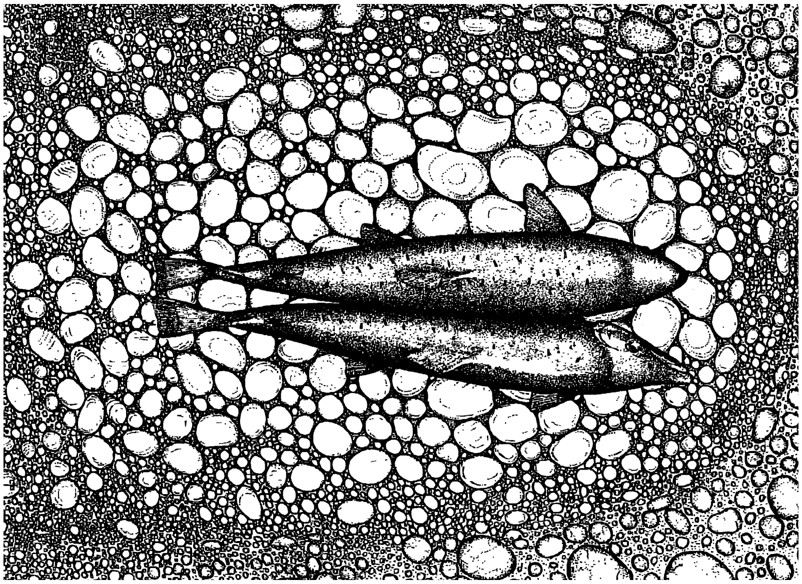
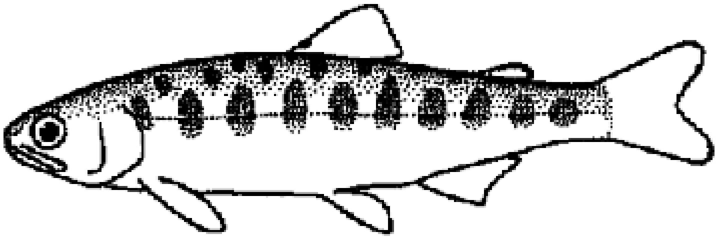
RELATIONSHIPS BETWEEN FLOW FLUCTUATIONS AND REDD DEWATERING AND JUVENILE STRANDING FOR CHINOOK SALMON AND STEELHEAD/RAINBOW TROUT IN THE YUBA RIVER





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

Prepared by staff of
The Energy Planning and Instream Flow Branch

CVPIA INSTREAM FLOW INVESTIGATIONS
YUBA RIVER CHINOOK SALMON AND STEELHEAD/RAINBOW TROUT REDD DEWATERING AND JUVENILE STRANDING

PREFACE

The following is the draft final report for the U. S. Fish and Wildlife Service's investigations on the effects of flow fluctuations on anadromous salmonid redd dewatering and juvenile stranding in the Yuba River between Englebright Dam and the Feather River. These investigations are part of the Central Valley Project Improvement Act (CVPIA) Instream Flow Investigations, a 6-year effort which began in October, 2001.[1] 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 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

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[1] This program is a continuation of a 7-year effort, also titled the Central Valley Project Improvement Act Instream Flow Investigations, which ran from February 1995 through September 2001.

ACKNOWLEDGMENTS

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ABSTRACT

The effects of Yuba River flow fluctuations on Chinook salmon and steelhead/rainbow trout redd dewatering and juvenile entrapment stranding were quantified in this study as the percentage of spawning habitat dewatered and the area stranded. The redd dewatering analysis used two-dimensional hydraulic and habitat modeling of 10 spawning sites on the Yuba River between Englebright Dam and the confluence with the Feather River, and redd dewatering criteria developed from measurements of Yuba River Chinook salmon and steelhead/rainbow trout redds. The velocity and depth dewatering criteria were developed, respectively, from measurements of Yuba River Chinook salmon and steelhead/rainbow trout redd velocities, and redd and tailspill depths. The juvenile entrapment stranding analysis was developed from observed or modeled stranding flows and measured stranding areas. Three approaches were taken to determine stranding flows for the 76 stranding sites we identified on the Yuba River between Englebright Dam and the Feather River: 1) use of the two-dimensional hydraulic model of our spawning and juvenile habitat modeling sites; 2) observation of the flow present during our identification of the stranding site; and 3) development of a stage-discharge relationship for the main river channel at the stranding site. Spawning habitat was considered to be dewatered when depths fell below 0.5 foot (0.15 m) for Chinook salmon and 0.2 foot (0.06 m) for steelhead/rainbow trout, or when velocities fell below 0.29 ft/s (feet per second) [0.088 m/s], 0.23 ft/s (0.070 m/s) and 0.09 ft/s (0.027 m/s) for, respectively, spring-run and fall-run Chinook salmon and steelhead/rainbow trout. Both redd dewatering and juvenile entrapment stranding increased with greater drops in flow. However, substantial juvenile stranding could be avoided by maintaining flows downstream of Daguerre Point Dam either above or below 1,200 cfs (cubic feet per second), and maintaining flows upstream of Daguerre Point Dam either: 1) above 3,700 cfs; 2) between 2,300 and 3,700 cfs; or 3) below 2,300 cfs.

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INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act provided for enactment of all reasonable efforts to double sustainable natural production of anadromous fish stocks including the four races of Chinook salmon (fall, late-fall, winter, and spring runs), steelhead, white and green sturgeon, American shad and striped bass. The Yuba River is a major tributary of the Feather River, located in the Sacramento River basin portion of the Central Valley of California. The Lower Yuba River, between Englebright Dam and the Feather River confluence, is a major contributor to anadromous salmonid production in the Central Valley and supports the largest stock of Chinook salmon that is not supplemented by hatcheries. The focus of the Yuba River study was the Lower Yuba River, the only portion of the Yuba River accessible for spring and fall-run Chinook salmon and steelhead spawning and juvenile rearing. For the Yuba River downstream of Englebright Dam, the Central Valley Project Improvement Act Anadromous Fish Restoration Plan calls for improved flows for all life history stages of Chinook salmon and steelhead (U.S. Fish and Wildlife Service 1995) as a high priority action to restore anadromous fish populations in the Yuba River. Subsequently, Yuba County Water Agency, collaboratively with the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the California Department of Fish and Game and Non-Governmental Organizations, developed a comprehensive set of improved flow regimes, which now are the Flow Schedules of the Lower Yuba River Accord (HDR/SWRI 2007).

In June 2001, the U.S. Fish and Wildlife Service prepared a study proposal to identify the instream flow requirements for anadromous fish in certain streams within the Central Valley of California, including the Yuba River. The Yuba River was selected for study because of a number of factors, including the presence of listed threatened or endangered species, the number of target species or races, whether current instream flows were inadequate and if there was an upcoming hydroelectric project relicensing. The goal of this study is to model the effects of flow fluctuations on Chinook salmon and steelhead/rainbow trout redd dewatering and juvenile entrapment stranding in the Yuba River between Englebright Dam and the Feather River within, to the extent feasible, the levels of accuracy specified in the methods section. The tasks and their associated objectives are given in Table 1. Spawning and incubation timing is shown in Table 2.

Stranding can either occur on gently sloping river bars, or in potholes and backchannels that become isolated as water levels decrease (Bradford *et al.* 1995). The latter type of stranding is commonly called fish isolation (California Department of Fish and Game 2001) or entrapment stranding. Stranding on gently sloping river bars is generally associated with rapidly varying flows, such as downstream of hydropeaking operations, and is typically addressed by ramping rates (Cushman 1985, Hunter 1992). In contrast, this report focuses on entrapment stranding and the effects of flow fluctuations which are independent of any practicable ramping rate, and flow variations with a temporal scale of one month. Thus, there is little potential for reconnecting entrapped areas before water temperatures or other habitat conditions, such as dessication or avian predation, result in juvenile mortality.

Table 1. Study tasks and associated objectives.

Task	Objective
study site selection	identify locations where juvenile spring and fall-run Chinook salmon and steelhead/rainbow trout could become isolated from the main channel with drops in flow
transect placement (study site setup)	delineate the location of the stranding sites
hydraulic and structural data collection	collect the data necessary to develop stage-discharge relationships at the stranding study sites and to measure the area of the stranding sites
hydraulic model construction and calibration	develop stage-discharge relationships at the stranding study sites
habitat suitability criteria development	determine the minimum depths and velocities below which spawning habitat would be lost with drops in flow
habitat simulation	determine the stranding area and percentage loss of spawning habitat associated with different drops in flow

Table 2. Spawning and incubation timing.

Race/species	Spawning timing	Incubation timing
Spring-run Chinook salmon	September	October-November
Fall-run Chinook salmon	October-December	November-February
Steelhead/rainbow trout	February-June	March-August

The Effective Habitat Analysis (HABEF) program in the Physical Habitat Simulation (PHABSIM[2]) component of the Instream Flow Incremental Methodology (IFIM) is capable of analyzing redd dewatering as a function of different drops in flow (Milhous *et al.* 1989). The HABEF program compares the conditions in a specific cell at alternative flows, setting the WUA (weighted useable area) for the higher flow (spawning flow) to zero if the WUA for that cell at the lower flow (incubation flow) is zero. Binary criteria are used for the incubation flow, so that WUA equals zero if the depth or velocity falls below the criteria. In this study, we applied this concept to two-dimensional hydraulic and habitat modeling.

The flows to be evaluated for management range from 150 cubic feet per second (cfs) downstream of Daguerre Point Dam (the lowest flow in the Yuba River Accord) and 400 cfs upstream of Daguerre Point Dam (the current State Water Resources Control Board minimum flow) to 4,170 cfs (the combined capacity of Narrows I and II). Accordingly, the range of study flows (400 to 4,500 cfs upstream Daguerre Point Dam and 150 to 4,500 cfs downstream of

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[2] PHABSIM is the collection of one dimensional hydraulic and habitat models which are used to predict the relationship between physical habitat availability and streamflow over a range of river discharges.

Daguerre Point Dam) encompasses the range of flows to be evaluated for management. The assumptions of this study are: 1) juvenile salmon would be stranded if the depth at the stranding point (located at the connection point from the main channel to the entrapment area) is less than the minimum depth at which we found juvenile salmon during our juvenile habitat suitability data collection; 2) there would be reduced survival of eggs or pre-emergent fry, and thus spawning habitat would be lost, if the tailspill was exposed or if velocities dropped to the point where there was insufficient intragravel flow through the redd; and 3) there would be insufficient intragravel flow through the redd if the mean water column velocity at the redd dewatering flow was less than the lowest velocity at which we found a fall-run and spring-run Chinook salmon and steelhead/rainbow trout redd in the Yuba River.

METHODS

A two-dimensional model, River2D Version 0.93 November 11, 2006 by P. Steffler, A. Ghanem, J. Blackburn and Z. Yang (Steffler and Blackburn 2002), was used for the redd dewatering portion of this modeling, instead of PHABSIM. River2D inputs include the bed topography and bed roughness, and the water surface elevation at the downstream end of the site. The amount of habitat present in the site is computed using the depths and velocities predicted by River2D, and the substrate and cover present in the site.

Study Site Selection

We divided the Yuba River study area into two stream segments (Figure 1), based on hydrology: Above Daguerre Point Dam and Below Daguerre Point Dam (U.S. Fish and Wildlife Service 2010a). We conducted mesohabitat mapping of the Yuba River between Englebright Dam and the Feather River. We designated 12 mesohabitat types: bar complex glides, bar complex pools, bar complex riffles, bar complex runs, flatwater glides, flatwater pools, flatwater riffles, flatwater runs, side channel glides, side channel pools, side channel riffles, and side channel runs (U.S. Fish and Wildlife Service 2010b). The mesohabitat units (MHUs) were used to reference the location of the stranding sites (Appendix A). See U.S. Fish and Wildlife Service (2010b) Appendix A Habitat Mapping Data for the locations of the MHUs.

The redd dewatering analysis was conducted using data from our 10 spawning sites (U.C. Sierra, Timbuctoo, Highway 20, Island, Hammond, Upper Daguerre, Lower Daguerre, Hallwood, Pyramids, and Plantz (Figure 1). Information on these sites is given in U.S. Fish and Wildlife Service (2010a).

Potential stranding areas were first identified in a Geographic Information System (GIS), using polygons of water's edge data supplied by Jones and Stokes for the flows in Table 3. We then surveyed both banks of the Yuba River from the Narrows (located 2.4 km downstream of Englebright Dam) to the confluence with the Feather River to evaluate these potential stranding areas, and to identify additional locations where juvenile Chinook salmon could become trapped in inundated areas isolated from the main river channel when flows drop. These field surveys

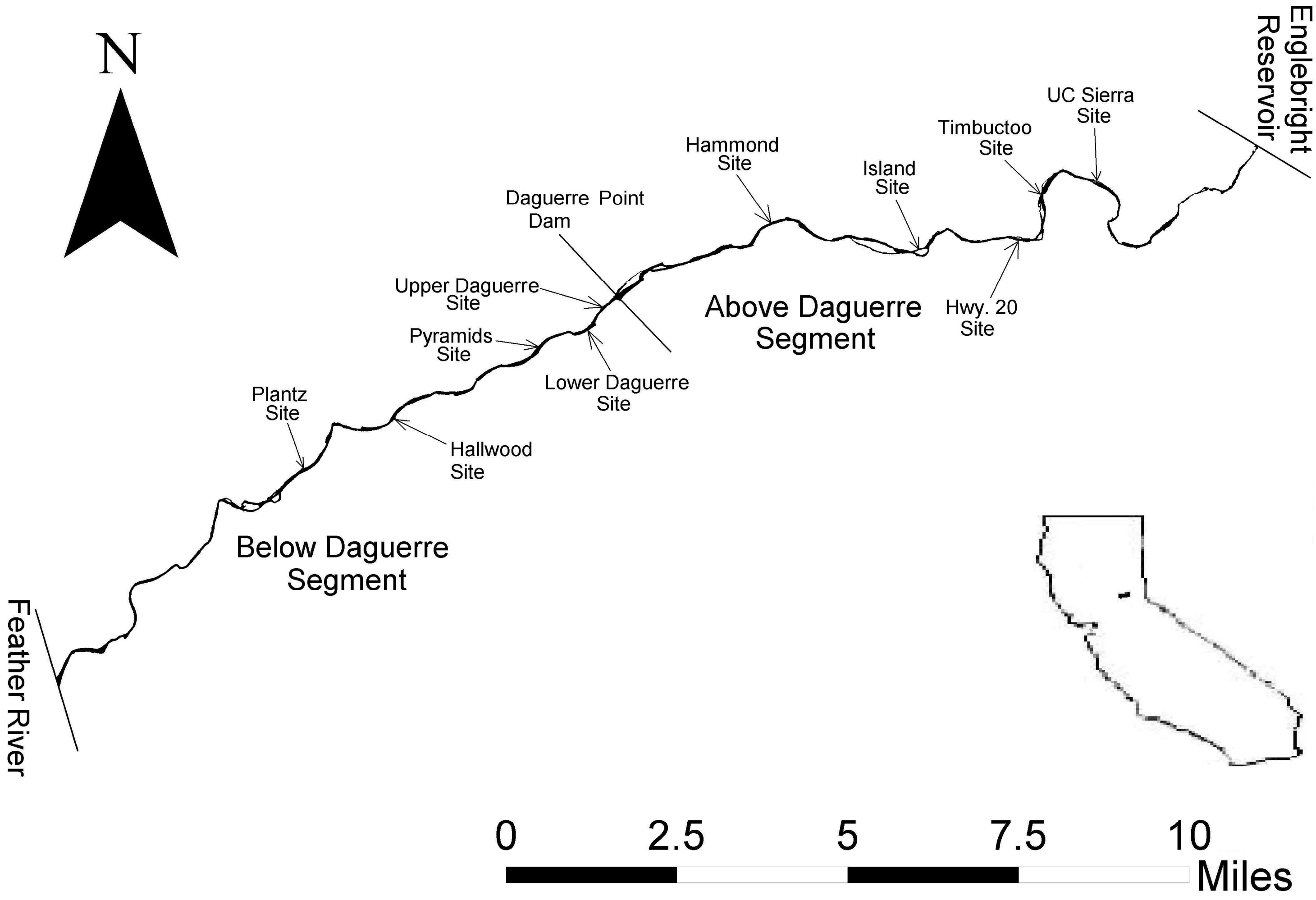

Figure 1. Yuba River stream segments and redd dewatering sites.

Table 3. Flows for water's edge polygons provided by Jones and Stokes.

Flow (cfs) Above Daguerre Point Dam	Flow (cfs) Below Daguerre Point Dam
718	473
909	627
1,218	947
1,589	1,265
2,015	1,642
2,674	2,915
4,307	4,564

were conducted at medium-to-low flows (943 to 2,054 cfs). The criteria that we used to identify stranding areas were: 1) the area would not completely drain to the main river channel; and 2) the area would strand at river flows ranging from 150 to 4,500 cfs.

Transect Placement (study site set-up)

Details on transect placement and study site set-up for the spawning sites are described in the spawning report (U.S. Fish and Wildlife Service 2010a). Details on transect placement and study site set-up for the juvenile habitat modeling sites (used as discussed below for some of the stranding sites) are described in the juvenile rearing report (U.S. Fish and Wildlife Service 2010b).

Three approaches were used to determine the stranding flows[3] for the stranding sites: 1) for those stranding sites located in one of our spawning or juvenile habitat modeling sites, the two-dimensional hydraulic model of that spawning or juvenile habitat site was used to determine the stranding flow for the stranding site; 2) for those stranding sites where the flow during our identification of the stranding site was at or slightly above or below the stranding flow for that site, we determined the stranding flow based on the flow on that date; and 3) for the remaining sites, we developed a stage-discharge relationship for the main river channel at the stranding site to determine the stranding flow. The first two categories of sites did not require any site setup or data collection, while the third category of site required the installation of a vertical benchmark (e.g., a lag bolt in a tree or stump; or a paint spot on a boulder, concrete, or bedrock point).

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[3] We defined the stranding flow as the flow where the connection between the stranding area and main river channel has a maximum depth of 0.1 foot. We selected 0.1 foot because the minimum depth at which we found juvenile salmon and steelhead/rainbow trout during our juvenile HSI data collection was 0.2 foot. When flows drop to or below the stranding flow, juvenile salmon and steelhead/rainbow trout will be isolated from the main river channel.

Hydraulic and Structural Data Collection

Fieldwork was conducted between January 2005 and January 2007.

Areas were determined for all of the stranding sites. For smaller sites, we determined the area by measuring the length and two to six widths of the stranding site, using an electronic distance meter; the area is calculated by multiplying the length times the average width. The areas of larger sites were computed in GIS from the water's edge polygons supplied by Jones and Stokes or from polygons delineated from water's edge output of the River2D modeling of our spawning and juvenile habitat modeling sites. As described above, vertical benchmarks were established at each of the stranding sites for which we developed flow-habitat relationships to serve as the reference elevations to which all elevations (streambed and water surface) were tied.

