BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION
APPLICATION FOR NEW LICENSE

APPLICATION OF
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

FOR THE
OROVILLE FACILITIES

FERC PROJECT NO. 2100

PURSUANT TO:
Code of Federal Regulations
Title 18—Conservation of Power and Water Resources
Chapter 1, Subchapter B
Part 4, Subpart D, Section 4.38
Part 4, Subpart F, Sections 4.50 and 4.51
and
Part 16, Subpart B

This page intentionally left blank.

STATE OF CALIFORNIA
Arnold Schwarzenegger, Governor

THE RESOURCES AGENCY
Mike Chrisman, Secretary for Resources

DEPARTMENT OF WATER RESOURCES
Lester A. Snow, Director

P. Joseph Grindstaff
Chief Deputy Director

Brian E. White
Assistant Director
Legislative Affairs

Nancy J. Saracino
Chief Counsel

Susan Sims Teixeira
Assistant Director
Public Affairs

Gerald E. Johns
Deputy Director

Stephen W. Verigin
Deputy Director

Tom Glover
Deputy Director

Peter S. Garris
Deputy Director

OROVILLE FACILITIES RELICENSING PROGRAM
Raphael A. Torres, Executive Manager
Henry M. “Rick” Ramirez, Program Manager
Nick Kontos, Supervising Engineer, WR

OROVILLE FACILITIES RELICENSING STEERING COMMITTEE
Stephen L. Kashiwada, Chief, Division of Operation and Maintenance
David V. Starks, Chief, Utility Operations
Ward A. Tabor, Assistant Chief Counsel
James F. Blood, Acting Chief, Oroville Field Division
Barbara J. McDonnell, Chief, Division of Environmental Services
Dwight P. Russell, Chief, DPLA Northern District
Richard Sanchez, Assistant Chief, Division of Operations and Maintenance

STATE WATER PROJECT ANALYSIS OFFICE
Dan Flory, Chief
Robert B. Cooke, Principal Engineer, Project Water Management
George T. Qualley, Principal Engineer, Project Power Management
Mark E. Andersen, Supervising Engineer, Chief, Oroville Facilities Relicensing Branch

RELICENSING TECHNICAL COORDINATORS

Christina R. Acken, Senior Engineer, WR, Cultural
Teodoro Z. Alvarez, Senior Engineer, WR, Environmental
Lori C. Brown, Senior HEP Utility Engineer, Engineering & Operations
James H. Upholt, Senior Engineer, WR, Recreation & Land Use/Land Management
David W. Lane, WR Engineering Associate, Web Master
Melanie D. Baillie, Associate Governmental Program Analyst, Budget
Susan M. Larsen, Staff Services Analyst, Contracts
Gary B. Lotspeich, Staff Services Manager II (Retired), Contracts
Raymond Valdez, Student Engineer, Graphics and Web Site Development

OROVILLE FACILITIES RESOURCE AREA MANAGERS

Rashid Ahmad, Supervising Engineer, WR, Engineering
William M. Cochran, Supervising HEP Utility Engineer, OFD Liaison
Curtis L. Creel, Supervising Engineer, WR, Operations
Stephen A. Ford, Environmental Program Manager II, Environmental
Victoria Foster, WR Engineering Associate, Engineering Drawings
Dale Hoffman-Floerke, Environmental Program Manager I, Environmental/Recreation
Laurence Kerckhoff, Staff Counsel, OCC Liaison
Carrol Leong, Senior Land Surveyor, Project Boundary
James L. Martin Jr, Recreation & Wildlife Res. Advisor, Land Use
William D. Mendenhall, Supervising Engineer, WR, GIS
Janis K. Offermann, Senior Environmental Planner, Cultural
Douglas C. Rischbieter, Staff Environmental Scientist, Recreation
Terry Mills, Environmental Program Manager I, Environmental
Russell G. Stein, Senior Environmental Scientist, Environmental Document Oversight

Note: Volume II is being provided to FERC only. It contains Critical Energy Infrastructure Information (CEII), which under FERC's Order No. 630-A is being withheld from public viewing. To view this information, a CEII request may be filed under the provisions of 18 C.F.R. Section 388.113 or a FOIA request may be filed under 18 C.F.R. Section 388.108.

The California Public Records Act does not require the disclosure of any record the disclosure of which is exempted or prohibited pursuant to federal law (Cal. Govt. Code Section 6254(k)).

APPLICATION FOR NEW LICENSE

OROVILLE FACILITIES
FERC PROJECT NO. 2100

Volume V: PDEA Appendices: Part 2 – Appendix G

G Resource Area-Specific Appendices on Aquatic Resources, Cultural Resources, Geology and Soils, Land Use, Water Quality and Water Quantity

This page intentionally left blank.

APPENDIX G

RESOURCE AREA–SPECIFIC APPENDICES

This page intentionally left blank.

LIST OF RESOURCE AREA–SPECIFIC APPENDICES

This page intentionally left blank.

APPENDIX G-AQUA1
AQUATIC RESOURCES
AFFECTED ENVIRONMENT

This appendix provides a summary of the detailed aquatics study plan reports prepared for the Oroville Facilities. The study plan reports provide a basis for the aquatics affected environment as described in Section 5.5.1 and Section 5.7.2.1. The completed study plan reports are provided in their entirety in an informational supplement and are also available on the Oroville Facilities website at http://orovillerelicensing.water.ca.gov/wg_plans_envir.html.

G-AQUA1.1 EVALUATION OF PROJECT EFFECTS ON NON-FISH AQUATIC RESOURCES (SP-F1)

G-AQUA1.1.1 Background Summary

Aquatic macroinvertebrate and plankton communities are important components of the biological food web in project waters. They are an important food source for fish species found within the Oroville Facilities and their community structure can provide general information on ecosystem health. The distribution and structure of non-fish aquatic resources in project waters is associated with four broad categories:

- Physiological constraints (e.g., respiration, osmoregulation, and temperature);
- Trophic considerations (e.g., food acquisition);
- Physical constraints (i.e., habitat); and
- Biotic interactions (e.g., competition, predation).

The purpose of this study was twofold. The first purpose was to document the status of existing macroinvertebrate and plankton communities and provide a description of the potential effects on these resources based on a review of the existing literature (Task 1). The second purpose of this study was site-specific—to evaluate the operational effects of the Oroville Facilities (Task 2) on aquatic macroinvertebrates, phytoplankton, and zooplankton residing in the project reservoirs and river habitats within the study area.

G-AQUA1.1.2 Report Conclusions (Task 1)

A review of existing literature, field studies, and project data was conducted to meet the requirements for Task 1. In addition, the report contains a description of the condition of aquatic macroinvertebrate and plankton communities present in both the impounded and free-flowing freshwater habitats within the boundary of the Oroville Facilities. Key results from data collection efforts in the study area are presented below.

G-AQUA1.1.2.1 Aquatic Macroinvertebrates

- Immature life stages (larvae or nymphs) of true flies, mayflies, and caddis flies were the most prevalent organisms sampled from all sites combined.
- Collectors, filterers, and grazers were the most dominant functional feeding groups in the study area from all sites combined.
- Generally, the highest taxa richness occurred in tributaries to Lake Oroville, while the lowest taxa richness occurred at the collection site in the Lake Oroville inundation zone, the Feather River site upstream of the Feather River Fish Hatchery, and at several Feather River sites between the Thermalito Afterbay Outlet and Honcut Creek.
- The number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa varied widely across all sites (4 to 29); the highest number of EPT taxa occurred in the area upstream of the Lake Oroville inundation zone and the lowest number was observed in the Lake Oroville inundation zone.
- Generally, macroinvertebrate diversity was consistent with expectations for large rivers in the watershed of the Sacramento–San Joaquin Rivers.
- In the concurrent California Department of Water Resources (DWR)/California State University (CSU), Chico, collaborative study, overall invertebrate densities in the Feather River below the dam varied substantially between seasons, but in the DWR study, dominant taxa were similar to Feather River sites.
- The benthic macroinvertebrate community downstream of the Fish Barrier Dam and in areas upstream of Lake Oroville had high percentages of filterers, suggesting that plankton (i.e., food for fish) is not limiting both upstream and downstream of Oroville Dam.
- The macroinvertebrate community at all the field stations included taxa that are important prey of the fish species in the river.

G-AQUA1.1.2.2 Phytoplankton and Zooplankton

- Phytoplankton from 9 taxonomic groups were identified from 14 collection sites.
- Overall, phytoplankton communities were dominated by diatoms (57 percent), green algae (16 percent), cryptomonads (9 percent), and blue-green algae (9 percent). Five other taxonomic groups accounted for the remaining 9 percent.
- Diatoms were the most abundant algae type in Lake Oroville, the Thermalito Complex, and the Fish Barrier Pool, while green algae were dominant in the Oroville Wildlife Area (OWA).

- Zooplankton from three taxonomic groups were identified from six collection sites.
- Rotifers were the most prevalent group at all Lake Oroville stations, followed by Copepoda and Cladocera.
- Thermalito Afterbay was dominated by copepods, followed by cladocerans and rotifers.

G-AQUA1.1.3 Report Conclusions (Task 2)

G-AQUA1.1.3.1 Potential Current Project Effects on Non-Fish Aquatic Resources

Field data and information from technical studies related to the Oroville Facilities provided information on current environmental conditions that was used to evaluate current project effects on macroinvertebrates. Project effects were evaluated using a “directional assessment,” based on a five-point rating system (strongly negative, negative, neutral, positive, and strongly positive).

Current project operations that have resulted in areas of armored substrates and altered temperature regimes in the Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet were considered "negative" effects on macroinvertebrates. Fish stocking also was considered a negative effect on macroinvertebrates in the Feather River below the dam. These three current project actions are believed to have helped cause the macroinvertebrate community to be less diverse below the dam than in the areas upstream of the Lake Oroville inundation zone, as noted in the list above. Note, however, that even before the Oroville Facilities existed, physical habitat upstream of the Lake Oroville inundation area was different from habitat below the current location of the Fish Barrier Dam. Thus, without historical data, it is difficult to estimate the influence of the Oroville Facilities on macroinvertebrate diversity in the Feather River. Current project operations that provide minimum instream flows downstream of the Fish Barrier Dam are believed to benefit macroinvertebrates, as dampening of the natural hydrograph has limited annual flushing flows and provided more favorable conditions for colonization and expansion.

A similar analysis methodology was used to evaluate current project effects on plankton resources. Current project effects were evaluated using a “directional assessment,” based on a five-point rating system (strongly negative, negative, neutral, positive, and strongly positive).

Project operations that increase water temperatures in Thermalito Afterbay and Lake Oroville are likely to increase plankton production in these waters. Habitat enhancement activities for fish species in Lake Oroville were assigned a "negative" rating for plankton resources because many fish species use plankton as a food source during some life stages. Therefore, based on current activities to improve habitat for these species, it was thought that predation on plankton has increased.

G-AQUA1.1.3.2 Potential Future Project Effects on Non-Fish Aquatic Resources

Data from related technical studies provided information on projected environmental conditions that was used to evaluate potential project effects on non-fish aquatic resources. Descriptions of PM&E measures being considered by the Environmental Work Group also were used for effect analysis. The PM&E measures that will be included in the project had not been finalized at the time of this report, and many contained only a coarse level of detail; therefore, the assessments of project effects on macroinvertebrate and plankton communities should be considered preliminary, and subject to change as PM&E measures or proposed changes to project operations are further refined and implemented. Project effects were evaluated using a “directional assessment,” based on a five-point rating system (strongly negative, negative, neutral, positive, and strongly positive).

With regard to aquatic macroinvertebrates, a rating of neutral or positive was assigned to all but one category of PM&E measures that were considered for this report. Gravel replenishment and side-channel restoration in the Feather River below the dam were considered to have strongly positive effects. Potential actions to lower water temperatures in the Feather River and proposed increased flow below the dam were considered positive for macroinvertebrate communities. A neutral rating was assigned to potential effects of ramping, as no net changes from baseline conditions would be expected. A negative rating was assigned to fish stocking based on the fact that fish are major consumers of macroinvertebrates.

With regard to plankton, ratings assigned to the categories of PM&E measures considered for this report ranged from negative to strongly positive. Side-channel restoration in the Feather River below the dam was considered to have a strongly positive effect on plankton. Potential actions to lower water temperatures in the Feather River, increase water levels in Thermalito Afterbay, and transport adult salmonids to Lake Oroville tributaries were considered to have positive effects on plankton communities. A positive rating was assigned to PM&E measures in the OWA designed to eliminate undesired plant species because restoring an open-water habitat would probably lead to greater phytoplankton productivity. A negative rating was assigned to fish stocking activities in project waters downstream of Oroville Dam.

G-AQUA1.2 EVALUATION OF PROJECT EFFECTS ON FISH DISEASES (SP-F2)

Fish diseases are related to a variety of factors, including fish species, densities, the presence and amounts of pathogens in the environment, and water quality conditions, such as temperature, dissolved oxygen (DO), and pH. Oroville Facilities operations have the potential to affect all of these factors in the Federal Energy Regulatory Commission (FERC) project waters, at the Feather River Fish Hatchery, and in the Feather River downstream of the Oroville Facilities. Of significance to disease issues are potential project effects on water temperature, as well as project and facilities operations that might introduce diseases, such as out-of-basin fish transfers.

Several endemic salmonid pathogens (disease in parenthesis) occur in the Feather River basin, including *Ceratomyxa shasta* (salmonid ceratomyxosis), *Flavobacterium columnare* (columnaris), the infectious hematopoietic necrosis (IHN) virus, *Renibacterium salmoninarum* (bacterial kidney disease [BKD]), and *Flavobacterium psychrophilum* (cold water disease). Although these pathogens occur naturally, the Oroville Facilities, nonproject reservoirs, water diversions, agriculture, and silviculture may have produced environmental conditions that are more favorable to these pathogens than historic conditions. For instance, impediments to fish migrations may have altered the timing and duration of exposure of anadromous salmonids to certain pathogens. Fish management practices, such as introductions of exotic fish species, hatchery production, and out-of-basin transplants, have inadvertently introduced foreign diseases. Water management activities such as transfers, pumpback operations, and flow manipulation can result in water temperature changes and/or increased fish density, which potentially increase the risk of disease.

Oroville Facilities operations may also reduce the transmission and extent of some fish diseases. For example, during the late spring and summer, the Oroville Facilities release cooler water into the Feather River Low Flow Channel than existed historically. Such releases provide more favorable conditions for the control of diseases, such as ceratomyxosis, in the steelhead populations residing in the river. In addition, the Oroville Facilities are used to provide desirable temperature conditions in the Feather River Fish Hatchery. Temperature control is one of the most important methods in regulating diseases such as IHN at the hatchery.

G-AQUA1.2.1 Background Summary

The objective of Study Plan (SP) F2 was to evaluate the effects of ongoing and future project operations on the establishment, transmission, extent, and control of IHN, BKD, and other significant fish diseases in the Feather River basin. Significant diseases are diseases that potentially cause substantial losses to fish populations. Of the fish diseases occurring in the Feather River basin, those that are main contributors to fish mortality (e.g., IHN, BKD, *Ceratomyxa shasta*) are of highest concern for fisheries management in the region. Other diseases associated with parasitic copepods (e.g., gill maggots, *Salmincola californiensis*, anchor worms, *Learnaea* sp.) and other ectoparasites (e.g., *Epistylis* sp., *Ichthyobodo* sp., *Gyrodactylus* sp.) may occur in Feather River fish; however, they do not necessarily lead to fish death, nor do they threaten fish populations in terms of increased mortality. The above listed pathogens and parasites do not encompass the complete listing for the Feather River basin.

G-AQUA1.2.2 Report Conclusions

At this time, it appears that disease outbreaks in project waters have been associated primarily with stocked hatchery fish. Disease outbreaks in stocked hatchery fish may have had more to do with the species and stock origin, with respect to using stocks with low natural resistance to endemic diseases, than with poor water quality conditions. However, the cause of specific disease outbreaks in project waters is poorly understood.

Little is known about diseases and pathogens of non-hatchery fish in the Feather River basin. Of the fish diseases occurring in the Feather River basin, those that are main contributors to fish mortality at the Feather River Fish Hatchery (IHN and ceratomyxosis) are of highest concern for fisheries management in the region. Although other pathogens associated with disease may occur in Feather River fish, they do not necessarily lead to significant fish mortality or threaten fish populations. Thus, they may be considered less important for the management of the Feather River fisheries.

G-AQUA1.3 EVALUATION OF PROJECT EFFECTS ON RESIDENT FISH AND THEIR HABITAT WITHIN LAKE OROVILLE, ITS UPSTREAM TRIBUTARIES, THE THERMALITO COMPLEX, AND THE OROVILLE WILDLIFE AREA (SP-F3.1)

The objective of SP-F3.1 was to collect and compile baseline information characterizing the fish species composition and habitat in each of five geographic areas. Because of differences in resources, project operations, and fisheries management in each area, each geographic area was evaluated in a separate task as follows: Lake Oroville's upstream tributaries (Task 1), Lake Oroville (Task 2), the Diversion Pool and Thermalito Forebay (Task 3), Thermalito Afterbay (Task 4), and OWA (Task 5). The need for this study evolved from the potential for ongoing project operations to affect water surface elevations, fish habitat, water temperature, and other factors influencing warmwater and coldwater fish populations.

G-AQUA1.3.1 Upstream Migration Barriers, Fish Species Composition, and Fish Habitat in Lake Oroville's Upstream Tributaries (Task 1)

G-AQUA1.3.1.1 Fish Passage Impediments Above Lake Oroville's High Water Mark (Task 1A)

Background Summary

The purpose of SP-F3.1, Task 1A, was to identify and characterize potential fish passage barriers for inland salmonids, anadromous salmonids, and sturgeon upstream of Lake Oroville. Ongoing operation of the Oroville Facilities has the potential to influence accessibility to upstream tributary habitat and the opportunity for interactions between tributary fishes and Lake Oroville fishes. The results of this study provide information regarding the ability of the fish that exist within Lake Oroville to access habitat upstream of Lake Oroville and to interact with the fish communities in the tributaries upstream of Lake Oroville. Additionally, the results of this study were used to define the upstream geographic extent of several direct effects study plans including SP-F3.1, SP-F5/7, SP-F8, and SP-F15.

To provide a quantitative, repeatable, and defensible assessment of fish passage at potential barriers, a fish passage assessment methodology for salmonids was adapted from Powers and Orsborn (1985) for use in this evaluation. The method uses hierarchical decision trees and standard data collection procedures to provide a consistent and repeatable evaluation of potential fish passage barriers (Powers and Orsborn 1985). An assessment team of biologists determined the likelihood of passage by anadromous-sized Chinook salmon, anadromous-sized steelhead, inland-sized Chinook salmon, and inland-sized coho salmon at each potential upstream migration barrier evaluated. Because of a lack of knowledge regarding sturgeon swimming and leaping performance metrics, the potential for sturgeon passage was not assessed.

Report Conclusions

Four major and ten minor tributaries of Lake Oroville were surveyed for features with the potential to constitute adult salmonid passage barriers during representative low-flow (October 2002) and high-flow (March 2003) conditions. The results of this evaluation are presented in Figure 5.5-1, a summary map of fish passage barriers assessed and their fish passage classifications.

Updates from the Interim Report to the Final Report for SP-F3.1, Task 1A, included evaluation of Lake Oroville sediment wedges in each of the four major tributaries, and the addition of the Falls below Big Kimshew Creek as a potential fish passage barrier on the West Branch of the North Fork Feather River. Results of the sediment wedge passage analysis indicated that during some years, anadromous salmonid passage could potentially be impeded by the sediment wedges in each of the four major tributaries to Lake Oroville.

G-AQUA1.3.1.2 Fish Species Composition in Lake Oroville's Upstream Tributaries (Task 1B)

Background Summary

The purpose of SP-F 3.1, Task 1B was to describe the fish species composition in tributaries of the Feather River upstream of Lake Oroville. Ongoing operation of the Oroville Facilities has the potential to influence fish species composition upstream of Lake Oroville due to surface level fluctuations of the reservoir caused by project operations. When Lake Oroville is at high water surface elevation (normally in the spring), fish are able to move freely between the reservoir and upstream tributaries. When Lake Oroville is at low surface elevation (normally in the fall), free movement of fish between the reservoir and upstream tributaries may be blocked. The results of this study provide information regarding fish species composition in the tributaries upstream of Lake Oroville and the effects of project operations on species composition. Additionally, the results of this study were used to evaluate the potential effect of PM&E measures altering project operations that may affect current fish species composition and distribution in the tributaries upstream of Lake Oroville.

Fish species composition in tributaries upstream of Lake Oroville was determined through a combination of surveys conducted by DWR during 2002 and 2003 as part of the FERC relicensing process for the Oroville Facilities and a review of the existing literature on fish distribution data collected on the North Fork Feather River through surveys conducted by PG&E as part of the Poe Hydroelectric Project FERC relicensing process.

Report Conclusions

The game fish species assemblage determined to reside in the upper Feather River by DWR surveys in 2002 and 2003 includes two species of salmonids; rainbow trout and brown trout, and three species of black bass; smallmouth bass, redeye bass, and spotted bass. In addition, several juvenile bluegill were observed in the South Fork Feather River. Of those game fish observed, only rainbow trout are considered native to the drainage. Non-game fish species observed in the upper Feather River tributaries include carp, Sacramento pikeminnow, and potentially more than one species each of sucker, sculpin and roach. In addition to those species observed during the DWR surveys, hardhead, largemouth bass, and brown bullhead were confirmed to be present in the North Fork Feather River in surveys conducted by PG&E prior to 2002. Of these three species, only hardhead are native to the Feather River drainage. The fish species composition upstream of the high water mark for Lake Oroville supports a typical California foothill stream-dwelling fish assemblage. No fish species of primary management concern was observed in upstream tributaries that had not been previously observed in Lake Oroville or downstream reaches of the Feather River.

G-AQUA1.3.1.3 Inventory of Potentially Available Habitat, and Distribution of Juvenile and Adult Fish Upstream from Lake Oroville (Task 1C; SP-F15, Task 2)

Background Summary

The feasibility of reintroducing migratory anadromous salmonids to the upper Feather River was evaluated; this analysis included evaluation of fish passage above Oroville Dam among other topics. Before determining the feasibility of fish passage alternatives, it was essential to evaluate which areas upstream of the Oroville Facilities may provide suitable habitat to meet the biological, hydrologic, and physical habitat requirements of both juvenile and adult migratory anadromous salmonids, and to inventory fish species present in the upper Feather River upstream of Lake Oroville. The objectives of the SP-F15, Task 2, and SP-F3.1, Task 1C, joint report were to inventory and assess the suitability of available habitat upstream of Lake Oroville for adult and juvenile anadromous salmonids, and to describe the distribution of species currently present. These objectives were accomplished by evaluating and assessing data regarding mesohabitat, water temperatures, instream flows, and resident fish distribution.

Report Conclusions

Based on broad-scale mesohabitat surveys, the major tributaries in the upper Feather River—the West Branch of the North Fork Feather River (West Branch), the North Fork Feather River (North Fork), the Middle Fork Feather River (Middle Fork), and the South Fork Feather River (South Fork)—generally provide suitable habitat for all life stages of Chinook salmon and steelhead. For both Chinook salmon and steelhead, spawning and embryo incubation is the life stage for which the smallest amount of suitable habitat is available in the upper Feather River. The greatest amount of suitable habitat is available for the following life stages: Chinook salmon juvenile rearing and downstream movement, steelhead adult immigration and holding, steelhead fry and fingerling rearing and downstream movement, and steelhead smolt emigration. Overall, the North Fork appears to be the most suitable for occupancy of anadromous salmonids, while the South Fork appears to be the least suitable.

Water temperatures, at the locations for which water temperature data were available, approached or exceeded potentially stressful levels generally from May through October. However, water temperature data loggers were generally located at low elevations near the tributary/reservoir boundary, which is the location within tributaries that is typically believed to experience the highest water temperatures. Results of additional studies conducted during June through September 2004 could further elucidate the suitability of water temperatures in the upper Feather River during the warmest months of the year. However, results of these water temperature investigations currently are not available.

Water temperatures in the upper Feather River are a function of natural processes, and in certain instances, are influenced by operations of privately owned facilities. DWR does not have the ability to manipulate water temperatures in the tributaries upstream of Lake Oroville because facilities above Oroville Dam are owned and operated by entities other than DWR. In the North Fork, Pacific Gas and Electric Company (PG&E) currently is investigating the feasibility of enhancing coldwater withdrawal from the Prattville Intake at Lake Almanor, which could potentially decrease water temperatures within the Oroville Facilities project area. However, the conclusions of this investigation have yet to be released for public review. Therefore, potential decreases in water temperatures in the North Fork attributed to modifications to PG&E facilities were not included in the water temperature suitability assessment in this report.

In-river conditions and water temperatures at low elevations in the upper Feather River were roughly similar to those in Mill Creek and Deer Creek. Because water temperatures at lower elevations Mill and Deer creeks are similar to those in the upper Feather River at similar elevations, and assuming that the water temperatures in the upper Feather River at higher elevations remain similar to those in the higher elevations in Mill and Deer creeks, water temperatures in the upper Feather River may be suitable for Chinook salmon and steelhead because populations currently persist in Mill and Deer creeks. An assessment of the suitability of instream flows in the upper Feather River was not performed because there is a paucity of available information linking flows to the suitability of salmonid habitat in the upper Feather River. Rainbow trout were found at all sampling sites in the upper Feather River. The presence of rainbow trout throughout the upper Feather River may indicate suitability for anadromous Chinook salmon and steelhead populations.

In general, the upper Feather River appears to be suitable for migratory Chinook salmon and steelhead based on available mesohabitat data, water temperature profiles, and the current distribution of resident rainbow trout populations. However, additional data is required to definitively determine the suitability of habitat in the upper Feather River for anadromous salmonids.

G-AQUA1.3.2 Lake Oroville Fish Species and Potential Effects on Coldwater Pool Availability and Water Surface Elevation Fluctuations (Task 2)

G-AQUA1.3.2.1 Fish Species Composition: Lake Oroville, Diversion Pool, Thermalito Forebay (Task 2A, Task 3A)

Background Summary

This study identifies the composition of fish species in Lake Oroville, the Diversion Pool, and Thermalito Forebay, and represents Tasks 2A and 3A of the SP-F3.1 study. Information from this study was to be used to identify the potential effects of the project on these fishery resources. It also was to be used in the analysis of the effect of the Oroville Facilities' resident fisheries on upstream tributary fish and downstream special-status fish, and in the development of a recreational fishery management plan and other potential protection, mitigation, and enhancement (PM&E) measures for the project.

Report Conclusions

A comprehensive list of all the fish species currently known to exist in Lake Oroville was developed. This list included the following species: Chinook salmon, coho salmon, largemouth bass, redeye bass, spotted bass, bluegill, green sunfish, black crappie, channel catfish, white catfish, wakasagi, and common carp (all observed frequently); brown trout, rainbow trout, smallmouth bass, redear sunfish, white crappie, Sacramento sucker, Sacramento pikeminnow, hardhead, threespine stickleback, sculpin, goldfish, threadfin shad, and golden shiner (all observed infrequently); white sturgeon, lake trout, and warmouth (all uncommon); and kokanee salmon, Sacramento perch, brook trout, and various rainbow trout strains (historic).

Some of these species (e.g., rainbow trout, Chinook salmon, Sacramento pikeminnow, smallmouth bass) came to exist in the reservoir as a result of the impoundment of Feather River species captured when Oroville Dam was constructed in the early 1960s. Other species were introduced intentionally (brown trout, various strains of rainbow trout, Chinook salmon, largemouth bass, spotted bass) and unintentionally (wakasagi). Illegal introductions have no doubt occurred as well. Movement of fish (e.g., rainbow trout) into Lake Oroville from the tributaries occurs on a regular basis, and the potential exists for fish to be moved from the Diversion Pool into Lake Oroville via pumpback operations.

Because of the methods employed to collect the data used in this report, a determination of fish species distribution at Lake Oroville could not be made. The angler survey was an "access point" survey where data were collected as anglers returned to the boat ramps. This kind of survey does not provide for an accurate determination of where the fish were caught because anglers often fish in various areas of the reservoir throughout the day, and they would not normally be able to recall where each of their fish were caught. In regard to electrofishing data, the survey locations were not randomly selected; rather, they were selected to increase the likelihood of encountering larger numbers of fish in the limited time frame provided.

A comprehensive list of all the fish species currently known to exist in Thermalito Forebay was also developed. This list included the following species: rainbow trout, brook trout, Sacramento sucker, Sacramento pikeminnow, hardhead, sculpin, common carp, and wakasagi (all observed frequently); largemouth bass, bluegill, and tule perch (all observed infrequently); striped bass (uncommon); and brown trout and various rainbow trout strains (historic).

In addition, a comprehensive list of all the fish species currently known to exist in the Diversion Pool was developed. This list included the following species: rainbow trout, brook trout, Sacramento sucker, Sacramento pikeminnow, hardhead, sculpin, and wakasagi (all observed frequently); Chinook salmon, largemouth bass, smallmouth bass, bluegill, black crappie, common carp, golden shiner, and tule perch (all observed infrequently); striped bass and coho salmon (uncommon); and brown trout (historic).

Some of the species listed above (e.g., rainbow trout, Chinook salmon, Sacramento pikeminnow, smallmouth bass) came to occur in Thermalito Forebay as a result of the impoundment of Feather River species captured when the Thermalito Diversion Dam was constructed in the 1960s. Other species were introduced intentionally (brown trout, various strains of rainbow trout, Chinook salmon) and unintentionally (wakasagi). Illegal introductions have no doubt occurred as well. In addition, all species occurring in Lake Oroville could potentially exist in these waters because they could have moved down through the power plant and/or via the spillway during high-water events. Anglers have reported higher numbers of brown trout and Chinook salmon in the Diversion Pool following prolonged spill events, something that did not occur during the sampling period of this analysis. Afterbay fish species could also be transferred into these waters via pumpback operations.

G-AQUA1.3.2.2 Evaluation of the Ability of Lake Oroville's Coldwater Pool to Support Salmonid Stocking Recommendations (Task 2B)

Background Summary

This task is related to the Oroville Facilities because the amount of cold water present in Lake Oroville (that is, the coldwater pool) is determined in part by project operations and in part by external factors such as air temperature and precipitation. The purpose of this study was to evaluate whether there is sufficient cold water in Lake Oroville to support current salmonid stocking goals (DWR 2002c). The conclusions of this analysis also had the potential for use as the basis for suggesting potential PM&E measures relating to coldwater pool habitat for salmonids in Lake Oroville.

Report Conclusions

The objective of this task was to evaluate whether there is sufficient cold water in Lake Oroville to support current annual salmonid stocking goals of 170,000 yearling-equivalent salmon. For the purpose of this analysis, useable coldwater habitat was defined as any zone in Lake Oroville in which both the water temperature criterion of less than 18 degrees Celsius (°C) (64.4 degrees Fahrenheit [°F]) and the DO criterion of greater than or equal to 6.5 milligrams per liter (mg/L) were met.

Water temperature and DO profiles collected over 51 months at as many as 8 different sampling locations in Lake Oroville were analyzed, and for each month of the period of record, the volume of useable coldwater habitat at each location for which data was available was calculated. Because of the variability in the volume of useable coldwater habitat between locations, the average volume of useable coldwater habitat was calculated for each month and year of the period of record. Results suggest that even in the months and years with the lowest calculated average volume of useable coldwater habitat in Lake Oroville, the volume of habitat available per fish far exceeds the volume of water provided for fish in settings such as hatcheries and experimental and commercial netpen operations.

The assumptions used in calculating the average volume of useable coldwater habitat in Lake Oroville were highly conservative, almost certainly resulting in an underestimation of the actual volume of useable coldwater habitat available in Lake Oroville. Additionally, available information regarding depth distribution of forage base suggests that there is forage base in Lake Oroville in the zones in which useable coldwater habitat exists. Therefore, continued operation of the Oroville Facilities in a manner consistent with current operations would be expected to result in a sufficient volume of useable coldwater habitat to support current salmonid stocking recommendations for Lake Oroville.

*G-AQUA1.3.2.3 Evaluation of Lake Oroville Water Surface Elevation Reductions on Bass (*Micropterus *spp.) Spawning Success (Task 2C)*

Background Summary

The Lake Oroville warmwater fishery is a self-sustained fishery consisting of fish of the *Centrarchidae* (sunfish) family, including species of black bass (*Micropterus* spp.), two species of sunfish (green sunfish [*Lepomis cyanellus*] and bluegill sunfish [*L. macrochirus*]), two species of crappie (black crappie [*Pomoxis nigromaculatus*] and white crappie [*P. annularis*]), two species of catfish (channel catfish [*Ictalurus punctatus*] and white catfish [*I. catus*]), as well as many other fish species. Project operations that influence warmwater fish habitat include fluctuations in the water surface elevation resulting from flood management, power generation, and downstream fisheries management activities. Fluctuations in the water surface elevation may hinder colonization of rooted aquatic vegetation in the reservoir's littoral zone, limiting the establishment of terrestrial vegetation within the fluctuation zone (DWR 2001). Terrestrial vegetation provides spawning and nursery habitat, offers protection from predation, and results in increased food availability for warmwater fisheries (DWR 2001; DWR and USBR 2000). The availability of such vegetation may affect the abundance and distribution of warmwater fish (DWR 2001). Fluctuations in the water surface elevation also may result in dewatering of bass nests during spawning and incubation periods.

Positive effects also may be associated with reservoir fluctuations. For example, aquatic weed growth is controlled by water surface fluctuations, and without these fluctuations, excessive aquatic plant growth may limit the amount of forgeable fish habitat. Fluctuations in the water surface elevation of Lake Oroville are currently sufficient to prevent excessive growth of aquatic vegetation.

The objective of this study was to evaluate the effects of reductions in the Lake Oroville water surface elevation on the survival of black bass *(Micropterus* spp.*)* spawning nests. The evaluation used criteria developed by the California Department of Fish and Game (DFG) to describe the relationship between reductions in water surface elevation and dewatering of black bass spawning nests (Lee 1999).

Report Conclusions

Spawning characteristics of largemouth bass, smallmouth bass, and spotted bass were researched and historical records were examined to determine whether seasonal reductions in Lake Oroville water surface elevations would result in dewatering of spawning nests, and thereby affect spawning nest survival rates. A literature review concluded that black bass (*Micropterus* spp.) spawning activity extends from March through June, with the majority of spawning activity occurring from March through May. DFG suggests that a spawning nest survival rate of at least 20 percent is necessary to maintain the long-term population levels of highly fecund, warmwater fish, such as black bass. Nest survival curves developed by DFG illustrate that reductions of approximately 0.11, 0.11, and 0.23 meter per day would result in 20 percent nest survival for largemouth bass, smallmouth bass, and spotted bass, respectively. These criteria for reductions in water surface elevations were compared to monthly historical records of Lake Oroville water surface elevations from 1967 to 2001.

Results indicate that reductions in water surface elevations—with their potential to adversely affect survival of black bass nests—may only occur up to approximately one-third of the time for the period extending from March through May. Survival of black bass spawning nests during each month of the main spawning period (March through May) is high—80–100 percent for largemouth and smallmouth bass, and 96–100 percent for spotted bass—relative to the 20 percent spawning nest survival criterion established to maintain long-term population levels of black bass. Even during June, when relatively few black bass spawning nests would be expected to be present, long-term average monthly spawning nest survival ranges from 47 to 77 percent. In addition, Lake Oroville is recognized as supporting a very popular and important recreational sport fishery. Therefore, historic and ongoing project operations affecting water surface elevations in Lake Oroville result in conditions sufficient to maintain long-term population levels of largemouth, smallmouth, and spotted bass.

G-AQUA1.3.2.4 Management Practices and Monitoring Studies for White Sturgeon (Task 2D)

Background Summary

This study was designed to summarize information regarding management practices from reservoirs that are actively managed for sturgeon. In addition to evaluating potential project effects, this study was designed to provide baseline information useful for future evaluations and development of potential PM&E measures. One potential PM&E measure may include active management of Lake Oroville for sturgeon. Therefore, a literature review summarizing management activities and the results of monitoring studies designed to evaluate the effectiveness of various management activities was conducted to provide a mechanism for developing a potential sturgeon management plan, and for evaluating the likelihood of success of such a program in Lake Oroville. Lake Shasta management policies, monitoring and tagging studies, and progress reports were reviewed and summarized for their potential applicability to Lake Oroville. Similar information from other reservoirs in the Western United States that are managed for sturgeon also were reviewed and summarized for their applicability to Lake Oroville.

Report Conclusions

Limited information was available for white sturgeon (*Acipenser transmontanus*) populations within California reservoirs, as there is little active management of sturgeon in California reservoirs. Therefore, reports detailing sturgeon management activities and monitoring studies from the Pacific Northwest region, primarily the Columbia River basin, were reviewed. The studies reviewed suggested that the particular habitat in which sturgeon prefer to spawn occurred in the swiftest water available; on substrates consisting mainly of cobble, boulder, and bedrock; in water temperatures ranging from 12ºC to 18ºC (53.6ºF–64.4ºF); and at depths of 4–24 meters (13–79 feet). There may be small portions of the North Fork Feather River and Middle Fork Feather River that provide the preferred spawning habitat for white sturgeon; however, additional information is needed to determine the quantity and availability of sturgeon habitat. Without availability of the proper spawning habitat, white sturgeon populations may not be sustainable; consequently, management practices used in the Pacific Northwest may not be applicable to Lake Oroville.

G-AQUA1.3.3 Fish Species Composition, Fish Habitat Characteristics, and Project Operations Influencing the Diversion Pool and Thermalito Forebay (Task 3)

G-AQUA1.3.3.1 Fish Species Composition: Lake Oroville, Diversion Pool, Thermalito Forebay (Task 3A)

SP-F3.1, Task 3A, was prepared in conjunction with Task 2A of this study plan. Refer to the summary of SP-F3.1, Task 2A, above for a summary of Task 3A activities and results.

G-AQUA1.3.3.2 Project Operations Influencing Fish Habitat and Water Quality in the Diversion Pool and the Thermalito Forebay (Task 3B, Task 3C)

Background Summary

The objective of Task 3B was to generally describe the fish habitat in the Diversion Pool and Thermalito Forebay. The physical reservoir characteristics of both the diversion pool and the forebay were described using existing information. Physical reservoir characteristics described included surface area, volume, morphometry, and substrate. Water temperature and water quality data were collected and summarized from SP-W1 and SP-W6 (DWR 2002c).

The objective of Task 3C was to describe project operations that influence fish habitat in the Diversion Pool and Thermalito Forebay, and to provide baseline information for use in future evaluations and development of potential PM&E measures. Project operations identified in SP-F3.1 as having the potential to affect fish habitat included pumpback operations, power generating operations, and water temperature control operations to meet regulatory requirements for the Feather River Fish Hatchery and downstream water temperatures. Pumpback operations, power generation operations, and operations designed to meet hatchery and downstream water temperature objectives were characterized and summarized from existing DWR reservoir and hatchery operations records. The analysis of how these operations influenced fish habitat components (i.e., water temperature and water level fluctuations) in the Diversion Pool and Thermalito Forebay was designed to be a qualitative, conceptual, descriptive narrative that would provide a baseline characterization of operations influencing these reservoirs. This analysis was based on information in existing operational guidelines and DWR operations records. The effect of pumpback operations and power generation on water temperatures was described using data collected for SP-E8 and SP-W6, respectively (DWR 2002c).

Tasks 3B and 3C of SP-F3.1 were combined because each task required the analysis of similar data and described the same geographic locations and project facilities. Data provided by SP-E8, SP-W1, and SP-W6 were compared to reported water temperature requirements and tolerance ranges for fish species currently stocked in Thermalito Forebay to determine whether pumpback operations generally resulted in water temperature regimes that supported those fish species. Therefore, an analysis of fish habitat and project operations that influence fish habitat in the Diversion Pool and Thermalito Forebay was necessary to provide the tools to determine whether PM&E measures affecting either reservoir would be feasible or beneficial (DWR 2002c).

Report Conclusions

Analysis of project operations shows that pumpback can result in some degree of warming during certain times of the year. However, warming associated with pumpback did not exceed the water temperature index range during the period of record for a brook trout and rainbow trout put-and-take sport fishery. Although pumpback may warm water in the forebay and diversion pool, water temperatures recorded at the transect or point profile locations during the study period were never above the index value of 24.0°C (75.2°F) established for a put-and-take salmonid fishery, and were rarely above 19°C (66.2°F).

The lowest DO concentration observed during the sampling period was 6.9 mg/L in the Diversion Pool and 8.0 mg/L in Thermalito Forebay. Because DO concentrations never fell below the minimum criterion of the U.S. Environmental Protection Agency (USEPA) for growth of adult and juvenile salmonids, it is likely that DO is not a limiting factor in the availability of coldwater habitat in the diversion pool or forebay. Additionally, the constant addition of oxygenated water from Lake Oroville likely assists in maintaining DO concentrations above 6.5 mg/L in the diversion pool and forebay.

Generally, project operations were observed to have a relatively minor influence on fish habitat within the forebay and diversion pool. Therefore, continued operation of the Thermalito Complex facilities in a manner consistent with current operations would be expected to result in available habitat to support continued stocking programs in Thermalito Forebay.

G-AQUA1.3.4 Fish Species Distribution, Juvenile Bass Recruitment, Coldwater Pool Availability and Water Level Fluctuation in the Thermalito Afterbay (Task 4)

G-AQUA1.3.4.1 Fish Species Composition and Evaluation of Juvenile Bass Recruitment in the Thermalito Afterbay (Task 4A)

Background Summary

The purpose of SP-F3.1, Task 4A is to describe the fish species composition and evaluate juvenile bass recruitment in the Thermalito Afterbay. Because of its complex hydrologic regime, ongoing operation of the Oroville Facilities has the potential to influence both the fish species composition and juvenile bass recruitment. Operations of the Oroville Facilities affect the quantity and quality of fish habitat through frequent water level fluctuations. The Thermalito Afterbay has multiple outlets that deliver water to several different agricultural canals and is used to regulate flows in the lower Feather River. Water from Thermalito Afterbay is also used in pump-back operations. The shallow nature of Thermalito Afterbay results in significant fluctuation effects with only small surface level changes. The results of this study provide information regarding fish species composition and juvenile bass recruitment in the Thermalito Afterbay. Additionally, the results of this study were used to evaluate effects of potential PM&E measures or changes in operations that may influence surface level fluctuations on the current fish assemblage in Thermalito Afterbay.

Only limited fish sampling has been conducted in Thermalito Afterbay, therefore determination of the fish species composition is largely based on personal observations and an electrofishing survey conducted in November of 2002. In May and June of 2003, snorkeling surveys were conducted in suspected bass spawning areas. Results of these surveys and incidental observations were used to develop a list of fish species common in Thermalito Afterbay. Observations of bass nests combined with records of surface level fluctuations provided the only quantitative data available to estimate juvenile bass recruitment. These data combined with a review of the fisheries literature were used to determine species composition and provide a qualitative assessment of juvenile bass recruitment in the Thermalito Afterbay.

Report Conclusions

Fish species observed in the Thermalito Afterbay include largemouth bass, smallmouth bass, rainbow trout, brown trout, bluegill, redear sunfish, black crappie, channel catfish, carp, and large schools of wakasagi. Salmonids have not been stocked in Thermalito Afterbay and spawning in tributaries of Thermalito Afterbay is unlikely, therefore rainbow trout and brown trout likely passed through the Thermalito Pumping-Generating Plant from the Forebay. Based on a review of the literature, the Thermalito Afterbay likely provides good habitat for black bass species and large schools of wakasagi likely provide a good source of forage fish. Bass nest de-watering is probably the limiting factor in juvenile recruitment. Based on four years of surface level fluctuation data it appears that bass nest dewatering would have a minimal effect on spotted bass, an intermediate effect on smallmouth bass and perhaps a significantly negative effect on largemouth bass. Based on this analysis, with limited data, it is likely that black bass populations in the Thermalito Afterbay will persist unless changes in operations create more surface level fluctuations during black bass spawning which occurs from April through June for smallmouth and spotted bass and March through June for largemouth bass.

G-AQUA1.3.4.2 Characterization of Coldwater Pool Availability in the Thermalito Afterbay (Task 4B)

Background Summary

Ongoing operation of the Oroville Facilities influences water temperatures and surface elevation fluctuations in Thermalito Afterbay. Water temperature and surface elevation are important factors in influencing the availability of habitat for salmonids in Thermalito Afterbay. As a component of SP-F3.1, Task 4B evaluated potential project effects on habitat available to coldwater fish species.

The objective of this task was to evaluate whether there is sufficient cold water in Thermalito Afterbay to support a year-round coldwater fishery. The two potential types of coldwater fisheries assessed were a put-and-grow salmonid trophy fishery, and a put-and-take salmonid sport fishery. Because residence times of stocked salmonids potentially would be different for put-and-grow or put-and-take fisheries, two thermal regimes were analyzed.

Report Conclusions

Based on the reported thermal tolerances of coho salmon (*Oncorhynchus kisutch*), an index of appropriate water temperatures for a put-and-grow salmonid fishery was established as water temperatures less than or equal to 18°C (64.4°F) year-round. A water temperature range of 18.1°C (64.6°F) to 23.9°C (75.0°F) was used as an index of water temperatures capable of supporting a put-and-take salmonid fishery. The potential for both fisheries also was evaluated using the USEPA reported 30-day mean DO requirement of 6.5 mg/L for the protection of adult and juvenile salmonids. During preliminary examination of the available water temperature data collected from Thermalito Afterbay, it was determined that during most of the year, there is sufficient cold water to sustain a salmonid fishery. Therefore, detailed analysis of coldwater availability was conducted on data collected during June, July, and August 2002, the summer months, when water temperatures were the warmest during 2002.

Water temperature and DO profiles were collected over an 11-month period at 5 point locations and across 4 transects in Thermalito Afterbay. Detailed analysis of the data was conducted for each of the three warmest months of the year (June, July, and August) because the water temperature profiles during those months were the warmest, most heterogeneous, and most dynamic of the water temperatures observed during the year. Additionally, surface-water elevation fluctuations were greatest during the summer months in 2002. Water temperature profiles collected from the fall, winter, and spring months showed little variation between sampling locations, and showed that sufficient cold water was available during those months at the sampling locations to support a coldwater fishery. Therefore, the fall, winter, and spring months were omitted from further analysis.

Based on analysis of available data, in the summer months in 2002 when water temperatures in Thermalito Afterbay were highest and water surface elevations fluctuated the most, water temperatures for both put-and-grow salmonid fishery management and put-and-take salmonid fishery management were suitable at the locations sampled. Therefore, continued operation of the Thermalito Complex facilities in a manner consistent with current operations would be expected to result in sufficient available coldwater habitat to support salmonid management goals in Thermalito Afterbay.

G-AQUA1.3.4.3 Characterization of Inundated Littoral Habitat and Evaluation of Effects of Surface Water Fluctuations on Bass Nest Dewatering in the Thermalito Afterbay (Task 4C)

Background Summary

One of the purposes of SP-F3.1, Task 4C, was to characterize inundated littoral habitat and estimate the relationship between water surface elevation and availability of nearshore littoral habitat in Thermalito Afterbay. A second purpose of this task was to estimate the proportion of bass nests in the afterbay subject to dewatering. The study evaluated potential ongoing effects of project operations by evaluating the incidence of bass nest dewatering in Thermalito Afterbay in 2003. The results of this study provide information regarding the feasibility of establishing a self-sustaining warmwater fishery.

Report Conclusions

The results of the characterization of inundated littoral habitat indicate that there likely is bass nesting habitat within the fluctuation zone of Thermalito Afterbay at all times. However, the scales at which the habitat mapping and vegetation classification were performed precluded quantification of the amount of littoral bass nesting habitat.

The assessment used to estimate the percentage of bass nests potentially affected by stage reductions from the date of nest construction through the end of the corresponding incubation period was data intensive. The approach requires all of the following information:

- Mean daily storage and stage data for Thermalito Afterbay throughout the bass species nesting period (from the date of nest construction through the end of the corresponding incubation period);
- The temporal distribution of nesting activity by bass species;
- The duration of the incubation period, expressed as days from fertilization of eggs (defined as date of nest construction) through larvae emergence; and
- Nest depth distributions.

Data from multiple sources were used to calculate the number of days during the spawning season and peak spawning period when bass nests were dewatered. Additionally, the average daily percentages of dewatered nests over both the spawning season and the peak spawning period for three species of black bass were evaluated. For purposes of this analysis, it was assumed that if a bass nest becomes dewatered, it is no longer viable and would be abandoned, resulting in complete mortality as a result of one or a combination of the following: desiccation, localized oxygen depletion, turbidity and siltation, wave disturbance, rapid nest depth water temperature change, fungal infection, and/or predation. The study analyzed the potential for dewatering of largemouth bass nests from March through June and the potential for dewatering of smallmouth bass and spotted bass nests from April through June. Peak spawning periods for all three species occurred during May. Furthermore, the study used DFG Senior Biologist Dennis Lee’s suggested criterion for maintenance of long-term population levels of high fecundity, warmwater fish—requiring a minimum of 20 percent survivability of year class larvae (Lee 1999).

Results from this analysis should be used with care because of the inherent limitations of the available data and information on bass nesting in Thermalito Afterbay. Based on available information, analysis indicated that during some years relatively low percentages of black bass nests would be dewatered. However, in some years, fluctuations in water surface elevations could result in a relatively high percentage of largemouth bass nests being dewatered. Overall, current project operations appear to favor spotted bass production. Continued project operation in a manner consistent with current operations could result in an intermediate negative effect on smallmouth bass and would result in the least favorable conditions for recruitment of largemouth bass.

G-AQUA1.3.5 Fish Species Composition and Habitat Characterization in the OWA Ponds (Task 5)

G-AQUA1.3.5.1 Fish Species Composition in One-mile Pond (Task 5A)

Background Summary

These study results identify the composition of fish species in the OWA and represent Task 5A of SP-F3.1. Information from this study plan report has been used to identify the potential effects of the project on these fishery resources, and in the development of potential PM&E measures for the project. A listing of the fish species was presented along with a general perspective regarding the relative abundance of these species. The relationship of the composition of these fish species to existing fishery management programs was also discussed.

Report Conclusions

Electrofishing was conducted in One-Mile Pond on several dates in 2002 and 2003. Fish species captured on November 21, 2002, included black crappie, bluegill, brown bullhead, golden shiner, green sunfish, largemouth bass, redear sunfish, Sacramento sucker, and warmouth. Species captured on May 29, 2003, included black crappie, bluegill, largemouth bass, mosquito fish, redear sunfish, Sacramento sucker, sculpin, and warmouth. Species captured on June 10, 2003, included black crappie, bluegill, carp, golden shiner, green sunfish, largemouth bass, redear sunfish, Sacramento blackfish, Sacramento sucker, sculpin, and warmouth.

Electrofishing also took place on Robinson Borrow Pond (also called Granite Pond) on April 17, 2003. Fish species sampled included carp, Chinook salmon, largemouth bass, and Sacramento sucker.

The OWA is currently being managed as a warmwater fishery (DFG 1990). There is sufficient habitat in many of the ponds for the natural reproduction of warmwater game fish such as largemouth bass, bluegill, redear sunfish, and crappie, reflecting the current management approach, in which no fish are currently being stocked and the general fishing regulations apply. As described previously, the OWA ponds vary in depth and configuration; it is the deeper ponds that stay flooded year round that possess the primary fisheries. However, some of the shallower ponds and wetland areas contain fish during some years because of flooding from high river levels or local runoff during periods of high precipitation. These flooding periods raise the water level in the low-lying, flat areas of the OWA enough that vast areas of water become directly connected, not only introducing fish to ponds that will ultimately go dry, but also redistributing fish in the deeper, perennial ponds. This condition is even more significant during times of very high releases from Lake Oroville.

The fish species collected during the surveys described above are consistent with those reported by DFG and DWR biologists and by local anglers. Warmwater game fish dominate the fishery, with bluegill, redear sunfish, and largemouth bass comprising 39, 26, and 24 percent of the catch, respectively. Warmouth, black crappie, and green sunfish made up another 8 percent; the other species accounted for less than 2 percent of the catch.

It should be noted that the electrofishing techniques used are biased toward the capture of larger fish; significant numbers of small (less than 80 millimeters [mm]) bluegill and redear sunfish were observed but not captured in the sampling. In addition, as mentioned previously, carp were observed frequently but seldom taken into the boats because of their undesirable behavior toward other fish within the boat livewell. The number of adult carp was estimated to be approximately 5–10 percent of the fish observed. In addition to those species captured, channel catfish should be added to the list of species present because, although they were not collected in these surveys, they have been reported by DFG and local anglers. Because of periodic Feather River flooding events, it should be assumed that any species present in the adjacent section of the Feather River could also be found in the OWA, at least for a short period of time.

The OWA only connects directly with the Feather River during high-flow events, so the presence of salmonids does not occur every year. The OWA ponds and wetland areas become too warm during the late spring to sustain salmonids, so any that are present will not survive past this time. The extent of this periodic salmonid presence and the stranding effect has not been determined.

The most significant issue affecting OWA fisheries in the last decade has been the invasion of water primrose (*Ludwigia peploides peploides)* in the OWA on the east side of the Feather River. The excessive amount of primrose in former seasonally flooded areas has spread across the deeper, perennial, fish-bearing ponds to a point that entire pond surfaces are covered with water primrose, sometimes to a height of more than 1 meter above the surface of the pond. High abundance of aquatic plants can have negative effects on recreational fisheries by reducing angler access and effectiveness; it can also result in a decline in largemouth bass foraging success and in population skewing toward smaller fish (Dibble et al. 1996; Killgore et al. 1989; Wrenn et al. 1996). Recent observations by DWR biologists and DFG personnel, as well as angler accounts, have estimated that 80 percent of the fish-bearing ponds in this area have been covered with water primrose, and this condition is increasing annually.

G-AQUA1.3.5.2 Characterization of Fish Habitat in One-mile Pond (Task 5B)

<u>Background Summary</u>

Water temperature and surface level fluctuation are important factors in influencing the availability of habitat for fishes in One-Mile Pond. As a component of SP-F3.1, Task 5B characterizes fish habitat in One-Mile Pond.

The habitat suitability analysis conducted for this report was based on a literature review of the water temperatures, DO concentrations, substrates, cover types, and depths reported as suitable, preferred, or optimal for each of the species with the potential to exist in One-Mile Pond. Habitat suitability was determined based on available literature for each life stage of each species with the potential to occur in the OWA. In addition, habitat suitability was determined for species identified during DWR electrofishing efforts in One-Mile Pond that were not listed in the SP-F3.2 report as existing in the lower Feather River below the Thermalito Afterbay Outlet. The reported habitat suitability criteria for each fish species were compared to actual habitat conditions recorded during DWR sampling efforts in One-Mile Pond.

Report Conclusions

Water temperatures in One-Mile Pond ranged from a low of 9.9°C (49.8°F) from 1–4 meters below the surface on January 21, 2003, to a high of 31.8°C (89.2°F) at the surface on July 24, 2003. DO concentrations ranged from a low of 0.0 mg/L at 3.5 meters below the surface at 2:30 p.m. on July 24, 2003, at a water temperature of 23.6°C (74.5°F) to a high of 12.9 mg/L at 1 meter below the surface at 5:45 p.m. on May 9, 2003, at a water temperature of 18.7°C (65.6°F) (pers. comm., Martin 2003).

The water depth of One-Mile Pond varies depending on the time of year and is generally between 3 meters and 4.5 meters, but can be as shallow as 2.5 meters (pers. comm., Martin 2003). Aquatic vegetative cover and substrate found in One-Mile Pond and the OWA were reported to be characterized by seasonally flooded terrestrial vegetation such as willow species, cottonwood and sycamore trees, large beds of submerged aquatic vegetation, and emergent marsh habitat with a cobbled bottom interspersed with boulders and sand, silt, and clay (DWR 2001; DWR 2002c). Aquatic vegetation coverage within One-Mile Pond was reported to be approximately 43 percent (pers. comm., Kuenster 2003).

Based on the reported water quality tolerance ranges and reported habitat preferences for the fish species potentially occurring in One-Mile Pond, it is likely that there is suitable habitat within portions of the pond for most non-native warmwater species identified as having the potential to occur within the pond.

Additionally, based on the reported water quality tolerance ranges and on reported habitat preferences, there likely is suitable habitat within One-Mile Pond for most native species identified as having the potential to exist in the pond.

G-AQUA1.4 EVALUATION OF PROJECT EFFECTS ON RESIDENT FISH AND THEIR HABITAT IN THE FEATHER RIVER DOWNSTREAM OF THE FISH BARRIER DAM (SP-F3.2)

Operations of the Oroville Facilities can result in varying flow rates in the Feather River, which in turn may alter plant composition in the fluctuation zone, namely changing the aquatic vegetation to terrestrial vegetation. Inundated vegetation provides spawning and nursery habitat for warmwater fish, offers protection from predation, and results in increased food availability for warmwater and coldwater fisheries (DWR 2001; DWR and USBR 2000). Additionally, variations in flow may affect water temperature, spawning habitat availability, egg incubation success, and juvenile survival, all of which are factors in determining fisheries success in the Feather River (DWR 2001). SP-F3.2 was designed to address non-salmonid fish that reside in the study area, including non-salmonid fish that migrate downstream of the Thermalito Diversion Dam. This study plan did not evaluate project effects on salmonids, as they were addressed in SP-F10.

G-AQUA1.4.1 Comparison of Fish Distribution to Fish Habitat in the Lower Feather River (Task 1, Task 4, and Task 5)

G-AQUA1.4.1.1 Background Summary

The purpose of SP-F3.2, Task 1, was to document the distribution of non-salmonid fish species in the lower Feather River from the Thermalito Diversion Dam to the confluence of the Sacramento and Feather Rivers. The purpose of SP-F3.2, Task 4, was to identify fish habitat in the lower Feather River as it pertains to species-specific habitat requirements. The purpose of SP-F3.2, Task 5, was to evaluate potential project effects on non-salmonid fish species, and to integrate information about the distribution of fish species and habitat requirements.

To complete Tasks 1, 4, and 5 of SP-F3.2, fish species distribution and species-specific habitat component information were analyzed. Fish species distribution information was developed using three distinctly different collection methods: snorkel surveys, rotary screw trapping, and seine surveys. Fish habitat quality, quantity, and distribution were defined through the presence or absence of combinations of specific fish habitat components that are required by each fish species. Fish habitat components characterized in the lower Feather River included mesohabitat type, substrate, water depth, instream cover complexity, water temperature, and DO concentration.

G-AQUA1.4.1.2 Report Conclusions

Three hundred seven mesohabitat units were identified in the Feather River, from the Thermalito Diversion Dam to the confluence with the Sacramento River. Mesohabitat units ranged in size from approximately 0.01 acre (535 sq ft) to 708 acres and were classified as backwater, pool, glide, run, boulder run, or riffle habitat. Substrate, depth, and instream cover complexity were characterized in each of the mesohabitat units. In general, mesohabitat type diversity decreased from the upstream to downstream portions of the lower Feather River; the proportion of fine substrates increased with distance downstream. Intermediate depth classes occurred more frequently downstream along with the greatest proportion of deep pools in the most upstream portions of the lower Feather River. The complexity of instream cover increased with distance downstream.

Water temperatures were recorded at 24 thermograph locations within the lower Feather River approximately every 15 minutes between January 2002 and December

2003, from which the mean daily water temperature was calculated. The lowest and highest recorded mean daily temperatures were 45.5°F (7.5°C) and 75.9° F (24.4°C), respectively. Water temperatures tended to be coldest in the upper portions of the lower Feather River near the Fish Barrier Dam and progressively warmer downstream during the spring, summer, and fall.

DO concentrations were collected in 19 pools in the lower Feather River during 2002. None of the samples collected in the lower Feather River had DO concentrations less than 6.5 mg/L.

Water quality samples were collected at 17 locations within the lower Feather River. Exceedances occurred for three constituents: total aluminum, iron, and copper. All of the water quality sampling locations in the lower Feather River exceeded the aquatic life standard included in the National Ambient Water Quality Criteria (NAWQC) for aluminum at least one time.

Fish habitat distribution was determined by dividing the lower Feather River into habitat units and assigning each habitat unit a proportion of relative habitat suitability class based on an analysis of each habitat component requirement for each species. Thus, fish habitat distribution was presented as the number of acres and the proportion of total habitat that fell within each proportion of relative habitat suitability class. The habitat distribution for 16 fish species was presented for each of 5 lower Feather River reaches as well as for the entire lower Feather River.

The proportion of total available habitat that fell into the highest proportion of relative habitat suitability class (90 percent–to–100 percent class) generally increased with distance downstream from the Fish Barrier Dam for American shad, centrarchids, hitch, Sacramento splittail, Sacramento sucker, tule perch, and white sturgeon, and generally decreased with distance downstream from the Fish Barrier Dam for green sturgeon and striped bass. The proportion of total available habitat that fell into the highest proportion of relative habitat suitability class (90 percent to 100 percent) for hardhead and Sacramento pikeminnow displayed a relatively homogeneous distribution throughout the lower Feather River. A small proportion of total available habitat fell into the highest proportion of relative habitat suitability class (90 percent–to–100 percent class) for Pacific lamprey and river lamprey in the most upstream reaches of the lower Feather River. Only the centrarchid fish species' habitat distribution fell into one of the reduced proportion of relative habitat suitability classes in the upstream-most reaches of the lower Feather River.

The amount of concurrence between habitat distribution and species distribution also was presented by species. In general, the reaches with the greatest area of the highest proportion of relative habitat suitability classes (75 percent to 89 percent and 90 percent to 100 percent) also had a high proportion of the "frequently observed" category of distribution for centrarchids.

Overall, operation of the Oroville Facilities in a manner consistent with current operations is unlikely to alter the distribution of species or their habitat in the lower

Feather River. However, specific changes to project operations could alter the quantity, quality, and distribution of habitat for some species depending on the type of operational change implemented.

G-AQUA1.4.2 Matrix of Life History and Habitat Requirements for Feather River Fish Species (Task 2; SP-F21, Task 1; SP-F15, Task 1)

G-AQUA1.4.2.1 Background Summary

The purpose of this report was to assemble and summarize information regarding fish species life history characteristics and habitat requirements (DWR 2002c). Operations of the Oroville Facilities can potentially affect, both directly and indirectly, the quality, quantity, and distribution of fish habitat components in the Feather River. Developing a profile of the life stage characteristics and habitat requirements of fish species establishes the basis for developing an understanding of the potential effects of Oroville Facilities operations on these fish resources. Specifically, this report provides an information base regarding life stage characteristics and habitat requirements of fish species in the Feather River, and is intended to support other study plan tasks.

The reporting format of a searchable and readily manipulatable matrix describing life stage characteristics and habitat requirements is designed to facilitate the use of this information for comparisons between specific fish species and selected life history and habitat requirement elements. For example, comparing water temperature tolerances of selected predator and prey species may aid in determining whether potential temperature exclusion zones exist. The approach of building a searchable database of fish characteristics (fish matrix) was chosen over the more conventional approach of narrative descriptions of the fish characteristics so that a “tool” could be provided that would more efficiently support the use of this information in the other study plan tasks.

This deliverable satisfies the requirement to develop and describe fish life stage characteristics and habitat requirements, as defined in several different study plans (SP-F3.1, SP-F3.2, SP-F5/7, SP-F10, SP-F15, and SP-F21). To ensure consistency of the treatment of the characterization of each fish species, and to avoid inefficiencies in the development of these similar deliverables, characterization of all fish species for which life stage characteristics and habitat requirements are to be described are presented in this draft report. Twenty-four species of special regulatory status and management concern were characterized, with respect to as many as 94 elements for each species. This report was developed based upon the review of more than 750 separate literature sources.

G-AQUA1.4.2.2 Report Conclusions

The principal conclusions from the information represented in the fish matrix were developed in the deliverables for the other study plans and tasks that the fish matrix was designed to support. Although the fish matrix will continue to evolve and be refined by additional information, it is already readily apparent that there is a wide range in the quality, quantity, consistency, and availability of information between various fish species. In the cases where the cited information disagrees or does not coincide, the interpretation and use of the information should be tempered and evaluated on the basis of the credibility of the source and the applicability of the cited materials. The fish matrix is flexible and capable of fulfilling the literature review needs identified in Task 2 of SP-F3.2 and Task 1 of SP-F21, as well as associated plans that draw upon this summary of life history characteristics and habitat requirements.

The fish matrix provides detailed information regarding status, abundance, and distribution, adult description, life history traits, habitat availability, predation, and recreational or commercial value for the following fish species: Fall-run and spring-run Chinook salmon, steelhead/rainbow trout, green sturgeon, white sturgeon, river lamprey, Pacific lamprey, coho salmon, American shad, brown trout, delta smelt, four species of black bass (largemouth, spotted, smallmouth, and redeye), Sacramento pikeminnow, hardhead, hitch, Sacramento splittail, green sunfish, bluegill, redear sunfish, black crappie, white crappie, channel catfish, white catfish, striped bass, Sacramento sucker, threadfin shad, wakasagi, and tule perch. Detailed species-specific information from the fish matrix is provided in the completed study plan report available on the Oroville Facilities website at http://orovillerelicensing.water.ca.gov/wg_plans_envir.html.

G-AQUA1.4.3 Sturgeon and Splittail Analyses (Task 3)

G-AQUA1.4.3.1 Final Assessment of Sturgeon Distribution and Habitat Use (Task 3A)

Background Summary

Oroville Dam and its associated facilities prevent sturgeon migration to the upper Feather River, so it is important to evaluate the suitability for sturgeon of spawning and holding areas in the lower river below the Fish Barrier Dam. This study was initiated to help identify how operation of the Oroville Facilities may affect sturgeon in the lower Feather River through its effects on flow, temperature, and habitat. The report for SP-F3.2, Task 3A, covers exploratory scuba surveys, radio tagging and tracking, and egg and larval surveys for sturgeon in the 2003 field season. The objectives of this study were to:

- Define sturgeon spawning and rearing distribution and timing;
- Relate habitat usage to environmental variables; and
- Provide data to evaluate management decisions concerning future monitoring programs, operational changes of the dam, and/or habitat enhancement within the lower Feather River.

Report Conclusions

The goal of SP-F3.2, Task 3A, was to determine the distribution, spawning locations and timing, habitat usage, residence time, and outmigration patterns of sturgeon in the lower Feather River. Flows were unlikely to have prevented passage, and temperature ranges of 48°F to 68°F were within the thermal tolerances of these fish. However, angling (for the planned radio telemetry study), a scuba survey, and egg and larval methodologies were unable to detect any sturgeon. Insufficient data were collected through the use of angling, diving, and egg and larval surveys conducted from March through August 2003 to evaluate project effects on adult and juvenile sturgeon.

