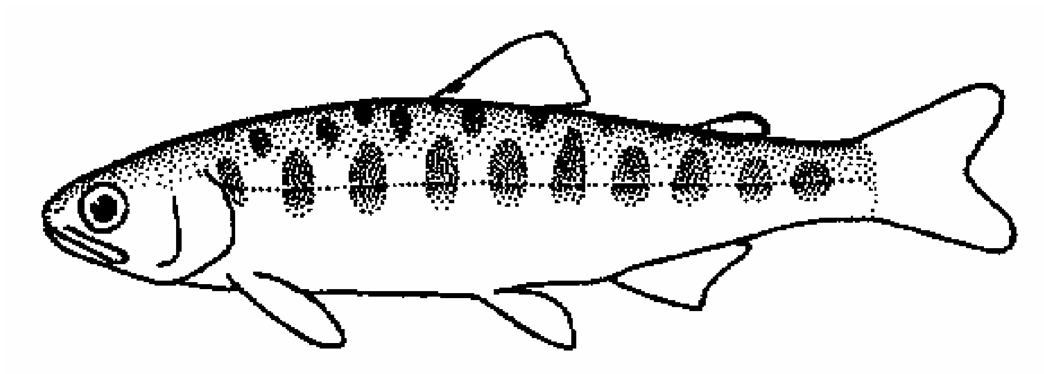
FLOW-OVERBANK INUNDATION RELATIONSHIP FOR POTENTIAL FALL-RUN CHINOOK SALMON AND STEELHEAD/RAINBOW TROUT JUVENILE OUTMIGRATION HABITAT IN THE TUOLUMNE RIVER



U. S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, CA 95825

Prepared by staff of The Energy Planning and Instream Flow Branch

CVPIA INSTREAM FLOW INVESTIGATIONS
TUOLUMNE RIVER FALL-RUN CHINOOK SALMON
AND STEELHEAD/RAINBOW TROUT OUTMIGRATION HABITAT

PREFACE

The following is the final report for the U.S. Fish and Wildlife Service's investigations on anadromous salmonid outmigration habitat in the Tuolumne River between La Grange Dam and river mile 22, using existing Geographic Information System (GIS) data. This current study is part of the Central Valley Project Improvement Act (CVPIA) Instream Flow Investigations. Title 34, Section 3406(b)(1)(B) of the CVPIA, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service, after consultation with the California Department of Fish and Game. The purpose of these investigations is to provide scientific information to the U.S. Fish and Wildlife Service (USFWS) Central Valley Project Improvement Act Program to assist in developing such recommendations for Central Valley rivers.

Written comments or information can be submitted to:

Mark Gard, Senior Biologist
Energy Planning and Instream Flow Branch
U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, CA 95825

Mark_Gard@fws.gov

ACKNOWLEDGMENTS

The database used for this study was provided by Scott McBain of McBain and Trush, Arcata, California, with the permission of Turlock Irrigation District (TID) and Modesto Irrigation District (MID). Invaluable assistance concerning the history of the data and location of documentation was provided by Brian Powell, Becky McBain, Darren Mierau, Tim Ford, Noah Hume, Rafael Real de Asua and Dirk Pedersen. Data analysis and report preparation were performed by Bill Pelle and Mark Gard. Funding was provided by the Central Valley Project Improvement Act.

ABSTRACT

A preliminary flow-overbank inundation area relationship was derived for the lower Tuolumne River downstream of La Grange Dam with the view that, with restoration, the inundated former natural floodplain could provide habitat for outmigrating juvenile rainbow/steelhead trout and fall-run Chinook salmon. ARC GIS data used for this study was originally developed as part of the Federal Energy Regulatory Commission hydro-relicensing proceedings for the Don Pedro Project (Project No. 2299). The GIS layers used were first developed from aerial photos taken at flows between 100 and 8,400 cubic feet per second (cfs) from 1988 through 1995. In our analyses, shape files were edited to remove islands and isolated pond areas, which are actually gravel pits. Total area was then recalculated for all the remaining polygons for each flow/layer. A curve was then generated by plotting area in acres versus flow. The initiation of overbank flow occurs between 1,100 cfs and 3,100 cfs. In addition, there were several flooded gravel pits that were not connected to the river until flows exceeded somewhere between 620 and 1,100 cfs, one large pit that was not connected to the river until flows exceeded somewhere between 4,030 and 5,300 cfs, and two large pits that were not connected to the river until flows exceeded somewhere between 5,300 and 8,400 cfs. Studies suggest that these pits may contain exotic predator species, particularly black bass, and concerns have been raised by others that flow connectivity between these pits and the river could result in predation or introduce predators to the river. However, there is substantial evidence that the benefits of floodplain inundation far outweigh the potential negative benefits of connectivity to these mine pits and there is no evidence that predatory refugia in off-channel mine pits contributes to in-channel predation of juvenile salmonids. It is hoped that these results of this study, combined with existing and future investigations, may provide input for ongoing restoration planning efforts for the lower Tuolumne River.

INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act (CVPIA) provided for enactment of all reasonable efforts to double sustainable natural production of anadromous fish stocks including the four races of Chinook salmon (fall, late-fall, winter, and spring runs), steelhead, white and green sturgeon, American shad and striped bass. For the Tuolumne River, the Central Valley Project Improvement Act Anadromous Fish Restoration Plan calls for supplementing Federal Energy Regulatory Commission (FERC) agreement flows as needed to improve conditions for all life history stages of Chinook salmon (USFWS 1995). Restoration efforts by the CVPIA, 4-Pumps Mitigation Agreement, and the California Water Policy Council and Federal Ecosystem Directorate (CALFED) Ecosystem Restoration Program since 1992 have increased the production of Chinook salmon in the Sacramento River Basin; whereas Chinook salmon production has declined in the San Joaquin River Basin, which includes the Stanislaus, Tuolumne, and Merced rivers. Population trends analyses for the San Joaquin River Basin suggest that salmon recruitment, which is the number of salmon that survive to the adult stage, is highly correlated with the magnitude and duration of spring flows when the fish were subyearling juveniles rearing in the tributaries (Mesick and Marston 2007). The number of smolt-sized outmigrants from the Stanislaus and Tuolumne rivers is also highly correlated with flow magnitude between February and mid-June (Mesick et al. 2007). These results suggest that fry survival in the tributaries is highest during prolonged periods of flooding and that adult recruitment is highly dependent on fry survival in the tributaries. It is likely that prolonged flooding affects fry survival by providing autochthonous food resources, providing refuge from predators, reducing water temperatures particularly during downstream migrations in May and June, slowing the rate of disease infestation, diluting contaminants, and reducing entrainment (Mesick et al. 2007). Some of these benefits such as increased food resources and refuge from predators could be provided either by higher flows inundating existing floodplains or by constructing lower-elevation floodplains that become inundated on an annual basis with existing flows. However, other benefits such as reduced water temperatures and contaminant dilution would probably only occur during high flows.

