reported that at the October meeting two points were made by participants: (1) that the draft goals statement represented a broad, overarching goal of the reintroduction program but possibly the addition of corollary statements could help provide greater specificity; and (2) a potential source of information to identify potential quantitative metrics to define recovery success may be found in Lindley (2007). Mr. Le said after review of Lindley (2007), a possible quantitative metric to define a successful recovery program might be achieving low extinction risk, which equates to an average of 2,500 adults over 3 years, with an annual effective population size of not less than 500 adults. Mr. Le asked if Mr. John Wooster (National Marine Fisheries Service) or others had thoughts on this. Mr. Wooster said NMFS views reintroduction differently than recovery. For example, you may have a system where the recovery goal is a certain population size, but the reintroduction goal is just a fraction of the recovery goal because the reintroduced population can be thought of as just a subset of the overall recovered population. Mr. Wooster said this may not be the case for the Tuolumne River (i.e., reintroduction and recovery may be the same), given that there are no spring-run Chinook and the steelhead population is very small.

Dr. Chuck Hanson (Hanson Environmental, consultant to the Districts) said Lindley (2007) contains criteria that state multiple independent populations are preferred over having just one population. Prior to development of the NMFS Recovery Plan, a guidance document was prepared that reviewed the criteria, approaches, and metrics that NMFS should consider when developing the Recovery Plan. Dr. Hanson said he believes the Recovery Plan has all the components necessary to inform the quantitative metrics needed to support a reintroduction goals statement. Mr. Wooster noted that Lindley (2007) is a much shorter document than the Recovery Plan and that the Recovery Plan leans heavily on Lindley (2007). Mr. Paul Bratovich (HDR) said the Recovery Plan speaks directly to the recovery of populations and talks about evolutionarily significant units (ESUs), diversity groups, and how many viable populations in each diversity group would constitute recovery. Mr. Bratovich said the Recovery Plan also uses the simpler criteria provided in Lindley et al. (2007) to define a viable population.

Dr. Hanson said during the planning phase of the San Joaquin River restoration effort, how far populations needed to be from one another to be considered independent was defined. In addition, for a population to be considered recovered, it must meet the cumulative criteria, which states there is no more than a 5 percent probability of extinction in 100 years. Dr. Hanson said the simpler criteria were developed because implementation of a population viability analysis (PVA) for each river was not feasible.

Ms. Gretchen Murphey (California Department of Fish and Wildlife) asked how steelhead on the Tuolumne River would be considered from the point of view of reintroduction, given that there are *O. mykiss* already above and below the dams. Ms. Murphey asked if those populations would be added together when considering whether the population is viable. Dr. Hanson said it is likely that both populations would be considered as one, given that they would not meet the distance criteria to be considered as two independent populations. Interbreeding would also be assumed. Mr. Bratovich noted that there is also a percent hatchery contribution criteria in the Recovery Plan. Mr. Wooster said he agrees that from a recovery perspective, the upper and lower Tuolumne River *O. mykiss* populations would be considered to be a single population. Mr. Wooster said it may be that the lower river group would have a different status than the upper river group. Dr. Hanson said that would be similar to what occurred for the San Joaquin River, where NMFS made spring-run Chinook an experimental/non-essential population from the perspective of the Endangered Species Act (ESA).

Regarding low extinction number, Mr. Bill Paris (Modesto Irrigation District) asked if for example 10,000 fish is the number needed to avoid extinction, does that mean 10,000 fish is the goal or that the goal is more than 10,000 fish. Mr. Bratovich said the low extinction risk number is based on the simpler criteria. One way to define the simpler criteria is an average of 833 fish over three years, no less than 500 fish per year, and a limit on hatchery contributions. Another component of the Recovery Plan states that the goal for a recovered population ranges from the abundance associated with low extinction risk up to carrying capacity. Dr. Hanson wondered how that criteria might apply if carrying capacity is less than the low extinction risk number.

Mr. John Devine (HDR) asked if it is correct to state that if a population is not viable and does not meet the effective population number, it would not add to recovery of the ESU or DPS. Dr. Hanson and Mr. Bratovich both said Mr. Devine is correct. Dr. Ron Yoshiyama (City and County of San Francisco) said it is possible that fish could be introduced into the upper river without there being enough habitat to support an effective population, but that population could be supplemented by the lower river population in order to achieve an effective population. Mr. Bratovich said that raises the question of how to define a population as independent, because if the lower river population is a metapopulation of strays and hatchery fish, it may not be independent. In that case, the question would be whether combining the lower river population with the upper river population results in a single independent population.

Mr. Le said an additional question regarding steelhead is protecting a population versus protecting a behavior. For example, in the Pacific Northwest, the intent of listing bull trout was to protect the migratory form. The resident form is not protected and is not considered when evaluating recovery success. Mr. Wooster said in California, resident fish do not have the same level of protection under ESA as the do the anadromous fish. Mr. Wooster said the population numbers from Lindley (2007) only consider the anadromous form, and the resident population is not taken into account. Ms. Murphey asked if there is consideration that resident fish are taking up part of the carrying capacity, especially when it comes to juvenile fish. Mr. Wooster said he does not know the answer to that question, but he thinks resident fish would contribute towards the carrying capacity goal, and not take away from it. Mr. Wooster said regarding juvenile steelhead, there is no way to differentiate between anadromous and resident fish. Mr. Le said it seems as though different life stages would require different criteria. Mr. Bratovich said regarding the Yuba Salmon Forum, thermally suitable habitat for spawning adult spring-run Chinook salmon was most limiting, whereas thermally suitable habitat during the over-summer rearing period was most limiting for steelhead.

