Appendix F

DRAFT—Habitat Assessment Model for Chinook Salmon and Steelhead

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Introduction

A monthly model was developed for chinook salmon (i.e., winter-, spring-, late fall–runs) and steelhead to facilitate assessment of each alternative included in the Battle Creek Salmon and Steelhead Restoration Project Draft Environmental Impact Statement and Environmental Impact Report (EIS/EIR). The habitat assessment model considers the habitat capacity index that depends on streamflow and then links streamflow and water temperature conditions to effects on key habitat quantity and survival. A relative estimate of fry and juvenile capacity and production indices is provided for each reach. The simulated indices are not intended as accurate predictions of magnitude for each life stage, but provide sufficient information to compare the relative life stage capacity and production expected to occur under the No Action and action alternatives.

A key premise of this impact assessment is that the tools applied support the comparison of alternatives based on the available physical and biological information. The water temperature survival indices, flow-habitat relationships, and other elements should not be considered as specific management recommendations or targets for the management of flow, water temperature, or other environmental conditions in Battle Creek or elsewhere in Central Valley rivers. These assessment tools are sufficient for evaluating the relative impacts of the restoration alternatives.

Evaluation of Battle Creek Minimum Flow Requirements

The monthly habitat model was used to simulate the predicted habitat area provided for the minimum flow requirements under each alternative. There are three sets of minimum flow requirements that must be compared among the five alternatives.

1. The No Action minimum flow requirements represent the existing Federal Energy Regulatory Commission (FERC) license flow requirements and are

3 cfs for the North Fork Battle Creek diversion dams and 5 cfs for the South Fork Battle Creek diversion dams.

2. The Anadromous Fish Restoration Program (AFRP) minimum flow requirements are assumed for the No Dam Removal and the Three Dam Removal Alternatives and have higher flow targets for the winter months (December through April) than for the summer months.

3. The 1999 Memorandum of Understanding (MOU) minimum flow requirements are somewhat higher than the AFRP flow requirements and have higher flow targets for the winter months than for the summer months. The MOU flow targets are specified for the Five Dam Removal and Six Dam Removal Alternatives.

Flow-Habitat Relationships

Streamflow directly influences the availability and function of important habitat elements, including water velocity, depth, wetted area, and cover. Flow-habitat relationships for Battle Creek are based on the Instream Flow Incremental Methodology (IFIM) and Physical Habitat Simulation (PHABSIM) system (Milhous et al. 1984, Thomas R. Payne and Associates 1998). IFIM and PHABSIM were applied to on-site studies on Battle Creek. In 1988, an instream flow study on Battle Creek was initiated via the Upper Sacramento River Fisheries and Riparian Habitat Management Plan process (USRFRHAC 1989). A comprehensive study that predicted habitat quantity as a function of flow was conducted under the guidance of a technical committee that included biologists from the fisheries agencies and PG&E (Thomas R. Payne and Associates 1998). The flow-habitat relationships that resulted from the study are presented in Tables F-1 through F-8.

In 1992, the modeling results were used by the fisheries agencies in an effort to identify Battle Creek flow needs below dams, along with other actions, that together might increase the abundance of anadromous fish populations. This effort was part of the AFRP and identified flow releases referred to as the *AFRP flows* (USFWS 2001). It was recognized that these AFRP flow releases for the dams on Battle Creek were subject to revision based upon future analysis (USFWS 2001).

In 1998, the Battle Creek Working Group's (BCWG's) Biological Technical Team analyzed the IFIM data and modeling results. The analysis identified:

1. priority species and life stages of focus for each reach of Battle Creek,
2. flows to facilitate upstream access over obstacles in the stream channel,
3. rates of flow changes to avoid stranding and isolation of juveniles, and
4. water temperatures influenced both by increased flows and releases of cold spring–fed water to adjacent reaches of Battle Creek.

The instream flow releases at each of the dam sites developed through this process are the *MOU flows*.

Spawning and rearing habitat area was calculated for the FERC (No Action Alternative), AFRP (No Dam Removal Alternative and Three Dam Removal Alternative), and MOU (Five Dam Removal Alternative and Six Dam Removal Alternative) minimum flow requirements. Example calculated habitat areas are shown in Table F-9. The habitat areas are based on the flow-habitat relationships in Tables F-1 through F-8.