G-AQUA1.4.3.2 Final Assessment of Potential Sturgeon Passage Impediments (Task 3A)

Background Summary

Sturgeon are observed neither commonly nor consistently in the Feather River. Operations of the Oroville Facilities, by influencing flows within the Feather River, may influence the ability of both green sturgeon and white sturgeon to upmigrate past potential passage impediments; therefore, the sturgeon passage assessment portion of SP-F3.2, Task 3A, was developed to evaluate the degree to which migration impediments may contribute to the relatively low number and inconsistent observations of sturgeon in the Feather River. This assessment report evaluates the potential for sturgeon passage at three preliminarily identified potential migration barriers during a "variety of flow conditions," including the "representative low-flow range" and "representative high-flow range" as directed in SP-F3.2, Task 3A, and represents the final conclusions from the sturgeon passage impediment assessment. In addition to the passage assessment, existing information about geographic and temporal distribution for sturgeon was augmented by the results of radio tracking, scuba, and creel surveys conducted during the 2003 field season.

The purpose of this assessment report was to document and communicate the findings of the field investigations of Feather River sturgeon passage for the range of flow observations evaluated visually during the representative low-flow and high-flow periods. As a subtask of SP-F3.2, the sturgeon passage assessment fulfilled a portion of the FERC application requirements by detailing the potential passage impediments associated with the Oroville Facilities project area for green sturgeon, which is a species of special regulatory status, and white sturgeon, which is a species of primary management concern (herein collectively denoted as "sturgeon").

Report Conclusions

Three potential physical upstream migration barriers for sturgeon in the Feather River were identified and field evaluated by a team of selected sturgeon passage experts during representative low-flow conditions (November 2002, approximately 2,074 cubic feet per second [cfs]) and high-flow conditions (July 2003, approximately 9,998 cfs). The three potential physical upstream migration barriers included Shanghai Bench, the Sunset Pumps, and Steep Riffle (located 2 miles upstream of the Thermalito Afterbay Outlet) (USFWS 1995).

At the observed representative low flow, Shanghai Bench is likely a sturgeon passage barrier because of the height of its waterfalls, water velocities of the mid-channel chute, and lack of attraction flow within the potentially passable side channel. These potential passage impediments virtually disappear at relatively higher flows, and Shanghai Bench is likely passable for sturgeon during the representative high-flow conditions. At the observed representative low-flow conditions, the Sunset Pumps is likely a sturgeon passage barrier because of the height of its waterfalls and water velocities of the mid-channel chute. Passage of the Sunset Pumps by sturgeon during the representative high-flow conditions is unlikely, although there may be a potential passage opportunity within a river-left cascade/willow bar complex.

Of the potential barriers assessed, Steep Riffle represents the most reasonably passable potential barrier during representative low-flow conditions, and sturgeon could likely ascend the riffle without complication. Steep Riffle was removed from evaluation during representative high-flow conditions because the expert team determined that it is likely passable during most river stages.

Passage determinations at each of the potential passage barriers in the lower Feather River will continue to be speculative without a greater understanding of sturgeon migration patterns and physiologic limitations.

G-AQUA1.4.3.3 Assessment of Potential Project Effects on Splittail Habitat (Task 3B)

Background Summary

The purpose of SP-F3.2, Task 3B, was to assess potential project effects on splittail habitat availability during the splittail spawning, egg incubation, and initial rearing period. The results of this study provide information regarding the frequency with which potential habitat is inundated during this period, as well as the frequency with which water temperatures fall within splittail tolerance levels. Additionally, the results of this study may support the identification or evaluation of potential PM&E measures that could increase the quantity or quality of splittail spawning and initial rearing habitat.

A review of available literature on Sacramento splittail life history was conducted to determine the period of analysis during which project operations could affect splittail habitat. Based on the results of the literature review, February through May was determined to be the appropriate time period for the analysis of splittail habitat present in the lower Feather River during the splittail spawning, egg incubation, and initial rearing period. A literature review also was used to determine suitable water depth and water temperature characteristics for splittail spawning, egg incubation, and initial rearing habitat. Such habitat is generally described as submerged vegetation typically found in riparian zones flooded to a depth between 3 and 6 feet.

Report Conclusions

DWR, through photo-interpretation and ground-truthing, created a geographic information systems (GIS) polygon data set depicting vegetation within the lower Feather River floodplain. The GIS data set was attributed using a modified version of the Holland Classification System. Two vegetation associations, *gravel/sandbar* and *mixed emergent vegetation*, were determined to be suitable for potential splittail spawning and were selected for further field survey.

In November 2003, ten of the GIS polygon locations were surveyed to determine the range of absolute surface elevations within each habitat unit. The surveyed sites comprised approximately 23 percent of the total area that was classified as *gravel/sandbar* or *mixed emergent vegetation*. Stage-discharge curves from U.S. Geological Survey (USGS) transects in the lower Feather River were used to calculate potential habitat within each polygon and the total potential habitat for all ten polygons. An index of relative habitat availability, or Index of Useable Flooded Area (UFA), was created based on the results of the field surveys. UFA is defined as the relative amount of habitat inundated to a minimum depth of 3 feet and a maximum depth of 6 feet during the defined spawning, incubation, and initial rearing period.

Feather River flows and the duration of inundation during the potential splittail spawning and initial rearing period are highly correlated with splittail year-class strength as reported by DFG. In this report, 21 years of instream flow data were analyzed. Within the 21 years, 8 years were reported by DFG as producing strong year-classes, which correlated to high flows in the Feather River; 6 years were described as producing weak year-classes, which correlated to low flows in the Feather River; and 7 years were reported to have produced either intermediate or unknown year-class strengths, which correlated to intermediate flows in the Feather River. Available literature suggests that because of the high fecundity, broad environmental tolerances, and relatively long life span of the Sacramento splittail, the population is resilient and able to recover quickly after a period of drought. Consecutive years of high flows creating significant habitat for spawning, egg incubation, and initial rearing are reported not to be necessary to ensure continued persistence of the species.

Published studies on Sacramento splittail spawning, egg incubation, and initial rearing have focused on floodplains outside the area directly influenced by Oroville Facilities operations; therefore, the relative importance of availability of habitat within the lower Feather River for continued splittail persistence is unknown. Likewise, studies on splittail abundance have focused on juvenile captures in the Sacramento–San Joaquin Delta (Delta), which is an indicator of basinwide productivity rather than specific production in the Feather River. Based on the results of the analysis of lower Feather River flows vs. splittail year-class strength, and in the absence of specifically directed studies on dynamics of the lower Feather River splittail population, it does not appear likely that continued operations of the Oroville Facilities under current operating practices would create conditions unfavorable to splittail spawning, egg incubation, and initial rearing habitat.

G-AQUA1.4.4 Fish Habitat in the Feather River from the Thermalito Diversion Dam to the Sacramento River Confluence, as it Pertains to Species-Specific Habitat Requirements (Task 4)

Task 4 of SP-F3.2 was combined with SP-F3.2, Task 5, and the Task 1 final report because the study plan objectives were related. Study plan results are presented above under SP-F3.2, Tasks 1, 4, and 5.

G-AQUA1.4.5 Potential Project Effects on Non-salmonid Fish Species (Task 5)

Task 5 of SP-F3.2 was combined with SP-F3.2, Task 4, and the Task 1 final report because the study plan objectives were related. Study plan results are presented above under SP-F3.2, Tasks 1, 4, and 5.

G-AQUA1.5 FISHERIES MANAGEMENT (SP-F5/7)

Lake Oroville and its tributaries, together with the Thermalito Complex, support “warmwater” and “coldwater” recreational fisheries. In 1994, FERC ordered DWR to formulate and implement a fisheries management plan. In response, DWR implemented salmon stocking and fish habitat improvement projects in Lake Oroville. The project-related fisheries in the reservoir may interact with the upstream tributary fisheries though interactions such as predation, competition for available food and habitat, disease transmission, and genetic introgression. Additionally, components of the coldwater and warmwater reservoir fisheries have the potential to interact with species in the Feather River that are listed under the federal Endangered Species Act (FESA). It was therefore necessary to identify current stocking goals and evaluate conditions of the fishery to assess compliance with the 1994 FERC mandate.

G-AQUA1.5.1 Potential Effects of Fisheries Management Activities on ESA-listed Fish Species (Task 1)

G-AQUA1.5.1.1 Background Summary

Ongoing operation of the Oroville Facilities has the potential to influence fish species listed under the federal ESA and fish species listed by DFG as fish Species of Special Concern in the DFG publication *Fish Species of Special Concern in California* (Moyle et al. 1995). Operations of the Oroville Facilities affect fisheries management activities occurring within the study area, and fisheries management activities occurring within the study area, could influence ESA-listed fish species and Species of Special Concern by providing opportunities for interaction between fish species that otherwise may not have occurred. As a component of SP-F5/7, Task 1 identified and characterized the potential effects of fisheries management activities occurring within the study area on ESA-listed fish species and Species of Special Concern, which are listed in Table G-AQUA1.5-1.

Table G-AQUA1.5-1. DFG fish species of concern and ESA-listed fish species in the study area.

Species	Run/Common Name	Status
Oncorhynchus tshawytscha	Spring-run Chinook Salmon	Federal ESA—Threatened; CESA—Endangered
Oncorhynchus tshawytscha	Fall-run Chinook Salmon	Federal ESA—Candidate; California SSC
Oncorhynchus mykiss	Central Valley Steelhead	Federal ESA—Threatened; CESA—Endangered
Acipenser medirostris	Green Sturgeon	Federal ESA—Candidate; CESA—Threatened
Lampetra ayresi	River Lamprey	California Watch List
Mylopharodon conocephalus	Hardhead	California Watch List
Pogonichthys macrolepidotus	Sacramento Splittail	CESA—Threatened

Notes: CESA = California Endangered Species Act; ESA = Endangered Species Act; SSC = Species of Special Concern
Source: Moyle et al. 1995; NOAA Fisheries 1998; NOAA Fisheries 1999

To complete Task 1 of SP-F5/7, fisheries management activities were divided into two components: stocking-related activities and non-stocking-related activities. Once these activities were summarized, a literature review was conducted to determine potential effects of fisheries management activities on fish species listed under ESA and listed by DFG as SSC downstream of the project area in the Feather River.

G-AQUA1.5.1.2 Report Conclusions

Current fish stocking practices in the project area include the stocking of catchable sized brook trout and rainbow trout in Thermalito Forebay and the stocking of coho salmon in Lake Oroville (DWR 2001; DWR 2003a). Potential interactions between stocked fish and fish species of concern in the project area and downstream of the project include competition, predation, disease transmission, and genetic introgression.

An examination of available reports indicates that few stocked fish escape from the reservoirs in which they are planted. A review of the literature on competition and predation, with emphasis on the species involved in project operations, indicates that the potential for competitive or predatory interactions with fish species of concern in the Feather River is minimal. In addition, current stocking practices minimize the likelihood of significant emigration of stocked fish from the reservoirs. For example, only catchable size fish are stocked in Thermalito Forebay, and the stocking protocols for coho salmon in Lake Oroville are designed to minimize the stocking of fingerlings during the spring, when higher flows may cause significant numbers of fish to escape the reservoir over the spillway.

The transmission of disease from hatchery fish to wild fish populations is often cited as a concern in fish stocking programs. There is, however, little evidence of disease transmission between hatchery fish and wild fish (Perry 1995). Normal hatchery operating procedures, such as periodic examinations of on-station fish by fish pathologists and disinfecting procedures, are designed to control disease in hatchery stocks. The Feather River Fish Hatchery has implemented disease control procedures that minimize both the outbreak of disease in the hatchery and the possibility of disease transmission to wild fish populations.

A review of available literature suggests two possibilities for genetic introgression among stocked salmonids and salmonids of concern in the Feather River. The first of these possibilities is intra-specific hybridization between coho salmon and Chinook salmon. Evidence of hybridization between these two species is weak. Additionally, there are no documented cases of fertile offspring as a result of coho salmon/Chinook salmon hybridization (Bartley et al. 1990). Coho salmon stocking protocols are designed to minimize the emigration of coho salmon from Lake Oroville so that the potential for hybridization is minimized.

The second possibility for genetic introgression of stocked salmonids and wild special-status species is between stocked rainbow trout from Thermalito Forebay and wild steelhead in the Feather River. A review of current stocking practices, combined with available information on wild-steelhead spawning distributions, indicate that the possibility of stocked rainbow trout mating with wild steelhead is not a likely scenario. Additionally, those few spawning events that may occur are not likely to affect the overall genetic makeup of the wild steelhead population (Leary et al. 1995).

Non-stocking management activities in the project area are confined to Lake Oroville and specifically target the warmwater fishery. The management activities in Lake Oroville include construction of habitat structures providing cover for juvenile black bass and the construction of catfish spawning structures. There have also been some activities promoting growth and longevity of warmwater sport fish that involve genetic enhancements to the populations, such as the stocking of Florida strain largemouth bass, which was implemented to enhance the bass fishery in Lake Oroville. It is unlikely that these activities would affect special-status fish species in the Feather River.

G-AQUA1.5.2 Achievement of Current Stocking Goals (Task 2)

G-AQUA1.5.2.1 Background Summary

The report for SP-F5/7, Task 2*, Achievement of Current Stocking Goals,* was prepared to identify and evaluate the fish stocking programs for Lake Oroville and Thermalito Forebay. These programs support sport fishing, one of the primary recreational activities occurring at the Oroville Facilities and an important component of local tourism. DFG exclusively managed these fisheries from 1968 until 1993, and since that time DWR has become a partner in this management.

The objective of the study was to evaluate the success of the current fish stocking programs at the Oroville Facilities, and determine the effects, if any, on these programs from project operations. The report is necessary because project operations may have an effect on recreational fishing at the Oroville Facilities. In addition, fish stocking at Lake Oroville is a component of DWR's FERC-required Recreation Plan. An analysis of the success of this program, as well as DFG's Thermalito Forebay stocking program, may be used in the development of future PM&E measures related to fish stocking at the Oroville Facilities.

To complete Task 2, a literature review of DWR and DFG files was conducted and interviews were held with DFG biologists and Feather River Fish Hatchery personnel. Lake Oroville and Thermalito Forebay are the two Oroville Facilities waters with fish stocking programs, and they were both identified along with their goals. The review also identified the existing fishery monitoring data for the current stocking activities. These data were compared with the management goals to determine the level of success of the stocking programs.

G-AQUA1.5.2.2 Report Conclusions

The two primary documents used to identify the Fishery Management Plans for Lake Oroville and Thermalito Forebay are the *1999 Lake Oroville Annual Report of Fish Stocking and Fish Habitat Improvements* (DWR 1999), and the DFG-prepared *Strategic Plan for Trout Management: A Plan for 2004 and Beyond* (DFG 2003). These documents discuss the goals and success criteria for each of these programs.

Lake Oroville

The goal of the current Lake Oroville stocking program is to annually stock approximately 170,000 coho salmon as part of a “put-and-grow” management strategy. Because this program is in its infancy, there are no established criteria currently in place to measure the success of this program. This determination will be based on the best available information, which currently is the criteria developed during the DFG/DWR fishery study conducted from 1993 through 1999, as well as DFG’s *Strategic Plan for Trout Management: A Plan for 2004 and Beyond* (DFG 2003). In addition, the definitive test of a successful recreational fishery program will also be applied, that of angler satisfaction. This program is meeting the established growth criteria and is highly regarded by the coldwater angling community, and therefore is deemed successful in achieving its stocking goals.

One issue that must be addressed is program reliability. Because of a broodstock disease problem, no coho were to be stocked in 2004, likely reducing fishing success in 2005. Efforts to alter the current program should be directed at ensuring more reliability in the egg supply; DFG and DWR are currently in the process of accomplishing this task. Alternative coho hatchery facilities are being investigated, and DWR and DFG planned to initiate studies during the fall of 2004 to explore the possibility of using Lake Oroville’s adult coho as a brood source. In addition, National Oceanic and Atmospheric Administration (NOAA) Fisheries has expressed concern that stocking coho salmon in Lake Oroville may have negative effects on Central Valley anadromous salmonids, as well as coastal coho populations if Lake Oroville coho pass downstream of the reservoir. These issues are currently being addressed by DWR, DFG, and NOAA Fisheries, and a final determination was expected by the end of 2004.

Thermalito Forebay

The current Thermalito Forebay stocking program consists of annual stocking of approximately 30,000 catchable rainbow trout by DFG as part of a "put-and-take" management strategy. Thermalito Forebay is ideal for a put-and-take fisheries program because it meets virtually every criterion described in the Strategic Plan. It has easy public access in multiple locations (including handicapped fishing access), ample shoreline availability, and improved boat launching facilities for both motorized and nonmotorized boats. Moreover, the forebay has high angler use, and it remains a coldwater reservoir all year, although it lacks sufficient habitat to support natural production. As a result, the fishery management at Thermalito Forebay has required very few changes over its history, and today the forebay remains a very popular fishery. This program is achieving the goals specified in the Strategic Plan for Trout Management by providing an attractive angling opportunity to the public, with a high degree of angler satisfaction, and in a way that is consistent with contemporary California recreational fishery management. A discussion of project operational effects is unnecessary because this program is achieving its stocking goals (DWR 2002c).

G-AQUA1.5.3 Interaction Between the Lake Oroville and Upstream Tributary Fisheries (Task 3)

G-AQUA1.5.3.1 Background Summary

The purpose of SP-F5/7, Task 3 is to evaluate potential interactions between the Lake Oroville fishery and fisheries in tributaries upstream of Lake Oroville. Ongoing operation of the Oroville Facilities has the potential to influence fish species interactions between the two fisheries due to surface level fluctuations of the reservoir caused by project operations and the maintenance of both a warmwater and coldwater fishery in Lake Oroville. When Lake Oroville is at high water surface elevation, fish are able to move freely between the reservoir and tributaries while at low surface elevations, passage between the fisheries may be blocked. The results of this study provide information regarding the potential interactions among fish species of the two fisheries including, competition for food and habitat, predation, disease transmission and genetic introgression. Additionally, the results of this study were used to evaluate particular PM&E measures that may affect connectivity between the two fisheries or species composition in either Lake Oroville or the upstream tributaries.

Fish species composition in the tributaries upstream of Lake Oroville was determined by surveys and literature review during the SP-F3.1, Task 1B reporting process, while fish species composition in Lake Oroville was determined during the SP-F1, Task 2A reporting process. Potential interactions between the two fish species assemblages were identified as competition for food and habitat, predation, disease transmission and genetic introgression. A review of the fisheries literature was conducted to provide a conceptual evaluation of the potential effects of these interactions.

G-AQUA1.5.3.2 Report Conclusions

Lake Oroville is managed as a two-story fishery composed of both warmwater and coldwater fish species. The warmwater fishery is self-sustaining and is primarily made up of four species of black bass, two species of catfish, two species of sunfish and two species of crappie. The coldwater fishery is maintained through stocking and currently consists of inland coho salmon although Chinook salmon, brown trout and lake trout have been stocked in the past. Tributaries upstream of Lake Oroville are managed as a coldwater salmonid fishery consisting primarily of rainbow trout and brown trout. Surveys conducted by DWR during 2002 and 2003 did not detect coho salmon in upstream tributaries, however redeye bass, spotted bass and smallmouth bass were observed in the lower reaches of the Middle Fork Feather River, while spotted bass were also observed in the South Fork Feather River. Surveys conducted by PG&E prior to 2000 also observed smallmouth bass in the North Fork Feather River. Additionally, one largemouth bass was observed in the lower reaches of the North Fork by a PG&E survey in 1992. Black bass are considered warmwater species and typically utilize different habitat types than salmonids for all life stages, it is doubtful that competition for habitat between the two assemblages would have any adverse effects. Additionally, food resources in tributaries upstream of Lake Oroville do not appear to be limiting, therefore competition for food is not a likely factor. Black bass species are piscivores and some level of predation on juvenile salmonids may exist by bass moving into upstream tributaries. The only salmonid species currently stocked in Lake Oroville is coho salmon. Because these fish have not been observed in upstream tributaries, interactions with other salmonid species are likely minimal. Coho salmon were selected for stocking in Lake Oroville specifically to minimize the potential for disease transmission and current Feather River Fish Hatchery stocking protocols are designed to minimize any potential of disease transmission between stocked salmonids and resident species. Coho salmon are not known to hybridize with rainbow trout or brown trout, therefore genetic introgression between stocked fish and resident species is not a factor under current management practices. Based on limited survey data and a review of the fisheries literature, it does not appear likely that interactions between fish assemblages in Lake Oroville and upstream tributaries are likely to negatively affect either assemblage under current fisheries management or project operations.

G-AQUA1.6 TRANSFER OF ENERGY AND NUTRIENTS BY ANADROMOUS FISH MIGRATIONS (SP-F8)

G-AQUA1.6.1 Background Summary

This report investigated the potential effect of the elimination of anadromous salmonid spawning runs on ecosystem productivity of the historical Feather River tributaries upstream of Lake Oroville. Salmon and steelhead transport nutrients and organic matter accumulated in the ocean upstream to their natal streams during their spawning migrations. These streams typically rely on these marine-derived nutrients for much of their productive capacity. A loss of the salmonids generally results in nutrient-poor conditions. Construction of the Oroville Facilities resulted in the elimination of anadromous salmonids upstream of the Fish Barrier Dam. The loss of Chinook salmon and steelhead from the inundation basin of Lake Oroville is compensated by the operation of the Feather River Fish Hatchery and other mitigation measures; however, the potential loss of marine-derived nutrients to the tributaries upstream of the reservoir has not been compensated for.

The principal objectives of this report were to determine the amount of nutrients and organic matter lost from the upstream tributaries as a result of the elimination of Chinook salmon and steelhead; to evaluate the effect of the losses on productivity of the tributaries; and to assess the need for nutrient mitigation or enhancement measures and potential approaches for implementing such measures. These objectives were only partially satisfied because of gaps in the availability of anticipated data. A range of estimates for the amount of nutrients and organic matter lost was computed, but the range was very broad because it was derived from estimates of potential escapement of anadromous salmonids in the upstream tributaries, and these estimates ranged broadly.

The significance of the losses of nutrients and organic matter and the need for mitigation could not be determined because data on the current nutrient status of the upstream tributaries are inadequate. However, the report is useful in elucidating the information and analyses required to determine the significance of the nutrient losses.

G-AQUA1.6.2 Report Conclusions

This study used estimates of spawning habitat availability in the historical Feather River tributaries upstream of Lake Oroville to estimate the potential losses of anadromous salmonid biomass and associated nutrients and organic matter as a result of construction of the Oroville Facilities. The estimated potential losses of nutrients and organic matter are substantial, but it was difficult to evaluate the significance of the losses because of limitations in the available information. Specifically, the estimates of potential spawning densities were imprecise and detection levels for measured nutrient concentrations in the upstream tributaries were insufficiently low.

In spite of these limitations, the report provided useful information for guiding future efforts to assess the significance of the loss of nutrients and organic matter, and for developing conservative target levels for potential future PM&E measures addressing nutrient conditions in the upstream tributaries.

G-AQUA1.7 EVALUATION OF PROJECT EFFECTS ON NATURAL SALMONIDID POPULATIONS (SP-F9)

The Feather River Fish Hatchery is an integral component of the Oroville Facilities, and its operation has the potential to adversely affect naturally spawning salmonid runs in the Feather River and other Central Valley streams. Hatchery activities considered in this study plan report include spawner selection, egg take and fertilization, incubation, rearing practices (including disease control) and release strategies, including release sites. The study plan report focuses on several potential effects of hatchery operations on naturally spawning salmonids, including effects on harvest, genetic effects, and domestication.

G-AQUA1.7.1 Hatchery Effects Phase 1 (Interim Report)

G-AQUA1.7.1.1 Background Summary

DWR developed the study plan for evaluating the effects of the Feather River Fish Hatchery on naturally spawning salmonids; during study plan development, an examination of the available literature regarding hatchery effects was requested. The original focus of this examination was to determine whether the literature could be used to suggest additional study elements/information needs that should be included in the study plan—elements that could be completed within the available time and that would add to the understanding of hatchery effects. The study plan evolved, creating the need to include a literature review as one of the study elements. Another purpose of the literature review was to acquire and review the literature that would be helpful in preparing the final project reports.

The interim report for SP-F9 will be followed at a later time by an annotated bibliography of the technical papers collected. It is important to note that the final SP-F9 report will include specific literature references in the individual sections. For example, the extensive work of Quinn and his colleagues (1997) will be used to put into perspective observed straying by fish from the Feather River Fish Hatchery (and other Central Valley hatcheries).

G-AQUA1.7.1.2 Report Conclusions

These concerns will be addressed in the final report to FERC on effects of the Feather River Fish Hatchery:

- Hatcheries and fisheries management;
- Hatchery goals;
- Science and hatcheries;
- Hatchery benefits;
- Fitness of hatchery fish;
- Empirical versus theoretical data;
- Elimination of hatchery effects;
- Straying;
- Disease transmission;
- Effects of the Feather River Fish Hatchery on naturally spawning salmonids; and
- Mixed stock fisheries.

G-AQUA1.7.2 Hatchery Effects Phase 2 (Draft Report)

G-AQUA1.7.2.1 Background Summary

This report was prepared to deal specifically with the effects of the Feather River Fish Hatchery on naturally spawning Chinook salmon and steelhead in the Feather River and other streams in California's Central Valley.

DWR constructed the Feather River Fish Hatchery in the mid 1960s to compensate for the loss of Chinook salmon and steelhead spawning habitat above Oroville Dam on the Feather River. The hatchery operates as part of California's water management system, mitigating the effects of one of the major storage reservoirs in the system. Water management, flood management, and hydroelectric power developments have resulted in major dams on most of the streams that flow from the Sierra Nevada and the Cascade mountains into the Sacramento and San Joaquin Rivers. The dams have blocked access to historic spawning grounds, affected instream flows, and reduced the quality of gravel on spawning grounds below the dams. The Delta, an essential migratory pathway and rearing habitat, has been converted from tidal marshes and floodplains to a series of leveed islands and channels lined with riprap. The changes have reduced the amount of high-quality salmonid habitat and, for many, have made hatcheries an attractive management option. This report describes the physical, institutional, and biological context in which the Feather River Fish Hatchery operates and examines some of its potential effects on Central Valley Chinook salmon and steelhead.

G-AQUA1.7.2.2 Report Conclusions

Hatchery effects and contributions that were evaluated included elements such as straying, genetics, and disease. In all, 16 separate tasks were summarized in the original study plan. For this report, however, some tasks could not be completed because of lack of data, while in other cases elements from one task were incorporated into other tasks.

Straying

To analyze the role that hatcheries play in influencing straying rates, DFG used mark-and-recapture data (coded wire recoveries) in the ocean fisheries to reconstruct the 1998 fall run cohort from the Feather River Fish Hatchery. This analysis was used to determine the rate at which fish released in the estuary return to the Feather River and to other streams (the stray rate). DFG estimated that of the approximately 44,100 fish that returned to the Central Valley, 85 percent returned to the Feather River (including the Feather River Fish Hatchery), 7 percent were caught in the lower Sacramento River sport fishery, and 8 percent strayed to streams outside the Feather River basin. If salmonids returned to the Feather River in the same proportion as observed in other river systems, the straying rate would be estimated to be around 10 percent.

The findings from the cohort analysis provided results in agreement with those from tag recoveries in Central Valley hatcheries and streams. Although tags from fish from the Feather River Fish Hatchery were collected in most Central Valley streams sampled, about 96 percent of the 12,438 tags recovered during the 1997–2002 period were collected in the Feather River or at the hatchery. A lower percentage of in-basin releases than bay releases survived to reenter the estuary as adults (0.3 percent vs. 0.9 percent); however, these fish returned to the Feather River with greater fidelity (around 95 percent as compared to around 90 percent for bay releases).

Although the straying rate from bay releases is less than might be expected based on earlier studies, it is still higher than natural straying rates and higher than the 5 percent recommended as a maximum by NOAA Fisheries. One also has to be careful interpreting the data. First, the cohort analysis was only for 1 broodyear. Second, and perhaps more importantly, tag recovery efforts on all Central Valley streams (including the Feather River) do not provide quantitative data on the number of tagged fish in the spawning populations. Third, there is a significant inland sport fishery, and in recent years sampling of this fishery, and collecting tags, has been spotty because of budget cuts.

Because of the lack of tags on most hatchery populations, and the relatively poor success at quantitatively estimating the numbers of tags on the spawners, it was not possible to obtain reliable estimates of the percentages of salmon from other Central Valley hatcheries that stray into the Feather River drainage. Most of the non-Feather River Fish Hatchery strays observed came either from experimental releases (releases of Merced Hatchery fall-run Chinook salmon or releases of Coleman Hatchery late-fall–run Chinook salmon, both in Delta studies) or from bay releases of fall-run Chinook salmon from the Mokelumne Hatchery that had originally came from the Feather River Fish Hatchery.

Genetics

There are several concerns about how hatcheries may affect naturally spawning salmonids, including hybridization between runs on the same stream, spawning with salmonids from other streams, and hanging in the genetic structure as a result of cultural practices. The approach to this study element involved contracting with geneticists with the University of California (UC) Davis Bodega Marine Laboratory and Oregon State University to examine the genetic structure of the Central Valley and Feather River Chinook salmon population. The California Bay-Delta Authority (formerly known as the CALFED Bay-Delta Program) funded similar analyses for steelhead. In both instances, DFG collected, archived, and distributed the tissue samples. A caveat on using these genetic data to examine hatchery effects is that the sample collections began in the mid-1990s, so there are no historical data to establish the baseline situation that was present before hatcheries and dams changed the physical and biological landscape.

The results of the genetic analyses of Central Valley Chinook salmon and steelhead showed the following:

- Winter-run Chinook salmon are genetically distinct from the other three Central Valley runs.
- There are two distinct spring-run Chinook salmon genotypes—one from Mill and Deer Creeks and the second from Butte Creek. The genotypes exhibit some phenotype differences as well, with the Mill and Deer Creek populations being more along the lines of “stream” type fish and the Butte Creek population exhibiting more of a mix between stream type (adult immigration and timing) and ocean type (juvenile emigration).
- The fall-run and late-fall run are genetically similar, although with a sufficient number of genetic markers, the two runs can be separated.

Using the present set of microsatellite markers, all Central Valley fall-run Chinook salmon are genetically identical. The observed results may have come from fish management and hatchery practices that caused increased straying of hatchery fish (offsite releases) and extensive transfer of genetic material from stream to stream and hatchery to hatchery.

There is still significant local genetic structure to Central Valley steelhead populations, although fish from the San Joaquin and Sacramento River basins cannot be distinguished genetically. Hatchery effects seem localized. For example, Feather River and Feather River Fish Hatchery steelhead are closely related, as are American River and Nimbus Hatchery fish.

One of the key questions about Feather River Chinook salmon involves the genetic and phenotypic existence of a spring run, and the potential effects of the Feather River Fish Hatchery on this run. The Feather River’s nominal spring run is part of the spring-run Evolutionarily Significant Unit (ESU) and is thus listed as threatened. The hatchery population, on the other hand, is not part of the ESU. The nominal spring and fall runs on the Feather River are genetically similar and are most closely related to Central Valley fall-run Chinook salmon. There is, however, a significant phenotypic spring run that arrives in the Feather River in May and June, numbering at least 3,400 in 2004. In 2004, the run entered the Feather River Fish Hatchery when the ladder to the hatchery was opened. Such observations cast doubt on the presence of a Feather River spring run, as opposed to a hatchery spring run.

All phenotypic and genetic evidence at this time points to a Feather River Chinook salmon run, some of which may arrive early. There do not appear to be stream and hatchery components to the run. The genetic evidence does not lead to a conclusion that there has been hybridization between an earlier Mill/Deer/Butte Creek genotype with a Feather River fall-run genotype. On the other hand, the Feather River steelhead population seems to be at least somewhat segregated into hatchery fish and naturally spawning fish. The aforementioned conclusion is reached by examining results that show that only hatchery-reared (adipose clipped) steelhead ever reach the hatchery, while an unclipped component has been observed to spawn naturally in the river.

Fraction of Chinook Salmon in Feather River Spawning Runs that are of Direct Hatchery Origin

Because of the non-quantitative nature of the tag recovery in the Feather River, it is not possible to obtain reliable estimates of the hatchery fraction of the Chinook salmon spawning run. Estimates indicate that somewhere between 30 and 50 percent of the Chinook salmon runs to the Feather River consists of fish that were released from the Feather River Fish Hatchery as juveniles. Smaller, but unquantifiable, fractions of fish from other Central Valley hatcheries are also part of the annual spawning runs.

Contribution of Feather River Fish Hatchery Fall-run to the Ocean and Inland Recreational Fisheries

The 1998 fall-run Chinook salmon cohort contributed an estimated 90,000 fish to the ocean's recreational and commercial fisheries from 2000 through 2003. Most of the contribution occurred when the fish were 3 years old. 1998 broodyear fall-run Chinook salmon from the Feather River Fish Hatchery that were released in San Pablo Bay at that age represented 13.3 percent and 9.3 percent of the coast-wide recreational and commercial landings, respectively. In-basin and experimental releases contributed much smaller fractions to the fisheries. Recreational anglers in the lower Sacramento River sport fishery caught an estimated 3,000 fish from the 1998 cohort of fall-run Chinook salmon from the Feather River Fish Hatchery. There are no estimates of how many of these fish were caught in the Feather River, but the catch was probably as least as great as in the lower Sacramento River. The ocean harvest occurs mainly off the coast of California and in Oregon with 76 percent and 21 percent, respectively, of the tags recovered in these two areas.

Disease Transmission from Feather River Fish Hatchery Naturally Spawning Fish

As part of this study, DWR contracted with UC Davis and U.S. Fish and Wildlife Service (USFWS) fish pathologists to examine the potential effects of one fish disease, the IHN virus, on Feather River and other Central Valley salmonids. The study was included in the disease transmission element because, after several years of not seeing IHN problems at the Feather River Fish Hatchery, severe epizootics broke out in 1999 and 2000.

The study consisted of several elements, including genetic typing of IHN and assessing the transmissibility of the virus to non-infected fish, the virulence of the virus, and the presence of IHN in juvenile and adult Chinook salmon and steelhead in the Feather River and Yuba River basins. The genetic typing showed that in the Central Valley, IHN has evolved from the original strain to several different strains, with the Feather River acting as the site of much of this activity. The strains do not seem to be developing into more virulent forms of the virus. The Central Valley strains are (and have been) part of a separate clade (the L clade) that is genetically distinct from the U and M clades found in the Pacific Northwest and Alaska.

The field surveys indicated that IHN was not present in juvenile salmonids or other fish in either the Yuba or Feather River watersheds. Adults returning to both watersheds were infected with IHN, with 28 percent (average of samples from 3 locations) and 18 percent, respectively, for the Yuba and Feather Rivers. There were no clinical signs of disease in these fish.

The hypothesis advanced by DFG pathologists for the cause of the recent IHN epizootics at the Feather River Fish Hatchery is that planting Chinook salmon in Lake Oroville (in the hatchery water supply) resulted in the virus entering the hatchery. Hatchery conditions can then lead to stress and the infections can rapidly escalate to clinical disease, as evidenced by high mortality. Because plantings of Chinook salmon in the reservoir were brought to an end, no additional epizootics have been observed, although only time will tell whether this measure will prevent future IHN outbreaks at the Feather River Fish Hatchery.

G-AQUA1.8 EVALUATION OF PROJECT EFFECTS ON SALMONIDS AND THEIR HABITAT IN THE FEATHER RIVER BELOW THE FISH BARRIER DAM (SP-F10)

Ongoing operation of the Oroville Facilities influences flows and water temperatures in the Feather River downstream of the Fish Barrier Dam. These influences vary both seasonally and geographically, and can act either independently or in combination to affect flow, water temperature, floodplain habitat, instream habitat, shaded riverine aquatic (SRA) habitat, coarse sediment supply, and other instream conditions in the Feather River. The overall objective of this study was to evaluate the potential effects of ongoing Oroville Facilities operations on Chinook salmon, steelhead, rainbow trout, and brown trout and their habitat in the Feather River below the Fish Barrier Dam. The study results also were used by other studies to help assess the project's ongoing effects on California and federal special-status species.

G-AQUA1.8.1 Project Effects on Upstream Migration of Adult Salmonids in the Feather River Below the Fish Barrier Dam (Task 1)

G-AQUA1.8.1.1 Influence of Oroville Facilities on Feather River Attraction Flows and Temperatures and Their Effects on Salmonids in the Feather River Below the Fish Barrier Dam (Task 1A and Task 1B)

SP-F10, Task 1A, *Influence of Oroville Facilities Operations on Feather River Attraction Flows and Their Effects on Salmonids in the Feather River Below the Fish Barrier Dam*, and Task 1B, *Influence of Oroville Facilities Operations on Feather River Attraction Water Temperatures and Their Effects on Salmonids in the Feather River Below the Fish Barrier Dam,* were dropped from the SP-F10 study. Insufficient data regarding straying prevented the construction of a useful analysis to fulfill Task 1 study plan objectives.

G-AQUA1.8.1.2 Flow-related Physical Impediments in the Feather River Below the Fish Barrier Dam (Task 1C)

Background Summary

Water temperatures and flow are both important factors influencing the ability of adult salmonids to migrate upstream. The purpose of Task 1C of SP-F10 was to evaluate potential relationships between flow and flow-related physical passage impediments to adult salmonid immigration in the Feather River. Various statistical analyses were conducted to identify any consistent temporal pattern among flow and escapement that might be suggestive of potential flow-related physical impediments to upstream passage. A linear regression approach was used to evaluate potential relationships between the estimate of total Chinook salmon escapement and various flow rate variables based on defined regulatory or flow level thresholds. In addition, an ANOVA approach compared two series of estimates of adult Chinook salmon escapement, which were separated and grouped based on a defined regulatory or flow level threshold.

Report Conclusions

The results of the above analytical approaches suggest that there is no consistent temporal pattern among flow and escapement that might be suggestive of potential flow-related physical impediments to upstream passage of adult salmonids. Using regression analyses, comparisons were made between total Chinook salmon escapement and several different measures of flow. These comparisons found no consistent relationship between low flow and escapement estimates that might be suggestive of potential flow-related physical impediments to upstream passage. At two of the three locations where flow data were used (near Gridley and below/at Shanghai Bend), none of the comparisons of flow to escapement illustrated a statistically significant ($P < 0.05$) relationship. Of the six regressions conducted using flow data from the Yuba City location, three regressions suggested a statistically significant relationship ($P < 0.05$), with all three analyses suggesting that the percentage of the variation in escapement that is explained by flow is relatively low (24–32 percent).

In addition to regression analyses, various series of total Chinook salmon escapements were compared using t-Tests to determine whether the mean escapement of one series differed from the mean escapement of another series. The series were constructed using several metrics describing flow and water-year type. Results of the t-Test comparisons suggested that the mean escapement for years with lower flows was not statistically different from the mean escapement for years with higher flows, and the mean escapement of dryer years was not statistically different from the mean escapement of wetter years, regardless of the method used for defining “lower flow” and “higher flow” years or “dryer” and “wetter” years.

In conclusion, various statistical examinations indicate that there is no statistically significant difference between adult Chinook salmon spawning escapement in dryer, lower flow years and that occurring in wetter, higher flow years. Therefore, a detailed evaluation of the relationships between flow and the passage of adult salmonids at Shanghai Bench was not recommended.

G-AQUA1.8.1.3 Evaluation of Oroville Facilities Operations on Water Temperature–related Effects on Pre-spawning Adult Chinook Salmon and Characterization of Holding Habitat (Task 1D)

The purpose of SP-F10, Task 1D, overlaps with the purpose of SP-F10, Task 1E, such that the results were included in the Task 1E and Task 1D Final Report, which are summarized below.

G-AQUA1.8.1.4 Evaluation of Oroville Facilities Operations on Water Temperature–related Effects on Pre-spawning Adult Chinook Salmon and Characterization of Holding Habitat (Task 1E and Task 1D) (Final Report)

Background Summary

Water temperature plays an important role in the timing of upstream migration of adult salmonids. Adult salmonids are transiently exposed to the warm water temperatures of the Delta and lower reaches of the Sacramento River before entering and ascending to cooler reaches of the Feather River. Under current conditions, exposure to cooler water in the lower Feather River is dependent largely on the operations of the Oroville Facilities. If water temperatures encountered by upmigrating salmonids in the Feather River were cooler than those in the upper Sacramento River, the Feather River salmonids may be encouraged to continue their migration to their natal spawning grounds in the Feather River, thus decreasing the likelihood of straying into the upper Sacramento River.

Flow and water temperature manipulations resulting from operation of the Oroville Facilities may affect production of spring-run Chinook salmon and the quality, quantity, and distribution of holding habitat for spring-run Chinook salmon below Oroville Dam. In addition, alteration of sediment recruitment in the Feather River channel below Oroville Dam may result in depletion of gravel and sand, and armoring of cobble and boulder substrates (DWR 2001). The current and future distribution of these substrate types also has the potential to affect the quality, quantity, and distribution of holding habitat for spring-run Chinook salmon.

The purpose of Task 1E of SP-F10 was to identify and characterize holding habitat for adult spring-run Chinook salmon (*Oncorhynchus tshawytscha*) in the Feather River below Thermalito Diversion Dam. The purpose of SP-F10, Task 1D, was to evaluate the effects of Oroville Facilities operations on water temperature–related effects on pre-spawning salmonid adult production. Because SP-F10, Task 1E, evaluated habitat for pre-spawning adult spring-run Chinook salmon, focusing on water temperatures in potentially suitable holding pools, portions of SP-F10, Task 1D, also were included in this report. However, SP-F10, Task 1D, conceptually overlaps with other study plans; information presented in the Final Reports associated with SP-F10, Task 2B, and

SP-F10, Task 2C, also help elucidate the effects of water temperatures on pre-spawning adult salmonid production.

To complete Tasks 1D and 1E of SP-F10, a literature review was conducted to determine the immigration and holding period for spring-run Chinook salmon in the lower Feather River, and to determine water temperatures at which there could be individual physiological or population effects. Two sets of thermal tolerance ranges were obtained from the literature review; these tolerance ranges were compared to observed water temperatures separately for the Interim and Final reports for SP-F10, Task 1E. The results of the literature review were provided as part of the reports associated with SP-F10, Task 1E, and SP-F10, Task 1D.

Report Conclusions

Analysis conducted for SP-F10, Task 1E (Final Report), was similar to analysis conducted for the Interim Report. However, the subjective nature of the three categories chosen for analysis in the Interim Report and additional thermograph data justified reevaluation of the analytical procedure. The Final Report included analysis of the percentage of time that water temperatures were above specific index water temperatures at each data collection location in the Feather River during the defined immigration and holding period for spring-run Chinook salmon in 2003. The reported biological effects that could occur when water temperatures are at or above each index value also were presented.

During the 2003 sampling period, an estimated total of 66 percent of mean water temperature profile data in 15 pools in the lower Feather River exceeded the index value of 15.6°C (60°F). Forty-eight percent of mean water temperature profile data in 11 pools exceeded the index value of 17.8°C (64°F). An estimated total of 9 percent of mean water temperature profile data in 10 pools exceeded the index value of 20°C (68°F).

Based on available literature, and analysis of water temperature data collected from thermographs in the lower Feather River, increased incidence of disease and mortality, in-vivo egg mortality, and developmental abnormalities could occur in some areas of the river during some portions of the immigration and holding period. Overall, however, results of thermograph data analyses indicate that water temperatures generally are below those reported by the literature to result in profound individual or population effects. Additionally, daily and weekly mean water temperatures generally did not exceed the water temperatures reported to inhibit migration (21°C to 22°C) (Berman and Quinn 1991). However, the results of analysis of thermograph water temperature data should be used carefully because of inherent data limitations.

Therefore, continued operation of the Oroville Facilities in a manner consistent with current operations would be expected to result in water temperatures conducive to adult immigration and holding of spring-run Chinook salmon in the lower Feather River.

G-AQUA1.8.2 Project Effects on Spawning, Incubation, and Initial Rearing of Salmonids in the Feather River (Task 2)

G-AQUA1.8.2.1 Spawning and Incubation Substrate Suitability for Salmonids in the Lower Feather River (Task 2A)

Background Summary

The purpose of SP-F10, Task 2A, was to evaluate the suitability of spawning and incubation substrate for salmonids in the lower Feather River. Intragravel and bulk gravel data were collected to help accomplish the objectives of this task. Intragravel variables included permeability, DO concentration, water temperature, and upwelling and downwelling potential.

Intragravel data were recorded at 15 riffles in the lower Feather River from August 6, 2003, through November 13, 2003. Bulk gravel samples were collected at 20 riffles in the lower Feather River from October 2, 2002, through September 18, 2003. The results of the intragravel sampling generally did not apply to steelhead because data were collected outside of dates coinciding with presence dates for the steelhead spawning and embryo incubation life stage.

Report Conclusions

Results suggested that intragravel permeability and DO concentrations were within suitable ranges, based on available literature. Intragravel water temperatures were below 56°F (13.3°C) from September 10, 2003, through November 13, 2003. Agreement exists within available literature and regulatory documents that water temperatures below 56°F (13.3°C) are suitable for incubating salmonid embryos. Upwelling or downwelling currents were detected in 86 percent of samples collected within Chinook salmon redds; this suggests that regardless of the direction of the vertical hydraulic gradient, intragravel flow is the critical variable associated with selection of spawning sites by Chinook salmon in the lower Feather River. Based on available literature, intragravel permeability, DO concentrations, water temperature, and upwelling and downwelling currents likely did not limit survival of incubating salmonid embryos in the lower Feather River during the time period that data were collected.

Results from gravel size distribution curves, armor index values, and the geometric sorting index suggested that surface strata in the lower Feather River are coarse, and that armoring is particularly evident in the Low Flow Channel. The size distributions of subsurface gravel samples from the Low Flow Channel and High Flow Channel were similar. The median gravel diameter (D_{50}) of surface samples suggested that gravels in the Low Flow Channel generally are too large for successful redd construction by Chinook salmon. The suitability of gravel sizes for spawning Chinook salmon generally increased with distance downstream of Oroville Dam. Analyses of fine sediment (gravels less than 6 mm in diameter) suggested that fine sediments within gravels in the lower Feather River were suitable for incubating Chinook salmon and steelhead embryos, and likely did not limit the percentage of embryos surviving through emergence.

G-AQUA1.8.2.2 Steelhead Spawning Methods (Task 2B) (Interim Report)

Background Summary

Flow, water temperature, and gravel quality are important factors influencing the spawning, incubation, and initial rearing life stages of salmonids. The purpose of this portion of SP-F10, Task 2B, was to conduct a literature review to summarize and evaluate potential methodologies for observing and measuring steelhead spawning.

The objective of this literature review and evaluation was to identify opportunities for improvement in a method to quantify steelhead spawning in the Feather River. To fulfill the requirements of SP-F10, Task 2B, a review was conducted of available literature describing devices and methods that could be used to enumerate migrating or spawning salmonids. A brief description of the survey type, advantages and disadvantages compared to other survey methods, examples of each survey method's previous uses, and a brief statement of applicability to the Feather River were presented. Additionally, because DWR had already begun surveying for steelhead in the Feather River, a brief description of the surveys completed to date was presented.

After all available literature covering all possible spawning survey methods was reviewed, boat, snorkel, bankside count, and stationary video surveys were selected for further analysis. Aerial, hydroacoustic, mark-recapture, and electrofishing surveys as well as use of stationary fishing gear (such as various types of nets and weirs) were immediately discarded from further analysis. (These methods were discarded because it was difficult to identify redds and species, distinguish individual redds, and differentiate a holding steelhead from a spawning steelhead, and because there was the potential for interference with spawning activities.)

An extensive literature review was conducted of the four survey methods chosen for further analysis. This literature review focused on the ability of the survey methods to provide information describing the location and relative abundance of steelhead spawners, the applicability of the method to the Feather River, and the ability to maintain continuity and consistency with previously collected data sets.

Report Conclusions

The results of the literature review of potential survey methods for observing spawning steelhead reveal that a combination of methods is best suited for use on the Feather River. Visual boat surveys were recommended for the current field season as a method to obtain information regarding the location, timing, and relative abundance of steelhead spawners in the Feather River. Boat surveys were recommended because they provide the opportunity to survey the entire reach of interest in the lower Feather River quickly, while collecting data that may be useful in determining specific spawning areas that may be surveyed by other survey methods. Additionally, snorkel surveys were recommended for the current field season for similar reasons.

The combination of snorkel surveys and boat surveys facilitates obtaining an inventory of steelhead spawning locations in the Feather River. Once survey methods such as boat surveys and snorkel surveys have been implemented and steelhead spawning areas are relatively well-defined, bankside surveys and stationary time-lapse video surveys may be useful in obtaining additional information at specific redd locations. Additional details that could be provided if needed include the number of steelhead spawners, spawning behavior, and the temporal distribution of spawners.

All of the survey methods reviewed are subject to the difficulties associated with the elusive nature of steelhead and the high turbidity and high-flow conditions that may occur during the steelhead spawning season. As a result, at times of high turbidity and high-flow conditions during the steelhead spawning season, the survey methods reviewed may not be safe to implement or may produce results of relatively limited utility. These conclusions and recommendations confirm the results of the preliminary research into steelhead spawning survey methodology conducted during study plan development and in the definition of the steelhead spawning survey associated with SP-F10, Task 2B.

G-AQUA1.8.2.3 Lower Feather River Steelhead Redd Survey (Task 2B)

Background Summary

Current knowledge of steelhead spawning distribution suggests that steelhead spawning activity appears to be concentrated in the Low Flow Channel, between the Fish Barrier Dam and the Thermalito Afterbay Outlet. In this river segment, flows remain relatively constant (approximately 600 cfs year-round); therefore, negative flow-related effects on steelhead spawning should be minimized. The current lack of detailed information on steelhead spawning locations and abundance curtails any attempt to test for the effects of flow or other environmental factors. Hence, the current priorities were:

- To obtain detailed information on the distribution of spawning steelhead;
- To obtain basic data on the physical characteristics of steelhead redds; and
- To provide a basis for the development of a long-term plan to monitor the abundance and distribution of steelhead spawning in the Feather River.

Most steelhead spawning activity appears to have been concentrated between the Fish Barrier Dam and the Thermalito Afterbay Outlet, because 91 percent, 77 percent, and 84 percent of all the young-of-the-year steelhead observations in 1999, 2000, and 2001, respectively, occurred within 1 mile downstream of the Fish Barrier Dam. Because newly emerged steelhead fry prefer calm shallow water and are incapable of swimming large distances upstream, this information would strongly indicate that spawning is occurring in nearby areas. As part SP-F10, Task 2B, steelhead redd surveys were conducted to identify the location, timing, and magnitude (if possible) of steelhead spawning in the Feather River between the Fish Barrier Dam (river mile [RM] 67.1) and Honcut Creek (RM 44).

Report Conclusions

A total of 13 weekly redd surveys were performed between January 6 and April 3, 2003. During this sampling period 108 steelhead and 75 redds were observed. Redd construction likely began sometime in late December, peaked in late January, and was essentially complete by the end of March. In the months of January, February, and March, steelhead constructed, at minimum, 45, 26, and 4 redds, respectively.

The surveys revealed that nearly half (48 percent) of all redds were constructed in the uppermost mile of river (between RM 66 and RM 67), between the Table Mountain Bicycle Bridge and Lower Auditorium Riffle. This section of river maintained 36 redds per mile, more than 10 times more than any other section of river. Hatchery Ditch alone had 26 redds constructed within it, 5 times more redds than were constructed in any other location.

No attempt was made to estimate the number of adult steelhead spawning. Difficulties associated with identifying all steelhead redds indicated only the minimum number of spawning steelhead for the 2002–2003 spawning period. Assuming one female per redd and a male-to-female ratio of 1.2:1, the minimum number of males and females expected to have spawned was 88 and 75, respectively, for a total of 163 steelhead.

Physical characteristics of constructed redds in both the High Flow Channel and Low Flow Channel appeared suitable for successful spawning and egg incubation. High flows in the High Flow Channel during three weeks in February may have reduced spawning in the High Flow Channel or forced steelhead to spawn near the river margin. There was no evidence that any redds were dewatered after the flow reduction. It is unknown whether a flow of 8,000 cfs (experienced on February 20, 21, and 22) would scour recently constructed redds in the High Flow Channel.

Future work must focus on determining the actual number of steelhead entering and spawning in the river proper. Redd surveys can only provide a sense of where spawning occurs and the physical attributes of individual redds. Redd surveys cannot accurately determine the number of steelhead actually spawning, nor can they determine the origin of the steelhead building them (hatchery or naturally spawned). A weir or other counting mechanism would be necessary to accurately determine the number of steelhead spawning in the Feather River. This would also allow individual counts of wild and hatchery steelhead, providing better data for long-term management goals.

G-AQUA1.8.2.4 Evaluation of Potential Effects of Oroville Facilities Operations on Spawning Chinook Salmon (Task 2B)

Background Summary

Operations of the Oroville Facilities affect water temperature, instream flow, and water surface elevation in the lower Feather River, which in turn influence spawning Chinook salmon. The purpose of Task 2B was to evaluate the effects of the Oroville Facilities' operational procedures on spawning Chinook salmon in the lower Feather River. Potential effects of ongoing project operations in the lower Feather River include alterations to flow, water temperature, floodplain habitat, instream habitat, SRA habitat, coarse sediment supply, and other in-river conditions. Such changes to these habitat characteristics and conditions can influence the various life stages (e.g., adult immigration and holding, spawning and incubation, rearing and emigration) of salmonids.

Carcass survey data from 2000 through 2003 were analyzed to determine the temporal and spatial distributions, as well as other characteristics, of spawning Chinook salmon in the lower Feather River from the Fish Barrier Dam (RM 67.25) downstream to Gridley Bridge (RM 51). Feather River Fish Hatchery operations may contribute to genetic introgression between spring-run and fall-run Chinook salmon in the lower Feather River. For example, repeatedly selecting early arriving fall-run Chinook salmon for brood fish could alter run timing, inadvertently contributing to an overlap in spawning timing and genetic flow between races. There could be a disproportionate number of earlier arriving salmon in the broodstock because hatcheries typically collect eggs until a certain quota is met. When large numbers of fish arrive at hatcheries early, quotas typically are met quickly and late arrivals may not be used as broodstock.

An extensive literature review was conducted to determine appropriate water temperature index values to use as technical evaluation guidelines to assess the potential thermal effects on spawning Chinook salmon from operation of the Oroville Facilities. In general, water temperatures in the Low Flow Channel appear to be suitable during the spawning and embryo incubation life stage. High water temperatures in the High Flow Channel from August through late September may have adverse effects, particularly on the earlier spawning spring-run Chinook salmon.

Report Conclusions

A review of flow data from 2000 through 2003 in the lower Feather River indicated that during the spawning season, in both the Low Flow Channel and the High Flow Channel, instream flows were relatively constant with little variation. Because of a relatively constant flow regime during the study period, the effects of flow fluctuations on spawning were excluded from this study plan report.

Combined results from the carcass surveys from 2000 through 2003 showed that 5.6 percent of inspected Chinook salmon carcasses had a clipped adipose fin. The highest percentages of carcasses with clipped adipose fins were detected during September, in the Low Flow Channel. Decoding of coded wire tags indicated that 96.6 percent of the sample originated from Feather River stock, with a 3.4 percent rate of straying into the Feather River by salmon originating from non–Feather River stock. Overlap in carcass detection dates between spring-run and fall-run Chinook salmon (run origin was designated at release) occurred from September 3 through October 17. In 2002, 81.1 percent of all carcasses were detected in the Low Flow Channel. Water temperatures in the Low Flow Channel and High Flow Channel between mid-August and the beginning of September averaged 58.3^{o}F (14.6^{o}C) and 65.4^{o}F (18.6^{o}C), respectively. Spawning escapement estimates from 2000 through 2003 were highest in the Low Flow Channel, and estimates for both reaches were much higher than historical averages, particularly for 2001.

Physical Habitat Simulation (PHABSIM) modeling predicted that spawning habitat availability would be maximized in the Low Flow Channel and High Flow Channel at flows of 700–725 cfs and 1,500 cfs, respectively. The Weighted Useable Area index value at the constant flow of 600 cfs in the Low Flow Channel during the spawning period was 97 percent of the maximum value. From 2000 through 2003, flows during the spawning period in the High Flow Channel ranged from 1,200 to 7,000 cfs, corresponding with approximately 20 percent to 95 percent of the maximum Weighted Useable Area index value. The 1995 superimposition indices (SIs) suggest that available spawning habitat is insufficient in the Low Flow Channel, but adequate in the High Flow Channel. The 2003 SIs suggest that available spawning habitat in both the Low Flow and High Flow Channels is insufficient. Because spawning habitat is finite, high Chinook salmon return rates may have caused spawning substrates to have been heavily used in the 2003 spawning season.

Pre-spawn mortality estimates in the lower Feather River from 2000 through 2003 were high. During this period, annual pre-spawn mortality rates in the Low Flow Channel and High Flow Channel averaged 42.5 percent and 39.7 percent, respectively. Pre-spawn mortality estimates were particularly high during September; combining all years and both reaches, September estimates ranged from 70 to 100 percent. However, an average of approximately 5 percent (ranging from 2.8 percent to 8.1 percent) of the total annual spawning population from 2000 through 2003 spawned during September. A combination of stress from water temperature, river flows, disease, high spawning returns, and recreational angling likely account for the high pre-spawn mortality estimates in the lower Feather River from 2000 through 2003.

G-AQUA1.8.2.5 Timing, Magnitude and Frequency of Water Temperatures and Their Effects on Chinook Salmon Egg and Alevin Survival (Task 2C)

<u>Background Summary</u>

The original objective of Task 2C of SP-F10 was to evaluate the timing, magnitude, and frequency of water temperatures and their effects on the distribution of salmonid spawning and on egg and alevin survival in the lower Feather River from the Fish Barrier Dam downstream to its confluence with the Sacramento River. Because the purpose of Task 2B was re-scoped to evaluate the effects of Oroville Facilities operations on spawning Chinook salmon in the lower Feather River, the purpose of Task 2C was re-scoped to evaluate the effects of Oroville Facilities operations on Chinook salmon egg and alevin survival in the lower Feather River. This study was intended to provide information regarding Chinook salmon egg and alevin losses in the lower Feather River from water temperature–induced mortality under current operations.

To complete Task 2C of SP-F10, the U.S. Bureau of Reclamation's (USBR) Chinook salmon water temperature mortality model was modified by updating spawning and pre-spawning distributions, and mean daily water temperature series. Cumulative Chinook salmon carcass distributions were smoothed to provide continuous spawning and pre-spawning distributions of Chinook salmon in the lower Feather River. Because of gaps in water temperature data collected by the monitoring loggers, spatial models of water temperature and river reach were used to estimate continuous series of average mean daily water temperature for each of the nine reaches used in the USBR Chinook water temperature mortality model. Upon completion of the spawning and pre-spawning distributions, and continuous water temperature data series, modeling was conducted to determine percentages of Chinook salmon egg and alevin losses in the lower Feather River caused by water temperature–induced mortality.

Report Conclusions

The analysis for SP-F10, Task 2C, indicates that the percentage of Chinook salmon egg and alevin losses during the 2002–2003 spawning and incubation season in the lower Feather River was 16.3 percent, with 10.6 percent occurring in the Low Flow Channel and 5.7 percent occurring in the High Flow Channel. Project operations apparently did not result in a substantial percentage of losses of eggs and alevins in the lower Feather River, compared to recent Chinook salmon mortality estimates published in the Biological Assessment for the Central Valley Project and State Water Project Operations Criteria and Plan (OCAP) in the Sacramento River and its tributaries (USBR 2004). Consequently, in the lower Feather River, project operations during the 2002–2003 Chinook salmon spawning and incubation season appear to have resulted in a rate of water temperature–induced mortality of Chinook salmon eggs and alevins similar to those recently estimated in the Sacramento River and tributaries.

G-AQUA1.8.2.6 Flow Fluctuation Effects on Chinook Salmon Redd Dewatering in the Lower Feather River (Task 2D)

Background Summary

Flow fluctuations are characterized as either rapid changes in streamflow that occur over relatively short periods (minutes, hours, or days), or changes from base conditions sustained during a season. Flow fluctuations in the lower Feather River can occur as a result of flood management activities, scheduled maintenance operations, storm events, or emergency shutdowns, and may subject salmonid redds to dewatering. Redd dewatering occurs when water levels fall below the level of egg deposition. Redd dewatering may lead to egg and alevin mortality (Becker et al. 1982; Becker et al. 1983; Reiser and Whitney 1983). Production by the initial year-class of Chinook salmon may be affected if a relatively high proportion of redds are dewatered during the spawning season.

The purpose of SP-F10, Task 2D, was to evaluate the potential for, and the effect of, dewatering of Chinook salmon redds as a result of flow fluctuations in the lower Feather River. Operations of the Oroville Facilities affect water surface elevation and instream flow in the lower Feather River, which in turn influence the potential for redd dewatering. The results of this study provide information regarding the percentage of Chinook salmon redds potentially affected under current operations.

Report Conclusions

The incidence of apparent redd dewatering events during the 2002–2003 and 2003–2004 spawning and egg incubation periods were compared with the estimated total number of Chinook salmon redds constructed during the 2002 and 2003 spawning seasons, respectively, in the lower Feather River. In the lower Feather River, the highest percentage of Chinook salmon reportedly spawn in the Low Flow Channel (Sommer et al. 2001). In 2002, an estimated 23,563 Chinook salmon redds (63.6 percent of the total) were constructed in the Low Flow Channel and an estimated 13,489 redds (36.4 percent of the total) were constructed in the High Flow Channel. In 2003, an estimated 21,088 Chinook salmon redds (57.4 percent of the total) were constructed in the Low Flow Channel and an estimated 15,624 redds (42.6 percent of the total) were constructed in the High Flow Channel.

Project operations apparently do not result in dewatering of Chinook salmon redds in the Low Flow Channel (within which an estimated 63.6 percent of all lower Feather River Chinook salmon redds were constructed in 2002), because of the relatively constant flows—approximately 600 cfs—that occur during the spawning and incubation periods. The analysis for SP-F10, Task 2D (Section 5.2.1), indicates that on average, an estimated 3.1 percent of Chinook salmon redds were subjected to dewatering during the 2002–2003 spawning and incubation periods in the High Flow Channel (within which an estimated 36.4 percent of all lower Feather River Chinook salmon redds were constructed in 2002). Therefore, an estimated total of 1.1 percent of all Chinook salmon redds constructed in the lower Feather River would have been subjected to dewatering during the 2002–2003 spawning and incubation season.

During the 2003–2004 Chinook salmon spawning and egg incubation season, project operations apparently did not result in dewatering of Chinook salmon redds in the Low Flow Channel (within which an estimated 57.4 percent of all Chinook salmon redds were constructed within the lower Feather River in 2003). The analysis conducted for SP-F10, Task 2D (Section 5.2.5), indicates that on average, an estimated 0.4 percent of Chinook salmon redds were subjected to dewatering during the 2003–2004 spawning and incubation period in the High Flow Channel (within which an estimated 42.6 percent of all lower Feather River Chinook salmon redds were constructed in 2003). Therefore, an estimated total of 0.2 percent of all Chinook salmon redds constructed in the lower Feather River would have been subjected to dewatering during the 2003–2004 spawning and incubation season.

G-AQUA1.8.3 Project Effects on Juvenile Rearing of Salmonids in the Feather River (Task 3)

G-AQUA1.8.3.1 Distribution and Habitat Use of Steelhead and Other Fishes in the Lower Feather River (Task 3A)

Background Summary

In studies of the Feather River downstream of Oroville Dam, a multi-scale sampling program was implemented akin to those discussed by Fausch and Torgersen (2002). In this report, data were presented from 3 years of snorkeling and mark-recapture studies, focusing on juvenile steelhead, but including other species. The purposes were to: (1) provide information on the seasonal distribution, relative abundance, growth, and habitat use of common Feather River fishes, particularly salmonids; and (2) identify river conditions, habitats, or ecological interactions that may limit the abundance of salmon and steelhead.

From 1999 to 2003, DWR conducted an intensive steelhead study in the Feather River below Oroville Dam. Investigations sought to describe characteristics of the wild steelhead population and identify factors potentially limiting steelhead success in the lower Feather River. Habitat, water temperature, flow conditions, predation, and food availability were all considered potentially important factors. To address these topics, multi-scale snorkeling surveys and seining were applied.

Report Conclusions

The distribution and abundance of fishes in the lower Feather River appears to be strongly structured by environmental conditions operating at large spatial scales. Results from all three types of snorkel surveys suggest that river mile, and by implication, its correlates (water temperature, High Flow Channel or Low Flow Channel, proximity to the Fish Barrier Dam), explained much of the observed variation in fish distribution. The Thermalito Afterbay Outlet causes a rapid transition in physical conditions that is mirrored clearly in the types and numbers of fish encountered both upstream (in the Low Flow Channel) and downstream (in the High Flow Channel). Salmonids, particularly juvenile steelhead, were always more abundant in the Low Flow Channel, while cyprinids, centrarchids, and tule perch were always more abundant in the High Flow Channel. The existence of two distinct fish assemblages is consistent with the findings from seining and rotary screw trap sampling reported in Seesholtz et al. (2003).

Results show that most steelhead spawning and early rearing occurs at the upstream end of the Low Flow Channel, near the Feather River Fish Hatchery. In-river spawning by hatchery steelhead in the vicinity of the hatchery may explain this skewed distribution. Juvenile steelhead disperse over time to suitable habitats throughout the Low Flow Channel, especially cover-rich side channels. Steelhead rearing in the downstream portion of the Low Flow Channel appeared to grow faster, and were generally larger than fish farther upstream. The abundance of steelhead less than 100 mm declined throughout the summer in each survey year. This may reflect the tendency of young-of-the-year steelhead to rapidly grow larger than 100 mm while rearing in the downstream portion of the Low Flow Channel. However, larger juvenile steelhead (putative age 1+) or resident rainbow trout were relatively rare, suggesting that few steelhead remain in the Feather River through their first year. Because water temperatures and flow conditions in the Low Flow Channel appear suitable for steelhead, the apparently low production of juveniles suggests other limiting factors. For example, suitable mesohabitats, such as cover-rich side channels, shallow channel margins, and mid-channel bars, seem to provide the best rearing habitat, yet these habitats are currently relatively rare in the lower Feather River.

In these studies, all fish species showed an association with certain microhabitat characteristics. For example, centrarchids were found most often in backwaters near submerged aquatic vegetation. Steelhead smaller than 100 mm selected shallow, relatively slow-moving waters with overhead and in-channel cover. However, these microhabitat types are common in the lower Feather River. That is, vegetated backwaters and shallow shoreline glides are not unique to the river reaches where these species consistently occurred. Thus, the selection of small-scale habitat (i.e., microhabitat) appears to be strongly constrained by large-scale physical conditions such as river mile and water temperature.

Suitable microhabitat features (current velocities, depth, and cover) were not restricted to the upstream end of the Low Flow Channel. Side channels, with abundant instream and overhead cover, were available at Hatchery Ditch, other locations in the Low Flow Channel (Eye Riffle, Steep Riffle), and even some locations in the High Flow Channel. Although densities of steelhead smaller than 100 mm were highest in Hatchery Ditch, overall abundance was generally high throughout the upper river mile of the Low Flow Channel. In light of these facts, the availability of rearing habitat at the upstream end of the Low Flow Channel does not seem to convincingly explain the observed distribution pattern.