Data required for developing a stage discharge relationship are: 1) water surface elevations (WSELs, or stages), measured to the nearest 0.01 foot (0.0031 m) at three flows using standard surveying techniques (i.e., differential leveling); and 2) the Stage of Zero Flow (SZF). We also measured the bed elevation of the stranding point (the lowest point at the connection between the stranding area and the main river channel) using differential leveling; the stage at the stranding flow was calculated by adding 0.1 foot (0.03 m) to the bed elevation of the stranding point. Once developed, the stage discharge relationship was used to determine the stranding flow. For most of the sites, the SZF was determined by making a traverse [4] with a 600 kHz Broad-Band Acoustic Doppler Current Profiler (ADCP) across the main channel at the stranding point, based on the assumption that there was not a downstream hydraulic control. The ADCP settings used are shown in Table 4. Additional details on the ADCP operation are given in Gard and Ballard (2003). For a few sites on side channels where the entire channel could be waded, the SZF was determined by measuring depths across the side channel with a wading rod. In both cases, the SZF was calculated as the difference between the WSEL on that date and the largest depth.

Flows for most sites were determined from gage data. For stranding sites located on split channels, regressions between the split channel flow and the total Yuba River discharge were developed from flow measurements made when the WSELs were collected. Flows were measured by making depth and velocity measurements by wading with a wading rod equipped with a Marsh-McBirney^R model 2000 or a Price AA velocity meter.

Hydraulic Model Construction and Calibration

See U.S Fish and Wildlife Service (2010a) and (2010b) for details on how the spawning and juvenile site River2D models were constructed and calibrated.

Flow-flow regressions were performed for sites located on split channels, using the flows measured in the site, and the corresponding total flows determined from gage readings. The site flows used in the regression were the flows measured with a wading rod and Price AA or Marsh-McBirney meter on the site.

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[4] A traverse refers to a set of data collected each time the ADCP is driven across the channel.

Table 4. CFG File Used for ADCP Data. The first four characters of the ADCP traverses designates which CFG file (containing the ADCP settings) was used for the traverses. WT is the water track transmit length.

CFG File	Mode	Depth Cell Size (m)	Depth Cell Number	Max Bottom Track Depth (m)	Pings	WT	First Depth Cell (m)	Blanking Dist. (m)
MD4E	4	0.20	30	7.9	4	5	0.56	0.10

American Standard Code for Information Interchange (ASCII) files of each ADCP traverse were produced using the Playback feature of the Transect program[5]. Each ASCII file was then imported into RHABSIM Version 2.0[6] to produce the bed elevations, the component of the average water column velocity perpendicular to the transect, and stations (relative to the start of the ADCP traverse). RHABSIM was then used to output a second ASCII file containing this data. For the SZF measurements, the second ASCII file was input into an Excel spreadsheet where the maximum depth was subtracted from the measured WSEL to compute the SZF.

For the stranding sites for which we developed stage-discharge relationships, all stage-discharge data were compiled and checked before entry into PHABSIM data files. A total of two to four sets of WSELs at widely spaced flows were used. Calibration flows in the data files were either from gage readings, or the flows calculated from gage reading/site flow regression equations. A separate file was constructed for each set of study sites with the same calibration flows.

The first step in the calibration procedure was to determine the best approach for WSEL simulation. Initially, the *IFG4* hydraulic model (Milhous et al. 1989) was run on each file to compare predicted and measured WSELs. This model produces a stage-discharge relationship using a log-log linear rating curve calculated from at least three sets of measurements taken at different flows. *IFG4* is considered to have worked well if the following criteria are met: 1) the beta value (a measure of the change in channel roughness with changes in streamflow) is between 2.0 and 4.5; 2) the mean error in calculated versus given discharges is less than 10%; 3) there is no more than a 25% difference for any calculated versus given discharge; and 4) there is no more than a 0.1 foot (0.031 m) difference between measured and simulated WSELs[7].
For sites where the initial *IFG4* calibration indicated that there was a significantly non-linear log-log relationship between stage and flow over the range of calibration flows, we applied a modification of *IFG4* where we only used two calibration flows. The calibration flows selected

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[5] The Transect program is the software used to receive, record and process data from the ADCP.

[6] RHABSIM is a commercially produced software (Payne and Associates 1998) that incorporates the modeling procedures used in PHABSIM.

[7] The first three criteria are from U.S. Fish and Wildlife Service (1994), while the fourth criterion is our own.

were those which bracketed the stranding flow. Since only two flows are used in this method, the mean error and calculated versus given discharge criteria of *IFG4* do not apply and the difference between measured and predicted WSELs will always be zero.

There were two categories of sites where we developed stage-discharge relationships using methods other than *IFG4*: 1) for sites located in the lower portion of the Yuba River where there are backwater effects from the Feather River, we developed a stage-discharge relationship using a multiple regression of log(WSEL - SZF) versus log(Yuba River flow) and log(Feather River flow); and 2) for sites where we only had two measurements of WSELs, we developed stage-discharge relationships using the WSELs measured at the site and the rating curve for the Marysville gage.

Habitat Suitability Criteria (HSC) Development

We assumed that there would be reduced survival of eggs or pre-emergent fry, and thus spawning habitat would be lost, if the tailspill was exposed or if velocities dropped to the point where there was insufficient intragravel flow through the redd. We took velocity, redd depth and tailspill depth measurements for 168 spring-run Chinook salmon, 851 fall-run Chinook salmon and 106 steelhead/rainbow trout/rainbow trout redds on the Yuba River. The velocity and redd depth measurements were generally made slightly upstream of the redd (U.S. Fish and Wildlife Service 2010a), while the tailspill depth was measured at the highest point of the tailspill. We first tested whether there was a significant correlation between the Yuba River redd depths and the difference between the redd and tailspill depth to determine how to develop the redd dewatering criteria. We selected the following for the redd dewatering criteria: 1) the average difference between tailspill and redd depths for fall-run and spring-run Chinook salmon and steelhead/rainbow trout redds with redd depths less than 2 feet; and 2) the lowest velocity at which we found a fall-run and spring-run Chinook salmon and steelhead/rainbow trout redd in the Yuba River.

Habitat Simulation

We conducted an effective spawning analysis (analogous to HABEF) with River2D to determine the percentage loss of fall-run and spring-run Chinook salmon and steelhead/rainbow trout spawning habitat in the Yuba River between Englebright Dam and the Feather River associated with drops in flow. An effective spawning analysis examines, on a node-by-node basis, the depths and velocities at lower flows. The weighted useable area represented by each node at a given flow is set to zero if the depth or velocity at a lower flow are less than the stranding criteria. Alternatively, if the depth and velocity at the lower flow are both greater than the stranding criteria, the weighted useable area represented by a given node is not changed. The resulting weighted useable areas represented by all the nodes are then summed to compute how much weighted useable area remains after the flow drops. The percentage loss in spawning habitat is then computed as:

$$\text{Percentage loss spawning habitat} = \frac{\Sigma\, \text{WUA}_{\text{higher flow}} - \Sigma\, \text{WUA}_{\text{lower flow}}}{\Sigma\, \text{WUA}_{\text{higher flow}}} \times 100$$

We conducted the effective spawning habitat analysis by opening the spawning flow file for a given site in River2D, and producing an output file containing the spawning combined habitat suitability. This file of combined habitat suitabilities was then used as a channel index[8] file for the River2D files for the dewatering flows for that site, along with the stranding criteria, to compute the remaining spawning habitat.

RESULTS

Study Site Selection

A total of 76 locations were found between the Narrows and the confluence with the Feather River which would potentially become isolated from the main channel at flows ranging from 150 to 4,500 cfs. Twenty-two of these stranding sites were located in the following spawning (U.C. Sierra, Timbuctoo, Highway 20, Island, Lower Daguerre, Hallwood, Pyramids, and Plantz) and juvenile rearing study sites (Narrows, Rose Bar, Side-Channel, and Whirlpool). Information on the spawning sites is given in U.S. Fish and Wildlife Service (2010a) and information on the juvenile rearing sites is given in U.S. Fish and Wildlife Service (2010b). Twenty-six of the stranding sites were identified in January 2005. Forty of these sites were identified in February 2005. The remaining sites were identified in March and May 2005. The locations of these sites, as designated by the mesohabitat unit (MHU) number, are identified in Appendix A. The MHUs were designated numerically, starting with MHU # 1 at the Feather River to MHU # 220 just downstream of Englebright Dam. See U.S. Fish and Wildlife Service (2010b) Appendix A Habitat Mapping Data for the locations of the MHUs.

Transect Placement (study site setup)

Of the 76 identified stranding sites, 22 were located in our spawning and juvenile rearing habitat modeling sites, 5 sites had the flow during our identification of the stranding site at or slightly above or below the stranding flow for that site, and the remaining 49 sites had stage-discharge relationships that we developed.

Hydraulic and Structural Data Collection

The flows used for stranding sites 1-16 and 26-47 were the sum of the flows from the Yuba River at Smartville (USGS gage # 11418000) and Deer Creek (USGS gage # 11418500) gages, while the flows used for stranding sites 17-25 and 54-68 were the flow from the Yuba River at Marysville (USGS gage # 11421000) gage. The flows used for stranding sites 48-53 were computed by subtracting the flow coming out of the Yuba Goldfields (see U.S. Fish and Wildlife Service 2010a) from the flow at the Marysville gage.

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[8] Normally a channel index file contains substrate or cover data.

Water surface elevations were measured at the following four flow ranges for 26 of these 49 stranding sites: 943-1,001 cfs, 1,740-2,054 cfs, 2,509-3,154 cfs, and 3,674-5,771 cfs. Twenty-two of the 49 stranding sites had WSELs measured at the following three flow ranges: 351-1,151 cfs, 1,686-2,517 cfs and 3,150-5,729 cfs. One of the sites (Site 65) had WSELs measured at the following two flows: 1,151 cfs and 3,768 cfs. When we returned to this site on June 29, 2005 to collect a third WSEL, the vertical benchmark for this site had been destroyed by high flows in late May 2005.

There were two of the 49 stranding sites for which we developed stage-discharge relationships that were located on split channels. For these two sites (Stranding Sites 19 and 36), flows were measured when the WSELs were collected, to enable the development of flow/flow regressions between the split channel flow and the total Yuba River discharge.

Hydraulic Model Construction and Calibration

The total flows used to develop the flow-flow regressions for sites located on split channels and to develop stage-discharge relationships for sites that included all of the Yuba River flow are given in Table 5. The flow-flow regressions were developed from three sets of flows, with the entire river discharge at 971-1,151 cfs, 1,898-2,054 cfs and 3,150-3,768 cfs. The total discharge in Table 5 and the appropriate regression equation in Table 6 were used to compute the calibration flows for Stranding Sites 19 and 36 (Table 7).

The SZF values used to develop the stage-discharge relationships are given in Appendix B. For a majority of the sites, *IFG4* met the criteria for *IFG4* identified in the methods (Appendix B). For stranding sites 10, 11, 18, 19, 20, 32, 34 and 63A and B, the initial *IFG4* calibration indicated that there was a significantly non-linear log-log relationship between stage and flow over the range of calibration flows. For these sites, we applied the modification of *IFG4* discussed in the methods of using only two calibration flows. For stranding sites 26, 29, 43, 44, and 50A/B/C, where we had measured WSELs at four flows, we were unable to meet the criteria for *IFG4* identified in the methods using all four flows, but were able to meet the criteria for *IFG4* identified in the methods using either the three lowest or three highest flows (see Appendix B).

There were three other sites (stranding sites 65, 67 and 68) for which we developed stage-discharge relationships using methods other than *IFG4.* The location where we measured WSELs for Stranding site 65 was 188 feet downstream of the Marysville gage (located at 39.1760°N, 121.5240°W). For both of the measured WSELs, the height of the Marysville gage at those flows, from the Marysville gage rating table, was exactly 33.68 feet lower than the measured WSEL[9]. We then determined the stranding flow by subtracting 33.68 from the stranding WSEL (96.2 feet), and looked up in the Marysville gage rating table what flow (907 cfs) corresponded to the above computed value (62.52 feet).

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[9] The difference in elevations between the measured WSELs and the gage height is because the measured WSELs were referenced to a vertical benchmark with an assigned local elevation of 100.00 feet, while the gage height is referenced to mean sea level.

Table 5. Total Yuba River flows (cfs) at stranding study sites used to develop stage-discharge relationships or flow/flow regressions. These flows are the same as the stranding study site flows only for those stranding sites that include all of the Yuba River flow (i.e., all sites except Stranding Sites 19 and 36, see Table 6).

	Stranding Sites		
Date	1-16 and 26-47	48-54	17-25 and 55-68
1/24/2005	1,021		
1/25/2005	1,018		
1/27/2005			991
2/22/2005	2,054		
2/23/2005	1,930		
2/24/2005		1,740	1,813
2/25/2005			1,151
3/7/2005			1,052
3/8/2005	971		
3/9/2005	965	943	1,001
5/2/2005	3,154		
5/3/2005	3,150		
5/4/2005		2,509	2,517
5/16/2005			3,768
5/17/2005	4,180	3,674	3,720
5/18/2007 10:00 AM	5,559		
5/18/2007 10:15 AM	5,651		
5/18/2007 10:30 AM	5,683		
5/18/2007 10:45 AM	5,653		
5/18/2007 11:00 AM	5,574		
5/18/2007 11:15 AM	5,727		
5/18/2007 11:30 AM	5,729		
5/18/2007 12:00 PM	5,786		
5/18/2007 12:15 PM	5,769		
5/18/2007 12:30 PM	5,771		
6/22/2005			1,898
6/29/2005			1,686
10/5/2005			391

Table 6. Flow/flow regression equations. Q is the total river flow, Site 19 Q is the flow in Stranding Site 19, etc.

Stranding Study Site	Regression Equation	R^2-value
19	$\log(\text{Site 19 Q}) = 0.4626 + 0.6026 \times \log(Q - 1145)$	0.9999
36	$\log(\text{Site 36 Q}) = 0.4609 + 0.7007 \times \log(Q - 132)$	0.9968

Table 7. Calibration flows for stranding study sites 19 and 36 (cfs). These were computed from the total Yuba River flows in Table 5 and the regression equations in Table 6.

Date	Site 19	Site 36
2/22/2005		578
2/25/2005	8.5	
3/8/2005		323
5/3/2005		793
5/16/2005	333	
5/18/2005 10:30 AM		1,215
6/22/2005	157	

Stranding sites 67 and 68 were located within the backwater effect of the Feather River. Accordingly, we used the multiple regression equation in the methods section with Yuba River flows from the Marysville gage and Feather River flows from the Feather River near Gridley gage (USGS gage # 11407150) (Table 8). To predict the stranding flow, we used these multiple regression equations with the stranding WSEL and the average Feather River flow (4,910 cfs) for the period January 1, 1993[10] to April 18, 2006.

We compared stage-discharge relationships for each site modeled with *IFG4* to the criteria described in the methods. The calculated-given discharge criterion was met for all of these sites. The mean error criterion was met in all cases except for stranding site 45. The measured-simulated WSEL difference criterion for *IFG4* was met in all cases except for stranding site 2. As shown in Appendix B, the beta coefficients were less than 2.0 for stranding sites 18, 19, 38, 55A/B, 58 and 61, and were greater than 4.5 for stranding sites 2, 26 and 29.

The stranding flows and areas for the 76 stranding sites are given in Appendix A. The stage-discharge relationships or River2D models for eight of the stranding sites located upstream of Daguerre Point Dam resulted in a stranding flow of less than 400 cfs. These eight sites were dropped from consideration, since we are identifying areas upstream of Daguerre Point Dam that strand at flows between 400 and 4,500 cfs.

Habitat Suitability Criteria (HSC) Development

There was a significant positive correlation between the depth of the redds and the difference between the redd depth and tailspill depth for spring-run Chinook salmon (R^2 = 0.06, p = 0.0015), fall-run Chinook salmon (R^2 = 0.74, p < 0.0001) and steelhead/rainbow trout (R^2 =

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[10] Flows are available at the California Data Exchange Center website (http://cdec.water.ca.gov/cgi-progs/queryDaily?GRL) for the Feather River at Gridley gage starting from January 1, 1993.

Table 8. Stage-discharge multiple regression equations for sites where stage-discharge relationships were developed using methods other than *IFG4*. Yuba Q is the Yuba River flow and Feather Q is the Feather River flow. The R^2-values for both regressions were by definition 1.00 since the regressions were computed from three measurements and had two independent variables

Stranding Study Site	Regression Equation	R^2-value
67	log (WSEL – SZF) = -0.3755 + 0.2716 x log (Yuba Q) + 0.1109 x log (Feather Q)	1.00
68	log (WSEL – SZF) = -0.704 + 0.03222 x log (Yuba Q) + 0.0681 x log (Feather Q)	1.00

0.04, p = 0.03) redds (Figures 2 to 4). When only redds with depths less than 2 feet[11] were considered, the correlations for spring-run Chinook salmon ($R^2 = 0.05$, $p = 0.006$), fall-run Chinook salmon ($n = 664$, $R^2 = 0.31$, $p < 0.0001$) and steelhead/rainbow trout ($n = 26$, $R^2 = 0.39$, $p = 0.0005$) were still significant. However, since we needed to choose a single value representing the difference between the tailspill and redd depths for the redd dewatering analysis because the analysis uses binary criteria, we selected the average difference for spring-run Chinook salmon (0.5 foot) [0.15 m], fall-run Chinook salmon (0.5 foot) [0.15 m] and steelhead/rainbow trout (0.2 foot) [0.06 m] redds with redd depths less than 2 feet (0.6 m). If the tailspill is 0.5 foot (0.15 m) higher than the depth at the head of the pit (the depth used to compute spawning habitat), Chinook salmon spawning habitat would be lost if the spawning depth fell below 0.5 foot (0.15 m). Similarly, if the tailspill is 0.2 foot (0.06 m) higher than the depth at the head of the pit (the depth used to compute spawning habitat), steelhead/rainbow trout spawning habitat would be lost if the spawning depth fell below 0.2 foot (0.06 m). We assumed that there would be insufficient intragravel flow through the redd if the spawning velocity was less than the lowest velocity at which we found a spring-run or fall-run Chinook salmon or steelhead/rainbow trout redd in the Yuba River. The lowest velocities we found in measurements of Yuba River spring-run and fall-run Chinook salmon and steelhead/rainbow trout were, respectively, 0.29 ft/s (0.088 m/s), 0.23 ft/s (0.070 m/s) and 0.09 ft/s (0.027 m/s) (U.S. Fish and Wildlife Service 2010a). The redd dewatering criteria used are given in Table 9.

Habitat Simulation

The total stranding area in the Yuba River between the Narrows and the Feather River for different drops in flow are shown in Figures 5 and 6 and Appendix C. For example, if the Yuba River flow downstream of Daguerre Point Dam drops from 1,200 to 1,100 cfs, the total stranding

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[11] Two feet (0.6 m) was selected because the drop in stage associated with a change in flow for the Yuba River sites is typically less than 2 feet (0.6 m).