Fry Capacity Index for Steelhead and Chinook Salmon

The fry capacity index is based on the estimated spawning habitat area provided by minimum flow requirements for each alternative during the spawning and incubation period. The relationship between streamflow and spawning habitat area was developed from existing instream flow studies (Thomas R. Payne and Associates 1998). Habitat area generally increases as flow increases, reaching a maximum area and declining at higher flows (Tables F-1 through F-8). Substrate, depth, and velocity are the primary determinants of spawning habitat quantity. The flow-habitat relationships are slightly different for steelhead and chinook salmon because of differences in substrate, depth, and velocity preferences.

The number of potential redds supported is calculated by dividing spawning habitat area by redd area. Redd size varies by species. A redd area of 56 square feet is assumed for steelhead and 100 square feet is assumed for chinook salmon. Observed redd size for Central Valley chinook salmon ranges from 75 square feet to 650 square feet (Reynolds et al. 1990). A smaller redd size has been documented in the lower American River, where Snider and Vyverberg (1996) calculated an average size of 62 square feet when measured on the ground and 196 square feet when measured from aerial photographs. The average size of a steelhead redd is smaller than a chinook salmon redd (Reynolds et al. 1990). Reiser and White (1981 in Reiser and Bjornn 1979) and Hunter (1973) estimated steelhead redd sizes from 47 to 58 square feet (4.4 square meters to 5.4 square meters). The Central Valley Salmon and Steelhead Restoration and Enhancement Plan indicated steelhead redd sizes ranging from 22.5 to 121 square feet and averaging 56 square feet (Reynolds et al. 1990).

The number of fry in each redd is based on the number of eggs potentially spawned by each species and the expected baseline survival of eggs. The number of eggs in each redd is assumed to be 4,000 for steelhead and 3,800 for chinook salmon (Kier Associates 1999). As a baseline survival, about 25% of the eggs in each redd are assumed to survive through emergence. Therefore, each redd could produce 1,000 steelhead fry or 950 chinook salmon fry. The baseline survival does not include effects of water temperature.

The potential number of redds that could be supported by the available habitat is calculated by dividing spawning habitat area, as predicted from the flow habitat relationships in Tables F-1 through F-8, by approximate redd area for each species. The total potential population of eggs is calculated as number of redds multiplied by the number of eggs for each species that are expected to survive through emergence. Spawning habitat is assumed to be saturated (i.e., all available spawning habitat is used by each species). The proportion of the total potential population of eggs spawned each month is calculated by multiplying the total potential population of eggs by the monthly proportion of the population that would be expected to spawn. Spawning habitat area is the minimum area that is provided by minimum flow requirements during the month of spawning and during subsequent months of incubation. Steelhead fry are assumed to emerge from the redd after 2 months of incubation and chinook after 3 months. Therefore, flow requirements during 2 consecutive months are considered in the calculation of fry capacity index for steelhead and flows during three consecutive months are considered in the calculation for chinook salmon.

The assumed proportion of the population spawning each month is based on existing information on life stage timing. The use of the proportion spawning each month avoids habitat saturation during the first month of spawning and weights spawning habitat use according to the assumed distribution of the life stage through the entire spawning period.

Effects of Water Temperature on the Fry Production Index

The estimated water temperature effect on survival of eggs and larvae varies with temperature and by species (Figure F-1). Survival during incubation is assumed to decline with warming temperature between 54ºF and 62ºF for chinook salmon and 53°F and 59°F for steelhead. Chinook salmon eggs and larvae require temperatures between 39.2ºF and 53.6ºF for the highest survival rates (Myrick and Cech 2001). Chinook salmon eggs that incubated in water above 62ºF experienced 100% mortality before the eyed stage (Hinze 1959 in Myrick and Cech 2001). Studies of fall-run chinook salmon in the Sacramento River showed that eggs survive temperatures between 35ºF and 62ºF (Myrick and Cech 2001). Alderice and Velsen (1978 in Healey 1991) and Seymour (1956 in Alderice and Velsen 1978) found less than 50% egg survival when temperature was greater than 60.8ºF. The optimal water temperature for steelhead spawning and incubation has been reported to fall in the range between 39ºF and 52ºF (Myrick and Cech 2001).

Monthly average water temperature is used to calculate a monthly survival rate (Figure F-1). Monthly average water temperature is simulated for each reach based on average meteorology and the minimum flow requirements for each alternative. Figure F-2 shows the expected water temperatures for the minimum flow requirements under each alternative for the month of July. The effect of water temperature on emergent fry production index is calculated by multiplying the number of emerging fry in a month by the product of water temperature survival rates during the period of incubation. The monthly survival rates include the rate for the month of spawning through the month of emergence (two consecutive months for steelhead and three consecutive months for chinook salmon). Additional temperature information is discussed in Appendix M.