In January 2007 the USFWS Anadromous Fish Restoration Program office requested a study of floodplain inundation as a function of flow for the entire anadromous reach on the Tuolumne, Stanislaus, Merced, or the San Joaquin River, using existing data. The objective of this study was to evaluate floodplain inundation area on the lower Tuolumne River at flows ranging from low flow summer conditions (100 cfs) to flood conditions (8,400 cfs). Results from this study will eventually be added to larger modeling studies with two larger/broader objectives. First, the data will be used for analyses of the relationship between floodplain inundation and tributary smolt production. Second, the estimated amount of available functional floodplain habitat will be used to estimate the amount of habitat to be restored to achieve the doubling goal for Chinook salmon.

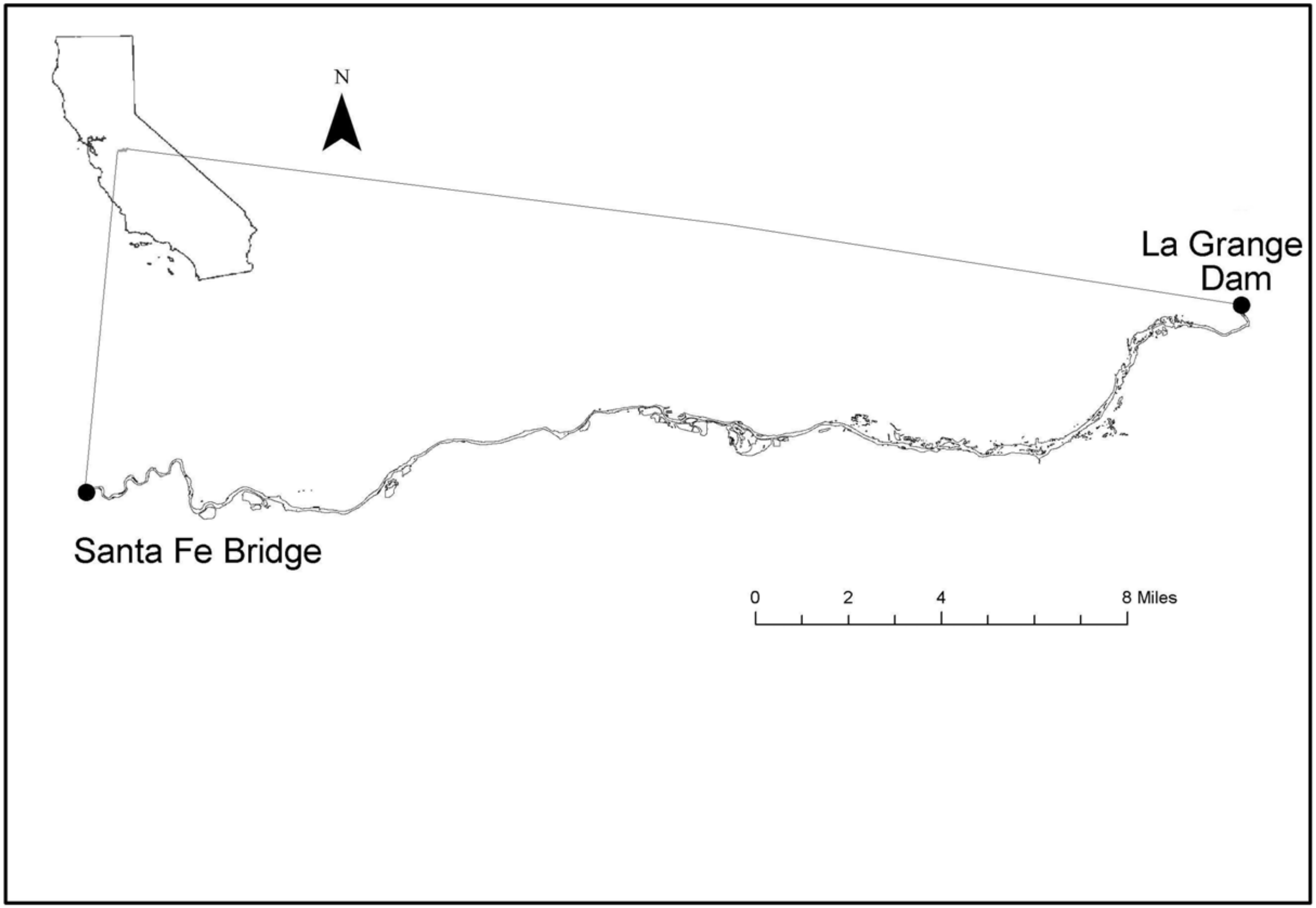


Figure 1. Lower Tuolumne River study area.

The lower Tuolumne River was chosen for this study, as appropriate GIS data was available for the reach between La Grange Dam at river mile (RM) 52 and just upstream of the Santa Fe Bridge, at RM 21.5, near the town of Empire (Figure 1). This area was selected for the study because snorkeling surveys suggest that most fall-run Chinook salmon and rainbow trout rear in this reach (Turlock Irrigation District (TID) and Modesto Irrigation District (MID) 2005).

With headwaters in Yosemite National Park, the Tuolumne River is part of the San Joaquin River system, which empties into the Sacramento-San Joaquin Delta. The lower Tuolumne begins at La Grange Dam, a diversion and reregulating facility located a short distance downstream of New Don Pedro Dam, which impounds the Don Pedro Reservoir (FERC 1996).

The channel and floodplain of the lower Tuolumne River has undergone enormous changes in response to reduction in flood regime, trapping of sediment by the New Don Pedro Reservoir, operation of gold dredgers, aggregate extraction from the active channel and floodplain, and encroachment of agriculture into the riparian zone. Capture of floodplain gravel pits by the active channel has had significant effects on channel morphology, turning many reaches from lotic to basically lentic ponds and ditch-like channels (FERC 1996). The altered channel and former floodplain of the study reach is also characterized by dredge tailings and rip-rap (TID/MID 2005).