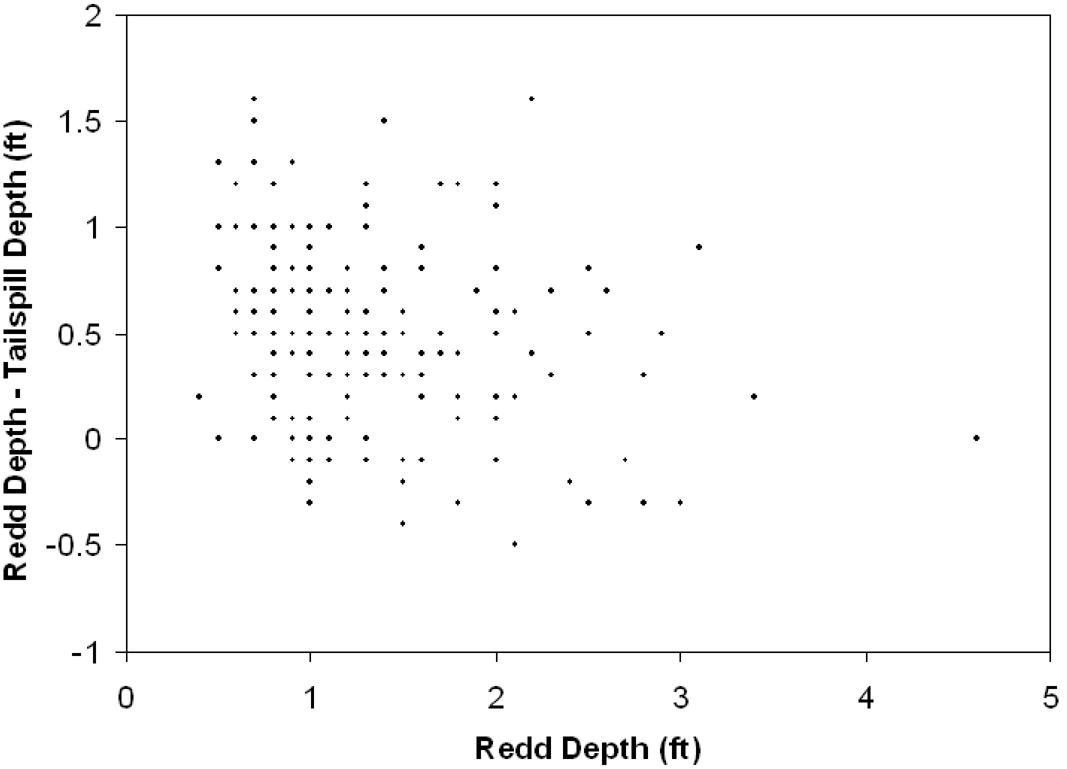

Figure 2. Tailspill and redd depth relationships for Yuba River spring-run Chinook salmon redds.

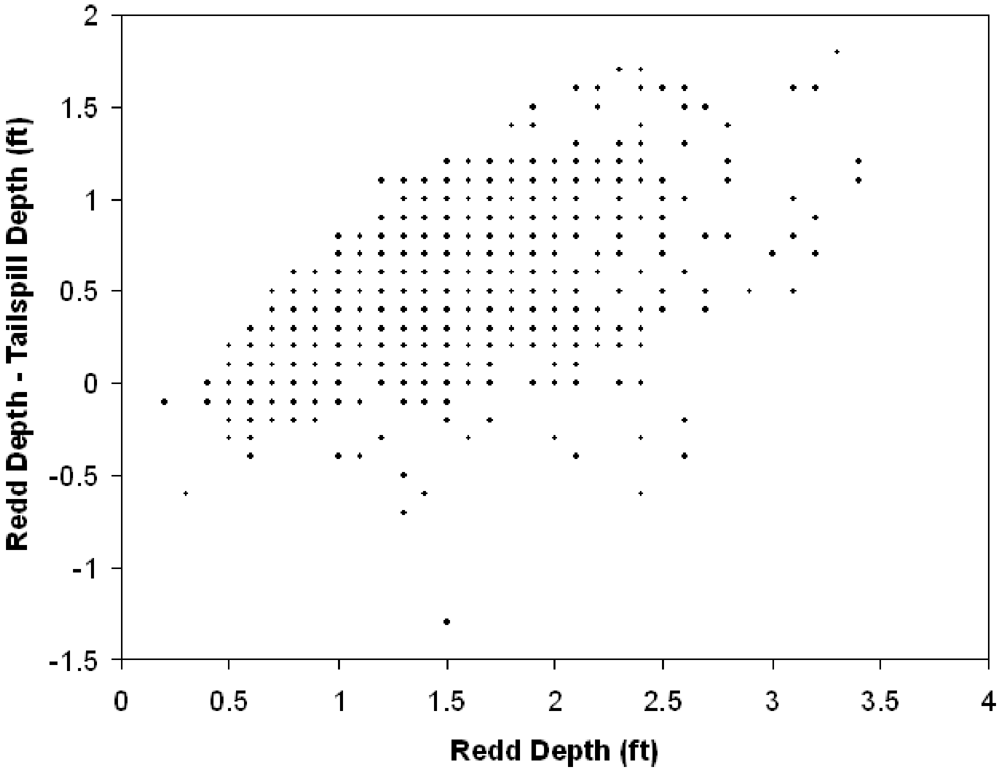

Figure 3. Tailspill and redd depth relationships for Yuba River fall-run Chinook salmon redds.

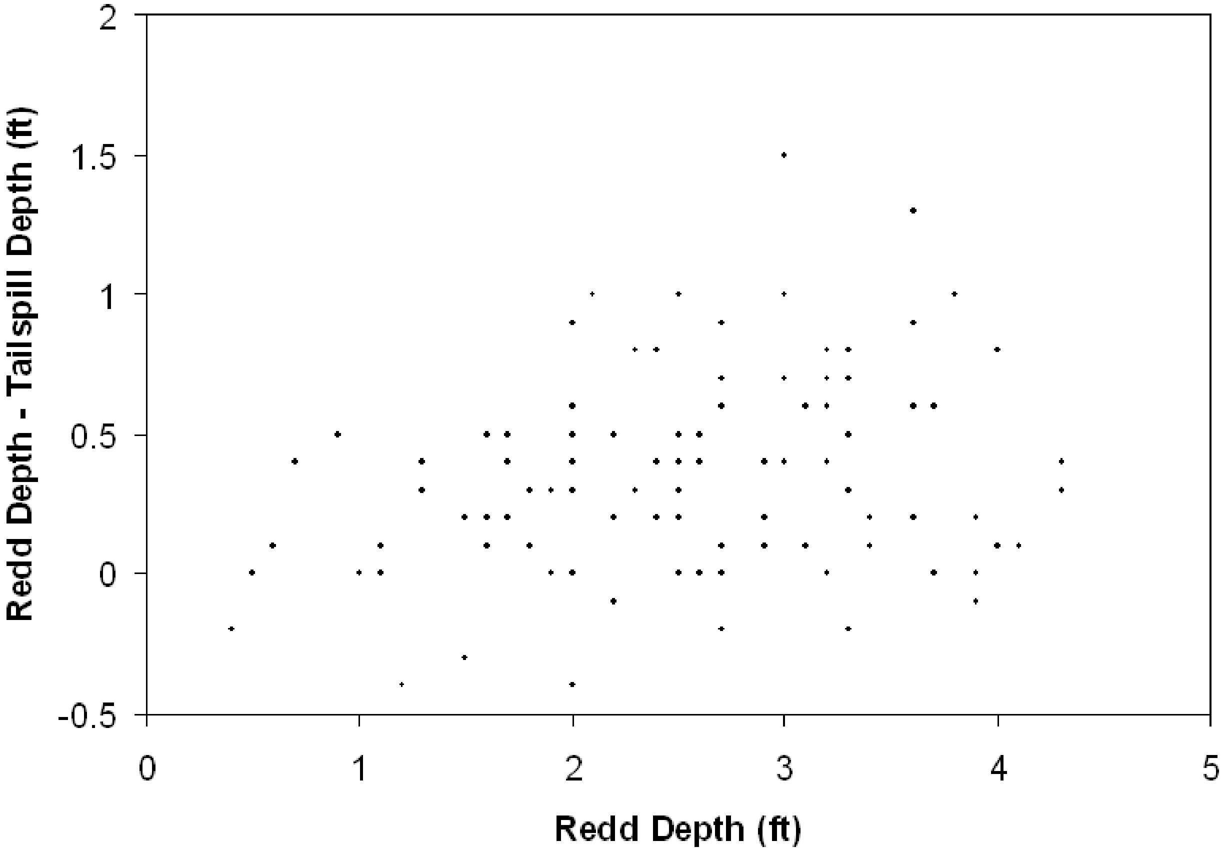

Figure 4. Tailspill and redd depth relationships for Yuba River steelhead/rainbow trout redds.

area downstream of Daguerre Point Dam would be 250,049 ft^2 [12] (23,230 m^2). In contrast, if the Yuba River flow downstream of Daguerre Point Dam drops from 1,900 to 1,200 cfs, the stranding area downstream of Daguerre Point Dam would be 6,078 ft^2 (565 m^2). The relationship of flow drops to redd dewatering are shown in Figures 7 to 12 and Appendix D. The definition of the dewatering and stranding flows shown in Figures 5 to 12 and Appendices C and D is the flow after the flow decrease has occurred. Table 10 shows the juvenile stranding and redd dewatering results for three example flow decreases: 2,900 to 2,000 cfs, 2,000 to 1,000 cfs and 2,900 to 1,000 cfs.

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[12] 250,049 ft^2 (23,230 m^2) is the total area of the stranding sites (site 57) that strand between 1,200 and 1,100 cfs.

Table 9. Redd dewatering Habitat Suitability Criteria for the Lower Yuba River. Binary Suitability Index (SI) have values of either 0 or 1.

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Channel Index Value	SI Value
		Spring-run Chinook Salmon			
0.00	0.00	0.00	0.00	0.00	0.00
0.28	0.00	0.50	0.00	1.00	1.00
0.29	1.00	0.52	1.00	100.0	1.00
100.0	1.00	100.0	1.00		
		Fall-run Chinook Salmon			
0.00	0.00	0.00	0.00	0.00	0.00
0.22	0.00	0.50	0.00	1.00	1.00
0.23	1.00	0.52	1.00	100.0	1.00
100.0	1.00	100.0	1.00		
		Steelhead/rainbow trout			
0.00	0.00	0.00	0.00	0.00	0.00
0.08	0.00	0.20	0.00	1.00	1.00
0.09	1.00	0.23	1.00	100.0	1.00
100.0	1.00	100.0	1.00		

DISCUSSION

Hydraulic Model Construction and Calibration

The modification of *IFG4* discussed in the methods where we only used two calibration flows is not usually considered acceptable for developing stage-discharge relationships. However, we believe that it is sufficiently accurate for interpolating a stranding flow in between two calibration flows in our study because errors in stage-discharge relationships are typically large only for extrapolation outside of the range of calibration flows. *IFG4* could not be used for sites located within the backwater effects of the Feather River because a basic assumption of *IFG4* is that the WSEL only varies as a function of the discharge at the stage-discharge relationship location.

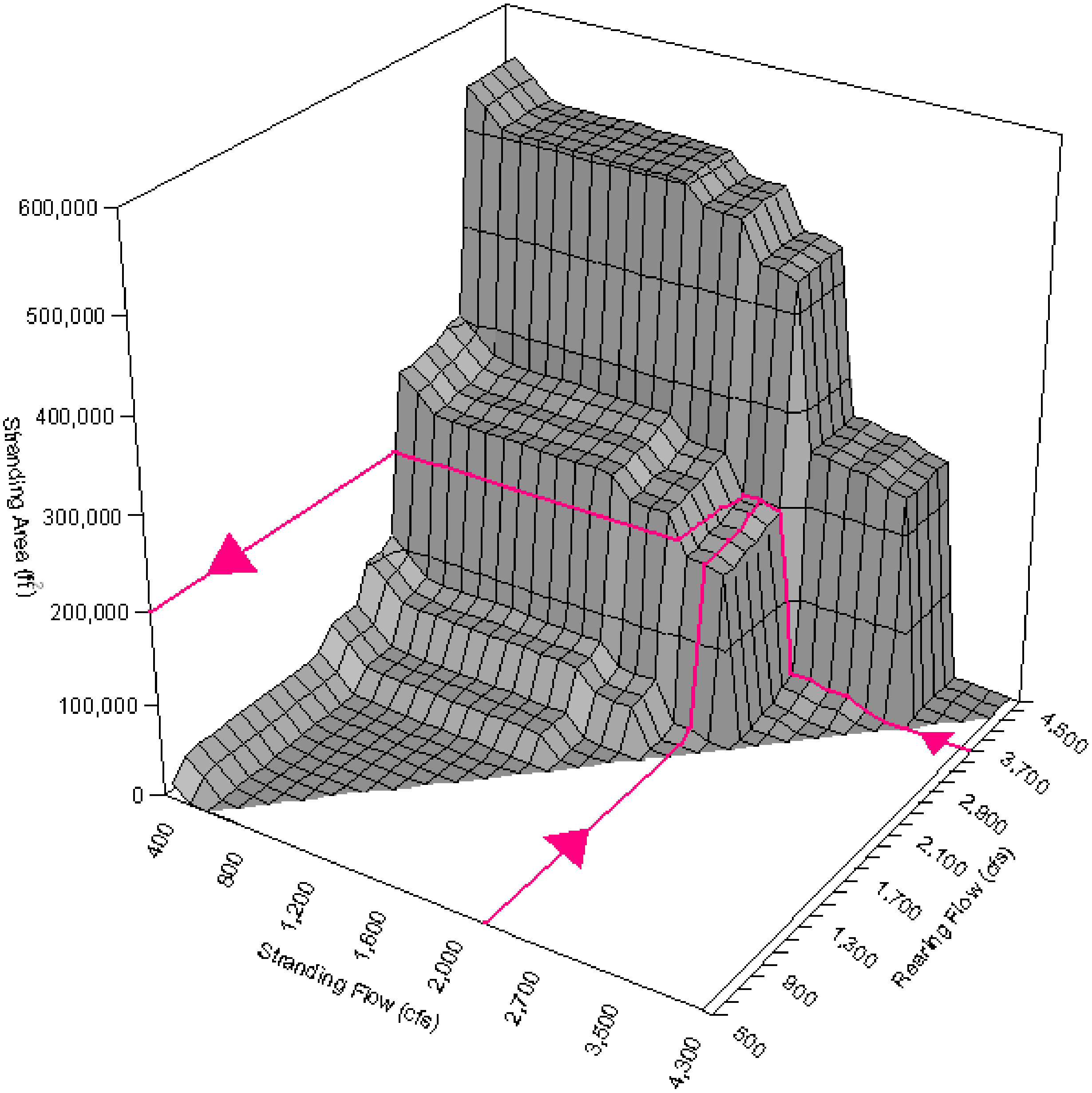

Figure 5. Stranding areas of juvenile anadromous salmonids for the Lower Yuba River upstream of Daguerre Point Dam. Substantial juvenile stranding could be avoided by keeping flows above 3,700 cfs, between 2,300 and 3,700 cfs, or below 2,300 cfs. These thresholds are shown as sharp drops in stranding area with declining rearing flows in the above graph. The red lines give an example of how to read this graph - if the flows drop from a rearing flow of 3,500 cfs to a stranding flow of 2,100 cfs, the total stranding area would be 201,707 ft^2 (18,739 m^2). The rearing flow is the flow prior to a flow reduction, while the stranding flow is the flow after a flow reduction.

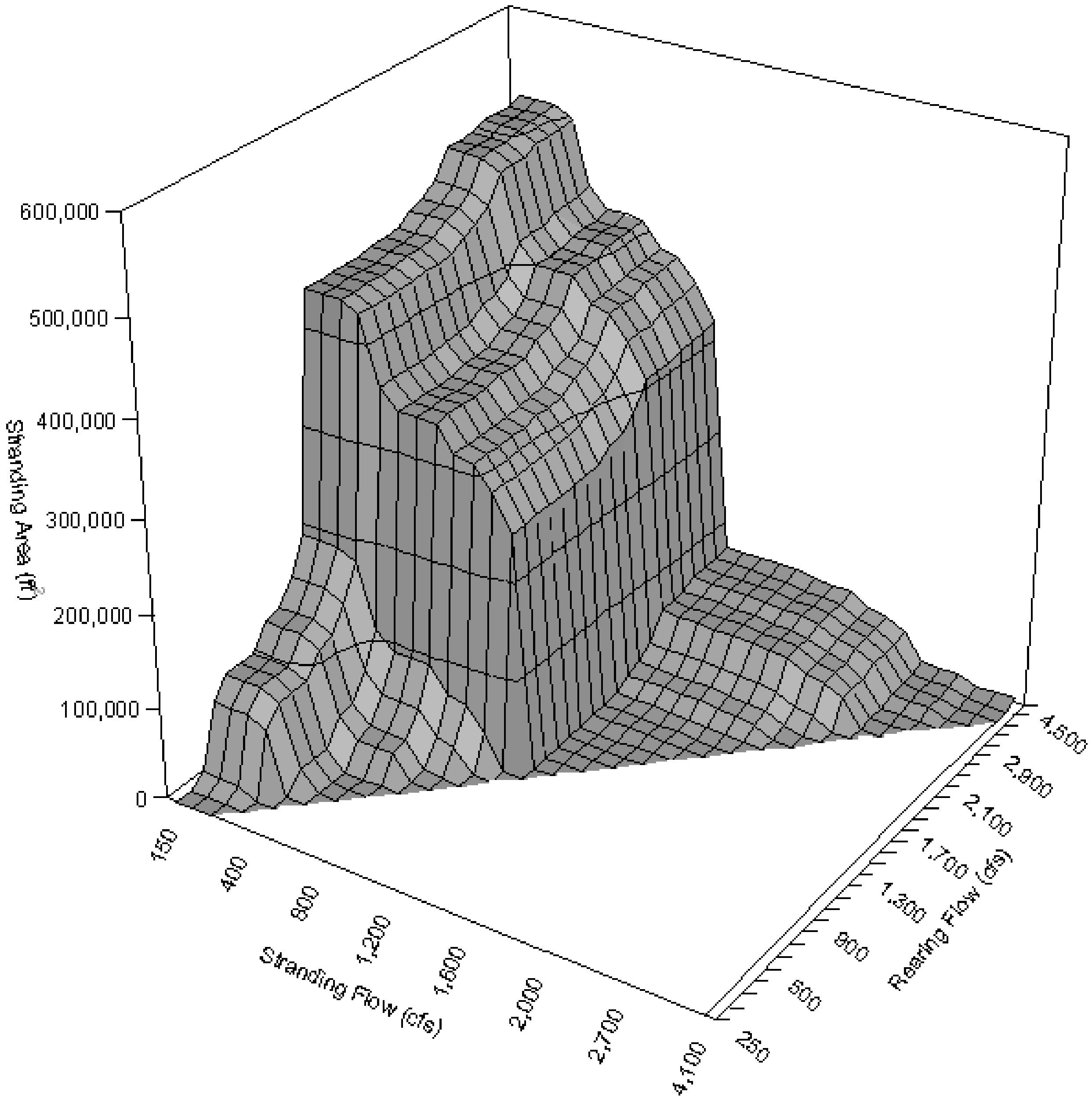

Figure 6. Stranding areas of juvenile anadromous salmonids for the Lower Yuba River downstream of Daguerre Point Dam. Substantial juvenile stranding could be avoided by keeping flows above or below 1,200 cfs. The rearing flow is the flow prior to a flow reduction, while the stranding flow is the flow after a flow reduction.