Juvenile Capacity Index for Steelhead and Chinook Salmon

The juvenile capacity index in each reach for each month is dependent on the minimum flow requirement under each alternative and associated habitat area (Table F-9), the fry capacity index in the reach, and the number of surplus fry from upstream reaches. The juvenile capacity index is juvenile rearing habitat area, as predicted from the flow-habitat relationships in Tables F-1 through F-8, divided by the habitat need for each juvenile. For steelhead, the assumed habitat need is 6 square feet for each juvenile. The habitat need is based on the observed density of juveniles in Keswick, North Battle Creek Feeder, and the southern reaches of Battle Creek (Kier Associates 1999) divided by an estimated habitat area calculated from flow estimates and application of the flow-habitat relationship (Tables F-1 through F-8). For chinook salmon, the assumed habitat need is 2 square feet (Kier Associates 1999).

For the purpose of this analysis, the flow-habitat relationships for juveniles are used to calculate the juvenile capacity indices. Flow-habitat relationships for fry are not used. Flow-habitat relationships for fry generally predict the greatest habitat area at low flow, indicating the observed preference of low velocity. Fry distribute themselves near low-velocity shoreline with very shallow depths and cover, such as rootwads, rocks, and debris. The instream flow model may underestimate the actual low-velocity area provided by microhabitat features. Fry habitat capacity, therefore, was not considered in this analysis. At higher flows, low-velocity areas will likely still occur near shore and near microhabitat features. In addition, the habitat area needed to support a fry is substantially less than the habitat need of a juvenile.

The calculated juvenile capacity index is assumed to be the upper limit for the number of juveniles rearing in the reach. If the sum of the number of fry emerging in the reach, the number of juveniles remaining in the reach from the previous month, and the number of surplus fry from the upstream reach is less than the calculated juvenile capacity index, all juveniles are assumed to rear in the reach. If the juvenile capacity index is exceeded, the remaining fry are considered surplus. The number of fry emerging was described above under the fry capacity index.

The surplus fry in a month are assumed to move downstream to the next reach with available habitat area, surviving at an assumed rate of 80%. For steelhead, juveniles are assumed to rear year-round, so the total annual capacity index is the number of juveniles remaining at the end of December, the last month of the simulation. For chinook salmon, fry migration occurs over several months, potentially vacating habitat that could be occupied by newly emergent fry. The monthly capacity index for juvenile chinook salmon is the number of rearing juvenile salmon times the proportion of the population migrating each month. The annual capacity index is the sum of the migrants for each month from all reaches.

Surplus fry may be considered as lost production or may contribute to production in the Sacramento River downstream of Battle Creek. Total surplus is the sum of surplus juveniles for all months that would exit the mainstem reach.

Effects of Water Temperature on the Juvenile Production Index

The estimated water temperature effect on survival of juveniles varies with temperature and by species (Figure F-3). Survival during rearing is assumed to decline with warming temperature between 64ºF and 73ºF for chinook salmon and 65°F and 75°F for steelhead. Marine (1997) and Myrick and Cech (2001) observed maximum growth rates for juvenile chinook salmon at water temperatures of 62.6ºF–68ºF and 66.2ºF, respectively. Rich (1987) found that fish from the Nimbus State Fish Hatchery reared at 75.2ºF died before the end of the experiment. Juvenile rearing success is assumed to deteriorate at water temperatures ranging from 62.6ºF to 77ºF. Nimbus Hatchery steelhead preferred temperatures between 62.6ºF and 68ºF (Cech and Myrick 1999). Steelhead can be expected to show significant mortality at temperatures exceeding 77ºF (Raleigh et al. 1984, Myrick and Cech 2001).

Monthly average water temperatures simulated for the minimum instream flow requirements are used to calculate a monthly survival rate (Figure F-3). Monthly average water temperature is simulated for each reach based on average meteorology and the minimum flow requirements for each alternative. Figure F-2 shows the expected water temperatures for the minimum flow requirements under each alternative for the month of July. The effect of water temperature on juvenile production index is calculated by multiplying the number of rearing juveniles in a month by the water temperature survival rate for the month. Water temperature is cooler at the upstream end of a reach and warmer at the downstream end. Survival rate is the average of the survival rates estimated for the monthly water temperatures at the upstream and downstream ends of the reach. Water temperature effects are not incorporated into the estimate of surplus fry.