G-AQUA1.8.3.2 Steelhead Rearing Temperatures (Task 3B) (Interim Report)

<u>Background Summary</u>

The purpose of this portion of SP-F10, Task 3B, was to conduct a literature review to summarize the reported suitable rearing water temperatures for juvenile steelhead and the effects of increased water temperatures on their physiology and behavior. The study area in which the results of the literature review could be applied includes the reach of the Feather River extending from the Fish Barrier Dam to the confluence with the Yuba River. This is the geographic range within the Feather River that encompasses areas in which juvenile Feather River steelhead may rear (DWR 2002c). To evaluate potential relationships between project operations and ESA listed steelhead, it was desirable to collect data regarding steelhead rearing locations and the effects of Feather River water temperatures on rearing juvenile steelhead.

The literature review compiled literature from a variety of laboratory and in-river studies using steelhead strains from rivers located throughout a wide geographic range of North America. Initial review of the literature revealed a relative paucity of information derived from field studies regarding suitable water temperatures for rearing juvenile steelhead in the Central Valley. However, anecdotal information derived from observations on rearing steelhead in various rivers was included in the review.

For the purposes of this review, the terms “suitable,” “preferred,” and “optimal” are used. Suitable water temperature ranges include those that are reported for which feeding occurs without signs of abnormal behavior. Optimal water temperatures are generally reported to be those at which physiological processes occur at the highest rates (Hokanson et al. 1977; McCullough 1999). Preferred water temperature ranges are generally those that steelhead juveniles selected when given a choice within a temperature gradient or under natural conditions.

Report Conclusions

A wide range of preferred and optimal water temperatures have been reported for juvenile steelhead rearing, as well as for steelhead without reference to any specific life stage. Table G-AQUA1.8-1 shows the reported preferred, optimum, critical thermal maximum (CTM), and upper incipient lethal (UIL) water temperatures for steelhead reported by various authors. Included in the table are LT10 values reported by some authors. The CTM is the arithmetic mean of the water temperatures required to produce loss of equilibrium (LE) or death (DT) in a series of trials. The LT10 values are the water temperatures at which 10 percent of the population suffers mortality. UIL, sometimes referred to as LT50, is the water temperature at which 50 percent of the population suffers mortality (McCullough 1999).

Table G-AQUA1.8-1. Preferred, optimum, critical thermal maximum, and upper incipient lethal water temperatures for steelhead.

Species	Source(s)	Origin	Preferred	Optimum	CTM	LT10	UIL (LT50)
Steelhead (juvenile)	Myrick and Cech Jr. 2000	Feather River Fish Hatchery	62.6°F – 68°F	*	83.12°F–85.82°F	*	*
Steelhead (juvenile)	Cech Jr. and Myrick 1999	Nimbus Fish Hatchery	62.6°F – 68°F	*	81.5°F–85.82°F	*	*
Rainbow trout (juvenile)	Hokanson et al. 1977	Lake Superior	*	62.96°F–65.48°F constant treatment; 59.9°F–63.14°F fluctuating treatment	*	*	78.08°F (acclimated at 60.8°F)
Rainbow trout (juvenile)	Cherry et al. 1975	Virginia	59°F – 64°F	*	*	*	*

Table G-AQUA1.8-1. Preferred, optimum, critical thermal maximum, and upper incipient lethal water temperatures for steelhead.

Species	Source(s)	Origin	Preferred	Optimum	CTM	LT10	UIL (LT50)
Steelhead (no age given)	Bell 1973, 1986, 1991 in Bjornn and Reiser 1991; Reiser and Bjornn 1979; McEwan and Jackson 1996; Barnhart 1986	Unknown	45°F–58°F	50°F–55°F	75°F	*	*
Steelhead (fry)	DWR and USBR 2000 (cites McEwan and Jackson 1996)	Unknown	45°F–60°F	*	*	*	*
Steelhead	Sullivan et al. 2000	Unknown	*	*	*	80.6°F at 1 hour 84.4 at 0.1 hour	See Table 5.3-3
Rainbow trout (juvenile)	Threader and Houston 1983 in McCullough 1999	Ontario	*	*	*	*	76.8°F acclimated at 53.6°F 77.72°F acclimated at 60.8°F 78.62°F acclimated at 68°F
Steelhead (juvenile)	Grabowski 1973 in McCullough 1999	Dworshak National Fish Hatchery, Idaho	*	59°F	*	*	*
Rainbow trout (unknown)	Charlon et al. 1970 in McCullough 1999	France	*	*	*	*	79.52°F acclimated at 75.2°F
Rainbow trout (unknown)	Bidgood and Berst 1969 in McCullough 1999	Great Lakes	*	*	*	*	77°F–78.8°F acclimated at 59°F
Rainbow trout (unknown)	Cherry et al. 1977 in McCullough 1999	Great Lakes	*	*	*	*	77°F acclimated at 75.2°F
Rainbow trout (unknown)	Stauffer et al. 1984 in McCullough 1999	Great Lakes	*	*	*	*	78.8°F acclimated at 75.2°F

Table G-AQUA1.8-1. Preferred, optimum, critical thermal maximum, and upper incipient lethal water temperatures for steelhead.

Species	Source(s)	Origin	Preferred	Optimum	CTM	LT10	UIL (LT50)
Rainbow trout (unknown)	Alabaster 1964 in McCullough 1999	Ontario	*	*	*	*	80.06°F acclimated at 68°F
Rainbow trout (unknown)	Black 1953 in McCullough 1999	Summerland Hatchery British Columbia	*	*	*	*	75.2°F acclimated at 51.8°F
Rainbow trout (unknown)	Kaya 1978 in McCullough 1999	Ennis Hatchery, Montana Winthrop Hatchery, Washington	*	*	*	*	79.16°F acclimated at 76.1°F 79.16°F acclimated at 76.1°F
Rainbow trout (2-3 months)	Grande and Anderson 1991 in McCullough 1999	Unknown	*	*	79.34°F acclimated at 62.6°F	*	*
Rainbow trout (unknown)	Lee and Rinne 1980 in McCullough 1999	Williams Creek Hatchery, Arizona	*	*	84.83°F when acclimated at 68°F 83.3°F when acclimated at 50°F (Both studies CTM determined to LE)	*	*
Steelhead (unknown)	Wurtsbaugh and Davis 1977 in McCullough 1999	Oregon Coastal Stream	*	Less than 61.7°F	*	*	*
Steelhead (fry and juvenile)	Rich 1987 (cites Bovee 1978)	Unknown	*	55°F–60°F	*	*	*
Steelhead (juvenile)	Reiser and Bjornn 1979	Unknown	*	45.1°F–58.3°F	*	*	*

The effects of increased water temperatures on rearing salmonids have been reported to range from behavioral modifications and physical and physiological changes, to death (Bjornn and Reiser 1991; Brett 1952; Crawshaw 1977; Evans 1990; Hokanson et al. 1977; Hughes et al. 1978; McCullough 1999; Rich 1987; Sullivan et al. 2000; Winfree et al. 1998). The type and severity of the effects of elevated water temperatures on salmonids have been reported to be related to the magnitude and duration of elevated water temperature exposure (Sullivan et al. 2000). In addition to physical, physiological, and behavioral changes associated with elevated water temperatures, decreased resistance to disease outbreaks and increased predation rates also have been reported (McCullough 1999; Sullivan et al. 2000).

Average monthly water temperatures in the reach of the Feather River from the Fish Barrier Dam to the Thermalito Afterbay Outlet range from 47°F (8.3°C) in winter to 65°F (18.3°C) in the summer. Water temperatures downstream of the Thermalito Afterbay Outlet are generally warmer, with the maximum mean daily water temperature at the Thermalito Afterbay Outlet reaching approximately 70°F (21.1°C) in the summer (DWR 2001).

Naturally spawned Feather River steelhead have been observed to rear successfully at water temperatures near 65°F (18.3°C) (DWR and USBR 2000). In addition, young-of-the-year Feather River steelhead have also been observed rearing in habitats where average daily water temperatures were 63°F (17.2°C), and where daily maximal water temperature exceeded 66°F (18.9°C) (DWR and USBR 2000).

Because Myrick and Cech (2000) and Myrick (1998) performed the only available studies on thermal preferences of Feather River steelhead, their results were used to determine the suitability of Feather River water temperatures for rearing juvenile steelhead. They reported the thermal preference of juvenile Feather River steelhead to be between 62.6°F to 68°F (17°C to 20°C). In addition, apparently healthy juvenile steelhead have been observed rearing in other rivers in California with daily maximum water temperatures as high as 72.5°F (pers. comm., Hanson 2003). Because the average monthly water temperatures between the Fish Barrier Dam and Thermalito Afterbay Outlet do not exceed 65°F, it is unlikely that there would be adverse physical or physiological effects on rearing Feather River juvenile steelhead in the reach between the Fish Barrier Dam and the Thermalito Afterbay Outlet. In addition, behavioral thermoregulation could attenuate localized, increased water temperatures should they occur. Because snorkel surveys on the Feather River indicate that there is little to no steelhead rearing below the Thermalito Afterbay Outlet (DWR and USBR 2000), it is unlikely that high water temperatures that occur below the outlet would have significant adverse effects on steelhead rearing in the Feather River.

G-AQUA1.8.3.3 Growth Investigations of Wild Juvenile Steelhead in the Feather River Using Mark and Recapture Techniques (Task 3B) (Final Report)

Background Summary

The operation of the Oroville Facilities may affect water temperature, which may influence rearing juvenile steelhead trout (*Oncorhynchus mykiss*). Exposure of juvenile steelhead to high water temperatures may result in acute direct mortality or in sublethal chronic thermal stress that can be evidenced through indicators such as disease outbreaks and reduction in growth.

Laboratory studies on Feather River Fish Hatchery and naturally spawned steelhead suggest that rearing juveniles prefer temperatures between 62°F and 68°F (16.7°C and 20°C) (Myrick and Cech 2000). Naturally spawned Feather River steelhead have been observed to rear successfully at water temperatures near 65°F (18.3°C) (DWR 2002a; DWR and USBR 2000). Young-of-the-year Feather River steelhead have also been observed rearing in habitats where average daily water temperatures were greater than

63°F (17.2°C), and where daily maximal water temperature exceeded 66°F (18.9°C) (DWR and USBR 2000). To complement the existing laboratory study and the continued gathering of observational data by snorkeling (SP-F10, Task 3A), additional field studies were proposed. As part of SP-F10, Task 3B, mark-and-recapture and enclosure growth experiments were conducted to evaluate the effects of temperature on growth and rearing behavior of juvenile steelhead in the Low Flow Channel.

More specifically, the purpose of SP-F10, Task 3B, was to identify growth rates of steelhead rearing in different sections of the Low Flow Channel of the lower Feather River. The intent was to identify any differences in growth rates between steelhead rearing in the upper (colder) and in the lower (warmer) areas of the Low Flow Channel. By experimentally enclosing and rearing individual steelhead for up to 3 months, any obvious sublethal effects of rearing in a warmer environment would be reflected in the growth rates observed. Additionally, naturally spawned steelhead were marked and recaptured throughout the Low Flow Channel to understand growth rates experienced in the wild. This report summarizes data collected from the enclosure and mark-and-recapture studies conducted in 2003.

Report Conclusions

In summer 2003, DWR performed an enclosure and mark-and-recapture study in the Feather River Low Flow Channel to assess growth, survival, and movement of juvenile steelhead. Sixty juvenile steelhead were individually marked and monitored in six steel-cage enclosures placed at two Low Flow Channel locations. In addition, 631 wild juvenile steelhead were captured and individually marked through seining and electrofishing sampling.

Mark-and-recapture studies suggest that steelhead rearing in lower sections of the Low Flow Channel grew faster than those rearing in upper sections. Furthermore, the recapture rates observed among marked steelhead confirm that many juvenile steelhead found throughout the Low Flow Channel are not actively emigrating, but are more likely rearing throughout the summer months. Mark-and-recapture studies reveal that slightly warmer temperatures, as observed near Eye Riffle (assuming adequate food and habitat resources) may provide better growing conditions for over-summering juvenile steelhead than upstream areas.

Results from enclosure studies showed that all fish held for greater than 30 days showed an increase in growth and condition factor (K). Growth data obtained from enclosure studies provide valuable insight into the growth of juvenile steelhead rearing in two highly different temperature regimes. Average condition factor (K) increased throughout the study period, indicating that overall physical condition was improving. However, unlike the mark-and-recapture study, no significant difference in growth rate was observed between upstream (Hatchery Riffle) and downstream (Eye Riffle Side Channel) sites. When compared to wild fish, steelhead reared in enclosures had only slightly lower condition factor values, an indication that they were receiving appropriate amounts of food with respect to their metabolic needs (based primarily on fish size, temperature, and current velocities). Additionally, except for one fish that was known to have died during the study (Eye Riffle), no steelhead showed visual signs of stress from either competition or temperature (i.e., skin lesions, fin rot, bite marks, emaciation, lethargy). On the contrary, nearly all steelhead sampled appeared satiated and energetic, and all displayed normal color.

The warmer temperature regime experienced in the lower Low Flow Channel in summer 2003 is probably more suitable for steelhead growth. However, the observed temperatures were approaching the limits of steelhead tolerance ranges. Any increase in temperature (beyond that observed at Eye Riffle) would likely have deleterious effects. However, wild steelhead rearing in the lower Low Flow Channel grew faster than their upstream counterparts. These fish are therefore more likely to avoid predation and smolt sooner, and probably have a better chance of returning as adults. Flow regimes proposed for the Low Flow Channel must consider basic physical habitat requirements and the effects that water temperature could have on the resulting growth rates of juvenile steelhead. It appears that the combination of small side channels (complex microhabitats), increased cover, and appropriate water temperatures create the most productive rearing habitat for juvenile steelhead in the lower Feather River.

G-AQUA1.8.3.4 Redd Dewatering and Juvenile Steelhead and Chinook Salmon Stranding in the Lower Feather River (Task 3C)

Background Summary

Juvenile salmonids can become stranded on gravel bars or isolated in off-channel habitats as a result of flow fluctuations in rivers. Stranding has been reported to occur under both natural and controlled-flow fluctuations, but significant stranding events have generally been associated with large, rapid flow reductions related to reservoir and hydroelectric power operations (Hunter 1992). The incidence of stranding is related to several factors, including channel morphology, substrate type, species and life stage presence and abundance, time of year, river stage, and the magnitude, rate, and frequency of flow fluctuations. The vulnerability of fish to stranding is a function of their size and their behavioral response to changing flows, which depends on species, water temperature, time of year, and time of day. Newly emerged fry appear to be most vulnerable to stranding because of their limited swimming ability, their tendency to use the substrate as cover, and their preference for shallow river margins. As juveniles grow, they tend to move to deeper, higher velocity water associated with main channel habitats where they are less susceptible to stranding (Jones & Stokes 1998).

There are two general types of stranding, beach stranding and isolation basins. While slow, gradual ramping rates are important in minimizing gravel bar stranding, isolation of juveniles in off-channel habitats may occur regardless of ramping rate because of favorable rearing conditions, the distance of these habitats to the main river, and an apparent reluctance of juveniles to move away from protective cover (Bradford et al. 1995; Bradford 1997; Higgins and Bradford 1996; Jones & Stokes 1999). Because of the nature of beach stranding, fish likely die quickly, but fish found in isolation basins can survive for long periods of time. Factors that may influence fish survival in these off-channel habitats include the duration of reduced flows, water temperatures, food abundance, cover, and predator abundance.

Previous DWR investigations on the Feather River demonstrate that flow fluctuations cause some stranding. In January 1997, DWR temporarily reduced flows from 1,800 cfs to 1,600 cfs in the Feather River below the Thermalito Afterbay Outlet. A subsequent survey found one pond with 47 juvenile salmon and 4 additional ponds that potentially had some stranding.

Flow fluctuation criteria were developed in response to the 2000 Biological Opinion from the National Marine Fisheries Service (NMFS) to minimize the effect of flow fluctuations on the two salmonid species downstream of Lake Oroville (DWR 2000). Subsequently, a stranding monitoring program was developed by DWR and approved by NMFS. The goal of stranding studies was to evaluate effects of flow fluctuations associated with project operations on juvenile salmonid stranding. Task 3C of SP-F10 had the following objectives:

- Quantify ongoing effects of juvenile stranding and evaluate the ability of current flow fluctuation guidelines to minimize stranding events and effects;
- Quantify the amount of stranding potential area and resulting fish stranding that occurs during flow reductions between various flow levels; and
- Determine the biological significance of the proportion of the juvenile salmonid population loss resulting from stranding.

Report Conclusions

There were four major flow reductions in the High Flow Channel of the Feather River over 3 survey years. Flows ranged from a minimum of 1,050 cfs to a maximum of 8,000 cfs. Releases to the Low Flow Channel largely remained at 600 cfs during this period. However, Low Flow Channel flows were increased to 1,800 cfs for 2 days in August 2003 as part of an instream flow study. Review of existing data, including aerial photos from 1998 and 1999, revealed 19 areas susceptible to stranding (flows between 1,000 and 8,000 cfs) between the Thermalito Afterbay Outlet and Honcut Creek. Ground surveys confirmed 17 of these areas as subject to isolation. Another 17 areas below Honcut Creek also were identified as potentially susceptible to isolation (RM 43 to RM 0). However, a March 18, 2003, aerial survey of this area following a major flow decrease showed that only two locations were actually isolated. The two ponded areas were located at Shanghai Bench (RM 25) and at RM 35.

Nearly all stranding areas upstream of Honcut Creek were inundated at some time during the period of study. The 8,000-cfs discharge below the Thermalito Afterbay Outlet was the highest flow observed in the Feather River since the beginning of the survey in fall 2001. Of the 17 potential stranding areas identified downstream of Honcut Creek, only 2 were isolated when flows receded to 1,050 cfs. However, flows in the downstream reaches of the Feather River are influenced strongly by other tributaries (like the Yuba River), and thus the direct influences of Oroville Facilities operations are more difficult to discern.

Upstream of Honcut Creek, the effect of stranding on Chinook salmon and steelhead populations appears to be very small when compared to the number of emigrants from the Feather River. Over 3 survey years, the only major water operation occurred in late February 2003. The peak of emigration for Chinook salmon occurred weeks before this event, which may have reduced the potential for effect. Also, substantial increases in discharge have been shown to stimulate emigration of juvenile salmonids.

The already relatively small number of rearing salmonids in the river at this time may have emigrated while discharge was increasing, thus reducing the overall risk of stranding to the population. Additionally, the fact that more than 75 percent of steelhead spawning and early rearing is thought to be in the Low Flow Channel suggests that, at this time of year, there is a very limited potential effect on juvenile steelhead. Although only 2 isolated ponds were identified after a reduction of nearly 7,000 cfs, areas below Honcut Creek were not sampled for stranded fish. This estimate of stranded fish is not representative of the entire Feather River, and likely underestimates the total effect of salmonid stranding. In subsequent surveys, sampling in reaches below Honcut Creek may improve the ability to assess broader stranding effects in the lower Feather River.

There was no significant difference between the mean size of stranded and non-stranded fish. Additionally, within an isolation event, there were no differences in the mean size of fish stranded between ponds. This is likely a reflection of the small size range of juvenile salmonids at this time of year in the Feather River. The majority of salmon emigrate as fry shortly following emergence.

There was no apparent pattern in the distribution and size of ponded areas, which is likely why no relationship was found between the relative abundance and density of stranded fish and river mile. Researchers have shown that stranding is more significant in large off-channel ponds because of favorable rearing conditions in these habitats, the distance of these habitats from the main river, and an apparent reluctance of juveniles to move away from protective cover (Bradford et al. 1995; Bradford 1997; Higgins and Bradford 1996; Jones & Stokes 1999). Furthermore, in the Feather River a substantial proportion of all ponded areas are off-channel ponds. However, the study failed to find a difference in the amount of stranding between these and different pond types.

Without experimentally manipulating flow, it was difficult to collect data over the repeated range of flows necessary for such analyses; therefore, the sample size may be too small to detect differences or to draw conclusions about the timing of flow fluctuations. No relationship was observed between the timing of flow fluctuations and the level of stranding. Evaluating factors that effect stranding rates was further complicated by the fact that they often act synergistically. The magnitude of the event can be equally as important as the timing of the event.

The generally low level of stranding suggests that current ramping rates in the High Flow Channel may be suitable. Yet, beach stranding for which ramping rates would have the highest effect is not field verified. Beach stranding was not considered during the field sampling for several reasons:

- This type of stranding is generally believed to be only a minor component of overall stranding potential in the lower Feather River.
- Ramping rates are very low (roughly 1-inch stage change per hour) and should minimize beach stranding effects.
- There were problems with predation by birds before a survey could be conducted, which would have frustrated any effort at accurate beach stranding survey results.
- This type of stranding would occur in intragravel spaces and therefore would be very difficult to quantify in any reliable manner.

However, much experimental research has been conducted regarding the effect of ramping rates on juvenile salmonid stranding. Bradford et al. (1995) and Bradford (1997) found that significantly more coho salmon and rainbow trout juveniles were stranded at ramping rates of 30 centimeters (cm) per hour (11.8 inches per hour) than at 6 cm per hour (2.4 inches per hour). Similar results were reported for juvenile Chinook salmon in simulated side channels during the fall (Bradford et al. 1995). Based on a field investigation of stranding of Chinook salmon and steelhead fry in the Sultan River, Washington, Olson and Metzgar (1987) recommended ramping rates ranging from 1 to 6 inches per hour (2.5–15 cm per hour) depending on flow range, season, and time of day.

Oroville Facilities operations are currently working under flow fluctuation guidelines designed to minimize the potential for fish stranding. Flow reductions in the Low Flow Channel are restricted to 200 cfs per day for within-bank flows. Under within-bank flow conditions, a flow reduction of 200 cfs per day is approximately equivalent to a 0.1-inch-per-hour stage elevation change in the Low Flow Channel of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet. Ramping rates of 1 inch per hour are among the slowest ramping rates currently used in other regulated rivers. Revision of ramping standards for the Low Flow Channel to at least 1 inch per hour would maintain desirable protective standards for fisheries but would also be less burdensome to project operations.

G-AQUA1.8.4 Project Effects on Emigration of Juvenile Salmonids in the Feather River (Task 4)

G-AQUA1.8.4.1 Literature Review of Devices Used for Enumeration of Juvenile Steelhead Outmigrants (Task 4A)

Background Summary

The purpose of this literature review was to evaluate the current juvenile steelhead enumeration program and determine whether there were opportunities for improvement that would increase the accuracy and precision of estimates of the number of outmigrating juvenile steelhead in the Feather River. The literature review conducted to satisfy this portion of Task 4A of SP-F10 was designed to answer three questions:

- Are rotary screw traps the most suitable device or method for enumerating juvenile steelhead in the Feather River?
- Is the capture efficiency of rotary screw traps in the Feather River comparable to capture efficiency of rotary screw traps in other similar rivers?
- Are there opportunities to modify the existing rotary screw traps using either physical modifications or behavioral modifications, such as the use of light or sound, to increase trap efficiencies?

The conclusions drawn from this literature review may be used as the basis for suggesting potential PM&E measures designed to increase trap efficiencies and provide a more rigorous estimate of the number of outmigrating juvenile steelhead.

Devices used to enumerate outmigrating juvenile steelhead (*Oncorhynchus mykiss*), including acoustic devices, camera monitoring, electric fish counters, fyke nets, inclined plane traps, inclined screen traps, rotary screw traps, seining, snorkel surveys, and trawls, were researched through a review of published peer-reviewed journal articles, government agency reports, and consultant literature.

Report Conclusions

Of the devices examined that could be used to enumerate outmigrating juvenile steelhead in the Feather River, including acoustic devices, camera monitoring, electric fish counters, fyke nets, inclined-plane traps, inclined-screen traps, rotary screw traps, seining, snorkel surveys, and trawls, rotary screw traps were determined to be the most appropriate for the purpose of enumerating outmigrating juvenile steelhead in the Feather River. Although there are several reasons that each alternative device was suggested to be inappropriate, there are several common reasons that alternative devices may have been suggested as inappropriate. For example, several devices require specific site conditions that are not present in the Feather River.

Because rotary screw traps appear to offer the most effective means of enumerating juvenile salmonids in the Feather River, comparisons to other similar river applications of these devices were examined to determine whether the performance of the current Feather River traps is likely to have any opportunity for improvement. Overall, findings indicated that the current Feather River efficiencies are comparable to those obtained with other devices under relatively similar conditions in comparably large rivers.

The physical modifications reviewed included diversion wings, ganged rotary screw traps, and multiple rotary screw traps. Although diversion wings are potentially applicable to the Feather River, the benefit of adding diversion wings to rotary screw traps has not been quantified, and as a result, adding diversion wings to the currently used rotary screw traps was not recommended as a modification for the next field season. Efficiencies reported for ganged rotary screw traps on the Stanislaus and Sacramento Rivers are comparable to, and in some lower than, trap efficiencies on the Feather River, in which one rotary screw trap is used at each location; therefore, using ganged rotary screw traps was not recommended as a modification to the currently used rotary screw traps for the next field season. Multiple rotary screw traps are already in use in the Feather River and continued use of multiple rotary screw traps is recommended for the next field season.

This investigation concluded that:

- No device or method examined would be expected to provide a more accurate, precise, or consistent estimation of the number of emigrating juvenile steelhead in the mainstem Feather River than the currently used rotary screw traps
- The Feather River rotary screw trap efficiencies are comparable to, and in some cases higher than, rotary screw trap efficiencies in other rivers;
- Physical rotary screw trap modification alternatives such as addition of diversion wings to rotary screw traps may provide some efficiency improvement, but the methods are experimental and the benefit of adding wings has not been quantified; and
- Behavioral modifications based on sound and light do not appear to be well developed enough to provide additional benefit for use with rotary screw traps.

G-AQUA1.8.4.2 River Flow Effects on Emigrating Juvenile Salmonids in the Lower Feather River (Task 4A)

Background Summary

The purposes of Task 4A of SP-F10 were to describe the relationship between river flow and juvenile salmonid emigration patterns, and to evaluate potential project effects on juvenile salmonid emigration in the Feather River downstream of the Fish Barrier Dam. As a subtask of SP-F10, Task 4A fulfilled a portion of the FERC application requirements by describing the relationship between river flow and juvenile salmonid emigration patterns, and evaluating potential project effects on juvenile salmonid emigration in the Feather River downstream of the Fish Barrier Dam.

Report Conclusions

Task 4A of SP-F10 was completed by conducting a literature review and an analysis of empirical data collected on the lower Feather River to determine the timing of emigration and the potential effects of river flow on emigrating juvenile salmonids.

As part of a 1983 agreement between DWR and DFG, minimum discharge into the Low Flow Channel increased from approximately 400 cfs to 600 cfs in 1988. Significant deviations from this pattern occur primarily during flood management releases. Consequently, mean daily flow (cfs) throughout the year is normally slightly above 600 cfs. Since 1988, mean daily flow has exceeded 1,000 cfs approximately 7 percent of the time. High-flow events in the Low Flow Channel (greater than 10,000 cfs) have occurred in 9 of the last 22 years. These higher flow events could have encouraged emigration of juvenile Chinook salmon and steelhead in the 9 years they were experienced.

Rotary screw trap sampling was performed between 1997 and 2003 to investigate the potential of environmental variables to affect Chinook emigration behavior. DWR data (collected between 1997 and 2003) indicate that the peak emigration of Chinook fry in the Low Flow Channel and High Flow Channel is consistently between January and March, regardless of flow variations. Regression analysis performed on Chinook catch between 1997 and 2003 illustrates that emigration timing is often poorly explained by environmental variables. In one model, flow, temperature, and female spawn timing collectively accounted for 95 percent of the variation in catch at the Thermalito rotary screw trap between 2001 and 2003. However, flow was not found to be a statistically significant influence. A similar analysis performed for the 1998–1999 and 1999–2001 screw trap catch at both Thermalito and Live Oak provided similar results. Similar to all years except 1997–1998 (Live Oak), regression analysis failed to show a significant flow effect for either Thermalito or Live Oak.

Emigration patterns for Chinook salmon in the Feather River were similar throughout the period of study (and similar to previous studies) in that they emigrated very early and at small sizes. The percentage of salmon that were categorized as smolts or intermediate between parr and smolt was less than 2 percent at Thermalito, and 15 percent at Live Oak. Most were smaller than 50 mm (97 percent at Thermalito and 81 percent at Live Oak). The high percentages of pre-smolt fish and fish smaller than 50 mm indicate that most salmon undergo smoltification downstream of Live Oak.

Rotary screw trap sampling in the Feather River is difficult or impossible when flows approach 15,000 cfs (primarily at Live Oak). Consequently, monitoring Chinook catch and associated environmental variables becomes problematic. Because of the difficulties associated with sampling at higher flows, no Feather River data are available to address the effect of these extreme events on emigration of juvenile Chinook salmon or steelhead. However, it is probable that substantial increases in flow released at the appropriate time could enhance emigration success. Under present operations, more subtle influences such as food availability, temperature, and adult spawn timing likely have more influence on emigration patterns than flow, both in the Low Flow Channel and during low or consistent flow periods in the High Flow Channel. This does not infer, however, that high-flow events are not valuable and preferential to low-flow conditions. It simply means that in the absence of flow variation, Chinook salmon continue to emigrate from the lower Feather River (past RM 42, Live Oak) at approximately the same time every year.

Juvenile steelhead in the lower Feather River were captured in DWR sampling programs from March through September, with peak capture occurring from March through mid-April (DWR 2002b; DWR and USBR 2000). Rotary screw trap catch of wild juvenile or yearling steelhead at Thermalito is inconsistent (especially for larger steelhead) between years, while catch at Live Oak is extremely low in all years. It is very likely that before emigration many steelhead grow to a size large enough to avoid capture at the rotary screw traps. Additionally, the varied life history of steelhead makes capture or monitoring emigration at any life stage difficult. Empirical data, literature review, and observational data suggest that steelhead potentially emigrate during all months of the year in the lower Feather River. The lack of quality data on steelhead emigration patterns impairs the ability of researchers to draw reliable conclusions about steelhead emigration behavior in the Feather River.

Although no detailed analysis of steelhead emigration patterns is available, certain aspects of project operations are important to the success of wild steelhead in the Feather River. Certainly, large increases in flow followed by quick reductions could cause significant stranding in both the Low Flow Channel and the High Flow Channel. Additionally, prolonged low-flow conditions in either the Low Flow Channel or the High Flow Channel are unlikely to benefit steelhead. Increased and, at times, varying flows in both sections of river are likely to provide additional rearing habitat, cover, and food resources (assuming that stranding issues are addressed). Many of the issues regarding adequate flow conditions are directly related to temperature and are better addressed in SP-F10, Task 4B. In general, flow (and correspondingly temperature) preferences of juvenile steelhead must be addressed when considering instream flow operational scenarios.

G-AQUA1.8.4.3 Timing, Thermal Tolerance Ranges, and Potential Water Temperature Effects on Emigrating Juvenile Salmonids in the Lower Feather River (Task 4B)

Background Summary

The purpose of Task 4B of SP-F10 was to describe the relationship between water temperature and juvenile salmonid emigration patterns, and evaluate potential project effects on juvenile salmonid emigration in the Feather River downstream of the Fish Barrier Dam. As a subtask of SP-F10, Task 4B fulfills a portion of the FERC application requirements by describing the relationship between water temperature and juvenile salmonid emigration patterns, and evaluating potential project effects on juvenile salmonid emigration in the Feather River downstream of the Fish Barrier Dam.

For the purpose of this analysis, the study area was divided into two major reaches: The Low Flow Channel from the Fish Barrier Dam to the Thermalito Afterbay Outlet, and the High Flow Channel from the Thermalito Afterbay Outlet to the mouth of the Feather River at its confluence with the Sacramento River.

Report Conclusions

Task 4B of SP-F10 was completed by conducting a literature review to determine the timing of emigration, thermal tolerance ranges, and the potential effects of water temperatures on emigrating juvenile salmonids in the lower Feather River. Upon completion of the literature review, spatial and temporal water temperature distributions in the lower Feather River were determined. Water temperature distributions were then combined with emigration dates to determine the potential effects on emigrating juvenile salmonids from thermal stress loading.

Juvenile Steelhead

Juvenile steelhead in the lower Feather River have been reported to emigrate from approximately February through September, with peak emigration occurring from March through mid-April (DWR 2002b; DWR and USBR 2000). However, empirical and observational data suggest that juvenile steelhead potentially emigrate during all months of the year in the lower Feather River. To evaluate potential project effects on emigrating juvenile steelhead, three thermal tolerance indices were established:

- Less than or equal to 55°F (12.8°C);
- More than 55°F and less than or equal to 65°F (18.3°C); and
- More than 65°F.

These three indices were generally defined as “suitable,” “potential sublethal effects,” and “unsuitable,” respectively.

In the Low Flow Channel from RM 67.4 (Thermalito Diversion Dam) to RM 66.0, mean daily water temperatures during the defined emigration period for juvenile steelhead generally remained within the “suitable” index range (less than 55°F) from February through May, and late August through early September. In the remainder of the Low Flow Channel (RM 64.1 to RM 59.4), temperatures generally remained within the suitable index range from February through March. Throughout the Low Flow Channel (RM 67.4 to RM 59.4), temperatures generally remained below 65°F year-round. At Robinson Riffle (RM 61.7), mean daily water temperatures exceeded 65°F once, on June 19, 2002.

In the High Flow Channel (RM 58.8 to RM 0.3), mean daily water temperatures during the defined emigration period generally remained within the suitable index range from February through early March. Temperatures from RM 58.8 to RM 41.8 generally remained below the defined index value of 65°F from February through May and

September, and sporadically from June through July. Temperatures at the mouth of the Yuba River (RM 27.5) generally remained below 65°F from February through August. In the remainder of the High Flow Channel (RM 25.2 to RM 0.3), mean daily water temperatures remained below 65°F from February through mid-May.

Juvenile steelhead potentially emigrate year-round, so a brief summary of water temperatures in the lower Feather River from October through January was provided in this report. In the Low Flow Channel (RM 67.4 to RM 59.4), mean daily water temperatures generally remained within the suitable index range from mid-November through January and remained below 65°F year-round.

Juvenile Chinook Salmon

Juvenile Chinook salmon in the lower Feather River have been reported to emigrate from approximately mid-November through June, with peak emigration occurring from January through March (DWR 2002a; Painter et al. 1977). For this evaluation, thermal tolerance indices for emigrating juvenile Chinook salmon were established as:

- Less than or equal to 62.6°F (17°C);
- More than 62.6°F and less than or equal to 68°F (20°C); and
- More than 68°F.

These three indices were generally defined as “suitable,” “potentially sublethal effects,” and “unsuitable (upper incipient lethal effects),” respectively.

In the Low Flow Channel from RM 67.4 (Thermalito Diversion Dam) to RM 64.1, mean daily water temperatures during the defined emigration period for juvenile Chinook salmon generally remained within the “suitable” index range (less than 62.6°F) year-round. Mean daily water temperatures in the Low Flow Channel from RM 67.4 to 59.4 did not exceed the defined index value of 68°F. Water temperatures in the Low Flow Channel remained within the suitable index range during the reported peak of emigration (January through March) when, based on rotary screw trap data (DWR 2002b), approximately 96 percent of juvenile Chinook salmon emigrate. Available water temperature data indicate that water temperatures did not exceed the suitable index range In the High Flow Channel during the reported peak of emigration by juvenile Chinook salmon.

Elevated water temperatures in the lower Feather River may affect emigrating juvenile steelhead more than emigrating juvenile Chinook salmon. Water temperatures in the Low Flow Channel are more conducive to emigrating salmonids than are water temperatures in the High Flow Channel. However, the ability of Oroville Facilities operations to manipulate water temperature through flow releases decreases with downstream distance from Oroville Dam. In the High Flow Channel during the warmest months of the year, coldwater inflow from the Yuba River may provide localized thermal refugia.

G-AQUA1.9 EVALUATION OF THE FEASIBILITY TO PROVIDE PASSAGE FOR ANADROMOUS SALMONIDS PAST OROVILLE FACILITY DAMS (SP-F15)

Providing passage into Lake Oroville's upstream tributaries may diminish certain project-related migration limitations caused by current barriers (e.g., the Fish Barrier Dam) and return fish to potentially suitable spawning, rearing, and holding habitats. Providing passage to the upstream tributaries potentially offers several benefits that differ from those currently provided by ongoing operations of the Feather River Fish Hatchery, and may serve as an alternative means of improving recovery of endangered species.

The Oroville Facilities currently rely heavily on hatchery production to repopulate depressed stocks of Chinook salmon and steelhead. Providing fish passage could enhance existing production in the Feather River system and could also develop a more robust and stable population over time; however, several issues, including disease propagation and temperature limitations, would need to be overcome. SP-F15 was designed to assess the feasibility of providing fish passage over, around, or through the Oroville Facilities. The overall objective of this study plan was to provide a GIS-driven decision support tool designed to describe the merits and desirability of individual fish capture, sorting, holding, and transport-and-release alternatives, or combinations thereof. A feasibility ranking would be assigned to each component that could be implemented in the upper Feather River basin to provide fish passage and improve self-sustaining in-river fish production within the system.

G-AQUA1.9.1 Life History and Habitat Requirements of Feather River Anadromous Salmonids and Other Migratory Species (Task 1)

The objectives and information needs of SP-F15, Task 1, SP-F3.2, Task 2, and SP-F21, Task 1 were found to be similar, so the results were presented together. The results of this study are provided in SP-F3.2, Task 2, described above.

G-AQUA1.9.2 Inventory of Potentially Available Habitat for Juvenile and Adult Fish Upstream of Lake Oroville (Task 2)

The objective of the joint report for SP-F15, Task 2, and SP-F3.1, Task 1C, was to inventory and assess the suitability of available habitat upstream of Lake Oroville for adult and juvenile anadromous salmonids, and to describe the distribution of species currently present. The study plan results were presented together, and the results can be found in SP-F3.1, Task 1C, described above.

G-AQUA1.9.3 Methods and Devices Used in the Capture, Sorting, Holding, Transport and Release of Fish (Task 3)

G-AQUA1.9.3.1 Background Summary

The objective of Task 3 of SP-F15 was to examine the feasibility of moving anadromous salmonids and other targeted migratory fish species, specifically green sturgeon, past the Oroville Facilities. To accomplish this task, a literature review was conducted to determine the devices and methods that could potentially be employed in a fish passage program. Although sturgeon and steelhead information was included in the report when available, the preponderance of information available was only directly applicable to evaluating the feasibility of a fish passage program for Chinook salmon. Chinook salmon are the most likely of the potential fish species evaluated to be feasible for use in a potential fish passage program. Therefore, the majority of the report focuses on the evaluation of Chinook salmon passage.

Under the fish passage program evaluated, migrating adult salmonids would be collected from the lower Feather River using the existing Feather River Fish Hatchery fish ladder downstream of the Fish Barrier Dam, and transported above Oroville Dam to the upstream tributary interface with Lake Oroville for release in the West Branch and North Fork Feather River. No suitable salmonid spawning habitat was identified below the high-pool level of Lake Oroville and below the next impassable fish barrier in any other tributary other than the West Branch and North Fork Feather River. Outmigrating juveniles would be captured in upstream tributaries or tributary arms of Lake Oroville in the West Branch and North Fork Feather River, transported by truck, and released downstream of the Fish Barrier Dam to continue their seaward migration. The potential effects of these actions were evaluated qualitatively based on information collected during preparation of the SP-F15 study plan report. This information includes evaluations of effects of the passage program on other fisheries resources (disease, genetic introgression, competition for food and habitat, stocking practices, fishing rules, etc.) and the expected biological performance of a fish passage program.

G-AQUA1.9.3.2 Report Conclusions

The SP-F15 Tasks 3 report identified several potential resource conflicts with a fish passage program. Potential conflicts or resources that may be affected by a fish passage program are listed below.

- Future upstream tributary flow regimes are controlled by upstream projects. These flows are not within the control of the Oroville Facilities, but could profoundly affect fish accessibility and habitat quality and quantity.

- Upstream water temperatures are controlled by upstream projects. If anadromous salmonids from a fish passage program were present, achievement of appropriate water temperature goals would likely be mandated for upstream facilities; however, it is uncertain whether upstream facilities can accomplish water temperature goals suitable for anadromous salmonids. Appropriate water temperature regimes in the tributaries above Lake Oroville could be a significant factor in the potential success or viability of a fish passage program.

- The presence of anadromous salmonids from a fish passage program may create disease pressures or incidences in the upstream tributaries, reservoir complex, Feather River Fish Hatchery, and downstream Feather River reaches.

The disease of primary concern is infectious hematopoetic necrosis (IHN). In California, the occurrence of this disease reportedly has been eliminated from most of its historic range by dam construction and the blocking of inland waters from spawning and rearing anadromous salmonids. Historically, the IHN virus was endemic to the entire Sacramento, American, Merced, and Feather River drainages. Currently, only those portions of these watersheds below terminal dams blocking anadromous salmonids contain this virus (pers. comm., Cox 2003).

- The presence of anadromous salmonids in and above Lake Oroville from the fish passage program would increase the incidence of fish disease and potentially amplify the cumulative fish disease pressure in the lower Feather River. Of potentially greater disease concern is the exposure of the intake waters of the Feather River Fish Hatchery to the transported anadromous salmonids from the fish passage program. Large fish kills can occur in hatcheries as a result of IHN. Any disease occurrence in the hatchery would further amplify the potential disease pressure occurring in the lower Feather River.

- Introduction of species listed under the federal Endangered Species Act (ESA) into new geographic areas from a fish passage program may precipitate changes in fishing regulations and affect recreational fishing. A fish passage program may also bring about ESA compliance requirements that currently do not exist in upstream areas.

- In the event of a steelhead fish passage program, genetic introgression may occur between resident rainbow trout stocks and anadromous steelhead. Leary et al. (1995) suggest that a 1 percent threshold of introgression is acceptable, while higher percentages present a risk of altering the biological characteristics of the fish assemblage. With significant numbers of naturally reproducing rainbow trout in the upper watershed, a 1 percent threshold would almost certainly be exceeded.

- Predation and competition for food and habitat between resident upstream tributary fish populations and fish from the fish passage program would likely occur. The presence of anadromous salmonid adults and juveniles would likely affect the species composition, number, and distribution of resident fish in upstream tributaries.

- Unlike Chinook salmon that die after spawning, some steelhead survive and are able to spawn repeatedly. If a portion of the steelhead population in the Feather River are repeat spawners, then it would be necessary to evaluate methods of recapturing outmigrating adults and transporting them downstream below Oroville Dam. However, little is known about repeat spawning by Feather River steelhead, and in other steelhead populations the number of individuals exhibiting repeat spawning behavior has been reported to be somewhat variable (Ward and Slaney 1988; Withler 1966). Ward and Slaney (1988) reported that 10 percent of adult steelhead spawned repeatedly in a British Columbia coastal stream, while Withler reported that between 4.4 and 31.3 percent of adult steelhead spawned repeatedly in three different British Columbia rivers. If the incidence of Feather River steelhead that spawn repeatedly is low, it may not be necessary to recapture outmigrating post-spawning adults. Conversely, if the proportion of fish exhibiting this spawning survival characteristic were high, a substantial effort to recapture these fish would be required. Successful recapture of adult steelhead may pose substantial challenges, and the stress experienced during recapture could increase post-spawning mortality compared to that which would have occurred naturally.

- Implementing a fish passage program in conjunction with other proposed PM&E measures may reduce some adverse effects associated with high densities of spawning anadromous salmonids in the reach of the Feather River extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet. Moving some of the salmonid spawning population from the lower Feather River to upstream habitat would proportionately reduce the amount of competition for habitat and the associated pre-spawn adult mortality, the rate of redd superimposition and the associated egg and alevin mortality, and high densities of rearing juveniles. High intensity usage of spawning and rearing habitat is hypothesized to have negative effects on survival and population viability.

- Implementing a fish passage program may also allow for the partial segregation of spring- and fall-run Chinook salmon. The temporal separation of the spawning run timing could be used to collect appropriate brood stock for different upstream tributaries. This, combined with a spatial separation in the release of adults to upstream areas, may aid in maintaining the genetic distinctness of the two populations. Because some fall-run Chinook salmon exhibit spring-run timing behavior, temporal differentiation may not be reliably effective to separate the runs.

- Allowing passage of anadromous salmonids to upstream tributaries would provide some level of nutrient and energy transfer. The SP-F8 report (see Section G-AQUA1.6 in Appendix G-AQUA1, Affected Environment) examined the effects of transfers of nutrients and organic matter to the upstream tributaries. Several studies have been completed that document increased stream productivity following the planting of salmon carcasses in streams, and compare stream productivity among streams with salmon spawning vs. nearby streams without salmon (Bilby et al. 1998; Finney et al. 2000; Minkawa and Gara 1999; Minkawa et al. 2002; Schuldt and Hershey 1995; Wipfli et al. 1998). It is generally expected that the transfer of nutrients and energy to the upstream tributaries would be a positive influence on stream productivity; however, the limits of the benefits of nutrient contributions and the risks of potential nutrient loading limits on water quality in the upstream tributaries or in Lake Oroville are evaluated in Section 5.4.2.2.

- Macroinvertebrate communities upstream of Lake Oroville may benefit from implementation of a fish passage program. The marine-derived nutrients contained in the bodies of salmon would be released in the streams after the salmon spawned and died, which may lead to increased production of benthic macroinvertebrates. Several studies have documented positive effects of salmon spawning migrations on stream invertebrates (see SP-F8 in Section G-AQUA1.6 in Appendix G-AQUA1). The greatest benefit to macroinvertebrates would occur in a situation where fish were restored to an area that was nutrient-limited or nutrient-starved. Although data indicate that streams upstream of Lake Oroville contain low levels of nutrients, streams above the reservoir are not categorized as nutrient-starved. The data also indicate that healthy populations of aquatic macroinvertebrates currently exist in the upstream tributaries. Therefore, while a fish passage program may offer some benefit to macroinvertebrate communities upstream of Lake Oroville, those benefits may fall below detectable limits.

- Implementation of the fish passage program would require some changes to fishing regulations. The types of changes, and the geographic scope of the effects on the recreational fishery in the tributaries upstream of Lake Oroville and on the coldwater fishery in Lake Oroville, would be determined by the regulating agencies including the California Department of Fish and Game (DFG), U.S. Fish and Wildlife Service (USFWS), and National Oceanic and Atmospheric Administration (NOAA) Fisheries. The nature of the fishing restrictions would depend on the location and timing of the releases of adult fish from the fish passage program, as well as tagging programs implemented either in conjunction with the fish stocking program or the fish passage program; the restrictions would be based on the level of protection required for the fish passage program.

Potential Fish Passage Program Effects on Anadromous Salmonids

Adult Immigration and Holding

Implementation of a fish passage program potentially would provide a benefit by reducing competition for holding habitat and increasing spatial separation between holding spring-run Chinook salmon and immigrating fall-run Chinook salmon. However, the fish passage program likely would expose transported adult Chinook salmon to elevated holding water temperatures. This would have a negative effect on exposed individuals, thus negatively affecting the portion of the immigrating population included in the fish passage program.

Spawning and Embryo Incubation

The fish passage program likely would have a beneficial effect on adult Chinook salmon by reducing spawning densities in the lower Feather River, thereby reducing redd superimposition, and increasing incubating embryo survival. However, implementation of a fish passage program likely would expose transported adult Chinook salmon to elevated early spawning season water temperatures, which causes increased rates of adult pre-spawning mortality and egg mortality rates.

In addition, implementation of a fish passage program would potentially negatively affect repeat steelhead spawners by subjecting surviving steelhead spawners to increased stress associated with recapture and transport below Oroville Dam or loss to the effective breeding population by failures to recapture the surviving adults. Adults not recaptured would contribute to increased predation on rearing fish passage program salmonids. Additionally, steelhead included in the fish passage program may interbreed with the resident rainbow trout, causing loss of genetic distinctness of both populations.

Juvenile Rearing and Downstream Movement

A fish passage program would potentially have a beneficial effect on rearing juveniles by decreasing rearing densities in the lower Feather River and by providing access to additional rearing habitat above Lake Oroville. However, implementation of a fish passage program likely would expose downstream migrating juvenile Chinook salmon to increased stress associated with capture and transport below Lake Oroville. Juveniles not recaptured in the downstream fish passage are effectively lost for population production purposes, which would have a negative effect on a proportion of the rearing and downstream migrating population.

Steelhead Smolt Emigration

A fish passage program would potentially have a negative effect on steelhead smolt emigration by exposing emigrating steelhead smolts to increased stress associated with capture and transport below Lake Oroville, which would have a negative effect on a proportion of the emigrating smolt population.

The adult fish passage phase elements include capture, sorting and tag reading, holding, transport, and release. The juvenile fish passage phase elements include capture, sorting and tagging, holding, transport, and release. The adult and juvenile phases and individual elements of the fish passage program, their alternatives, interactions, interdependencies, functional requirements, logistics, and characteristics were described and evaluated in the report. The advantages and disadvantages of each program and device alternative were evaluated against their ability to successfully accomplish the potential fish passage program goals.

Program and device alternatives were recommended based on their favorable characteristics compared to the other alternatives to fulfill the program functions, and for their compatibility with the potential fish passage program goals. Selection of program and device alternatives, in some cases, depends on the goal of the program.

G-AQUA1.9.4 Fish Passage Model (Task 4)

G-AQUA1.9.4.1 Background Summary

In the SP-F15, Task 4 report, a model was developed to evaluate various combinations of alternative goals and elements for a fish passage program. The model is user interactive and allows evaluation and sensitivity analysis of multiple model elements and scenarios in a single model run. The model incorporates many variables to represent conditions and interactions in a fish passage program, and is designed to evaluate fish passage. A “Fish Passage Model Output Report” is generated by the model; this report includes metrics for evaluation of model results by providing ratios of production performance for critical program elements. For example, the ratio of returning adult fish to adult fish passed is a critical performance metric for a fish passage program. If the number of returning adults in the program is lower than the number of fish required for passage in the program, then the program is not sustainable for establishing or protecting a unique population or run. The example model scenario included in the SP-F15, Task 4 report was designed for the goal of “Protect or Enhance Spring-Run Chinook Salmon Genetic Integrity,” with the fish passage options selected to produce the highest biological performance of the fish passage program. The evaluation of the example model scenario was not expected to be biologically sustainable; however, this example was for illustrative purposes only. It was not intended to provide a definitive conclusion regarding the viability of all potential fish passage programs or other scenarios with these same goals.

Many of the elements included within a potential fish passage program are not definitively quantifiable, so the model uses “Best Case,” “Expected,” and “Worst Case” values for each fish passage program variable. The user can provide input values for the “Expected” scenario. Model results are output in aggregations of all the “Best Case” values calculated as a group to characterize results under the most favorable conditions and assumptions. The “Worst Case” values are treated similarly to demonstrate the worst likely outcome of the selected elements of the fish passage program. The use of “Worst Case” does not incorporate eventualities for catastrophic events, as almost all elements represented in the model are potentially subject to complete failure. The “Expected” values provide an example of how the program is expected to perform.

The model results are interpreted by evaluating whether the range of outcomes, from best case to worst case, is “acceptable” or not. If the range of the outcomes from best case to worst case is considered to be acceptable, then the program could be feasible. If the range of outcomes from best case to worst case were considered unacceptable, then the proposed fish passage program would not be feasible. If portions of the range of outcomes were determined to be both partially acceptable and unacceptable, then further refinement of the values used in the ranges would be required to achieve definitive conclusions regarding the feasibility of fish passage.

The model incorporates many variables to represent fish passage program conditions and interactions. It is designed to evaluate fish passage; this model should not be confused with “stream productivity models” that use intensive habitat characterization information to estimate the number of fish produced by a given area of stream.

This model is limited by available habitat data and some critical assumptions. The quantification of available spawning habitat upstream is based on SP-G1 survey data that provided estimates of available “riffle” type mesohabitat, but did not address the variability in the amount of suitable habitat under various upstream tributary flows. Consequently, the actual amount of potentially suitable spawning habitat is likely less than the amounts used in the model, and the model estimates provide optimistic assessments of potential fish passage production. Upstream water temperatures were assumed to be suitable for Chinook salmon, on the assumption that the upstream facilities would provide appropriate water temperature conditions if anadromous salmonids were present in the upstream tributaries. Potential biases in the values used in the model do not affect the ability to compare between passage program alternatives because of consistent application across all scenarios.

G-AQUA1.9.4.2 Report Conclusions

The model automatically generates a “Fish Passage Model Output Report” that includes metrics for evaluation of model results by providing ratios of production performance for critical program elements. These performance ratios allow for comparisons with other passage programs and fishery production systems (e.g., hatcheries or alternative programs to accomplish the same goals), and serve as a basis for evaluating whether model outputs are providing realistically anticipated results. For example, the ratio of returning program adult fish to adult fish passed is a critical performance metric for a fish passage program. If the number of returning program adults is lower than the number of fish required for passage in the program, then the program is not sustainable for establishing or protecting a unique population or run.

The basis for evaluation of the model results depends on the objective of the fish passage program selected by the user. Potential fish passage program objectives could include:

- Access to additional habitat or increases in total salmonid production in the Feather River;
- Protection or enhancement of the genetic integrity or distinctness of a run or species; and
- Access to conditions more closely approximating historical habitat.

To evaluate the viability of a fish passage program with the objective to create access to additional spawning and rearing habitat, the “Total Cost Per Spawning Habitat Accessed” of the fish passage program should be compared to the alternative costs of creating comparable amounts of habitat or increased fish production in the lower Feather River. Costs for these alternative programs to accomplish this same goal will be available as the cost evaluations of the proposed PM&E measures are completed by DWR.

If the objective of the fish passage program is to develop, reestablish, or protect the genetic integrity or distinctiveness of a run, then the cost of such a fish passage program should be compared to the costs, effectiveness, and risks of a program for the lower Feather River using fish weirs to accomplish the goal. Proposed PM&E Measure EWG-2, “Fish Barrier Weirs in the Lower Feather River,” is intended to achieve the same resource objective to protect or enhance the genetic integrity or distinctness of spring-run Chinook salmon. The fish barrier weirs are included in the Proposed Action as well as Alternative 2.

If the objective of the fish passage program is to provide fish with access to conditions that more closely approximate historical conditions, there is no meaningful metric available from the model other than comparing cost per fish of the fish passage program to that of other passage programs to determine whether the fish passage scenario would provide a comparable rate of return to the other fish passage programs. If this objective is pursued, then conditions in the upstream tributaries (e.g., water temperature regimes) should be evaluated against “historical conditions” to determine whether a passage program would actually result in fish accessing habitat more closely resembling historical conditions.

The example model scenario included in this report was designed for the goal of “Protect or Enhance Spring-Run Chinook Genetic Integrity”. There are many possible combinations of alternatives and assumptions associated with options to a fish passage program that could also have this same goal. The evaluation of the example model scenario was determined to be not sustainable; however, this example is for illustrative purposes only. It is not intended as a definitive conclusion about the viability of all potential fish passage programs or other scenarios with these same goals.

Because SP-F15 was designed to evaluate the feasibility of a potential PM&E measure, it is appropriate to indicate that some of the potential goals of a fish passage program could be accomplished through alternative PM&E measures. Those alternative methods to achieve the same resource goals could potentially be accomplished at lower risk, cost, and conflict with other resource management goals.

Potential fish passage program goals include protecting, enhancing, or restoring the genetic integrity of a fish stock; increasing total salmonid production; or providing access to habitat conditions more closely resembling historical conditions. The genetic integrity of a fish stock could be protected, enhanced, or restored without a fish passage program by segregating a fish population in the lower Feather River with the use of fish barrier weirs. Total salmonid production also could be increased without a fish passage program by enhancing existing habitat and creating new habitat in the lower Feather River. Both of these alternative methods of accomplishing specific potential goals of the fish passage program could potentially be accomplished at lower cost, with lower levels of uncertainty of success, and at lower levels of risk of failure than a fish passage program. Only the potential fish passage goal of providing access to conditions more closely approximating historical conditions could not be accomplished through alternative PM&E measures.

Overall, the results of the feasibility analysis indicate that fish passage could potentially be physically feasible, but it is likely that the goals of a fish passage program could potentially be accomplished by other PM&E measures at lower costs and risks, and with fewer resource conflicts. Additionally, the likelihood of success of a potential fish passage program accomplishing those goals is unclear because existing fish passage programs do not address the same physical, social, and economic issues associated with fish passage past the Oroville Facilities.

G-AQUA1.10 EVALUATION OF PROJECT EFFECTS ON INSTREAM FLOWS AND FISH HABITAT (SP-F16)

Instream flows have been suggested to be the key limiting factor for Chinook salmon and steelhead production in the Feather River (USFWS 1995), potentially limiting spawning and rearing habitat for anadromous salmonids. The general objective of this study plan was to analyze flow-habitat relationships to evaluate potential project effects on spawning and rearing habitat for anadromous salmonids within the study area. The general approach of this study was to review and evaluate existing information, conducting additional analyses of existing data using recent modeling and analytical techniques.

G-AQUA1.10.1 Evaluation of Project Effects on Instream Flows and Fish Habitat (Phase 1) (Draft Report)

G-AQUA1.10.1.1 Background Summary

DWR and other participating agencies have been collecting physical and biological data on the Feather River downstream of Oroville Dam for many years. One aspect of these studies is the application of the Instream Flow Incremental Methodology (IFIM) and its associated PHABSIM computer models, which create indices describing the physical habitat suitability of alternative instream flow releases.

PHABSIM incorporates highly technical hydraulic models linked to criteria regarding the suitability of fish species habitat to compute these indices; the Oroville Facilities Relicensing Environmental Work Group requested an independent review. All available reports, articles, and summary data were assembled by DWR and reviewed. Information included instream flow study plans, data compilations, hydraulic data files, draft results, aerial photographs, fish spawning and rearing observations, and related materials.

The instream flow studies conducted by DWR provide a significant and useful tool for evaluating potential flow management strategies. The IFIM process used by DWR remains the most defensible method available for identifying and establishing environmental flows and is considered state-of-the-art internationally for in-depth studies of flow and instream biota interactions. The studies are strong in terms of general river representation and the acquisition and use of site-specific habitat criteria data for the target fish species (Chinook salmon and steelhead).

The general objective was to analyze flow-habitat relationships to evaluate potential project effects on spawning and rearing habitat for anadromous salmonids within the study area. The Phase 1 objective was to examine existing PHABSIM studies for their applicability to the needs of Oroville Facilities study plans. This included evaluating the changes in the Feather River since these other studies were completed, as those changes apply to determination of the amount of available habitat. Additionally, this evaluation included an assessment of the habitat suitability criteria generated in previous PHABSIM studies, as well as recent habitat usage data collected by DWR.

G-AQUA1.10.1.2 Report Conclusions

Two general areas of the DWR studies were identified as needing to be addressed to bring them to the highest acceptable standards. First, additional river study sites should be selected for collection of supplemental hydraulic data, using improved measurement and modeling techniques, for the following reasons:

- The cross sections (transects) used do not account for possible geomorphic change in the river since they were established and measured.
- Some river habitat types were under-represented or not represented.
- The process of transect selection was not strictly objective.
- Partial transects (mostly split channels) were merged in with complete ones.

At least 12 one-dimensional transects are recommended, along with 2 two-dimensional sites, after which all hydraulic data should be recalibrated. Second, supplemental biological data should be collected (much of which is currently being acquired by DWR) to strengthen information on aspects such as:

- Focal versus mean column velocity use;
- Use of greater depths by larger fish; and
- Correction of habitat use data with habitat availability data.

Following completion of this data collection effort, all data should be pooled together and new final habitat suitability criteria should be created and linked with the hydraulic data to create new flow suitability indices. Recommendations, therefore, are as follows:

- Collect additional targeted hydraulic data.
- Recalibrate the amended hydraulic database.
- Determine the habitat suitability of deep water.

- Create new combined and adjusted habitat suitability criteria.
- Validate the new final habitat suitability criteria.

G-AQUA1.10.2 Evaluation of Project Effects on Instream Flows and Fish Habitat (Phase 2)

G-AQUA1.10.2.1 Background Summary

DWR and DFG jointly conducted an instream flow study using PHABSIM beginning in 1991. Initial analysis suggested that the maximum area of suitable spawning habitat for Chinook salmon between the Fish Barrier Dam and the Thermalito Afterbay Outlet occurred at a flow of approximately 1,000 cfs (Sommer et al. 2001). In the 15 miles of river between the Thermalito Afterbay Outlet and Honcut Creek, the maximum area of suitable spawning habitat was indicated to occur at a flow of about 3,250 cfs (Sommer et al. 2001).

A review was conducted to examine existing PHABSIM results, collect and analyze additional hydraulic and biologic data to supplement existing data, and establish tools to evaluate future potential operational scenarios and other PM&E measures. The review was completed in two phases: the Phase 1 review of existing information was previously reported in TRPA (2002) and the remainder of the work is presented in the report for SP-F16, Phase 2. Phase 2 derived from the conclusions of Phase 1 and includes collection of supplemental hydraulic data and incorporation of additional biological data to calculate revised habitat-flow relationships in the two reaches of the Feather River. Phase 2 establishes tools to evaluate future potential operational scenarios and other PM&E measures.

G-AQUA1.10.2.2 Report Conclusions

Principal activities of Phase 2 included placing supplemental PHABSIM cross section transects, measuring patterns of depth, velocity, substrate, and cover along the transects, merging old and new data, calibrating revised PHABSIM computer models, and computing updated habitat indexes relating suitable spawning habitat to discharge in the two reaches.

The Phase 2 study corrected one of the primary weaknesses of the original PHABSIM studies, which was the excessive weight given to too few transects. Weights given to the other habitat types were similarly reduced, thereby decreasing the potential for habitat index results to be driven by a small sample size.

The Weighted Useable Area/relative suitability index results for Chinook salmon and steelhead spawning are a combination of physical habitat conditions in the Feather River and habitat suitability criteria developed from the Feather River. The revised analysis showed Chinook spawning habitat between the Fish Barrier Dam and Thermalito Afterbay Outlet to be maximized between 800 and 825 cfs, and between the outlet and Honcut Creek at 1,200 cfs.

As noted above, there are differences in habitat index response for the modeled species between the upper and lower reaches of the Feather River study area. These differences may be caused either by channel change since project construction or by natural channel characteristics, and PHABSIM cannot determine which (or both) may be the principal cause. PHABSIM is a “fixed bed” model, and results will remain applicable only if the river channel maintains similar proportions of mesohabitat types, otherwise known as dynamic equilibrium. If the channel evolves through overall aggradation or degradation (often from changes in bedload volume), the habitat indices will no longer remain applicable. Natural changes or management actions that create an observable or quantifiable difference in existing channel characteristics would warrant a replication of the current study.

G-AQUA1.11 PROJECT EFFECTS ON PREDATION OF FEATHER RIVER JUVENILE ANADROMOUS SALMONIDS (SP-F21)

The Oroville Facilities, including dams and other artificial structures, and Oroville Facilities operations, including flow and water temperature regimes, may create in-river conditions that are favorable for predators of juvenile anadromous salmonids (NOAA Fisheries 2000; Roby et al. 1997). Specifically, project facilities and operations may influence habitat conditions in the Feather River for predator species that feed on juvenile salmonids, potentially altering predation pressure and possibly resulting in artificially enhanced predation rates on juvenile salmonids. The literature reviews associated with this study plan reviewed and summarized studies that investigate the effects of artificial structures and project operations on predation of juvenile salmonids.

G-AQUA1.11.1 Life History and Habitat Requirements of Predator and Prey Species of Primary Management Concern (Task 1)

The objectives and information needs of SP-F21, Task 1, SP-F3.2, Task 2, and SP-F15, Task 1 were found to be similar, so the results were presented together. The results of this study are provided in SP-F3.2, Task 2, described above.

G-AQUA1.11.2 Fish Distribution in the Feather River below the Thermalito Diversion Dam to the Confluence with the Sacramento River (Task 2; SP-F3.2, Task 1)

The purpose of the reports for SP-F3.2, Tasks 1, 4, and 5, and SP-F21, Task 2, were to establish an informational baseline describing the current knowledge of fish distribution in the Feather River. The study plan results were presented together, and the results are provided in SP-F3.2, Task 1,4,5, described above.

G-AQUA1.11.3 Project Effects on Predation of Feather River Juvenile Anadromous Salmonids (Task 3)

G-AQUA1.11.3.1 Background Summary

The purpose of SP-F21, Task 3, was to summarize existing literature on predation of juvenile anadromous salmonids associated with artificial structures and hydroelectric power project operations in river systems other than the Feather River, and to determine their applicability to the Feather River. In addition, available literature on the effects of the Oroville Facilities and operations on predation of juvenile anadromous salmonids in the lower Feather River was evaluated. Comparisons of species composition, in-river conditions and artificial structures, and operations that alter natural conditions were used to assess applicability of other river systems to the Oroville Facilities and the lower Feather River. The results of this study provide information on the likely effects on the level of predation on juvenile anadromous salmonids associated with project structures and operations.

G-AQUA1.11.3.2 Report Conclusions

Most studies on predation of juvenile anadromous salmonids associated with dam operations focus on juvenile fish bypass facilities. According to the body of available literature, high predation rates at most hydroelectric power facilities generally are a result of unnaturally high concentrations of juveniles, stress related to passage through the facilities, and disorientation of juveniles associated with passing through the facilities. Although the Oroville Facilities do not currently contain facilities for juvenile fish passage, similar conditions can be created by project operations and facilities. For example, the Fish Barrier Dam, which forces most anadromous salmonid spawning to occur in the Low Flow Channel, contributes to high concentrations of juvenile salmonids. Additionally, high-flow events at the Thermalito Afterbay Outlet may create turbulent conditions that cause juvenile salmonids to become disoriented, making them more susceptible to predation.

Water temperatures reportedly appear to be the most significant factor in determining species compositions in the lower Feather River (Seesholtz et al. 2003). Counts of known predators on juvenile anadromous salmonids in the Low Flow Channel are reported to be very low (Seesholtz et al. 2003). Naturally spawned steelhead are an exception because little is known about their relative abundance. Because water temperatures in the Low Flow Channel are relatively low, it is doubtful that significant predation by non-salmonid species occurs in the reach. However, significant numbers of predators reportedly do exist in the High Flow Channel below the Thermalito Afterbay Outlet (Seesholtz et al. 2003). Based on the relative abundance of predatory species in the High Flow Channel, it can be assumed that some predation on juvenile anadromous salmonids occurs in the reach.

One aspect of Oroville Facilities operations that may enhance predation in the High Flow Channel is that the high density of juvenile salmonids in the Low Flow Channel may cause early emigration of juvenile salmonids. Because juvenile rearing habitat in the Low Flow Channel is limited, juveniles may be forced to emigrate from the area early as a result of competition for resources. Relatively small juvenile salmonids may be less capable of avoiding predators than those that rear to a larger size in the Low Flow Channel before beginning their seaward migration through the High Flow Channel.