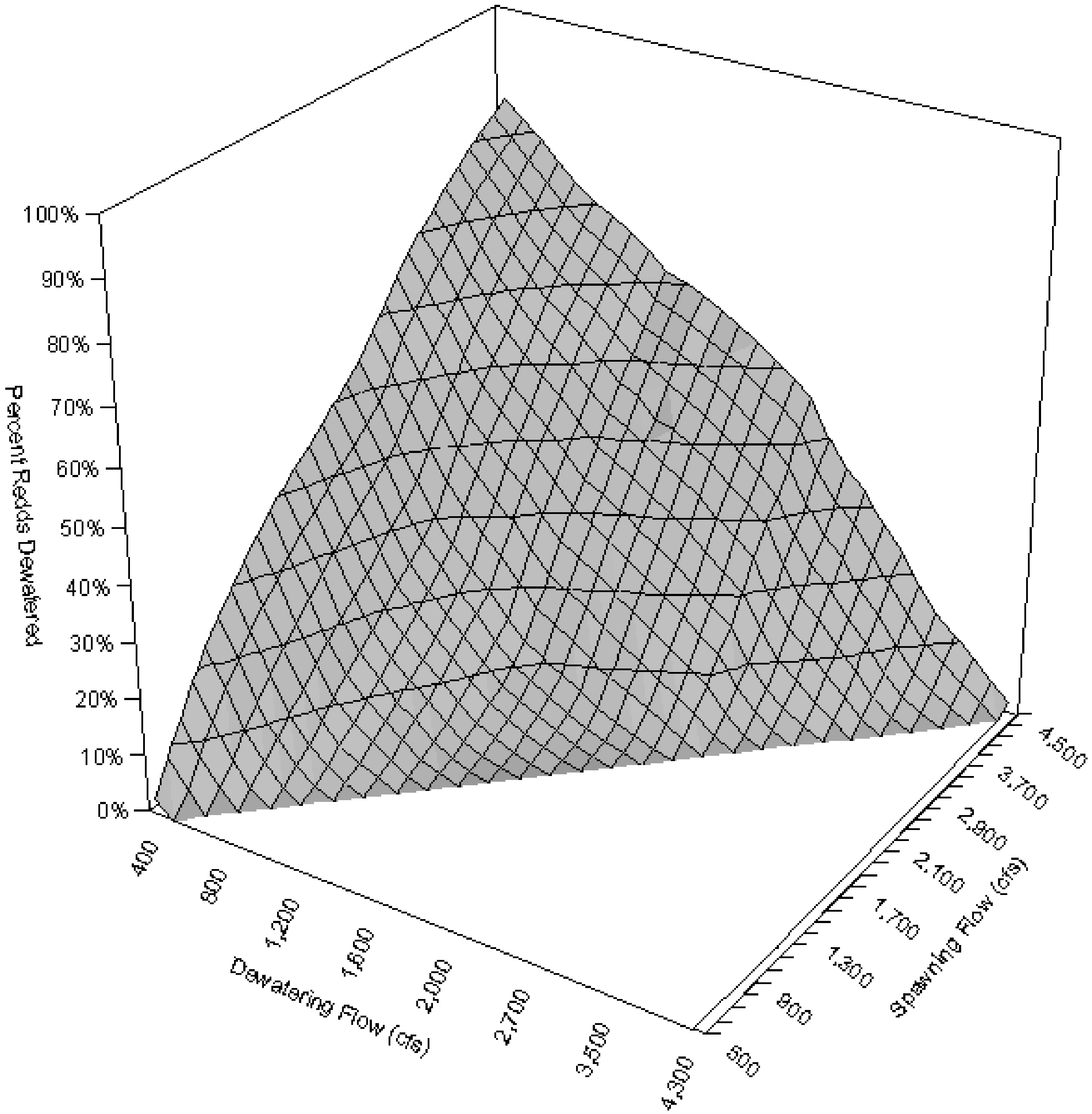

Figure 7. Predicted dewatering of fall-run Chinook salmon redds for the Lower Yuba River upstream of Daguerre Point Dam. The spawning flow is the flow prior to a flow reduction, while the dewatering flow is the flow after a flow reduction.

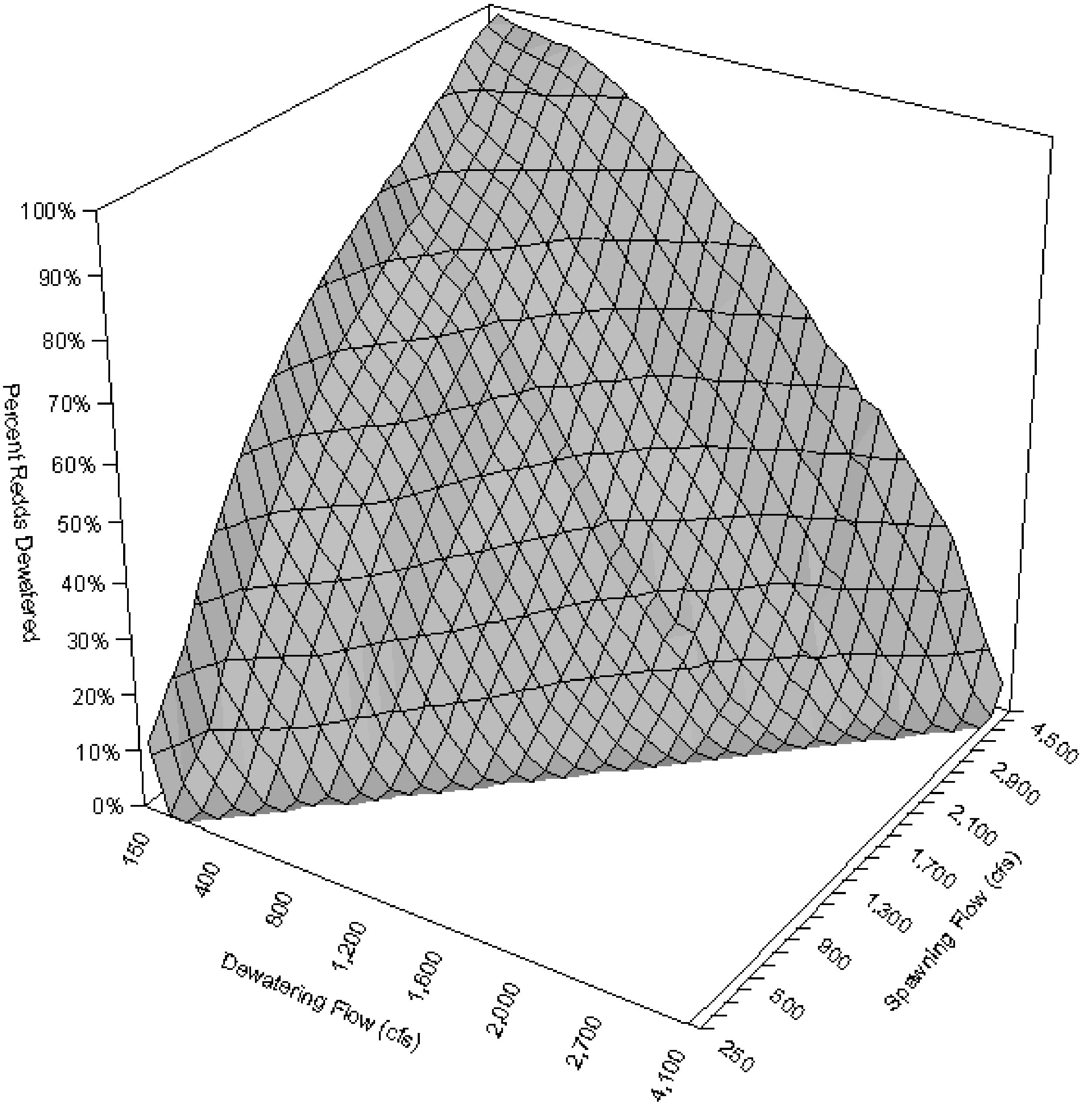

Figure 8. Predicted dewatering of fall-run Chinook salmon redds for the Lower Yuba River downstream of Daguerre Point Dam. The spawning flow is the flow prior to a flow reduction, while the dewatering flow is the flow after a flow reduction.

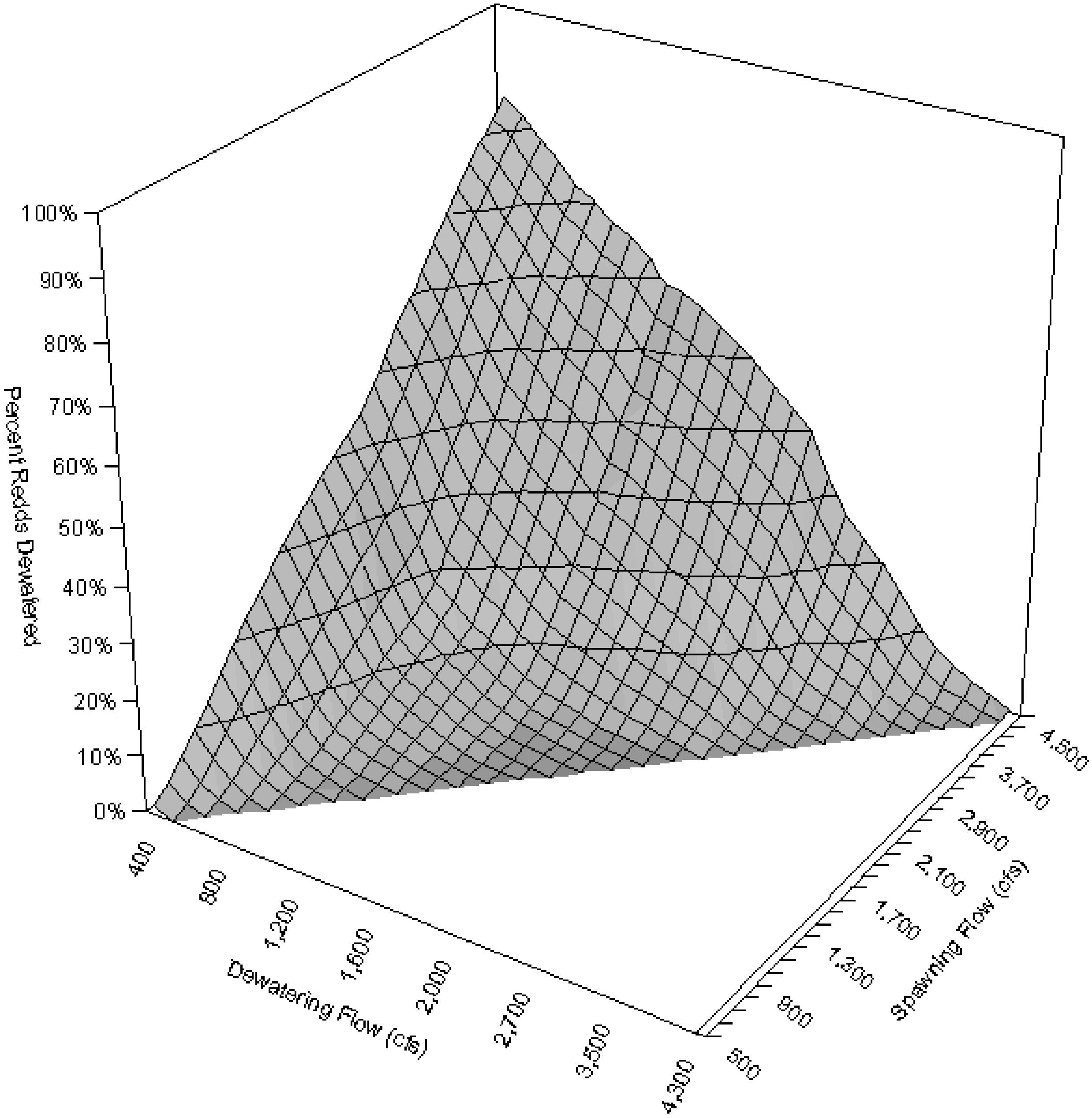

Figure 9. Predicted dewatering of spring-run Chinook salmon redds for the Lower Yuba River upstream of Daguerre Point Dam. The spawning flow is the flow prior to a flow reduction, while the dewatering flow is the flow after a flow reduction.

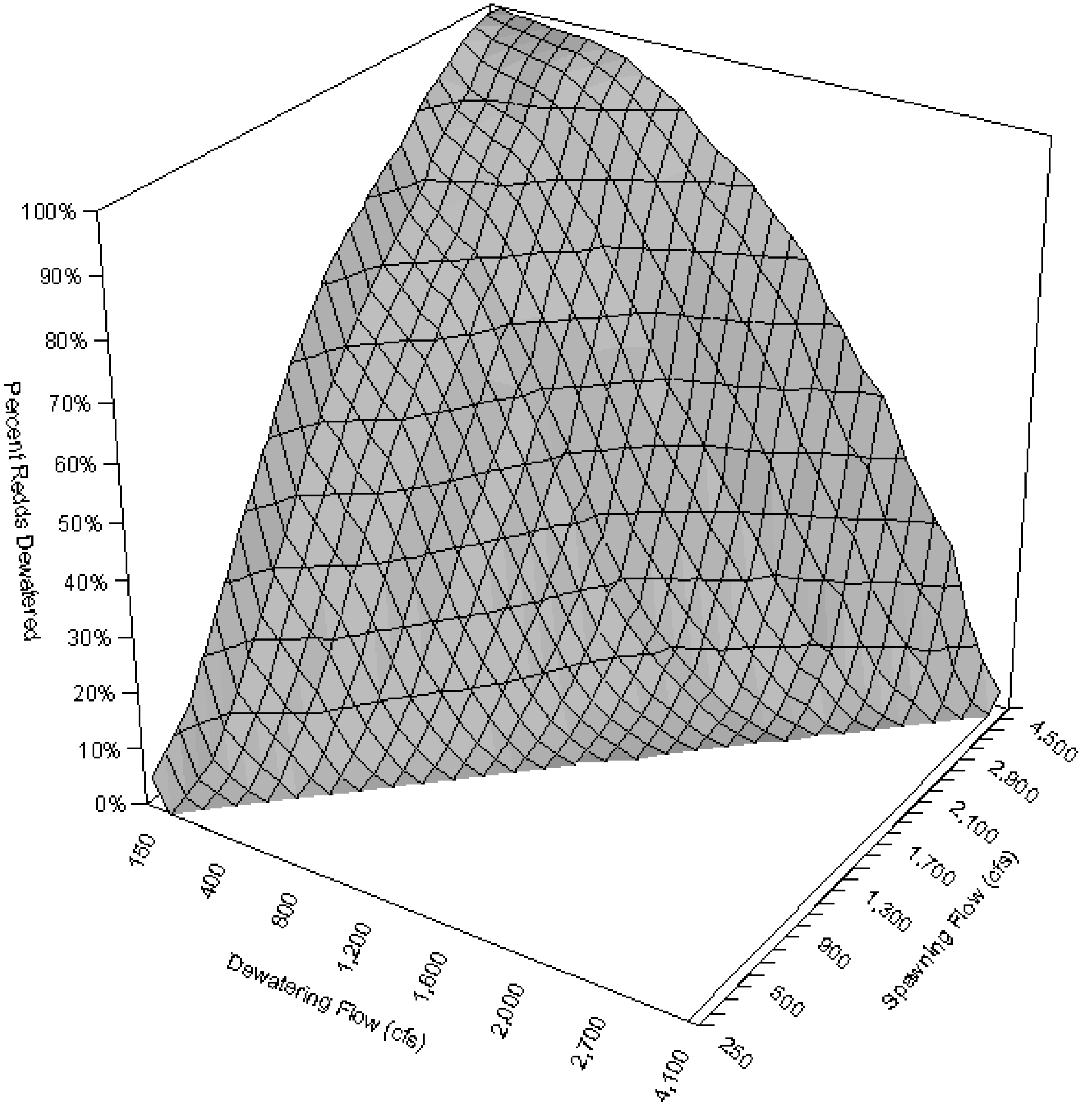

Figure 10. Predicted dewatering of spring-run Chinook salmon redds for the Lower Yuba River downstream of Daguerre Point Dam. The spawning flow is the flow prior to a flow reduction, while the dewatering flow is the flow after a flow reduction.

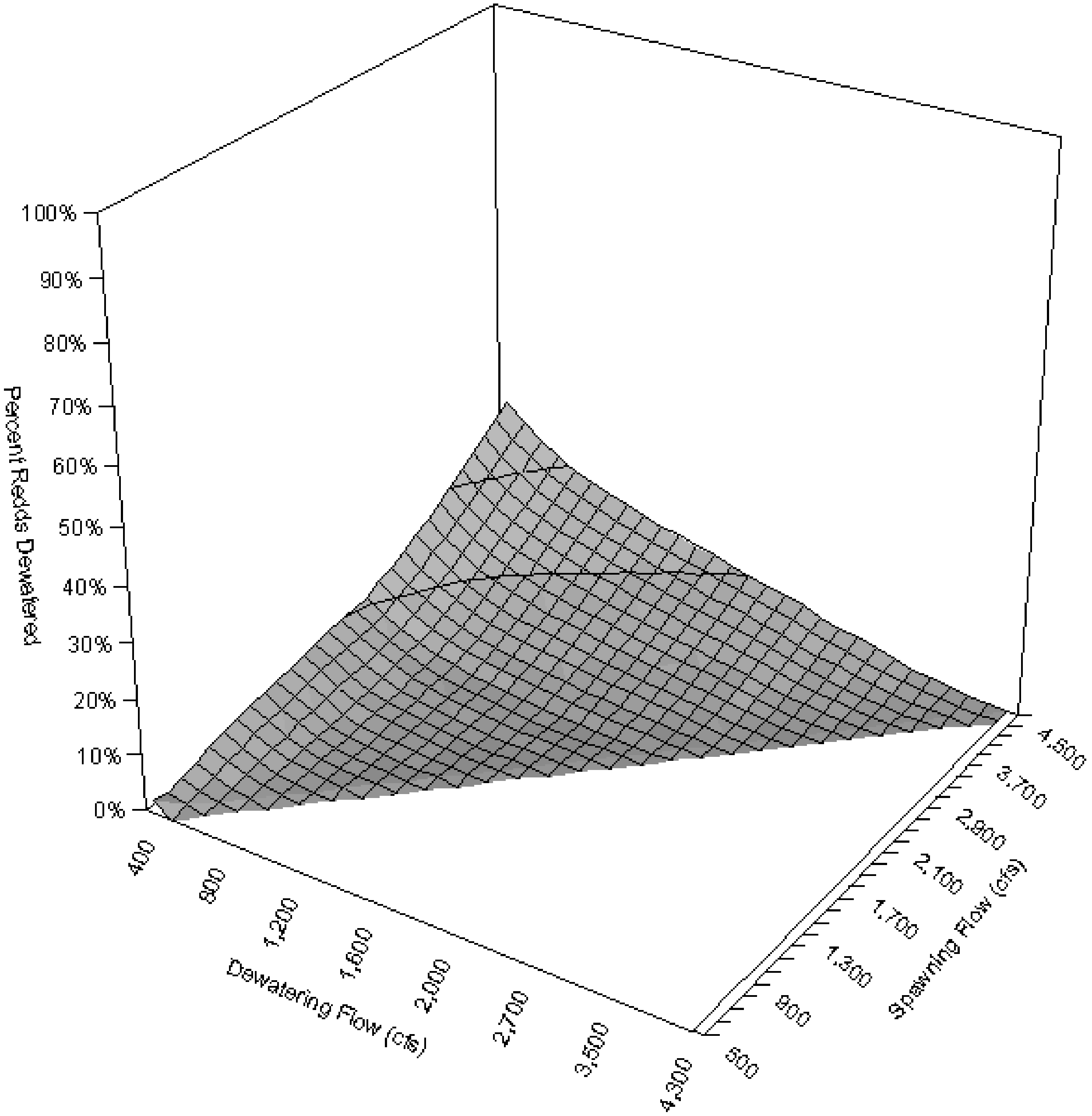

Figure 11. Predicted dewatering of steelhead/rainbow trout redds for the Lower Yuba River upstream of Daguerre Point Dam. The spawning flow is the flow prior to a flow reduction, while the dewatering flow is the flow after a flow reduction.