METHODS

The method used in this study is similar to a demonstration flow assessment, as described in Clackamas Instream Flow/Geomorphology Subgroup (CIFGS 2003). Direct observation of river habitat conditions are recorded at several flows and habitat is delineated in the field at each flow. Several other alternative methods, which were not selected for use in this study, are available to evaluate outmigrant flows. An empirical, and probably the most widely-used technique used to evaluate rearing habitat utility at outmigrant flows, is the use of screw traps. Also available are passage studies, where transects are placed at relatively shallow areas, water surface elevation (WSEL) and discharge data are collected at a range of flows, and a Physical Habitat Simulation System (PHABSIM) (Milhous et al. 1989) program is used to establish stage-discharge relationships. This information is then used to determine what flow results in depths at the minimum required for passage of the target species/life-stage. This method, however, seems to be more commonly used for determining upstream migration flows for adults and is described in more detail in USFWS (1994).

To develop a flow regime which will accommodate the habitat needs of anadromous species inhabiting streams it is necessary to determine the relationship between stream flow and habitat availability for each life stage of those species. The ARC GIS program, developed by ESRI, was used to calculate area inundated at a range of flows, as one way of establishing this relationship. Assumptions of this method included: 1) that there is a linear change in area between measured data; 2) that the water’s edge data was sufficiently accurate to calculate the change in inundated area with change in flow; and 3) that the relationship between inundated area and flow did not significantly change over the period of time in which the data was collected.

ARC GIS data used for this study were originally developed by EA Engineering, Science and Technology for TID/MID, as part of the 1992 Fisheries Study Report that was included in the FERC hydrolicensing proceedings for the New Don Pedro Project - Project No. 2299 (TID/MID 1992). The specific study in the report was an assessment of spawning gravel availability as a measure of potential spawning habitat. The data was also included in the 2005 Ten Year Summary Report by TID/MID for the FERC (TID/MID 2005).

Background information on the aerial photos and initial GIS development is given in TID/MID (1992). Those photos were taken during 1986-1991 at La Grange flows ranging from 96-622 cubic feet per second (cfs). TID/MID (2005) lists all the aerial photos with added flows ranging from 1,070-8,400 cfs. The photos at these higher flows were taken in 1992-1995 and were used to make four additional GIS layers. The GIS mapping products were described and provided, on CD, in TID/MID (2005), Appendix F. The mapping at flows below 1,000 cfs was done by EA (1992). The later wetted perimeter data at the higher flows came from HJW Geospatial, Inc. (Rafael Real de Asua, personal communication 2007). Polygons and wetted perimeters were hand-drawn, digitized and georeferenced using landmarks found both in the photographs and on the 7.5 minute USGS topographic quadrangles, as control points. A summary of flows with year of data collection is included in Table 1. A more detailed description of development of the layers can be found in the full reports.

As we were only interested in inundated areas connected to the main channel for our calculations, preliminary edits were made to the shapefiles to remove island and isolated pond area polygons. The majority, if not all, of these “ponds” are gravel pits and dredging scars of various sizes with a water table connection to the river itself. Some of the larger of these are visible in Figure 1. For the sake of simplicity, the terms “pits” and “ponds” are used to describe any depressions in the former floodplain caused by dredge mining and gravel operations and subject to filling with water at some flow. Flows/layers used for the analysis were 100, 230, 620, 1,100, 3,100, 5,300 and 8,400 cfs.

More subjective secondary modifications were then made in an attempt to clean up the data for the purpose of this study. Here we tried to reconcile instances of disagreement between layers, which were relatively small compared to the total area of the study reach.[1] Although photos were taken over the span of almost 10 years, the authors feel that it was appropriate for the intended analyses to edit the layers to try to approach some semblance of consistency. When there was lack of agreement between layers, other adjacent flows were examined to determine which layer(s) would be modified and which would be used as a model for the change. Editing was generally needed when the wetted perimeter on a lesser flow layer extended farther than that of a greater flow. In this case these layers would be compared with the adjacent layers above and below and a judgment made on which of the first two layers was more in agreement with the others. The perimeter of the layer in lesser agreement was then modified. In addition, some

---

[1] The decision to edit does in no way infer that the original data was flawed. Modifications were made as the data was being used for a purpose other than that for which it was originally intended.

Table 1. Timing of flow photogrammetry.

Flow (cfs)	Year Photographed
100	1988
230	1986
620	1991
1,100	1992
3,100	1993
5,300	1995
8,400	1995

small, disconnected, areas in the 100 and 230 cfs layers were modified to provide continuity of flow in the main, or low-flow, channel. In some instances the perimeters were directly over each other in channel areas with relatively steep channel banks.

USGS georeferenced topo layers and National Agricultural Imagery Program (NAIP) imagery taken at known flows were used for the truthing of features and identifying locations on the polygon layers. The U.S. Department of Agriculture acquires the NAIP imagery during the agricultural growing seasons in the continental U.S. A primary goal of the NAIP program is to enable availability of digital ortho photography within a year of acquisition. Most of the NAIP imagery was taken on June 11 and 12, 2005, when discharges below La Grande Dam were 4,030 cfs and 4,070 cfs respectively. The approximately 5 mile area from La Grange dam to about RM 47, however, was flown on June 29 with the discharge at 2,680 cfs.

After modifications to all layers were finished, total area in acres was recalculated for all the remaining polygons for each flow/layer. Area versus discharge was plotted for all flows in MS Excel 2003. After review of this plot, it was decided to focus on the area of inundation out of the channel to simulate overbank areas. The three lowest flows were dropped and the area value at 1,100 cfs was subtracted from the remaining higher three values. The resulting overbank area values were then plotted versus discharge.

In addition, the original, unedited, wetted perimeter polygon layers and NAIP imagery were examined to explore at what flows the pits began filling with water and at what flows they possibly connected with the channel.

RESULTS

The area versus discharge curve including in-river channel is displayed in Figure 2, with the tabular data in Table 2. This area includes the area of the. A primary inflection is seen around 1,000 cfs, which suggests that this is the minimum point where flows may begin to become "overbank", or out of the channel and into the former floodplain. However, as there is no data between 1,100 and 3,100 cfs the actual initiation of overbank flow is between these two values.