Recent studies have shown high numbers of juvenile Chinook salmon emigrating from the lower Feather River (Seesholtz et al. 2003). At the same time, high spawning escapements, equivalent to pre-dam years, reportedly have been observed (Yoshiyama et al. 2000). Additionally, a review of the literature indicated that environmental conditions in the lower Feather River are less suitable than those reported in the body of literature as optimal for predators of anadromous salmonids, particularly during the peak outmigration period. Analysis of recovery data from coded wire tags suggests that mortality of hatchery-reared Feather River Chinook salmon released in the Feather River is high, but that it is very similar to mortality observed at downstream locations, beyond potential project effects. Therefore, it does not appear likely that continued operation of the Oroville Facilities under current operating conditions would create conditions favoring unnaturally high predation rates on juvenile anadromous salmonids in the lower Feather River. However, multiple confounding variables such as differences in river size, water temperature regimes, and migration distance between the Sacramento and Feather Rivers makes it difficult to interpret the differences in survival rates between juvenile Chinook salmon released at different locations.

G-AQUA1.11.4 Predation PM&E Literature Review (Task 4) (Interim Report)

G-AQUA1.11.4.1 Background Summary

Oroville Facilities features and artificial structures may produce turbulence, eddies, and other in-river conditions that are advantageous for predatory species. Therefore, this study was conducted to summarize previously conducted predation management and monitoring plans designed to decrease predation on juvenile anadromous salmonids and assess their potential applicability to the Feather River and the Oroville Facilities. The applicability of PM&E measures conducted in other river basins to the Feather River was evaluated qualitatively, and the degree of applicability was used to conceptually evaluate the potential value associated with implementing a similar PM&E measure in the Feather River.

A “reconnaissance level” literature review was conducted to summarize predation management and monitoring studies to determine their effectiveness and their potential applicability to the Oroville Facilities. The purpose of the reconnaissance level approach for this interim report was to provide an overview and categorization of the variety of types of predation management and monitoring studies, a synopsis of study results, and a statement regarding their potential applicability to the Oroville Facilities. This information was to be reviewed by the Environmental Work Group, which would provide guidance on the types of management and monitoring programs that merit further investigation and documentation during the identification and evaluation of potential PM&E measures.

G-AQUA1.11.4.2 Report Conclusions

A total of 30 different predation management and monitoring studies were reviewed and summarized in this interim report. The types of predation management studies reviewed thus far fall into the following generalized categories:

- Removal of the predatory species (mainly northern pikeminnow (*Ptychocheilus oregonensis*) using a variety of methods;
- Release of hatchery-reared prey species at varying times and locations;
- Eradication of spawning fish, newly hatched fry, and pikeminnow eggs through a variety of methods;
- Modifications to the water management regime;
- Evaluations of predator consumption rates;
- Model simulations to determine interactions between predators and prey; and
- Identification of the characteristics of predatory species.

Of the literature reviewed, it appeared that most of the management plans could conceptually be applied to the conditions at the Oroville Facilities. Most of the predation management literature reviewed did not use rigorous scientific methods of sampling or monitoring, nor did they document conditions before and after implementation of predation management. Consequently, most of the reviewed literature provided only qualitative and subjective interpretation of study results. Therefore, the specific potential benefits of implementing any of these plans are not readily quantifiable.

G-AQUA1.12 REFERENCES

G-AQUA1.12.1 Printed References

Barnhart, R. A. 1986. Species Profiles: Life Histories and Environmental Requirements of Coast Fishes and Invertebrates (Pacific Southwest)—Steelhead. U.S. Fish and Wildlife Service Biological Report 82 (11.60). U.S. Army Corps of Engineers, TR EL-82-4.

Bartley, D. M., A. E. Graham, and B. Bentley. 1990. Biochemical Genetic Detection of Natural and Artificial Hybridization of Chinook and Coho Salmon in Northern California. Transactions of the American Fisheries Society 119:431-437.

Becker, C. D., D. A. Neitzel, and D. H. Fickeisen. 1982. Effects of Dewatering on Chinook Salmon Redds: Tolerance of Four Development Phases to Daily Dewaterings. Transactions of the American Fisheries Society 111:624-637.

Becker, C. D., D. A. Neitzel, and C. S. Abernethy. 1983. Effects of Dewatering on Chinook Salmon Redds: Tolerance of Four Development Phases to One-Time Dewatering. North American Journal of Fisheries Management 3:373-382.

Berman, C. H., and T. Quinn. 1991. Behavioural Thermoregulation and Homing by Spring Chinook Salmon, *Oncorhynchus tshawytscha* (Walbaum), in the Yakima River. Journal of Fish Biology 39:301-312.

Bilby, R. E., P. A. Fransen, P. A. Bisson, and J. K. Walter. 1998. Response of Juvenile Salmon (*Onchorhynchus kisutch*) and Steelhead (*Onchorhynchus mykiss*) to the Addition of Salmon Carcasses to Two Streams in Southwestern Washington, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 39:426-447.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. In: W. R. Meehan (ed.), Influences of Forest and Rangeland Management of Salmonid Fishes and their Habitats, pp. 83-138. American Fisheries Society Special Publication 19.

Bradford, M. J. 1997. An Experimental Study of Stranding of Juvenile Salmonids on Gravel Bars and in Sidechannels during Rapid Flow Decreases. Regulated Rivers: Research and Management 13:395-401.

Bradford, M. J., G. C. Taylor, J. A. Allan, and P. S. Higgins. 1995. An Experimental Study of the Stranding of Juvenile Coho Salmon and Rainbow Trout During Rapid Flow Decreases Under Winter Conditions. North American Journal of Fisheries Management 15:473-479.

Brett, J. R. 1952. Temperature Tolerance in Young Pacific Salmon, Genus Oncorhynchus. Journal of the Fisheries Research Board of Canada 9:265-323.

Cech Jr., J. J., and C. A. Myrick. 1999. Steelhead and Chinook Salmon Bioenergetics: Temperature, Ration, and Genetic Effects. Technical Completion Report, Project No. UCAL-WRC-W-885. University of California Water Resources Center.

Cherry, D. S., K. L. Dickson, and J. Jr. Cairns. 1975. Temperatures Selected and Avoided by Fish at Various Acclimation Temperatures. Journal of the Fisheries Research Board of Canada 32:485-491.

Crawshaw, L. I. 1977. Physiological and Behavioral Reactions of Fishes to Temperature Change. Journal of the Fisheries Research Board of Canada 34:730-734.

DFG (California Department of Fish and Game). 1990. Draft Management Plans for Oroville and Spenceville Wildlife Areas. Wildlife Management Division, Sacramento, California.

DFG (California Department of Fish and Game). 2003. Strategic Plan for Trout Management: A Plan for 2004 and Beyond. Sacramento, California. November 2003.

Dibble, E. D., K. J. Killgore, and S. L. Harrel. 1996. Assessment of Fish-Plant Interactions. In: L. E. Miranda and D. R. Devries (eds.), Mulitdimensional Approaches to Reservoir Fisheries Management, pp. 357-372. American Fisheries Society, Symposium 16.

DWR (California Department of Water Resources). 1999. 1999 Lake Oroville Annual Report of Fish Stocking and Fish Habitat Improvements. Oroville Facilities Relicensing, FERC Project No. 2100-054.

DWR (California Department of Water Resources). 2000. Study Plan: Steelhead and Spring-Run Salmon Redd Dewatering and Juvenile Stranding in Lower Feather River. Sacramento, California.

DWR (California Department of Water Resources). 2001. Initial Information Package, Relicensing of the Oroville Facilities. Oroville Facilities Relicensing, FERC Project No. 2100. Sacramento, California. January 2001.

DWR (California Department of Water Resources). 2002a. Distribution of Fishes in the Lower Feather River in Relation to Season and Temperature, 1997-2001. August 2002.

DWR (California Department of Water Resources). 2002b. Emigration of Juvenile Chinook Salmon in the Feather River, 1998-2001. Division of Environmental Services, Sacramento, California.

DWR (California Department of Water Resources). 2002c. Study Plan Package Presented to the Plenary Group by the Collaborative Work Groups: Land Use, Land Management & Aesthetics, Recreation & Socioeconomics, Cultural Resources, Engineering & Operations, Environmental. Sacramento, California.

DWR (California Department of Water Resources). 2003a. Lake Oroville Salmonid Stocking Program.

DWR and USBR (California Department of Water Resources and U.S. Bureau of Reclamation). 2000. Biological Assessment—Effects of the Central Valley Project and State Water Project on Steelhead and Spring-run Chinook Salmon. Appendices A through I. Sacramento, California.

Evans, D. O. 1990. Metabolic Thermal Compensation by Rainbow Trout: Effects on Standard Metabolic Rate and Potential Usable Power. Transactions of the American Fisheries Society 119:585-600.

Fausch, K. D., and C. E. Torgersen. 2002. Landscape to Riverscapes: Bridging the Gap between Research and Conservation of Stream Fishes. Bioscience 52:

Finney, B. P., I. Gregory-Eaves, J. Sweetnam, M. S. V. Douglas, and J. P. Smol. 2000. Impacts of Climatic Change and Fishing on Pacific Salmon Abundance Over the Past 300 Years. Science 290:795-799.

Higgins, P. S., and M. J. Bradford. 1996. Evaluation of a Large-Scale Fish Salvage to Reduce the Impacts of Controlled Flow Reductions in a Regulated River. North American Journal of Fisheries Management 16:666-673.

Hokanson, K. E. F., C. F. Kleiner, and T. W. Thorslund. 1977. Effects of Constant Temperatures and Diel Temperature Fluctuations on Specific Growth and Mortality Rates and Yield of Juvenile Rainbow Trout, *Salmo gairdneri*. Journal of the Fisheries Research Board of Canada 34:639-648.

Hughes, R. M., G. E. Davis, and C. E. Warren. 1978. Temperature Requirements of Salmonids in Relation to Their Feeding, Bioenergetics, Growth, and Behavior. Research Grant B-041-ORE. Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

Hunter, M. A. 1992. Hydropower Flow Fluctuations and Salmonids: A Review of the Biological Effects, Mechanical Causes, and Options for Mitigation. Technical Report No. 119. Washington Department of Fisheries, Olympia, Washington.

Jones & Stokes. 1998. Assessment of Potential Fish Stranding Impacts Associated with April 1998 Flow Reductions on the Yuba River. Prepared for the Yuba County Water Agency, Marysville, California. Sacramento, California.

Jones & Stokes. 1999. An Evaluation of Fish Stranding and Entrapment on the Lower Yuba River During a Controlled, Short-term Flow Reduction. Prepared for the Yuba County Water Agency, Marysville, California. Sacramento, California.

Killgore, K. J., R. P. Morgan, and N. B. Rybicki. 1989. Distribution and Abundance of Fishes Associated with Submersed Aquatic Plants in the Potomac River. North American Journal of Fisheries Management 9:101-111.

Leary, R. F., F. W. Allendorf, and G. K. Sage. 1995. Hybridization and Introgression between Introduced and Native Fish. American Fisheries Society Symposium 15:91-101.

Lee, D. P. 1999. Water Level Fluctuation Criteria for Black Bass in California Reservoirs. Reservoir Research and Management Project: Informational Leaflet No. 12:

McCullough, D. A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon. Report No. EPA 910-R-99-010. U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

McEwan, D., and T. A. Jackson. 1996. Steelhead Restoration and Management Plan for California. California Department of Fish and Game. February 1996.

Minkawa, N. and R. I. Gara. 1999. Ecological Effects of a Chum Salmon (Oncorhynchus keta) Spawning Run in a Small Stream of the Pacific Northwest. Journal of Freshwater Ecology 14:327-335.

Minkawa, N., R. I. Gara, and J. M. Honea. 2002. Increase Growth Rate and Community Biomass of Stream Insects Associated With Salmon Carcasses. Journal of the North American Benthological Society 21:651-659.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Fish Species of Special Concern in California. California Department of Fish and Game, Sacramento, California.

Myrick, C. A. 1998. Temperature, Genetic, and Ration Effects on Juvenile Rainbow Trout (*Oncorhynchus mykiss*) Bioenergetics. University of California, Davis, California.

Myrick, C. A., and J. J. Cech Jr. 2000. Growth and Thermal Biology of Feather River Steelhead Under Constant and Cyclical Temperatures. Technical Completion Report. California Department of Water Resources.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1998. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California. Federal Register, 63(53):13347-13371, March 19, 1998.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1999. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two Chinook Salmon Evolutionarily Significant Units (ESUs) in California. Federal Register, 64(179):50394-50415, September 16, 1999.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 2000. Predation on Salmonids Relative to the Federal Columbia River Power System. White Paper. National Marine Fisheries Service, Northwest Fisheries Center, Seattle, Washington.

Olson, F. W., and R. G. Metzgar. 1987. Downramping to Minimize Stranding of Salmonid Fry. In: B. W. Clowes (ed.), Waterpower '87, Proceedings of the International Conference on Hydropower, pp. 691-701. American Society of Civil Engineers, New York.

Painter, R. E., L. H. Wixom, and S. N. Taylor. 1977. An Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River. Prepared by the California Department of Fish and Game for the California Department of Water Resources re: Federal Power Commission License No. 2100.

Perry, E. A. 1995. Salmon Stock Restoration and Enhancement: Strategies and Experiences in British Columbia. American Fisheries Society Symposium 15:152-160.

Powers, P. D., and J. F. Orsborn. 1985. Analysis of Barriers to Upstream Migration: An Investigation of the Physical and Biological Conditions Affecting Fish Passage Success at Culverts and Waterfalls. BPA Report No. DOE/BP-36523-1.

Quinn, T. P. 1997. Homing, Straying, and Colonization. In: W. S. Grant (ed.), Genetic Effects of Straying on Non-Native Hatchery Fish into Natural Populations, pp. 73-85. U.S. Department of Commerce.

Reiser, D. W., and T. C. Bjornn. 1979. Influence of Forest and Rangeland Management of Anadromous Fish Habitat in Western North America—Habitat Requirements of Anadromous Salmonids. USDA Forest Service General Technical Report PNW-96.

Reiser, D. W., and R. R. Whitney. 1983. Effects of Complete Redd Dewatering on Salmonid Egg-Hatching Success and Development of Juveniles. Transactions of the American Fisheries Society 112:532-540.

Rich, A. A. 1987. Report on Studies Conducted by Sacramento County to Determine the Temperatures Which Optimize Growth and Survival in Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*). Prepared for the County of Sacramento.

Roby, D. D., D. P. Craig, S. Adamany, and K. Collis. 1997. Avian Predation on Juvenile Salmonids in the Lower Columbia River. BPA Report No. DOE/BP-33475-1. Annual Report 1997 to Bonneville Power Administration.

Schuldt, J. A. and A. E. Hershey. 1995. Effect of Salmon Carcass Decomposition on Lake Superior Tributary Streams. Journal of the North American Benthological Society 14:259-268.

Seesholtz, A., B. Cavallo, J. Kindopp, R. Kurth, and M. Perrone. 2003. Lower Feather River Juvenile Communities: Distribution, Emigration Patterns, and Association with Environmental Variables. Early Life History of Fishes in the San Francisco Estuary and Watershed. California Department of Water Resources.

Sommer, T., D. McEwan, and R. Brown. 2001. Factors Affecting Chinook Salmon Spawning in the Lower Feather River. In: R. L. Brown (ed.), Contributions to the Biology of Central Valley Salmonids, pp. 269-297. California Department of Fish and Game, Sacramento, California.

Sullivan, K., D. J. Martin, R. D. Cardwell, J. E. Toll, and S. Duke. 2000. An Analysis of the Effects of Temperature on Salmonids of the Pacific Northwest with Implications for Selecting Temperature Criteria. Sustainable Ecosystems Institute, Portland, Oregon. December 2000.

USBR (U.S. Bureau of Reclamation). 2004. Long-Term Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment. Mid-Pacific Region, Sacramento, California.

USFWS (U.S. Fish and Wildlife Service). 1995. Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California. Vol. 2. Stockton, California.

Ward, B. R. and P. A. Slaney. 1988. Life History and Smolt-to-Adult Survival of Keogh River Steelhead Trout (*Salmo gairdneri*) and the Relationship to Smolt Size. Canadian Journal of Fisheries and Aquatic Science 45:1110-1122.

Wipfli, M. S., J. Hudson, and J. Caouette. 1998. Influence of Salmon Carcasses on Stream Productivity: Response of Biofilm and Benthic Macroinvertebrates in Southeastern Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 55:1503-1511.

Withler, I. L. 1966. Variability in Life History Characteristics of Steelhead Trout (*Salmo gairdneri*) Along the Pacific Coast of North America. Journal Fisheries Research Board of Canada 23:365-393.

Winfree, R. A., G. A. Kindschi, and H. T. Shaw. 1998. Elevated Water Temperature, Crowding, and Food Deprivation Accelerate Fin Erosion in Juvenile Steelhead. The Progressive Fish-Culturist 60:192-199.

Wrenn, W. B., D. R. Lowery, M. J. Maceina, and W. C. Reeves. 1996. Relationship between Largemouth Bass and Aquatic Plants in Guntersville Reservoir, Alabama. In: L. E. Miranda and D. R. Devries (eds.), Multidimensional Approaches to Reservoir Fisheries Management, pp. 382-393. American Fisheries Society, Symposium 16.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2000. Chinook Salmon in the California Central Valley: An Assessment. Fisheries 25:6-20.

G-AQUA1.12.2 Personal Communications

Cox, W. T., Senior Fish Pathologist, DFG, Sacramento, California; E-mail communication with E.Theis, Fishery Biologist, NOAA, Sacramento, California; DFG Disease Concerns Regarding Upstream Passage, September 12, 2003.

Hanson, C., Hanson Environmental, Inc.; personal communication with A. Pitts, Associate Environmental Scientist, SWRI, Sacramento, California; April 21, 2003.

Kuenster, G., Biologist, DWR, Sacramento, California; e-mail communication with A. Pitts, Associate Environmental Scientist, SWRI, Sacramento, California; October 9, 2003.

Martin, R., DWR, Sacramento, California; e-mail communication with J. Hornback, Environmental Scientist, SWRI, Sacramento, California; August 28, 2003.

This page intentionally left blank.

APPENDIX G-AQUA2
AQUATIC RESOURCES
METHODOLOGY

Appendix G-AQUA2 describes the processes and bases used to evaluate the No-Action Alternative, the Proposed Action, and Alternative 2 and their potential effects on aquatic and fisheries resources. Implementation of any of the alternatives is anticipated to produce two distinct types of effects: (1) direct effects related to construction activities or changes in Oroville Facilities operations; and (2) indirect effects related to changes in hydrologic conditions. The potential effects related to changes in hydrologic conditions may affect environmental resources beyond the project study area and are addressed under the cumulative analysis (see Section 5.7.4, Cumulative Effects).

Both quantitative and qualitative assessments were completed to evaluate potential effects on aquatic resources. Qualitative analyses were conducted based on a combination of literature reviews, study plan results, and the best professional judgment and experience of qualified individuals. These qualitative analyses examined potential effects associated with all of the following:

- Fish interactions (e.g., competition for food or habitat, genetic introgression, predation);
- Fisheries resources management (stocking program and disease management); and
- Potential effects on Chinook salmon spawning segregation, macroinvertebrate populations, woody debris distribution, gravel recruitment, and water quality criteria for aquatic life in relationship to aquatic resources and habitat quality.

Hydrologic and water temperature modeling was performed to provide a quantitative basis from which to assess potential effects of the alternatives on fisheries resources and aquatic habitats within the project study area.

G-AQUA2.1 HYDROLOGIC MODEL SUMMARY

Extensive hydrologic and water temperature modeling was performed to provide a quantitative basis from which to assess potential effects of each alternative on fisheries resources and aquatic habitats within the project study area. Model outputs of project operations used in the quantitative analyses of effects on aquatics and fisheries resources included reservoir water surface elevation, lower Feather River flows, and lower Feather River water temperatures. Appendix C, Modeling Tools and Results, provides a detailed discussion of the hydrologic modeling process and its application to the Oroville Facilities project analysis, including: (1) the primary assumptions and model inputs used to represent hydrologic, regulatory, structural, and operational conditions; and (2) the simulations performed from which effects were estimated.

The models used in this analysis (CALSIM II, HYDROPS^{TM}, WQRSS, and other water temperature models) have been developed for comparative planning purposes, rather than for predicting actual river and reservoir conditions at specific locations and times. Although mathematically precise, these models should be viewed as having "reasonable detection limits." Establishing reasonable detection limits is useful when analyzing the modeling output for effect assessment purposes. Additionally, interpreting model output in terms of reasonable detection limits prevents making effect determinations beyond the model's capabilities and its ability to measure changes.

Data from the models are reported to the nearest thousand acre-feet (taf) and feet in elevation above mean sea level (msl) for reservoir conditions, cubic feet per second (cfs) for instream flow, and tenths of degrees Fahrenheit (°F) for river temperatures; however, these values were rounded to the nearest reasonable value when interpreting differences for a given parameter between two modeling simulations. For example, 2 simulations having instream flows at a given location within 1 percent of each other were considered to be essentially equivalent. Differences in reservoir storage were evaluated similarly. Modeled output was similarly rounded for all output parameters to ensure that the effect assessments would be reasonable.

The methodologies used to predict comparative operational scenarios under the No-Action Alternative, the Proposed Action, and Alternative 2 are included below, along with the bases for comparison. Methods for quantitatively determining potential effects on aquatic resources related to potential changes in reservoir storage, reservoir water surface elevations, river flows, and river water temperatures are presented in Section G-AQUA2.2. Section G-AQUA2.3 describes the qualitative methods used to determine potential effects on habitat components; this description is followed by species-specific discussions for lower Feather River fish species of primary management concern (Section G-AQUA2.4). Methodology describing the synthesis of results of the analyses to identify potential effects on individual fish species is discussed in Section G-AQUA2.5, Determination of Effects.

G-AQUA2.2 QUANTITATIVE EVALUATION USING MODEL OUTPUTS

The model outputs provide a basis for comparison of the No-Action Alternative, the Proposed Action, and Alternative 2. They allow identification of the types of changes that could be expected to occur with implementation of a specified set of operational conditions. Reservoir storage, river flow and stage elevation, and water temperature output for the period modeled should not be interpreted or used as definitive absolutes depicting actual river and reservoir conditions in the future. Rather, model outputs for each alternative can be used as a basis of comparison to determine:

- Whether reservoir storage or river flows and water temperatures would be expected to change with implementation of each alternative;
- During what time periods there could be changes to reservoir storage, reservoir surface elevation, river flow, and water temperature; and
- Approximately how large, how lengthy, and how frequent such changes could be with implementation of each alternative.

Modeling output provided hourly values for each year of the hydrologic simulation period modeled for reservoir storage and water surface elevation, river flows, and water temperatures. Daily mean values of these model outputs were used as the basis of comparison for the aquatic resource assessments associated with each alternative.

Modeling results were evaluated quantitatively against criteria that are indicators of biological effects associated with changes in Oroville Facilities operations, including changes in reservoir surface elevations, lower Feather River flows, and lower Feather River water temperatures. These evaluation criteria were developed for each species of primary management concern and were based on review of available literature and study plan results. Evaluation criteria used in the analysis are described in detail in Section G-AQUA2.2.1, Operations-related Effects on Reservoir Fish Species; Section G-AQUA2.2.2, Flow-related Effects on Lower Feather River Fish Habitat; and Section G-AQUA2.2.3, Water Temperature–related Effects on Lower Feather River Fish Habitat, of this appendix.

G-AQUA2.2.1 Operations-related Effects on Reservoir Fish Species

Implementation of the No-Action Alternative, the Proposed Action, or Alternative 2 could result in alterations to storage volumes and water surface elevations within Oroville Facilities reservoirs. Day-to-day operations and changes in runoff patterns could result in changes in the timing and magnitude of reservoir drawdown. The resulting fluctuation of the reservoirs could potentially affect recreationally important reservoir fish species of primary management concern. Methods used to determine potential effects on reservoir fish species within Lake Oroville and other project reservoirs are discussed below.

The analysis of aquatic biological resources focuses on how reductions and fluctuations in the coldwater pools and water surfaces of Oroville Facilities reservoirs could affect coldwater and warmwater fish habitat and aquatic resources. For example, the seasonal timing and rate of reductions in reservoir water surface elevation during the black bass spawning period determines the proportion of bass nests that potentially could be dewatered. Bass populations reportedly require approximately 60 percent nest success to remain self-sustaining (Friesen 1998; Goff 1996; Hunt and Annett 2002; Hurley 1975; Knotek and Orth 1998; Kramer and Smith 1962; Latta 1956 in Steinhart 2004; Lukas and Orth 1995; Neves 1975; Philipp et al. 1997; Raffetto et al. 1990; Steinhart 2004; Turner and MacCrimmon 1970). Reservoir coldwater pool volume is affected by project releases and coldwater pool is required for coldwater fish habitat. Changes in the proportion of available coldwater pool volume are an indicator of the potential changes in the amount of available coldwater fish habitat.

Extensive sediment deposits, or sediment wedges, were identified in all four major tributaries of the Feather River at approximately 720 feet msl and below during field investigations conducted during October and December 2002. Sediment wedges are subject to periodic exposure events when the reservoir surface elevation drops below the elevations at which the wedges occur. Such exposure events may inhibit or prohibit the movement of fish from the reservoir to tributaries upstream of Lake Oroville.

Currently, the upper Feather River watershed is reportedly producing high sediment loads because of accelerated erosion. The Natural Resources Conservation Service's East Branch North Fork Feather River Erosion Inventory Report estimated that 90 percent of the erosion in the 1,209-square-mile study area was accelerated erosion (NRCS 1998). Accelerated erosion is a soil loss greater than natural geologic conditions, which can reduce reservoir capacity, degrade water quality, and harm fish and wildlife.

The presence or absence of exposed sediment wedges is a potentially important factor to be considered in the analysis of project operations on aquatic resources. If sediment wedges are exposed during large portions of the upstream migration periods of spring-run Chinook salmon, fall-run Chinook salmon, or steelhead, access to upstream spawning habitat could be affected substantially. In contrast, if the sediment wedges are not exposed for large portions of the migration periods of anadromous salmonids, it is likely that upstream migration would not be affected substantially by sediment wedge exposure. Additionally, the absence of exposed sediment wedges may allow for the undesirable upstream migration of stocked salmonid species or warmwater species currently in Lake Oroville.

As reported in Study Plan Report SP-G1, sediment wedges are dynamic and mobilize differently based on different hydrologic conditions in tributaries and reservoirs. If the reservoir elevation is greater than the uppermost elevation of the wedge, lentic conditions predominate and wedge material does not move appreciably. If the reservoir elevation is lower than the wedge material, fluvial conditions predominate and typical stream processes transport wedge materials downstream. Because of the dynamic nature of the sediment wedges in the upper Feather River/Lake Oroville interface, it is difficult to assess the frequency, magnitude, and duration of sediment wedge exposure over time and its resulting effect on fisheries interactions in the reservoir and upstream tributaries. Further, the ability to determine that an exposed sediment wedge is a potential fish migration barrier depends on a number of conditions that are variable and cannot be reliably predicted. Therefore, a qualitative evaluation of the potential effects of sediment wedge exposure and resulting fish migration conditions was performed for the No-Action Alternative, the Proposed Action, and Alternative 2.

G-AQUA2.2.1.1 Warmwater Reservoir Fish Species of Primary Management Concern

Warmwater fish species present in Lake Oroville (including largemouth bass, smallmouth bass, spotted bass, green sunfish, crappie, and catfish) use the warm upper layer of the reservoir and nearshore littoral habitats throughout most of the year. Therefore, seasonal changes in reservoir storage, as they affect reservoir water surface elevation, and the rates at which the water surface elevation changes during specific periods of the year, can directly affect the reservoir's warmwater fisheries resources. Reduced water surface elevations can potentially reduce the availability of nearshore littoral habitats used by warmwater fish for spawning and rearing, thereby reducing spawning and rearing success and subsequent year-class strength. In addition, decreases in reservoir water surface elevation during the primary spawning period for warmwater fish nest building may result in reduced initial year-class strength as a result of nest "dewatering."

Spawning and Initial Rearing

A two-phased approach was used to assess potential effects of changes in reservoir water surface elevation on warmwater fish in Lake Oroville and Thermalito Afterbay. First, the magnitude of change (feet msl) in reservoir water surface elevation during each month of the primary spawning period for nest-building fish (March through June) was determined for each alternative, then compared to that modeled for the basis of comparison. Review of available literature suggests that, on average, self-sustaining black bass populations in North America experience a rate of nest success (i.e., the nest produces swim-up fry) of 60 percent or more (Friesen 1998; Goff 1996; Hunt and Annett 2002; Hurley 1975; Knotek and Orth 1998; Kramer and Smith 1962; Latta 1956 in Steinhart 2004; Lukas and Orth 1995; Neves 1975; Philipp et al. 1997; Raffetto et al. 1990; Steinhart 2004; Turner and MacCrimmon 1970).

A study by the California Department of Fish and Game (DFG), which examined the relationship between rates of fluctuation in reservoir water surface elevation and nesting success for black bass, suggests that a reduction rate of approximately 6 feet per month or less would result in 60 percent nest success for largemouth bass and smallmouth bass (Lee 1999). Therefore, a decrease in reservoir water surface elevation of 6 feet or more per month was selected as the threshold beyond which spawning success of nest-building, warmwater fish could potentially result in long-term population declines. To evaluate effects on largemouth bass, smallmouth bass, and spotted bass, the number of times that reservoir reductions of 6 feet or more per month could occur under the Proposed Action was compared to the number of occurrences that were modeled.

Criteria for reservoir elevation increases (nest flooding events) have not been developed by DFG. Because of overall reservoir fishery benefits (e.g., an increase in the availability of littoral habitat for warmwater fish rearing), greater reservoir surface elevations that would be associated with rising water levels would offset negative effects caused by nest flooding (Lee 1999). Therefore, the effects on spawning warmwater fishes from increases in reservoir water surface elevations are not addressed for reservoir fisheries. A qualitative assessment of the availability of littoral habitat for juvenile bass rearing was conducted for both Lake Oroville and Thermalito Afterbay. Additionally, a qualitative assessment was conducted of the potential effects of changes in reservoir surface elevations, drawdown rate and timing, and habitat enhancement programs on stocking and fish interactions (competition for food and habitat, genetic introgression, predation, and disease).

G-AQUA2.2.1.2 Coldwater Reservoir Fish Species of Primary Management Concern

During the period when Lake Oroville is thermally stratified (April through November), coldwater fish within the reservoir reside primarily within the reservoir's metalimnion and hypolimnion, where water temperatures remain suitable. Reduced reservoir storage during this period could reduce the reservoir's coldwater pool volume, thereby reducing the quantity of potential habitat available to coldwater fish species. The size of the reservoir coldwater pool generally decreases as reservoir storage decreases, although not always in direct proportion because of the influence of reservoir basin morphometry and management of water temperature releases from the reservoir.

The water temperature criterion used in the analysis of potential effects on coldwater fish habitat is based on the most stringent criteria recommended by the U.S. Environmental Protection Agency (USEPA) for protection of aquatic life and for growth of adult and juvenile salmonids. The criterion chosen was based on the weekly maximum average water temperature because no monthly criterion is recommended by USEPA for protection of aquatic life. USEPA suggests two types of criteria for water temperature for coho salmon:

- Maximum weekly average water temperature for growth of juvenile and adult coho salmon (18 degrees Celsius [°C] or 64.4°F); and
- Maximum weekly average water temperature for survival of juvenile and adult coho salmon (24°C or 75.2°F) (USEPA 2002).

Eighteen degrees Celsius was chosen as the water temperature defining the upper layer of the usable coldwater salmonid habitat, for two reasons: (1) 18°C (64.4°F) was a more protective estimate than the 24°C (75.2°F) water temperature criterion for survival of juvenile and adult coho salmon; and (2) of all the salmonids for which specific criteria are recommended, coho salmon had the most stringent water temperature recommendations. Additionally, coho salmon have recently been stocked in Lake Oroville. For the purpose of this analysis, water with a temperature less than 18°C (64.4°F) was considered usable coldwater salmonid habitat.

Coldwater fish habitat also requires dissolved oxygen (DO) concentrations at or above 6.5 milligrams per liter (mg/L), based on USEPA criteria for sustainable coldwater fisheries, as well as a food base appropriate for coldwater fisheries. No characterizations of DO or food base are available from project modeling results, so the relative proportion of change in the coldwater pool volume was used as an indicator of the potential change in the quantity of coldwater fish habitat.

End-of-month storage modeled for each year of the 72-year period of record under each alternative was compared to end-of-month storage under the basis of comparison for each month of the April-through-November period. Substantial reductions in reservoir storage were considered to result in substantial reductions in coldwater pool volume and, therefore, habitat availability for coldwater fish.

Coldwater pool volume was not modeled for Thermalito Afterbay. The water temperature regime for Thermalito Afterbay is dynamic and is controlled by Oroville Facilities water temperature releases, peaking and pumpback operations, and rates of agricultural diversions and afterbay releases. Sections 5.4.1.2 and 5.4.2.2 provide information relating to the characteristics of coldwater conditions in Thermalito Afterbay.

Therefore, project-related changes were qualitatively assessed for their potential effects on coldwater fish habitat in Thermalito Afterbay.

Additionally, qualitative assessments were conducted of potential changes in reservoir surface elevations, drawdown rate and timing, and effects of habitat enhancement programs on stocking and fish interactions (competition for food, habitat, introgression, predation, and disease).

G-AQUA2.2.2 Flow-related Effects on Lower Feather River Fish Habitat

Changes in flow affect water surface elevations based on site-specific stage discharge relationships in the river. Changes in water surface elevations, in turn, potentially change the suitability of water depth for some species with minimum or maximum water depth requirements, of water depth for inundation of habitat, and of water velocity for some fish species and life stages.

Flows in the Low Flow Channel of the Feather River, which extends from the Fish Barrier Dam to the Thermalito Afterbay Outlet, are governed by a 1983 agreement between the California Department of Water Resources (DWR) and DFG (DWR and DFG 1983). The agreement specifies that DWR "…shall release into the Feather River from the Thermalito Diversion Dam for fishery purposes a flow of 600 cfs…" (DWR and DFG 1983). With implementation of one of the alternatives, flow in this reach of the river could potentially change from the basis of comparison, 600 cfs. Total releases to the lower Feather River below the Thermalito Afterbay Outlet would not change, nor would the minimum flow requirements for the lower Feather River change. As a result of the potential flow changes in the Low Flow Channel and High Flow Channel with implementation of the No-Action Alternative, the Proposed Action, or Alternative 2, both the quantitative and qualitative analyses evaluate the Low Flow Channel and High Flow Channel separately for flow-related effects on aquatic resources. See Chapter 3.0, Proposed Action and Alternatives, for additional information describing flows.

Quantitative analyses were conducted to determine the relationship between flow changes and the quantity and distribution of fish habitat. These analyses were based on site-specific stage-discharge relationships developed to characterize the availability of habitat for the spawning life stage of Chinook salmon and steelhead. See Section G-AQUA2.4.1 and Section G-AQUA2.4.2, respectively, of this appendix for additional information about how Weighted Useable Area (WUA) indices from the Physical Habitat Simulation (PHABSIM) model were used in the effect analyses to evaluate the relationship of flows to availability of spawning habitat for Chinook salmon and steelhead. Quantitative analyses were also conducted to determine the relationship of flow to the availability of spawning and initial rearing habitat for Sacramento splittail (see Section G-AQUA2.4.8 of this appendix).

For each of the alternatives, qualitative analyses of flow changes and their potential effects were conducted for fish species and life stages for which specific, quantified flow-habitat relationships have not been established. Qualitative analyses of flow changes occurring with implementation of the alternatives were conducted to characterize the type of effects expected on the relative quality and quantity of fish habitat for all of the following fish species and life stages:

- American shad adult immigration and spawning;
- Chinook salmon adult immigration and holding;
- Chinook salmon juvenile rearing and downstream movement;
- Steelhead/rainbow trout adult immigration and holding/residence;
- Steelhead/rainbow trout juvenile rearing and downstream movement;
- Steelhead smolt emigration; and
- Striped bass adult spawning.

Flow changes were evaluated qualitatively to determine the relative changes to habitat with respect to water depth, water velocity, and the amount of inundated habitat area compared to the known distribution and relative abundance for each species and life stage evaluated.

G-AQUA2.2.3 Water Temperature–related Effects on Lower Feather River Fish Habitat

The process used to evaluate potential water temperature–related effects on habitat for fish species of primary management concern in the lower Feather River is divided into three steps, each with multiple elements. The first part of this analytical approach was to combine the available information about fish habitat in the lower Feather River with the water temperature distribution information from the model outputs. Based on this information, a comprehensive evaluation was made of the total relative quantity and quality of fish habitat by species and life stage. Finally, the amount of change in fish habitat and aquatic resources with the No-Action Alternative, the Proposed Action, and Alternative 2, was determined, relative to the basis of comparison.

Fish species and life stages evaluated using the water temperature index value process described in the following sections include:

- American shad adult immigration and spawning;
- Black bass spawning;
- Chinook salmon adult immigration and holding;
- Chinook salmon adult spawning and embryo incubation;
- Chinook salmon juvenile rearing and downstream movement;

- Green sturgeon adult immigration;
- Green sturgeon adult spawning and embryo incubation;
- Green sturgeon juvenile rearing;
- Hardhead spawning;
- River lamprey spawning;
- Sacramento splittail spawning;
- Steelhead/rainbow trout adult immigration and holding/residence;
- Steelhead/rainbow trout adult spawning and embryo incubation;
- Steelhead/rainbow trout fry and fingerling rearing and downstream movement;
- Steelhead smolt emigration; and
- Striped bass adult spawning.

The following generalized example illustrates the benefits of using this integrated approach to evaluate the No-Action Alternative, the Proposed Action, and Alternative 2.

Chinook salmon spawning occurs from September through December, and habitat component requirements include suitable spawning substrate (gravel), water depth (0.8 foot–3.3 feet), mesohabitat (riffle or run), and water temperatures (index values of 56°F, 58°F, 60°F, and 62°F). If an alternative results in colder water temperatures, but at a time and/or location in which the habitat component requirements for Chinook salmon spawning are not present, then the species and life stage has not benefited from the colder water temperatures; the overall habitat suitability index value calculated for this species life stage will not reflect any change. Conversely, water temperatures may be more suitable, or may be suitable over a longer portion of the spawning period, at the locations in which all of the required suitable habitat components are present. In such a case, the overall habitat suitability index value calculated would proportionately increase to reflect the improvement in conditions and the benefit to this species and life stage.

In the case of the Chinook salmon spawning life stage, water temperature index values used for the evaluation are reported in available literature to be associated with specific types of biological effects. By evaluating water temperature changes that are biologically relevant to the suitability of habitat to the fish species and life stage, it is possible to learn the potential nature of the changes and potential biological effects associated with the alternatives.

Current criteria for managing water temperatures in the lower Feather River were established in the 1983 agreement between DFG and DWR, which stated that:

(1) water temperatures below the Thermalito Afterbay Outlet must be suitable for fall-run Chinook salmon after September 15; (2) water temperatures below the Thermalito Afterbay Outlet must be suitable for American shad, striped bass, and other warmwater fish from May through August; and (3) daily average temperatures for water supplied to the Feather River Fish Hatchery must not exceed the following:

- 60°F from June 16 through August 15;
- 58°F from August 16 through August 31;
- 56°F from June 1 through June 15;
- 55°F from December 1 through March 31, and May 16 through May 31;
- 52°F from September 1 through September 30; and
- 51°F from October 1 through November 30, and April 1 through May 15.

(A deviation of plus or minus 4°F for these average daily water temperatures is allowed between April 1 through November 30 [DWR 2001a].)

With implementation of the Proposed Action or the No-Action Alternative, the current water temperature criteria for management of aquatic resources in the lower Feather River would remain in place. Alternative 2 would modify the water temperature targets at Robinson Riffle. No alternative would modify hatchery water supplies such that water temperature management constraints for the lower Feather River would change. However, flow change in the Low Flow Channel from 600 cfs (Proposed Action and No-Action Alternative) to 800 cfs (Alternative 2) also would alter the water temperature regime in the lower Feather River. See Chapter 3.0, Proposed Action and Alternatives, for further definition of the water temperature management and flow standards proposed under the No-Action Alternative, the Proposed Action, and Alternative 2.

The three steps of the water temperature analysis illustrated in Figure G-AQUA2.2-1 include: (1) identifying potentially suitable fish habitat for each fish species and life stage to be evaluated; (2) evaluating the suitability of water temperatures against the requirements of these fish species and life stages; and (3) for each alternative, comparing the results for each of the fish species and life stages to the basis of comparison to identify the proportion of total change and quality of change in the fish habitat.

The first step in developing the index to show the proportion of relative habitat suitability was to identify the location and distribution of potentially suitable fish habitat for each species and life stage selected for analysis. Suitable habitat requirements for each species and life stage evaluated were defined using the matrices from SP-F3.2, Task 2, *Literature Review of Fish Life History and Habitat Requirements for Feather River Fish Species*, which were produced from a comprehensive literature review, as well as from the results of other study plan reports. Fish habitat component requirements included

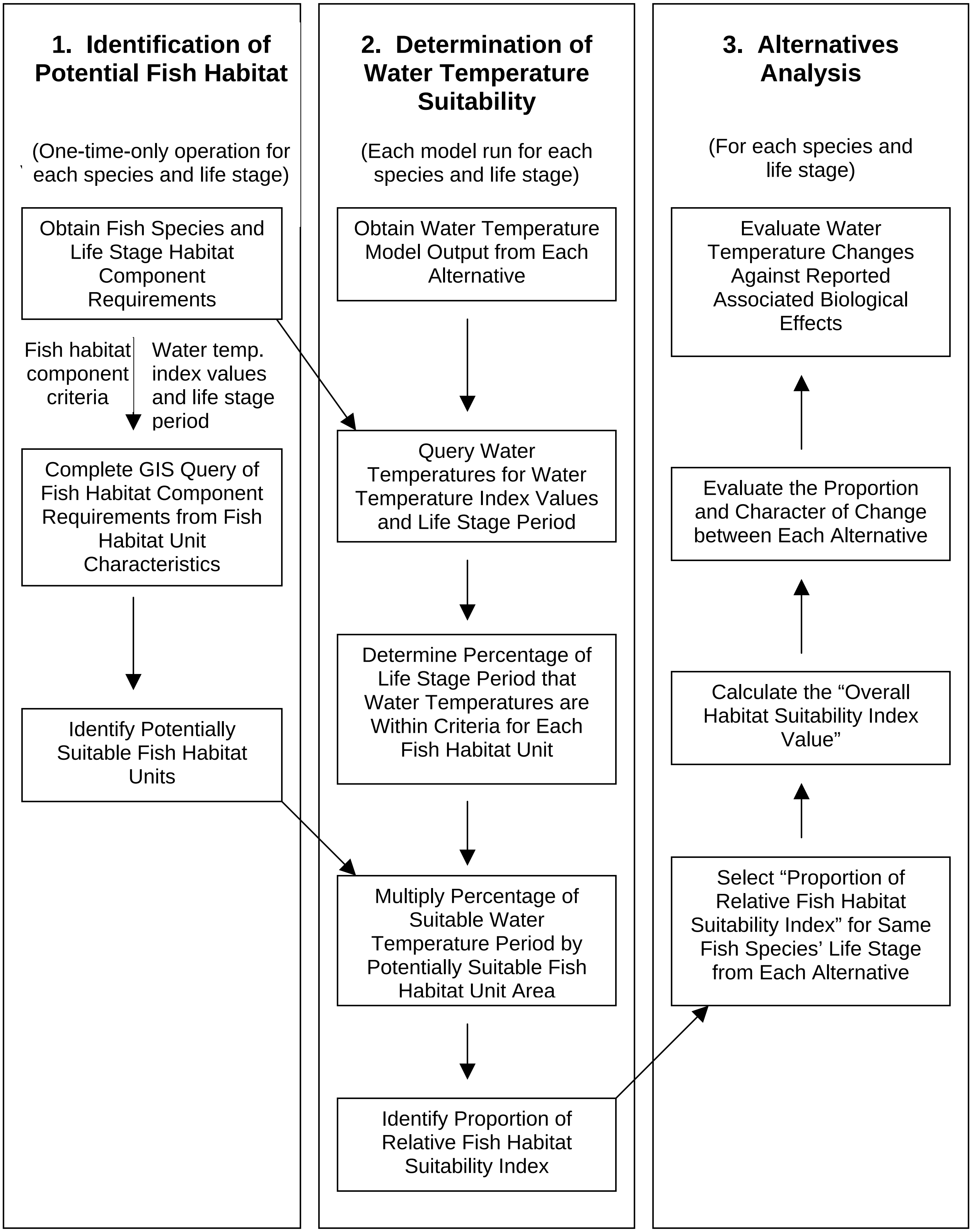


Figure G-AQUA2.2-1. Water temperature/habitat suitability analysis flow diagram.

mesohabitat (generalization of hydraulic conditions, i.e., glide, pool, riffle, run), substrate type, and water depth. Fish habitat component distribution in the lower Feather River was mapped in SP-G2 and was used as the basis of the SP-F3.2, Task 4 report, *Comparison of Fish Distribution to Habitat Distribution and Maps (by species)*. Appendix G-AQUA1, Affected Environment, provides summaries of the aquatic resources study plan reports, and Appendix G-AQUA2.4, Lower Feather River Fish Species of Primary Management Concern, identifies habitat component requirements for specific species and life stages.

Fish habitat requirements by species and life stage were evaluated against the characteristics and distribution of fish habitat components in the lower Feather River to identify those locations that meet the habitat requirements of each species and life stage. The locations meeting the requirements of a fish species and life stage were identified as “potential habitat” and were used in the second step of the process during evaluation of the water temperature suitability of the habitat units. This identification of potential fish habitat was conducted for the lower Feather River from the Fish Barrier Dam to the confluence with the Sacramento River for each fish species and life stage of primary management concern identified in Section 5.5.1, Aquatic Resources Affected Environment.

Figure G-AQUA2.2-2 (in the separate figures volume) illustrates the geographic distribution of potential fish habitat for an example fish species for the Low Flow Channel of the lower Feather River. The map legend lists habitat criteria used to identify locations meeting the fish habitat requirements and includes a pie chart depicting the amount and proportion of potentially suitable fish habitat identified for the river reach depicted. Those locations that did not meet the requirements for physical habitat components for a fish species and life stage were eliminated from the index value calculation; regardless of the potential water temperature suitability of these areas, they do not contribute to the quantity of habitat available to each species and life stage.

The second step in the water temperature suitability analysis used output from the water temperature models to further refine the relative quantity of potentially suitable habitat available for each species and life stage evaluated. During the second step, an overall habitat suitability index value was calculated based on the results of the modeled water temperatures throughout the lower Feather River under each alternative during the specific time periods defined for each species and life stage. Each of the 101 locations of water temperature output nodes from the water temperature model for the lower Feather River were defined using geographic information systems (GIS). Modeled water temperature results were coded relative to their respective habitat units. The query of the model output returned the proportion of time during which water temperatures met the criteria for the water temperature index in the time period associated with each species and life stage for each fish habitat unit. The percentage of time during which the water temperatures are suitable, compared to the water temperature index value for the period that the species and life stage is present, is multiplied by the amount of area for each respective fish habitat unit. These amounts are summed for the entire lower Feather River to determine the overall habitat suitability index value (OHSIV). Figure G-AQUA2.2-3 illustrates the GIS query process for calculating the index value.

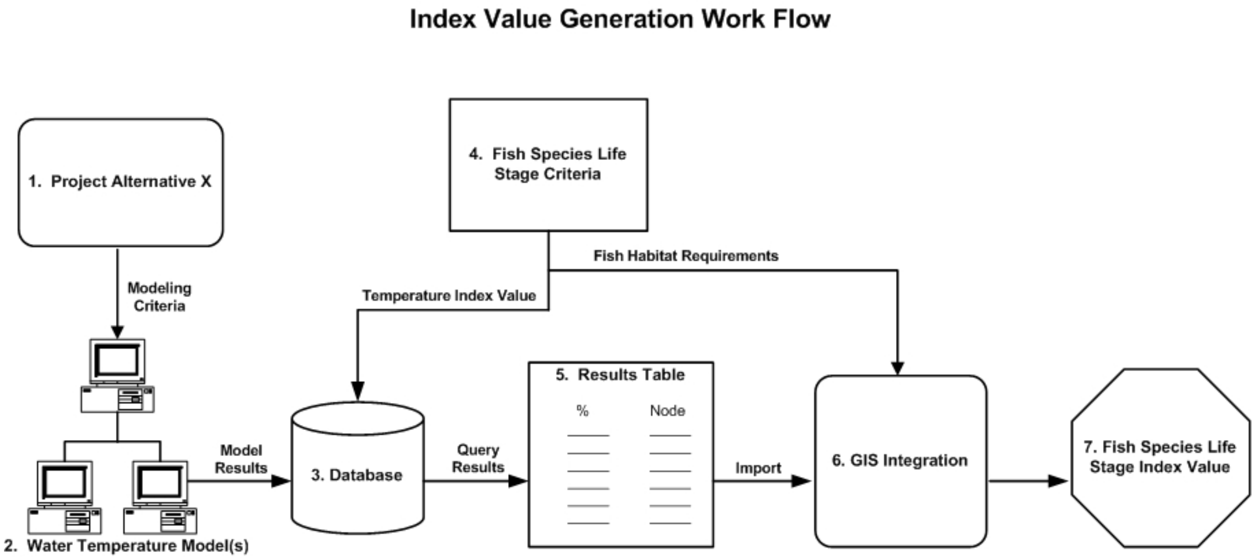


Figure G-AQUA2.2-3. Workflow process for calculating fish habitat index values.

In the third step illustrated in Figure G-AQUA2.2-1, the OHSIV for the Proposed Action, Alternative 2, and the existing condition were compared to the No-Action Alternative to determine proportional changes in overall habitat suitability index values among alternatives.

The graph of the distribution of the proportion of relative habitat suitability in Figure G-AQUA2.2-4 illustrates the nature of the distribution of the calculated overall habitat suitability index values. A similar graph of the distribution of the proportion of the relative fish habitat suitability is included for each water temperature index value calculated for each fish species and life stage evaluated. "Relative Fish Habitat Suitability Units" on the X axis of the graph indicates the quantity of potential fish habitat and "Proportion of Suitability" on the Y axis indicates the percentage of time within the time period for each species and life stage that water temperatures are below (for coldwater fish species) a water temperature index value. For warmwater and other fish species, water temperature index values are calculated based on the percentage of time that the water temperatures are between the minimum and maximum water temperature index values reported as suitable for the species and life stage.

Elements from the graph that depict the distribution of the proportions of relative fish habitat suitability are summarized in the example Table G-AQUA2.2-1. These elements compare differences in the amount and proportion of relative fish habitat suitability for each water temperature index value evaluated between the basis of comparison and each alternative. When changes in the proportions of the amount of potentially suitable habitat are identified in any of the comparisons, if the water temperature index values are based on conditions that are reportedly associated with specific biological effects,

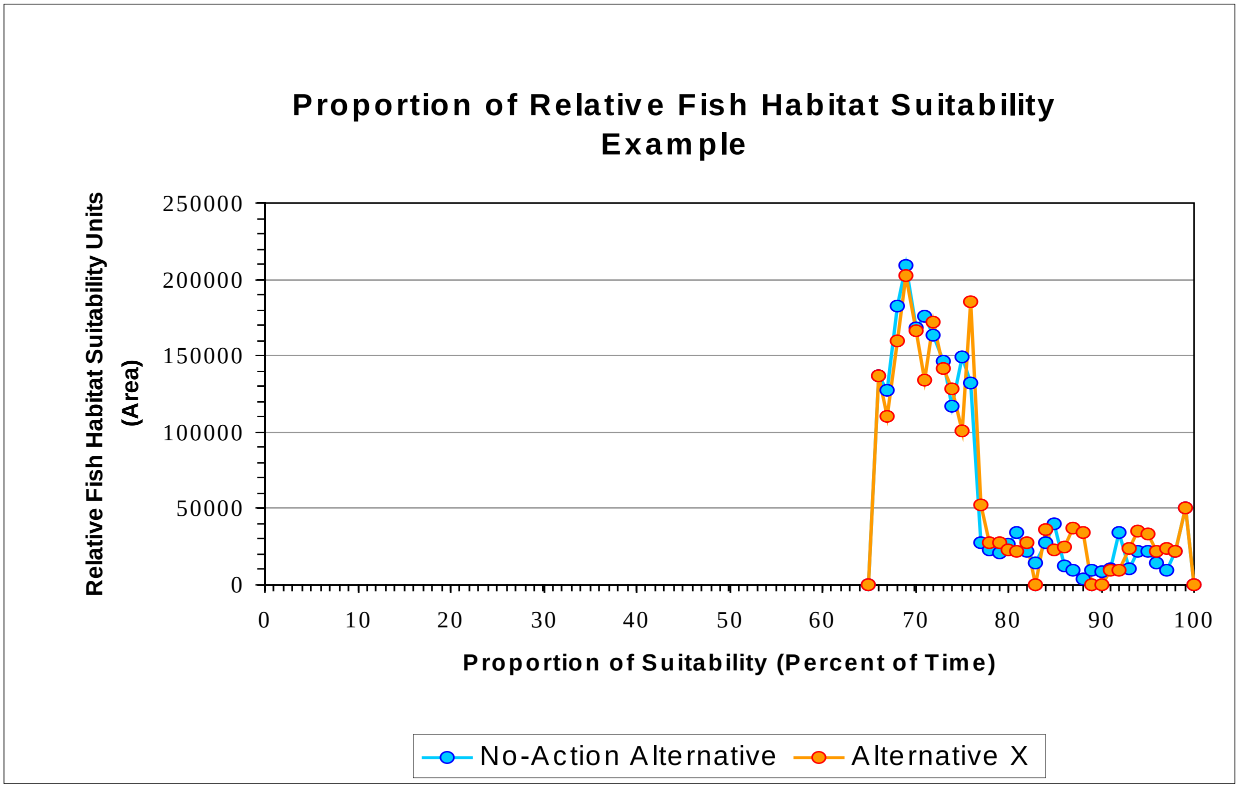


Figure G-AQUA2.2-4. Example distribution of the proportion of relative fish habitat suitability.

Table G-AQUA2.2-1. Example of overall habitat suitability index comparison between the No-Action Alternative and Alternative "X."

Water Temperature Index Value	**60°F**
No-Action Alternative	
Minimum Percentage of Time Value	68 percent
Maximum Percentage of Time Value	100 percent
Habitat Units at 100 Percent of Time	9,000
Percentage of Time at Maximum Habitat Units	72 percent
Total OHSIV	**944,853**
Alternative "X"	
Minimum Percentage of Time Value	92 percent
Maximum Percentage of Time Value	100 percent
Habitat Units at 100 Percent of Time	22,000
Percentage of Time at Maximum Habitat Units	97 percent
Total OHSIV	**953,016**
Percent Change	**0.86 percent**

then the nature of the biological effects also is reported with the analysis of the proportion of change.

The total overall habitat suitability index value presented in the example table as “Total OHSIV” describes the overall relative habitat suitability for the entire lower Feather River for each water temperature index value used for the evaluation of each fish species and life stage. The total OHSIV is calculated by multiplying the amount of habitat unit area by the proportion of time during which the water temperatures are considered suitable based on the water temperature index value definition for each data point on the graph, and is represented as the sum of all of the data point values. The resulting index value literally represents the amount of area and time of potentially suitable habitat for a fish species and life stage. Comparison of the Total OHSIV metric between alternatives indicates which alternative has the greatest amount of suitable habitat with water temperatures equal to or below each water temperature index value for coldwater fish species, and the greatest amount of suitable habitat with water temperatures between the water temperature index values for warmwater and other fish species.

The first analysis was to compare the percentage of change in the OHSIV between the basis of comparison and each alternative to determine the proportion of total habitat change resulting from the implementation of each alternative. The analysis of the percent change of OHSIV was performed using the following calculation:

$$\text{Total OHSIV Change (\%)} = \left(\frac{\text{Total OHSIV}_{ALTERNATIVE\text{"}X\text{"}}}{\text{Total OHSIV}_{NO-ACTION}} - 1 \right) \times 100$$

The results of the calculation of proportion of total habitat change are represented in the example Table G-AQUA2.2-1 as “Percent Change” on the bottom line of the table. Positive percentages indicate increases in the proportion of fish habitat available for a species and life stage for the existing condition, the Proposed Action, and Alternative 2 compared to the No-Action Alternative; conversely, negative percentages indicate a reduced proportion of relative fish habitat. This calculation provides a quantitative value for the magnitude of change in suitable fish habitat as a function of implementation of each alternative. OHSIV is the principal metric for comparing alternatives because it is the most global representation of all fish habitat potentially available for each fish species and life stage evaluated.

The example graph in Figure G-AQUA2.2-4 shows the lowest proportion of time during which the habitat units are suitable with the data values farthest to the left and are reported in the example Table G-AQUA2.2-1 as “Minimum Percentage of Time Value.” In this example, the lowest proportion of suitability for the No-Action Alternative is 68 percent, whereas for Alternative “X” it is 92 percent. The comparison between Alternative “X” and the No-Action Alternative was made by subtracting the No-Action Alternative value for the “Minimum Percentage of Time Value” from the “Minimum Percentage of Time Value” for Alternative “X” and reporting the difference between the values. In this example, the difference between the No-Action Alternative and Alternative “X” indicates that the worst water temperature suitability proportions are suitable for this water temperature index value for Alternative “X” for 24 percent more of the life stage period than under No-Action Alternative conditions.

The “Maximum Percentage of Time Value” metric presented in the example Table G-AQUA2.2-1 represents the percentage of time that water temperatures in the most suitable habitat unit are below each specified water temperature index value. This value is represented as the data point the farthest to the right on the example graph in Figure G-AQUA2.2-4 for Alternative “X.” Again, the difference in the values is reported in the table. In the example case, both Alternative “X” and the No-Action Alternative display data points at the 100 percent proportion of habitat suitability; therefore, there is no difference in values for this example comparison.

Another comparison between the alternatives that can be made using the example graph presented in Figure G-AQUA2.2-4 is a comparison of the amount of habitat that is suitable during 100 percent of presence period for the fish species and life stage. The number of relative fish habitat suitability units in the graph of the proportion of relative fish habitat suitability that occur at 100 percent of proportion of suitability is reported in the example Table G-AQUA2.2-1 as “Habitat Units at 100% of Time.” In this example, the No-Action Alternative would have 9,000 habitat units that are suitable during 100 percent of the presence period for the fish species and life stage, while Alternative “X” would have 22,000 habitat units that are suitable 100 percent of the time. This example indicates that there is 2.4 times more suitable habitat for 100 percent of the fish species’ life stage period under Alternative “X” than under the No-Action Alternative.

The percentage of time within the life stage period in which the highest quantity of fish habitat occurs for both Alternative “X” and the No-Action Alternative is reported in the example Table G-AQUA2.2-1 as “Percentage of Time at Maximum Habitat Units.” In the example graph (Figure G-AQUA2.2-4) these values are 72 percent and 97 percent, respectively, for the No-Action Alternative and Alternative “X.” This metric shows the peak of the population distribution of the proportion of relative fish habitat suitability; comparisons are reported as differences calculated similarly as the comparison of the “Minimum Percentage of Time Value.”

The evaluation of the resulting proportions of OHSIV discusses the types of effects that, according to available literature, may result in fish exposed to water temperatures associated with the selected water temperature index values. The discussion of potential biological effects associated with exposure to water temperatures at or above a water temperature index value contributes to the understanding of the nature and severity of the potential effects on fisheries resources associated with implementation of each alternative.

For each alternative evaluated, the three evaluation steps illustrated in Figure G-AQUA2.2-1 were repeated for each life stage for which each fish species of primary management concern was present in the lower Feather River, for each water temperature index value. The results of the evaluation of the proportion of relative habitat suitability for each life stage for a fish species were synthesized with the relevant qualitative analyses applicable to that fish species for an evaluation of the overall effects on a fish species.

Like the model outputs described in Section G-AQUA2.1, Hydrologic Model Summary, the GIS analysis should be viewed as having “reasonable detection limits” due to the limitations inherent in the GIS software, fineness of the available data, and model output node locations. For example, 101 model output nodes are not evenly distributed throughout the lower Feather River, creating unevenly sized habitat units to which the proportion of time within a water temperature range was assigned. Additionally, the GIS software utilized for the analysis utilized only whole integers for the proportion of time that each habitat unit was within a specific water temperature range, allowing rounding errors to occur. Thus, the proportion of time within all the possible water temperature ranges assigned to any given river segment between model output nodes did not always sum to 100 percent. Additionally, because model output nodes were not evenly distributed throughout the lower Feather River, and because each species had different habitat requirements, the compounded errors differed for each life stage analysis performed. In order to maintain consistency and to be as protective as possible, a detection limit of one percent was assigned to the GIS analysis. Due to the accumulation of errors associated with rounding the percentage of time within each water temperature range associated with each river segment, OHSIV values less than 1 percent were not detectable using the analysis methodology. Therefore, for purposes of alternatives analyses, values of less than 1 percent were considered equivalent.

G-AQUA2.3.1 Water Temperature Index Values

Water temperature index values are used as indicators of water temperatures that are potentially biologically suitable or at which biological effects could occur. The water temperature index values are based on a comprehensive review of available literature on the potential biological effects of water temperatures for each specific fish species and life stage evaluated. When literature describing specific effects of specific water temperatures on a salmonid species was available, it was used as the basis for water temperature index values, above which specific biological effect could potentially occur. When literature describing specific biological effects was not available, the highest and lowest water temperatures reportedly tolerated by the species were used as endpoints of a range of water temperatures considered suitable. Because water temperature index values were developed as indicators of potential biological effects, they were used as a basis for comparing the conditions associated with implementation of the No-Action Alternative, the Proposed Action, or Alternative 2 with the basis of comparison. Water temperature indices and analysis periods for each life stage of each species of primary management concern used in the evaluation of alternatives are presented in Table G-AQUA2.2-2.

Table G-AQUA2.2-2. Life stage timing for fish species and water temperature index values.

Species	Life Stage	Start Date	End Date	Water Temperature Index Values (°F)					
Spring-run Chinook salmon	Adult Immigration and Holding	Mar 1	Oct 31	60<	64<	68<			
Spring-run Chinook salmon	Adult Spawning and Embryo Incubation	Sep 1	Feb 15	56<	58<	60<	62<		
Spring-run Chinook salmon	Juvenile Rearing and Downstream Movement	Jan 1	Dec 31	60<	63<	65<	68<	70<	75<
Fall-run Chinook salmon	Adult Immigration and Holding	Jul 15	Dec 31	60<	64<	68<			
Fall-run Chinook salmon	Adult Spawning and Embryo Incubation	Sep 1	Feb 15	56<	58<	60<	62<		
Fall-run Chinook salmon	Juvenile Rearing and Downstream Movement	Nov 15	Jun 30	60<	63<	65<	68<	70<	75<
Steelhead	Adult Immigration and Holding	Sep 1	Apr 15	52<	56<	70<			
Steelhead	Adult Spawning and Embryo Incubation	Dec 1	May 31	52<	54<	57<	60<		
Steelhead	Fry & Fingerling Rearing and Downstream Movement	Jan 1	Dec 31	65<	68<	72<	75<		
Steelhead	Smolt Emigration	Jan 1	Jun 30	52<	55<				
American Shad	Adult Immigration and Spawning	Apr 1	Jun 30	>46	79<				
Black Bass (spp.)	Adult Spawning	Mar 1	Jun 30	>54	75<				
Green Sturgeon	Adult Immigration and Holding	Feb 1	Jul 31	>44	61<				
Green Sturgeon	Adult Spawning and Embryo Incubation	Mar 1	Jul 31	>46	68<				
Green Sturgeon	Juvenile Rearing	Jan 1	Dec 31	>50	66<				
Green Sturgeon	Juvenile Emigration	May 1	Sep 30	>50	66<				
Hardhead	Adult Spawning	Apr 1	Aug 31	>55	75<				
River Lamprey	Adult Spawning	Apr 1	Jun 30	>43	72<				
Sacramento Splittail	Adult Spawning, Embryo Incubation, and Initial rearing	Feb 1	May 31	>45	75<				
Striped Bass	Adult Spawning	April 1	Jun 30	>59	68<				

The availability of species-specific literature describing water temperature effects determined the availability and accuracy of water temperature index values. For example, little literature was available describing the effects of water temperatures on river lamprey, while an abundance of literature was available describing the effects of water temperatures on Chinook salmon. Thus, water temperature index values provided for various life stages of Chinook salmon are supported by more literature and are likely more accurate, and the biological effects of water temperatures associated with each water temperature index value are more well documented than those index values presented for river lamprey.

Additionally, because more documentation was available regarding thermal tolerances and potential effects of elevated water temperatures on anadromous salmonids than for other species analyzed, multiple water temperature index values were developed for all life stages of anadromous salmonids (except steelhead smolt emigration, for which only two water temperature index values were available). For example, 6 water temperature target values were identified for the juvenile rearing and downstream movement life stage for fall-run Chinook salmon, based on information presented in 22 literature sources (Banks et al. 1971; Brett et al. 1982; Burck 1980; Cech and Myrick 1999; Clarke and Shelbourn 1985; USEPA 2001; USEPA 2003; Independent Scientific Group 1996; Johnson and Brice 1953; Marine 1997; McCullough 1999; Myrick and Cech 2001; NOAA Fisheries 1993; NOAA Fisheries 1995; NOAA Fisheries 1997b; NOAA Fisheries 2000; NOAA Fisheries 2002a; Ordal and Pacha 1963; Rich 1987; Seymour 1956; USFWS 1999; Zedonis and Newcomb 1997). Two water temperature index values were developed for each life stage analyzed for the rest of the warmwater and other species evaluated.

The anadromous salmonid species and life stages for which water temperature target values were chosen included:

- Spring-run Chinook salmon (adult immigration and holding, adult spawning and embryo incubation, and juvenile rearing and downstream movement);
- Fall-run Chinook salmon (adult immigration and holding, adult spawning and embryo incubation, and juvenile rearing and downstream movement); and
- Steelhead (adult immigration and holding, adult spawning and embryo incubation, fry and fingerling rearing and downstream movement, and smolt emigration).

Because anadromous salmonids are coldwater species and water temperatures approaching their coldwater tolerances do not occur in the lower Feather River, no water temperature index values were developed to represent water temperatures that are too cold to be considered suitable habitat for anadromous salmonids. The lowest water temperature index value developed for each coldwater fish species and life stage is generally agreed upon in the available literature to have no adverse biological effects on the species. Each successive increase in water temperature index value has specific incremental detrimental effects that reportedly can occur in association with the exposure of a species and life stage to water temperatures at or above the subsequent index value. Additional discussion on salmonid thermal tolerances is provided in the study plan reports described in Appendix G-AQUA1, Affected Environment. Species and life stage–specific documentation regarding the basis for the water temperature index values is presented in Section G-AQUA2.4, Lower Feather River Fish Species of Primary Management Concern, of this appendix.