The calculation of the juvenile production index assumes that adult steelhead can access all reaches of Battle Creek and that chinook salmon can access all reaches except Keswick. Late fall–run chinook salmon may be limited primarily to reaches downstream of Wildcat and Coleman Diversion Dams; therefore, the production index may be overestimated. Including the production represented by the mainstem of Battle Creek, Coleman and Wildcat reaches might be a better estimate of the expected production index. Production indices for fall-run chinook salmon are not simulated because current management objectives include blocking fall-run chinook salmon from continuing upstream at the

Coleman National Fish Hatchery. Although the timing of spawning, rearing, and outmigration are different between the two runs, the production index for fall-run chinook salmon may be similar in magnitude and pattern to the production index represented by late fall–run chinook salmon.

Additional temperature information is discussed in Appendix M.

Table F-1. Flow-Habitat Relationships for the Mainstem Reach of Battle Creek

Flow (cfs)	Steelhead Rearing (acres)	Steelhead Spawning (acres)	Chinook Rearing (acres)	Spring Spawning (acres)
5	13.2	0.3	4.4	0.5
10	15.1	0.4	6.4	0.8
15	16	0.7	8.6	1.2
20	16.5	1	10.4	1.6
25	16.6	1.1	11.9	1.9
30	16.3	1.2	13.6	2.2
35	15.9	1.3	14.6	2.3
40	15.6	1.4	15.4	2.3
45	15.2	1.5	16	2.4
50	14.7	1.5	16.5	2.3
60	13.8	1.5	17	2.3
70	13.1	1.5	17.1	2.1
80	12.3	1.5	17.1	2
90	11.5	1.5	17	1.8
100	11.2	1.4	16.8	1.8
120	9.9	1.4	16.1	1.7
140	8.9	1.3	15.2	1.5
160	8.1	1.2	14.2	1.4
180	7.4	1.1	13.1	1.3
200	7	1	12.1	1.2
250	6	0.8	10.1	1
300	5.4	0.6	8.7	0.8
350	4.8	0.5	7.5	0.6

Note: cfs = cubic feet per second.

Table F-2. Flow-Habitat Relationships for the Wildcat Reach of Battle Creek

Flow (cfs)	Steelhead Rearing (acres)	Steelhead Spawning (acres)	Chinook Rearing (acres)	Spring Spawning (acres)
3	0.9	0	0.4	0
10	1.9	0	1.1	0.2
15	2.3	0.1	1.6	0.3
20	2.4	0.1	1.8	0.3
25	2.6	0.2	2	0.3
30	2.6	0.2	2.2	0.3
35	2.6	0.3	2.2	0.3
40	2.6	0.3	2.3	0.3
45	2.5	0.3	2.2	0.2
50	2.5	0.4	2.2	0.2
60	2.4	0.4	2.1	0.2
70	2.3	0.4	2	0.2
80	2.3	0.4	1.9	0.1
90	2.3	0.3	1.8	0.1
100	2.2	0.3	1.8	0.1
120	2.1	0.3	1.7	0.1
140	2	0.2	1.7	0.1
160	1.8	0.2	1.6	0.1
180	2	0.1	1.5	0.1
200	1.6	0.1	1.4	0.1
220	1.5	0.1	1.4	0.1
240	1.4	0.1	1.3	0

Note: cfs = cubic feet per second.

Table F-3. Flow-Habitat Relationships for the Eagle Canyon Reach of Battle Creek

Flow (cfs)	Steelhead Rearing (acres)	Steelhead Spawning (acres)	Chinook Rearing (acres)	Spring Spawning (acres)
3	1	0	0.4	0.1
10	2.1	0.1	1.2	0.3
15	2.6	0.1	1.7	0.4
20	2.7	0.2	2	0.5
25	2.9	0.3	2.2	0.5
30	3	0.4	2.4	0.5
35	2.9	0.5	2.4	0.4
40	2.9	0.5	2.5	0.4
45	2.9	0.6	2.4	0.4
50	2.8	0.6	2.4	0.4
60	2.7	0.6	2.3	0.3
70	2.6	0.6	2.2	0.3
80	2.6	0.6	2.1	0.2
90	2.6	0.5	2.1	0.2
100	2.5	0.5	2	0.2
120	2.4	0.4	2	0.1
140	2.2	0.3	1.9	0.1
160	2.1	0.3	1.9	0.1
180	1.9	0.2	1.8	0.1
200	1.8	0.2	1.7	0.1
220	1.7	0.2	1.6	0.1
240	1.6	0.1	1.5	0.1

Note: cfs = cubic feet per second.