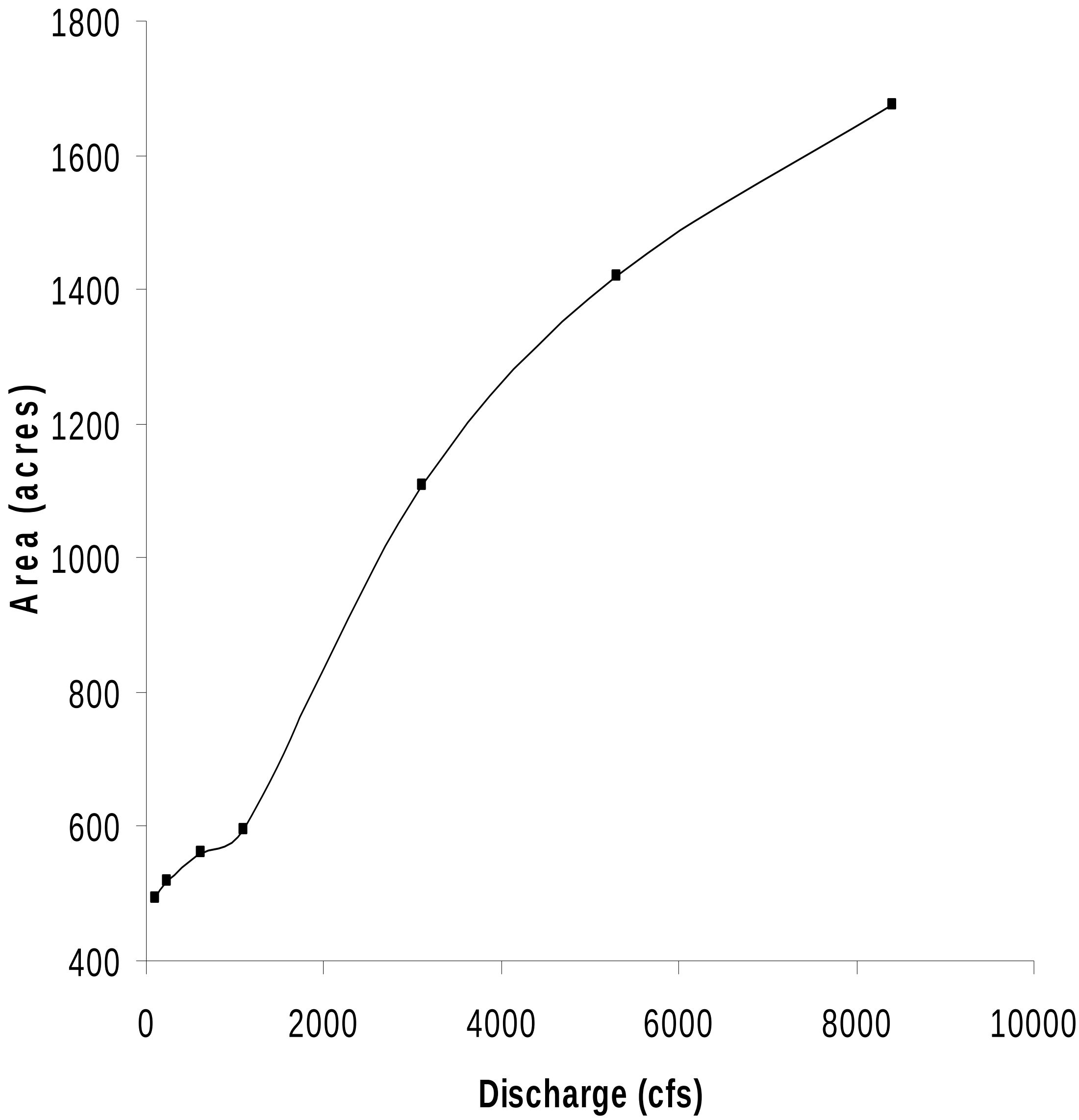


Figure 2. Lower Tuolumne inundated area as a function of discharge.

Table 2. Lower Tuolumne inundated area versus discharge.

Discharge (cfs)	Area (acres)
100	493
230	519
620	562
1,100	596
3,100	1,109
5,300	1,419
8,400	1,675

The plot in Figure 3 shows only the amount of acreage of potential overbank area inundated, without the in-channel acreage (as shown in Figure 2). Inundation is seen to continue to increase with discharge from around 1,000 cfs up to the maximum studied flow of 8,400 cfs. The greatest rate of increase in overbank area occurred between 1,000 to 3,100 cfs. The rate of increase in area, however, decreases as discharge rises, as may be expected with an increase in the slope of the floodplain as distance from the channel increases. As this decrease in rate of inundation appears relatively steady, a second inflection point, that might indicate a strong point of diminishing returns from further increases in discharge, is not seen. This would seem to indicate that the entire formerly floodplain area was not yet inundated at 8,400 cfs. Further inspection of the topographic layers overlaid with the 8,400 cfs wetted perimeter layer supports this premise.

Looking at the original EA wetted perimeter polygons with increasing flows, ponds first appear in the 1,100 cfs layer, indicating that the pits begin to fill somewhere between 620 and 1,100 cfs (Figures 4 and 5). Pits at river mile (RM) 30.5 were seen to be captured by flow in the channel somewhere between 3,100 and 5,300 cfs (Figures 6 and 7). However, with the exception of this area, gravel pits, and any other unconnected low areas outside of the channel, are not seen to be captured even at the 5,300 cfs level. We were unable to discern what happens to the pits at the 8,400 cfs level, as they were not included in the original GIS layer, although overlays of the 8,400 cfs layer with the NAIP imagery indicated two additional pits that were connected to the main channel at flows between 5,300 and 8,400 cfs: 1) a 41 acre pit at RM 36; and 2) a 14.3 acre pit at RM 34.5.

The NAIP imagery showed water in the pits at all flows in which the photos were taken. To give an example of how the pit areas appear, the same RM 30.5 area shown in Figures 4 and 5 is shown in Figure 8. In addition, the large pit also seen in Figures 4 and 5 is not seen to be connected to the main channel at 4,030 to 4,070 cfs, the range of flows at which the area was photographed. This is in agreement with the wetted perimeter data and suggests that the minimum flow at which the pit may be connected with the channel is closer to 4,050 cfs, rather than 3,100 cfs.

DISCUSSION

With regards to the influence of flood-induced and anthropogenic geomorphological changes that have occurred since the data used for this study was collected, we are assuming here that, due to the size of the study reach, changes to the channel and former floodplain since the data were collected are small relative to the size of the reach. In addition, considering "natural" geomorphological changes, there is some evidence to suggest that while the locations and sizes of hydrological features, such as meanders, riffles and bars, in alluvial reaches may change, the flow-habitat relationship does not (USFWS 2003).