The warmwater and other fish species and life stages for which water temperature index values were developed included:

- American shad adult immigration and spawning;
- Black bass (largemouth bass, smallmouth bass, spotted bass, and redeye bass) adult spawning;
- Green sturgeon adult immigration and holding;
- Green sturgeon adult spawning and embryo incubation;
- Green sturgeon juvenile rearing;
- Green sturgeon juvenile emigration;
- Hardhead adult spawning;
- River lamprey adult spawning;
- Sacramento splittail adult spawning, embryo incubation, and initial rearing; and
- Striped bass adult spawning.

In the case of the warmwater and other fish species evaluated, the water temperature index values were selected based on the reported water temperature ranges or preferences of the species and life stages. Available literature generally reported either preferred, suitable, or optimal water temperatures without describing the biological effects of lowered or elevated water temperatures or simply provided ranges of water temperatures in which the species were observed. Therefore, these water temperature indices are not necessarily associated with specific biological effects on the species. To provide the most protective water temperature targets for the bases of the warmwater fisheries analyses, the water temperature target values for most warmwater and other fish species represent the lowest water temperature presented in the literature and the highest water temperature presented in the literature, regardless of the context in which the water temperatures were described. For example, of the warmwater and other fish species evaluated, literature describing the thermal ranges of spawning adult black bass was the most abundant because the life stage includes four species.

The lowest water temperature at which largemouth bass spawning begins was reported in available literature to be 53.6°F (12°C) (Miller and Storck 1984); the lowest water temperatures at which smallmouth bass, redeye bass, and spotted bass are reported to spawn are 54.5°F (12.5°C), 62.6°F (17°C), and 57°F (14°C), respectively (Graham and Orth 1986; Moyle 2002). The highest water temperatures at which largemouth bass, smallmouth bass, redeye bass, and spotted bass are reported to spawn are 75.2°F (24°C), 74.3°F (23.5°C), 69.8°F (21°C), and 73.4°F (23°C), respectively (Aasen and Henry 1981; Graham and Orth 1986; Moyle 2002; Wang 1986). Based on these available reports, after rounding reported values to the nearest degree Fahrenheit, the water temperature index values chosen for black bass spawning life stage analyses were 54°F (12.2°C) and 75°F (23.9°C). Because the index values for warmwater and other fish species are based on the range of water temperatures for suitability, the index value calculations are interpreted differently than the index values for the coldwater fish water temperatures. In the case of the warmwater fishes, the amount of time and area with water temperatures between the water temperature index values are the basis of comparison for the alternatives. For example, the percentage of time during which water temperatures are between 54°F (12.2°C) and 75°F (23.9°C) multiplied by the area containing all of the physical habitat components required by black bass was compared among alternatives.

G-AQUA2.3 QUALITATIVE FISH HABITAT COMPONENT EVALUATIONS

G-AQUA2.3.1 Chinook Salmon Spawning Segregation

Blocking upstream migration has eliminated the spatial separation between spawning by fall-run and spring-run Chinook salmon. Reportedly, spring-run Chinook salmon migrated to the upper Feather River and its tributaries from mid-March through the end of July (DFG 1998). Fall-run Chinook salmon reportedly migrated later and spawned in lower reaches of the Feather River than spring-run Chinook salmon (Yoshiyama et al. 2001). Restricted access to historic spawning grounds cause spring-run Chinook salmon to spawn in the same lowland reaches that fall-run Chinook salmon use as spawning habitat. The overlap in spawning site location, combined with a slight overlap in spawning timing (Moyle 2002) with temporally adjacent runs, may be responsible for inbreeding between spring-run and fall-run Chinook salmon in the lower Feather River (Hedgecock et al. 2001).

The Proposed Action and Alternative 2 include actions that would address effects on anadromous fishes caused by the blockage of upstream passage by the Oroville Facilities. In both scenarios, fish barrier weirs would be installed downstream of the Fish Barrier Dam to segregate spring-run and fall-run Chinook salmon. The reason for implementing this action is that spring-run Chinook salmon migrate upstream earlier in the year than fall-run Chinook salmon, which allows the runs to be segregated by allowing fish passage on a temporal basis. The effects of this action were evaluated on a qualitative basis using historic information on escapements, information collected during preparation of the SP-F10 Study Plan Report, and various agency reports on Chinook salmon run timing in the Feather River.

G-AQUA2.3.2 Macroinvertebrate Populations

Aquatic macroinvertebrates consist primarily of insects, snails, clams, shrimp, and zooplankton. The current status of macroinvertebrate populations in the project study area was described in the interim and final reports for SP-F1, Task 1, *Evaluation of Project Effects on Non-Fish Aquatic Resources*, and is summarized in Section G-AQUA1.1 of Appendix G-AQUA1. Construction of Oroville Dam changed the hydrologic cycle of the Feather River. These changes likely affected invertebrate life cycles and communities that evolved over time. Fluctuating reservoir levels, controlled flows, and less frequent scouring events have likely affected non-fish aquatic resources. Macroinvertebrates and plankton communities may be directly affected by future changes in project operations that affect the amount of surface water, flow rates, water temperatures, or water quality in the project area.

Aquatic macroinvertebrates and plankton are important components of the biological food web in any aquatic ecosystem. Many invertebrate species are important to the recycling of nutrients in aquatic systems. They also are an important food source for fish, and their community structure and diversity are important factors in determining general ecosystem conditions. Stream health is usually determined by the species diversity of the assemblage present or through groupings at higher taxonomic levels. Negative effects from environmental shifts or anthropogenic effects are shown by decreasing species diversity, organism size, or changes in taxa composition (Erman 1996).

As a basis for the assessment, projected physical and chemical changes associated with future project operations were compared with ecological requirements for macroinvertebrates and plankton populations within waters affected by the project. A qualitative assessment of potential effects was conducted that determined the general direction of such effects. Professional judgment was used to qualitatively assess effects, as supported by biological information.

G-AQUA2.3.3 Woody Debris Recruitment

The Oroville Facilities prevent the recruitment of large woody debris from the upstream reaches of the Feather River and its tributaries to the lower Feather River below Oroville Dam. Current sources of large woody debris in the lower Feather River are the riparian zone along the river, occasional inputs from orchards adjacent to the river, and other tributaries flowing into the lower Feather River. Moderated flow regimes in the lower Feather River also have reduced recruitment of large woody debris. In addition, current large woody debris recruitment is different in quality than under pre-dam conditions because the origin of the pre-dam wood would have been from mixed hardwood and coniferous forests not present in riparian zones downstream of Lake Oroville.

Large woody debris is an important component of geomorphic processes and ecological functions in rivers and streams. Woody debris enhances the complexity of fish habitat and may redirect streamflow to create pools that serve as holding areas for anadromous salmonids. In addition, decaying large woody debris provides a source of nutrients for aquatic organisms. Generally, the influence of large woody debris on stream geomorphology and ecology varies with stream size (Lassettre and Harris 2001). On larger streams such as the Feather River the effects of large woody debris on geomorphic processes are limited, but it still performs important ecological functions. In these larger streams, large woody debris can provide shelter for salmonids, and when associated with secondary channels, it contributes to the quality and diversity of juvenile rearing habitat.

Large woody debris supplementation programs for the lower Feather River are included under the Proposed Action and Alternative 2. Effects of large woody debris supplementation were evaluated qualitatively for the Proposed Action and Alternative 2 using a literature review, and comparisons were made between the current quantity, distribution, and habitat function of large woody debris in the lower Feather River and fish habitat quality.

G-AQUA2.3.4 Gravel/Sediment Recruitment

Spawning habitat for anadromous salmonids below Oroville Dam has been affected by changes to the geomorphic processes caused by several factors, including hydraulic mining, land use practices, construction of flood management levees, regulated flow regimes, and operation of Oroville Dam. The dam blocks sediment recruitment from the upstream areas of the watershed. In the lower reaches of the river, levees and bank armoring prevent gravel recruitment. Periodic flows of sufficient magnitude to mobilize smaller sized gravel from spawning riffles result in armoring of the remaining substrate. DWR (1996) evaluated the quality of spawning gravels in the lower Feather River based on bulk gravel samples and Wolman surface samples obtained in the spring of 1996. The study concluded that the worst scoured areas had an armored surface layer too coarse for spawning salmonids. Additionally, much of the streambed substrate in the reach from the Fish Barrier Dam to the Thermalito Afterbay Outlet is composed of large gravel and cobble, which is too large for construction of spawning redds for Chinook salmon and steelhead. This reach of the lower Feather River is by far the most intensively used spawning habitat of the river for salmon and steelhead.

Chinook salmon, steelhead, and river lamprey use riffles and runs with a gravel substrate for spawning. Females of each species construct nests (redds) in the substrate by creating a shallow depression in the gravel. Eggs are then deposited in the depression while males release sperm over the eggs for fertilization. Next, eggs are covered with a layer of gravel where they incubate, and juveniles emerge from the gravel at a later date depending on egg incubation time required for the species. Because the incubating eggs require a constant supply of oxygenated water, gravel is the required substrate.

Gravel supplementation is a proposed action under both the Proposed Action and Alternative 2. Both the Proposed Action and Alternative 2 would implement rip and raking of selected armored stream bottoms, in addition to the placement of gravel at targeted sites in the river reach between the Fish Barrier Dam and the Thermalito Afterbay Outlet. Effects of the Gravel Supplementation and Improvement Program on the quality of fish habitat were evaluated qualitatively for both alternatives using a literature review and professional judgment.

The Proposed Action and Alternative 2 include actions to improve the quality and quantity of salmonid spawning gravel, as well as to potentially create new spawning habitat. The effects of superimposition on egg mortality and alevin survival were qualitatively evaluated for the Proposed Action and Alternative 2 based on changes in habitat quality, quantity, and distribution in relation to salmonid spawning habitat use characteristics.

G-AQUA2.3.5 Channel Complexity

For purposes of this analysis, channel complexity refers to the diversity of geomorphologic features in a particular river reach. Such features include undercut stream banks, meanders, point bars, side channels, backwaters, etc. Regulation of the lower Feather River by the Oroville Facilities has changed both streamflow and sediment discharge. More than 97 percent of the sediment is trapped in the reservoir, resulting in sediment starvation downstream. Attenuation of peak flows, decreased winter flows, increased summer flows, and changes to historic flow frequencies have led to a general decrease in channel complexity downstream of Oroville Dam.

Because several fish species of management concern and different life stages of these species occur in the lower Feather River, a diversity of habitat types is required. Increases in channel complexity lead to an increase in habitat diversity and habitat quality. Increases in channel complexity are proposed in several different actions under the Proposed Action and Alternative 2. These actions include gravel and large woody debris supplementation, as well as the restoration and creation of side channels to increase spawning and juvenile rearing habitat for steelhead and Chinook salmon. Effects of increasing channel complexity were evaluated qualitatively for the Proposed Action and Alternative 2 using a literature review and professional judgment.

G-AQUA2.3.6 Water Quality Criteria for Aquatic Life

Water quality, as it affects aquatic life in the project area, was evaluated in the Final SP-F3.2, Task 1, 4, 5 Report, *Comparison of Fish Distribution to Fish Habitat and Maps (by species)*, which is summarized in Section G-AQUA1.4.1 of Appendix G-AQUA1, Affected Environment. DO concentrations were evaluated separately in the report but are included in the discussion of water quality effects on aquatic life in this appendix. The National Ambient Water Quality Criteria (NAWQC) is the applicable regulatory standard that is calculated by USEPA. These criteria represent half the value of toxic substance concentration that would cause 50 percent mortality in 5 percent of a briefly exposed population (USEPA 2002). In addition to NAWQC criteria, on May 18, 2000, USEPA published 40 Code of Federal Regulations (CFR) 131, Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California, generally known as the California Toxics Rule (CTR). Section 5.4.2, Environmental Effects—Water Quality, provides additional information on these water quality standards.

USEPA reports that the 30-day mean water column DO concentration required for the protection of adult life stages of coldwater fish species is 6.5 mg/L (USEPA 2002). USEPA also reports criteria for a single-day minimum to be 4.0 mg/L and 7-day mean minimum to be 3.0 mg/L; however, both of these criteria are less protective than the 30-day mean value provided by USEPA as a minimum DO concentration suitable for coldwater aquatic life (USEPA 2002).

Although no protection, mitigation, and enhancement (PM&E) measures included in the No-Action Alternative, Proposed Action, or Alternative 2 directly target water quality in the project area as it pertains to aquatic species, construction activities within and adjacent to the Oroville Facilities and the lower Feather River could result in short-term effects on water quality. Water quality effects on aquatic life were evaluated qualitatively for the Proposed Action and Alternative 2 using a literature review and professional judgment. Water quality–related effects associated with instream construction activities are included in Section 5.4.2, Environmental Effects—Water Quality.

G-AQUA2.4 LOWER FEATHER RIVER FISH SPECIES OF PRIMARY MANAGEMENT CONCERN

Changes in Oroville Facilities operations could potentially alter seasonal drawdown rates in Lake Oroville and, thus, Feather River flows and water temperatures, which could change the relative availability of habitat for fish species present in the lower Feather River. The lower Feather River is used by a number of fish species of primary management concern, primarily as habitat during one or more of their life stages, but also as a migration corridor to upstream habitat in other river systems (e.g., the Yuba River). For these reasons, species-specific effect assessments were conducted for the following species of primary management concern:

- Fall-run Chinook salmon;
- Spring-run Chinook salmon;
- Steelhead/rainbow trout;
- American shad;
- Black bass (largemouth bass, smallmouth bass, redeye bass, and spotted bass);
- Green sturgeon;
- Hardhead;
- River lamprey;
- Sacramento splittail; and
- Striped bass.

Implementation of the No-Action Alternative, the Proposed Action, or Alternative 2 could potentially alter Feather River water temperatures. Changes in Feather River water temperatures are oriented primarily to meet coldwater fisheries water temperature requirements for salmonids, so the salmonid fish species of management concern are the primary focus of the evaluations of the alternatives with regard to water temperature. Moreover, thermal requirements of Chinook salmon and steelhead are generally similar; and the National Oceanic and Atmospheric Administration (NOAA) Fisheries Biological Opinion on interim operations of the Central Valley Project (CVP) and State Water Project (SWP) on Federally listed threatened Central Valley spring-run Chinook salmon and Central Valley steelhead (NOAA Fisheries 2002a) has established quantitative water temperature criteria for the lower Feather River at the Feather River Fish Hatchery and for the Low Flow Channel (monitored near Robinson Riffle [below River Mile 62]) to protect spring-run Chinook salmon and steelhead; therefore, the assessment methodologies focus primarily on the Chinook salmon and steelhead life stages. The species and life stage–specific flow and water temperature assessment methodologies for the Feather River effect analyses are discussed in the following sections.

G-AQUA2.4.1 Spring- and Fall-run Chinook Salmon

Potential fisheries effects in the two reaches of the lower Feather River were evaluated separately because of the differences in the characteristics of the flow regimes, and because each reach provides different values to the different life stages of anadromous salmonids (adult immigration and holding, adult spawning and embryo incubation, and juvenile rearing and downstream movement). Detailed descriptions of fall-run Chinook salmon life stages and periods are provided in Section 5.5.1 and are summarized in Table G-AQUA2.2-2. Detailed descriptions of spring-run Chinook salmon life stages and periods are provided in Section 5.7.2.1.

G-AQUA2.4.1.1 Flow-related Effects

Because of the differences in the proposed changes in flow in the Low Flow Channel and High Flow Channel for the No-Action Alternative, the Proposed Action, and Alternative 2, the reaches were evaluated separately for flow-related effects on aquatic resources. Chapter 3.0, Proposed Action and Alternatives, provides additional information describing flows.

Site-specific flow-related effects on the spawning and egg incubation life stage of Chinook salmon and steelhead were determined by analyzing the results of Instream Flow Incremental Methodology (IFIM) studies. IFIM is a decision-support analytical tool designed to aid resources managers and stakeholders in determining the effects of different water management alternatives (Bovee et al. 1998), and currently is reported to be the most widely used and defensible technique worldwide for assessing instream flow requirements for fisheries purposes. IFIM includes a wide variety of analytical tools of varying complexity to address multiple aspects of riverine dynamics and ecology, including sophisticated computer models such as a physical habitat simulation

(PHABSIM) model. PHABSIM results were used to quantify changes in available habitat between alternatives.

In general, three main components are needed to obtain PHABSIM results. First, hydraulic data along with substrate and cover data characterizing the conditions in the river are required. The data are subsequently used to create hydraulic models (i.e., models that describe the movement and force of water), which evaluate and predict habitat variables (e.g., water depth, water velocity, substrate, and cover) throughout a selected study site at different flows. The hydraulic models, in turn, are combined with habitat suitability criteria (HSC) models that evaluate the relative incremental utility of habitat attributes to each life stage and species under consideration. HSC curves are derived from observations of hydraulic and physical habitat variables associated with each species and life stage being analyzed (Bovee et al. 1998). PHABSIM results are an index of the quantity and quality of the relative amount of fish habitat by species and life stage and typically are referred to as WUA RSI.

Because the results of the PHABSIM model calculations, expressed as WUA, were used in the quantification of flow changes among alternatives, a brief explanation of WUA is necessary. WUA is a relative indicator of suitability and, as such, is an index representing available habitat area. WUA does not represent actual physical area available for use by the species. Because WUA is an index of habitat suitability, it cannot be directly related to the number of individuals that could occupy the lower Feather River at modeled flows. WUA does, however, indicate the differences in relative habitat suitability among alternatives. Figures G-AQUA2.4-1 and G-AQUA2.4-2 show the Chinook salmon WUA index curves for the Low Flow Channel and High Flow Channel, respectively.

Analysis was completed of flow-related effects on fisheries and aquatic resources in the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet (the Low Flow Channel) and from the Thermalito Afterbay Outlet to Honcut Creek (the High Flow Channel). For each alternative, changes in WUA were compared to determine the relative amount of change in availability of spawning habitat for anadromous salmonids based on the proposed flow changes. To assess flow-related effects on spring- and fall-run Chinook salmon spawning life stages in the lower Feather River, PHABSIM results at flows associated with each alternative were compared to those associated with the basis of comparison.

Detailed descriptions of the methodology associated with the IFIM studies conducted on the lower Feather River, including descriptions of the PHABSIM model and HSC curves used for calculation of Chinook salmon spawning WUA, are available in the Final Report for SP-F16 (see Section G-AQUA1.10 of Appendix G-AQUA1, Affected Environment).

Analysis of available spawning area using PHABSIM model results does not provide information regarding the potential for stage reductions during the embryo incubation portion of the adult spawning and embryo incubation life stage. However, because flows under the alternatives would remain constant in the Low Flow Channel, and fluctuate within the minimum flow and maximum flow agreed upon by DFG and DWR in

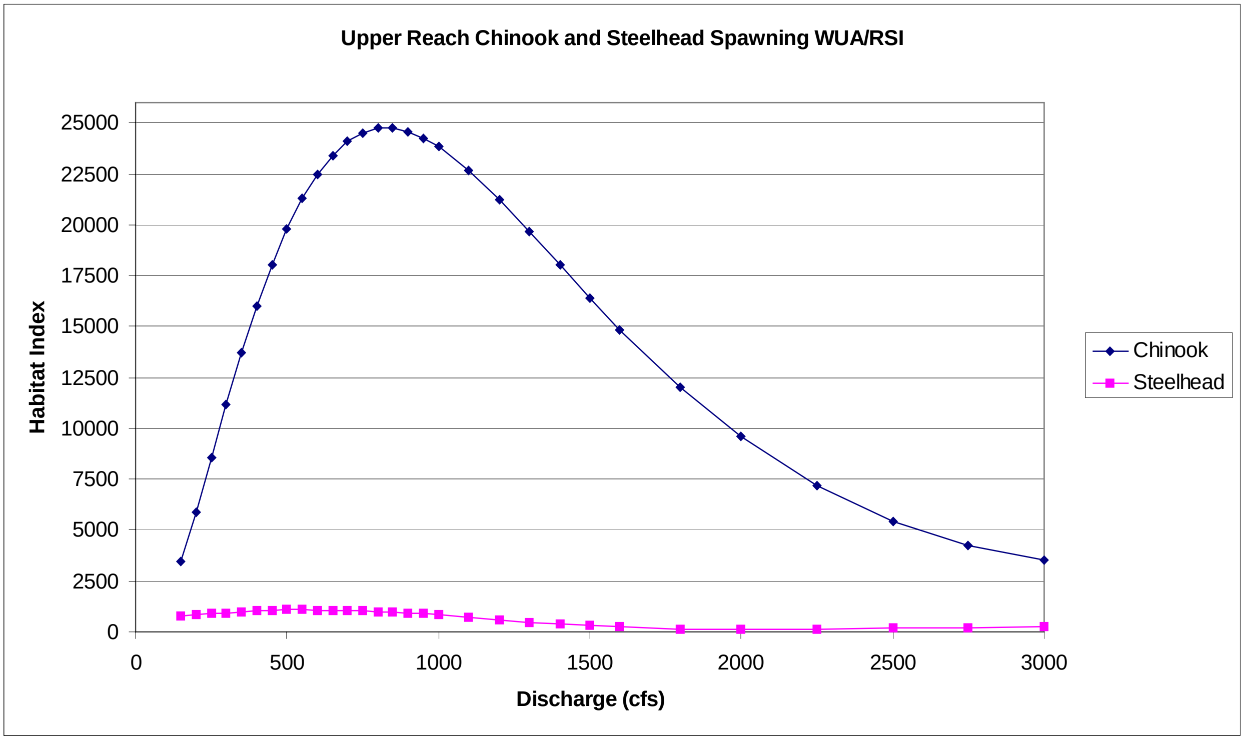


Figure G-AQUA2.4-1. WUA/relative suitability index for Chinook salmon and steelhead spawning in the Low Flow Channel of the lower Feather River.

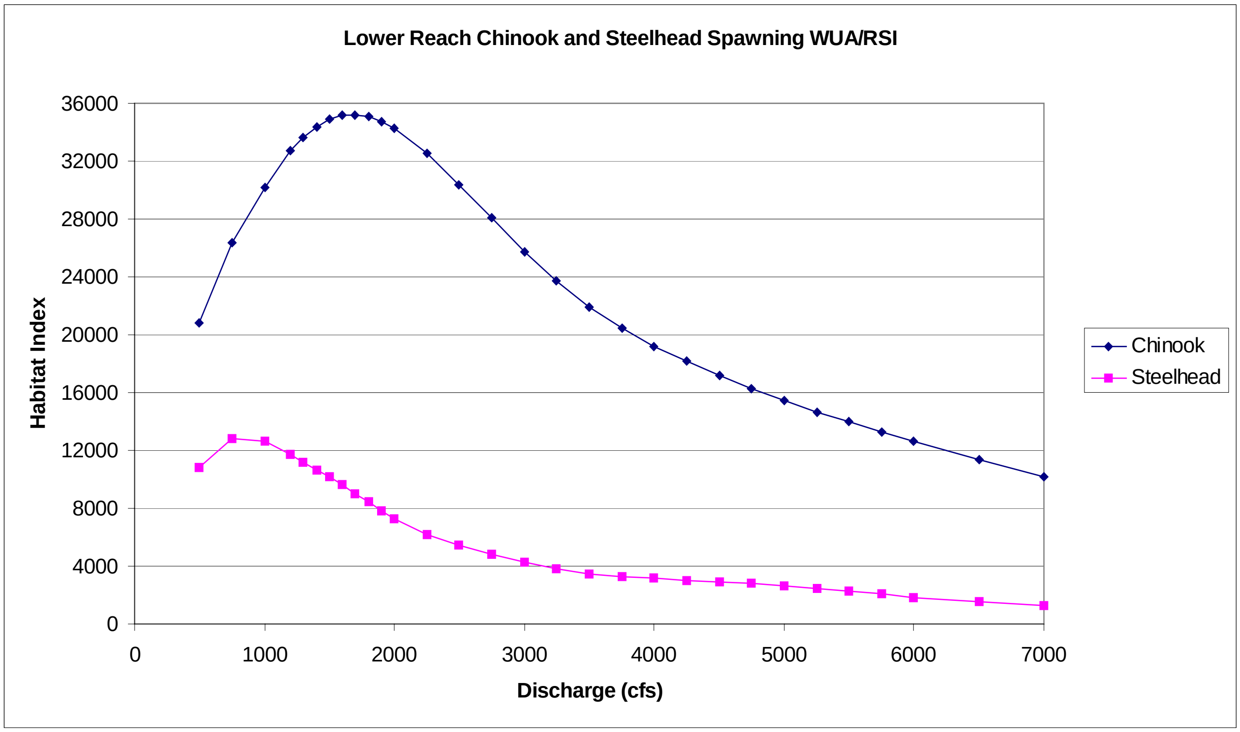


Figure G-AQUA2.4-2. WUA/relative suitability index for Chinook salmon and steelhead spawning in the High Flow Channel of the lower Feather River.

the High Flow Channel, further quantitative analysis of flow fluctuations in the Low Flow Channel or High Flow Channel is unnecessary.

Flow changes and flow fluctuations associated with the alternatives were evaluated qualitatively for potential effects on Chinook salmon adult immigration (see Section G-AQUA1.8.1 of Appendix G-AQUA1, Affected Environment), and Chinook salmon juvenile rearing and downstream movement (see Section G-AQUA1.8.4 of Appendix G-AQUA1). The analysis focused on determining the relative changes to fish habitat with respect to water depth, water velocity, and the amount of inundated habitat area compared to the known fish distribution and relative abundance.

G-AQUA2.4.1.2 Water Temperature–related Effects

A three-phased assessment was performed to evaluate potential water temperature–related effects for spring-run Chinook salmon adult immigration and holding, fall-run Chinook salmon adult immigration, Chinook salmon adult spawning and embryo incubation, and Chinook salmon juvenile rearing and downstream movement. The balance of this section documents the basis of the selection of the water temperature index values and defines the biological effects that are reported to be associated with exposure at or above the water temperature index values used in the analysis.

Water temperature index values were developed for spring- and fall-run Chinook salmon life stages from an extensive review of the available literature to be used as guidelines for assessing potential effects of each alternative. The specific index values developed for each Chinook salmon life stage (the index values are the same for spring- and fall-run Chinook salmon) are discussed below. The derivation and description of each water temperature index value and life stage also is included in the following discussion.

Adult Immigration and Holding (Spring-run, March through August; Fall-run, September through November)

Description of Life Stage

After spending 3–4 years in the ocean, Chinook salmon begin their return to fresh water to spawn (Moyle 2002). Chinook salmon show considerable temporal variation in the timing of their spawning migrations; this life history variation is evident in the classification of Chinook salmon by run type (i.e., fall-run, late fall–run, winter-run, and spring-run). In the Central Valley, adult spring-run Chinook salmon generally migrate upstream from March to September, and fall-run migrate upstream from June to December (Fisher 1994). The holding period extends from the time that adult Chinook salmon enter their natal stream until the onset of spawning site selection. On the Feather River, the entire adult immigration and holding period lasts from March through October for spring-run Chinook salmon and from mid-July through December for fall-run (Eaves 1982; Moyle 2002; NOAA Fisheries 1999; Sommer et al. 2001).

The adult immigration and adult holding life stages are evaluated together, because it is difficult to determine the thermal regime to which Chinook salmon have been exposed in the river before spawning. Additionally, to sufficiently protect pre-spawning fish, water temperatures that provide high adult survival and high egg viability must be available throughout the entire pre-spawning freshwater period. Although studies examining the effects of thermal stress on immigrating Chinook salmon are lacking, it has been demonstrated that thermal stress during the upstream spawning migration of sockeye salmon negatively affected the secretion of hormones controlling sexual maturation, causing numerous reproductive impairment problems (Macdonald et al. in McCullough et al. 2001).

Index Value Selection Rationale

Water temperatures of 60°F, 64°F, and 68°F were used as index values to assess the potential effects of each alternative relative to the basis of comparison. Table G-AQUA2.4-1 provides some of the sources used to select each water temperature index value. For each month of the adult immigration and holding period, modeled water temperatures under each alternative were compared to those modeled under the basis of comparison to evaluate potential water temperature–related effects on immigration and holding of adult Chinook salmon.

Table G-AQUA2.4-1. Water temperature index values and supporting literature for Chinook salmon adult immigration and holding.

Index Value	Supporting Literature
60°F	• The maximum water temperature for adults holding, while eggs are maturing, is approximately 59°F to 60°F (NOAA Fisheries 1997b). • Acceptable water temperatures for adults migrating upstream range from 57°F to 67°F (NOAA Fisheries 1997b). • The upper limit of the optimal water temperature range for adults holding while eggs are maturing is 59°F to 60°F (NOAA Fisheries 2000). • Many of the diseases that commonly affect Chinook salmon become highly infectious and virulent above 60°F (ODEQ 1995). • Mature females subjected to prolonged exposure to water temperatures above 60°F have poor survival rates and produce less viable eggs than females exposed to lower water temperatures (USFWS 1995).
64°F	• The acceptable range for adults migrating upstream is from 57°F to 67°F (NOAA Fisheries 1997b). • Disease risk becomes high at water temperatures above 64.4°F (USEPA 2003). • Latent embryonic mortalities and abnormalities associated with exposure of pre-spawning adults to particular water temperatures occur at 63.5°F to 66.2°F (Berman 1990).
68°F	• The acceptable range for adults migrating upstream is 57°F to 67ºF (NOAA Fisheries 1997b). • For chronic exposures, an incipient upper lethal water temperature limit for pre-spawning adult salmon probably falls within the range of 62.6°F to 68.0°F (Marine 1992). • Spring-run Chinook salmon embryos from adults held at 63.5ºF to 66.2°F had greater numbers of pre-hatch mortalities and developmental abnormalities than embryos from adults held at 57.2°F to 59.9°F (Berman 1990). • Water temperatures of 68°F resulted in nearly 100 percent mortality of Chinook salmon during columnaris outbreaks (Ordal and Pacha 1963).

Water temperature index values for adult immigration and holding were established for all Chinook salmon run types collectively. This was done to show an evenly spaced water temperature range that provides conditions reportedly ranging from optimal to lethal for adult Chinook salmon during upstream immigration and holding. Although 56°F is referenced in the literature frequently as the upper water temperature limit required for upstream migration and holding, the references are not foundational studies and often are inappropriate citations. For example, many of the references to 56°F are based on Hinze (1959), which is a study examining the effects of water temperature on incubating Chinook salmon eggs. Boles et al. (1988), Marine (1992), and NOAA Fisheries (1997b) all cite Hinze (1959) in support of recommendations for a water temperature of 56°F for Chinook salmon immigration. Because 56°F is not strongly supported by foundational literature, it was not selected as an index value.

The lowest water temperature index value selected was 60°F, because in the NOAA Fisheries Biological Opinion for the proposed operation of the CVP and SWP, 59°F to 60°F is reported as "The upper limit of the optimal temperature range for adults holding while eggs are maturing" (NOAA Fisheries 2000). NOAA Fisheries (1997b) states, "Generally, the maximum temperature of adults holding, while eggs are maturing, is about 59°F to 60°F" and the "acceptable range for adults migrating upstream range from 57°F to 67°F. The Oregon Department of Environmental Quality (ODEQ 1995) reports that "…many of the diseases that commonly affect Chinook become highly infectious and virulent above 60°F."

64°F was chosen as an index value because Berman (1990) suggested that effects of thermal stress to pre-spawning adults are evident at water temperatures near 64°F, and also because 64°F represents a midpoint value between the water temperature index values of 60°F and 68°F. Berman (1990) conducted a laboratory study to determine whether water temperatures experienced by adult Chinook salmon before spawning influenced reproductive success, and found evidence suggesting that latent embryonic abnormalities associated with exposure of pre-spawning adults to particular water temperatures occur at 63.5°F to 66.2°F.

68°F was selected as an index value because available foundational and regulatory literature suggests that thermal stress at water temperatures greater than or equal to 68°F is pronounced, and severe adverse effects on immigrating and holding pre-spawning adults, including mortality, can be expected (Berman 1990; Marine 1992; NOAA Fisheries 1997b).

Because significant effects on immigrating and holding adult Chinook salmon reportedly occur at water temperatures greater than or equal to 68°F, it was not necessary to select index values higher than 68°F.

Adult Spawning and Embryo Incubation (September through mid-February)

Description of Life Stage

In the Sacramento River basin, spring-run Chinook salmon spawn from late August to October and fall-run spawn from late September to December (Fisher 1994). In the Feather River, adult spawning and embryo incubation occurs from September through mid-February. The duration of embryo incubation is dependent on water temperature and can be variable (NOAA Fisheries 2002a). In Butte and Big Chico Creeks, emergence of spring-run Chinook salmon generally occurs from November through January (NOAA Fisheries 2002a). In Mill and Deer Creeks, colder water temperatures delay emergence to January through March (DFG 1998). In the lower American River, fall-run Chinook salmon emergence generally begins in March (SWRI 2004).

The adult spawning and embryo (i.e., eggs and alevins) incubation life stage includes redd construction and egg deposition, and embryo incubation through emergence. Potential effects on the adult spawning and embryo incubation life stages are evaluated together using one set of water temperature index values. It is difficult to separate the effects of water temperature between life stages that are closely linked temporally; studies elucidating how water temperature affects embryonic survival and development based on varying water temperature treatments on holding adults often report results similar to those of water temperature experiments conducted on fertilized eggs (Marine 1992; McCullough 1999; Seymour 1956; SWRI 2004).

Index Value Selection Rationale

Water temperatures of 56°F, 58°F, 60°F, and 62°F were used as index values to assess the potential effects of each of the alternatives relative to the basis of comparison. Table G-AQUA2.4-2 provides some of the sources used to select each water temperature index value. For each month of the adult spawning and embryo incubation period for spring- and fall-run Chinook salmon, each alternative was compared to the basis of comparison to evaluate potential water temperature–related effects.

Water temperature index values were selected from a comprehensive literature review. This was done to show an evenly spaced water temperature range that provides conditions reportedly ranging from optimal to lethal for Chinook salmon eggs during spawning site selection, spawning, and incubation. Relative to the large body of literature pertaining to water temperature effects on Chinook salmon embryos, there are few laboratory experiments that specifically examine Chinook salmon embryo survival under different constant or fluctuating water temperature treatments, and only one of these experiments is recent (Combs and Burrows 1957; Hinze 1959; Johnson and Brice 1953; Seymour 1956; USFWS 1999). In large part, supporting evidence for index value selections was derived from the aforementioned laboratory studies and from regulatory documents (NOAA Fisheries 1993; NOAA Fisheries 1997b; NOAA Fisheries 2002a). Field studies reporting river water temperatures during spawning also were considered (Dauble and Watson 1997; Groves and Chandler 1999).

Table G-AQUA2.4-2. Water temperature index values and supporting literature for Chinook salmon spawning and embryo incubation.

Index Value	Supporting Literature
56°F	• Less than 56°F results in a natural rate of mortality for fertilized Chinook salmon eggs (USBR 2003 unpublished work). • Optimum water temperatures for egg development are between 43°F and 56°F (NOAA Fisheries 1993). • 56.0°F is the upper value of the water temperature range (i.e., 41.0°F to 56.0°F) suggested for maximum survival of eggs and yolk-sac larvae in the Central Valley of California (USFWS 1995). • 56.0°F is the upper value of the range (i.e., 42.0°F to 56.0°F) reported as the preferred water temperature for Chinook salmon egg incubation in the Sacramento River (NOAA Fisheries 1997b). • Incubation temperatures above 56°F result in significantly higher alevin mortality (USFWS 1999). • 56.0°F is the upper limit of suitable water temperatures for spring-run Chinook salmon spawning in the Sacramento River (NOAA Fisheries 2002a). • Water temperatures averaged 56.5°F during the week of fall-run Chinook salmon spawning initiation on the Snake River (Groves and Chandler 1999).
58°F	• 58.0°F is the upper value of the range reported as preferred water temperatures (i.e., 53.0°F to 58.0°F) for eggs and fry (NOAA Fisheries 2002a). • Constant egg incubation temperatures between 42.5°F and 57.5°F resulted in normal development (Combs and Burrows 1957). • The natural rate of mortality for alevins occurs at 58°F or less (USBR 2003 unpublished work).
60°F	• 100 percent mortality occurs during the yolk-sac stage when embryos are incubated at 60°F (Seymour 1956). • An October 1 to October 31 water temperature criterion of less than or equal to 60°F in the Sacramento River from Keswick Dam to Bend Bridge has been established for protection of late incubating larvae and newly emerged fry (NOAA Fisheries 1993). • Mean weekly water temperature at first observed Chinook salmon spawning in the Columbia River was 59.5°F (Dauble and Watson 1997). • Consistently higher egg losses resulted at water temperatures above 60.0°F than at lower temperatures (Johnson and Brice 1953)
62°F	• 100 percent mortality of fertilized Chinook salmon eggs after 12 days at 62°F (USBR 2003 unpublished work). • Incubation temperatures of 62°F to 64°F appear to be the physiological limit for embryo development, resulting in 80–100 percent mortality before emergence (USFWS 1999). • There is 100 percent loss of eggs incubated at water temperatures above 62°F (Hinze 1959). • 100 percent mortality occurs during the yolk-sac stage when embryos are incubated at 62.5°F (Seymour 1956).

The water temperature index values selected to evaluate the Chinook salmon spawning and embryo incubation life stages are 56°F, 58°F, 60°F, and 62°F. Some literature suggests that water temperatures must be less than or equal to 56°F for maximum survival of Chinook salmon embryos (i.e., eggs and alevins) during spawning and incubation. NOAA Fisheries (1993) reported that optimum water temperatures for egg development are between 43°F and 56°F. The U.S. Bureau of Reclamation (USBR)

(2003 unpublished work) reports that water temperatures less than 56°F result in a natural rate of mortality for fertilized Chinook salmon eggs. USFWS (1995) reported a water temperature range of 41.0°F to 56.0°F for maximum survival of eggs and yolk-sac larvae in the Central Valley of California. A range of 42.0°F to 56.0°F was suggested as the preferred water temperature for Chinook salmon egg incubation in the Sacramento River (NOAA Fisheries 1997b).

Alevin mortality is reportedly significantly higher when Chinook salmon embryos are incubated at water temperatures above 56°F (USFWS 1999). NOAA Fisheries (2002a) reported 56.0°F as the upper limit of suitable water temperatures for spring-run Chinook salmon spawning in the Sacramento River.

High survival rates of Chinook salmon embryos have also been suggested to occur at incubation temperatures at or near 58.0°F. For example, USBR (2003 unpublished work) reported that the natural rate of mortality for alevins occurs at 58°F or less; Combs and Burrows (1957) concluded that constant incubation temperatures between 42.5°F and 57.5°F resulted in normal development of Chinook salmon eggs; and NOAA Fisheries (2002a) suggested that a range of 53.0°F to 58.0°F is the preferred water temperature range for Chinook salmon eggs and fry.

Johnson and Brice (1953) found that there were consistently higher rates of Chinook salmon egg losses at water temperatures above 60.0°F than at lower temperatures. To protect late-incubating Chinook salmon embryos and newly emerged fry, NOAA Fisheries (1993) has established a water temperature criterion of less than or equal to 60.0°F for the Sacramento River from Keswick Dam to Bend Bridge from October 1 to October 31. However, Seymour (1956) provided evidence that there is 100 percent mortality of late-incubating Chinook salmon embryos when they are held at a constant water temperature greater than or equal to 60.0°F.

Available literature largely agrees that there will be 100 percent mortality of Chinook salmon embryos incubated at water temperatures greater than or equal to 62.0°F (Hinze 1959; Seymour 1956; USBR 2003 unpublished work; USFWS 1999). Therefore, it was not necessary to select index values above 62°F. Similarly, mortality of spawning adult Chinook salmon before egg deposition (Berman 1990; Marine 1992) reportedly occurs at water temperatures above those at which embryo mortality results (i.e., 62°F) (Hinze 1959; Seymour 1956; USBR 2003 unpublished work; USFWS 1999); therefore, an index value above 62°F was not required. Pre-spawning mortality of adult Chinook salmon associated with exposure to high water temperatures is addressed in the adult immigration and holding life stage.

Juvenile Rearing and Downstream Movement (Spring-run, November through June; Fall-run, February through June)

Description of Life Stage

The juvenile life stage is composed of fry, fingerlings, and smolts; the parr stage is included in the fingerling category. Chinook salmon are fry from the time that the juvenile leaves the gravel of the spawning redd to swim up into the water column as a free-swimming fish until skeletal development is complete, at which point it reaches the fingerling stage (Bovee et al. 1998). Chinook salmon fry make the transition to the fingerling stage at approximately 45 millimeters (mm) to 60 mm (NOAA Fisheries 1997b; NOAA Fisheries 2003b). Fingerling Chinook salmon become smolts when physiological changes occur that allow juveniles to survive the transition from fresh water to salt water during seaward migration. In addition to physiological changes, morphological changes also take place during smoltification (Hoar 1988). Salmonid smolts can be distinguished from pre-smolts by their silvery appearance and relatively slim, streamlined bodies (Hoar 1988).

In the Sacramento River basin, the length of time that juvenile Chinook salmon rear in natal streams varies according to run type. Juveniles displaying spring-run (stream type) life history characteristics emerge from the spawning substrate from November to March and rear for 3–15 months (Fisher 1994), while juveniles displaying fall-run (ocean type) life history characteristics emerge from the spawning substrate from December to March and rear for 1–7 months (Fisher 1994). Recent studies from the American and Feather Rivers indicate that most juvenile Chinook salmon move downstream as fry shortly after they emerge from the spawning gravel (DWR 2002; Snider and Titus 2000). In the Sacramento River, juvenile Chinook salmon move downstream during all months, as both fry and smolts (Moyle 2002).

Water temperature is a major limiting factor for juvenile Chinook salmon because it strongly affects survival and growth. Water temperatures that are too high can be lethal or cause sublethal effects such as reduced appetite and growth, increased incidence of disease, increased metabolic costs, and decreased ability to avoid predators. Available scientific literature indicates that a similar range of water temperatures provides positive growth and high survival for Chinook salmon fry, fingerlings, and smolts. Chinook salmon juveniles reportedly rear and move downstream year-round as fry, fingerlings, or smolts, and available scientific literature indicates that a range of water temperatures that is important for fry also is important for fingerlings and smolts; therefore, effects on each phase of the juvenile life stage can be evaluated using a single set of water temperature index values.

Index Value Selection Rationale

Water temperatures of 60°F, 63°F, 65°F, 68°F, 70°F, and 75°F were used as evaluation guidelines to assess the potential affects of each alternative, relative to the basis of comparison. Table G-AQUA2.4-3 provides some of the sources used to select each water temperature index value. For each month of the juvenile rearing and downstream movement periods of spring- and fall-run Chinook salmon, each alternative was compared to the basis of comparison to evaluate potential water temperature–related effects.

Water temperature index values were selected from a comprehensive literature review. This was done to show an evenly spaced water temperature range that provides conditions reportedly ranging from optimal to lethal for juvenile rearing and downstream movement by Chinook salmon. Water temperature index values were determined

Table G-AQUA2.4-3. Water temperature index values and supporting literature for Chinook salmon juvenile rearing and downstream movement.

Index Value	Supporting Literature
60°F	• The optimum water temperature for Chinook salmon fry growth is between 55.0°F and 60°F (Seymour 1956). • The water temperature range that produced optimum growth in juvenile Chinook salmon was between 54.0°F and 60.0°F (Rich 1987). • A water temperature criterion of less than or equal to 60.0°F is required for the protection of Sacramento River winter-run Chinook salmon from Keswick Dam to Bend Bridge (NOAA Fisheries 1993). • The upper optimal water temperature limit for Sacramento River fall-run Chinook salmon fry and fingerlings is 60.8°F (Marine 1997). • An upper water temperature limit of 60.0°F is preferred for growth and development of spring-run Chinook salmon fry and fingerlings (NOAA Fisheries 2000; NOAA Fisheries 2002a). • To protect salmon fry and juvenile Chinook salmon in the upper Sacramento River, daily average water temperatures should not exceed 60°F after September 30 (NOAA Fisheries 1997b). • A water temperature of 60°F appears closest to the optimum for growth of fingerlings (Banks et al. 1971). • Optimum growth of Nechako River Chinook salmon juveniles would occur at 59°F at a feeding level that is 60 percent of that required to satiate them (Brett et al. 1982)
63°F	• Acceleration and inhibition of development of Sacramento River Chinook salmon smolts reportedly may occur at water temperatures above 62.6°F (Marine 1997). • Laboratory evidence suggests that survival and smoltification become compromised at water temperatures above 62.6°F (Zedonis and Newcomb 1997). • Juvenile Chinook salmon growth was highest at 62.6°F (Clarke and Shelbourn 1985).

Table G-AQUA2.4-3. Water temperature index values and supporting literature for Chinook salmon juvenile rearing and downstream movement.

Index Value	Supporting Literature
65°F	• Water temperatures between 45°F and 65°F are preferred for growth and development of fry and juvenile spring-run Chinook salmon in the Feather River (NOAA Fisheries 2002a). • The recommended summer maximum water temperature for migration and non-core rearing is 64.4°F (USEPA 2003). • Water temperatures greater than 64.0°F are considered not "properly functioning" by NOAA Fisheries in Amendment 14 to the Pacific Coast Salmon Plan (NOAA Fisheries 1995). • Fatal infection rates caused by *Cytophaga columnaris* are high at temperatures greater than or equal to 64.0°F (Fryer and Pilcher 1974 in USEPA 2001). • Disease mortalities diminish at water temperatures below 65.0°F (Ordal and Pacha 1963). • Fingerling Chinook salmon reared in water temperatures greater than 65.0°F contracted *C. columnaris* and exhibited high mortality (Johnson and Brice 1953). • Water temperatures greater than 64.9°F are identified as being stressful in the Columbia River Ecosystem (Independent Scientific Group 1996). • Juvenile Chinook salmon have an optimum temperature for growth that appears to occur at about 66.2°F (Brett et al. 1982). • Juvenile Chinook salmon reached a growth maximum at 66.2°F (Cech and Myrick 1999).
65°F (continued)	• The optimal range for Chinook salmon survival and growth is from 53.0°F to 64.0°F (USFWS 1995). • Survival rates of Central Valley juvenile Chinook salmon decline at water temperatures greater than 64.4°F (Myrick and Cech 2001). • There is an increased incidence of disease, reduced appetite, and reduced growth rates at water temperatures of 66.2°F ± 1.4°F (Rich 1987).
68°F	• Sacramento River juvenile Chinook salmon reared at water temperatures greater than or equal to 68.0°F suffer reductions in appetite and growth (Marine 1997). • There may be significant inhibition of gill sodium ATPase activity and associated reductions of hyposmoregulatory capacity, and significant reductions in growth rates, when chronic elevated water temperatures exceed 68°F (Marine 1997). • Water temperatures supporting smoltification of fall-run Chinook salmon range between 50°F and 68°F; the colder water temperatures represent more optimal conditions (50°F to 62.6°F), and the warmer conditions (62.6°F to 68°F) represent marginal conditions (Zedonis and Newcomb 1997). • Juvenile spring-run Chinook salmon were not found in areas having mean weekly water temperatures between 67.1°F and 71.6°F (Burck 1980). • Results from a study on wild spring-run Chinook salmon in the John Day River system indicate that juvenile fish were not found in areas having mean weekly water temperatures between 67.1°F and 72.9°F (Lindsay et al. 1986 in (McCullough 1999),

Table G-AQUA2.4-3. Water temperature index values and supporting literature for Chinook salmon juvenile rearing and downstream movement.

Index Value	Supporting Literature
70°F	• No growth at all would occur in Nechako River juvenile Chinook salmon at 70.5°F (Brett et al. 1982). • Juvenile spring-run Chinook salmon were not found in areas having mean weekly water temperatures between 67.1°F and 71.6°F (Burck 1980). • Results from a study on wild spring-run Chinook salmon in the John Day River system indicate that juvenile fish were not found in areas having mean weekly water temperatures between 67.1°F and 72.9°F (Lindsay et al. 1986 in (McCullough 1999). • Increased incidence of disease, hyperactivity, reduced appetite, and reduced growth rates was found at 69.8°F ± 1.8°F (Rich 1987).
75°F	• For juvenile Chinook salmon in the lower American River fed maximum rations under laboratory conditions, 75.2°F was determined to be 100 percent lethal due to hyperactivity and disease (Rich 1987). • The lethal water temperature threshold for fall-run juvenile Chinook salmon was between 74.3°F and 76.1°F (NAS 1972 in McCullough 1999).

largely by emphasizing the results of laboratory experiments that examined how water temperature affects Central Valley Chinook salmon and by considering regulatory documents, such as Biological Opinions from NOAA Fisheries. Studies on fish from outside the Central Valley were used to supplement findings from local studies.

The lowest water temperature index value selected was 60°F; this temperature was chosen because regulatory documents and several source studies, including ones recently conducted on Central Valley Chinook salmon fry, fingerlings, and smolts, report 60°F as an optimal water temperature for growth (Banks et al. 1971; Brett et al. 1982; Marine 1997; NOAA Fisheries 1997b; NOAA Fisheries 2000; NOAA Fisheries 2001a; NOAA Fisheries 2002b; Rich 1987). Water temperatures below 60°F also have been reported as providing conditions optimal for fry and fingerling growth, but these were not selected as index values because the studies were conducted on fish from outside of the Central Valley (Brett 1952; Seymour 1956). Studies conducted using local fish may be particularly important because *Oncorhynchus* species show considerable variation in morphology, behavior, and physiology along latitudinal gradients (Myrick 1998; Taylor 1990a; Taylor 1990b). More specifically, it has been suggested that salmonid populations in the Central Valley prefer higher water temperatures than those from more northern latitudes (Myrick and Cech 2000).

Laboratory experiments suggest that water temperatures at or below 62.6°F provide conditions that allow for successful transformation to the smolt stage (Clarke and Shelbourn 1985; Marine 1997). 62.6°F was rounded and used to support an index value of 63ºF.

65°F was selected as an index value because it represents an intermediate value between 64.0°F and 66.2°F, at which both adverse and beneficial effects on juvenile salmonids have been reported. For example, at temperatures approaching and exceeding 65°F, sublethal effects associated with increased incidence of disease reportedly become severe for juvenile Chinook salmon (USEPA 2003; Johnson and Brice 1953; Ordal and Pacha 1963; Rich 1987). Conversely, numerous studies report that water temperatures between 64.0°F and 66.2°F provide conditions reportedly ranging from suitable to optimal for juvenile Chinook salmon growth (Brett et al. 1982; Cech and Myrick 1999; Myrick and Cech 2001; NOAA Fisheries 2002a; USFWS 1995).

68°F was selected as an index value because at water temperatures above 68°F, further sublethal effects, such as reductions in appetite and growth of juveniles as well as prohibition of smoltification, become severe (Marine 1997; Rich 1987; Zedonis and Newcomb 1997).

Chronic stress associated with water temperature can be expected when conditions reach the index value of 70°F. For example, growth becomes drastically reduced at water temperatures close to 70.0°F and growth was reported to be completely prohibited at 70.5°F (Brett et al. 1982; Marine 1997).

75°F was chosen as the highest water temperature index value because high levels of direct mortality of juvenile Chinook salmon reportedly result at this water temperature (Rich 1987). Other studies have suggested higher upper lethal water temperature levels (Brett 1952; Orsi 1971), but 75°F was chosen because it was derived from experiments using Central Valley Chinook salmon and because it is a more rigorous index value that represents a more protective upper lethal water temperature level. Furthermore, the lethal level determined by Rich (1987) was derived using slow rates of water temperature change and thus is ecologically relevant. Additional support for an index value of 75°F is provided from a study conducted by Baker et al. (1995), in which a statistical model is presented that treats survival of Chinook salmon smolts fitted with coded wire tags in the Sacramento River as a logistic function of water temperature. Using data obtained from mark-recapture surveys, the statistical model suggests 95 percent confidence that the upper incipient lethal water temperature for Chinook salmon smolts is 71.5°F to 75.4°F.

G-AQUA2.4.1.3 Predation-related Effects

The high concentration of spawning salmonids in the reach of the Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet results in a high concentration of juvenile salmonids (Seesholtz et al. 2003). Additionally, Seesholtz et al. (2003) reported that most outmigration of juvenile Chinook salmon occurs between January and March. Based on historic accounts of juvenile salmonid emigration, the current peak in the emigration period is somewhat earlier than under pre-dam conditions (Painter et al. 1977; Warner 1955). Seesholtz et al. (2003) speculate that the early emigration may be caused by competition for resources resulting from unnaturally high populations of juvenile salmonids.

Water temperature and flow changes included as components of the alternatives affect predator fish species distribution, relative abundance, feeding behavior, and consumption rates. Water temperature changes, flow changes, and actions anticipated to improve the quantity, quality, and distribution of rearing habitat for juvenile salmonids (i.e., large woody debris placement and side-channel habitat improvement and creation) also affect rearing behavior and duration, growth rates, predator avoidance cover, and emigration timing and behavior of juvenile Chinook salmon. The alternatives were evaluated qualitatively to determine the nature and general magnitude of potential predation-related effects on juvenile rearing and downstream movement by Chinook salmon. Section G-AQUA1.11.3 of Appendix G-AQUA1 contains a summary report and additional information on project effects on salmonid predation.

G-AQUA2.4.1.4 Fisheries Management–related Effects

There would be no changes in fish stocking or reservoir fisheries habitat enhancement programs under the alternatives; therefore, these programs are not included in the evaluation of alternatives. Adaptive hatchery management practices are included in the Proposed Action and Alternative 2, and include proposals for experimental releases of different sized juvenile fish at different times and locations, predator avoidance and cover utilization conditioning, changes to brood stock selection, disease management and screening, and other hatchery management changes. These changes in hatchery management were evaluated qualitatively for their potential effects on predation, juvenile rearing and emigration survival rates, adult immigration straying rates, genetic introgression, and the incidences of fish diseases. Section G-AQUA1.5.1 of Appendix G-AQUA1 contains additional information related to salmonid management–related effects.

Fishing Regulations

Increases in recreation access, including increases in visitation and fisheries-related use of recreational resources, are anticipated under all of the alternatives. Chapter 3.0, Proposed Action and Alternatives, contains descriptions of recreation-related changes included in each of the alternatives, and Section 5.10 contains evaluations of recreation-related effects. Effects of increased recreational fishing and poaching on angling-related mortality and the contribution to adult pre-spawning mortality rates were evaluated qualitatively to determine the effects on fisheries resources, and specifically, on Chinook salmon.

Fish barrier weirs for Chinook salmon are included in the Proposed Action and Alternative 2, which are described in detail in Chapter 3.0, Proposed Action and Alternatives. These actions would result in changes in fishing regulations. Therefore, placement of barrier weirs was evaluated qualitatively to determine their effects on fishing take limits and poaching. Effects on recreational activities resulting from changes in fishing regulations associated with these actions are included in Section 5.10.

G-AQUA2.4.2 Steelhead/Rainbow Trout

Similar to the Chinook salmon analyses, the steelhead effects analysis is based upon individual life stages, because each life stage has specific flow and water temperature requirements. The steelhead life stages included in this analysis are:

- Adult immigration and holding (September through April 15);
- Adult spawning and embryo incubation (December through May);
- Fry and fingerling rearing and downstream movement (year-round); and
- Smolt emigration (January through June).

More detailed descriptions of steelhead life stages and periods are provided in Section 5.7.2.1, Affected Environment—Fish Species.

G-AQUA2.4.2.1 Flow-related Effects

Quantitative analyses of the alternatives were conducted for steelhead adult spawning and embryo incubation using the available PHABSIM WUA index of the relationship of flow to availability of steelhead spawning habitat for the Low Flow Channel and High Flow Channel in the lower Feather River. Section G-AQUA2.4.1 of this appendix provides additional detail describing the PHABSIM analysis conducted; Figures G-AQUA2.4-1 and G-AQUA2.4-2 show the steelhead WUA index curves for the Low Flow Channel and High Flow Channel, respectively.

Analysis of available spawning area using PHABSIM model results does not provide information regarding the potential for stage reductions during the embryo incubation portion of the adult spawning and embryo incubation life stage. Flows under the alternatives would remain constant in the Low Flow Channel, however, and would fluctuate within the minimum flow and maximum flow agreed upon by DFG and DWR in the High Flow Channel; therefore, further quantitative analysis of flow fluctuations in the Low Flow Channel or High Flow Channel is unnecessary.

Flow changes and flow fluctuations associated with the alternatives were evaluated qualitatively for potential effects on steelhead/rainbow trout adult immigration and holding, steelhead/rainbow trout fry and fingerling rearing and downstream movement, and steelhead smolt emigration. The objective of this analysis was to determine the relative changes to the fish habitat with respect to water depth, water velocity, and the amount of inundated habitat area compared to the known fish distribution and relative abundance.

G-AQUA2.4.2.2 Water Temperature–related Effects

A three-phased water temperature assessment was performed to evaluate potential water temperature–related effects on adult immigration and holding by steelhead/rainbow trout, adult spawning and embryo incubation by steelhead/rainbow trout, rearing and downstream movement by steelhead/rainbow trout fry and fingerlings, and emigration by steelhead smolts. For a detailed description of the water temperature–related effects analysis process, see Section G-AQUA2.2.3 of this appendix. The balance of this subsection documents the basis of selection of the water temperature index values and defines the biological effects that are reported to be associated with exposure at or above the water temperature index values used in the analysis.

Water temperature index values were developed for steelhead/rainbow trout life stages from an extensive review of available literature to be used as guidelines for assessing potential effects associated with each alternative. The specific index values developed for each steelhead/rainbow trout life stage are discussed below. The derivation and description of each water temperature index value and each life stage also is included in the following discussion.

Adult Immigration and Holding (September through April 15)

Description of Life Stage

Most Central Valley steelhead spend 1–2 years in the ocean before entering fresh water in August, with a peak in late September to October. Steelhead then hold in fresh water until spawning. Movement of adult steelhead from freshwater holding areas to spawning grounds generally can occur any time from December to March, with peak activities occurring in January and February (Moyle 2002). In the Feather River, the adult immigration and holding time period lasts from September through mid-April, with peak migration extending from October through November (pers. comm., Cavallo 2004; McEwan 2001; Moyle 2002; S. P. Cramer & Associates 1995).

The adult immigration and adult holding life stages are evaluated together in this subsection because it is difficult to determine the thermal regime to which steelhead have been exposed before spawning. Additionally, to be sufficiently protective of pre-spawning fish, water temperatures that provide high adult survival and high in-vivo egg survival must be available throughout the entire pre-spawning freshwater period. Although there is a paucity of studies examining the effects of thermal stress on immigrating steelhead, it has been demonstrated that thermal stress during the upstream spawning migration of sockeye salmon negatively affected the secretion of hormones controlling sexual maturation, causing numerous reproductive impairments (Macdonald et al. in McCullough et al. 2001).

Index Value Selection Rationale

Water temperatures of 52°F, 56°F, and 70°F were used as evaluation guidelines to assess the potential effects of each alternative relative to the basis of comparison. For each month of the adult immigration and holding period, each alternative was compared to the basis of comparison to evaluate potential water temperature–related effects on steelhead adult immigration and holding. Water temperatures can control the timing of adult spawning migrations and can affect the viability of eggs in holding females. Few studies have been published that examine the effects of water temperature on either steelhead immigration or holding, and none of these studies have been recent (Billard and Breton 1977, Billard and Gillet 1981, and Strickland 1967 in McCullough et al. 2001; Bruin and Waldsdorf 1975). The available studies suggest that there are adverse effects on immigrating and holding steelhead at water temperatures exceeding the mid

50°F range, and that immigration would be delayed if water temperatures approach approximately 70°F (see Table G-AQUA2.4-4).

Table G-AQUA2.4-4. Water temperature index values and supporting literature for steelhead adult immigration and holding.

Index Value	Supporting Literature
52°F	• The preferred temperature range for adult steelhead immigration is 46.0°F to 52.0°F (NOAA Fisheries 2000; NOAA Fisheries 2002a; State Water Resources Control Board 2003). • The optimum temperature range for adult steelhead immigration is 46.0°F to 52.1°F (USBR 1997). • The recommended temperature range for adult steelhead immigration is 46.0°F to 52.0°F (USBR 2003).
56°F	• To produce rainbow trout eggs of good quality, brood fish must be held at water temperatures not exceeding 56.0°F (Leitritz and Lewis 1980). • Rainbow trout brood fish must be held at water temperatures not exceeding 56°F for a period of 2–6 months before spawning to produce eggs of good quality (Bruin and Waldsdorf 1975). • Holding migratory fish at constant water temperatures above 55.4°F to 60.1°F may impede spawning success (McCullough et al. 2001).
70°F	• Migration barriers have frequently been reported for Pacific salmonids when water temperatures reach 69.8°F to 71.6°F (McCullough et al. 2001). • Snake River adult steelhead immigration was blocked when water temperatures reached 69.8 (Strickland 1967 in McCullough et al. 2001). • A water temperature of 68°F was found to drop egg fertility in vivo to 5 percent after 4.5 days (Billard and Breton 1977 in McCullough et al. 2001).

Water temperatures of 52°F, 56°F, and 70°F were chosen because they incorporate a range of conditions—from conditions that are reported to have no adverse affects to conditions that are highly adverse—and because the available literature provided the strongest support for these values. Because of the paucity of literature pertaining to steelhead adult immigration and holding, an evenly spaced range of water temperature index values could not be achieved. 52°F was selected as a water temperature index value because it has been referred to as a “recommended” (USBR 2003), “preferred” (NOAA Fisheries 2002a), and “optimum” (USBR 1997) water temperature for steelhead adult immigration. 56°F was selected because 56°F represents a water temperature above which adverse effects on migratory and holding steelhead begin to arise (Leitritz and Lewis 1980; McCullough et al. 2001; Smith et al. 1983). 70°F was selected as the highest water temperature index value because the literature suggests that water temperatures near and above 70.0°F present a thermal barrier to adult steelhead migrating upstream (McCullough et al. 2001); Strickland 1967 in McCullough et al. 2001).

Adult Spawning and Embryo Incubation (December through May)

Description of Life Stage

Steelhead spawning includes the time period from redd construction until spawning is completed with the deposition and fertilization of eggs. The embryo incubation period extends from egg deposition through alevin emergence from the substrate. In the

Central Valley, steelhead spawning reportedly occurs from October through June (McEwan 2001) and embryo (i.e., eggs and alevins) incubation generally lasts 2–3 months after deposition (McEwan 2001; Moyle 2002; Myrick and Cech 2001). In the Feather River, steelhead spawning and embryo incubation extends from December through May, with peak spawning occurring in January and February (Busby et al. 1996; pers. comm., Cavallo 2004; California Bay-Delta Authority Website; Moyle 2002). As with Chinook salmon, the steelhead embryo life stage is the most sensitive to water temperature. Because the initial embryo incubation water temperatures are a function of spawning water temperatures, one set of water temperature index values was established to evaluate spawning adults and incubating embryos.

<u>Index Value Selection Rationale</u>

Water temperatures of 52°F, 54°F, 57°F, and 60°F were used as evaluation guidelines to assess the potential effects of each alternative relative to the basis of comparison. For each month of the adult spawning and embryo incubation period, each alternative was compared to the basis of comparison to evaluate potential water temperature–related effects on adult spawning and egg incubation. Few studies have been published regarding the effects of water temperature on steelhead spawning and embryo incubation (Redding and Schreck 1979; Rombough 1988). Because anadromous steelhead and non-anadromous rainbow trout are genetically and physiologically similar, studies on non-anadromous rainbow trout also were considered in the development of water temperature index values for steelhead spawning and embryo incubation (McEwan 2001; Moyle 2002). From the available literature, water temperatures in the low 50°F range appear to support high embryo survival rates, with substantial mortality of steelhead eggs reportedly occurring at water temperatures in the high 50°F range and above (see Table G-AQUA2.4-5).

Table G-AQUA2.4-5. Water temperature index values and supporting literature for steelhead spawning and embryo incubation.

Index Value	Supporting Literature
52°F	• Rainbow trout from Mattighofen (Austria) had higher egg survival rates at 52.0°F than at 45.0°F, 59.4°F, and 66.0°F (Humpesch 1985). • Water temperatures from 48.0°F to 52.0°F are suitable for steelhead incubation and emergence in the American River and Clear Creek (NOAA Fisheries 2000; NOAA Fisheries 2001a; NOAA Fisheries 2002a). • The optimum water temperature range for steelhead spawning in the Central Valley is 46.0°F to 52.0°F (USFWS 1995). • The optimum water temperature range is 46.0°F to 52.1°F for steelhead spawning and 48.0°F to 52.1°F for steelhead egg incubation (USBR 1997). • The upper limit of preferred water temperature for steelhead spawning and egg incubation is 52.0°F (State Water Resources Control Board 2003).

Table G-AQUA2.4-5. Water temperature index values and supporting literature for steelhead spawning and embryo incubation.

Index Value	Supporting Literature
54°F	• Big Qualicum River steelhead eggs had 96.6 percent survival to hatch at 53.6°F (Rombough 1988). • The highest survival rate from fertilization to hatch for *Oncorhynchus mykiss* was for those incubated at 53.6°F (Kamler and Kato 1983). • Emergent fry were larger when North Santiam River (Oregon) winter steelhead eggs were incubated at 53.6°F rather than at 60.8°F (Redding and Schreck 1979). • The upper optimal water temperature regime based on constant or acclimation water temperatures necessary to achieve full protection of steelhead is 51.8°F to 53.6°F (USEPA 2001). • From fertilization to hatch, rainbow trout eggs and larvae had 47.3 percent mortality (Timoshina 1972). • Survival of rainbow trout eggs declined at water temperatures between 52.0°F and 59.4°F (Humpesch 1985). • The optimal constant incubation water temperature for steelhead occurs below 53.6°F (McCullough et al. 2001).
57°F	• From fertilization to 50 percent hatch, Big Qualicum River steelhead had 93 percent mortality at 60.8°F, 7.7 percent mortality at 57.2°F, and 1 percent mortality at 47.3°F and 39.2°F (Velsen 1987). • A sharp decrease in survival was observed for rainbow trout embryos incubated above 57.2°F (Kato 1980 in Kamler and Kato 1983).
60°F	• From fertilization to 50 percent hatch, Big Qualicum River steelhead had 93 percent mortality at 60.8°F, 7.7 percent mortality at 57.2°F, and 1 percent mortality at 47.3°F and 39.2°F (Velsen 1987). • From fertilization to 50 percent hatch, rainbow trout eggs from Ontario Provincial Normendale Hatchery had 56 percent survival when incubated at 59.0°F (Kwain 1975).

Water temperatures of 52°F, 54°F, 57°F, and 60°F were selected for two reasons. First, the available literature provided the strongest support for water temperature index values at or near these levels, and second, the index values reflect an evenly distributed range reported as optimal to lethal conditions for steelhead spawning and embryo incubation. Some literature suggests that water temperatures less than or equal to 50°F are optimal for steelhead spawning and embryo survival (Myrick and Cech 2001; Timoshina 1972); however, a larger body of literature suggests that optimal conditions occur at water temperatures less than or equal to 52°F (Humpesch 1985; NOAA Fisheries 2000; NOAA Fisheries 2001a; NOAA Fisheries 2002a; State Water Resources Control Board 2003; USBR 1997; USFWS 1995). Therefore, 52°F was selected as the lowest water temperature index value.