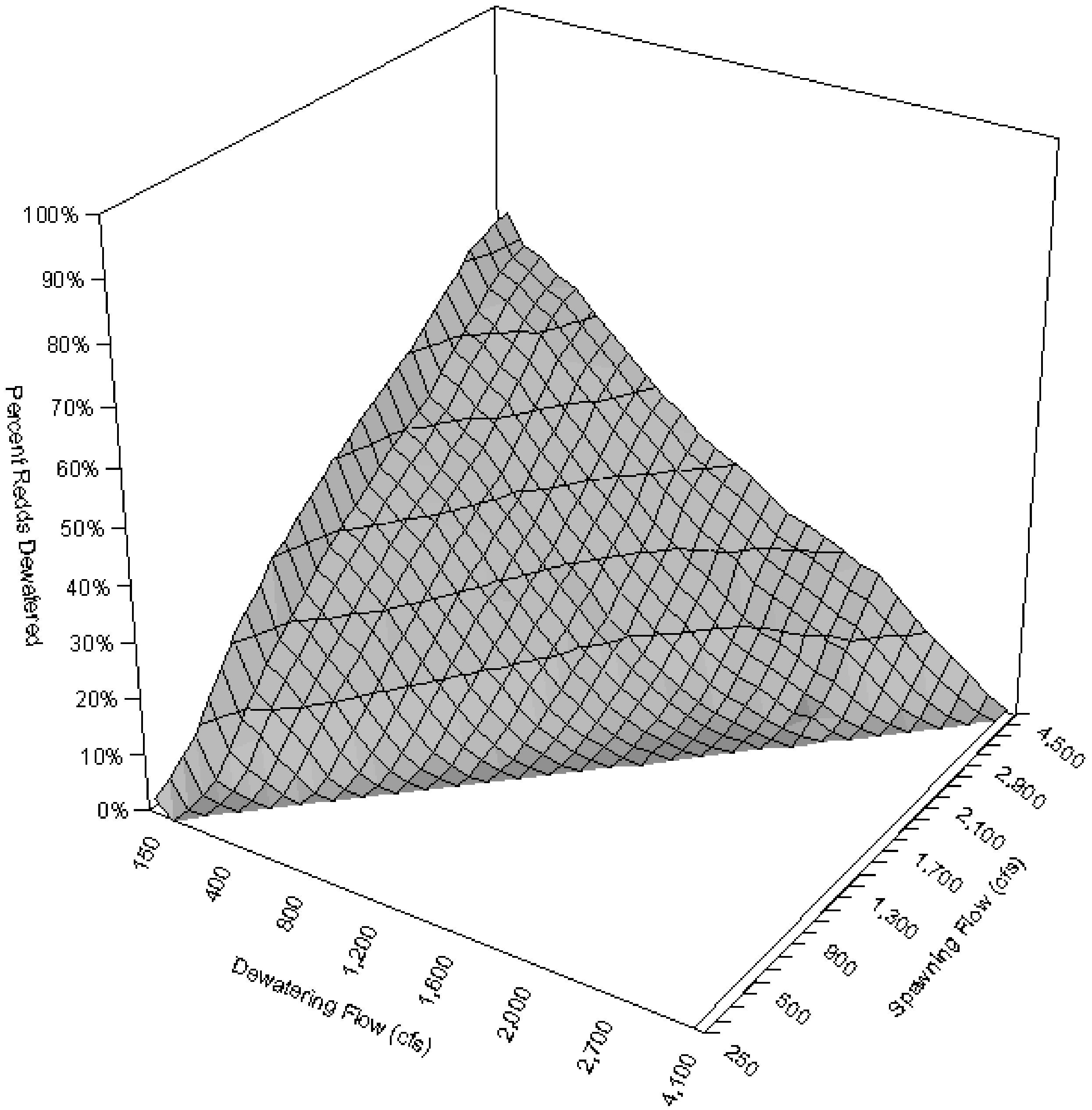

Figure 12. Predicted dewatering of steelhead/rainbow trout redds for the Lower Yuba River downstream of Daguerre Point Dam. The spawning flow is the flow prior to a flow reduction, while the dewatering flow is the flow after a flow reduction.

Table 10. Stranding area (ft^2) for juvenile anadromous salmonids and predicted percentage of Chinook salmon and steelhead/rainbow trout redds dewatered with flow changing from 2,900 to 2,000 cfs, 2,000 to 1,000 cfs and 2,900 to 1,000 cfs. This table provides examples (for the above three flow decreases) of the data in Appendices C and D.

Lifestage/race/species/segment	2,900 to 2,000 cfs	2,000 to 1,000 cfs	2,900 to 1,000 cfs
Juvenile salmonids above Daguerre Point Dam	188,564	66,486	255,050
Juvenile salmonids below Daguerre Point Dam	43,310	302,451	345,761
Fall-run Chinook redds above Daguerre Point Dam	14.9%	20.1%	41.0%
Fall-run Chinook redds below Daguerre Point Dam	14.2%	42.7%	56.9%
Spring-run Chinook redds above Daguerre Point Dam	7.5%	10.9%	28.9%
Spring-run Chinook redds below Daguerre Point Dam	6.8%	40.7%	60.3%
Steelhead/rainbow trout redds above Daguerre Point Dam	1.5%	2.4%	6.4%
Steelhead/rainbow trout redds below Daguerre Point Dam	2.1%	19.6%	29.0%

We still used *IFG4* for stranding site 2, which did not meet the measured-simulated WSEL difference criterion for *IFG4*, and stranding site 45, which did not meet the mean error criterion, because: 1) the difference between measured and simulated WSELs for both sites was less than 0.12 foot[13] (0.037 m); 2) in both cases the stranding flow was not greater than the highest calibration flow; and 3) the calibration plots indicated that there was a linear log-log relationship over the range of calibration flows. It seems likely that that beta coefficient values less than 2.0 were caused by channel characteristics at certain sites which form hydraulic controls at some flows but not at others (compound controls), thus affecting upstream water elevations. Specifically, at lower flows the channel at these sites controlled the water surface elevations, while at higher flows the water surface elevations were controlled by downstream hydraulic controls. Accordingly, the performance of *IFG4* for these sites was considered adequate despite the beta coefficient criterion not being met. Beta coefficient values greater than 4.5 likely were caused by the presence of a downstream hydraulic control, such that the actual SZFs of these sites were greater than those in Appendix B. We determined that the correct SZF would have had a minimal effect on the estimated stranding flows for these sites - for example, a SZF which produced a beta coefficient of 4.5 for stranding site 2 would have only decreased the stranding flow from 685 cfs to 680 cfs. As a result, we concluded that the SZFs in Appendix B were sufficiently accurate for the purposes of estimating stranding flows.

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[13] For much of the Yuba River, the WSEL going across the river will differ by more than 0.2 foot.

Habitat Suitability Criteria (HSC) Development

The average difference between the redd and tailspill depths of 0.5 foot (0.15 m) for Yuba River spring-run and fall-run Chinook salmon redds shallower than 2 feet (0.6 m) in this study is similar to the average tailspill height of 0.6 foot (0.18 m) for Columbia River fall-run Chinook salmon (Chapman et al. 1986). Devries (1997) in a literature review found considerable variation in estimates of egg burial depths, ranging from 0 to 0.80 m, and proposed a criterion of 0.15 m for the depth of the top of the egg pocket below the original stream bed level for both Chinook salmon and steelhead. Based on this criterion, we would estimate that the top of the egg pocket was 0.30 m (0.15 m + 0.15 m) below the tailspill elevation for Chinook salmon and 0.21 m (0.15 m + 0.06 m) for steelhead. Chapman et al. (1986) found that the depth of gravel over eggs in Columbia River fall-run Chinook salmon redds was at least 0.3 foot (0.09 m), while Reiser and White (1983) did not find increased mortality of steelhead/rainbow trout or Chinook salmon eggs when water levels were 0.3 feet (0.09 m) below the eggs for up to 4 to 5 weeks. In contrast, Becker et al. (1982) found substantial mortality for alevins that were dewatered for 1 to 4 hours per day. Given the uncertainty as to the location of the egg pockets within the redd, we believe that exposure of the tailspill is a reasonable conservative estimate of reduced survival. McMichael et al. (2005) found a survival rate averaging 29.2% from eggs to fry for redds which were dewatered 3.1% of the time during the posthatch intragravel rearing period. In contrast, since our dewatering analysis is based on flow variations with a temporal scale of one month, and thus dewatering during 100% of the time during the posthatch intragravel period, we would expect no survival of eggs and pre-emergent alevins for our redd dewatering estimates.

Miller et al. (2008) found reduced growth rates of rainbow trout that were exposed to hypoxic conditions associated with low intragravel flow rates. In some situations, downwelling currents can provide adequate intragravel velocities through redds even with very low mean water column velocities. We do not consider this to be likely in the Yuba River - if there had been conditions where downwelling currents had provided sufficient intragravel velocities at low mean water column velocities, we would have expected to find salmon and steelhead constructing redds in such situations.

Habitat Simulation

The results indicate that, as expected, greater drops in flow are associated with increased juvenile anadromous salmonid stranding areas, but that substantial juvenile stranding could be avoided by maintaining flows downstream of Daguerre Point Dam either above or below a threshold of 1,200 cfs, and maintaining flows upstream of Daguerre Point Dam either: 1) above a threshold of 3,700 cfs; 2) between thresholds of 2,300 and 3,700 cfs; or 3) below 2,300 cfs. The results of this juvenile stranding study could be refined by combining the results of this study with the results of Jones and Stokes' studies on juvenile salmonid densities found in stranding areas. A further refinement of this juvenile stranding study would be to develop separate relationships for different seasons or water year types. Specifically, Stranding Sites 37, 51 and 57 had flow, originating from the Yuba Goldfields, exiting the stranding sites, when the stranding sites were identified. Juvenile anadromous salmonids would only be stranded in these sites when there was no longer flow exiting these sites (for example in the fall or during dry years). Similar to juvenile stranding, the results of the redd dewatering analysis indicate that, as expected, greater drops in flow result in a greater percentage of salmon and steelhead/rainbow trout redds being dewatered. However, the redd dewatering analysis did not show flow threshold patterns, as were observed for juvenile stranding.

A basic assumption of all instream flow studies is that a stream is in dynamic equilibrium. When a channel is in dynamic equilibrium, there is an approximate balance between sediment supply and transport, so that the channel pattern and cross-sectional profile of the entire stream is consistent (Bovee 1996). For a stream in dynamic equilibrium, it would be expected that large flow events would not result in a significant change in flow-habitat relationships. Recent high flows on the Yuba River (Figure 13) have resulted in significant channel changes. While we do not have direct evidence that the Yuba River is in dynamic equilibrium, our findings on the American River that the January 1997 flood did not result in a substantial change in Chinook salmon or steelhead spawning flow-habitat relationships (US Fish and Wildlife Service 2000) offer support that the results of this study are still applicable to the Yuba River.

CONCLUSION

The model developed in this study is predictive for flows ranging from 400 cfs to 4,500 cfs for redd dewatering and juvenile stranding upstream of Daguerre Point Dam, and for flows ranging from 150 cfs to 4,500 cfs downstream of Daguerre Point Dam. This study supported and achieved the objective of modeling the effects of flow decreases on Chinook salmon and steelhead/rainbow trout spawning habitat and maximum potential juvenile entrapment in the Yuba River between Englebright Dam and the Feather River.

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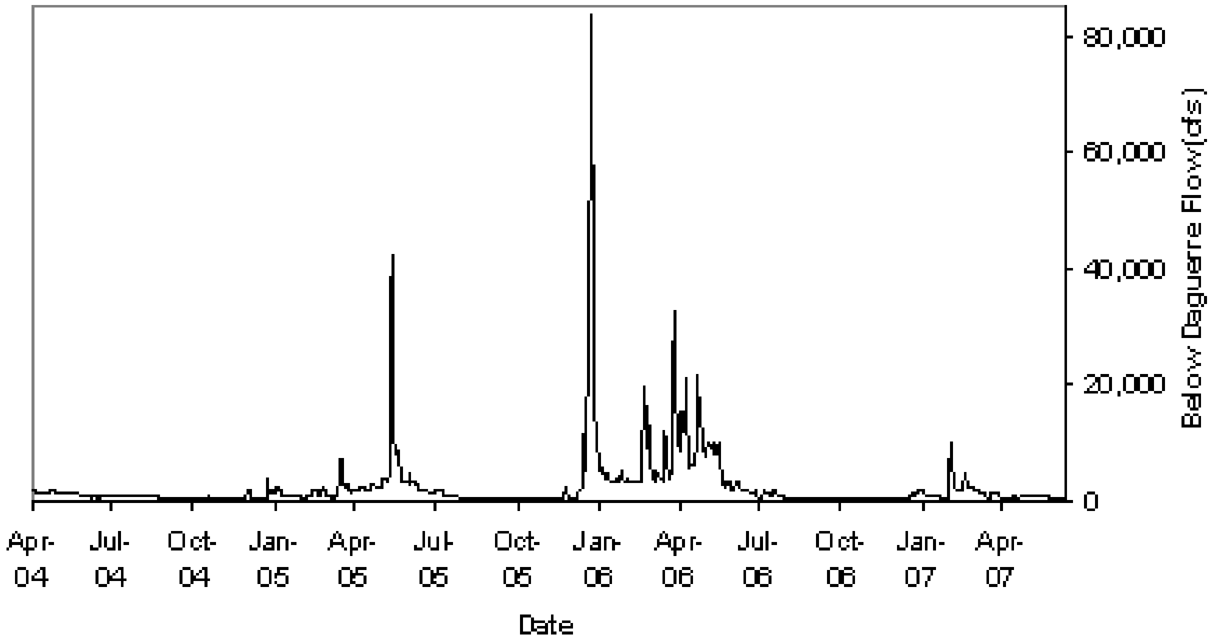

Figure 13. Yuba River flows below Daguerre Point Dam subsequent to the completion of most of the data collection for this study. High flows in May 2005 and January and April 2006 resulted in substantial channel changes in the Yuba River.

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APPENDIX A
STRANDING SITE LOCATIONS AND STRANDING FLOWS

Stranding Site #	MHU #	Stranding Flow[14] (cfs)	Stranding Area (ft^2)
1	179-180	< 400	27,144
2	173	685	1,400
3	169	2,128	253
4	170	2,110	7,356
5	168	3,317	750
7	160-163	< 400	48,742
7A	158-159	494	14,712
8	141	< 400	14,208
8A	141	829	268
8B	142	516	104
9	139/135	3,338	3,653
10	135	1,672	4,870
11	137/138	545	9
12	134	< 400	7,980
13	131	< 400	7,471
15	128	< 400	31,534
16	117/119	1,667	16,434
17	50	307	10,337
18	49	354	38,045
19	45	2,096	4,205
20	45	891	3,413
21	41, 43, 44	395	29,859
22	40	1,696	3,231
23	37	1,879	1,057
24	35	991	5,433
25	28-33	750	14,519

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[14] The stranding flow is the flow where the connection between the stranding area and main river channel has a maximum depth of 0.1 foot.

Stranding Site #	MHU #	Stranding Flow (cfs)	Stranding Area (ft^2)
26	201	3,597	10,279
27	201	1,953	16
28	201	2,300	1,511
29	199	3,135	2,230
30	194	2,707	5,625
31	192	1,790	1,200
32	190	634	1,473
33	187	1,188	246
34	120	< 400	1,800
35	117	1,908	2,083
36	118	1,735	351
37	113	2,416	153,129
38	113	1,175	1,000
39	112	4,907	3,547
40	112	3,525	227,615
41	112	3,993	2,068
42	112	1,563	1,339
43	112	3,192	6,510
44	94	597	18,854
45	96-98	< 400	1,219
46	100	1,930	38,947
47	100-104	2,309	20,690
48	89	1,002	800
49	89	1,813	1,220
49A	89	857	1,200
49B	89	1,001	750
50A	89	3,069	300
50B	89	2,702	15
50C	89	1,249	420
51	83	2,474	26,917

Stranding Site #	MHU #	Stranding Flow (cfs)	Stranding Area (ft^2)
52	82	990	476
53	80	1,079	20,576
54	80	1,060	6,600
55A	78	1,017	7,613
55B	78	3,974	330
56	74	1,813	150
57	71	1,136	250,049
58	69	2,906	5,685
59A	68/69	2,698	960
59B	68/69	3,409	861
60	63	485	18,607
61	59	790	10,774
62	56	2,247	10,989
63A	56	4,380	3,460
63B	56	2,300	224
64	53	1,949	9,985
65	51	907	15,168
66	24	903	3,040
67	4	738	100
68	1	467	583

Shapefiles for the above stranding areas are available in electronic format upon request from:

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

APPENDIX B
PHABSIM WSEL CALIBRATION

Stage of Zero Flow Values[15]

Stranding Site	SZF
2	91.8
10	97.1
11	97.6
12	95.6
16	99.4
18	93.0
19	92.5
20	97.0
21	97.2
22	95.9
24	97.6
26	94.8
28	98.7
29	97.2
30	97.7
31	99.5
32	97.4
34	95.5
35	96.0
36	98.7
37	98.4
38	96.9
39	93.3
40	93.3

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[15] Elevations are set relative to a benchmark arbitrarily assigned an elevation of 100.00 ft.