Table F-4. Flow-Habitat Relationships for the North Battle Feeder Reach of Battle Creek

Flow (cfs)	Steelhead Rearing (acres)	Steelhead Spawning (acres)	Chinook Rearing (acres)	Spring Spawning (acres)
3	1.6	0	0.6	0
10	3.8	0	2.1	0.2
15	4.7	0.1	3.1	0.3
20	5.1	0.1	3.5	0.4
25	5.6	0.2	4	0.5
30	5.8	0.3	4.3	0.6
35	6	0.4	4.5	0.6
40	6	0.4	4.6	0.7
45	6.1	0.5	4.7	0.7
50	6.1	0.5	4.7	0.7
60	5.9	0.7	4.6	0.7
70	5.6	0.8	4.4	0.7
80	5.3	0.9	4.1	0.6
90	5.1	1	4	0.6
100	4.8	1	3.8	0.5
120	4.3	1	3.4	0.4
140	3.9	0.9	3.2	0.3
160	3.6	0.8	2.9	0.2
180	3.4	0.6	2.9	0.2
200	3.2	0.5	2.6	0.1

Note: cfs = cubic feet per second.

Table F-5. Flow-Habitat Relationships for the Keswick Reach of Battle Creek

Flow (cfs)	Steelhead Rearing (acres)	Steelhead Spawning (acres)	Chinook Rearing (acres)	Spring Spawning (acres)
3	1.9	0.1		
10	4	0.1		
15	4.5	0.2		
20	4.6	0.2		
25	4.7	0.3		
30	4.7	0.3		
35	4.7	0.3		
40	4.5	0.4		
45	4.4	0.4		
50	4.4	0.4		
60	4.4	0.4		
70	4.3	0.4		
80	4.3	0.4		
90	4.2	0.3		
100	4.1	0.3		

Note: cfs = cubic feet per second.

Table F-6. Flow-Habitat Relationships for the Coleman Reach of Battle Creek

Flow (cfs)	Steelhead Rearing (acres)	Steelhead Spawning (acres)	Chinook Rearing (acres)	Spring Spawning (acres)
5	0.1	0	0.4	0.2
10	2	0	0.8	0.4
15	2.7	0.1	1.4	0.7
20	2.9	0.2	1.8	0.8
25	3.2	0.3	2.1	0.9
30	3.4	0.4	2.4	0.9
35	3.5	0.6	2.6	1
40	3.5	0.7	2.7	1
45	3.5	0.8	2.8	1
50	3.5	0.9	2.9	1
60	3.4	1	2.9	1
70	3.3	1.1	2.8	0.9
80	3.2	1.2	2.7	1
90	3.1	1.3	2.6	0.9
100	3	1.4	2.5	0.9
120	2.8	1.5	2.3	0.7
140	2.6	1.4	2.1	0.6
160	2.3	1.3	2	0.5
180	2.1	1.2	1.8	0.5
200	1.9	1.1	1.7	0.4
220	1.8	1	1.6	3.2
240	1.8	0.9	1.5	0.3
260	1.8	0.8	1.4	0.2

Note: cfs = cubic feet per second.

Table F-7. Flow-Habitat Relationships for the Inskip Reach of Battle Creek

Flow (cfs)	Steelhead Rearing (acres)	Steelhead Spawning (acres)	Chinook Rearing (acres)	Spring Spawning (acres)
5	2.3	0	0.5	0.2
10	4.1	0.1	1.6	0.6
15	5.6	0.2	3	1.2
20	6.2	0.3	3.7	1.4
25	6.8	0.5	4.4	1.5
30	7.1	0.8	5	1.6
35	7.3	1.1	5.5	1.6
40	7.4	1.3	5.8	1.6
45	7.4	1.4	6	1.6
50	7.3	1.6	6.1	1.6
60	7	1.8	6.1	1.6
70	6.8	1.9	5.9	1.4
80	6.5	2.1	5.7	1.5
90	6.3	2.2	5.5	1.4
100	6.1	2.3	5.2	1.4
120	5.6	2.4	4.8	1.2
140	5.2	2.3	4.5	1.1
160	4.8	2.1	4.2	1
180	4.3	1.9	3.9	0.8
200	4	1.8	3.6	0.7
220	3.7	1.6	3.3	0.6
240	3.7	1.5	3.1	0.5
260	3.6	1.3	2.9	0.4

Note: cfs = cubic feet per second.