54°F was selected as the next index value because, although most of the studies conducted at or near 54.0°F report high survival rates and normal development (Kamler and Kato 1983; Redding and Schreck 1979; Rombough 1988), some evidence suggests that symptoms of thermal stress begin to appear at or near 54.0°F (Humpesch 1985; Timoshina 1972). Thus, water temperatures near 54°F may represent an inflection point between properly functioning water temperature conditions and conditions that cause negative effects on steelhead spawning and embryo incubation.

57°F was selected as an index value because embryonic mortality increases sharply and development becomes retarded at incubation temperatures greater than or equal to 57.0°F. Velsen (1987) provided a compilation of data on rainbow trout and steelhead embryo mortality to 50 percent hatch under incubation temperatures ranging from 33.8°F to 60.8°F, and demonstrated a twofold increase in mortality for embryos incubated at 57.2°F compared to embryos incubated at 53.6°F.

The 60°F index value was selected because further increases in embryonic abnormalities occurred at water temperatures near 60°F. For example, a laboratory study using gametes from Big Qualicum River, Vancouver Island, reported that steelhead mortality increased to 15 percent at a constant temperature of 59.0°F compared to less than 4 percent mortality at constant water temperatures of 42.8°F, 48.2°F, and 53.6°F (Rombough 1988). Also, alevins hatching at 59.0°F were considerably smaller and appeared less well developed than those incubated at the lower water temperature treatments. From fertilization to 50 percent hatch, Big Qualicum River steelhead had 93 percent mortality at 60.8°F, 7.7 percent mortality at 57.2°F, and 1 percent mortality at 47.3°F and 39.2°F (Velsen 1987).

Fry and Fingerling Rearing and Downstream Movement (Year-round)

Description of Life Stage

The juvenile life stage is composed of fry and fingerlings. Steelhead are fry from the time that the juvenile leaves the gravel of the spawning redd to swim up into the water column as a free-swimming fish until skeletal development is complete, at which point it reaches the fingerling stage (Bovee et al. 1998). Steelhead fry make the transition to the fingerling stage at approximately 45 to 60 mm (Bovee et al. 1998; Moyle 2002; NOAA Fisheries 1997a). After Central Valley steelhead emerge from the gravel, juveniles remain in fresh water for 1–3 years before smolting and migrating to salt water (Myrick and Cech 2001). Shapovalov and Taft (1954) suggest that most Waddell Creek, California, steelhead rear in fresh water for 2 years.

Index Value Selection Rationale

Water temperatures of 65°F, 68°F, 72°F, and 75°F were used as index values to assess the potential effects of each alternative relative to the basis of comparison. For each month of the rearing and downstream movement period for steelhead fry and fingerlings, each alternative was compared to the basis of comparison to evaluate potential water temperature–related effects on fry and fingerling rearing and downstream movement.

As with other salmonids, growth, survival, and successful smoltification of juvenile steelhead are controlled largely by water temperature. The duration of freshwater residence for juvenile steelhead is long relative to that of Chinook salmon, making steelhead more vulnerable to changes in the natural water temperature regime. Central Valley juvenile steelhead have high growth rates at water temperatures in the mid 60°F range, but require lower water temperatures to successfully undergo transformation to the smolt stage (see Tables G-AQUA2.4-6 and G-AQUA2.4-7). Water temperature index values of 65°F, 68°F, 72°F, and 75°F were selected to represent an evenly distributed range of water temperatures that reportedly provide optimal to lethal conditions for steelhead fry and fingerling rearing and downstream movement.

65°F was selected as the lowest water temperature index value because NOAA Fisheries (2002a) reported 65°F as the upper limit preferred for growth and development of Sacramento and American River juvenile steelhead. Also, 65°F was found to be within the reportedly preferred water temperature range (i.e., 62.6°F to 68.0°F) and the range that supported high growth of Nimbus strain juvenile steelhead (Cech and Myrick 1999).

Table G-AQUA2.4-6. Water temperature index values and supporting literature for steelhead fry and fingerling rearing and downstream movement.

Index Value	Supporting Literature
65°F	• An upper limit of 65°F is preferred for growth and development of Sacramento River and American River juvenile steelhead (NOAA Fisheries 2002a). • Nimbus strain juvenile steelhead growth showed an increasing trend with water temperature to 66.2°F, irrespective of ration level or rearing temperature (Cech and Myrick 1999). • The final preferred water temperature for rainbow trout fingerlings was between 66.2°F and 68°F (Cherry et al. 1977). • Nimbus strain juvenile steelhead preferred water temperatures between 62.6°F and 68.0°F (Cech and Myrick 1999). • Rainbow trout fingerlings selected water temperatures in the 62.6°F to 68.0°F range (McCauley and Pond 1971).
68°F	• Nimbus strain juvenile steelhead preferred water temperatures between 62.6°F and 68.0°F (Cech and Myrick 1999). • The final preferred water temperature for rainbow trout fingerlings was between 66.2°F and 68°F (Cherry et al. 1977). • The upper avoidance water temperature for juvenile rainbow trout was measured at 68°F to 71.6°F (Kaya et al. 1977).
72°F	• Increased physiological stress, increased agonistic activity, and a decrease in forage activity in juvenile steelhead occur after ambient stream temperatures exceed 71.6°F (Nielsen et al. 1994). • The upper avoidance water temperature for juvenile rainbow trout was measured at 68°F to 71.6°F (Kaya et al. 1977). • Estimates of upper thermal tolerance or avoidance limits for juvenile rainbow trout (at maximum ration) ranged from 71.6°F to 79.9°F (Ebersole et al. 2001 in USEPA 2002).
75°F	• The maximum weekly average water temperature for survival of juvenile and adult rainbow trout is 75.2°F (USEPA 2002). • Rearing steelhead juveniles have an upper lethal limit of 75.0°F (NOAA Fisheries 2001b). • Estimates of upper thermal tolerance or avoidance limits for juvenile rainbow trout (at maximum ration) ranged from 71.6°F to 79.9°F (Ebersole et al. 2001 in USEPA 2002).

Table G-AQUA2.4-7. Water temperature index values and supporting literature for steelhead smolt emigration.

Index Value	Supporting Literature
52°F	• Steelhead successfully undergo the smolt transformation at water temperatures in the 43.7°F to 52.3°F range (Myrick and Cech 2001). • Steelhead undergo the smolt transformation when reared in water temperatures below 52.3°F, but not at higher water temperatures (Adams et al. 1975). • The optimum water temperature range for successful smoltification in young steelhead is 44.0°F to 52.3°F (Rich 1987).
55°F	• ATPase activity was decreased and migration reduced for steelhead at water temperatures greater than or equal to 55.4°F (Zaugg and Wagner 1973). • Water temperatures should be below 55.4°F at least 60 days before the release of hatchery steelhead to prevent premature smolting and desmoltification (Wedemeyer et al. 1980). • In winter steelhead, a water temperature of 54.1°F is nearly the upper limit for smolting (McCullough et al. 2001). • Water temperatures less than or equal to 54.5°F are suitable for emigrating juvenile steelhead (USEPA 2003).

Cherry et al. (1977) and Kaya et al. (1977) both reported an upper preferred water temperature near 68.0°F for juvenile rainbow trout, duplicating the upper preferred limit for juvenile steelhead reported by Cech and Myrick (1999). Because a body of evidence supporting 68.0°F as the upper preferred limit for juvenile *Oncorhynchus mykiss* existed, 68°F was selected as a water temperature index value.

72°F was selected as a water temperature index value because symptoms of thermal stress in juvenile steelhead have been reported to occur at water temperatures approaching 72°F. For example, physiological stress to juvenile steelhead in Northern California streams was demonstrated by increased gill flare rates, decreased foraging activity, and increased agonistic activity as stream temperatures rose above 71.6°F (Nielsen et al. 1994). Also, 72°F was selected as an index value because 71.6°F has been reported as an upper avoidance water temperature (Kaya et al. 1977) and an upper thermal tolerance water temperature (Ebersole et al. 2001 in USEPA 2002) for juvenile rainbow trout.

Smolt Emigration (January through June)

Description of Life Stage

Fingerling steelhead become smolts when physiological changes occur that allow the juvenile to survive the transition from fresh water to salt water during seaward migration. In addition to physiological changes, morphological changes also take place during smoltification (Hoar 1988). Salmonid smolts can be distinguished from pre-smolts by their silvery appearance and relatively slim, streamlined bodies (Hoar 1988). Steelhead smolts migrate out to sea between 1 and 3 years of age, between 10 and 25 centimeters (cm) fork length (FL) (Moyle 2002). In the Feather River, steelhead smolt emigration occurs from January through June (pers. comm., Cavallo 2004; McEwan 2001; Newcomb and Coon 2001; Snider and Titus 2000; USFWS 1995).

Index Value Selection Rationale

Water temperatures of 52°F and 55°F were used as index values to assess the potential effects of each alternative relative to the basis of comparison. For each month of the steelhead smolt emigration period, each alternative was compared to the basis of comparison to evaluate potential water temperature–related effects on smolt emigration. Laboratory data suggest that smoltification, and therefore successful emigration of juvenile steelhead, is directly controlled by water temperature (Adams et al. 1973; Adams et al. 1975).

Water temperature index values of 52°F and 55°F were selected to evaluate the steelhead smolt emigration life stage because most literature on the effects of water temperature on steelhead smolting suggest that water temperatures less than 52°F (Adams et al. 1975; Myrick and Cech 2001; Rich 1987) or less than 55°F (USEPA 2003; McCullough et al. 2001; Wedemeyer et al. 1980; Zaugg and Wagner 1973) are required for successful smoltification to occur. Adams et al. (1975) tested the effect of water temperature (43.7°F, 50.0°F, 59.0°F, or 68.0°F) on the increase of gill microsomal Na^+-, K^+-stimulated ATPase activity associated with parr-smolt transformation in steelhead; this study found a twofold increase in Na^+-, K^+-ATPase at 43.7°F and 50.0°F, but no increase at 59.0°F or 68.0°F. In a subsequent study, the highest water temperature where a parr-smolt transformation occurred was at 52.3°F (Adams et al. 1973). The results of Adams et al. (1973) were reviewed by Myrick and Cech (2001) and Rich (1987); in both cases the authors recommended that water temperatures below 52.3°F are required to successfully complete the parr-smolt transformation.

Zaugg and Wagner (1973) examined the influence of water temperature on gill ATPase activity related to parr-smolt transformation and migration in steelhead; this study found that ATPase activity was decreased and migration reduced when juveniles were exposed to water temperatures of 55.4°F or greater. In a technical document prepared by USEPA to provide temperature water quality standards for the protection of native salmon and trout in the Northwest, water temperatures less than or equal to 54.5°F were recommended for emigrating juvenile steelhead (USEPA 2003).

G-AQUA2.4.2.3 Predation-related Effects

As discussed above for Chinook salmon, the high concentration of spawning salmonids in the reach of the Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet results in a high concentration of juvenile salmonids (Seesholtz et al. 2003). In addition, water temperature and flow changes included as components of the alternatives affect predator fish species distribution, relative abundance, feeding behavior, and consumption rates. Water temperature, flow changes, and actions anticipated to improve the quantity, quality, and distribution of rearing habitat for juvenile salmonids (large woody debris placement and side-channel habitat improvement and creation) also affect steelhead fry and fingerling rearing behavior and distribution, growth rates, predator avoidance cover, and smolt emigration timing and behavior. The alternatives were evaluated qualitatively to determine the nature and general magnitude of potential predation-related effects on rearing and downstream movement by steelhead fry and fingerlings. Section G-AQUA1.11.3 of Appendix G-AQUA1 contains additional information related to salmonid predation.

G-AQUA2.4.2.4 Fisheries Management–related Effects

There would be no changes in fish stocking or reservoir fisheries habitat enhancement programs under the alternatives; therefore, these programs are not included in the evaluation of alternatives. Adaptive hatchery management practices are included in the Proposed Action and Alternative 2 and include proposals for experimental releases of different sized juvenile fish at different times and locations, predator avoidance and cover utilization conditioning, changes to brood stock selection, disease management and screening, and other hatchery management changes. These changes in hatchery management were evaluated qualitatively for their potential effects on predation, juvenile rearing and emigration survival rates, adult immigration straying rates, genetic introgression, and the incidences of fish diseases. Section G-AQUA1.5.1 of Appendix G-AQUA1 contains additional information related to the effects of salmonid management on Feather River fishes.

Fishing Regulations

Increases in recreation access, including increases in visitation and fisheries-related use of recreational resources, are anticipated under all of the alternatives. Chapter 3.0, Proposed Action and Alternatives, contains descriptions of recreation-related changes included in each of the alternatives; Section 5.10 contains evaluations of recreation-related effects. Effects of increased recreational fishing and poaching on angling-related mortality and the contribution to adult pre-spawning mortality rates were evaluated qualitatively to determine effects on fisheries resources, and specifically, on steelhead.

Fish barrier weirs for Chinook salmon are included in the Proposed Action and Alternative 2, which are described in detail in Chapter 3.0, Proposed Action and Alternatives. These actions would result in changes in fishing regulations. Therefore, placement of barrier weirs was evaluated qualitatively to determine their effects on fishing take limits and poaching. Effects on recreational activities resulting from changes in fishing regulations associated with these actions are included in Section 5.10.

G-AQUA2.4.3 American Shad

G-AQUA2.4.3.1 Flow-related Effects

Flow changes and flow fluctuations associated with the alternatives were evaluated qualitatively to determine the potential effects on adult immigration and spawning by American shad based on the relative changes to the fish habitat with regard to water depth, water velocity, and fish passage impediments compared to the known fish distribution and relative abundance. The American shad spawning migration period in the Feather River occurs from April through June. Sections G-AQUA1.4.2 and

G-AQUA1.4.3 of Appendix G-AQUA1 provide additional information on American shad immigration and potential flow-related passage impediments in the lower Feather River.

G-AQUA2.4.3.2 Water Temperature–related Effects

Water temperature–related effects were evaluated using the three-step process described in Section G-AQUA2.2.3 of this appendix. The reported suitable water temperature range for adult immigration and spawning by American shad is 46°F to 79°F, and this life stage occurs from April through June in the lower Feather River (DFG 1986; Leggett and Whitney 1972; Moyle 2002; Painter et al. 1979; USFWS 1995; Walburg and Nichols 1967; Wang 1986).

Because of the limitations of available literature in reporting effects of specific water temperatures on adult immigration and spawning by American shad, the water temperature index values selected represent the range of water temperatures reported as “preferred,” “optimal,” or “suitable,” or water temperatures in which the species has been observed. The water temperature analysis for American shad habitat compares the number of days of daily mean water temperatures that fall within the water temperature range reported as suitable American shad habitat during the life stage period evaluated. Section 5.5.1.3, Fish Species Overview, and Section G-AQUA1.4.2 of Appendix G-AQUA1 provide additional information on American shad life history, and habitat and water temperature requirements.

G-AQUA2.4.4 Black Bass

G-AQUA2.4.4.1 Water Temperature–related Effects

Water temperature–related effects were evaluated using the three-step process described in Section G-AQUA2.2.3 of this appendix. The reported suitable water temperature range for black bass adult spawning is 54°F to 75°F, and this life stage occurs from March through June in the lower Feather River (Aasen and Henry 1981; Davis and Lock 1997; Graham and Orth 1986; Lee 1999; Lukas and Orth 1995; McKechnie 1966; Miller and Storck 1984; Moyle 2002; Sammons et al. 1999; pers. comm., See 2003; Wang 1986).

The water temperature analysis for black bass habitat compares the number of days of daily mean water temperatures that fall within the water temperature range reported as suitable black bass habitat during the life stage period evaluated. The black bass analysis includes several fish species with similar water temperature requirements, including largemouth bass, smallmouth bass, redeye bass, and spotted bass. Because of the limitations of available literature in reporting effects of specific water temperatures on black bass adult spawning, the water temperature index values selected represent the range of water temperatures reported as “preferred,” “optimal,” or “suitable,” or water temperatures in which the species has been observed. Section 5.5.1.3, Fish Species Overview, and Sections G-AQUA1.4.2, G-AQUA1.3.2, and G-AQUA1.3.4 of Appendix G-AQUA1 contain additional information on black bass life history, and habitat and water temperature requirements.

G-AQUA2.4.5 Green Sturgeon

The green sturgeon effect analysis is based upon individual life stages because each life stage has specific flow and water temperature requirements. The green sturgeon life stages included in this analysis are:

- Adult immigration and holding (February through July);
- Adult spawning and embryo incubation (March through July);
- Juvenile rearing (year-round); and
- Juvenile emigration (May through September).

More detailed descriptions of green sturgeon life stage water temperature requirements and periods are provided in Section 5.5.1.3, Fish Species Overview, and Section G-AQUA1.4.2 of Appendix G-AQUA1.

G-AQUA2.4.5.1 Water Temperature–related Effects

Water temperature–related effects were evaluated using the three-step process described in Section G-AQUA2.2.3 of this appendix. Green sturgeon water temperature index values were developed from an extensive review of the available literature to be used as guidelines for assessing potential effects of each alternative. The specific index values developed for each green sturgeon life stage are discussed below. Because of the limitations of available literature in reporting effects of specific water temperatures on green sturgeon, the water temperature index values selected represent the range of water temperatures reported as “preferred,” “optimal,” or “suitable,” or were the water temperatures in which the species has been observed. The water temperature analysis for green sturgeon habitat compares the number of days of daily mean water temperatures that fall within the water temperature range reported as suitable green sturgeon habitat during the life stage period evaluated.

Adult Immigration and Holding (February through July)

Water temperatures ranging from 44°F to 61°F are reported as “preferred,” “optimal,” “suitable,” or “observed” for adult immigration and holding by green sturgeon (Beamesderfer and Webb 2002; DFG 2001; DFG Website; Emmett et al. 1991; Environmental Protection Information Center et al. 2001; Erickson et al. 2002; USFWS 1995). The range of reported water temperatures was used as an evaluation guideline to assess the potential effects of each alternative on adult immigration and holding by green sturgeon relative to the basis of comparison.

Adult Spawning and Embryo Incubation (March through July)

Water temperatures ranging from 46°F to 68°F are reported as “preferred,” “optimal,” “suitable,” or “observed” for adult spawning and embryo incubation by green sturgeon (Artyukhin and Andronov 1990; Beamesderfer and Webb 2002; Cech Jr. et al. 2000;

DFG 2001; DFG Website; Environmental Protection Information Center et al. 2001; Erickson et al. 2002; Moyle et al. 1995; USFWS 1995). The range of reported water temperatures was used as an evaluation guideline to assess the potential effects of each alternative on adult spawning and embryo incubation by green sturgeon relative to the basis of comparison.

Juvenile Rearing (Year-round)

Water temperatures ranging from 50°F to 66°F are reported as "preferred," "optimal," "suitable," or "observed" for green sturgeon juvenile rearing (Cech Jr. et al. 2000; Conservation Management Institute, Virginia Tech Website; Environmental Protection Information Center et al. 2001; Farr et al. 2001; Moyle 2002; NOAA Fisheries 2003a). The range of reported water temperatures was used as an evaluation guideline to assess the potential effects of each alternative on green sturgeon juvenile rearing relative to the basis of comparison.

Juvenile Emigration (May through September)

Water temperatures ranging from 50°F to 66°F are reported as "preferred," "optimal," "suitable," or "observed" for green sturgeon juvenile emigration (Adams et al. 2002; Beamesderfer and Webb 2002; Cech Jr. et al. 2000; Conservation Management Institute, Virginia Tech Website; Environmental Protection Information Center et al. 2001; Erickson et al. 2002; Farr et al. 2001; Moyle 2002; NOAA Fisheries 2003a). The range of reported water temperatures was used as an evaluation guideline to assess the potential effects of each alternative on green sturgeon juvenile emigration relative to the basis of comparison.

G-AQUA2.4.6 Hardhead

G-AQUA2.4.6.1 Water Temperature–related Effects

Water temperature–related effects were evaluated using the three-step process described in Section G-AQUA2.2.3 of this appendix. The reported suitable water temperature range for hardhead adult spawning is 55°F to 75°F, and this life stage occurs from April through August in the lower Feather River (Cech Jr. et al. 1990; Moyle 2002; Wang 1986). The water temperature analysis for hardhead habitat compares the number of days of daily mean water temperatures that fall within the water temperature range reported as suitable hardhead habitat during the life stage period evaluated.

Because of the limitations of available literature in reporting effects of specific water temperatures on hardhead adult spawning, the water temperature index values selected represent the range of water temperatures reported as "preferred," "optimal," or "suitable," or are the water temperatures in which the species has been observed. Section 5.5.1.3, Fish Species Overview, and Section G-AQUA1.4.2 of Appendix G-AQUA1 provide additional information on hardhead life history, and habitat and water temperature requirements.

G-AQUA2.4.7 River Lamprey

G-AQUA2.4.7.1 Water Temperature–related Effects

Water temperature–related effects were evaluated using the three-step process described in Section G-AQUA2.2.3 of this appendix. The water temperature range defined as suitable for adult spawning and embryo incubation by river lamprey is 43°F to 72°F, and this life stage reportedly occurs from April through June in the lower Feather River (Beamish 1980; Kostow 2002; Meeuwig et al. 2003; Meeuwig et al. 2002; Moyle 2002; Stone et al. 2001; Wang 1986). Because little literature was available regarding the life stage timing of and water temperature tolerance range for adult spawning and embryo incubation, literature describing Pacific lamprey (*Lampetra tridentata)* also was used as a substitute given the reported similarities between the two species. The water temperature analysis for river lamprey habitat compares the number of days of daily mean water temperatures that fall within the water temperature range reported as suitable river lamprey habitat during the life stage period evaluated.

Because of the limitations of available literature in reporting effects of specific water temperatures on adult spawning by river lamprey, the water temperature index values selected represent the range of water temperatures reported as “preferred,” “optimal,” or “suitable,” or are the water temperatures in which the species has been observed. Section 5.5.1.3, Fish Species Overview, and Section G-AQUA1.4.2 of Appendix G-AQUA1 provide additional information on river lamprey life history, and habitat and water temperature requirements.

G-AQUA2.4.8 Sacramento Splittail

G-AQUA2.4.8.1 Flow-related Effects

Site-specific flow-related effects on the availability of habitat for the adult spawning, embryo incubation, and initial rearing life stages of the Sacramento splittail were evaluated using a relative habitat availability index (see Section G-AQUA1.4.3 of Appendix G-AQUA1 for additional information). Splittail adult spawning, embryo incubation, and initial rearing occur in the lower portions of the lower Feather River from February through May. The relative amount of available habitat for adult spawning, embryo incubation, and initial rearing by splittail was identified by locating habitat units that met the substrate requirements for the life stage (grass, shrub, and forb) from the SP-T4 vegetation classification mapping. Elevation data on selected potentially suitable habitat units were collected by DWR surveyors. The elevation ranges of the potential habitat units were compared to the nearest available U.S. Geological Survey (USGS) survey transect containing stage-discharge relationships established by SP-E1.6, Feather River Flow-Stage Model Development, to determine the flow ranges that would inundate each habitat unit to the reported suitable depth range of 3–6 feet deep. The amount of habitat with suitable substrate and inundation depth available at each flow was summed to create an index of the relative amount of spawning and initial rearing habitat for splittail available in the lower Feather River at any given flow. This index is shown in Figure G-AQUA2.4-3.

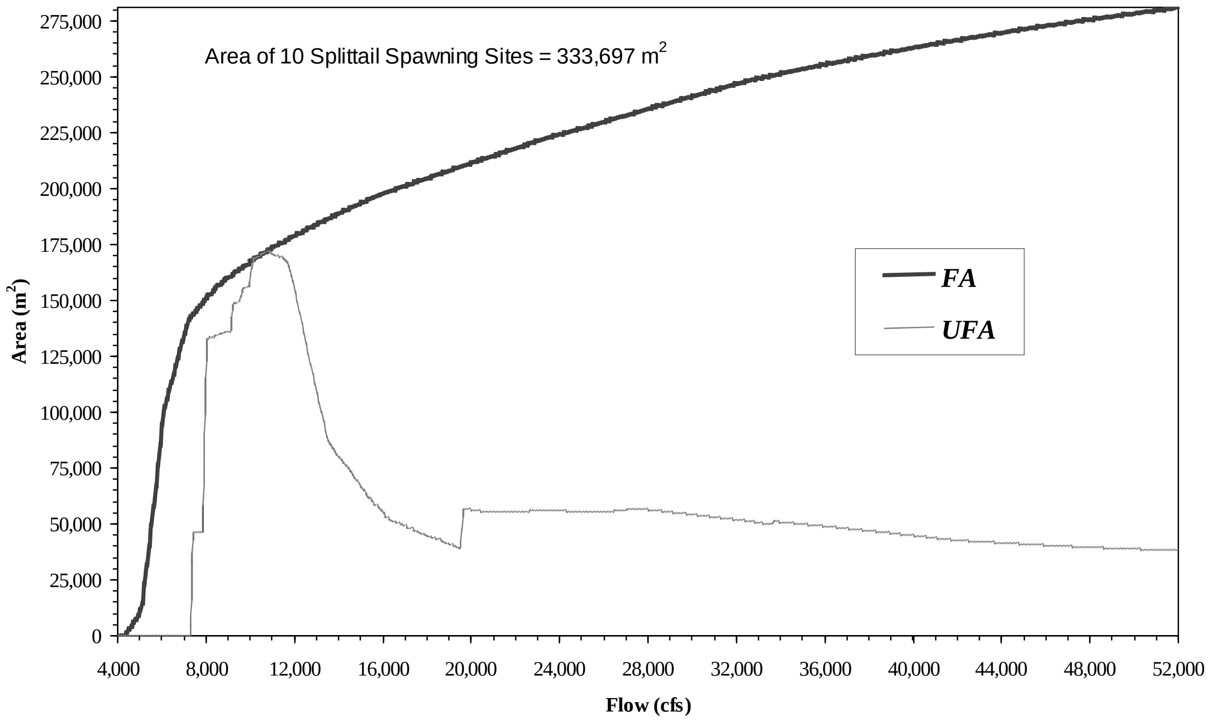


Figure G-AQUA2.4-3. Flow, or flooded area (FA), vs. useable flooded area (UFA) for adult spawning, egg incubation, and initial rearing by Sacramento splittail in the High Flow Channel.

The modeling results, which show lower Feather River flows under the alternatives during the February-through-May splittail adult spawning, embryo incubation, and initial rearing period over the 72-year period of record, were evaluated to determine the differences in the total resulting amount of available habitat. The total resulting amount of habitat available was calculated by multiplying the amount of useable flooded area (UFA) by the flows that occur during the February-through-May life stage period. The amounts of total available habitat were compared proportionately between the alternatives and the basis of comparison to determine the type and relative magnitude of habitat availability change that would occur with implementation of the alternatives. Section 5.5.1.3, Fish Species Overview, and Sections G-AQUA1.4.2 and G-AQUA1.4.3 of Appendix G-AQUA1 provide additional information on Sacramento splittail life history and habitat requirements.

G-AQUA2.4.8.2 Water Temperature–related Effects

Water temperature–related effects were evaluated using the three-step process described in Section G-AQUA2.2.3 of this appendix. The reported suitable water temperature range for adult spawning, egg incubation, and initial rearing by Sacramento splittail is 45°F to 75°F, and this life stage occurs from February through May in the lower Feather River. Young and Cech Jr. (1996) investigated thermal tolerances for juvenile splittail and reported a tolerance range of 7°C to 32°C (44.6°F to 89.6°F). Caywood (1974) reported splittail spawning in water temperatures from 9°C to 20°C

(48.2°F to 68.0°F). Sommer et al. (2002) reported splittail spawning in water temperatures from 11°C to 24°C (51.8°F to 75.2°F). The water temperature analysis for splittail habitat compares the number of days of daily mean water temperatures that fall within the water temperature range reported as suitable splittail habitat during the life stage period evaluated.

Because of the limitations of available literature in reporting the effects of specific water temperatures on splittail adult spawning, embryo incubation, and initial rearing, the water temperature index values selected represent the range of water temperatures reported as "preferred," "optimal," or "suitable," or were water temperatures in which the species has been observed. Section 5.5.1.3, Fish Species Overview, and Sections G-AQUA1.4.2 and G-AQUA1.4.3 of Appendix G-AQUA1 provide additional information on Sacramento splittail life history habitat and water temperature requirements.

G-AQUA2.4.9 Striped Bass

G-AQUA2.4.9.1 Flow-related Effects

Flow changes and flow fluctuations associated with the alternatives were evaluated qualitatively for the potential effects on striped bass adult spawning for the relative changes to the fish habitat with regard to water depth, water velocity, and fish passage impediments compared to the known fish distribution and relative abundance. The striped bass adult spawning period in the lower Feather River occurs from April through June. Section 5.5.1.3, Fish Species Overview, and Section G-AQUA1.4.2 of Appendix G-AQUA1 provide additional information on striped bass adult spawning, egg incubation, and initial rearing and life history habitat requirements.

G-AQUA2.4.9.2 Water Temperature–related Effects

Water temperature–related effects were evaluated using the three-step process described in Section G-AQUA2.2.3 of this appendix. The reported suitable water temperature range for striped bass adult spawning is 59°F to 68°F, and this life stage occurs from April through June in the lower Feather River (Bell 1991; Hassler 1988; Hill et al. 1989; Moyle 2002). The water temperature analysis for striped bass adult spawning habitat compares the number of days of daily mean water temperatures that fall within the water temperature range reported as suitable striped bass adult spawning habitat during the life stage period evaluated.

Because of the limitations of available literature in reporting effects of specific water temperatures on striped bass adult spawning, the water temperature index values selected represent the range of water temperatures reported as "preferred," "optimal," or "suitable," or were the water temperatures in which the species has been observed. Section 5.5.1.3, Fish Species Overview, and Section G-AQUA1.4.2 of Appendix G-AQUA1 provide additional information on striped bass life history habitat and water temperature requirements.

G-AQUA2.5 DETERMINATION OF EFFECTS

The evaluation process for determining potential effects resulting from implementation of the alternatives was based on the integration of the effects identified for each species and life stage selected for evaluation. The results of the evaluation of each life stage and qualitative analyses for a species were aggregated and evaluated to determine the overall effect of an alternative on a species. Positive and negative effects on the species and life stages were evaluated using professional experience and judgment to weigh the relative magnitude, biological effects, and importance of a life stage in contributing to the overall success and condition of the species. The overall effect of an alternative on a species was the basis for the evaluation of the alternatives. Sections 5.5.2 and 5.7.3.1 provide a summary of the overall effects of the alternatives on each species of primary management concern.

G-AQUA2.6 REFERENCES

G-AQUA2.6.1 Printed References

Aasen, K. D., and F. D. Henry. 1981. Spawning Behavior and Requirements of Alabama Spotted Bass, *Micropterus punctulatus henshalli,* in Lake Perris, Riverside City, California. California Fish and Game 67:118-125.

Adams, B. L., W. S. Zaugg, and L. R. McLain. 1973. Temperature Effect on Parr-Smolt Transformation in Steelhead Trout (*Salmo gairdneri*) as Measured by Gill Sodium-Potassium Stimulated Adenosine Triphosphatase. Comparative Biochemistry and Physiology 44A:1333-1339.

Adams, B. L., W. S. Zaugg, and L. R. McLain. 1975. Inhibition of Salt Water Survival and Na-K-ATPase Elevation in Steelhead Trout (*Salmo gairdneri*) by Moderate Water Temperatures. Transactions of the American Fisheries Society 104:766-769.

Adams, P. B., C. B. Grimes, J. E. Hightower, S. T. Lindley, and M. L. Moser. 2002. Status Review for North American Green Sturgeon, *Acipenser Medirostris*. National Oceanic and Atmospheric Administration.

Artyukhin, E. N., and A. E. Andronov. 1990. A Morphobiological Study of the Green Sturgeon, *Acipenser medirostris* (Chondrostei, Acipenseridae), from the Tumnin (Datta) River and Some Aspects of the Ecology and Zoogeography of Acipenseridae. Journal of Ichthyology 30:11-22.

Baker, P. F., T. P. Speed, and F. K. Ligon. 1995. Estimating the Influence of Temperature on the Survival of Chinook Salmon Smolts (*Oncorhynchus tshawytscha*) Migrating through the Sacramento-San Joaquin River Delta of California. Canadian Journal of Fisheries and Aquatic Science 52:855-863.

Banks, J. L., L. G. Fowler, and J. W. Elliot. 1971. Effects of Rearing Temperature on Growth, Body Form, and Hematology on Fall Chinook Fingerlings. The Progressive Fish-Culturist 33:20-26.

Beamesderfer, R. C., and M. A. H. Webb. 2002. Green Sturgeon Status Review Information.

Beamish, R. J. 1980. Adult Biology of the River Lamprey (*Lampetra ayresi*) and the Pacific Lamprey (*Lamptera tridentata*) from the Pacific Coast of Canada. Canadian Journal of Fisheries and Aquatic Science 37:1906-1923.

Bell, M. C. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. U.S. Army Corps of Engineers, Fish Passage Development and Evaluation Program, Sacramento, California.

Berman, C. H. 1990. The Effect of Holding Temperatures on Adult Spring Chinook Salmon Reproductive Success. M.S. thesis. University of Washington, Seattle, Washington.

Bilby, R. E., B. R. Fransen, and P. A. Bisson. 1996. Incorporation of Nitrogen and Carbon from Spawning Coho Salmon into the Trophic System of Small Streams: Evidence from Stable Isotopes. Canadian Journal of Fisheries and Aquatic Sciences 53:164-173.

Bilby, R. E., P. A. Fransen, P. A. Bisson, and J. K. Walter. 1998. Response of Juvenile Salmon (*Onchorhynchus kisutch*) and Steelhead (*Onchorhynchus mykiss*) to the Addition of Salmon Carcasses to Two Streams in Southwestern Washington, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 39:426-447.

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

Bovee, K. D., B. L. Lamb, J. M. Bartholow, C. B. Stalnaker, J. Taylor, and J. Henriksen. 1998. Stream Habitat Analysis Using the Instream Flow Incremental Methodology. Report No. USGS/BRD-1998-0004. U.S. Geological Survey, Biological Resources Division Information and Technology Report.

Brett, J. R. 1952. Temperature Tolerance in Young Pacific Salmon, Genus Oncorhynchus. Journal of the Fisheries Research Board of Canada 9:265-323.

Brett, J. R., W. C. Clarke, and J. E. Shelbourn. 1982. Experiments on Thermal Requirements for Growth and Food Conversion Efficiency of Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1127:1-28.

Bruin, D., and B. Waldsdorf. 1975. Some Effects on Rainbow Trout Broodstock, of Reducing Water Temperature From 59 F to 52 F. U.S. Fish and Wildlife Service, National Fish Hatchery, Hagerman, Idaho.

Burck, W. A. 1980. Spring Chinook Studies in the John Day River, Federal Aid Progress Reports—Fisheries. Oregon Department of Fish and Wildlife, Fish Division, Portland, Oregon.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. Report No. NMFS-NWFSC-27. National Oceanic and Atmospheric Administration Technical Memorandum, U.S. Department of Commerce.

Caywood, M. L. 1974. Contributions to the Life History of the Splittail *Pogonichthys Macrolepidotus* (Ayres). M.S. thesis. California State University, Sacramento, California.

Cech Jr., J. J., S. I. Doroshov, G. P. Moberg, B. P. May, R. G. Schaffter, and D. M. Kohlhorst. 2000. Biological Assessment of Green Sturgeon in the Sacramento-San Joaquin Watershed (Phase 1). Final Report to CALFED Bay-Delta Program.

Cech Jr., J. J., S. J. Mitchell, D. T. Castleberry, and M. McEnroe. 1990. Distribution of California Stream Fishes: Influence of Environmental Temperature and Hypoxia. Environmental Biology of Fishes 29:95-105.

Cech, J. J., and C. A. Myrick. 1999. Steelhead and Chinook Salmon Bioenergetics: Temperature, Ration, and Genetic Effects. Technical Completion Report, Project No. UCAL-WRC-W-885. University of California Water Resources Center.

Cherry, D. S., K. L. Dickson, J. Cairns, and J. R. Stauffer. 1977. Preferred, Avoided, and Lethal Temperatures of Fish During Rising Temperature Conditions. Journal of the Fisheries Research Board of Canada 34:239-246.

Clarke, W. C., and J. E. Shelbourn. 1985. Growth and Development of Seawater Adaptability by Juvenile Fall Chinook Salmon (*Oncorhynchus tshawytscha*) in Relation to Temperature. Aquaculture 45:21-31.

Combs, B. D., and R. E. Burrows. 1957. Threshold Temperatures for the Normal Development of Chinook Salmon Eggs. Progressive Fish Culturist 19:3-6.

Conservation Management Institute. Taxonomy—Species Green Sturgeon. Site accessed October 30, 2003. URL = http://fwie.fw.vt.edu/indexnew.html.

Dauble, D. D., and D. G. Watson. 1997. Status of Fall Chinook Salmon Populations in the Mid-Columbia River, 1948-1992. North American Journal of Fisheries Management 17:283-300.

Davis, J. T., and J. T. Lock. 1997. Largemouth Bass: Biology and Life History. Southern Regional Aquaculture Center Publication No. 200.

DFG (California Department of Fish and Game). 1986. Instream Flow Requirements of the Fish and Wildlife Resources of the Lower American River, Sacramento County, California.

DFG (California Department of Fish and Game). 1998. A Status Review of the Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) in the Sacramento River Drainage. Candidate Species Status Report 98-01. Sacramento, California.

DFG (California Department of Fish and Game). 2001. California's Living Marine Resources: A Status Report. California Department of Fish and Game Bulletin 465-466. December 2001.

DFG (California Department of Fish and Game). California's Plants and Animals: Green Sturgeon. URL = http://www.dfg.ca.gov/hcpb/index.shtml. Site accessed September 23, 2002.

DWR (California Department of Water Resources). 1996. Feather River Gravel Study—Fish Diversion Dam to Honcut Creek.

DWR (California Department of Water Resources). 2002. Emigration of Juvenile Chinook Salmon in the Feather River, 1998-2001. Division of Environmental Services, Sacramento, California.

DWR and DFG (California Department of Water Resources and California Department of Fish and Game). 1983. Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife. Sacramento, California. August 1983.

DWR and USBR (California Department of Water Resources and U.S. Bureau of Reclamation). 2000. Biological Assessment—Effects of the Central Valley Project and State Water Project on Steelhead and Spring-Run Chinook Salmon.

Eaves, J. N. 1982. Feather River Spawning Gravel Baseline Study. California Department of Water Resources, Northern District, Red Bluff, California.

Emmett, R. L., S. L. Stone, S. A. Hinton, and M. E. Monaco. 1991. Distribution and Abundance of Fishes and Invertebrates in West Coast Estuaries, Volume II: Species Life History Summaries. ELMR Report No. 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, Maryland.

Environmental Protection Information Center, Center for Biological Diversity, and WaterKeepers Northern California. 2001. Petition to List the North American Green Sturgeon (*Acipenser medirostris*) as an Endangered or Threatened Species Under the Endangered Species Act. Garberville, Berkeley, and San Francisco, California. June 2001.

Erickson, D. L., J. A. North, J. E. Hightower, J. Weber, and L. Lauck. 2002. Movement and Habitat use of Green Sturgeon (*Acipenser medirostris*) in the Rogue River, Oregon, USA. Journal of Ichthyology 18:565-569.

Erman, N. A. 1996. Sierra Nevada Ecosystem Project: Final Report to Congress. Vol. II, Assessments and Scientific Basis for Management Options. University of California, Davis, Centers for Water and Wildland Resources, Davis, California.

Farr, R. A., M. L. Hughes, and T. A. Rien. 2001. Green Sturgeon Population Characteristics in Oregon—Annual Progress Report. Sport Fish Restoration Project F-178-R. Oregon Department of Fish and Wildlife, Portland, Oregon.

Fisher, F. W. 1994. Past and Present Status of Central Valley Chinook Salmon. Conservation Biology 8:870-873.

Friesen, T. G. 1998. Effects of Food Abundance and Temperature on Growth, Survival, Development and Abundance of Larval and Juvenile Smallmouth Bass. Ph.D. Dissertation. University of Guelph, Guelph, Ontario.

Goff, G. P. 1996. Reproductive Success of Male Smallmouth Bass in Long Point Bay, Lake Erie. Transactions of the American Fisheries Society 115:415-423.

Graham, R. J., and D. J. Orth. 1986. Effects of Temperature and Streamflow on Time and Duration of Spawning by Smallmouth Bass. Transactions of the American Fisheries Society 115:693-702.

Groves, P. A., and J. A. Chandler. 1999. Spawning Habitat Used by Fall Chinook Salmon in the Snake River. North American Journal of Fisheries Management 19:912-922.

Hassler, T. J. 1988. Species Profiles: Life Histories and Environmental Requirements of Coast Fishes and Invertebrates (Pacific Southwest)—Striped Bass. U.S. Fish and Wildlife Service Biological Report 82(11.82). U.S. Army Corps of Engineers, TR EL-82-4.

Hedgecock, D., M. A. Banks, V. K. Rashbrook, C. A. Dean, and S. M. Blankenship. 2001. Applications of Population Genetics to Conservation of Chinook Salmon Diversity in the Central Valley. In: R. L. Brown (ed.), Contributions to the Biology of Central Valley Salmonids, pp. 45-70. California Department of Fish and Game, Sacramento, California.

Hill, J., J. W. Evans, and M. J. Van Den Avyle. 1989. Species Profiles: Life Histories and Environmental Requirements of Coast Fishes and Invertebrates (South Atlantic)—Striped Bass. U.S. Fish and Wildlife Service Biological Report 82(11.118). U.S. Army Corps of Engineers, TR EL-82-4.

Hinze, J. A. 1959. Nimbus Salmon and Steelhead Hatchery: Annual Report, Fiscal Year 1957-1958. DFG Inland Fisheries Administrative Report No. 59-4.

Hoar, W. S. 1988. The Physiology of Smolting Salmonids. Fish Physiology 11:275-343.

Humpesch, U. H. 1985. Inter- and Intra-Specific Variation in Hatching Success and Embryonic Development of Five Species of Salmonids and *Thymallus thymallus*. Archiwum Hydrobiologia 104:129-144.

Hunt, J., and C. A. Annett. 2002. Effects of Habitat Manipulation on Reproductive Success of Individual Largemouth Bass in an Ozark Reservoir. North American Journal of Fisheries Management 22:1201-1208.

Hurley, G. V. 1975. The Reproductive Success and Early Growth of Smallmouth Bass, *Micropterus Dolomieu Lacepede,* at Baie Du Dore, Lake Huron, Ontario. M.S. Thesis. University of Toronto, Toronto.

Independent Scientific Group. 1996. Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem. Northwest Power and Conservation Council, Portland, Oregon.

Interagency Ecological Program Steelhead Project Work Team. Monitoring, Assessment, and Research on Central Valley Steelhead: Status of Knowledge, Review of Existing Programs, and Assessment of Needs. Accessed 2004. URL = http://calwater.ca.gov/Programs/Science/cmarp/a7a11.html.

Johnson, H. E., and R. F. Brice. 1953. Effects of Transportation of Green Eggs, and of Water Temperature During Incubation, on the Mortality of Chinook Salmon. The Progressive Fish-Culturist 15:104-108.

Kamler, E., and T. Kato. 1983. Efficiency of Yolk Utilization by *Salmo gairdneri* in Relation to Incubation Temperature and Egg Size. Polskie Archiwum Hydrobiologii 30:271-306.

Kaya, C. M., L. R. Kaeding, and D. E. Burkhalter. 1977. Use of Cold-Water by Rainbow and Brown Trout in a Geothemally Heated Stream. The Progressive Fish-Culturist 39:37-38.

Knotek, W. L., and D. J. Orth. 1998. Survival for Specific Life Intervals of Smallmouth Bass, *Micropterus dolomieu,* during Parental Care. Environmental Biology of Fishes 51:285-296.

Kostow, K. 2002. Oregon Lampreys: Natural History, Status and Analysis of Management Issues. Oregon Department of Fish and Wildlife.

Kramer, R. H., and L. L. Smith. 1962. Formation of Year Classes in Largemouth Bass. Transactions of the American Fisheries Society 91:29-41.

Kwain, W. 1975. Effects of Temperature on Development and Survival of Rainbow Trout, *Salmo gairdneri*, in Acid Waters. Journal of the Fisheries Research Board of Canada 32:493-497.

Lassettre, N. S., and R. R. Harris. 2001. The Geomorphic and Ecological Influence of Large Woody Debris in Streams and Rivers. University of California, Berkeley, California.

Lee, D. P. 1999. Water Level Fluctuation Criteria for Black Bass in California Reservoirs. Reservoir Research and Management Project: Informational Leaflet No. 12:

Leggett, W. C., and R. R. Whitney. 1972. Water Temperature and the Migration of American Shad. Fishery Bulletin 70:659-670.

Leitritz, E., and R. C. Lewis. 1980. Trout and Salmon Culture (Hatchery Methods). California Fish Bulletin Number 164. University of California.

Lukas, J. A., and D. J. Orth. 1995. Factors Affecting Nesting Success of Smallmouth Bass in a Regulated Virginia Stream. Transactions of the American Fisheries Society 124:726-735.

Marine, K. R. 1992. A Background Investigation and Review of the Effects of Elevated Water Temperature on Reproductive Performance of Adult Chinook Salmon (*Oncorhynchus tshawytscha*) with Suggestions for Approaches to the Assessment of Temperature Induced Reproductive Impairment of Chinook Salmon Stocks in the American River, California. Department of Wildlife and Fisheries Biology, University of California, Davis, California.

Marine, K. R. 1997. Effects of Elevated Water Temperature on Some Aspects of the Physiological and Ecological Performance of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*): Implications for Management of California's Central Valley Salmon Stocks. University of California, Davis, California.

McCauley, R. W., and W. L. Pond. 1971. Temperature Selection of Rainbow Trout (*Salmo gairdneri*) Fingerlings in Vertical and Horizontal Gradients. Journal of the Fisheries Research Board of Canada 28:1801-1804.

McCullough, D. A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon. Report No. EPA 910-R-99-010. U.S. Environmental Protection Agency Region 10, Seattle, Washington.

McCullough, D. A., S. Spalding, D. Sturdevant, and M. Hicks. 2001. Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids—Issue Paper 5. Report No. EPA-910-D-01-005. U.S. Environmental Protection Agency.

McEwan, D. 2001. Central Valley Steelhead. In: R. L. Brown (ed.), Contributions to the Biology of Central Valley Salmonids, pp. 1-43. California Department of Fish and Game, Sacramento, California.

McKechnie, R. J. 1966. Chapter No. 46, Spotted Bass. In: A. Calhoun (ed.), Inland Fisheries Management, pp. 366-370. California Department of Fish and Game.

Meeuwig, M. H., J. M. Bayer, J. G. Seelye, and R. A. Reiche. 2002. Identification of Larval Pacific Lampreys (*Lamptera tridentata*), River Lampreys (*L. ayresi*), and Western Brook Lampreys (*L. richardson*) and Thermal Requirements of Early Life History Stages of Lampreys. Annual Report 2001, Report to Bonneville Power Administration. Bonneville Power Administration, Portland, Oregon.

Meeuwig, M. H., J. M. Bayer, J. G. Seelye, and R. Reiche. 2003. Identification of Larval Pacific Lampreys (*Lampetra tridentata*), River Lampreys (*L. ayresi*), and Western Brook Lampreys (*L. richardsoni*) and Thermal Requirements of Early Life History Stages of Lampreys. Annual Report 2002, Report to Bonneville Power Administration. Bonneville Power Administration, Portland, Oregon.

Miller, S. J. and T. Storck. 1984. Temporal Spawning Distribution of Largemouth Bass and Young of Year Growth, Determined from Daily Otolith Rings. Transactions of the American Fisheries Society 113:571-578.

Moyle, P. B. 2002. Inland Fishes of California. University of California Press, Berkeley, California.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Fish Species of Special Concern in California. California Department of Fish and Game, Sacramento, California.

Myrick, C. A. 1998. Temperature, Genetic, and Ration Effects on Juvenile Rainbow Trout (*Oncorhynchus mykiss*) Bioenergetics. University of California, Davis, California.

Myrick, C. A., and J. J. Cech. 2000. Swimming Performance of Four California Stream Fishes: Temperature Effects. Environmental Biology of Fishes 58:289-295.

Myrick, C. A., and J. J. Cech. 2001. Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations. Bay-Delta Modeling Forum. Technical Publication 01-1.

Neves, R. J. 1975. Factors Affecting Nesting Success of Smallmouth (*Micropterus dolomieui*) in South Branch Lake, Maine. Transactions of the American Fisheries Society 103:83-87.

Newcomb, T. J., and T. G. Coon. 2001. Evaluation of Three Methods for Estimating Numbers of Steelhead Smolts Emigrating from Great Lakes Tributaries. North American Journal of Fisheries Management 21:548-560.

Nielsen, J. L., T. E. Lisle, and V. Ozaki. 1994. Thermally Stratified Pools and their Use by Steelhead in Northern California Streams. Transactions of the American Fisheries Society 123:613-626.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1993. Biological Opinion for the Operation of the Federal Central Valley Project and the California State Water Project. National Marine Fisheries Service, Southwest Region, Long Beach, California.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1995. Endangered Species Act Section 7 Biological Opinion on the Land and Resources Management Plans for the Boise, Challis, Nez Perce, Payette, Salmon, Sawtooth, Umatilla, and Wallowa-Whitman National Forests. National Marine Fisheries Service, Northwest Region, Seattle, Washington.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1997a. Fish Screening Criteria for Anadromous Salmonids.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1997b. NMFS Proposed Recovery Plan for the Sacramento River Winter-Run Chinook Salmon. National Marine Fisheries Service, Southwest Region, Long Beach, California.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1999. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two Chinook Salmon Evolutionarily Significant Units (ESUs) in California. Federal Register, 64(179):50394-50415. September 16, 1999.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 2000. Biological Opinion for the Proposed Operation of the Federal Central Valley Project and the State Water Project for December 1, 1999 through March 31, 2000. National Marine Fisheries Service, Southwest Region, Long Beach, California.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 2001a. Biological Opinion on Interim Operations of the Central Valley Project and State Water Project Between January 1, 2001, and March 31, 2002. Report No. SWR-01-SA-5667:BFO. National Marine Fisheries Service, Southwest Region, Long Beach, California.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 2001b. The Effects of Summer Dams on Salmon and Steelhead in California Coastal Watersheds and Recommendations for Mitigating Their Impacts. National Marine Fisheries Service, Southwest Region, Santa Rosa, California.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 2002a. Biological Opinion on Interim Operations of the Central Valley Project and State Water Project Between April 1, 2002 and March 31, 2004. National Marine Fisheries Service, Southwest Region, Long Beach, California.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 2002b. Biological Opinion on Interim Operations of the CVP and SWP Between April 2000 and March 2004 on Federally Listed Threatened Central Valley Spring-Run Chinook Salmon and Threatened Central Valley Steelhead in Accordance With Section 7 of the ESA.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 2003a. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to List North American Green Sturgeon as a Threatened or Endangered Species. Federal Register, 68(19):4433-4441. January 29, 2003.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 2003b. July 2000 4(d) Rule Implementation Binder for Threatened Salmon and Steelhead on the West Coast.

NRCS (Natural Resources Conservation Service). 1998. East Branch North Fork Feather River Erosion Inventory Report.

ODEQ (Oregon Department of Environmental Quality). 1995. Temperature: 1992-1994 Water Quality Standards Review. Final Issue Paper. Oregon Department of Environmental Quality Standards, Portland, Oregon.

Ordal, E. J., and R. E. Pacha. 1963. The Effects of Temperature on Disease in Fish. In: Proceedings of the 12th Pacific Northwest Symposium on Water Pollution Research, pp. 39-56.

Orsi, J. J. 1971. Thermal Shock and Upper Lethal Temperature Tolerances of Young King Salmon, *Oncorhynchus tshawytscha*, from the Sacramento-San Joaquin River System. Report No. 71-11. Anadromous Fisheries Branch Administrative Report. California Department of Fish and Game.

Painter, R. E., L. H. Wixom, and S. N. Taylor. 1977. An Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River.

Painter, R. L., L. Wixom, and L. Meinz. 1979. American Shad Management Plan for the Sacramento River Drainage. Anadromous Fish Conservation Act Project AFS-17, Job 5. California Department of Fish and Game, Sacramento, California.

Philipp, D. P., C. A. Toline, M. F. Kubacki, and D. B. F. Philipp. 1997. The Impact of Catch-and-Release Angling on the Reproductive Success of Smallmouth Bass and Largemouth Bass. North American Journal of Fisheries Management 17:557-567.

Raffetto, N. S., J. R. Baylis, and S. L. Serns. 1990. Complete Estimates of Reproductive Success in a Closed Population of Smallmouth Bass (*Micropterus dolomieui*). Ecology 7:1523-1535.

Redding, J. M., and C. B. Schreck. 1979. Possible Adaptive Significance of Certain Enzyme Polymorphisms in Steelhead Trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 36:544-551.

Rich, A. A. 1987. Report on Studies Conducted by Sacramento County to Determine the Temperatures Which Optimize Growth and Survival in Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*). Prepared for the County of Sacramento.

Rombough, P. J. 1988. Growth, Aerobic Metabolism, and Dissolved Oxygen Requirements of Embryos and Alevins of Steelhead, *Salmo gairdneri*. Canadian Journal of Zoology 66:651-660.

S. P. Cramer & Associates. 1995. The Status of Steelhead Populations in California in Regards to the Endangered Species Act. Report Submitted to the National Marine Fisheries Service on Behalf of the Association of California Water Agencies. Gresham, Oregon.

Sammons, S. M., L. G. Dorsey, P. W. Bettoli, and F. C. Fiss. 1999. Effects of Reservoir Hydrology on Reproduction by Largemouth Bass and Spotted Bass in Normandy Reservoir, Tennessee. North American Journal of Fisheries Management 19:78-88.

Seesholtz, A., B. Cavallo, J. Kindopp, and R. Kurth. 2003. Juvenile Fishes of the Lower Feather River: Distribution, Emigration Patterns, and Association with Environmental Variables. Early Life History of Fishes in the San Francisco Estuary and Watershed. California Department of Water Resources.

Seymour, A. H. 1956. Effects of Temperature on Young Chinook Salmon. University of Washington, Seattle, Washington.

Shapovalov, L., and A. C. Taft. 1954. The Life Histories of the Steelhead Rainbow Trout (*Salmo gairdneri gairdneri*) and Silver Salmon (*Oncorhynchus kisutch*). Fish Bulletin No. 98. California Department of Fish and Game.

Smith, C. E., W. P. Dwyer, and R. G. Piper. 1983. Effect of Water Temperature on Egg Quality of Cutthroat Trout. The Progressive Fish-Culturist 45:176-178.

Snider, B., and R. G. Titus. 2000. Lower American River Emigration Survey October 1996–September 1997. Stream Evaluation Program Technical Report No. 00-2. California Department of Fish and Game.

Sommer, T., D. McEwan, and R. Brown. 2001. Factors Affecting Chinook Salmon Spawning in the Lower Feather River. In: R. L. Brown (ed.), Contributions to the Biology of Central Valley Salmonids, pp. 269-297. California Department of Fish and Game, Sacramento, California.

Sommer, T. R., L. Conrad, G. O'Leary, F. Feyrer, and W. C. Harrell. 2002. Spawning and Rearing of Splittail in a Model Floodplain Wetland. Transactions of the American Fisheries Society 131:966-974.

State Water Resources Control Board. 2003. Revised Water Right Decision 1644 in the Matter of Fishery Resources and Water Right Issues of the Lower Yuba River. Sacramento, California.

Steinhart, G. B. 2004. Exploring Factors Affecting Smallmouth Bass Nest Success. Doctor of Philosophy, Ohio State University.

Stone, J., T. Sundlov, S. Barndt, and T. Coley. 2001. Evaluate Habitat Use and Population Dynamics of Lampreys in Cedar Creek. Project No. 2000-01400, BPA Report DOE/BP-00000014-1. Bonneville Power Administration, Portland, Oregon. March 2001.

SWRI (Surface Water Resources, Inc.). 2004. Aquatic Resources of the Lower American River: Draft Baseline Report. Sacramento, California.

Taylor, E. B. 1990a. Environmental Correlates of Life-History Variation in Juvenile Chinook Salmon, *Oncorhynchus tshawytscha* (Walbaum). Journal of Fish Biology 37:1-17.

Taylor, E. B. 1990b. Variability in Agonistic Behavior and Salinity Tolerance between and within Two Populations of Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*, with Contrasting Life Histories. Canadian Journal of Fisheries and Aquatic Science 47:2172-2180.

Timoshina, L. A. 1972. Embryonic Development of the Rainbow Trout (*Salmo gairdneri irideus* (Gibb.)) at Different Temperatures. Journal of Ichthyology 12:425-432.

Turner, G. E., and H. R. MacCrimmon. 1970. Reproduction and Growth of Smallmouth Bass, *Micropterus dolomieui*, in a Precambrian Lake. Journal Fisheries Research Board of Canada 27:395-400.

USBR (U.S. Bureau of Reclamation). 1997. Central Valley Improvement Act, Draft Programmatic Environmental Impact Statement: Technical Appendix, Volume III. Sacramento, California.

USBR (U.S. Bureau of Reclamation). 2003. Long-Term Central Valley Project Operating Criteria and Plan Biological Assessment, Central Valley Project—Operating Criteria and Plan. Preliminary Working Draft.

USBR (U.S. Bureau of Reclamation). 2003. Summary of USBR Chinook Salmon Temperature Mortality Models for Use With CALSIM II. Unpublished Work.

USEPA (U.S. Environmental Protection Agency). 2001. Temperature Interaction—Issue Paper 4. Report No. EPA-910-D-01-004.

USEPA (U.S. Environmental Protection Agency). 2002. National Recommended Water Quality Criteria: 2002. Report No. EPA-822-R-02-047.

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

USFWS (U.S. Fish and Wildlife Service). 1995. Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California. Vol 2. Stockton, California.

USFWS (U.S. Fish and Wildlife Service). 1999. Effect of Temperature on Early-Life Survival of Sacramento River Fall- and Winter-Run Chinook Salmon. Final Report.

Velsen, F. P. 1987. Temperature and Incubation in Pacific Salmon and Rainbow Trout: Compilation of Data on Median Hatching Time, Mortality and Embryonic Staging. Canadian Data Report of Fisheries and Aquatic Sciences 626. Department of Fisheries and Oceans, Fisheries Research Branch, Nanaimo, British Columbia.

Walburg, C. H., and P. R. Nichols. 1967. Biology and Management of the American Shad and Status of the Fisheries, Atlantic Coast of the United States, 1960.

Wang, J. C. S. 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories. IEP Technical Report No. 9. California Department of Water Resources, California Department of Fish and Game, U.S. Bureau of Reclamation, and U.S. Fish and Wildlife Service.

Warner, G. H. 1955. Studies on the Downstream Migration of Young Salmon in the Feather River. Unpublished Report. California Department of Fish and Game.

Wedemeyer, G. A., R. L. Saunders, and W. C. Clarke. 1980. Environmental Factors Affecting Smoltification and Early Marine Survival of Anadromous Salmonids. Marine Fisheries Review 42:1-14.

Wipfli, M. S., J. Hudson, and J. Caouette. 1998. Influence of Salmon Carcasses on Stream Productivity: Response of Biofilm and Benthic Macroinvertebrates in Southeastern Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 55:1503-1511.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical Abundance and Decline of Chinook Salmon in the Central Valley Region of California. North American Journal of Fisheries Management 18:487-521.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Molye. 2001. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. In: R. L. Brown (ed.), Contributions to the Biology of Central Valley Salmonids, pp. 71-176. California Department of Fish and Game, Sacramento, California.

Young, P. S., and J. J. Cech Jr. 1996. Environmental Tolerances and Requirements of Splittail. Transactions of the American Fisheries Society 125:664-678.

Zaugg, W. S., and H. H. Wagner. 1973. Gill ATPase Activity Related to Parr-Smolt Transformation and Migration in Steelhead Trout (*Salmo gairdneri*): Influence of Photoperiod and Temperature. Comparative Biochemistry and Physiology 45B:955-965.

Zedonis, P. A., and T. J. Newcomb. 1997. An Evaluation of Flow and Water Temperatures during the Spring for Protection of Salmon and Steelhead Smolts in the Trinity River, California. U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, California.

G-AQUA2.6.2 Personal Communications

Cavallo, B., Environmental Scientist, California Department of Water Resources, Sacramento, California; verbal communication with B. Ellrott, SWRI Fisheries Biologist, Sacramento, California; February 4, 2004.

See, E., Environmental Specialist, California Department of Water Resources, Oroville, California; conference call with D. Olson, A. Pitts, and J. Hornback, Senior Environmental Scientist, Associate Environmental Scientist, and Environmental Scientist, SWRI, Sacramento, California; October 28, 2003.

APPENDIX G-AQUA3
AQUATIC RESOURCES
EFFECTS OF THE NO-ACTION ALTERNATIVE

This appendix provides quantitative and qualitative analyses of potential effects on aquatic resources under the No-Action Alternative, relative to existing conditions. Although the following topical outline is consistent for analysis of all alternatives, effects in several issue areas are not anticipated to occur under the No-Action Alternative. From an aquatic resources perspective, there are only a few differences between existing conditions and the No-Action Alternative. (See Section 3.1, No-Action Alternative, for a detailed description of the No-Action Alternative, and Section 5.5, Aquatic Resources, for a detailed description of existing conditions.)

Quantitative and qualitative analyses were performed using the methodology described in Appendix G-AQUA2, Methodology. These analyses evaluated reservoir surface elevations, net flow releases from the Oroville Facilities, blockage of gravel and large woody debris recruitment in the lower Feather River, water quality criteria for aquatic life, predation, straying, genetic introgression and redd superimposition by Chinook salmon, water temperature in the lower Feather River, and availability of fish species habitat.

Although future operations of the Oroville Facilities are expected to differ from existing conditions, some effects of the No-Action Alternative on aquatic resources—such as potential effects on predation and salmonid adult straying—are not expected to differ from those that would occur under existing conditions. Detailed descriptions of the effects of Oroville Facilities operations on predation and salmonid adult straying are provided in Appendix G-AQUA1, Affected Environment.

G-AQUA3.1 HABITAT COMPONENTS AFFECTED BY THE OROVILLE FACILITIES

G-AQUA3.1.1 Chinook Salmon Spawning Segregation

Under the No-Action Alternative, the Oroville Facilities would continue to block the upstream migration of anadromous salmonids into historical spawning habitat in Lake Oroville's upstream tributaries. A continued lack of access to historical upstream conditions would continue to affect natural selection processes, eventually resulting in effects on the genetic characteristics of the fish species. However, habitat between Oroville Dam and the next upstream barrier is not suitable.

In addition, with continued restricted access to historic spawning grounds, spring-run Chinook salmon would continue to spawn in the same lowland reaches that fall-run Chinook salmon use for spawning habitat. Continued geographic overlap in spawning habitat between spring-run and fall-run Chinook salmon would result in the continued incremental degradation of the genetic distinctness between the runs.

The Fish Barrier Dam would continue to block upstream migration of anadromous salmonids and increase the intensity of habitat use in the Low Flow Channel. This increased intensity of habitat use would continue to cause increased competition for spawning habitat and continue to contribute to increased adult pre-spawning mortality rates and redd superimposition rates, which contributes to egg and alevin mortality. (See Section G-AQUA1.8, Tasks 2B, 2C, and 2D, in Appendix G-AQUA1 for additional information on salmonid life stages and associated project effects.)

Under the No-Action Alternative, the continued increased intensity of existing habitat use likely would cause additional incremental effects on spring-run and fall-run Chinook salmon genetic introgression, and adult pre-spawning mortality and redd superimposition rates.

G-AQUA3.1.2 Macroinvertebrate Populations

Under the No-Action Alternative, operation of the Oroville Facilities likely would continue to incrementally contribute to the reduction of macroinvertebrate species diversity and abundance in the lower Feather River. Study Plan (SP) F1 (see Section G-AQUA1.1 in Appendix G-AQUA1) provides a detailed description of the current effects of the Oroville Facilities on macroinvertebrate communities. Continued decreased large woody debris and gravel recruitment to the lower Feather River would continue to decrease the quality, quantity, and diversity of macroinvertebrate habitat.

G-AQUA3.1.3 Woody Debris Recruitment

Under the No-Action Alternative, the Oroville Facilities would continue to block the upstream contribution of large woody debris to the lower Feather River. (See Section 5.3, Geology, Soils, and Paleontological Resources, for additional information on large woody debris recruitment.) The lowest proportion of large woody debris availability likely would continue to occur in the upstream-most reach of the lower Feather River, from the Fish Barrier Dam to the Thermalito Afterbay Outlet. Downstream of the Thermalito Afterbay Outlet, the river likely would continue to support a greater availability of large woody debris cover than the reach upstream of the outlet because opportunities for large woody debris recruitment likely would remain higher in the High Flow Channel. The continued lack of large woody debris recruitment to the lower Feather River would result in an incremental degradation of the quantity and quality of large woody debris present in the lower Feather River and would result in reduced quality and diversity of habitat for aquatic resources.

G-AQUA3.1.4 Gravel Recruitment

Under the No-Action Alternative, Oroville Dam, the Thermalito Diversion Dam, and the Fish Barrier Dam would continue to block gravel contribution from the upper Feather River to the lower Feather River. (See Section 5.3, Geology, Soils, and Paleontological Resources, for additional information on gravel recruitment and lower Feather River substrate conditions.) High Oroville Facilities releases, such as those implemented for flood management purposes, would mobilize smaller substrate particle sizes. Subsequently, the smaller substrate sizes would not be replaced by upstream gravel contributions, which would result in a gradual relative coarsening of the particle size distribution of the substrate in the upper portions of the lower Feather River. Currently, the reach of river with the highest proportion of coarse substrate components is the upstream-most portion of the lower Feather River, below the Fish Barrier Dam and above the Thermalito Afterbay Outlet. Under the No-Action Alternative, the upper reaches of the lower Feather River likely would become more armored, resulting in an incremental detrimental effect on the quality and quantity of suitable salmonid spawning gravels in the lower Feather River.

In addition to reduced gravel recruitment, fine sediments also would continue to become trapped upstream of the Oroville Facilities. Currently, more than 97 percent of the sediment from the upstream watershed is trapped in the upstream reservoirs, resulting in sediment deprivation downstream. (See Section 5.3, Geology, Soils, and Paleontological Resources, for additional information on sediment recruitment.) Only very fine sediment is discharged from Lake Oroville to the stream below. Continued deprivation of the sediment load in the lower Feather River would result in reduced formation of sediment benches, which affects riparian vegetation colonization and succession. (See the Botanical Resources discussion in Section 5.6, Terrestrial Resources, for additional information on riparian vegetation.) Riparian vegetation provides overhanging cover for rearing fish, riparian shade, invertebrate contributions to the fish food base, and future large woody debris site contributions. Additionally, soft sediment substrates also contribute to the function of capture and retention of large woody debris. Therefore, under the No-Action Alternative, a continued lack of sediment recruitment to the lower Feather River would result in the incremental degradation of geomorphic processes, contributing to a decrease in the quality and diversity of habitat for aquatic resources in the lower Feather River.