Stranding Site	SZF
41	90.1
42	94.1
43	94.0
44	95.3
45	96.7
47	94.6
48	89.9
49A	93.9
50	92.3
55	95.7
57	94.1
58	93.6
59	90.1
61	87.7
62	92.6
63	93.5
64	93.5
65	92.8
66	90.7
67	90.0
68	86.1

	BETA	%MEAN	Calculated vs. Given Disch. (%)[16]			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	1,021 cfs	3,154 cfs	5,786 cfs	1,021 cfs	3,154 cfs	5,786 cfs
2	4.66	4.0	2.4	6.2	3.6	0.04	0.11	0.08

	BETA	%MEAN	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
SITE	COEFF.	ERROR	1,018 cfs	3,154 cfs	1,018 cfs	3,154 cfs
10	3.26	---	---	---	0.00	0.00
11	4.17	---	---	---	0.00	0.00

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	1,018 cfs	3,154 cfs	5,574 cfs	1,018 cfs	3,154 cfs	5,574 cfs
12	3.49	1.9	1.0	2.9	1.8	0.01	0.04	0.04

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	1,018 cfs	3,150 cfs	5,559 cfs	1,018 cfs	3,150 cfs	5,559 cfs
16	2.07	0.2	0.1	0.4	0.2	0.00	0.01	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
SITE	COEFF.	ERROR	1,151 cfs	1,898 cfs	1,151 cfs	1,898 cfs
18	1.74	---	---	---	0.00	0.00
20	2.69	---	---	---	0.00	0.00

	BETA	%MEAN	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
SITE	COEFF.	ERROR	1,898 cfs	3,150 cfs	1,898 cfs	3,150 cfs
19	1.35	---	---	---	0.00	0.00

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	991 cfs	1,898 cfs	3,768 cfs	991 cfs	1,898 cfs	3,768 cfs
21	3.21	4.2	2.8	6.0	3.5	0.03	0.09	0.06

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[16] For Calculated versus Given Discharge and Difference, the direction of deviation is omitted.

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	991 cfs	1,898 cfs	3,768 cfs	991 cfs	1,898 cfs	3,768 cfs
22	4.13	1.8	1.5	2.8	1.3	0.02	0.04	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	2,054 cfs	3,150 cfs	5,771 cfs	2,054 cfs	3,150 cfs	5,771 cfs
26	5.20	2.2	2.1	3.4	1.2	0.05	0.08	0.03

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs. pred. WSELs)			
SITE	COEFF.	ERROR	971 cfs	2,054 cfs	3,150 cfs	5,771 cfs	971 cfs	2,054 cfs	3,150 cfs	5,771 cfs
28	2.26	1.0	1.1	1.6	0.4	0.9	0.01	0.02	0.01	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	2,054 cfs	3,150 cfs	5,769 cfs	2,054 cfs	3,150 cfs	5,769 cfs
29	8.36	0.5	0.4	0.7	0.3	0.01	0.01	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	971 cfs	2,054 cfs	3,150 cfs	971 cfs	2,054 cfs	3,150 cfs
30	3.26	5.2	3.6	8.3	4.2	0.03	0.07	0.04

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs. pred. WSELs)			
SITE	COEFF.	ERROR	971 cfs	2,054 cfs	3,150 cfs	5,769 cfs	971 cfs	2,054 cfs	3,150 cfs	5,769 cfs
31	4.34	1.2	0.5	1.9	1.9	0.5	0.01	0.03	0.04	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
SITE	COEFF.	ERROR	971 cfs	2,054 cfs	971 cfs	2,054 cfs
32	3.65	---	---	---	0.00	0.00
34	3.03	---	---	---	0.00	0.00

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs. pred. WSELs)			
SITE	COEFF.	ERROR	971 cfs	2,054 cfs	3,150 cfs	5,651 cfs	971 cfs	2,054 cfs	3,150 cfs	5,651 cfs
35	3.15	1.6	1.3	1.5	1.6	1.8	0.01	0.01	0.02	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs. pred. WSELs)			
SITE	COEFF.	ERROR	971 cfs	2,054 cfs	3,150 cfs	5,683 cfs	971 cfs	2,054 cfs	3,150 cfs	5,683 cfs
36	2.34	1.8	1.9	2.7	0.9	1.7	0.02	0.04	0.01	0.03

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs. pred. WSELs)			
SITE	COEFF.	ERROR	971 cfs	1,930 cfs	3,154 cfs	4,180 cfs	971 cfs	1,930 cfs	3,154 cfs	4,180 cfs
37	2.71	5.0	5.5	8.7	1.7	4.4	0.04	0.08	0.02	0.05
38	1.29	2.1	2.0	4.2	0.7	1.6	0.02	0.06	0.01	0.04

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs. pred. WSELs)			
SITE	COEFF.	ERROR	971 cfs	1,930 cfs	3,150 cfs	4,180 cfs	971 cfs	1,930 cfs	3,150 cfs	4,180 cfs
39	2.48	1.6	1.2	1.6	1.6	2.0	0.01	0.02	0.03	0.04
40	2.78	3.4	3.0	4.2	2.7	3.7	0.03	0.05	0.04	0.06
41	3.07	0.6	0.6	1.2	0.1	0.5	0.01	0.02	0.00	0.01
42	4.26	2.9	2.1	2.2	3.5	3.5	0.03	0.04	0.07	0.08

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	965 cfs	1,930 cfs	3,150 cfs	965 cfs	1,930 cfs	3,150 cfs
43	2.61	3.0	2.1	4.6	2.4	0.02	0.07	0.04
44	3.03	3.6	1.9	5.3	3.6	0.01	0.04	0.04
45	2.55	13.2	2.3	17.8	18.9	0.01	0.09	0.09
47	2.21	1.4	0.8	2.1	1.3	0.01	0.03	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs. pred. WSELs)			
SITE	COEFF.	ERROR	943 cfs	1,740 cfs	2,509 cfs	3,674 cfs	943 cfs	1,740 cfs	2,509 cfs	3,674 cfs
48	2.68	0.9	0.0	0.1	1.8	0.8	0.00	0.01	0.03	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	943 cfs	2,517 cfs	3,674 cfs	943 cfs	2,517 cfs	3,674 cfs
49A	2.23	2.3	0.8	3.3	2.6	0.01	0.07	0.07

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	943 cfs	1,740 cfs	2,509 cfs	943 cfs	1,740 cfs	2,509 cfs
50A/B/C	2.27	2.7	1.3	4.0	2.9	0.02	0.08	0.05

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs. pred. WSELs)			
SITE	COEFF.	ERROR	1,001 cfs	1,813 cfs	2,517 cfs	3,720 cfs	1,001 cfs	1,813 cfs	2,517 cfs	3,720 cfs
55A/B	1.73	1.6	0.2	2.2	3.1	1.0	0.00	0.03	0.06	0.02
58	1.81	2.7	1.8	5.2	2.9	0.7	0.02	0.10	0.07	0.02
59A/B	3.92	1.4	0.3	1.1	2.8	1.4	0.00	0.02	0.05	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	1,001 cfs	1,813 cfs	2,517 cfs	1,001 cfs	1,813 cfs	2,517 cfs
57	3.05	3.7	1.4	5.4	4.2	0.01	0.07	0.05

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	1,151 cfs	2,517 cfs	3,768 cfs	1,151 cfs	2,517 cfs	3,768 cfs
61	1.38	0.1	0.0	0.1	0.1	0.00	0.00	0.00
62	2.43	1.2	0.6	1.8	1.1	0.01	0.04	0.03

	BETA	%MEAN	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
SITE	COEFF.	ERROR	1,151 cfs	2,823 cfs	1,151 cfs	2,823 cfs
63A/B	2.62	---	---	---	0.00	0.00

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	1,151 cfs	2,823 cfs	3,768 cfs	1,151 cfs	2,823 cfs	3,768 cfs
64	2.31	0.9	0.4	1.4	1.0	0.00	0.03	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	1,052 cfs	1,898 cfs	3,768 cfs	1,052 cfs	1,898 cfs	3,768 cfs
66	2.26	2.7	2.0	4.0	2.1	0.03	0.08	0.06

APPENDIX C
JUVENILE STRANDING RESULTS

Area (ft^2) Stranded Above Daguerre

Rearing Flow (cfs)

Stranding flow (cfs)	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000
4,300																
4,100																
3,900																
3,700																
3,500																
3,300																
3,100																
2,900																
2,700																
2,500																
2,300																
2,100																
2,000																
1,900																41,046
1,800															0	41,046
1,700														1551	1551	42,597
1,600													21,304	22,855	22,855	63,901
1,500												1,339	22,643	24,194	24,194	65,240
1,400											0	1,339	22,643	24,194	24,194	65,240
1,300										0	0	1,339	22,643	24,194	24,194	65,240
1,200									0	0	0	1,339	22,643	24,194	24,194	65,240
1,100								1,246	1,246	1,246	1,246	2,585	23,889	25,440	25,440	66,486
1,000							0	1,246	1,246	1,246	1,246	2,585	23,889	25,440	25,440	66,486
900						0	0	1,246	1,246	1,246	1,246	2,585	23,889	25,440	25,440	66,486
800					268	268	268	1,514	1,514	1,514	1,514	2,853	24,157	25,708	25,708	66,754
700				0	268	268	268	1,514	1,514	1,514	1,514	2,853	24,157	25,708	25,708	66,754
600			2,873	2,873	3,141	3,141	3,141	4,387	4,387	4,387	4,387	5,726	27,030	28,581	28,581	69,627
500		18,967	21,840	21,840	22,108	22,108	22,108	23,354	23,354	23,354	23,354	24,693	45,997	47,548	47,548	88,594
400	14,712	33,679	36,552	36,552	36,820	36,820	36,820	38,066	38,066	38,066	38,066	39,405	60,709	62,260	62,260	103,306

Area (ft^2) Stranded Above Daguerre (continued)

	Rearing Flow (cfs)												
Stranding flow (cfs)	2,100	2,300	2,500	2,700	2,900	3,100	3,300	3,500	3,700	3,900	4,100	4,300	4,500
4,300													0
4,100												0	0
3,900											2,068	2,068	2,068
3,700										0	2,068	2,068	2,068
3,500									237,894	237,894	239,962	239,962	239,962
3,300								4,403	242,297	242,297	244,365	244,365	244,365
3,100							8,740	13,143	251,037	251,037	253,105	253,105	253,105
2,900						0	8,740	13,143	251,037	251,037	253,105	253,105	253,105
2,700					5,625	5,625	14,365	18,768	256,662	256,662	258,730	258,730	258,730
2,500				0	5,625	5,625	14,365	18,768	256,662	256,662	258,730	258,730	258,730
2,300			175,330	175,330	180,955	180,955	189,695	194,098	431,992	431,992	434,060	434,060	434,060
2,100		7,609	182,939	182,939	188,564	188,564	197,304	201,707	439,601	439,601	441,669	441,669	441,669
2,000	0	7,609	182,939	182,939	188,564	188,564	197,304	201,707	439,601	439,601	441,669	441,669	441,669
1,900	41,046	48,655	223,985	223,985	229,610	229,610	238,350	242,753	480,647	480,647	482,715	482,715	482,715
1,800	41,046	48,655	223,985	223,985	229,610	229,610	238,350	242,753	480,647	480,647	482,715	482,715	482,715
1,700	42,597	50,206	225,536	225,536	231,161	231,161	239,901	244,304	482,198	482,198	484,266	484,266	484,266
1,600	63,901	71,510	246,840	246,840	252,465	252,465	261,205	265,608	503,502	503,502	505,570	505,570	505,570
1,500	65,240	72,849	248,179	248,179	253,804	253,804	262,544	266,947	504,841	504,841	506,909	506,909	506,909
1,400	65,240	72,849	248,179	248,179	253,804	253,804	262,544	266,947	504,841	504,841	506,909	506,909	506,909
1,300	65,240	72,849	248,179	248,179	253,804	253,804	262,544	266,947	504,841	504,841	506,909	506,909	506,909
1,200	65,240	72,849	248,179	248,179	253,804	253,804	262,544	266,947	504,841	504,841	506,909	506,909	506,909
1,100	66,486	74,095	249,425	249,425	255,050	255,050	263,790	268,193	506,087	506,087	508,155	508,155	508,155
1,000	66,486	74,095	249,425	249,425	255,050	255,050	263,790	268,193	506,087	506,087	508,155	508,155	508,155
900	66,486	74,095	249,425	249,425	255,050	255,050	263,790	268,193	506,087	506,087	508,155	508,155	508,155
800	66,754	74,363	249,693	249,693	255,318	255,318	264,058	268,461	506,355	506,355	508,423	508,423	508,423
700	66,754	74,363	249,693	249,693	255,318	255,318	264,058	268,461	506,355	506,355	508,423	508,423	508,423
600	69,627	77,236	252,566	252,566	258,191	258,191	266,931	271,334	509,228	509,228	511,296	511,296	511,296
500	88,594	96,203	271,533	271,533	277,158	277,158	285,898	290,301	528,195	528,195	530,263	530,263	530,263
400	103,306	110,915	286,245	286,245	291,870	291,870	300,610	305,013	542,907	542,907	544,975	544,975	544,975

Area (ft^2) Stranded Below Daguerre

Rearing Flow (cfs)

Stranding flow (cfs)	250	300	350	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600
4,100																
3,700																
3,300																
2,900																
2,700																
2,500																
2,300																
2,100																
2,000																
1,900																
1,800																
1,700																
1,600																
1,500																0
1,400															0	0
1,300														0	0	0
1,200													420	420	420	420
1,100												250,049	250,469	250,469	250,469	250,469
1,000											36,339	286,388	286,808	286,808	286,808	286,808
900										24,117	60,456	310,505	310,925	310,925	310,925	310,925
800									4,613	28,730	65,069	315,118	315,538	315,538	315,538	315,538
700								25,393	30,006	54,123	90,462	340,511	340,931	340,931	340,931	340,931
600							0	25,393	30,006	54,123	90,462	340,511	340,931	340,931	340,931	340,931
500						0	0	25,393	30,006	54,123	90,462	340,511	340,931	340,931	340,931	340,931
400					19,190	19,190	19,190	44,583	49,196	73,313	109,652	359,701	360,121	360,121	360,121	360,121
350				67,904	87,094	87,094	87,094	112,487	117,100	141,217	177,556	427,605	428,025	428,025	428,025	428,025
300			10,337	78,241	97,431	97,431	97,431	122,824	127,437	151,554	187,893	437,942	438,362	438,362	438,362	438,362
250		0	10,337	78,241	97,431	97,431	97,431	122,824	127,437	151,554	187,893	437,942	438,362	438,362	438,362	438,362
150	0	0	10,337	78,241	97,431	97,431	97,431	122,824	127,437	151,554	187,893	437,942	438,362	438,362	438,362	438,362

Area (ft^2) Stranded Below Daguerre (continued)

Rearing Flow (cfs)

Stranding flow (cfs)	1,700	1,800	1,900	2,000	2,100	2,300	2,500	2,700	2,900	3,300	3,700	4,100	4,500
4,100													3,460
3,700												330	3,790
3,300											861	1,191	4,651
2,900										5,985	6,846	7,176	10,636
2,700									15	6,000	6,861	7,191	10,651
2,500								960	975	6,960	7,821	8,151	11,611
2,300							27,141	28,101	28,116	34,101	34,962	35,292	38,752
2,100						10,989	38,130	39,090	39,105	45,090	45,951	46,281	49,741
2,000					4,205	15,194	42,335	43,295	43,310	49,295	50,156	50,486	53,946
1,900				9,985	14,190	25,179	52,320	53,280	53,295	59,280	60,141	60,471	63,931
1,800			2,427	12,412	16,617	27,606	54,747	55,707	55,722	61,707	62,568	62,898	66,358
1,700		0	2,427	12,412	16,617	27,606	54,747	55,707	55,722	61,707	62,568	62,898	66,358
1,600	3,231	3,231	5,658	15,643	19,848	30,837	57,978	58,938	58,953	64,938	65,799	66,129	69,589
1,500	3,231	3,231	5,658	15,643	19,848	30,837	57,978	58,938	58,953	64,938	65,799	66,129	69,589
1,400	3,231	3,231	5,658	15,643	19,848	30,837	57,978	58,938	58,953	64,938	65,799	66,129	69,589
1,300	3,231	3,231	5,658	15,643	19,848	30,837	57,978	58,938	58,953	64,938	65,799	66,129	69,589
1,200	3,651	3,651	6,078	16,063	20,268	31,257	58,398	59,358	59,373	65,358	66,219	66,549	70,009
1,100	253,700	253,700	256,127	266,112	270,317	281,306	308,447	309,407	309,422	315,407	316,268	316,598	320,058
1,000	290,039	290,039	292,466	302,451	306,656	317,645	344,786	345,746	345,761	351,746	352,607	352,937	356,397
900	314,156	314,156	316,583	326,568	330,773	341,762	368,903	369,863	369,878	375,863	376,724	377,054	380,514
800	318,769	318,769	321,196	331,181	335,386	346,375	373,516	374,476	374,491	380,476	381,337	381,667	385,127
700	344,162	344,162	346,589	356,574	360,779	371,768	398,909	399,869	399,884	405,869	406,730	407,060	410,520
600	344,162	344,162	346,589	356,574	360,779	371,768	398,909	399,869	399,884	405,869	406,730	407,060	410,520
500	344,162	344,162	346,589	356,574	360,779	371,768	398,909	399,869	399,884	405,869	406,730	407,060	410,520
400	363,352	363,352	365,779	375,764	379,969	390,958	418,099	419,059	419,074	425,059	425,920	426,250	429,710
350	431,256	431,256	433,683	443,668	447,873	458,862	486,003	486,963	486,978	492,963	493,824	494,154	497,614
300	441,593	441,593	444,020	454,005	458,210	469,199	496,340	497,300	497,315	503,300	504,161	504,491	507,951
250	441,593	441,593	444,020	454,005	458,210	469,199	496,340	497,300	497,315	503,300	504,161	504,491	507,951
150	441,593	441,593	444,020	454,005	458,210	469,199	496,340	497,300	497,315	503,300	504,161	504,491	507,951