Table F-8. Flow-Habitat Relationships for the South Reach of Battle Creek

Flow (cfs)	Steelhead Rearing (acres)	Steelhead Spawning (acres)	Chinook Rearing (acres)	Spring Spawning (acres)
5	4.3	0.1	2.2	0.4
10	5.3	0.2	3	0.6
15	6.4	0.4	3.6	0.6
20	6.7	0.5	4	0.6
25	6.9	0.6	4.3	0.7
30	7	0.6	4.6	0.7
35	6.9	0.7	4.7	0.7
40	6.8	0.7	4.7	0.7
45	6.7	0.7	4.8	0.7
50	6.7	0.8	4.8	0.7
60	6.4	0.8	4.6	0.8
70	6.2	0.9	4.5	0.8
80	5.9	0.9	4.4	0.7
100	5.5	1	4.1	0.5
120	5.2	1	3.9	0.4
140	5	0.9	3.7	0.4
160	4.8	0.8	3.7	0.3
180	4.7	0.7	3.7	0.3
200	4.6	0.6	3.6	0.3

Note: cfs = cubic feet per second.

Table F-9. Calculated Rearing and Spawning Area (acres) for Peak Months of Steelhead and Chinook Salmon Lifestage Occurrence Under Minimum Flows

	Steelhead Rearing Area [i]	Steelhead Spawning Area [ii]	Spring-run Chinook Rearing Area [iii]	Spring-run Chinook Spawning Area [iv]	Winter-run Chinook Rearing Area [v]	Winter-run Chinook Spawning Area [vi]	Late Fall–run Chinook Rearing Area [vii]	Late Fall–run Chinook Spawning Area [viii]
No Action								
Keswick	1.92	0.06	–	–	–	–	–	–
NBC Feeder	1.62	0.01	0.62	0.04	0.62	0.04	0.62	0.04
Eagle Canyon	1.02	0.01	0.41	0.07	0.41	0.07	0.41	0.07
Wildcat	0.9	–	0.36	0.05	0.36	0.05	0.36	0.05
South	4.26	0.12	2.17	0.39	2.17	0.39	2.17	0.39
Inskip	2.3	–	0.53	0.2	0.53	0.2	0.53	0.2
Coleman	0.11	–	0.37	0.17	0.37	0.17	0.37	0.17
Main	13.18	0.27	4.39	0.55	4.39	0.55	4.39	0.55
Total	**25.31**	**0.47**	**8.85**	**1.47**	**8.85**	**1.47**	**8.85**	**1.47**
Five Dam Removal								
Keswick	1.92	0.06	–	–	–	–	–	–
NBC Feeder	6.06	0.89	4.14	0.69	4.68	0.69	4.68	0.63
Eagle Canyon	2.93	0.57	2.42	0.44	2.42	0.44	2.42	0.39
Wildcat	2.62	0.34	2.23	0.28	2.23	0.28	2.23	0.25
South	6.82	0.95	4.38	0.71	4.75	0.71	4.75	0.67
Inskip	7.37	2.08	5.72	1.62	5.85	1.62	5.85	1.47
Coleman	3.53	1.22	2.74	0.98	2.73	0.98	2.73	0.96
Main	12.3	1.36	16.15	1.96	17.14	1.96	17.14	1.67
Total	**43.55**	**7.47**	**37.78**	**6.68**	**39.8**	**6.68**	**39.8**	**6.04**

Table F-9. Continued

	Steelhead Rearing Area [i]	Steelhead Spawning Area [ii]	Spring-run Chinook Rearing Area [iii]	Spring-run Chinook Spawning Area [iv]	Winter-run Chinook Rearing Area [v]	Winter-run Chinook Spawning Area [vi]	Late Fall–run Chinook Rearing Area [vii]	Late Fall–run Chinook Spawning Area [viii]
No Dam Removal								
Keswick	1.92	0.06	–	–	–	–	–	–
NBC Feeder	5.81	0.42	4.63	0.66	4.63	0.59	4.28	0.66
Eagle Canyon	2.96	0.6	2.39	0.46	2.35	0.46	2.35	0.35
Wildcat	2.65	0.36	2.2	0.29	2.17	0.29	2.17	0.23
South	6.74	0.63	4.56	0.62	3.99	0.62	3.99	0.68
Inskip	7.12	1.27	5.85	1.58	5.05	1.58	5.05	1.62
Coleman	3.37	0.88	2.88	1.02	2.88	0.92	2.36	1.02
Main	13.84	1.44	16.81	1.96	17.14	2.25	17.03	1.8
Total	**44.41**	**5.66**	**39.32**	**6.59**	**38.21**	**6.71**	**37.23**	**6.36**
Six Dam Removal								
Keswick	1.92	0.06	–	–	–	–	–	–
NBC Feeder	6.06	0.89	4.14	0.69	4.68	0.69	4.68	0.63
Eagle Canyon	2.93	0.57	2.42	0.44	2.42	0.44	2.42	0.39
Wildcat	2.62	0.34	2.23	0.28	2.23	0.28	2.23	0.25
South	6.82	0.95	4.38	0.71	4.75	0.71	4.75	0.67
Inskip	7.37	2.08	5.72	1.62	5.85	1.62	5.85	1.47
Coleman	3.53	1.22	2.74	0.98	2.73	0.98	2.73	0.96
Main	12.3	1.36	16.15	1.96	17.14	1.96	17.14	1.67
Total	**43.55**	**7.47**	**37.78**	**6.68**	**39.8**	**6.68**	**39.8**	**6.04**