The observed inflection point at 1,100 cfs is thought to be largely an effect of TID/MID removal of dredge tailings during the construction of New Don Pedro Dam (Scott McBain, personal communication 2007). It is important to point out, however, that while 1,100 cfs was used as the point at which flows became overbank, due to the inflection point in the original plot, this flow could actually be somewhere in between 1,100 and 3,300 cfs, the next highest data point. In

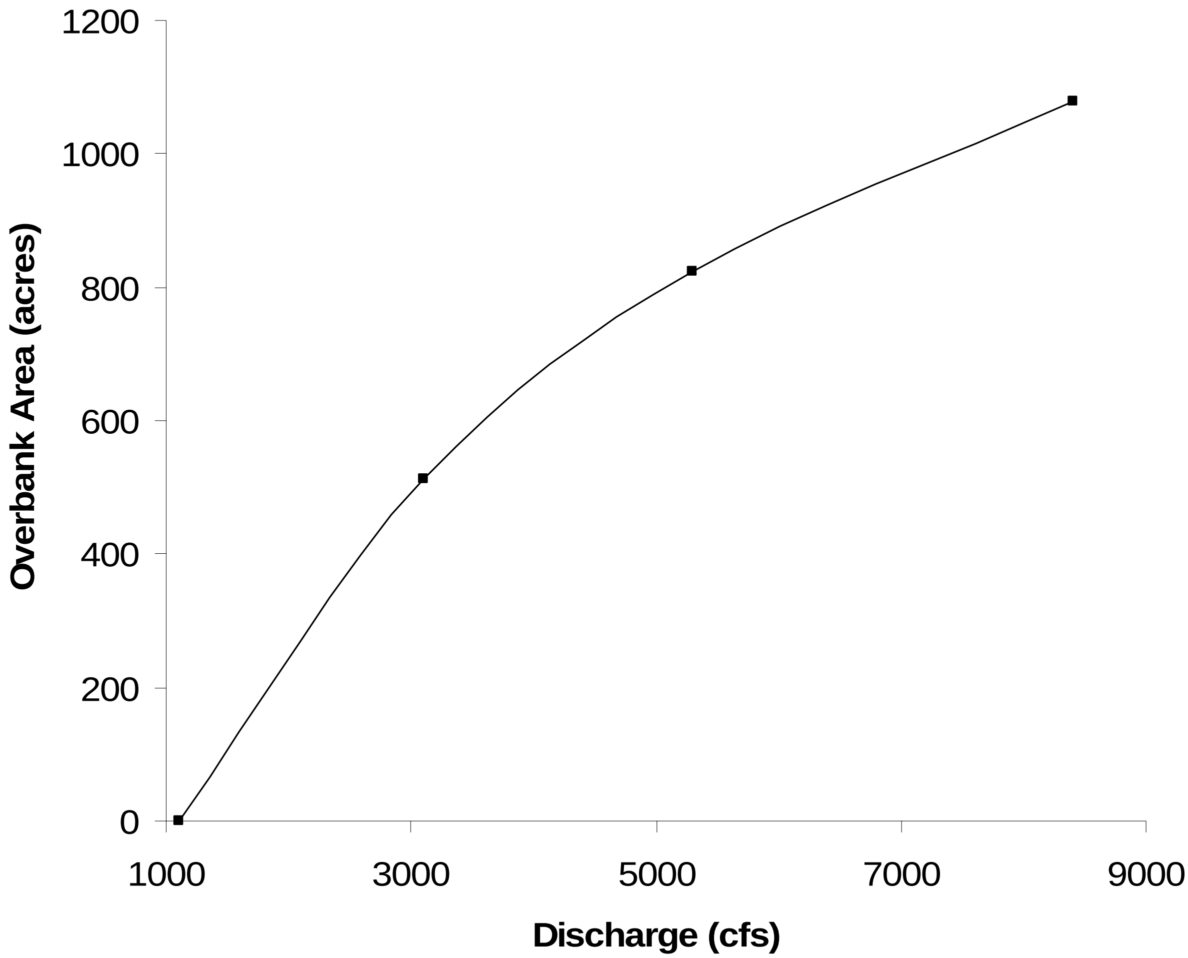


Figure 3. Lower Tuolumne overbank inundated area as a function of discharge.

addition “bankful” should not be confused with “bankful discharge”, which has been defined as “the amount of stream flow that is equal to a peak flow event that occurs on average every 1.2 to 2 years.” This flow might not be literally to the top of the stream banks (Ellis-Sugai and Godwin 2002). A hydrograph of mean daily flows from 1970-2007 is given in Figure 9.

Benefits to fish populations from floodplain inundation are thought to be linked to reduced predation rates, increased habitat availability, and increased food supply (Bennett and Moyle 1996). Most of the energy that drives aquatic food chains in rivers is derived from terrestrial sources (Allan 1995) and aquatic productivity is related to flood magnitude and the area inundated in some rivers (Large and Petts 1996). Flooding, particularly the rising limb of the hydrograph, typically results in high concentrations of both dissolved and particulate organic matter being released into the river (Allan 1995). Juvenile salmonids that utilize floodplain habitats on the Yolo Bypass (Sommer et al. 2001) and the Cosumnes River (Jeffres 2006), consume more prey and grow faster than those in mainstem habitats. It is also theorized that higher flows have multiple indirect effects on growth through other factors such as reduced water temperatures (Sommer et al. 2001) and the timing of smoltification. Further work by Sommer et