G-AQUA3.1.5 Channel Complexity

Under the No-Action Alternative, channel complexity would be reduced through continued riverbed incision and channel confinement. (See Section 5.3, Geology, Soils, and Paleontological Resources, for additional information on channel complexity.) Continued operation of the Oroville Facilities with relatively static and moderated flow regimes in the Low Flow Channel under the No-Action Alternative likely would continue to limit the geomorphic processes that result in channel complexity, resulting in the ongoing incremental degradation of the quality and diversity of aquatic resource habitat relative to existing conditions.

G-AQUA3.1.6 Water Quality Criteria for Aquatic Life

Operation of the Oroville Facilities under the No-Action Alternative is not expected to result in any changes to water quality conditions for aquatic life. Therefore, the number of exceedances of water quality criteria for aquatic life is not expected to change relative to existing conditions.

G-AQUA3.2 WARMWATER RESERVOIR FISHERIES

G-AQUA3.2.1 Operations-related Effects

G-AQUA3.2.1.1 Spawning and Initial Rearing

Under the No-Action Alternative, changes in reservoir water surface elevations, rates of reduction, or surface level fluctuations in Lake Oroville would occur relative to existing conditions because reservoir operations would change to reflect changes in future demand patterns. (See the Water Quantity discussion in Section 5.4, Water Quantity and Quality, for additional information on changes in demand patterns, reservoir operations, and water surface elevations.) However, there would be no appreciable change in the rate of Lake Oroville surface elevation reductions during the March through June bass nesting period; therefore, no change in the rate of bass nest dewatering in Lake Oroville is anticipated under the No-Action Alternative relative to existing conditions. The operation and resulting fluctuations in water surface elevation within Thermalito Afterbay would not change under the No-Action Alternative; therefore, no change in the rate of bass nest dewatering within Thermalito Afterbay is anticipated.

G-AQUA3.2.1.2 Fish Interactions

Under the No-Action Alternative, stocked salmonid species and warmwater fish species within Lake Oroville could potentially continue to interact with upstream tributary fisheries through predation, competition for food and habitat, disease transmission, and genetic introgression. (See Section G-AQUA1.5, Task 1, in Appendix G-AQUA1 for additional information on potential fisheries interactions.) Lake Oroville reservoir operations would continue to influence the accessibility of the upstream tributaries to fish species within Lake Oroville through changes in reservoir water surface elevations. When Lake Oroville water surface elevations are near full pool, Big Bend Dam becomes passable to fish; when reservoir stage elevations are reduced, sediment wedges in the tributary arms of the reservoir may be exposed and may inhibit or prohibit fish movement from the reservoir into the upstream tributaries. Increases or decreases in reservoir stage elevations also would increase or decrease the distance from the reservoir to habitat in the upstream tributaries above the reservoir high-pool mark, which also may influence the amount and frequency of interactions between the reservoir fishes and fishes in the upstream tributaries.

The Oroville Facilities would continue to influence fish species interactions and sediment wedge locations in the upstream tributaries and reservoir arms, respectively. However, the nature and relative effect of the reservoir surface elevations are not expected to change with implementation of the No-Action Alternative relative to existing conditions.

No changes in fish stocking or in the frequency or nature of sediment wedge exposure associated with Lake Oroville water surface elevations are anticipated. Therefore, no effects on warmwater reservoir fish interactions are expected under the No-Action Alternative.

G-AQUA3.2.2 Fisheries Management–related Effects

G-AQUA3.2.2.1 Stocking

No changes in warmwater fish stocking or the habitat enhancement program are anticipated under the No-Action Alternative.

G-AQUA3.2.2.2 Disease

No changes in the types or rates of warmwater fish diseases are anticipated under the No-Action Alternative.

G-AQUA3.2.2.3 Recreational Access or Fishing Regulations

Section 5.10.2, Recreation Resources Environmental Effects, forecasts a one-third increase in recreation and angling activities under the No-Action Alternative. A one-third increase in angling with no other fisheries changes would equate to increased sport fish harvest rates and potentially result in reduced catch sizes and catch rates. No changes in fishing access or regulations for warmwater sport fishing are anticipated under the No-Action Alternative.

G-AQUA3.2.3 Summary of Potential Effects on Warmwater Reservoir Fisheries

The quality of the warmwater sport fishery would be reduced under the No-Action Alternative by increased angling and resulting reduced catch rates and sizes. Increased warmwater sport fish harvest rates could potentially affect population sustainability under the No-Action Alternative.

G-AQUA3.3 COLDWATER RESERVOIR FISHERIES

G-AQUA3.3.1 Operations-related Effects

G-AQUA3.3.1.1 Habitat Availability

Changes in reservoir water surface elevations and drawdown rates in the summer months likely would not affect the availability of coldwater habitat in Lake Oroville. Reservoir water surfaces likely would not reach low enough elevations to affect the amount of coldwater pool availability below the thermocline. Additionally, drawdown rates likely would not be sufficiently rapid to cause reservoir mixing. Water temperature management targets for the Feather River Fish Hatchery and Robinson Riffle would not change under the No-Action Alternative; therefore, release of the coldwater pool from Lake Oroville is not expected to change under the No-Action Alternative, relative to existing conditions. For these reasons, Oroville Facilities operations under the No-Action Alternative likely would have no effect on the availability of coldwater habitat in Lake Oroville.

Operations of Thermalito Afterbay would not change under the No-Action Alternative; therefore, there are no anticipated effects on the availability of coldwater habitat, relative to existing conditions.

G-AQUA3.3.1.2 Fish Interactions

No changes in fish stocking or in the frequency or nature of sediment wedge exposure associated with Lake Oroville water surface elevations are anticipated under the No-Action Alternative. (See Section G-AQUA3.2.1.2, Fish Interactions, for further discussion.) Therefore, no effects on coldwater reservoir fish interactions are expected under the No-Action Alternative.

G-AQUA3.3.2 Fisheries Management–related Effects

G-AQUA3.3.2.1 Stocking

No changes in coldwater fish stocking are anticipated under the No-Action Alternative.

G-AQUA3.3.2.2 Disease

No changes in the incidence of disease are anticipated under the No-Action Alternative.

G-AQUA3.3.2.3 Recreational Access or Fishing Regulations

Section 5.10.2, Recreation Resources Environmental Effects, forecasts a one-third increase in recreation and angling activities with the No-Action Alternative. A one-third increase in angling with no other fisheries changes would equate to increased sport fish harvest rates and potentially result in reduced catch sizes and catch rates. No changes to recreational access or fishing regulations are anticipated under the No-Action Alternative.

G-AQUA3.3.3 Summary of Potential Effects on Coldwater Reservoir Fisheries

The quality of the coldwater sport fishery would be reduced in the No-Action Alternative as a result of increased angling and resulting reduced catch rates and sizes.

G-AQUA3.4 LOWER FEATHER RIVER FISH SPECIES

Qualitative and quantitative analyses were performed on various potential effects resulting from Oroville Facilities operations under the No-Action Alternative to determine the incremental effects of continued operations. The results of the effects analysis of each PM&E measure on each life stage were synthesized to determine the overall effects of the alternative on the species.

G-AQUA3.4.1 Fall-run Chinook Salmon

G-AQUA3.4.1.1 Flow-related Effects

Under the No-Action Alternative, there would be no changes to flows in the Low Flow Channel. Effects of flow changes in the High Flow Channel are expressed in the qualitative and quantitative analyses presented below.

Adult Immigration and Holding

Mean monthly flow changes under the No-Action Alternative compared to existing conditions during the fall-run Chinook salmon adult immigration and holding period would occur in the High Flow Channel. Increased mean monthly flows in July and August and decreased mean monthly flows for the remainder of the immigration and holding period would cause very small changes in river stage. Because the flow-related changes in river stage during the Chinook salmon adult immigration and holding period would be small, they would not be sufficiently large to affect immigration at potential critical riffles and would not be sufficiently large to appreciably affect holding habitat depths.

Flow fluctuations that could potentially occur under the No-Action Alternative would be similar to flow fluctuations that occur under existing conditions. Because flow fluctuations currently do not affect fall-run Chinook salmon adult immigration and holding, flow fluctuation under the No-Action Alternative also would not affect fall-run Chinook salmon adult immigration and holding.

Adult Spawning and Embryo Incubation

Under the No-Action Alternative flow in the Low Flow Channel would be 600 cfs year-round. However, flow fluctuations in the Low Flow Channel could potentially occur under the No-Action Alternative in order to meet water temperature objectives prescribed to protect fisheries resources. Minimum average daily water temperatures in the lower Feather River at Robinson Riffle (RM 61.6) would be required to be less than 65°F (18.3°C) from June 1 through September 30. Increased flow releases to meet water temperature objectives at Robinson Riffle from June 1 through August 31 would not be expected to affect fall-run Chinook salmon spawning because the spawning period in the lower Feather River begins in September (pers. comm., Cavallo 2004 ; DWR 2004). Increased flow releases to meet water temperature objectives during September could potentially affect fall-run Chinook salmon spawning and embryo incubation by causing redd dewatering, which could occur as flows return to normal after water temperature objectives are met. Because increasing flows to meet water temperature objectives increases river stage, thereby increasing available spawning habitat, spawning individuals could potentially construct redds in areas that could be dewatered as flows are lowered to normal levels (600 cfs). However, based on available stage-discharge relationships and PHABSIM results it is unlikely that substantial amounts of additional spawning habitat would be created in which fall-run Chinook salmon could spawn when increasing flows to meet water temperature objectives. Additionally, based on modeling data, the frequency with which flows have been increased from 600 cfs to meet water temperature objectives is rare (once in 67 years based on modeling data). Flow changes for water temperature management are typically 200 cfs flow increases. The stage elevation change from 800 cfs back down to 600 cfs is substantially less than the shallowest documented redd depth reported in the lower Feather River, therefore no redd dewatering from water temperature management releases is anticipated. Therefore, increasing flows to meet water temperature objectives in the Low Flow Channel under the No-Action Alternative is unlikely to affect spawning adult fall-run Chinook salmon.

Evaluation of the WUA index generated by the PHABSIM model for the adult spawning life stage of Chinook salmon indicated that the maximum amount of spawning area in the Low Flow Channel, given the current channel configuration, would occur at flows around 850 cfs. Figure G-AQUA3.4-1 shows the WUA curve generated by the PHABSIM model for Chinook salmon spawning in the Low Flow Channel.

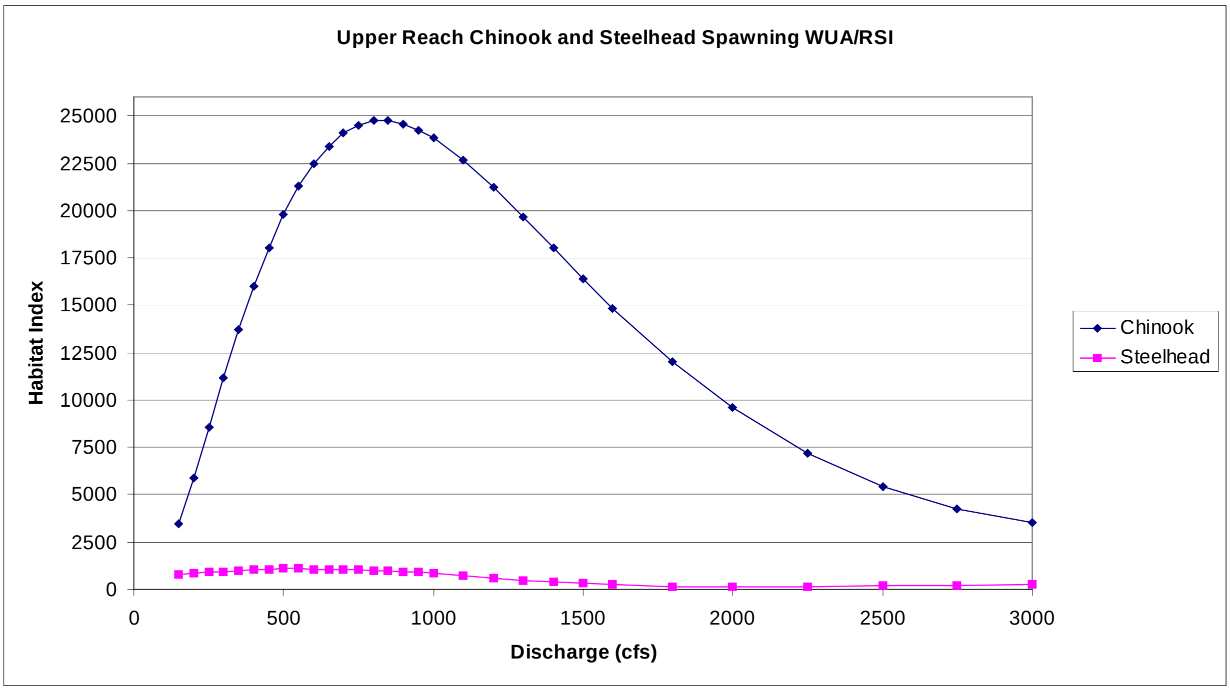


Figure G-AQUA3.4-1. Low Flow Channel WUA curves for steelhead and Chinook salmon.

Current flows in the Low Flow Channel during the fall-run Chinook salmon spawning period are 600 cfs, which, according to PHABSIM model results, result in approximately 91 percent of maximum WUA. Because proposed flows in the Low Flow Channel under the No-Action Alternative would be the same as existing conditions, flows under the No-Action Alternative also would result in approximately 91 percent of maximum WUA, representing no change from existing conditions.

Under the No-Action Alternative, flow fluctuations in the High Flow Channel are not expected to differ from flow fluctuations that occur under existing conditions. However, flow releases would change monthly compared to existing conditions. Daily minimum and maximum flows within the fall-run Chinook salmon spawning period would not differ from those described in the 1983 agreement between DFG and DWR, which govern current operations. Under existing conditions, during normal operations, flows in the High Flow Channel are maintained above specified minimum and below specified maximum flows in order to protect fisheries resources. Flow requirements for the High Flow Channel under existing conditions and the No-Action Alternative are described in Section 5.4.1.1, Water Quantity Affected Environment. Under normal operating conditions in the No-Action Alternative, daily releases into the High Flow Channel would not fluctuate outside the minimum and maximum flows described in Section 5.4.1.1, which are the same minimum and maximum flows described for existing conditions. During drought conditions, flows would be lowered to a constant minimum flow of 750 cfs prior to the onset of fall-run Chinook salmon spawning and raised to 900 cfs in the beginning of October. According to the U.S. Bureau of Reclamation (USBR) (2004), the minimum and maximum flow requirements as well as the fluctuations permitted during the fall-run Chinook salmon spawning and embryo incubation period in the High Flow Channel under existing conditions have not affected this life stage. Therefore, it is expected that the flow requirements and the associated flow fluctuations in the High Flow Channel under the No-Action Alternative, also would not affect this life stage.

Evaluation of the WUA index generated by the PHABSIM model for the adult spawning life stage of Chinook salmon indicated that the maximum amount of spawning area in the High Flow Channel, given the current channel configuration, would occur at flows around 1,700 cfs. Figure G-AQUA3.4-2 shows the WUA curve generated by the PHABSIM model for Chinook salmon spawning in the High Flow Channel.

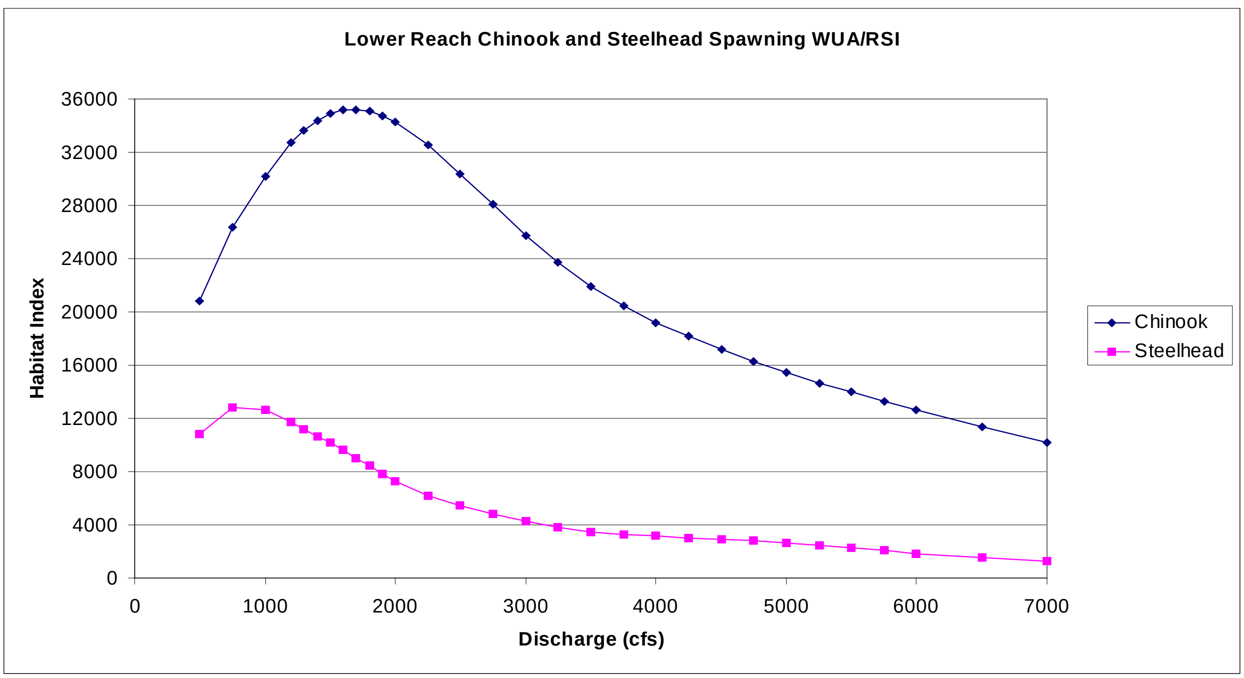


Figure G-AQUA3.4-2. High Flow Channel WUA curves for steelhead and Chinook salmon.

Based on modeling results, mean monthly flows under the No-Action Alternative during the fall-run Chinook salmon spawning period would be lower than under existing conditions. Mean monthly flows under the No-Action Alternative would be 1,864 cfs in September, representing a mean decrease of 43 cfs from existing conditions. In October mean monthly flows would be 2,213 cfs, representing a decrease of 96 cfs. In November mean monthly flows would be 1,991 cfs, representing a decrease of 206 cfs from existing conditions, while mean monthly flows in December would be 3,575 cfs, which represents a 88 cfs decrease from existing conditions. Changes in mean monthly flows during the fall-run Chinook salmon spawning period would result in changes in Chinook salmon spawning WUA. Due to the generalized nature of the WUA index and the inherent limitations in the methodology associated with IFIM and PHABSIM models, small changes in flow at the flows modeled were not able to determine exact changes in WUA. However, examination of Figure G-AQUA3.4-2 shows that, in September, a decrease in flow of 43 cfs would result in a slight increase in WUA compared to existing conditions. In October, a decrease in flow of 96 cfs would result in a slight increase in WUA. In November, a decrease in flow of 206 cfs would result in a slight increase in WUA, and in December, a decrease in flow of 88 cfs would result in a slight increase in WUA. Overall, the average monthly change in flow under the No-Action Alternative would result in an increase in Chinook salmon spawning WUA over the course of the spawning period compared to existing conditions.

Juvenile Rearing and Downstream Movement

Under the No-Action Alternative, flow fluctuations in the High Flow Channel would be similar to those occurring under existing conditions. Because the flow fluctuation characteristics are the same from the existing condition to the No-Action Alternative, the No-Action Alternative would have no change in effect on fall-run Chinook salmon juvenile rearing and downstream movement.

Under the No-Action Alternative mean monthly flows would decrease compared to existing conditions from November through April and increase for the remainder of the fall-run Chinook salmon juvenile rearing and downstream movement period (through June). Figures G-AQUA3.4-3 and G-AQUA3.4-4 show the WUA curves for Chinook salmon fry (<50mm) and juveniles (>50mm) in the High Flow Channel. The final report for SP-F16 provides detailed description of the differences between the weighting of the no-cover habitat suitability criteria in the PHABSIM model. Due to the generalized nature of the WUA index and the inherent limitations in the methodology associated with IFIM and PHABSIM models, small changes in flow at the flows modeled were not able to determine exact quantitative changes in WUA. However, utilizing the no-cover weighting of 0.15 for fry and 0.28 for juveniles shown in Figures G-AQUA3.4-3 and G-AQUA3.4-4, the flow decreases compared to existing conditions would result in an overall slight decrease in WUA during December January and would not change appreciably during the rest of the life stage period. Therefore, mean monthly flow changes under the No-Action alternative would have a slight adverse effect on fall-run Chinook salmon juvenile rearing and downstream movement.

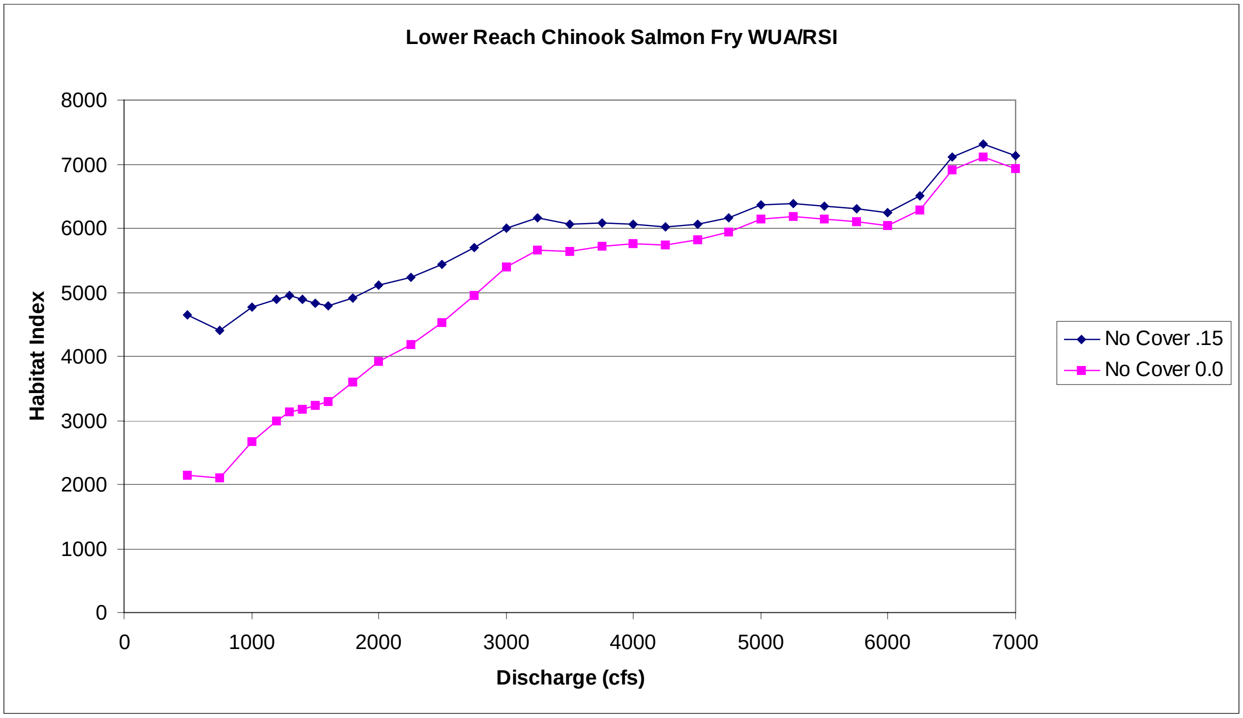


Figure G-AQUA3.4-3. High Flow Channel WUA curves for Chinook salmon fry <50mm.

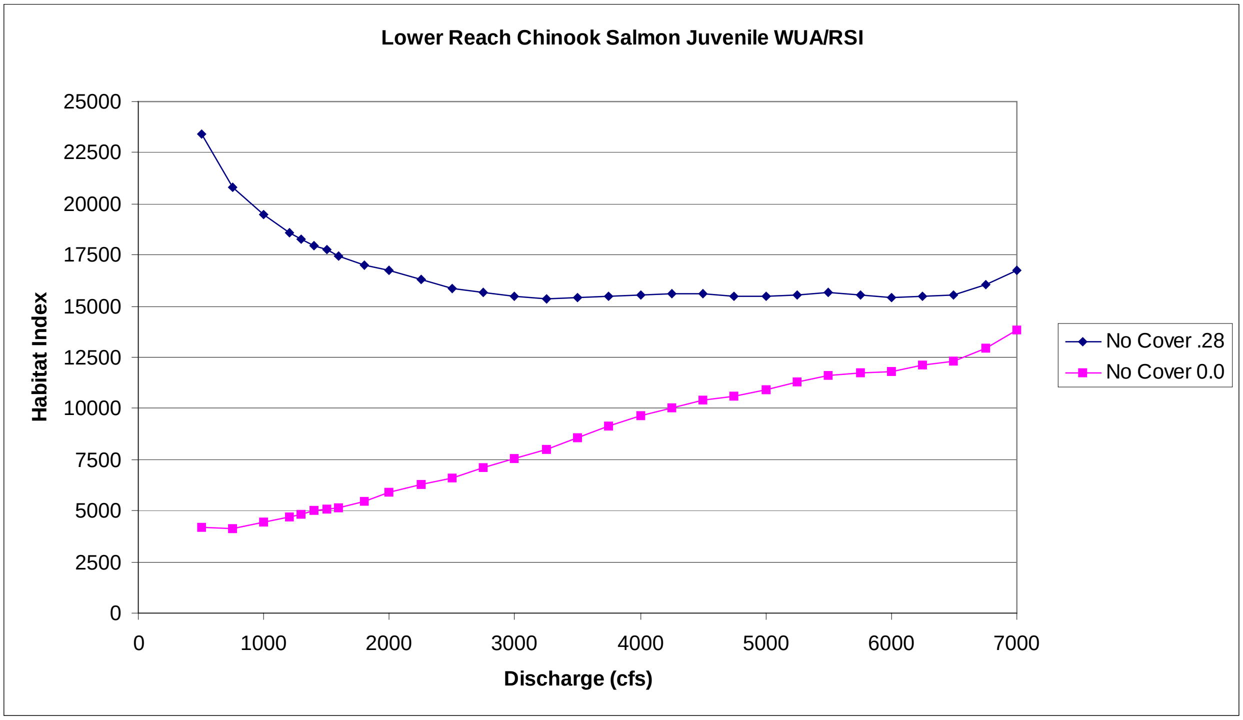


Figure G-AQUA3.4-4. High Flow Channel WUA curves for juvenile Chinook salmon 50mm+.

G-AQUA3.4.1.2 Water Temperature–related Effects

Effects of water temperature changes associated with the No-Action Alternative are expressed in the quantitative analyses of relative habitat suitability presented below.

The relative habitat suitability analyses include an evaluation of overall relative habitat suitability based on water temperature index values. These analyses include a comparison of habitat suitability component metrics between the No-Action Alternative and existing conditions.

The Overall Habitat Suitability Index Value (OHSIV) presented on the bottom row of the habitat suitability analysis table describes the overall relative habitat suitability for each water temperature index value used for the evaluation of each fish species and life stage. This metric represents the total amount of time and area of suitable habitat for each fish species and life stage. Comparison of the OHSIV metric between alternatives indicates which alternative has the greatest amount of suitable habitat with water temperatures equal to or below each water temperature index value.

The “Minimum Percentage of Time Value” and “Maximum Percentage of Time Value” metrics presented in the habitat suitability analysis tables describe the percentage of time that water temperatures within the least and most suitable habitat unit are below each specified index value for each fish species and life stage evaluated, respectively.

In addition, the “Habitat Units at 100 Percent of Time” metric presented in the habitat suitability analysis tables describes the number of habitat units in which water temperatures are always at or below each index value used for each fish species and life stage evaluated.

The “Percentage of Time at Maximum Habitat Units” metric presented in the habitat suitability analysis tables describes the distribution of the population of data, which indicates the percentage of time that water temperatures are equal to or below each water temperature index value selected for each fish species and life stage evaluated in the greatest amount of habitat area. That is, the most area in which water temperatures are below each water temperature index value occurs for some percentage of the total time within the fish species and life stage period. The “Percentage of Time at Maximum Habitat Units” metric describes that peak amount of habitat percentage of time. Detailed descriptions of the methodology used in the derivation and calculation of each of the above metrics are presented in Section G-AQUA2.2.3 in Appendix G-AQUA2.

<u>Adult Immigration and Holding</u>

Figures G-AQUA3.4-5, G-AQUA3.4-6, and G-AQUA3.4-7 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA3.4-5, G-AQUA3.4-6, and G-AQUA3.4-7 is equal, which allows for direct comparison of habitat suitability between alternatives.

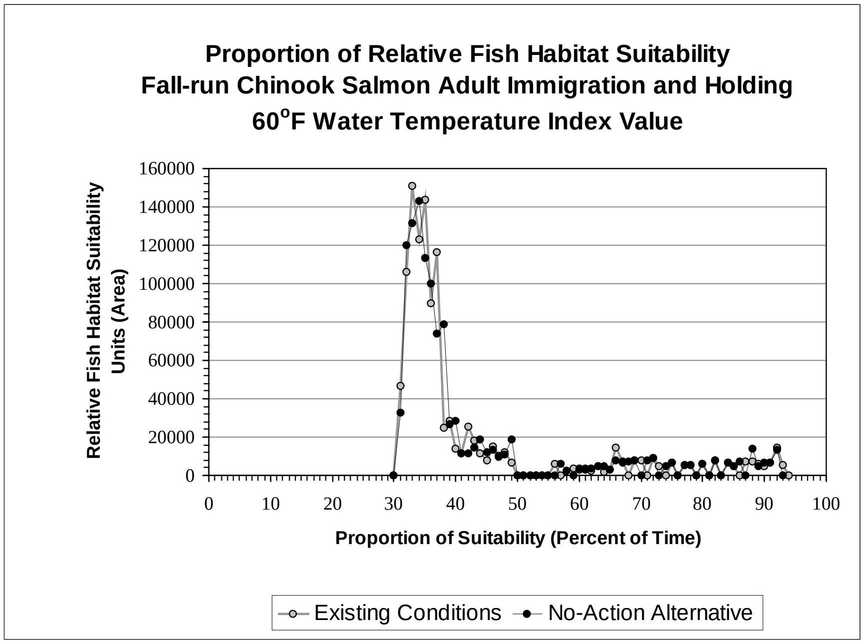


Figure G-AQUA3.4-5. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult immigration and holding for the 60°F water temperature index value.

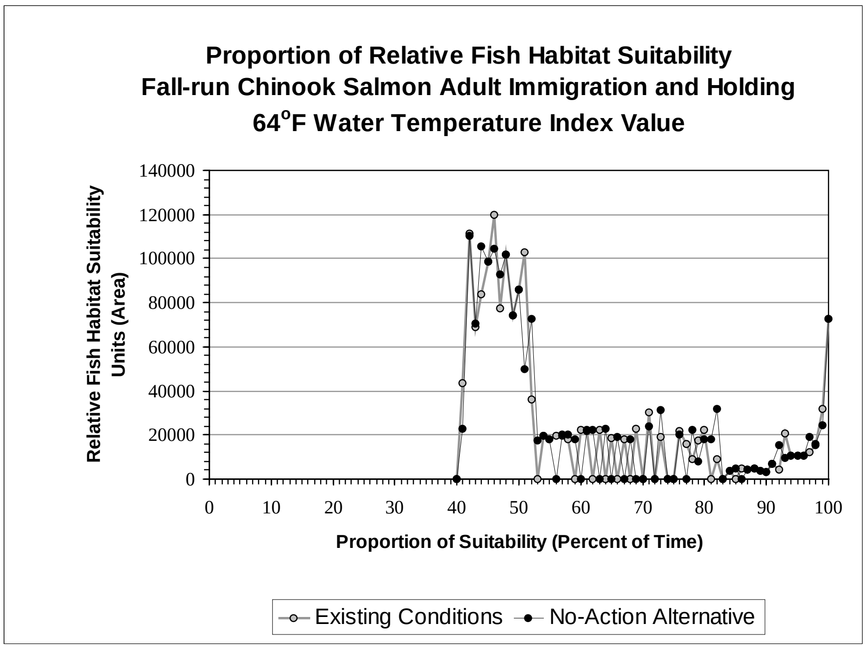


Figure G-AQUA3.4-6. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult immigration and holding for the 64°F water temperature index value.

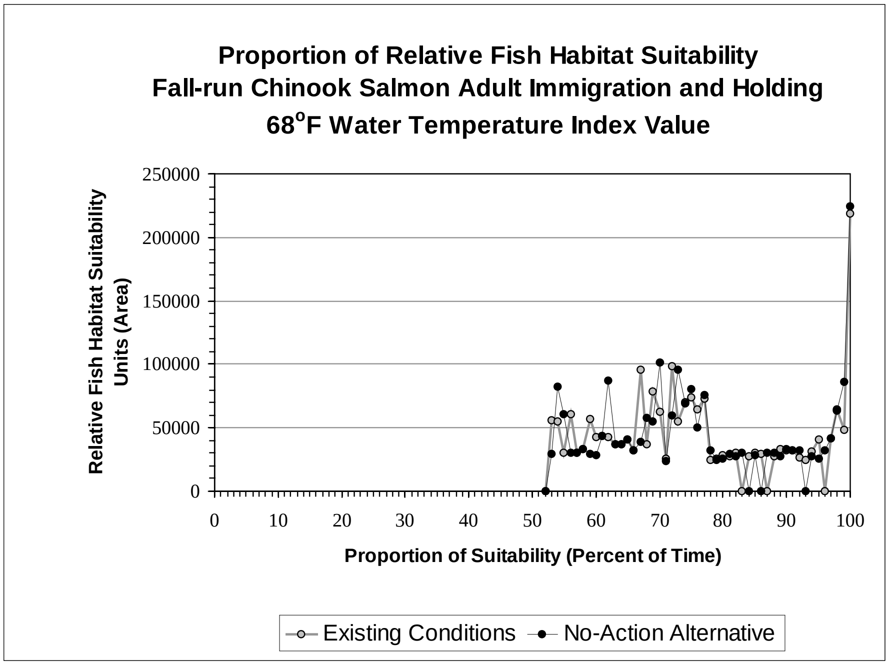


Figure G-AQUA3.4-7. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult immigration and holding for the 68°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA3.4-1 for fall-run Chinook salmon adult immigration and holding for the 60°F water temperature index value under existing conditions and the No-Action Alternative are 1,141,760 and 1,148,851, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 7,091, which represents a 0.62 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 64°F water temperature index value under existing conditions and the No-Action Alternative are 1,588,825 and 1,599,013, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 10,188, which represents a 0.64 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 68°F water temperature index value under existing conditions and the No-Action Alternative are 2,175,751 and 2,191,674, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 15,923, which represents a 0.73 percent increase in OHSIV under the No-Action Alternative compared to existing conditions.

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-1 for the fall-run Chinook salmon adult immigration and holding life stage did not change between existing conditions and the No-Action Alternative for any of the water temperature index values selected.

Table G-AQUA3.4-1. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for fall-run Chinook salmon adult immigration and holding.

Water Temperature Index Value	60°F	64°F	68°F
Existing Conditions			
Minimum Percentage of Time Value	31%	41%	53%
Maximum Percentage of Time Value	93%	100%	100%
Habitat Units at 100 Percent of Time	0	72,837	218,450
Percentage of Time at Maximum Habitat Units	33%	46%	100%
OHSIV	**1,141,760**	**1,588,825**	**2,175,751**
No-Action Alternative			
Minimum Percentage of Time Value	31%	41%	53%
Maximum Percentage of Time Value	92%	100%	100%
Habitat Units at 100 Percent of Time	0	72,837	224,272
Percentage of Time at Maximum Habitat Units	34%	42%	100%
OHSIV	**1,148,851**	**1,599,013**	**2,191,674**
Percent Change	**0.62%**	**0.64%**	**0.73%**

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-1 for the fall-run Chinook salmon adult immigration and holding did not change between existing conditions and the No-Action Alternative for the 64°F and 68°F water temperature index values. The Maximum Percentage of Time Value metric for the 60°F water temperature index value under existing conditions and the No-Action Alternative are 93 percent and 92 percent, respectively. The 1 percent difference in Maximum Percentage of Time Value between existing conditions and the No-Action Alternative represents a small decrease in the number of habitat units with the greatest amount of time and area with water temperatures below 60°F under the No-Action Alternative compared to existing conditions.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-1 for the fall-run Chinook salmon adult immigration and holding life stage did not change between existing conditions and the No-Action Alternative for the 60°F and 64°F water temperature index values. The Habitat Units at 100 Percent of Time for the 68°F water temperature index value under existing conditions and the No-Action Alternative are 218,450 and 224,272, respectively. The difference in Habitat Units at 100 Percent of Time between the No-Action Alternative and existing conditions is 5,822, which represents a 2.67 percent increase in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are always at or below 68°F.

A 2.67 percent increase in the number of habitat units in which water temperatures are always at or below 68°F and above 64°F represents an increase in habitat under the No-Action Alternative in which specific biological effects could potentially occur to immigrating and holding adult fall-run Chinook salmon, such as increased incidence of disease, decreased adult survival, decreased egg viability, and latent embryonic abnormalities and mortalities (Berman 1990; EPA 2003; Marine 1992; Ordal and Pacha 1963). A detailed description of the potential effects that could occur to immigrating and holding adult fall-run Chinook salmon from exposure to water temperatures above each water temperature index value is presented in Appendix G-AQUA2.2.3.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-1 for the fall-run Chinook salmon adult immigration and holding life stage did not change between existing conditions and the No-Action Alternative for the 68°F water temperature index value. The Percentage of Time at Maximum Habitat Units metric presented for the fall-run Chinook salmon adult immigration and holding life stage for the 60°F, water temperature index value under existing conditions and the No-Action Alternative are 33 percent and 34 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between the No-Action Alternative and existing conditions is 1 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area. The Percentage of Time at Maximum Habitat Units metric for the fall-run Chinook salmon adult immigration and holding life stage for the 64°F, water temperature index value under existing conditions and the No-Action Alternative are 46 percent and 42 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between existing conditions and the No-Action Alternative is four percent, which represents a decrease in the percentage of time that the habitat is suitable in the greatest area.

Adult Spawning and Embryo Incubation

Figures G-AQUA3.4-8, G-AQUA3.4-9, G-AQUA3.4-10, and G-AQUA3.4-11 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA3.4-8, G-AQUA3.4-9, G-AQUA3.4-10, and G-AQUA3.4-11 is equal, which allows for direct comparison of habitat suitability between alternatives.

The OHSIV metrics presented in Table G-AQUA3.4-2 for fall-run Chinook salmon adult spawning and embryo incubation for the 56°F water temperature index value under existing conditions and the No-Action Alternative are 90,931 and 91,070, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 139, which represents a 0.15 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 58°F water temperature index value under existing conditions and the No-Action Alternative are 104,890 and 105,231, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 341, which represents a 0.33 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 60°F water temperature index value under the existing conditions and the No-Action Alternative are 117,933 and 118,429, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 496, which represents a 0.42 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 62°F water temperature index value under the existing conditions and the No-Action Alternative are 130,430 and 130,823, respectively. The difference in OHSIV between

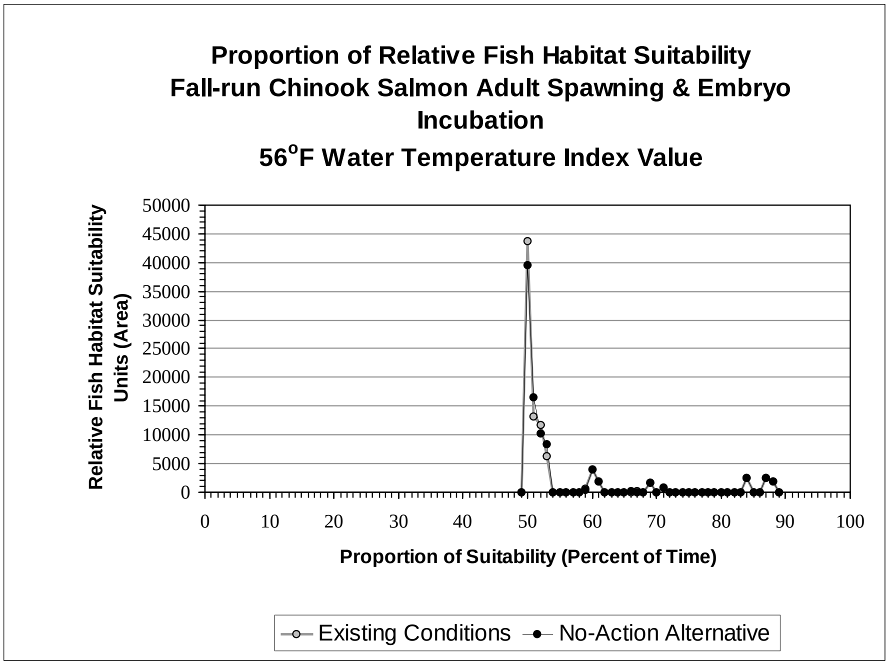


Figure G-AQUA3.4-8. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult spawning and embryo incubation for the 56°F water temperature index value.

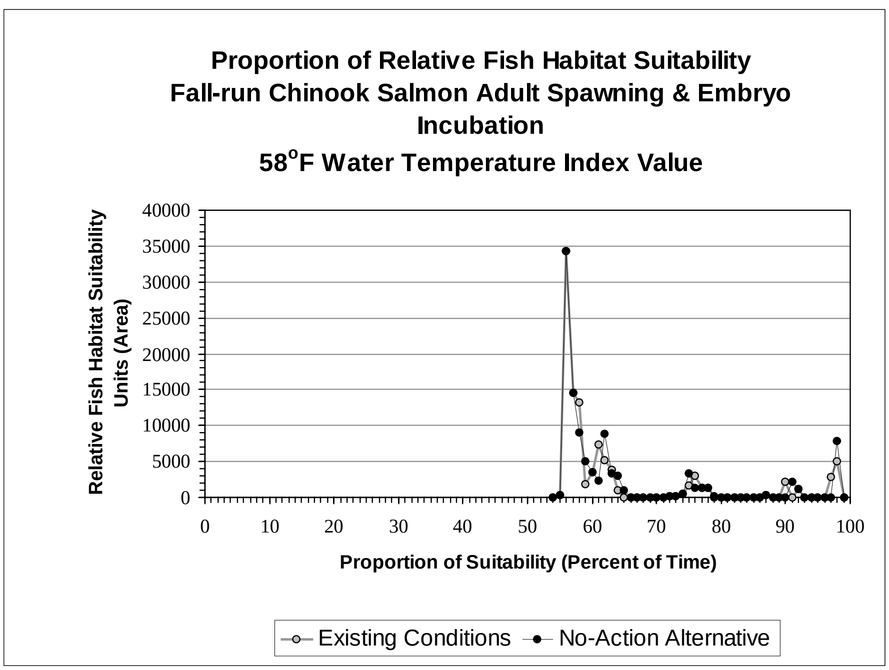


Figure G-AQUA3.4-9. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult spawning and embryo incubation for the 58°F water temperature index value.

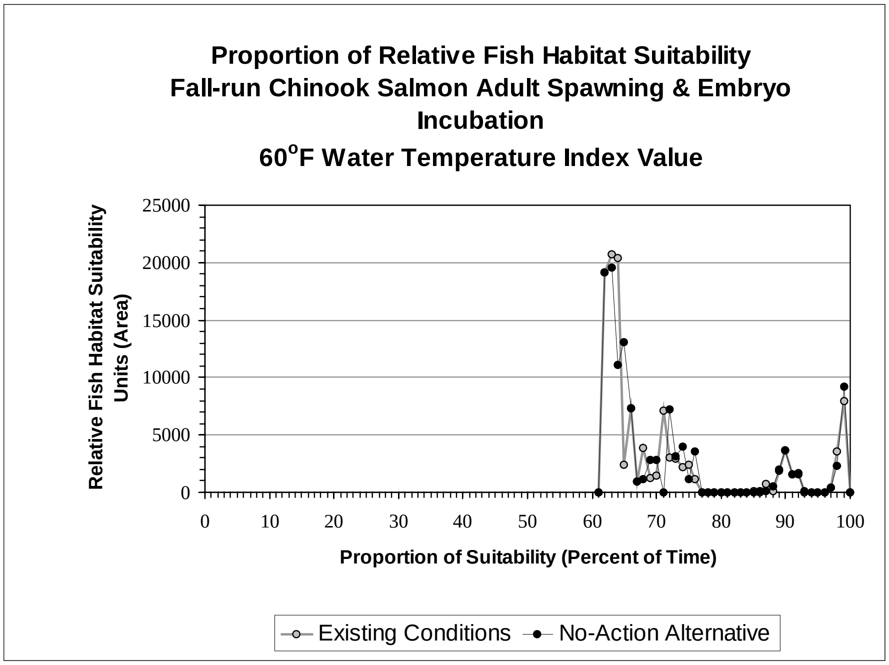


Figure G-AQUA3.4-10. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult spawning and embryo incubation for the 60°F water temperature index value.

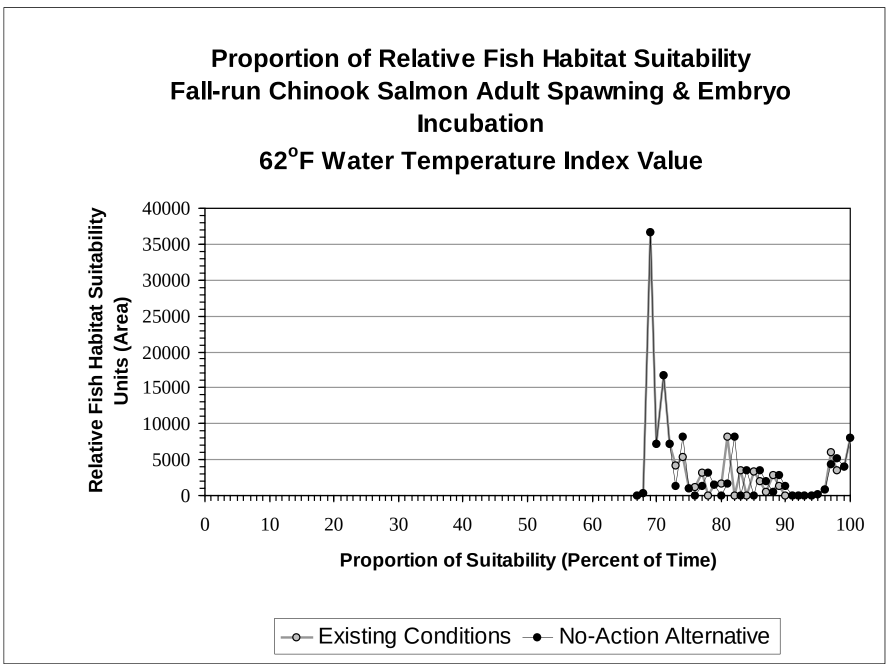


Figure G-AQUA3.4-11. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult spawning and embryo incubation for the 62°F water temperature index value.

Table G-AQUA3.4-2. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for fall-run Chinook salmon adult spawning and embryo incubation.

Water Temperature Index Value	56°F	58°F	60°F	62°F
Existing Conditions				
Minimum Percentage of Time Value	50%	55%	62%	68%
Maximum Percentage of Time Value	88%	98%	99%	100%
Habitat Units at 100 Percent of Time	0	0	0	8,020
Percentage of Time at Maximum Habitat Units	50%	56%	63%	69%
OHSIV	**90,931**	**104,890**	**117,933**	**130,430**
No-Action Alternative				
Minimum Percentage of Time Value	50%	55%	62%	68%
Maximum Percentage of Time Value	88%	98%	99%	100%
Habitat Units at 100 Percent of Time	0	0	0	8,020
Percentage of Time at Maximum Habitat Units	50%	56%	63%	69%
OHSIV	**91,070**	**105,231**	**118,429**	**130,823**
Percent Change	**0.15%**	**0.33%**	**0.42%**	**0.30%**

the No-Action Alternative and existing conditions is 393, which represents a 0.30 percent increase in OHSIV under No-Action Alternative compared to existing conditions.

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-2 for the fall-run Chinook salmon adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-2 for the fall-run Chinook salmon adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-2 for the fall-run Chinook salmon adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-2 for the fall-run Chinook salmon adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

Juvenile Rearing and Downstream Movement

Figures G-AQUA3.4-12, G-AQUA3.4-13, G-AQUA3.4-14, G-AQUA3.4-15, G-AQUA3.4-16, and G-AQUA3.4-17 show the proportion of time that habitat units are

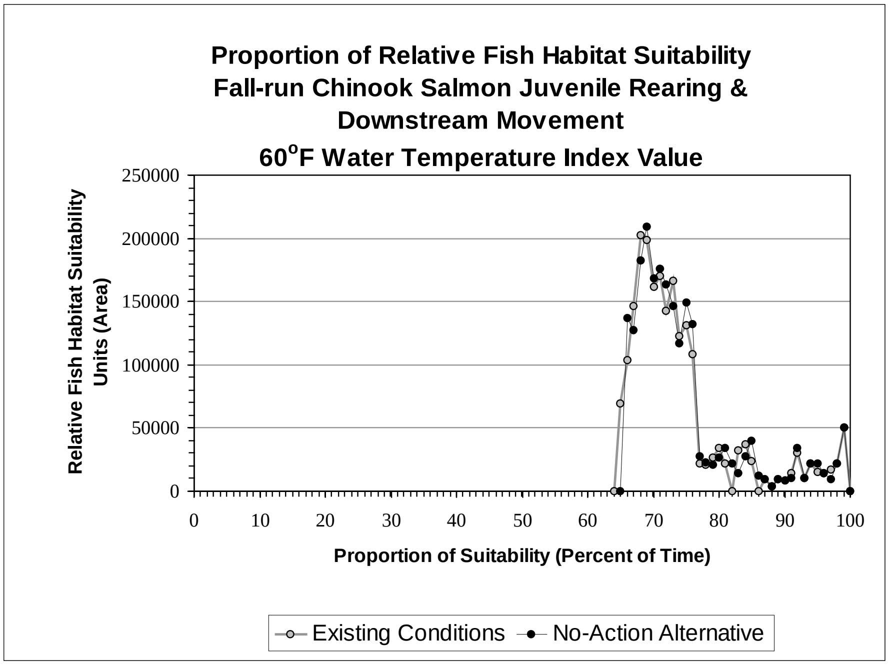


Figure G-AQUA3.4-12. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 60°F water temperature index value.

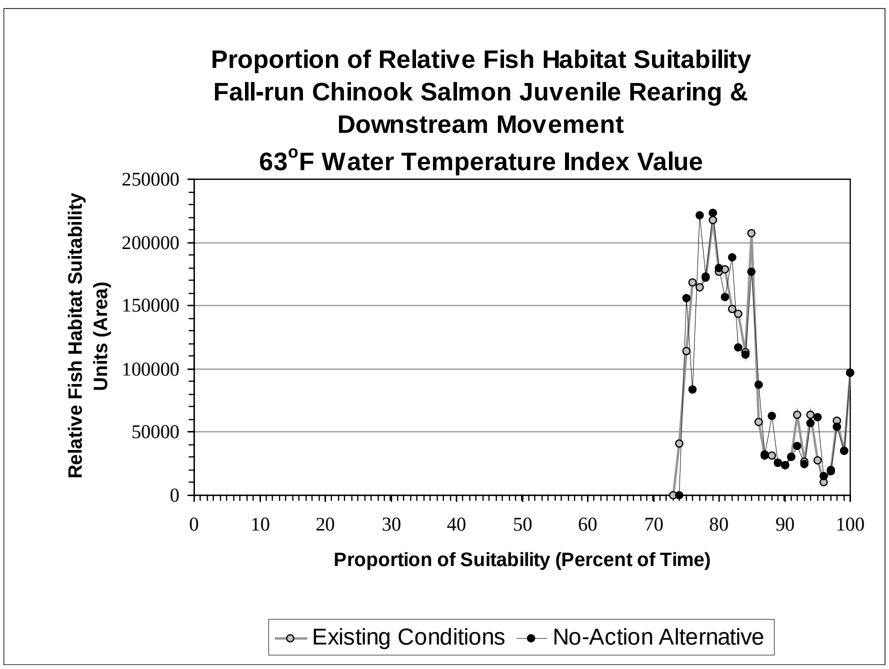


Figure G-AQUA3.4-13. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 63°F water temperature index value.

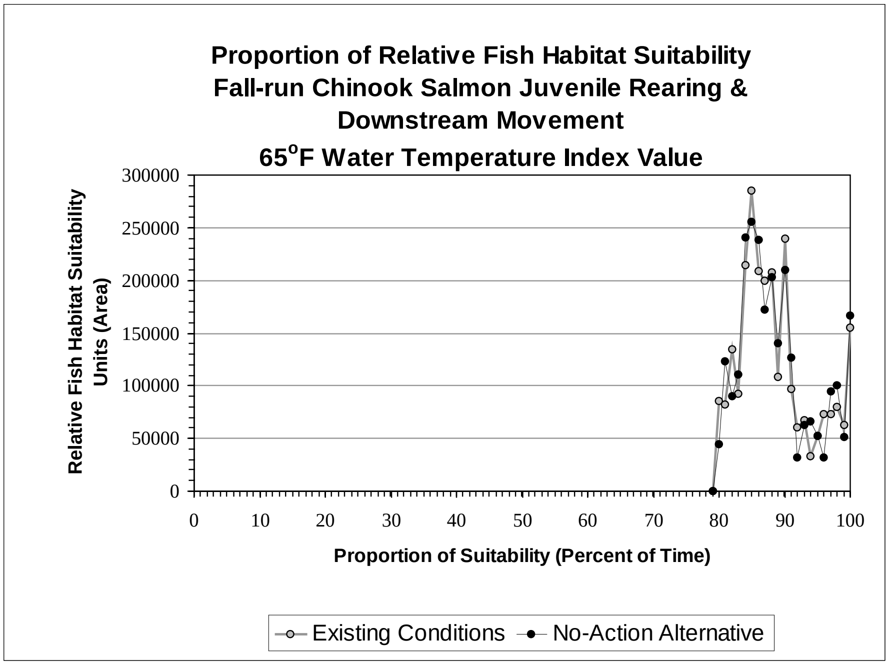


Figure G-AQUA3.4-14. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 65°F water temperature index value.

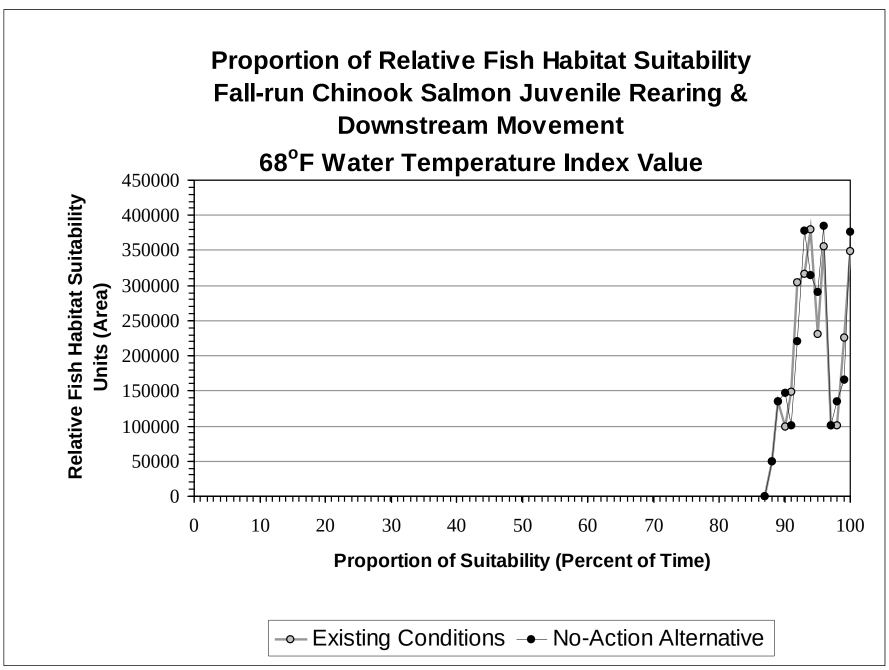


Figure G-AQUA3.4-15. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 68°F water temperature index value.

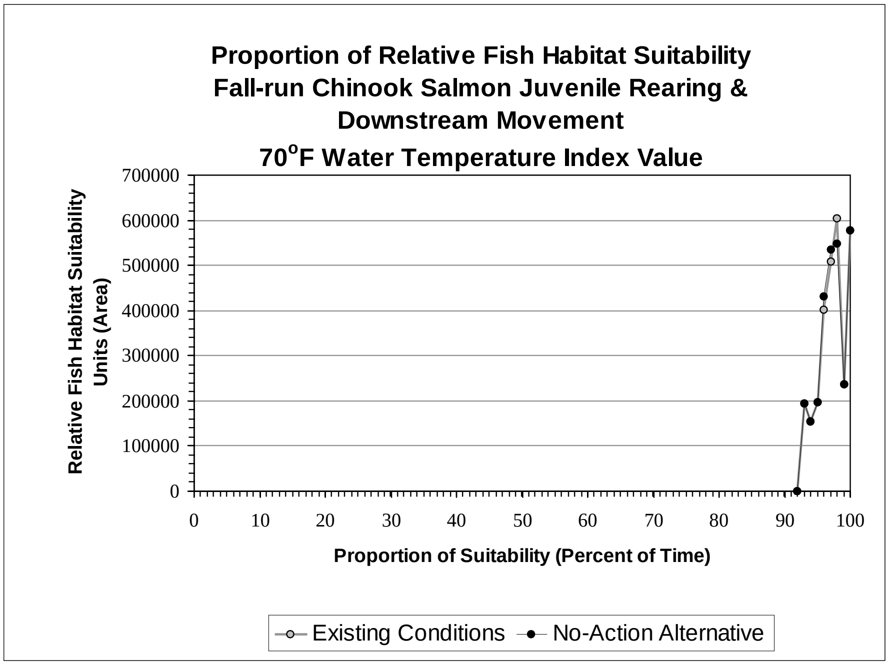


Figure G-AQUA3.4-16. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 70°F water temperature index value.

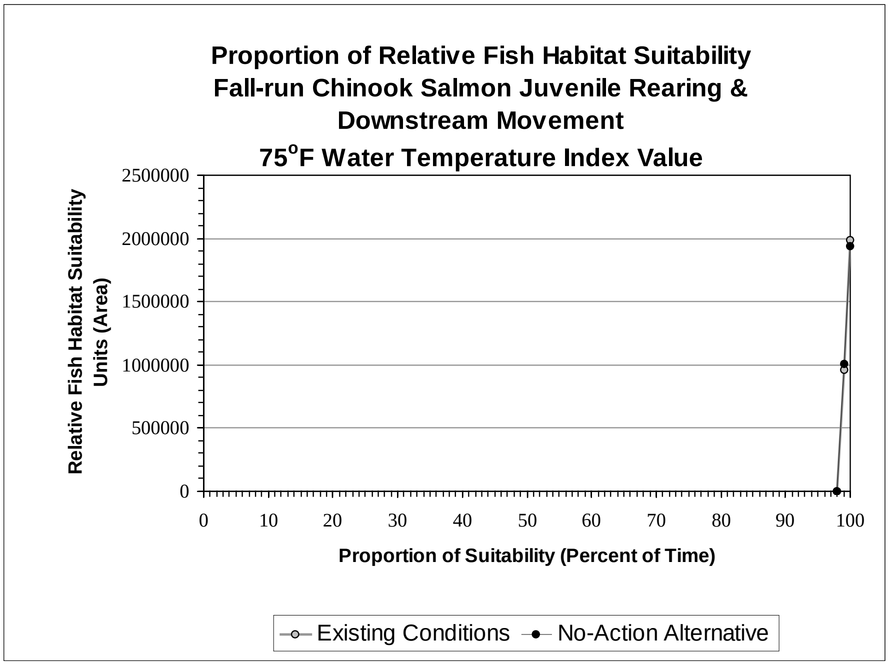


Figure G-AQUA3.4-17. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 75°F water temperature index value.

considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA3.4-12, G-AQUA3.4-13, G-AQUA3.4-14, G-AQUA3.4-15, G-AQUA3.4-16, and G-AQUA3.4-17 is equal, which allows for direct comparison of habitat suitability between alternatives.

The OHSIV metrics presented in Table G-AQUA3.4-3 for fall-run Chinook salmon juvenile rearing and downstream movement for the 60°F water temperature index value under existing conditions and the No-Action Alternative are 2,168,400 and 2,180,180, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 11,780, which represents a 0.54 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 63°F water temperature index value under existing conditions and the No-Action Alternative are 2,447,381 and 2,453,678, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 6,297, which represents a 0.26 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 65°F water temperature index value under existing conditions and the No-Action Alternative are 2,612,481 and 2,616,587, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 4,106, which represents a 0.16 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 68°F water temperature index value under existing conditions and the No-Action Alternative are 2,798,871 and 2,800,642, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 1,771, which represents a 0.06 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 70°F water temperature index value under existing conditions and the No-Action Alternative are 2,875,168 and 2,874,312, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 857, which represents a 0.03 percent decrease in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 75°F water temperature index value under existing conditions and the No-Action Alternative are 2,947,407 and 2,946,916, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 491, which represents a 0.02 percent decrease in OHSIV under the No-Action Alternative compared to existing conditions.

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-3 for the fall-run Chinook salmon juvenile rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for the 65°F, 68°F, 70°F, or 75°F water temperature index values selected. The Minimum Percentage of Time Value metric for the fall-run Chinook salmon juvenile rearing and downstream movement for the 60°F water temperature index value under existing conditions and the No-Action Alternative are 65 percent and 66 percent, respectively. The 1 percent difference in Minimum Percentage of Time Value between the No-Action Alternative and existing conditions represents an increase in the number of habitat units with the smallest amount of time and area with water temperatures below 60°F under the No-Action Alternative compared to existing conditions. The Minimum Percentage of Time Value metric for the 63°F water temperature index value under existing Conditions and the No-Action Alternative are 74 percent and 75 percent, respectively. The

Table G-AQUA3.4-3. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for fall-run Chinook salmon juvenile rearing and downstream movement.

Water Temperature Index Value	60°F	63°F	65°F	68°F	70°F	75°F
Existing Conditions						
Minimum Percentage of Time Value	65%	74%	80%	88%	93%	99%
Maximum Percentage of Time Value	99%	100%	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	0	97,307	155,395	349,749	578,584	1,987,302
Percentage of Time at Maximum Habitat Units	68%	79%	85%	94%	98%	100%
OHSIV	**2,168,400**	**2,447,381**	**2,612,481**	**2,798,871**	**2,875,168**	**2,947,407**
No-Action Alternative						
Minimum Percentage of Time Value	66%	75%	80%	88%	93%	99%
Maximum Percentage of Time Value	99%	100%	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	0	97,307	166,409	376,160	578,584	1,938,161
Percentage of Time at Maximum Habitat Units	69%	79%	85%	96%	100%	100%
OHSIV	**2,180,180**	**2,453,678**	**2,616,587**	**2,800,642**	**2,874,312**	**2,946,916**
Percent Change	**0.54%**	**0.26%**	**0.16%**	**0.06%**	**-0.03%**	**-0.02%**

1 percent difference in Minimum Percentage of Time Value between the No-Action Alternative and existing conditions represents an increase in the number of habitat units with the smallest amount of time and area with water temperatures below 63°F under the No-Action Alternative compared to Existing conditions.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-3 for the fall-run Chinook salmon juvenile rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-3 for the fall-run Chinook salmon juvenile rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for the 60°F, 63°F, and 70°F water temperature index values. The Habitat Units at 100 Percent of Time for the 65°F water temperature index value under existing conditions and the No-Action Alternative are 155,395 and 166,409, respectively. The difference in Habitat Units at 100 Percent of Time between the No-Action Alternative and existing conditions is 11,014, which represents a 7.09 percent increase in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are always at or below 65°F. The Habitat Units at 100 Percent of Time for the 68°F water temperature index value under the existing conditions and the No-Action

Alternative are 349,749 and 376,160, respectively. The difference in Habitat Units at 100 Percent of Time between the No-Action Alternative and existing conditions is 26,411, which represents a 7.55 percent increase in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are always at or below 68°F. The Habitat Units at 100 Percent of Time for the 75°F water temperature index value under the existing conditions and the No-Action Alternative are 1,987,586 and 1,938,161, respectively. The difference in Habitat Units at 100 Percent of Time between existing conditions and the No-Action Alternative is 49,141, which represents a 2.47 percent decrease in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are always at or below 75°F.

A 7.09 percent increase in the number of habitat units in which water temperatures are always at or below 65°F and above 63°F represents an increase in habitat under the No-Action Alternative in which specific biological effects could potentially occur to rearing and downstream migrating juvenile fall-run Chinook salmon, such as acceleration or inhibition of smoltification, decreased growth rates, and increased mortality rates (Clarke and Shelbourn 1985; Marine 1997; Zedonis and Newcomb 1997). A 7.55 percent increase in the number of habitat units in which water temperatures are always at or below 68°F and above 65°F represents an increase in habitat under the No-Action Alternative in which specific biological effects could potentially occur to rearing and downstream migrating juvenile fall-run Chinook salmon, such as acceleration or inhibition of smoltification, decreased appetite, decreased growth rates, and increased mortality rates (Clarke and Shelbourn 1985; Marine 1997; Zedonis and Newcomb 1997). A 2.47 percent decrease in the number of habitat units in which water temperatures are always at or below 75°F and above 70°F represents an decrease in habitat under the No-Action Alternative in which specific biological effects could potentially occur to rearing and downstream migrating juvenile fall-run Chinook salmon, such as increased incidence of disease, hyperactivity, decreased appetite, reduced growth rates, and substantially increased mortality rates (McCullough 1999; Rich 1987). A detailed description of the potential effects that could occur to rearing and downstream migrating juvenile fall-run Chinook salmon from exposure to water temperatures above each water temperature index value is presented in Section G-AQUA2.2.3 of Appendix G-AQUA2.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-3 for the fall-run Chinook salmon juvenile rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for the 63°F, 65°F, or the 75°F water temperature index values. The Percentage of Time at Maximum Habitat Units for the fall-run Chinook salmon juvenile rearing and downstream movement life stage for the 60°F water temperature index value under existing conditions and the No-Action Alternative are 68 percent and 69 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between existing conditions and the No-Action Alternative is 1 percent, which represents a small increase in the percentage of time that the habitat is suitable in the greatest area. The Percentage of Time at Maximum Habitat Units for the fall-run Chinook salmon juvenile rearing and downstream movement life stage for the 68°F water temperature index value under existing conditions and the No-Action Alternative are 94 percent and 96 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between existing conditions and the No-Action Alternative is two percent, which represents a small increase in the percentage of time that the habitat is suitable in the greatest area. The Percentage of Time at Maximum Habitat Units for the fall-run Chinook salmon juvenile rearing and downstream movement life stage for the 70°F water temperature index value under existing conditions and the No-Action Alternative are 98 percent and 100 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between existing conditions and the No-Action Alternative is two percent, which represents a small increase in the percentage of time that the habitat is suitable in the greatest area.