	Steelhead Rearing Area [i]	Steelhead Spawning Area [ii]	Spring-run Chinook Rearing Area [iii]	Spring-run Chinook Spawning Area [iv]	Winter-run Chinook Rearing Area [v]	Winter-run Chinook Spawning Area [vi]	Late Fall–run Chinook Rearing Area [vii]	Late Fall–run Chinook Spawning Area [viii]
Three Dam Removal								
Keswick	1.92	0.06	–	–	–	–	–	–
NBC Feeder	5.81	0.42	4.63	0.66	4.63	0.59	4.28	0.66
Eagle Canyon	2.96	0.6	2.39	0.46	2.35	0.46	2.35	0.35
Wildcat	2.65	0.36	2.2	0.29	2.17	0.29	2.17	0.23
South	6.74	0.63	4.56	0.62	3.99	0.62	3.99	0.68
Inskip	7.12	1.27	5.85	1.58	5.05	1.58	5.05	1.62
Coleman	3.37	0.88	2.88	1.02	2.88	0.92	2.36	1.02
Main	13.84	1.44	16.81	1.96	17.14	2.25	17.03	1.8
Total	**44.41**	**5.66**	**39.32**	**6.59**	**38.21**	**6.71**	**37.23**	**6.36**

Note: If the removal of a dam under an alternative precludes the need for a minimum flow requirement, the minimum flow requirement for the adjacent upstream or downstream dam is applied.

[i] Values are for the month of July.

[ii] Values are for the month of February.

[iii] Values are for the month of February.

[iv] Values are for the month of September.

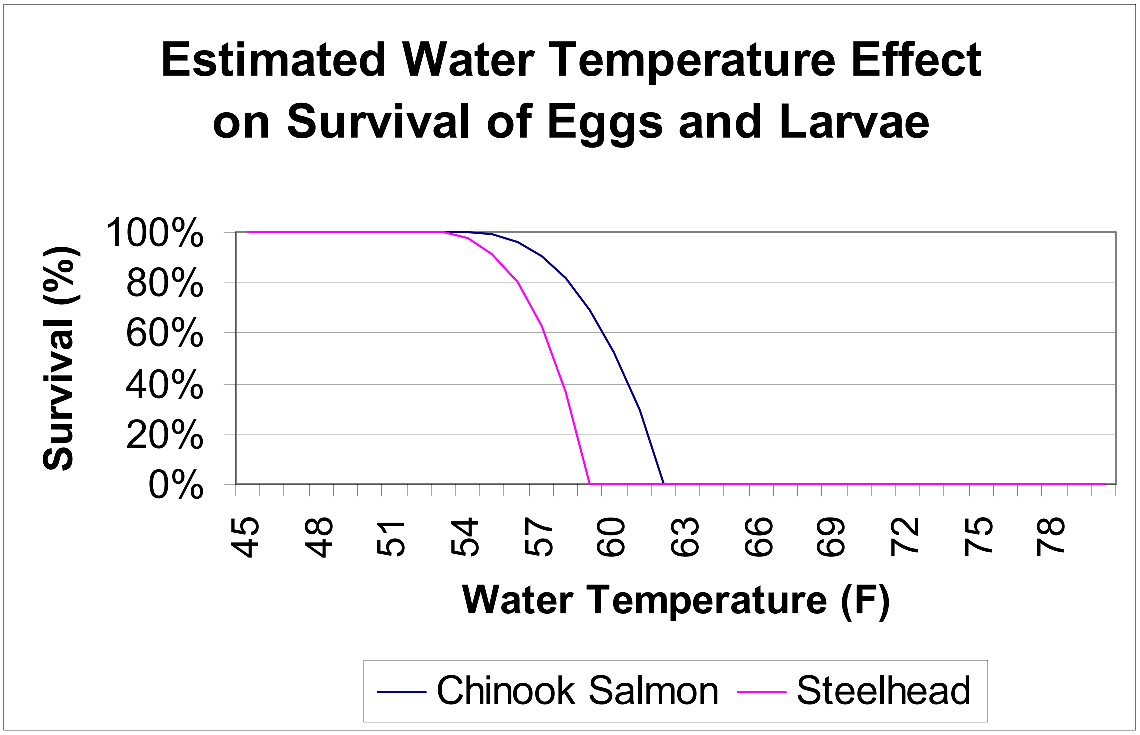
[v] Values are for the month of October.