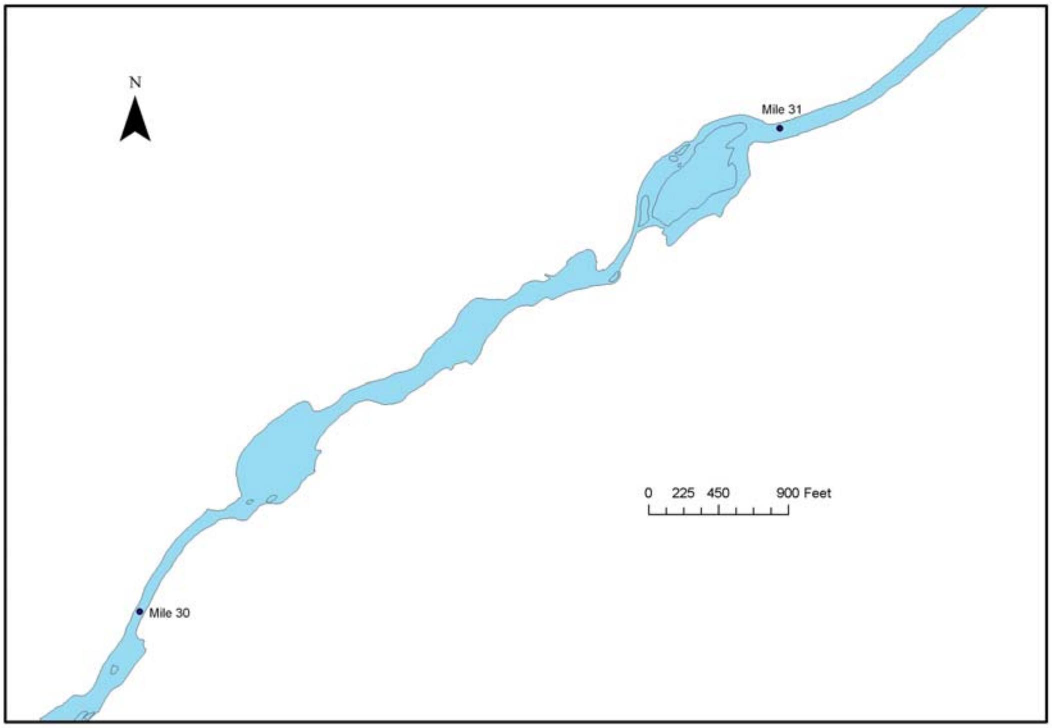


Figure 4. 620 cfs wetted perimeter between RM 30 and 31. No ponds visible.

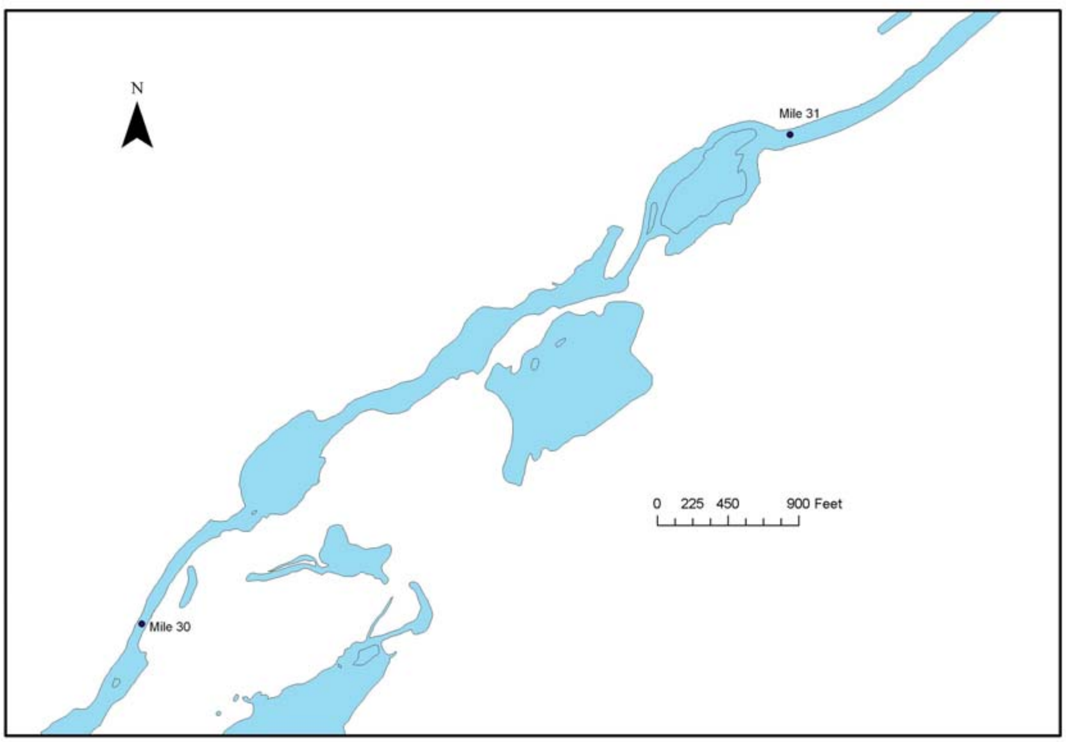


Figure 5. 1,100 cfs wetted perimeter between RM 30 and 31. Ponds visible, but not connected.

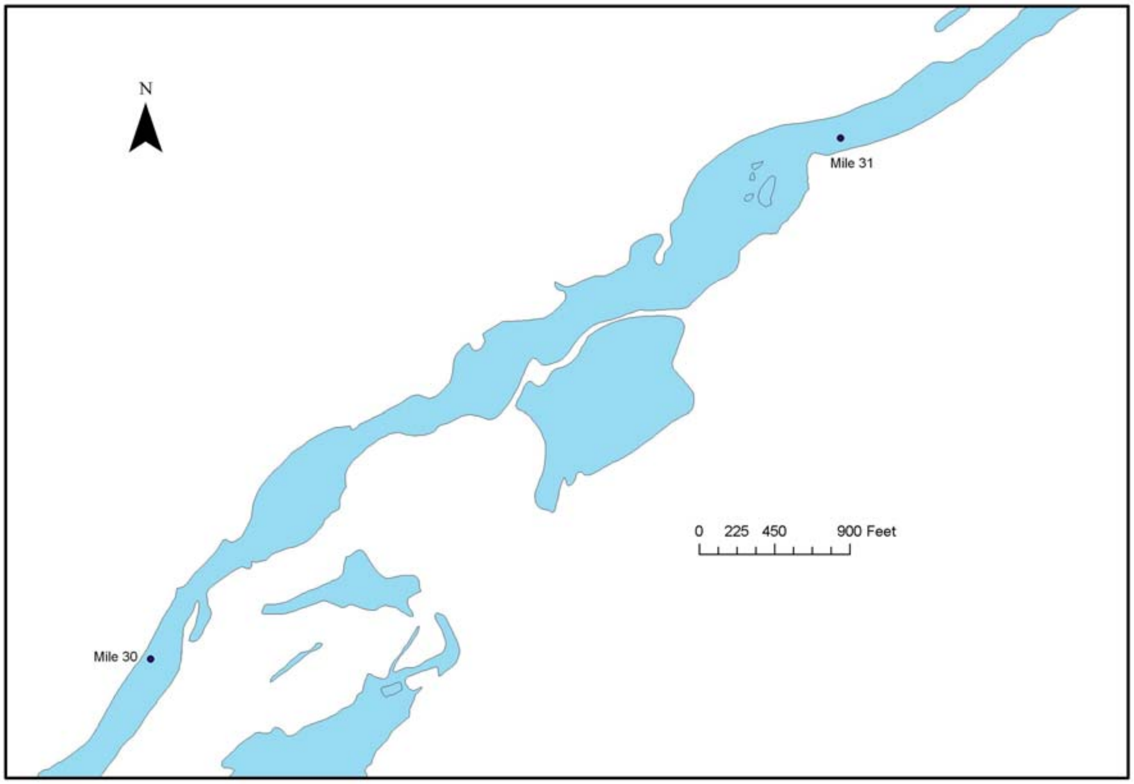


Figure 6. 3,100 cfs wetted perimeter RM 30.5. Ponds visible, disconnected.