APPENDIX D
REDD DEWATERING RESULTS

Percentage of Fall-run Chinook Salmon Redds Dewatered Above Daguerre

	Spawning Flow (cfs)															
Dewatering flow (cfs)	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000
4,300																
4,100																
3,900																
3,700																
3,500																
3,300																
3,100																
2,900																
2,700																
2,500																
2,300																
2,100																
2,000																
1,900																0.9%
1,800															0.8%	1.9%
1,700														0.8%	1.7%	3.1%
1,600													0.9%	1.9%	3.1%	4.8%
1,500												0.8%	1.9%	3.3%	4.7%	6.5%
1,400											0.9%	1.7%	3.1%	4.7%	6.4%	8.3%
1,300										1.1%	2.0%	3.1%	4.7%	6.5%	8.2%	10.3%
1,200									1.3%	2.5%	3.9%	5.4%	7.2%	9.2%	11.1%	13.4%
1,100								1.7%	3.2%	4.9%	6.6%	8.4%	10.4%	12.7%	14.8%	17.2%
1,000							1.6%	3.1%	5.0%	7.0%	8.9%	10.9%	13.0%	15.3%	17.6%	20.1%
900						1.7%	3.3%	5.3%	7.5%	9.8%	12.0%	14.1%	16.4%	18.9%	21.2%	23.8%
800					2.1%	3.8%	5.9%	8.3%	10.8%	13.2%	15.6%	17.9%	20.3%	22.8%	25.1%	27.7%
700				2.7%	5.4%	7.8%	10.4%	13.1%	15.8%	18.4%	20.9%	23.1%	25.5%	28.0%	30.4%	32.9%
600			3.2%	6.6%	10.1%	13.2%	16.3%	19.3%	22.2%	24.9%	27.5%	29.8%	32.2%	34.6%	36.9%	39.3%
500		3.7%	7.9%	12.3%	16.4%	19.8%	23.0%	26.1%	29.0%	31.7%	34.2%	36.4%	38.7%	41.1%	43.3%	45.6%
400	2.6%	8.1%	13.3%	18.2%	22.6%	26.3%	29.7%	32.9%	35.7%	38.4%	40.8%	43.0%	45.2%	47.5%	49.6%	51.8%

Percentage of Fall-run Chinook Salmon Redds Dewatered Above Daguerre (continued)

Spawning Flow (cfs)

Dewatering flow (cfs)	2,100	2,300	2,500	2,700	2,900	3,100	3,300	3,500	3,700	3,900	4,100	4,300	4,500
4,300													1.5%
4,100												2.2%	4.5%
3,900											1.9%	4.7%	7.9%
3,700										1.7%	3.9%	7.3%	10.9%
3,500									1.6%	3.6%	6.4%	10.2%	14.0%
3,300								1.8%	4.2%	6.9%	10.2%	14.2%	18.3%
3,100							2.2%	4.7%	7.9%	11.1%	14.7%	19.0%	23.2%
2,900						1.8%	4.5%	7.7%	11.4%	14.8%	18.6%	23.0%	27.3%
2,700					2.0%	4.0%	7.4%	11.2%	15.4%	19.1%	23.2%	27.8%	32.3%
2,500				1.5%	3.9%	6.5%	10.2%	14.3%	18.6%	22.4%	26.6%	31.1%	35.5%
2,300			1.8%	4.2%	7.3%	10.3%	14.3%	18.6%	23.1%	27.1%	31.2%	35.7%	40.0%
2,100		2.2%	5.1%	8.5%	12.5%	15.9%	20.3%	24.9%	29.4%	32.7%	36.9%	42.0%	46.1%
2,000	1.0%	3.6%	7.0%	10.8%	14.9%	18.6%	23.1%	27.7%	32.3%	36.3%	40.4%	44.7%	48.7%
1,900	2.0%	5.3%	9.0%	13.0%	17.3%	21.1%	25.7%	30.3%	34.8%	38.8%	42.9%	47.1%	51.0%
1,800	3.5%	7.2%	11.2%	15.4%	19.9%	23.8%	28.4%	33.0%	37.5%	41.5%	45.4%	49.6%	53.4%
1,700	4.8%	8.9%	13.1%	17.6%	22.2%	26.1%	30.7%	35.3%	39.7%	43.6%	47.5%	51.6%	55.3%
1,600	6.7%	10.9%	15.3%	19.7%	24.3%	28.3%	32.8%	37.3%	41.7%	45.5%	49.3%	53.3%	56.9%
1,500	8.6%	13.1%	17.5%	22.1%	26.7%	30.6%	35.2%	39.6%	42.2%	47.7%	51.4%	55.2%	58.8%
1,400	10.5%	15.1%	19.7%	24.2%	28.8%	32.7%	37.1%	41.5%	45.7%	49.4%	53.1%	56.8%	60.4%
1,300	12.5%	17.1%	21.6%	26.1%	30.7%	34.4%	38.8%	43.0%	47.1%	50.7%	54.3%	58.0%	61.4%
1,200	15.8%	20.6%	25.3%	29.9%	34.3%	38.0%	42.2%	46.3%	50.3%	53.7%	57.2%	60.7%	64.0%
1,100	19.7%	24.6%	29.3%	33.8%	38.2%	41.7%	45.8%	49.7%	53.4%	56.7%	60.0%	63.4%	66.5%
1,000	22.6%	27.6%	32.3%	36.7%	41.0%	44.5%	48.4%	52.2%	55.8%	59.0%	62.2%	65.4%	68.5%
900	26.3%	31.2%	35.8%	40.2%	44.3%	47.6%	51.4%	55.0%	58.4%	61.5%	64.5%	67.6%	70.5%
800	30.3%	35.2%	39.6%	43.8%	47.8%	51.0%	54.6%	58.1%	61.4%	64.3%	67.2%	70.2%	72.9%
700	35.5%	40.2%	44.5%	48.5%	52.3%	55.4%	58.8%	62.0%	65.1%	67.8%	70.5%	73.2%	75.7%
600	41.8%	46.3%	50.3%	54.1%	57.6%	60.5%	63.6%	66.5%	69.3%	71.8%	74.1%	76.6%	78.8%
500	48.0%	52.2%	56.0%	59.5%	62.7%	65.4%	68.2%	70.9%	73.3%	75.5%	77.6%	79.8%	81.7%
400	54.1%	58.0%	61.5%	64.7%	67.6%	70.1%	72.6%	75.0%	77.2%	79.1%	81.0%	82.8%	84.5%

Percentage of Fall-run Chinook Salmon Redds Dewatered Below Daguerre

Spawning Flow (cfs)

Dewatering flow (cfs)	250	300	350	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600
4,100																
3,700																
3,300																
2,900																
2,700																
2,500																
2,300																
2,100																
2,000																
1,900																
1,800																
1,700																
1,600																
1,500																1.9%
1,400															2.4%	4.4%
1,300														2.1%	4.5%	7.0%
1,200													2.1%	4.4%	7.5%	10.3%
1,100												2.8%	5.6%	8.7%	12.2%	15.3%
1,000											2.7%	6.7%	10.3%	13.8%	17.5%	20.7%
900										2.8%	6.2%	10.8%	14.9%	18.6%	22.4%	25.7%
800									3.4%	7.0%	11.3%	16.3%	20.6%	24.4%	28.3%	31.6%
700								3.3%	7.0%	11.3%	16.0%	21.2%	25.5%	29.4%	33.1%	36.4%
600							4.1%	8.4%	13.0%	17.9%	22.8%	28.0%	32.2%	36.0%	39.6%	42.7%
500						4.4%	9.5%	14.6%	19.6%	24.7%	29.6%	34.5%	38.6%	42.2%	45.6%	48.6%
400					5.0%	10.1%	15.8%	21.2%	26.2%	31.1%	35.9%	40.6%	44.4%	47.9%	51.2%	54.0%
350				3.1%	8.2%	13.8%	19.6%	25.1%	30.1%	34.9%	39.5%	44.0%	47.8%	51.1%	54.2%	57.0%
300			3.6%	6.3%	12.4%	18.4%	24.2%	29.7%	34.6%	39.3%	43.7%	48.0%	51.6%	54.8%	57.8%	60.4%
250		4.1%	7.0%	10.3%	16.9%	23.1%	29.0%	34.5%	39.3%	43.8%	48.1%	52.2%	55.6%	58.7%	61.6%	64.1%
150	12.1%	16.5%	20.7%	24.6%	31.8%	37.7%	43.1%	48.0%	52.2%	56.1%	59.8%	63.4%	66.3%	69.0%	71.4%	73.6%

Percentage of Fall-run Chinook Salmon Redds Dewatered Below Daguerre (continued)

Spawning Flow (cfs)

Dewatering flow (cfs)

	1,700	1,800	1,900	2,000	2,100	2,300	2,500	2,700	2,900	3,300	3,700	4,100	4,500
4,100													4.5%
3,700												3.8%	11.6%
3,300											3.6%	10.8%	19.9%
2,900										4.1%	10.5%	19.1%	28.6%
2,700									1.4%	7.3%	14.3%	23.1%	32.6%
2,500								1.6%	4.1%	11.0%	18.7%	27.7%	37.1%
2,300							1.8%	4.8%	8.0%	15.5%	23.4%	32.4%	41.7%
2,100						2.3%	5.6%	9.5%	13.2%	21.2%	29.1%	37.9%	47.1%
2,000					0.9%	3.4%	7.0%	10.9%	16.6%	23.0%	30.9%	39.7%	48.8%
1,900				1.8%	2.9%	6.8%	11.0%	15.3%	19.4%	27.8%	35.7%	44.5%	53.4%
1,800			1.3%	3.6%	4.9%	9.3%	13.8%	18.3%	22.6%	31.0%	38.9%	47.6%	56.3%
1,700		2.1%	4.1%	7.4%	8.9%	13.9%	18.8%	23.6%	27.9%	36.3%	44.2%	52.7%	61.0%
1,600	2.1%	4.5%	7.2%	10.9%	14.2%	18.1%	23.1%	28.0%	32.4%	40.8%	48.7%	56.9%	64.9%
1,500	3.9%	6.9%	9.8%	13.8%	15.6%	21.3%	26.5%	31.4%	35.8%	44.1%	51.9%	60.0%	67.8%
1,400	7.2%	10.4%	13.6%	17.9%	19.7%	25.4%	30.7%	35.6%	39.9%	48.2%	56.0%	63.9%	71.4%
1,300	10.0%	13.6%	16.9%	21.2%	23.1%	28.8%	34.0%	38.7%	43.0%	51.2%	58.8%	66.5%	73.7%
1,200	13.6%	17.3%	20.6%	25.0%	26.9%	32.6%	37.7%	42.4%	46.6%	54.5%	61.9%	69.3%	76.2%
1,100	18.7%	22.3%	25.7%	29.9%	31.8%	37.4%	42.3%	46.9%	51.1%	58.8%	66.0%	73.0%	79.3%
1,000	24.2%	27.9%	31.2%	35.3%	37.2%	42.6%	47.4%	51.9%	55.9%	63.4%	70.3%	76.8%	82.6%
900	29.2%	32.8%	36.1%	40.0%	41.9%	47.2%	51.9%	56.2%	60.1%	67.4%	74.0%	80.1%	85.4%
800	34.9%	38.4%	41.5%	45.2%	47.1%	52.2%	56.7%	60.9%	64.7%	71.6%	77.9%	83.6%	88.3%
700	39.6%	43.0%	46.0%	49.6%	51.5%	56.4%	60.7%	64.7%	68.4%	75.1%	81.0%	86.2%	90.4%
600	45.8%	49.0%	51.8%	55.2%	56.9%	61.5%	65.6%	69.4%	72.8%	78.9%	84.4%	89.0%	92.6%
500	51.6%	54.6%	57.3%	60.4%	62.1%	66.4%	70.2%	73.7%	76.9%	82.6%	87.5%	91.5%	94.5%
400	56.9%	59.7%	62.2%	65.1%	66.7%	70.7%	74.2%	77.4%	80.3%	85.5%	89.8%	93.2%	95.7%
350	59.8%	62.4%	64.9%	67.7%	69.2%	73.0%	76.3%	79.4%	82.2%	87.0%	91.0%	94.1%	96.4%
300	63.1%	65.6%	68.0%	70.6%	72.1%	75.7%	78.8%	81.7%	84.2%	88.7%	92.3%	95.1%	97.0%
250	66.6%	69.0%	71.2%	73.7%	75.0%	78.4%	81.4%	84.0%	86.4%	90.4%	93.6%	96.0%	97.6%
150	75.6%	77.6%	79.4%	81.3%	82.5%	85.1%	87.5%	89.5%	91.4%	94.3%	96.5%	98.0%	98.9%

Percentage of Spring-run Chinook Salmon Redds Dewatered Above Daguerre

Spawning Flow (cfs)

Dewatering flow (cfs)	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000
4,300																
4,100																
3,900																
3,700																
3,500																
3,300																
3,100																
2,900																
2,700																
2,500																
2,300																
2,100																
2,000																
1,900																0.3%
1,800															0.3%	0.6%
1,700														0.3%	0.5%	1.0%
1,600													0.3%	0.7%	1.2%	1.8%
1,500												0.2%	0.6%	1.1%	1.7%	2.6%
1,400											0.3%	0.5%	1.0%	1.7%	2.4%	3.4%
1,300										0.4%	0.8%	1.2%	2.0%	2.8%	3.6%	4.7%
1,200									0.5%	1.0%	1.7%	2.3%	3.3%	4.2%	5.2%	6.5%
1,100								0.6%	1.3%	2.2%	3.1%	4.0%	5.3%	6.4%	7.6%	9.1%
1,000							0.6%	1.2%	2.2%	3.2%	4.3%	5.4%	6.7%	8.0%	9.3%	10.9%
900						0.8%	1.3%	2.2%	3.4%	4.7%	6.1%	7.4%	8.9%	10.4%	11.9%	13.7%
800					0.9%	1.8%	2.5%	3.7%	5.2%	6.7%	8.3%	9.8%	11.5%	13.1%	14.7%	16.5%
700				1.0%	2.3%	3.9%	5.2%	6.9%	8.7%	10.6%	12.6%	14.4%	16.4%	18.3%	20.2%	22.2%
600			1.2%	2.7%	4.7%	6.9%	8.9%	11.2%	13.6%	16.0%	18.4%	20.6%	23.0%	25.1%	27.1%	29.2%
500		1.4%	3.3%	5.7%	8.5%	11.4%	13.9%	16.6%	19.3%	22.1%	24.8%	27.2%	29.7%	31.9%	34.1%	36.2%
400	1.8%	3.8%	6.5%	9.5%	12.9%	16.4%	19.4%	22.5%	25.5%	28.4%	31.2%	33.6%	36.1%	38.4%	40.5%	42.6%

Percentage of Spring-run Chinook Salmon Redds Dewatered Above Daguerre (continued)

	Spawning Flow (cfs)												
Dewatering flow (cfs)	2,100	2,300	2,500	2,700	2,900	3,100	3,300	3,500	3,700	3,900	4,100	4,300	4,500
4,300													0.5%
4,100												0.8%	2.0%
3,900											0.7%	1.9%	3.5%
3,700										0.6%	1.6%	3.2%	5.4%
3,500									0.6%	1.5%	2.9%	5.0%	7.5%
3,300								0.7%	1.8%	3.4%	5.4%	8.1%	11.2%
3,100							0.9%	2.4%	4.4%	6.6%	9.3%	12.5%	16.1%
2,900						0.7%	1.8%	3.8%	6.3%	9.0%	12.1%	15.8%	19.8%
2,700					0.7%	1.6%	3.2%	5.6%	8.5%	11.5%	15.0%	19.1%	23.4%
2,500				0.5%	1.4%	2.8%	4.7%	7.5%	10.7%	14.1%	17.9%	22.3%	26.9%
2,300			0.8%	1.7%	3.2%	5.4%	8.0%	11.3%	15.2%	19.0%	23.2%	28.0%	32.8%
2,100		0.7%	2.0%	3.6%	5.9%	8.6%	10.5%	16.1%	20.5%	24.9%	29.7%	34.8%	39.8%
2,000	0.3%	1.3%	3.0%	4.9%	7.5%	10.6%	14.3%	18.7%	23.5%	28.1%	33.0%	38.1%	43.2%
1,900	0.7%	2.0%	4.0%	6.3%	9.2%	12.5%	16.5%	21.2%	26.2%	30.9%	35.9%	41.1%	46.2%
1,800	1.3%	2.9%	5.2%	7.8%	11.0%	14.6%	18.9%	23.9%	29.0%	33.9%	39.0%	44.3%	49.3%
1,700	1.8%	3.7%	6.3%	9.0%	12.5%	16.3%	20.8%	26.0%	31.3%	36.3%	41.5%	46.8%	51.9%
1,600	2.8%	5.1%	7.9%	10.9%	14.6%	18.6%	23.2%	28.5%	33.8%	38.8%	44.0%	49.3%	54.2%
1,500	3.6%	6.2%	9.3%	12.7%	16.6%	20.8%	25.6%	31.0%	36.4%	41.4%	46.5%	51.6%	56.5%
1,400	4.6%	7.4%	10.7%	14.3%	18.3%	22.7%	27.6%	33.0%	38.3%	43.3%	48.4%	53.5%	58.2%
1,300	6.1%	9.0%	12.4%	15.9%	19.9%	24.2%	29.0%	34.3%	39.5%	44.4%	49.4%	54.3%	59.0%
1,200	8.0%	11.3%	15.1%	19.0%	23.2%	27.8%	32.8%	38.3%	43.6%	48.5%	53.5%	58.4%	62.9%
1,100	10.7%	14.3%	18.2%	22.3%	26.6%	31.2%	36.2%	41.6%	46.9%	51.7%	56.5%	61.2%	65.6%
1,000	12.6%	16.3%	20.4%	24.5%	28.9%	33.5%	38.4%	43.8%	49.0%	53.7%	58.5%	63.1%	67.3%
900	15.6%	19.6%	23.9%	28.2%	32.8%	37.4%	42.3%	47.6%	52.7%	57.3%	61.9%	66.2%	70.3%
800	18.4%	22.5%	26.8%	31.1%	35.6%	40.2%	45.0%	50.2%	55.2%	59.7%	64.2%	68.4%	72.3%
700	24.2%	28.4%	32.7%	36.9%	41.3%	45.7%	50.3%	55.2%	59.9%	64.1%	68.1%	72.0%	75.6%
600	31.3%	35.4%	39.6%	43.5%	47.7%	51.7%	55.9%	60.3%	64.5%	68.3%	71.9%	75.3%	78.5%
500	38.3%	42.3%	46.3%	50.3%	54.1%	57.8%	61.6%	65.7%	69.5%	72.9%	76.1%	79.1%	81.9%
400	44.6%	48.4%	52.2%	55.8%	59.4%	62.7%	66.2%	69.9%	73.2%	76.2%	79.1%	81.9%	84.3%