Regarding the draft goals statement, Mr. Le said, the Districts made an effort to develop a statement that represented the diversity of positions on the issue of reintroduction. Mr. Le said given today's discussion, it appears that Lindley (2007) and the NMFS Recovery Plan contain information that would be helpful for developing additional objectives and quantitative metrics.

In addition to contributing to the recovery of ESA listed salmonids in the Central Valley, Mr. Le said socioeconomic and economic concerns are also captured in the draft goal statement. Mr. Le said in the past, individuals have stated that it would not be prudent for the Districts to spend millions of dollars to benefit just a handful of fish. Mr. Le asked meeting participants to provide feedback on this topic.

Mr. Devine said the phrases "establish a viable population" and "at fair cost" or "at reasonable cost" could be added to the draft statement after "Identify and evaluate, in collaboration with stakeholders, reasonable efforts to…". Mr. Devine asked if an updated draft goals statement might be to *"Contribute to the recovery of ESA listed salmonids in the Central Valley by establishing viable populations in the Tuolumne River at fair and reasonable cost."* Ms. Jean Castillo (NMFS) asked if "viable population" is a quantifiable metric. Mr. Devine said it is quantifiable. Ms. Castillo said "fair and reasonable cost" is open to interpretation, and we need to be clear on what that phrase really means. Mr. Le said there the subcommittee could further define both "viable population" and "fair and reasonable cost" in corollary statements. Ms. Castillo asked if the first two parts of the goals statement were met, does cost matter? Mr. Devine said that from the Districts' perspective, the cost matters, even if it does achieve a viable population. For example, if the cost to achieve a viable population is a billion dollars, the Districts would certainly question whether the program is worth doing. Mr. Lonnie Moore (private citizen) said "fair and reasonable" is very debatable, but possibly "cost effective" is a better way to phrase it. Mr. Bill Ketscher (private citizen) said it is important to consider impacts to the local economy. If the program costs a certain amount of money to achieve a viable population, the cost may still not be reasonable because the impacts to the local economy are so great. Ms. Murphey suggested using something more vague, such as "economic feasibility", and that the Socioeconomic Study might produce information that could be developed into a corollary statement. Mr. Moore said the group could look at the costs of similar projects to determine what is "cost effective." Mr. Devine said such true cost data would very likely be hard to come by, that it would be difficult to compare projects to one another, and that "cost effective" is also a phrase open to debate.

Mr. Paris requested that the new draft statement be sent out to the group. Mr. Le said the Districts will send the statement out to allow time for folks to consider it and provide their thoughts. Mr. Bratovich noted that the draft narrative goal statement is meant to be an overarching statement that addresses a number of different elements at a high level. Given the discussion of better defining terms and identifying quantifiable metrics to better measure recovery success, a potential next step might be to develop a series of objectives that support the draft goal statement. Mr. Le stated that he sees these objective statements as being synonymous to corollary statements. Mr. Moore asked if the Districts would be drafting corollary statements. Mr. Le suggested it might be better as a first step for participants to review the new draft statement and provide any further input. In the course of this review, suggestions for potential corollary statements would be helpful as well. Dr. Yoshiyama asked that language be added to the end of the statement that would lead into the corollaries, such as "specific issues and concerns are addressed in more detail in the following corollaries". Mr. Le agreed that such additional language could be added.

Meeting participants discussed a date for next meeting. Mr. Le said he send out a Doodle poll.

The meeting concluded.

<u>Action Items</u>

1. The Districts will circulate the revised draft narrative goals statement to the Goals Subcommittee for review and comment (complete)

2. The Districts will send out a Doodle poll (complete)

La Grange Hydroelectric Project
Reintroduction Assessment Framework
Water Temperature/Reintroduction Goals Subcommittees – In-person Meeting

Thursday, December 1, 2016, 1:00 pm to 4:00 pm

Modesto Irrigation District, 1231 11th St., Modesto, CA 95354
Conference Line: 1-866-583-7984; Passcode: 814-0607

Meeting Objectives:

1. Review and discuss updated water temperature literature review summary, glossary of terms/acronym list based upon comments received.
2. Presentation and discussion on relevant temperature terms.
3. Discuss water temperature indices (WTI) when considering anadromous fish reintroduction in the Upper Tuolumne River.
4. Discuss next steps and schedule for WTI selection.
5. Review, discuss and modify draft narrative reintroduction goals statement.
6. Discuss next steps and schedule for finalizing a reintroduction goals statement.

TIME	TOPIC
1:00 pm – 1:10 pm	Introduction of Participants (All) Review Agenda and Meeting Objectives (Districts)
1:10 pm – 2:30 pm	Water Temperature Subcommittee Topics (All) a. Updated Literature Review Summary and Acronym List– comments received (Districts) b. Presentation and discussion on relevant temperature terms (Districts) c. Subcommittee discussion of potential WTI values (All) - NMFS Input
2:30 pm – 3:50 pm	Reintroduction Goals Subcommittee Topics (All) a. Additional discussion on current draft narrative reintroduction goals statement (All) b. Subcommittee discussion of further development of draft narrative goal statement (All) - Additional corollary statements? - Quantitative input (Lindley 2007)?
3:50 pm – 4:00 pm	Next Steps (All) a. Schedule next call and agenda topics b. Action items from this call