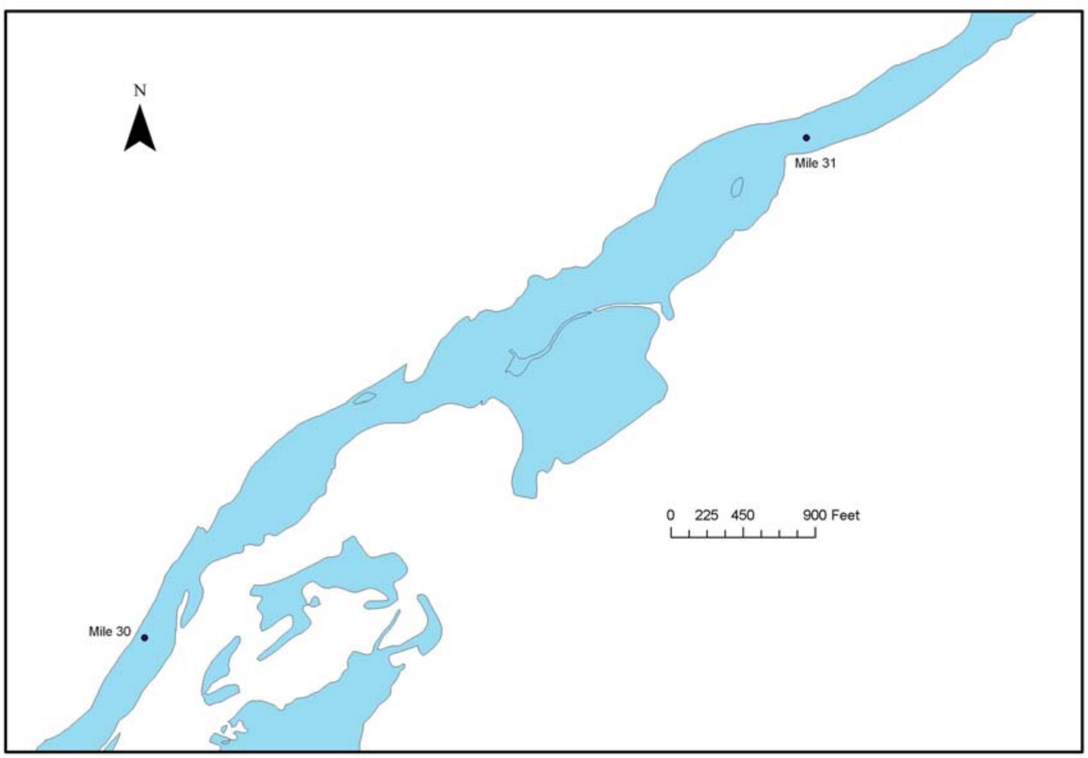


Figure 7. 5,300 cfs ponds visible and connected to channel RM 30.5.

Figure 8. 4,030 – 4,070 cfs ponds visible and connected to channel RM 30.5.

Figure 9. Mean daily flows for the Tuolumne River below Lagrange, 1970-2007.

al. (2005) on the Yolo Bypass gave additional evidence that outmigrating juvenile Chinook salmon benefit from time spent in floodplain habitat with benefits overall outweighing risk from stranding. This reinforces the belief that seasonal habitat should be considered as part of restoration plans for the species. We expect steelhead would benefit from seasonal floodplain habitat in a similar way as salmon.

Floodplain inundation may affect the timing of smoltification by increasing growth rates. The smolting process is triggered by a combination of conditions, such as body size, rate of growth, increasing day length, and increasing water temperatures (summarized in Quinn 2005). There is a smoltification window during spring, after which slow growing, small individuals lose their ability to smoltify. It is possible that by increasing food resources, floodplain inundation increases juvenile growth rates so that smoltification begins earlier during the spring, when water temperatures and other factors in the lower river are more conducive to their survival.

While the gravel pits/ponds were not the original focus of this study some discussion of their possible role in predator prey interactions, and how these might affect floodplain restoration efforts is called for. It is assumed that flood flows reduce predation by numerous largemouth bass, smallmouth bass, striped bass, and Sacramento pikeminnow that occur in the Tuolumne River and the other San Joaquin tributaries (TID/MID 2005, Mesick et al. 2007). Studies suggest that these pits may contain exotic predator species, particularly black bass (McBain and Trush, Stillwater Sciences 2006), and concerns have been raised by others that flow connectivity between these pits and the river could result in predation or introduce predators to the river. However, there is substantial evidence that the benefits of floodplain inundation far outweigh the potential negative benefits of connectivity to these mine pits and there is no evidence that predatory refugia in off-channel mine pits contributes to in-channel predation of juvenile salmonids. No predation studies have been conducted in off-channel pits that are connected to the river only at high flows. All of the predation studies in the San Joaquin Basin, such as McBain and Trush, Stillwater Sciences (2006), were conducted in in-channel pits during dry and normal water years when base flow releases were made. There is no reason to assume that predation is a source of mortality in off-channel pits that are connected only during flood flows, because predation would be inhibited by the high turbidity, low temperatures, and high velocities that occur during flooding. The McBain and Trush, Stillwater Sciences (2006) predation study was not conclusive regarding effects of predation, given that only three largemouth bass and one smallmouth bass were caught and tracked. None of these fish had juvenile salmon in their stomachs and only one moved into an off-channel pond after it had been tagged (McBain and Trush, Stillwater Sciences 2006). Floodplain inundation may provide refuge for juvenile salmonids from predators that inhabit in-channel mining pits (Orr 1997, Mesick et al. 2007).