Percentage of Spring-run Chinook Salmon Redds Dewatered Below Daguerre

	Spawning Flow (cfs)															
Dewatering flow (cfs)	250	300	350	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600
4,100																
3,700																
3,300																
2,900																
2,700																
2,500																
2,300																
2,100																
2,000																
1,900																
1,800																
1,700																
1,600																
1,500																0.8%
1,400															0.8%	1.8%
1,300														0.8%	2.0%	3.5%
1,200													0.9%	2.1%	4.0%	6.1%
1,100												1.1%	2.8%	4.8%	7.4%	10.1%
1,000											1.2%	3.0%	5.7%	8.6%	12.0%	15.3%
900										1.2%	3.0%	6.0%	9.6%	13.2%	17.2%	20.9%
800									1.4%	3.2%	6.0%	9.7%	14.1%	18.5%	23.0%	27.2%
700								1.3%	3.4%	6.0%	9.6%	14.2%	19.2%	23.9%	28.9%	33.3%
600							1.4%	3.8%	6.9%	10.7%	15.2%	20.6%	26.1%	31.2%	36.2%	40.7%
500						1.7%	4.2%	7.8%	12.0%	16.7%	21.8%	27.7%	33.3%	38.4%	43.5%	47.8%
400					1.9%	5.0%	8.6%	13.0%	18.2%	23.0%	28.4%	34.4%	39.9%	44.9%	49.6%	53.7%
350				0.9%	3.3%	6.9%	10.8%	15.7%	20.8%	26.2%	31.7%	37.6%	43.0%	47.9%	52.5%	56.4%
300			1.0%	2.1%	5.4%	9.6%	14.1%	19.6%	25.1%	30.7%	36.3%	42.2%	47.4%	52.1%	56.5%	60.3%
250		1.2%	2.4%	4.0%	8.1%	12.8%	17.7%	23.3%	29.1%	34.7%	40.3%	46.1%	51.2%	55.8%	60.0%	63.6%
150	5.4%	8.1%	10.8%	13.6%	19.6%	25.6%	31.3%	37.3%	42.9%	48.2%	53.3%	58.6%	63.2%	67.2%	70.9%	73.9%

Percentage of Spring-run Chinook Salmon Redds Dewatered Below Daguerre (continued)

	Spawning Flow (cfs)												
Dewatering flow (cfs)	1,700	1,800	1,900	2,000	2,100	2,300	2,500	2,700	2,900	3,300	3,700	4,100	4,500
4,100													2.6%
3,700												1.6%	7.4%
3,300											1.6%	6.3%	15.2%
2,900										2.4%	7.4%	15.4%	27.0%
2,700									0.5%	4.0%	10.1%	19.0%	31.3%
2,500								0.5%	1.9%	6.9%	14.2%	24.2%	36.8%
2,300							0.6%	2.3%	4.6%	11.2%	19.6%	30.1%	42.7%
2,100						0.8%	2.7%	5.6%	9.1%	17.7%	27.4%	38.2%	50.1%
2,000					0.3%	1.5%	3.7%	7.0%	10.7%	20.2%	30.6%	41.7%	53.5%
1,900				0.7%	1.0%	3.2%	6.4%	10.5%	15.1%	25.7%	36.8%	47.9%	59.1%
1,800			0.5%	1.6%	2.2%	5.1%	8.9%	13.7%	18.9%	30.3%	41.6%	52.4%	63.0%
1,700		0.7%	1.8%	3.7%	4.6%	8.7%	13.6%	19.4%	25.5%	38.0%	49.7%	59.9%	69.5%
1,600	0.7%	1.7%	3.4%	5.7%	6.8%	11.7%	17.4%	23.7%	30.2%	43.2%	54.8%	64.5%	73.4%
1,500	1.6%	3.1%	4.9%	7.9%	9.2%	14.6%	20.9%	27.7%	34.5%	47.7%	59.1%	68.3%	76.4%
1,400	3.1%	5.0%	7.2%	10.9%	12.3%	18.6%	25.5%	32.8%	39.7%	52.9%	63.8%	72.3%	79.9%
1,300	5.3%	7.6%	10.3%	14.4%	16.1%	22.9%	30.1%	37.4%	44.4%	57.0%	67.4%	75.4%	82.5%
1,200	8.4%	11.2%	14.2%	18.7%	20.5%	27.6%	35.0%	42.2%	49.0%	61.0%	70.7%	78.2%	84.7%
1,100	13.0%	16.3%	19.7%	24.7%	26.7%	34.0%	41.4%	48.4%	54.8%	66.0%	74.9%	81.7%	87.2%
1,000	18.8%	22.6%	26.5%	31.8%	33.9%	41.4%	48.8%	55.5%	61.5%	71.7%	79.9%	85.8%	90.6%
900	24.7%	28.8%	32.9%	38.4%	40.6%	48.1%	55.2%	61.4%	66.9%	76.3%	83.7%	88.9%	92.6%
800	31.4%	35.7%	40.0%	45.6%	47.9%	55.3%	61.9%	67.5%	72.5%	80.9%	87.4%	91.6%	94.5%
700	37.6%	42.0%	46.2%	51.6%	53.9%	60.9%	67.2%	72.4%	77.0%	84.8%	90.5%	94.1%	96.2%
600	44.9%	49.1%	53.1%	58.1%	60.3%	66.7%	72.4%	77.1%	81.2%	88.0%	92.6%	95.4%	97.2%
500	51.9%	55.9%	59.7%	64.2%	66.4%	72.3%	77.5%	81.6%	85.2%	91.0%	94.7%	96.8%	98.0%
400	57.5%	61.2%	64.7%	68.6%	70.8%	76.2%	80.8%	84.3%	87.4%	92.4%	95.6%	97.4%	98.4%
350	60.1%	63.6%	66.9%	70.7%	72.8%	77.9%	82.2%	85.5%	88.4%	93.0%	96.0%	97.7%	98.6%
300	63.7%	67.0%	70.1%	73.6%	75.6%	80.4%	84.3%	87.3%	89.9%	94.0%	96.7%	98.2%	98.9%
250	66.9%	70.0%	73.1%	76.3%	78.3%	82.8%	86.3%	88.9%	91.3%	94.9%	97.3%	98.6%	99.2%
150	76.7%	79.2%	81.7%	84.3%	85.9%	89.0%	91.6%	93.5%	95.1%	97.3%	98.9%	99.5%	99.7%

Percentage of Steelhead/Rainbow Trout Redds Dewatered Above Daguerre

Spawning Flow (cfs)

Dewatering flow (cfs)	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000
4,300																
4,100																
3,900																
3,700																
3,500																
3,300																
3,100																
2,900																
2,700																
2,500																
2,300																
2,100																
2,000																
1,900																0.3%
1,800															0.4%	0.3%
1,700														0.3%	0.4%	0.4%
1,600													0.3%	0.3%	0.5%	0.5%
1,500												0.4%	0.3%	0.4%	0.6%	0.7%
1,400											0.3%	0.4%	0.4%	0.5%	0.8%	1.0%
1,300										0.3%	0.4%	0.5%	0.5%	0.7%	1.1%	1.3%
1,200									0.5%	0.4%	0.5%	0.7%	0.7%	1.0%	1.4%	1.5%
1,100								0.5%	0.6%	0.6%	0.7%	1.0%	1.1%	1.4%	1.8%	2.0%
1,000							0.5%	0.6%	0.7%	0.8%	1.0%	1.3%	1.5%	1.8%	2.2%	2.4%
900						0.4%	0.6%	0.8%	1.0%	1.1%	1.4%	1.8%	2.0%	2.3%	2.8%	3.0%
800					0.7%	0.6%	0.9%	1.2%	1.5%	1.7%	2.0%	2.5%	2.7%	3.1%	3.6%	3.8%
700				0.5%	1.0%	1.1%	1.6%	1.9%	2.3%	2.6%	3.0%	3.5%	3.7%	4.1%	4.6%	4.9%
600			0.8%	1.0%	1.8%	2.2%	2.8%	3.2%	3.7%	4.0%	4.5%	5.0%	5.3%	5.7%	6.2%	6.6%
500		0.8%	1.3%	1.9%	3.0%	3.6%	4.2%	4.7%	5.3%	5.7%	6.1%	6.7%	7.0%	7.4%	8.0%	8.3%
400	2.4%	1.7%	2.6%	3.4%	4.6%	5.3%	6.0%	6.5%	7.1%	7.5%	8.0%	8.6%	8.9%	9.3%	9.9%	10.3%

Percentage of Steelhead/Rainbow Trout Redds Dewatered Above Daguerre (continued)

Spawning Flow (cfs)

Dewatering flow (cfs)	2,100	2,300	2,500	2,700	2,900	3,100	3,300	3,500	3,700	3,900	4,100	4,300	4,500
4,300													0.2%
4,100												0.2%	0.3%
3,900											0.2%	0.4%	0.7%
3,700										0.2%	0.3%	0.7%	1.1%
3,500									0.2%	0.3%	0.6%	1.1%	1.6%
3,300								0.2%	0.3%	0.6%	1.0%	1.6%	2.1%
3,100							0.2%	0.3%	0.7%	1.1%	1.6%	2.3%	2.9%
2,900						0.1%	0.3%	0.6%	1.1%	1.6%	2.2%	3.0%	3.7%
2,700					0.2%	0.3%	0.6%	1.0%	1.6%	2.2%	2.9%	3.8%	4.6%
2,500				0.3%	0.3%	0.5%	0.9%	1.4%	2.1%	2.7%	3.4%	4.4%	5.3%
2,300			0.2%	0.4%	0.6%	1.0%	1.5%	2.1%	2.9%	3.5%	4.3%	5.3%	6.3%
2,100		0.4%	0.4%	0.8%	1.2%	1.7%	2.3%	3.0%	3.8%	4.6%	5.4%	6.5%	7.5%
2,000	0.2%	0.4%	0.6%	1.0%	1.5%	2.1%	2.8%	3.4%	4.3%	5.1%	6.0%	7.1%	8.2%
1,900	0.2%	0.6%	0.8%	1.3%	1.9%	2.5%	3.3%	4.0%	5.0%	5.8%	6.8%	8.0%	9.1%
1,800	0.3%	0.8%	1.0%	1.6%	2.2%	2.9%	3.8%	4.6%	5.6%	6.5%	7.5%	8.7%	9.9%
1,700	0.5%	1.0%	1.3%	2.0%	2.7%	3.4%	4.2%	5.1%	6.1%	7.1%	8.0%	9.3%	10.5%
1,600	0.7%	1.3%	1.7%	2.4%	3.2%	4.0%	4.9%	5.8%	6.9%	7.9%	9.0%	10.3%	11.5%
1,500	0.8%	1.5%	2.0%	2.8%	3.5%	4.4%	5.3%	6.3%	7.4%	8.4%	9.5%	10.9%	12.1%
1,400	1.2%	1.9%	2.4%	3.3%	4.1%	5.0%	6.0%	7.0%	8.2%	9.3%	10.4%	11.8%	13.2%
1,300	1.4%	2.3%	2.8%	3.7%	4.6%	5.6%	6.6%	7.6%	8.9%	10.0%	11.2%	12.5%	13.8%
1,200	1.8%	2.7%	3.3%	4.2%	5.1%	6.2%	7.3%	8.4%	9.7%	10.8%	12.1%	13.5%	14.9%
1,100	2.3%	3.2%	3.8%	4.8%	5.8%	6.9%	8.0%	9.2%	10.4%	11.7%	13.0%	14.5%	15.9%
1,000	2.7%	3.7%	4.3%	5.4%	6.4%	7.5%	8.8%	10.0%	11.4%	12.7%	14.1%	15.7%	17.2%
900	3.3%	4.3%	5.0%	6.2%	7.2%	8.4%	9.7%	10.9%	12.4%	13.7%	15.1%	16.7%	18.2%
800	4.2%	5.2%	6.0%	7.1%	8.2%	9.5%	10.8%	12.1%	13.5%	14.9%	16.3%	17.8%	19.3%
700	5.3%	6.4%	7.2%	8.4%	9.5%	10.9%	12.2%	13.5%	15.1%	16.5%	17.9%	19.6%	21.1%
600	6.9%	8.1%	9.0%	10.2%	11.4%	12.7%	14.1%	15.4%	16.9%	18.3%	19.8%	21.4%	22.9%
500	8.7%	10.0%	10.9%	12.2%	13.5%	14.7%	16.1%	17.6%	19.2%	20.7%	22.2%	23.8%	25.5%
400	10.7%	12.0%	13.0%	14.4%	15.8%	17.1%	18.7%	20.2%	21.9%	23.5%	25.1%	26.8%	28.4%

Percentage of Steelhead/Rainbow Trout Redds Dewatered Below Daguerre

	Spawning Flow (cfs)															
Dewatering flow (cfs)	250	300	350	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600
4,100																
3,700																
3,300																
2,900																
2,700																
2,500																
2,300																
2,100																
2,000																
1,900																
1,800																
1,700																
1,600																
1,500																0.0%
1,400															0.1%	0.4%
1,300														0.1%	0.5%	1.2%
1,200													0.1%	0.5%	1.5%	2.7%
1,100												0.0%	0.4%	1.4%	2.8%	4.3%
1000											0.1%	0.8%	2.0%	3.4%	5.3%	7.1%
900										0.0%	0.6%	2.1%	3.9%	5.8%	7.8%	9.8%
800									0.1%	0.6%	1.9%	4.2%	6.2%	8.4%	10.6%	12.8%
700								0.1%	0.9%	2.3%	4.2%	6.9%	9.4%	11.7%	14.1%	16.3%
600							0.2%	1.3%	3.0%	4.9%	7.2%	10.1%	12.7%	15.0%	17.4%	19.6%
500						0.2%	1.5%	3.6%	5.9%	8.3%	11.3%	14.4%	16.4%	18.8%	21.1%	23.2%
400					0.4%	2.4%	4.9%	7.8%	10.3%	12.7%	15.1%	18.0%	20.5%	22.8%	25.0%	27.1%
350				0.0%	1.5%	4.3%	7.2%	10.2%	12.8%	15.3%	17.7%	20.6%	23.0%	25.2%	27.4%	29.4%
300			0.1%	0.6%	2.9%	6.8%	10.1%	13.4%	16.0%	18.5%	20.9%	23.8%	26.2%	28.3%	30.4%	32.4%
250		0.0%	0.5%	1.4%	5.0%	8.7%	12.1%	15.4%	18.2%	20.6%	23.0%	25.9%	28.3%	30.4%	32.5%	34.4%
150	2.5%	4.4%	6.5%	8.4%	13.2%	17.2%	20.7%	24.0%	26.6%	30.0%	31.4%	34.1%	36.4%	38.4%	40.3%	42.1%

Percentage of Steelhead/Rainbow Trout Redds Dewatered Below Daguerre (continued)

Spawning Flow (cfs)

Dewatering flow (cfs)	1,700	1,800	1,900	2,000	2,100	2,300	2,500	2,700	2,900	3,300	3,700	4,100	4,500
4,100													0.4%
3,700												0.3%	1.9%
3,300											0.3%	2.0%	4.4%
2,900										0.4%	1.8%	4.3%	7.0%
2,700									0.1%	1.5%	3.4%	6.1%	9.0%
2,500								0.2%	1.1%	3.8%	6.1%	9.1%	11.9%
2,300							0.1%	0.9%	2.6%	6.2%	8.9%	11.9%	14.8%
2,100						0.1%	1.8%	2.3%	4.5%	8.8%	11.7%	14.8%	17.7%
2,000					0.0%	0.3%	1.3%	3.0%	5.4%	9.6%	12.5%	15.7%	18.6%
1,900				0.0%	0.1%	0.9%	2.4%	4.4%	6.9%	11.4%	14.4%	17.5%	20.3%
1,800			0.0%	0.2%	0.6%	1.9%	3.7%	5.9%	8.5%	13.0%	16.0%	19.0%	21.7%
1,700		0.0%	0.1%	0.6%	1.2%	2.7%	4.6%	6.9%	9.5%	14.2%	17.2%	20.2%	22.8%
1,600	0.0%	0.2%	0.6%	1.4%	2.1%	4.0%	6.0%	8.4%	11.1%	15.8%	18.8%	21.7%	24.3%
1,500	0.3%	0.8%	1.6%	2.8%	3.6%	5.8%	8.1%	10.6%	13.4%	18.9%	21.1%	23.9%	26.4%
1,400	1.1%	2.1%	3.3%	4.8%	5.8%	8.4%	10.9%	13.4%	16.2%	20.8%	23.6%	26.3%	28.5%
1,300	2.3%	3.6%	4.9%	6.6%	7.7%	10.4%	13.0%	15.5%	18.4%	22.8%	25.5%	28.1%	30.2%
1,200	4.1%	5.7%	7.3%	9.1%	10.3%	13.2%	15.8%	18.4%	21.1%	25.3%	27.8%	30.2%	32.1%
1,100	6.0%	7.7%	9.4%	11.4%	12.6%	15.6%	18.2%	20.8%	23.5%	27.6%	30.0%	32.2%	34.0%
1,000	9.0%	10.9%	12.7%	14.8%	16.0%	19.0%	21.6%	24.1%	26.7%	30.6%	32.8%	34.8%	36.5%
900	11.9%	13.9%	15.7%	17.8%	19.2%	22.2%	24.8%	27.2%	29.7%	33.4%	35.5%	37.5%	39.0%
800	14.9%	16.9%	18.8%	20.9%	22.2%	25.3%	27.8%	30.1%	32.5%	36.1%	38.1%	40.0%	41.5%
700	18.5%	19.5%	22.4%	24.5%	25.9%	28.9%	31.4%	33.7%	36.1%	39.6%	41.6%	43.4%	44.8%
600	21.7%	23.7%	25.6%	27.6%	29.0%	32.0%	34.6%	36.8%	39.2%	42.7%	44.5%	46.2%	47.6%
500	25.3%	27.3%	29.2%	31.2%	32.7%	35.7%	38.3%	40.6%	42.9%	46.2%	47.9%	49.4%	50.6%
400	29.2%	31.1%	32.9%	34.9%	36.3%	39.3%	41.9%	44.1%	46.3%	49.6%	51.3%	52.8%	53.8%
350	31.4%	33.3%	35.1%	37.0%	38.4%	41.4%	43.9%	46.0%	48.2%	51.4%	53.0%	54.5%	55.5%
300	34.4%	36.2%	38.0%	39.8%	41.3%	44.2%	46.6%	48.8%	50.9%	53.9%	55.4%	56.8%	57.7%
250	36.4%	38.2%	39.9%	41.8%	43.2%	46.0%	48.5%	50.6%	52.6%	55.6%	57.0%	58.2%	59.1%
150	44.0%	45.7%	47.3%	49.0%	50.3%	52.9%	55.1%	57.0%	58.8%	61.3%	62.5%	63.5%	64.2%

APPENDIX E
ACRONYMS

LIST OF ACRONYMS

2-D	Two dimensional
ADCP	Acoustic Doppler Current Profiler
ASCII	American Standard Code for Information Interchange
cfs	cubic feet per second
GIS	Geographic Information System
HABEF	Effective Habitat Analysis
HSC	Habitat Suitability Criteria
IFG4	Instream Flow Group Program 4
IFIM	Instream Flow Incremental Methodology
MHU	mesohabitat unit
PHABSIM	Physical Habitat Simulation Model
RHABSIM	Riverine Habitat Simulation Model
River2D	Two dimensional depth averaged model of river hydrodynamics and fish habitat
SZF	stage of zero flow
USGS	U.S. Geological Survey
WSEL	Water Surface Elevation
WUA	Weighted Useable Area