[vi] Values are for the month of June.

[vii] Values are for the month of July.

[viii] Values are for the month of March.

Figure F-1. Estimated Water Temperature Effect on Survival of Eggs and Larvae of Chinook Salmon and Steelhead



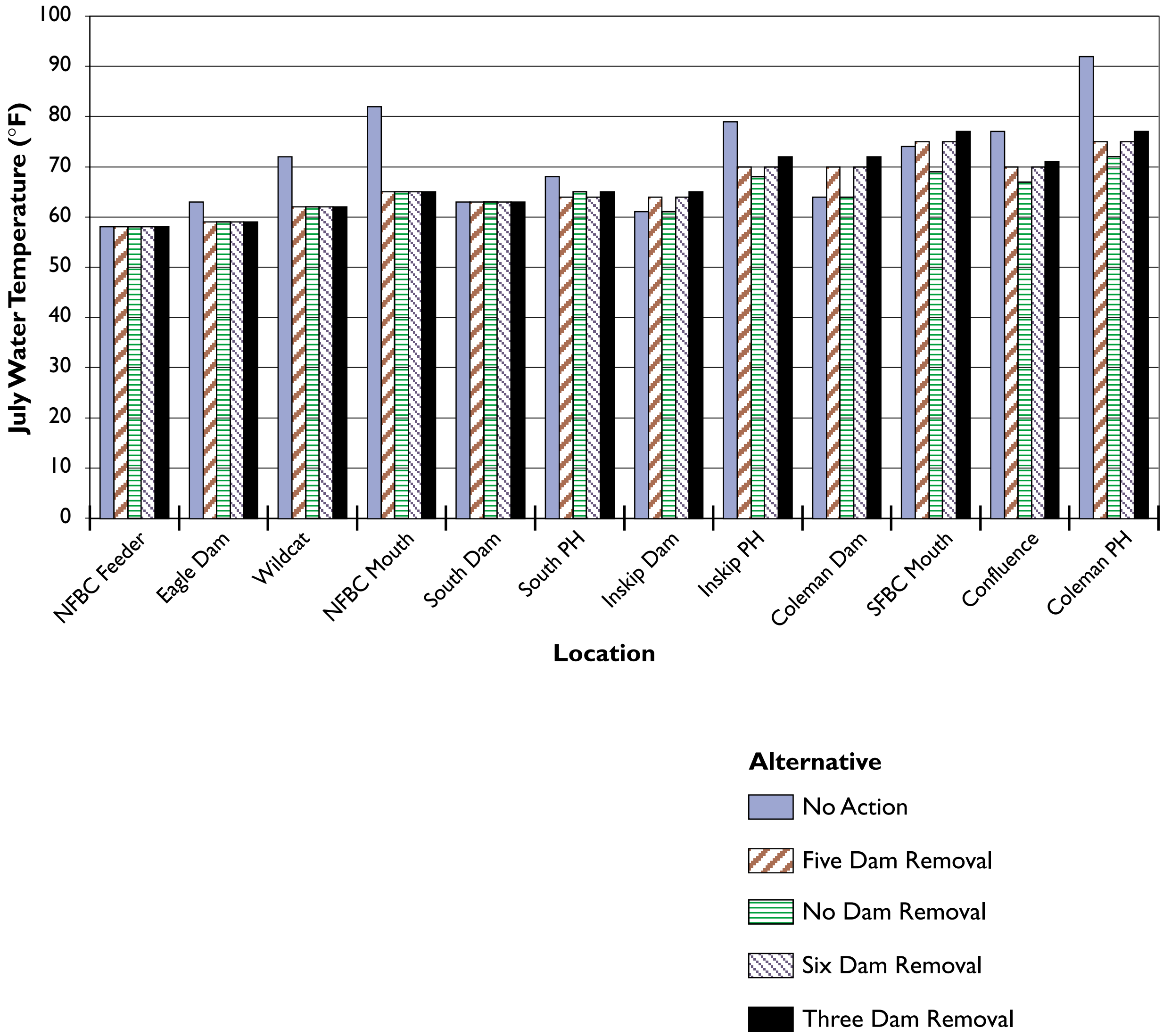


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Figure F-2
Simulated Water Temperatures for the Month of July at all Locations for Each Alternative

Figure F-3. Estimated Water Temperature Effect on Survival of Juvenile Chinook Salmon and Steelhead