Results from this study show connectivity with a single, but relatively large (15.75 acres), pit at RM 30.5, at flows beginning somewhere between 4,030 and 5,300 cfs. This area may need to be examined more closely to determine if a black bass population currently exists, and if so, to find the flow at which connectivity begins and determine if restoration actions are needed to isolate this pit from the main channel at flows greater than 4,030 cfs. Factors to consider in evaluating the need to isolate this mining pit include: 1) that the pit represents less than two percent of the overbank area inundated at 5,300 cfs; and 2) that previous restoration activities which isolated a large pond from the Tuolumne River did not reduce predation rates or improve the survival of juvenile salmon in the Tuolumne River (Mesick et al. 2007). Similar factors should be considered for the two pits that connect to the main channel at flows between 5,300 and 8,400 cfs.

It seems apparent that using spring pulse flows to benefit outmigrating juvenile salmonids on the lower Tuolumne River need to be combined with consideration of the pits/ponds both in and out of the channel. While pulse flows establish connectivity with gravel pits outside the channel, these same higher flows increase velocity and might make the instream pools less of a trap for the juveniles and assist their downstream progress. A possible next step could be to establish a stage-discharge relationship at the bottom of the study reach and conduct a 2D instream flow study of the entire reach. This would allow an evaluation of current hydrological and topographical conditions, in addition to providing more precise information on the inundation-discharge relationship, as results would be less incremental than those presented in this study.

The results of this study suggest that flows in excess of 1,100 to 3,100 cfs will begin to inundate overbank habitat for anadromous salmonids, with resulting benefits for increased survival and growth of outmigrant anadromous salmonids. Further increases of flows, up to at least 8,400 cfs, would be expected to have additional incremental benefits in terms of increased overbank habitat and thus increased survival and growth of outmigrant anadromous salmonids. While habitat restoration efforts that lowered overbank areas to enable inundation at flows less than 1,100 cfs would be expected to increase food resources and refuge from predators, in a similar manner to increases in outmigrant flows, such efforts would not provide other benefits of higher outmigrant flows, such as reduced water temperatures and contaminant dilution.

REFERENCES

Allan, J.D. 1995. Stream ecology: structure and function of running waters. Chapman & Hall, London. 388 pp.

Bennett, W.A., and Moyle, P.B. 1996. Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento– San Joaquin Estuary. *In* San Francisco Bay: the ecosystem. *Edited* by J.T. Hollibaugh. American Association for the Advancement of Science, San Francisco, CA. pp. 519–542.

Clackamas Instream Flow/Geomorphology Subgroup (CIFGS) 2003. Estimating salmonid habitat availability in the lower oak grove fork using expert habitat mapping, summary of methods and preliminary results. Report prepared by McBain and Trush Inc., Arcata, California, for Clackamas Instream Flow/Geomorphology Subgroup, March 5, 2003.

EA Engineering, Science and Technology. 1992. Fisheries Study Report. Report of Turlock Irrigation District and Modesto Irrigation District, Pursuant to Article 39 of the License for the Don Pedro Project. Vol. IV

Ellis-Sugai, B and D.C. Godwin. 2002. Going with the flow: understanding effects of land management on rivers, floods and floodplains. Oregon State University. pp 38.

Federal Energy Regulatory Commission. 1996. Final Environmental Impact Statement. Reservoir release requirements for fish at the New Don Pedro Project, California, FERC Project No. 2299-024.

Jeffres, C.A. 2006. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. M.S. Thesis. University of California, Davis.

Large, A.R.G. and G. Petts. 1996. Rehabilitation of River Margins. *In* G. Petts and P. Calow editors. River restoration: selected extracts from the Rivers handbook. Blackwell Science Ltd., Oxford. Pages 106-123.

McBain, S. 2007. Personal communication. McBain and Trush, Arcata, CA.

McBain and Trush, Stillwater Sciences. 2006. Lower Tuolumne River predation assessment final report. Prepared for the Tuolumne River Technical Advisory Committee, Turlock and Modesto Irrigation districts, USFWS Anadromous Fish Restoration Program and California Bay-Delta Authority.

Mesick, C.F. and D. Marston. 2007. Provisional Draft: Relationships between fall-run Chinook salmon recruitment to the major San Joaquin River tributaries and streamflow, Delta exports, the Head of the Old River Barrier, and tributary restoration projects from the early 1980s to 2003.

Mesick, C.F., J. McLain, D. Marston, and T. Heyne. Draft limiting factor analyses & recommended studies for fall-run Chinook salmon and rainbow trout in the Tuolumne River. Report submitted to the Federal Energy Regulatory Commission. March 2007.

Milhous, R.T., M.A. Updike and D.M. Schneider. 1989. Physical habitat simulation system reference manual - version II. Instream Flow Information Paper No. 26. U. S. Fish and Wildlife Service Biological Report 89(16).

Orr, B.K. 1997. Ecosystem health and salmon restoration: a broader perspective. 1997 Proceedings of the Congress – International Association for Hydraulic Research.

Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. University of Washington Press, Seattle.

Real de Asua, R. 2007. Personal communication. Stillwater Sciences, Berkeley, CA.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325–333.

Sommer, T.R, W.C. Harrell and M.L. Nobriga. 2005. Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain.

Turlock Irrigation District and Modesto Irrigation District. 1992. Report of Turlock Irrigation District and Modest Irrigation District pursuant to article 39 of the license for the Don Pedro Project, Appendix 6, Attachment B (in Vol. IV).

Turlock Irrigation District and Modesto Irrigation District. 2005. 2005 Ten Year Summary Report pursuant to Paragraph (G) of the 1996 FERC Order issued July 31, 1996. Report to Federal Energy Regulatory Commission for FERC Project No. 2299-024.

U.S. Fish and Wildlife Service. 1994. The relationship between instream flow, adult immigration, and spawning habitat availability for fall-run Chinook salmon in the upper San Joaquin River, California. U.S. Fish and Wildlife Service, Sacramento, CA.

U.S. Fish and Wildlife Service. 1995. Working paper on restoration needs: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volume 1. May 9, 1995. Prepared for the U. S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group. U.S. Fish and Wildlife Service, Stockton, CA.

U.S. Fish and Wildlife Service. 2003. Comparison of PHABSIM and 2-D modeling of habitat for steelhead and fall-run Chinook salmon and spawning in the lower American River. U.S. Fish and Wildlife Service, Sacramento, CA.