G-AQUA3.4.1.3 Predation-related Effects

The slight change in water temperatures resulting from slight changes in seasonal flow patterns in the High Flow Channel under the No-Action Alternative is not anticipated to affect predation rates or the composition of predator species.

G-AQUA3.4.1.4 Fisheries Management–related Effects

Hatchery

No changes to hatchery management are anticipated under the No-Action Alternative. Therefore, no hatchery-related effects on fall-run Chinook salmon are expected.

Disease

The slight change in water temperatures resulting from slight changes in seasonal flow patterns in the High Flow Channel under the No-Action Alternative is not anticipated to affect the incidence of disease.

Fishing Regulations, Poaching, and Change in Recreational Access and Visitation

Section 5.10.2, Recreation Resources Environmental Effects, forecasts a one-third increase in recreation and angling activities with the No-Action Alternative. A one-third increase in angling, with no other PM&E measures related to fisheries, would equate to increased sport fish harvest rates. No changes to fishing regulations are anticipated to occur under the No-Action Alternative.

G-AQUA3.4.1.5 Summary of Potential Effects on Fall-run Chinook Salmon

Study plan report summaries addressing project effects on fall-run Chinook salmon are presented in Section G-AQUA1.5, Fisheries Management; Section G-AQUA1.7, Feather River Fish Hatchery; Section G-AQUA1.8, Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam; Section G-AQUA1.9, Upstream Fish Passage; Section G-AQUA10, Instream Flows and Fish Habitat; and Section G-AQUA1.11, Predation, in Appendix G-AQUA1, Affected Environment. A description of each fall-run

Chinook salmon life stage and the time period associated with it is presented in Appendix G-AQUA1.

Adult Immigration and Holding

Changes in flows under the No-Action Alternative would provide no effect on fall-run Chinook salmon adult immigration and holding. Differences in habitat suitability due to decreased water temperatures are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect fall-run Chinook salmon adult immigration and holding.

Overall, operation of the Oroville Facilities under the No-Action Alternative would result in no effect on fall-run Chinook salmon adult immigration and holding.

Adult Spawning and Embryo Incubation

Changes in mean monthly flow under the No-Action Alternative would result in a slight beneficial effect on fall-run Chinook salmon adult spawning and embryo incubation due to slight increases in WUA. Differences in habitat suitability (OHSIV) for each water temperature index value due to decreased water temperatures are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect fall-run Chinook salmon adult spawning and embryo incubation. However, continued degradation of gravel spawning substrate in the lower Feather River would result in an adverse effect on fall-run Chinook salmon adult spawning and embryo incubation by reducing the quantity and quality of available habitat. Also, continued occupation of the same spawning areas would continue to adversely affect the genetic distinctness between the spring-run and fall-run Chinook salmon in the lower Feather River.

Overall, operation of the Oroville Facilities under the No-Action Alternative would result in an adverse effect on fall-run Chinook salmon adult spawning and embryo incubation habitat. However, the Feather River Fish Hatchery was constructed to offset the loss of access to upstream habitat.

Juvenile Rearing and Downstream Movement

Changes in average monthly flow under the No-Action Alternative likely would have a slightly adverse effect on fall-run Chinook salmon juvenile rearing and downstream movement due to an overall slight decrease in WUA during the life stage period. Differences in habitat suitability due to decreased water temperatures are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect fall-run Chinook salmon juvenile rearing and downstream movement. However, continued degradation of large woody debris, gravel, and side-channel habitat quality would result in an adverse effect on the quality and quantity of available habitat.

Overall, operation of the Oroville Facilities under the No-Action Alternative would have an adverse effect on fall-run Chinook salmon juvenile rearing and downstream movement.

Conclusion

Based on the above summary of potential effects, it is likely that the No-Action Alternative would have an overall adverse effect on fall-run Chinook salmon relative to existing conditions.

G-AQUA3.4.2 Spring-run Chinook Salmon

G-AQUA3.4.2.1 Flow-related Effects

Under the No-Action Alternative, there would be no changes to flows in the Low Flow Channel. Effects of flow changes in the High Flow Channel are expressed in the qualitative and quantitative analyses of habitat suitability presented below.

Adult Immigration and Holding

Mean monthly flow changes under the No-Action Alternative compared to existing conditions during the spring-run Chinook salmon adult immigration and holding period would occur in the High Flow Channel. Increased mean monthly flows from May through August and decreased mean monthly flows in March and April, and in September and October would cause very small changes in river stage. Because the flow-related changes in river stage during the spring-run Chinook salmon adult immigration and holding period would be small, they would not be sufficiently large to affect immigration at potential critical riffles and would not be sufficiently large to appreciably affect holding habitat depths.

Flow fluctuations that could potentially occur under the No-Action Alternative would be similar to flow fluctuations that occur under existing conditions. Because flow fluctuations currently do not affect spring-run Chinook salmon adult immigration and holding, flow fluctuation under the No-Action Alternative also would not affect spring-run Chinook salmon adult immigration and holding.

Adult Spawning and Embryo Incubation

Under the No-Action Alternative, flow fluctuations in the High Flow Channel are not expected to differ from flow fluctuations that occur under existing conditions. However, flow releases would change monthly compared to existing conditions. Daily minimum and maximum flows within the spring-run Chinook salmon spawning period likely would not differ from those described in the 1983 agreement between DFG and DWR, which govern current operations. Under existing conditions, during normal operations, flows in the High Flow Channel are maintained above specified minimum and below specified maximum flows in order to protect fisheries resources. Flow requirements for the High Flow Channel under existing conditions and the No-Action Alternative are described in Section 5.4.1.1, Water Quantity Affected Environment. Under normal operating conditions in the No-Action Alternative, daily releases into the High Flow Channel would not fluctuate outside the minimum and maximum flows described in Section 5.4.1.1, which are the same minimum and maximum flows described for existing conditions. During drought conditions, flows likely would be lowered to a constant minimum flow of 750 cfs prior to the onset of fall-run Chinook salmon spawning and raised to 900 cfs in the beginning of October. According to USBR (2004), the minimum and maximum flow requirements as well as the fluctuations permitted during the spring-run Chinook salmon spawning and embryo incubation period in the High Flow Channel under existing conditions have not affected this life stage. Therefore, it is expected that the flow requirements and the associated flow fluctuations in the High Flow Channel under the No-Action Alternative, also would not affect this life stage.

Evaluation of the WUA index generated by the PHABSIM model for the adult spawning life stage of Chinook salmon indicated that the maximum amount of spawning area in the High Flow Channel, given the current channel configuration, would occur at flows around 1,700 cfs. Figure G-AQUA3.4-18 shows the WUA curve generated by the PHABSIM model for Chinook salmon spawning in the High Flow Channel.

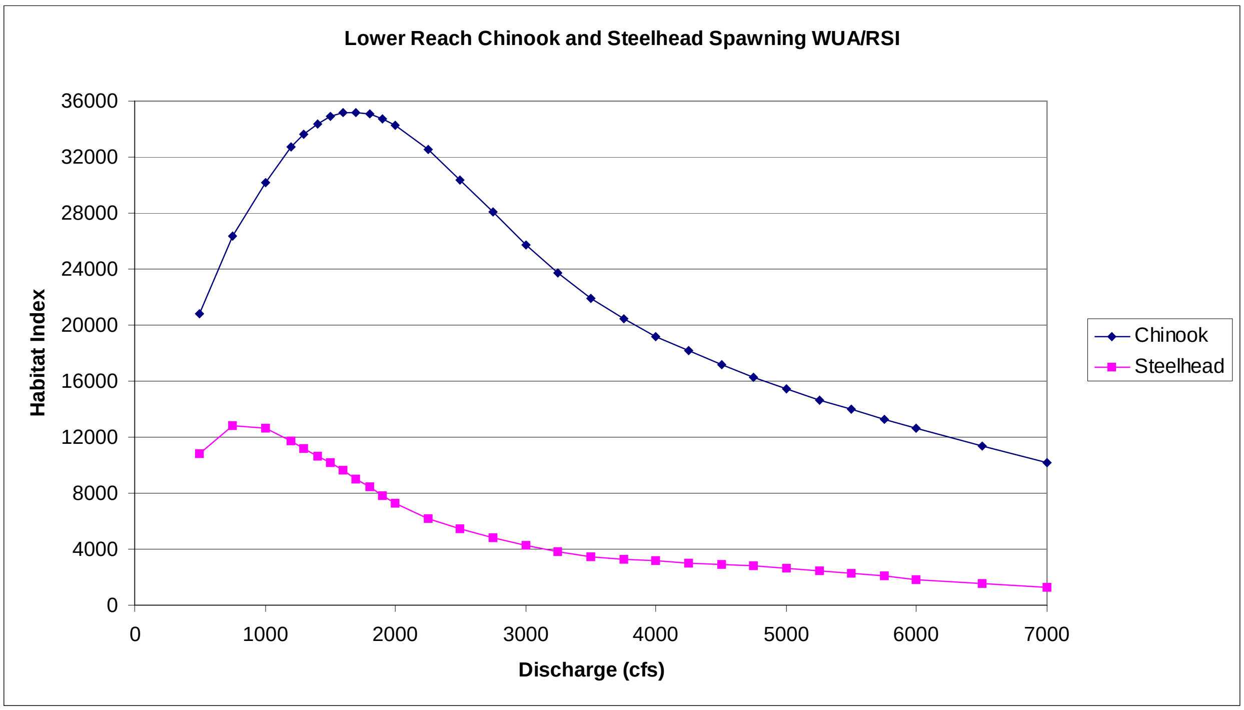


Figure G-AQUA3.4-18. High Flow Channel WUA curves for steelhead and Chinook salmon.

Current minimum flows in the High Flow Channel during the spring-run Chinook salmon spawning period are 1,000 cfs in September and 1,700 cfs in October, November and December, which produce approximately 86 percent, and 100 percent of maximum WUA, respectively. Minimum flows under the No-Action Alternative likely would not change from existing conditions. Therefore, minimum flows in the High Flow Channel under the No-Action Alternative also would produce approximately 86 percent of maximum WUA in September, and 100 percent of maximum WUA for Chinook salmon spawning from October through December, representing no change from existing conditions.

Based on modeling results, mean monthly flows under the No-Action Alternative during the spring-run Chinook salmon spawning period would be lower than under existing conditions. Mean monthly flows under the No-Action Alternative would be 1,864 cfs in September, representing a mean decrease of 43 cfs from existing conditions. In October mean monthly flows would be 2,213 cfs, representing a decrease of 96 cfs. In November mean monthly flows would be 1,991 cfs, representing a decrease of 206 cfs from existing conditions, while mean monthly flows in December would be 3,575 cfs, which represents an 88 cfs decrease from existing conditions. Changes in mean monthly flows during the spring-run Chinook salmon spawning period would result in changes in Chinook salmon spawning WUA. Due to the generalized nature of the WUA index and the inherent limitations in the methodology associated with IFIM and PHABSIM models, small changes in flow at the flows modeled were not able to determine exact changes in WUA. However, examination of Figure G-AQUA3.4-18 shows that, in September, a decrease in flow of 43 cfs would result in a slight increase in WUA compared to existing conditions. In October, a decrease in flow of 96 cfs would result in a slight increase in WUA. In November, a decrease in flow of 206 cfs would result in a slight increase in WUA, and in December, a decrease in flow of 88 cfs would result in a slight increase in WUA. Overall, the average monthly change in flow under the No-Action Alternative would result in an increase in Chinook salmon spawning WUA over the course of the spawning period compared to existing conditions.

Juvenile Rearing and Downstream Movement

Under the No-Action Alternative, flow fluctuations in the High Flow Channel would be similar to those occurring under existing conditions. Because flow fluctuations under existing conditions have no effect on juvenile spring-run Chinook salmon, it is likely that flow fluctuations occurring under the No-Action Alternative also would have no effect on spring-run Chinook salmon juvenile rearing and downstream movement.

Under the No-Action Alternative mean monthly flows would decrease compared to existing conditions from January through April and from September through December, and increase from May through August. Figures G-AQUA3.4-19 and G-AQUA3.4-20 show the WUA curves for Chinook salmon fry (<50mm) and juveniles (>50mm) in the High Flow Channel. The final report for SP-F16 provides detailed description of the differences between the weighting of the no-cover habitat suitability criteria in the PHABSIM model. Due to the generalized nature of the WUA index and the inherent limitations in the methodology associated with IFIM and PHABSIM models, small changes in flow at the flows modeled were not able to determine exact quantitative changes in WUA. However, utilizing the no-cover weighting of 0.15 for fry and 0.28 for juveniles shown in Figures G-AQUA3.4-19 and G-AQUA3.4-20, the flow decreases compared to existing conditions would result in an overall slight decrease in WUA during December and January and would not change appreciably during the remaining months in which average monthly flows decreased. Additionally, the flow increases

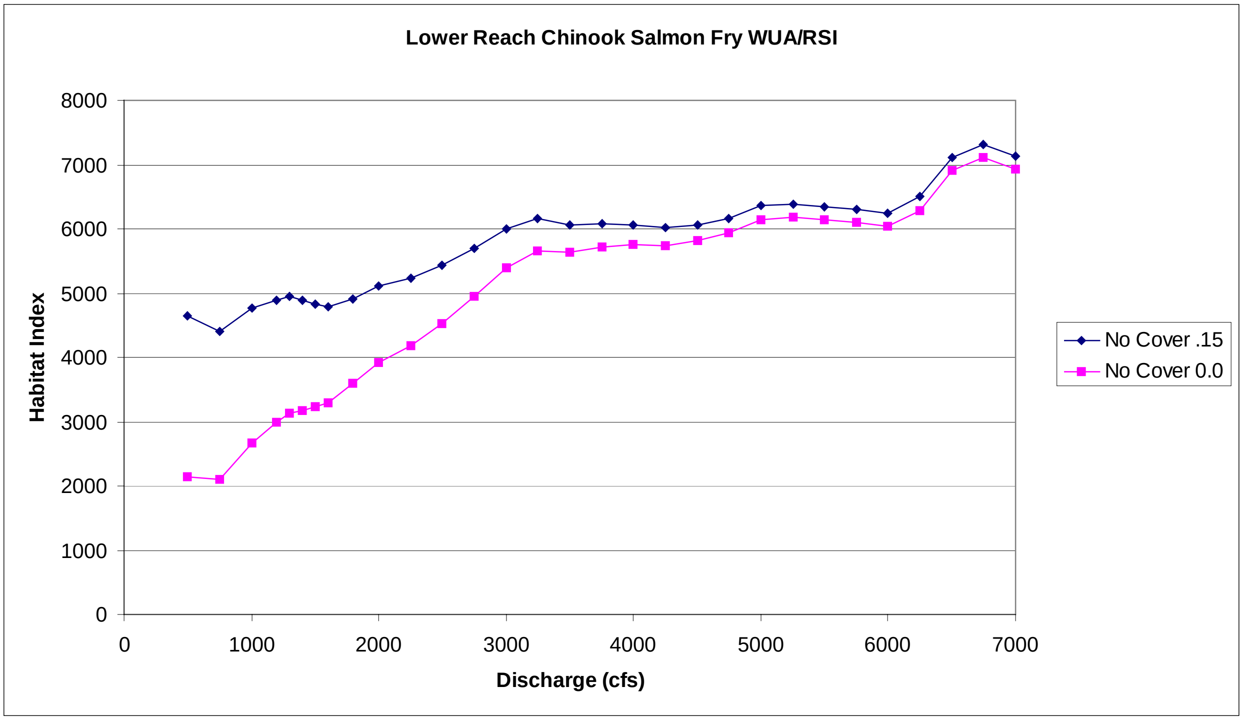


Figure G-AQUA3.4-19. High Flow Channel WUA curves for Chinook salmon fry <50mm.

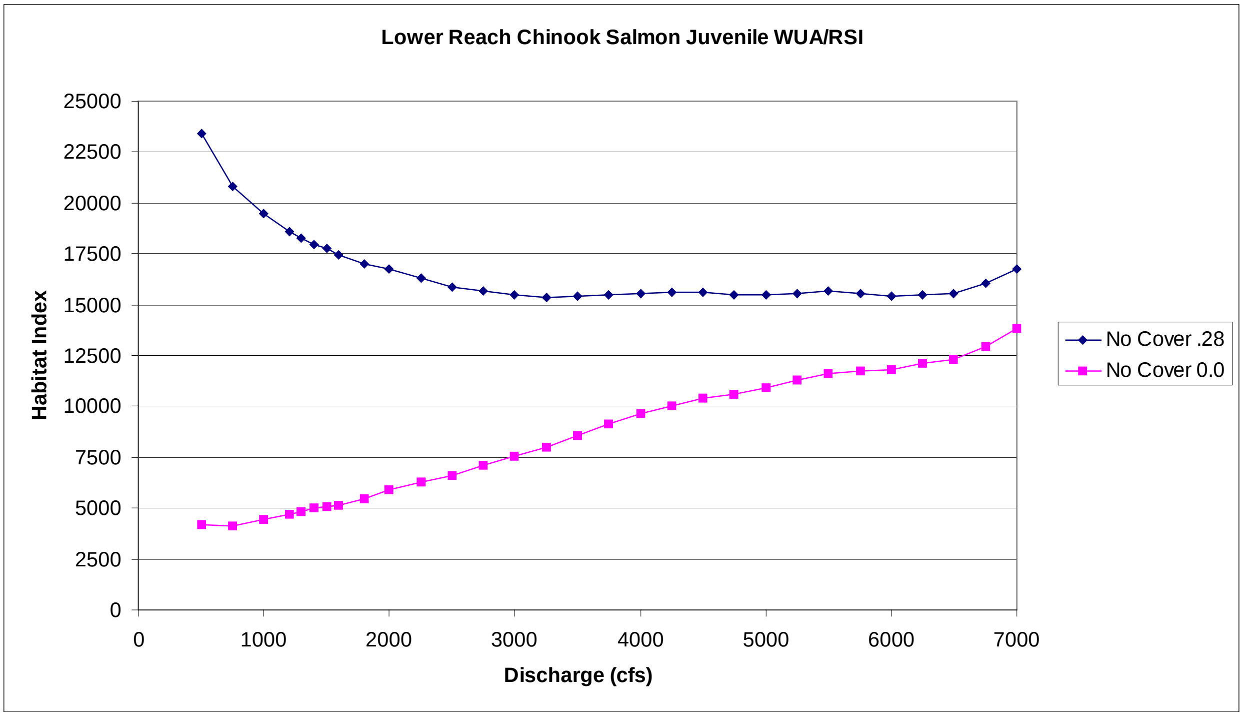


Figure G-AQUA3.4-20. High Flow Channel WUA curves for juvenile Chinook salmon 50mm+.

would result in slight increase in WUA during July and would not change appreciably during the remaining months during which average monthly flows increased. Therefore, mean monthly flow changes under the No-Action alternative would have no effect on spring-run Chinook salmon juvenile rearing and downstream movement.

G-AQUA3.4.2.2 Water Temperature–related Effects

Effects of water temperature changes associated with the No-Action Alternative are expressed in the quantitative analyses of relative habitat suitability presented below.

The relative habitat suitability analysis includes an evaluation of overall relative habitat suitability based on water temperature index values. The analysis includes a comparison of habitat suitability component metrics between the No-Action Alternative and existing conditions. Detailed descriptions of the methodology used in the derivation and calculation of each metric in the evaluation of relative habitat suitability are presented in Section G-AQUA2.2.3 in Appendix G-AQUA2.

__Adult Immigration and Holding__

Figures G-AQUA3.4-21, G-AQUA3.4-22, and G-AQUA3.4-23 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA3.4-21, G-AQUA3.4-22, and G-AQUA3.4-23 is equal, which allows for direct comparison of habitat suitability between alternatives.

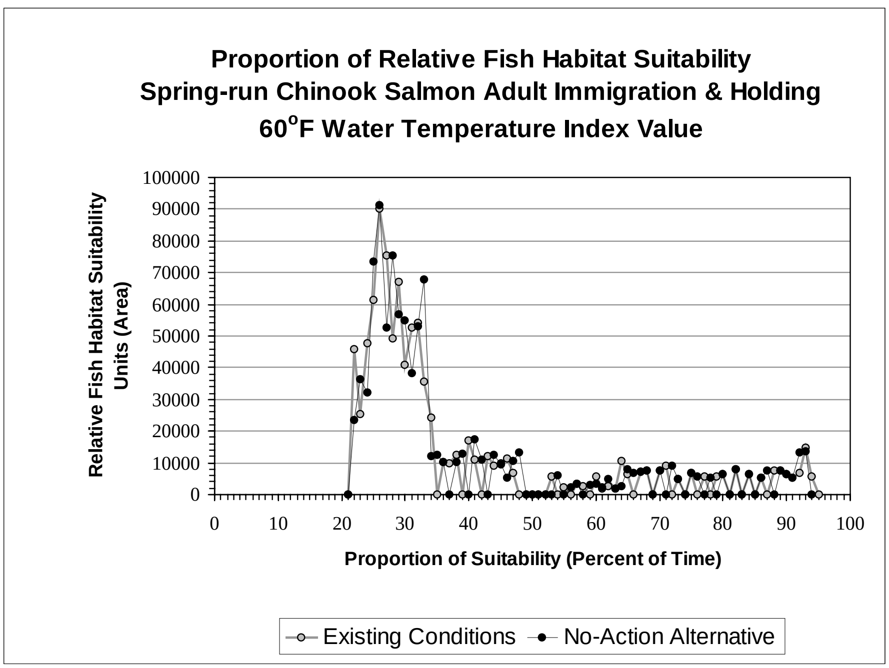


Figure G-AQUA3.4-21. Proportion of relative fish habitat suitability for spring-run Chinook salmon adult immigration and holding for the 60°F water temperature index value.

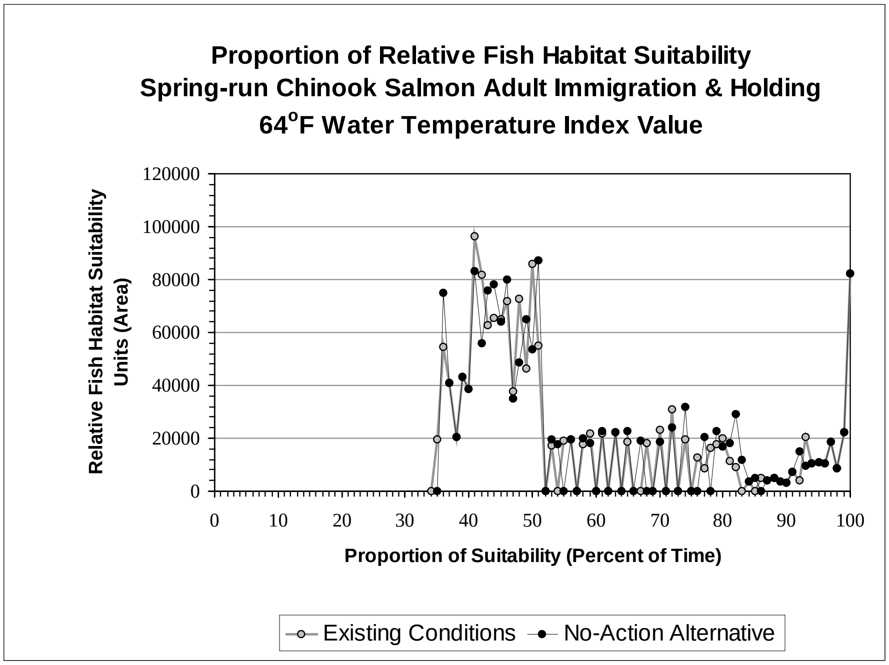


Figure G-AQUA3.4-22. Proportion of relative fish habitat suitability for spring-run Chinook salmon adult immigration and holding for the 64°F water temperature index value.

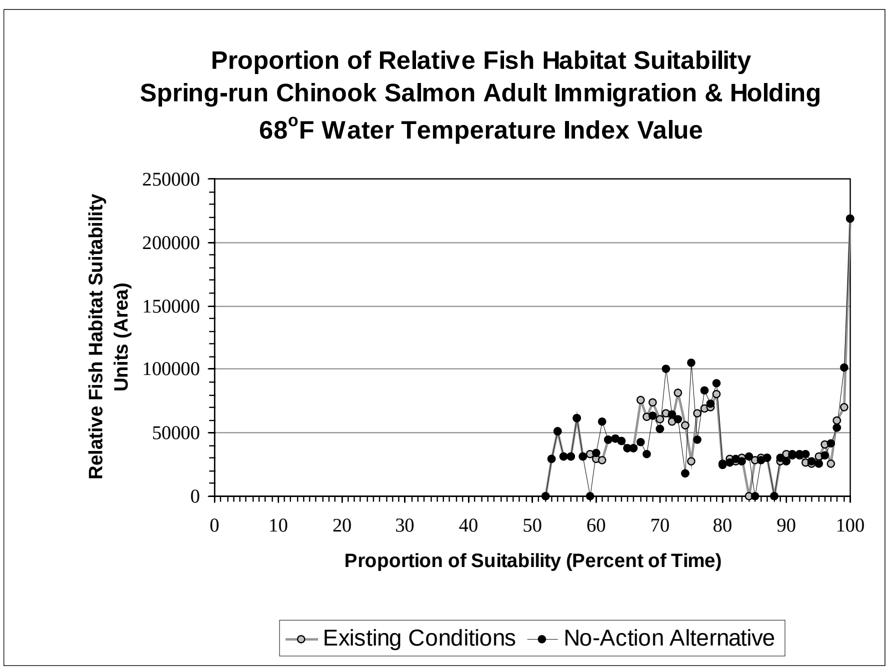


Figure G-AQUA3.4-23. Proportion of relative fish habitat suitability for spring-run Chinook salmon adult immigration and holding for the 68°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA3.4-4 for spring-run Chinook salmon adult immigration and holding for the 60°F water temperature index value under existing conditions and No-Action Alternative are 957,807 and 970,626, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 12,819, which represents a 1.34 percent increase in OHSIV under the No-Action Alternative compared to the existing conditions. The OHSIV for the 64°F water temperature index value under existing conditions and the No-Action Alternative are 1,522,915 and 1,538,763, respectively. The difference in OHSIV between No-Action Alternative and existing conditions is 15,848, which represents a 1.04 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 68°F water temperature index value under existing conditions and the No-Action Alternative are 2,208,686 and 2,225,207, respectively. The difference in OHSIV between No-Action Alternative and existing conditions is 16,522, which represents a 0.75 percent increase in OHSIV under the No-Action Alternative compared to the existing conditions.

Table G-AQUA3.4-4. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for spring-run Chinook salmon adult immigration and holding.

Water Temperature Index Value	**60°F**	**64°F**	**68°F**
Existing Conditions			
Minimum Percentage of Time Value	22%	35%	53%
Maximum Percentage of Time Value	94%	100%	100%
Habitat Units at 100 Percent of Time	0	82,362	218,450
Percentage of Time at Maximum Habitat Units	26%	41%	100%
OHSIV	**957,807**	**1,522,915**	**2,208,686**
No-Action Alternative			
Minimum Percentage of Time Value	22%	36%	53%
Maximum Percentage of Time Value	93%	100%	100%
Habitat Units at 100 Percent of Time	0	82,362	218,450
Percentage of Time at Maximum Habitat Units	26%	51%	100%
OHSIV	**970,626**	**1,538,763**	**2,225,207**
Percent Change	**1.34%**	**1.04%**	**0.75%**

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-4 for the spring-run Chinook salmon adult immigration and holding life stage did not change between existing conditions and the No-Action Alternative for the 60°F, and 68°F water temperature index values. The Minimum Percentage of Time Value for the 64°F water temperature index value under the existing conditions and the No-Action Alternative are 35 percent and 36 percent, respectively. The 1 percent difference in Minimum Percentage of Time Value between the No-Action Alternative and existing conditions represents an increase in the number of habitat units with the smallest amount of time and area with water temperatures below 64°F under the No-Action Alternative compared to existing conditions.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-4 for the spring-run Chinook salmon adult immigration and holding life stage did not change between existing conditions and the No-Action Alternative for the 64°F, and 68°F water temperature index values. The Maximum Percentage of Time Value for the 60°F water temperature index value under existing conditions and the No-Action Alternative are 94 percent and 93 percent, respectively. The 1 percent difference in Maximum Percentage of Time Value between the No-Action Alternative and existing conditions represents a small decrease in the number of habitat units with the greatest amount of time and area with water temperatures below 60°F under the No-Action Alternative compared to existing conditions.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-4 for the spring-run Chinook salmon adult immigration and holding life stage did not change between existing conditions and the No-Action Alternative for any of the water temperature index values selected.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-4 for the spring-run Chinook salmon adult immigration and holding life stage did not change between existing conditions and the No-Action Alternative for the 60°F or the 68°F water temperature index values. The Percentage of Time at Maximum Habitat Units for the 64°F water temperature index value under the existing conditions and the No-Action Alternative are 41 percent and 51 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between existing conditions and the No-Action Alternative is 10 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area.

Adult Spawning and Embryo Incubation

Figures G-AQUA3.4-24, G-AQUA3.4-25, G-AQUA3.4-26, and G-AQUA3.4-27 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA3.4-24, G-AQUA3.4-25, G-AQUA3.4-26, and G-AQUA3.4-27 is equal, which allows for direct comparison of habitat suitability between alternatives.

The OHSIV metrics presented in Table G-AQUA3.4-5 for spring-run Chinook salmon adult spawning and embryo incubation for the 56°F water temperature index value under existing conditions and the No-Action Alternative are 90,931 and 91,070, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 139, which represents a 0.15 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 58°F water temperature index value under existing conditions and the No-Action Alternative are 104,890 and 105,231, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 341, which represents a 0.33 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 60°F water temperature index value under the existing conditions and the No-Action Alternative are 117,933 and 118,429, respectively. The difference in OHSIV between

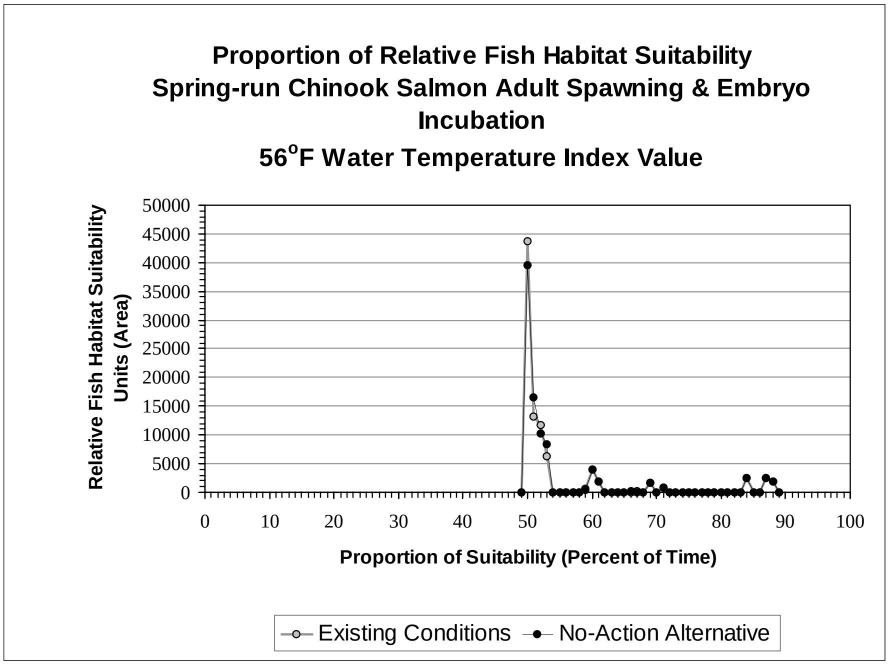


Figure G-AQUA3.4-24. Proportion of relative fish habitat suitability for spring-run Chinook salmon adult spawning and embryo incubation for the 56°F water temperature index value.

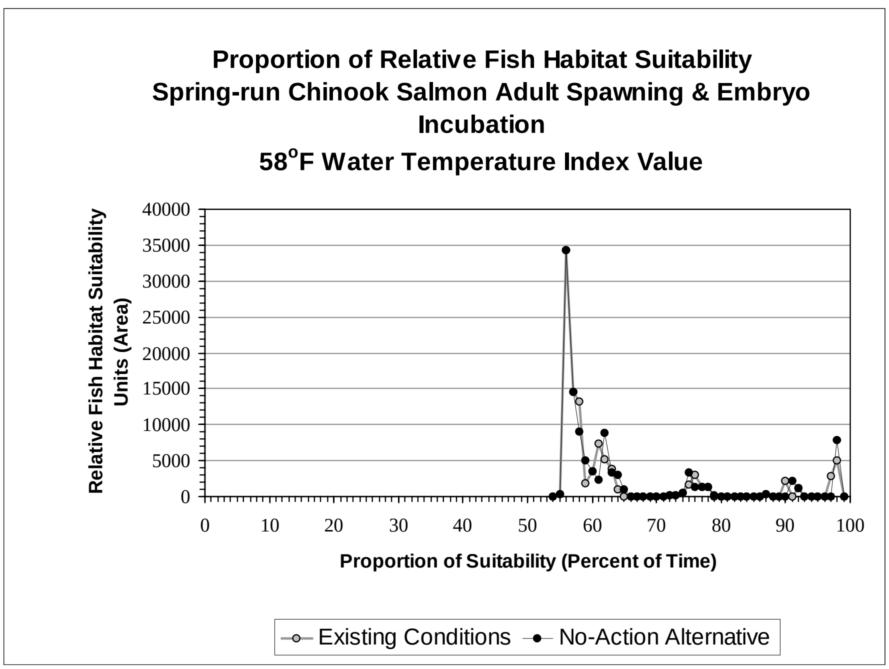


Figure G-AQUA3.4-25. Proportion of relative fish habitat suitability for spring-run Chinook salmon adult spawning and embryo incubation for the 58°F water temperature index value.

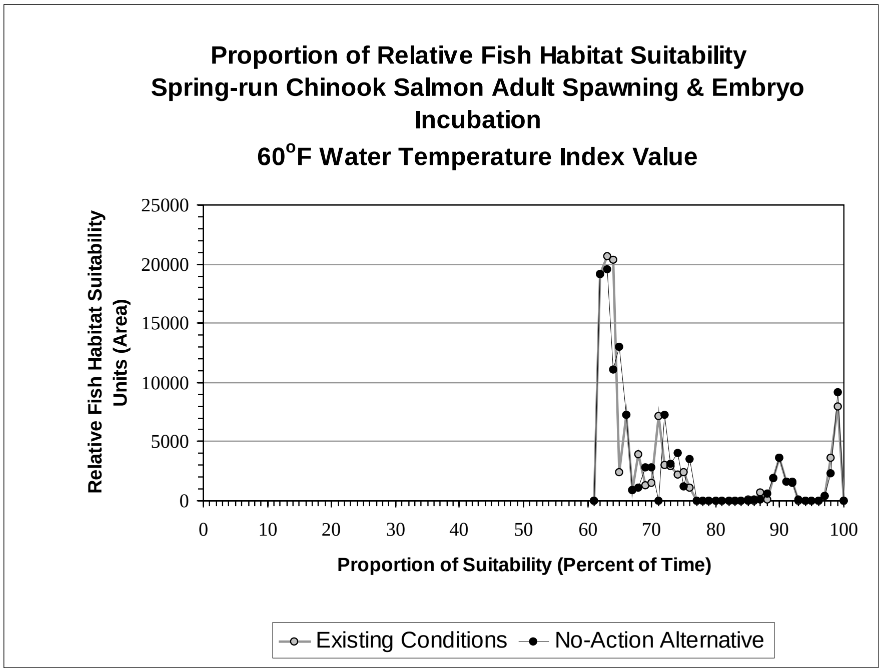


Figure G-AQUA3.4-26. Proportion of relative fish habitat suitability for spring-run Chinook salmon adult spawning and embryo incubation for the 60°F water temperature index value.

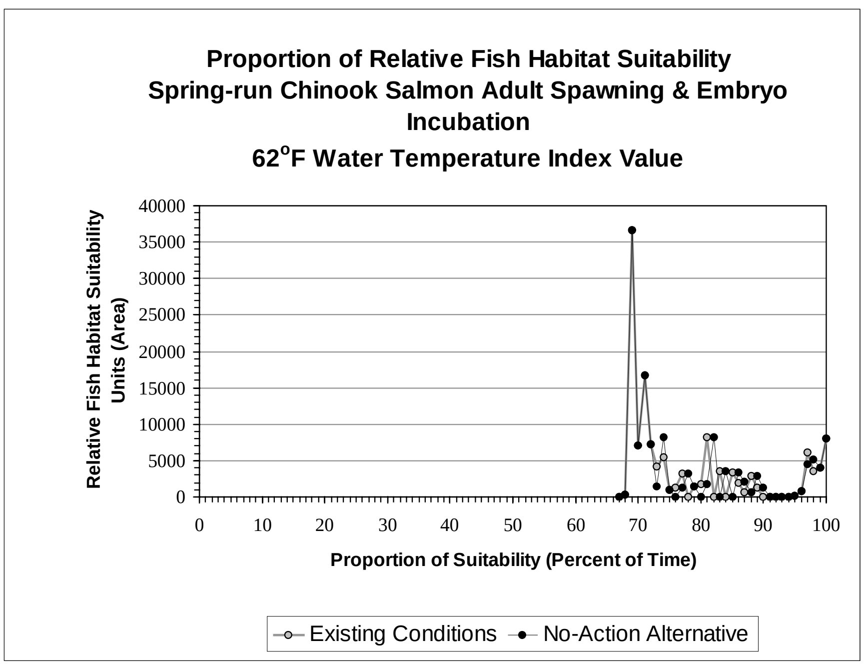


Figure G-AQUA3.4-27. Proportion of relative fish habitat suitability for spring-run Chinook salmon adult spawning and embryo incubation for the 62°F water temperature index value.

Table G-AQUA3.4-5. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for spring-run Chinook salmon adult spawning and embryo incubation.

Water Temperature Index Value	**56°F**	**58°F**	**60°F**	**62°F**
Existing Conditions				
Minimum Percentage of Time Value	50%	55%	62%	68%
Maximum Percentage of Time Value	88%	98%	99%	100%
Habitat Units at 100 Percent of Time	0	0	0	8,020
Percentage of Time at Maximum Habitat Units	50%	56%	63%	69%
OHSIV	**90,931**	**104,890**	**117,933**	**130,430**
No-Action Alternative				
Minimum Percentage of Time Value	50%	55%	62%	68%
Maximum Percentage of Time Value	88%	98%	99%	100%
Habitat Units at 100 Percent of Time	0	0	0	8,020
Percentage of Time at Maximum Habitat Units	50%	56%	63%	69%
OHSIV	**91,070**	**105,231**	**118,429**	**130,823**
Percent Change	**0.15%**	**0.33%**	**0.42%**	**0.30%**

the No-Action Alternative and existing conditions is 496, which represents a 0.42 percent increase in OHSIV under No-Action Alternative compared to existing conditions.

The OHSIV for the 62°F water temperature index value under the existing conditions and the No-Action Alternative are 130,430 and 130,823, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 393, which represents a 0.30 percent increase in OHSIV under No-Action Alternative compared to existing conditions.

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-5 for the spring-run Chinook salmon adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-5 for the spring-run Chinook salmon adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-5 for the spring-run Chinook salmon adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-5 for the spring-run Chinook salmon adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

Juvenile Rearing and Downstream Movement

Figures G-AQUA3.4-28, G-AQUA3.4-29, G-AQUA3.4-30, G-AQUA3.4-31, G-AQUA3.4-32, and G-AQUA3.4-33 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA3.4-28, G-AQUA3.4-29, G-AQUA3.4-30, G-AQUA3.4-31, G-AQUA3.4-32, and G-AQUA3.4-33 is equal, which allows for direct comparison of habitat suitability between alternatives.

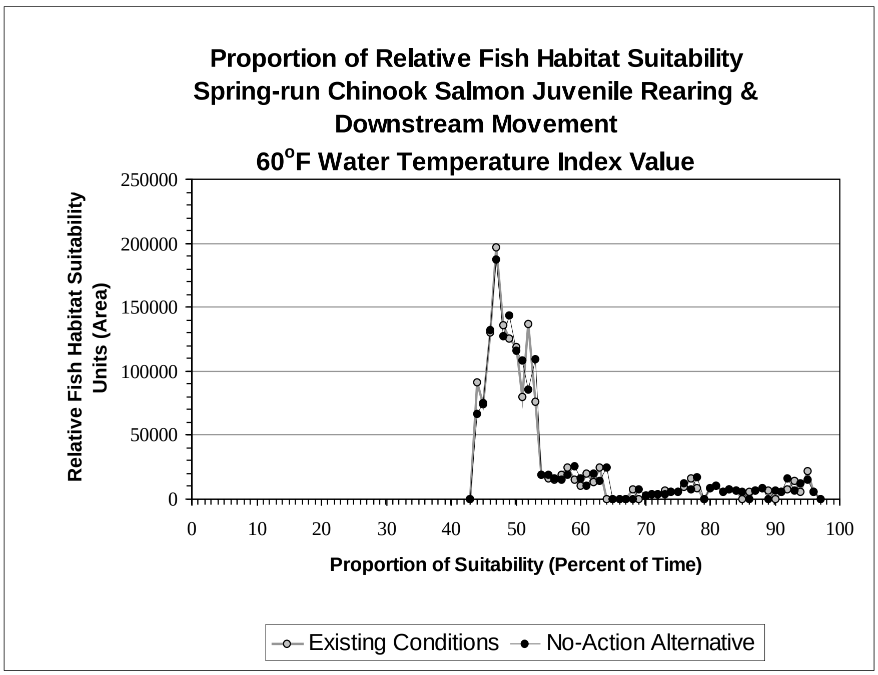


Figure G-AQUA3.4-28. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 60°F water temperature index value.

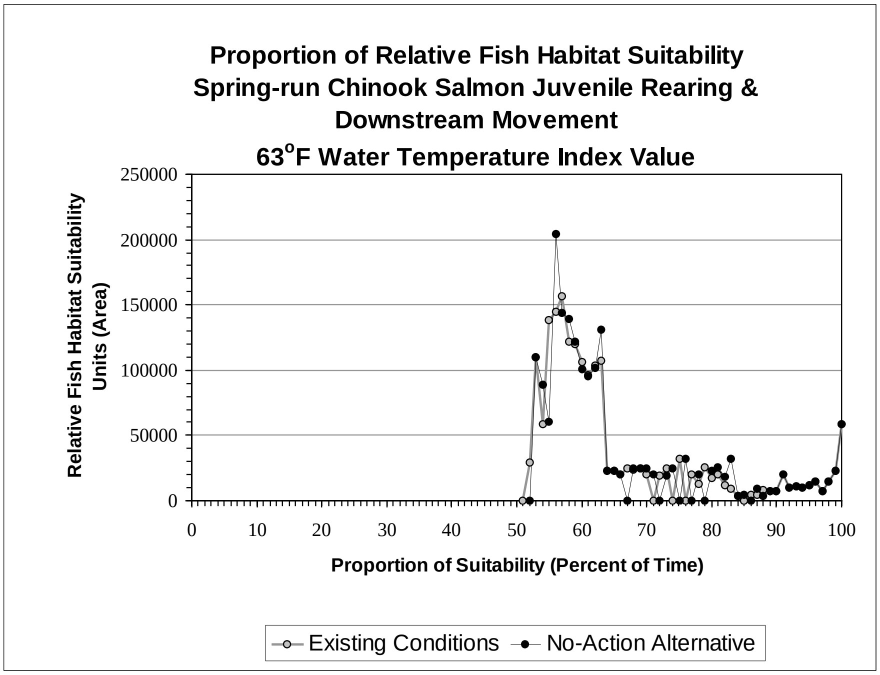


Figure G-AQUA3.4-29. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 63°F water temperature index value.

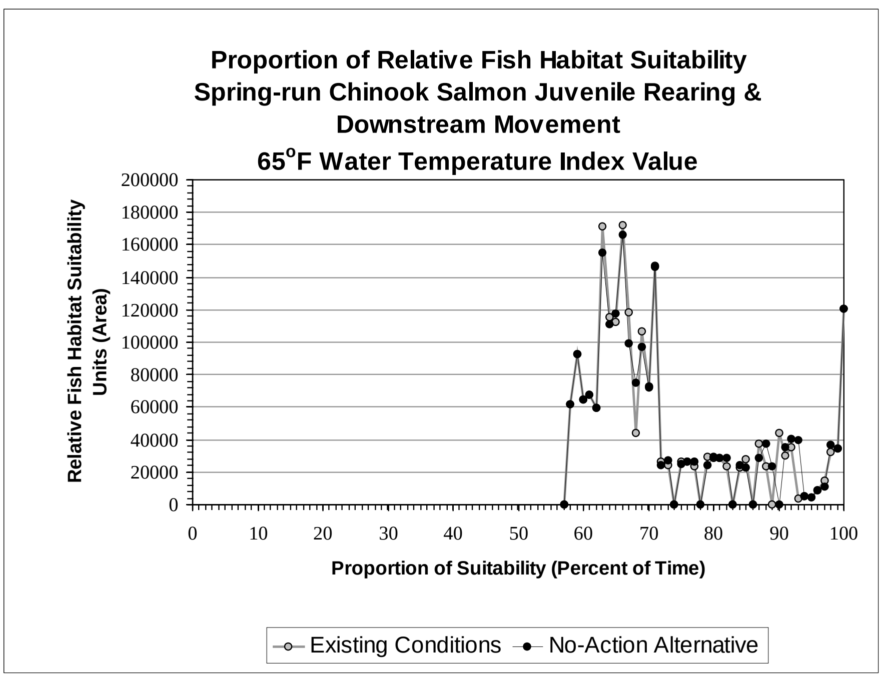


Figure G-AQUA3.4-30. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 65°F water temperature index value.

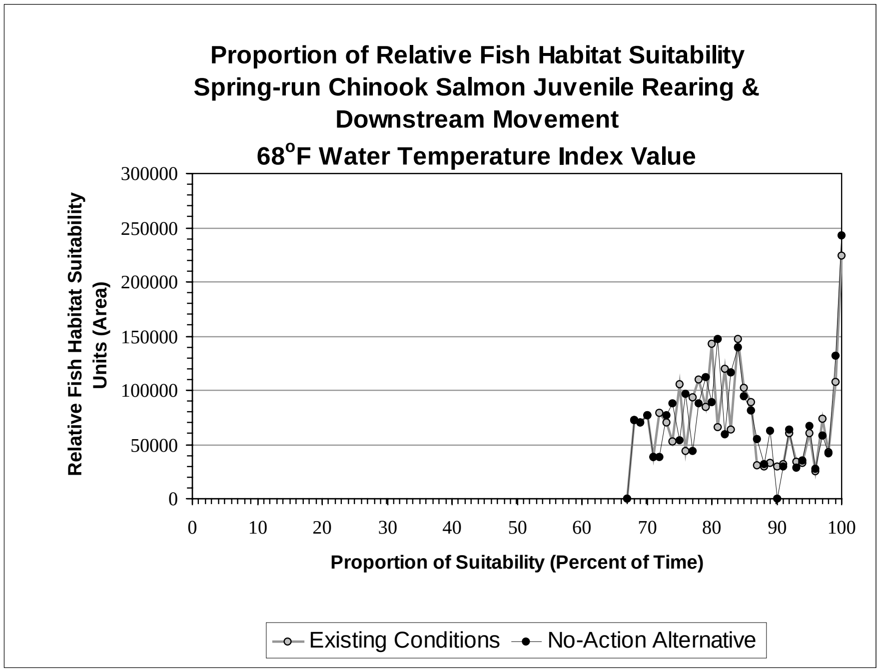


Figure G-AQUA3.4-31. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 68°F water temperature index value.

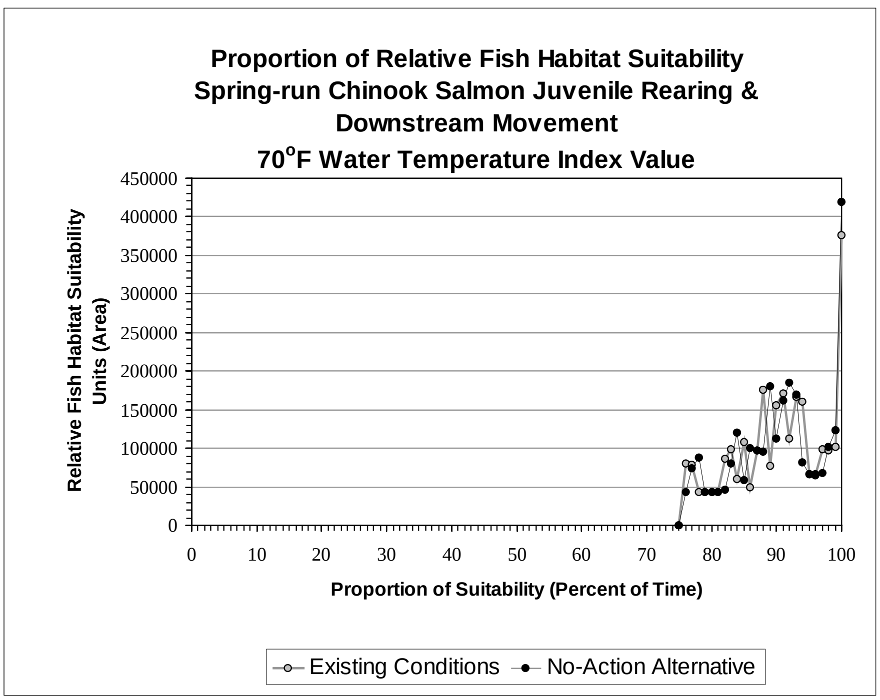


Figure G-AQUA3.4-32. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 70°F water temperature index value.

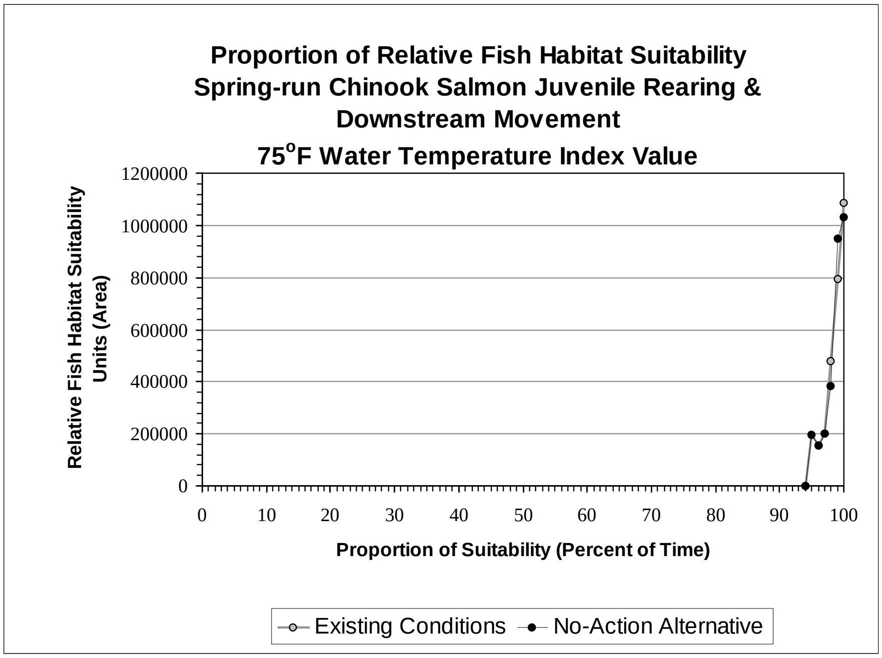


Figure G-AQUA3.4-33. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 75°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA3.4-6 for fall-run Chinook salmon juvenile rearing and downstream movement for the 60°F water temperature index value under existing conditions and the No-Action Alternative are 1,540,928 and 1,549,710, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 8,781, which represents a 0.57 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 63°F water temperature index value under existing conditions and the No-Action Alternative are 1,860,950 and 1,870,208, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 9,259, which represents a 0.50 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 65°F water temperature index value under existing conditions and the No-Action Alternative are 2,090,300 and 2,100,251, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 9,951, which represents a 0.48 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 68°F water temperature index value under existing conditions and the No-Action Alternative are 2,447,867 and 2,460,196, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 12,329, which represents a 0.50 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 70°F water temperature index value under existing conditions and the No-Action Alternative are 2,658,561 and 2,664,592, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 6,030, which represents a 0.23 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 75°F water temperature index value under existing conditions and

Table G-AQUA3.4-6. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for spring-run Chinook salmon juvenile rearing and downstream movement.

Water Temperature Index Value	60°F	63°F	65°F	68°F	70°F	75°F
Existing Conditions						
Minimum Percentage of Time Value	44%	52%	58%	68%	76%	95%
Maximum Percentage of Time Value	96%	100%	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	0	59,019	120,339	224,272	376,160	1,087,451
Percentage of Time at Maximum Habitat Units	47%	57%	66%	100%	100%	100%
OHSIV	**1,540,928**	**1,860,950**	**2,090,300**	**2,447,867**	**2,658,561**	**2,916,165**
No-Action Alternative						
Minimum Percentage of Time Value	44%	53%	58%	68%	76%	95%
Maximum Percentage of Time Value	96%	100%	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	0	59,019	120,339	242,537	418,862	1,030,745
Percentage of Time at Maximum Habitat Units	47%	56%	66%	100%	100%	100%
OHSIV	**1,549,710**	**1,870,208**	**2,100,251**	**2,460,196**	**2,664,592**	**2,916,561**
Percent Change	**0.57%**	**0.50%**	**0.48%**	**0.50%**	**0.23%**	**0.01%**

the No-Action Alternative are 2,916,165 and 2,916,561, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 396, which represents a 0.01 percent increase in OHSIV under No-Action Alternative compared to existing conditions.

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-6 for the spring-run Chinook salmon juvenile rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for the 60°F, 65°F, 68°F, 70°F, or 75°F water temperature index values selected. The Minimum Percentage of Time Value metric for the 63°F water temperature index value under existing conditions and the No-Action Alternative are 52 percent and 53 percent, respectively. The 1 percent difference in Minimum Percentage of Time Value between the No-Action Alternative and existing conditions represents an increase in the number of habitat units with the smallest amount of time and area with water temperatures below 63°F under the No-Action Alternative compared to existing conditions.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-6 for the spring-run Chinook salmon juvenile rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-6 for the spring-run Chinook salmon juvenile rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for the 60°F, 63°F, and 65°F water temperature index values. The Habitat Units at 100 Percent of Time for the 68°F water temperature index value under existing conditions and the No-Action Alternative are 224,272 and 242,537, respectively. The difference in Habitat Units at 100 Percent of Time between the No-Action Alternative and existing conditions is 18,265, which represents an 8.14 percent increase in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are always at or below 68°F. The Habitat Units at 100 Percent of Time for the 70°F water temperature index value under the existing conditions and the No-Action Alternative are 376,160 and 418,862, respectively. The difference in Habitat Units at 100 Percent of Time between the No-Action Alternative and existing conditions is 42,702, which represents an 11.35 percent increase in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are always at or below 70°F. The Habitat Units at 100 Percent of Time for the 75°F water temperature index value under the existing conditions and the No-Action Alternative are 1,087,451 and 1,030,745, respectively. The difference in Habitat Units at 100 Percent of Time between existing conditions and the No-Action Alternative is 56,706, which represents a 5.21 percent decrease in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are always at or below 75°F.

An 8.14 percent increase in the number of habitat units in which water temperatures are always at or below 68°F and above 65°F represents an increase in habitat under the No-Action Alternative in which specific biological effects could potentially occur to rearing and downstream migrating juvenile spring-run Chinook salmon, such as acceleration or inhibition of smoltification, decreased appetite, decreased growth rates, and increased mortality rates (Clarke and Shelbourn 1985; Marine 1997; Zedonis and Newcomb 1997). An 11.35 percent increase in the number of habitat units in which water temperatures are always at or below 70°F and above 68°F represents an increase in habitat under the No-Action Alternative in which specific biological effects could potentially occur to rearing and downstream migrating juvenile spring-run Chinook salmon, such as increased incidence of disease, hyperactivity, decreased appetite, decreased growth rates, and increased mortality rates (McCullough 1999; Rich 1987). A 5.21 percent decrease in the number of habitat units in which water temperatures are always at or below 75°F and above 70°F represents a decrease in habitat under the No-Action Alternative in which specific biological effects could potentially occur to rearing and downstream migrating juvenile spring-run Chinook salmon, such as substantially increased incidence of disease, hyperactivity, decreased appetite, reduced growth rates, and substantially increased mortality rates (McCullough 1999; Rich 1987). A detailed description of the potential effects that could occur to rearing and downstream migrating juvenile spring-run Chinook salmon from exposure to water temperatures between above each water temperature index value is presented in Section G-AQUA2.2.3 of Appendix G-AQUA2.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-6 for the spring-run Chinook salmon juvenile rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for the 60°F, 65°F, 68°F, 70°F or the 75°F water temperature index values. The Percentage of Time at Maximum Habitat Units presented for the spring-run Chinook salmon juvenile rearing and downstream movement life stage for the 63°F water temperature index value under existing conditions and the No-Action Alternative are 57 percent and 56 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between existing conditions and the No-Action Alternative is 1 percent, which represents a small decrease in the percentage of time that the habitat is suitable in the greatest area.

G-AQUA3.4.2.3 Predation-related Effects

The slight change in water temperatures resulting from slight changes in seasonal flow patterns in the High Flow Channel under the No-Action Alternative are not anticipated to affect predation rates or the composition of predator species.

G-AQUA3.4.2.4 Fisheries Management–related Effects

Hatchery

No changes to hatchery management are anticipated. Therefore, no hatchery-related effects on spring-run Chinook salmon are expected.

Disease

The slight change in water temperatures resulting from slight changes in seasonal flow patterns in the High Flow Channel under the No-Action Alternative is not anticipated to affect the incidence of disease associated with spring-run Chinook salmon.

Fishing Regulations, Poaching, and Change in Recreational Access and Visitation

Section 5.10.2, Recreation Resources Environmental Effects, forecasts a one-third increase in recreation and angling activities with the No-Action Alternative. A one-third increase in angling with no other fisheries changes would equate to increased sport fish harvest rates. No changes to fishing regulations are anticipated to occur under the No-Action Alternative.

G-AQUA3.4.2.5 Summary of Potential Effects on Spring-run Chinook Salmon

Study plan report summaries addressing project effects on spring-run Chinook salmon are presented in Section G-AQUA1.5, Fisheries Management; Section G-AQUA1.7, Feather River Fish Hatchery; Section G-AQUA1.8, Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam; Section G-AQUA1.9, Upstream Fish

Passage; Section G-AQUA10, Instream Flows and Fish Habitat; and Section G-AQUA1.11, Predation, in Appendix G-AQUA1, Affected Environment. A description of each spring-run Chinook salmon life stage and the time period associated with it is presented in Appendix G-AQUA1.

Adult Immigration and Holding

Changes in flows under the No-Action Alternative would provide no effect on spring-run Chinook salmon adult immigration and holding. Increased habitat suitability due to decreased water temperatures under the No-Action Alternative would provide a slight beneficial effect on spring-run Chinook salmon adult immigration and holding. Increased angling and sport harvest would have an adverse effect on spring-run Chinook salmon adult immigration and holding.

Overall, operation of the Oroville Facilities under the No-Action Alternative would provide a slightly adverse effect on spring-run Chinook salmon adult immigration and holding.

Adult Spawning and Embryo Incubation

Changes in flow under the No-Action Alternative would provide a slight beneficial effect on spring-run Chinook salmon adult spawning and embryo incubation due to a slight overall increase in WUA. Differences in habitat suitability due to decreased water temperatures during the spring-run Chinook salmon adult spawning and embryo incubation period are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect spring-run Chinook salmon adult spawning and embryo incubation. Additionally, continued degradation of spawning gravel quality in the lower Feather River would result in an adverse effect on spring-run Chinook salmon adult spawning and embryo incubation by reducing the quality and quantity of available habitat. Also, continued use of the same spawning areas by spring-run and fall-run Chinook salmon would continue to affect the genetic distinctness of the Chinook salmon runs that spawn in the lower Feather River.

Overall, operation of the Oroville Facilities under the No-Action Alternative would result in an adverse effect on spring-run Chinook salmon adult spawning and embryo incubation.

Juvenile Rearing and Downstream Movement

Changes in flow under the No-Action Alternative would have no effect on spring-run Chinook salmon juvenile rearing and downstream movement because the associated changes in river stage likely would result in very small changes in available rearing habitat area. Differences in habitat suitability due to decreased water temperatures are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect spring-run Chinook salmon juvenile rearing and downstream movement. However, continued degradation of large woody debris, gravel, and side-channel habitat quality would result in an adverse effect on juvenile rearing and downstream movement.

Overall, operation of the Oroville Facilities under the No-Action Alternative would result in an adverse effect on spring-run Chinook salmon juvenile rearing and downstream movement.

Conclusion

Based on the above summary of potential effects, it is likely that the No-Action Alternative would have an overall adverse effect on spring-run Chinook salmon relative to existing conditions.

G-AQUA3.4.3 Steelhead

G-AQUA3.4.3.1 Flow-related Effects

Under the No-Action Alternative, there would be no changes to flows in the Low Flow Channel. Effects of flow changes in the High Flow Channel are expressed in the qualitative and quantitative analyses of habitat suitability presented below.

Adult Immigration and Holding

Mean monthly flow decreases under the No-Action Alternative compared to existing conditions during the steelhead adult immigration and holding period would occur in the High Flow Channel, which would cause very small changes in river stage. Because the flow-related changes in river stage during the steelhead adult immigration and holding period would be small, they would not be sufficiently large to affect immigration at potential critical riffles and would not be sufficiently large to appreciably affect holding habitat depths.

Flow fluctuations that could potentially occur under the No-Action Alternative would be similar to flow fluctuations that occur under existing conditions. Because flow fluctuations currently do not affect steelhead adult immigration and holding, flow fluctuations under the No-Action Alternative also would not affect steelhead adult immigration and holding.

Adult Spawning and Embryo Incubation

Under the No-Action Alternative, flows in the Low Flow Channel would be 600 cfs year-round. Flow fluctuations in the Low Flow Channel could potentially occur under the No-Action Alternative in order to meet water temperature objectives prescribed by NOAA Fisheries. Minimum average daily water temperatures in the lower Feather River at Robinson Riffle (RM 61.6) would be required to be less than 65°F (18.3°C) from June 1 through September 30. Increased flow releases to meet water temperature objectives at Robinson Riffle from June 1 through September 30 would not be expected to affect steelhead spawning because the spawning period in the lower Feather River begins in December (pers. comm., Cavallo 2004 ; DWR 2004).

Evaluation of the WUA index generated by the PHABSIM model for the adult spawning life stage of steelhead indicated that the maximum amount of spawning area in the Low Flow Channel, given the current channel configuration, would occur at flows around 500 cfs. Figure G-AQUA3.4-34 shows the steelhead spawning WUA curve generated by the PHABSIM model for the Low Flow Channel.

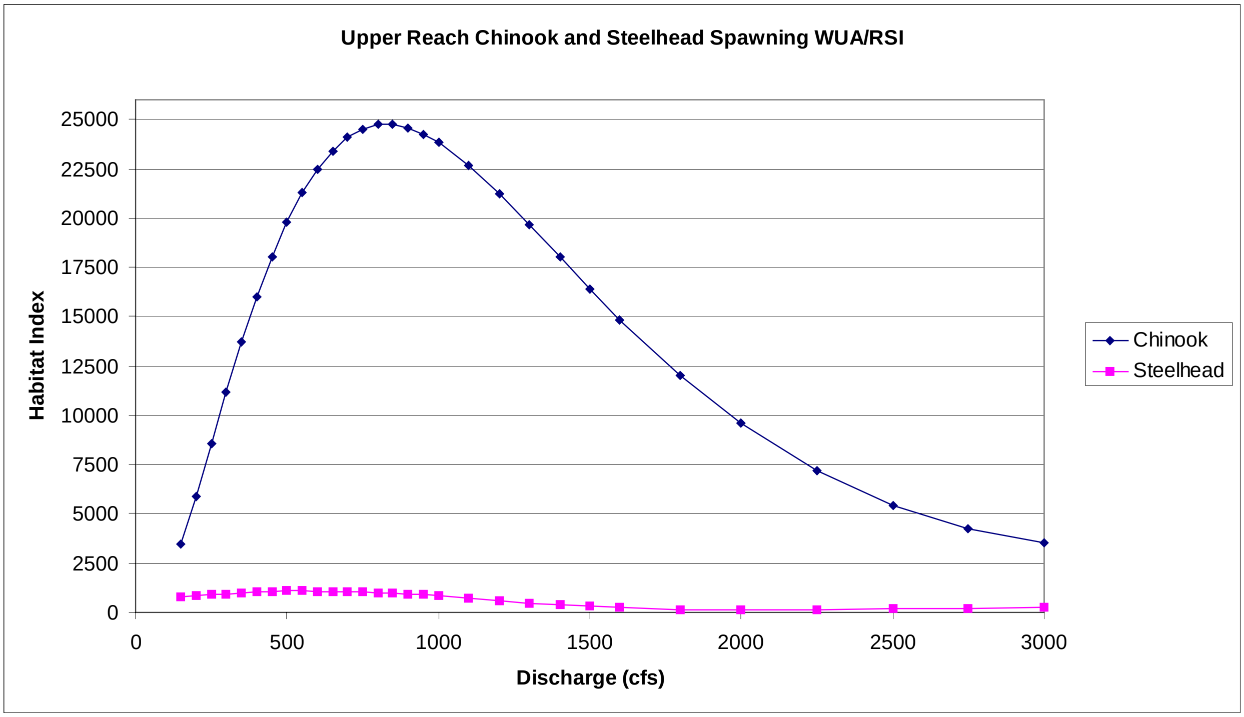


Figure G-AQUA3.4-34. Low Flow Channel WUA curves for steelhead and Chinook salmon.

Current flows in the Low Flow Channel during the steelhead spawning period are 600 cfs, which result in approximately 98 percent of maximum WUA. Flows under the No-Action Alternative also would result in approximately 98 percent of maximum WUA representing no change from current conditions.

Under the No-Action Alternative, flow fluctuations in the High Flow Channel are not expected to differ substantially from flow fluctuations that occur under current operations. Under the No-Action Alternative, flow releases likely would change seasonally, but daily minimum and maximum releases within the steelhead spawning period likely would not differ from existing conditions. Current operations maintain flows within the minimum and maximum flows prescribed in the 1983 agreement between DWR and DFG during the spring-run Chinook salmon spawning and embryo incubation period. According to USBR (2004), the minimum and maximum flow requirements as well as the fluctuations permitted during the steelhead spawning and embryo incubation period in the High Flow Channel have not affected this life stage. Therefore, it is expected that the flow requirements and the associated flow fluctuations in the High Flow Channel under the No-Action Alternative, also would not affect this life stage.

Under the No-Action Alternative, flow fluctuations potentially occurring in the High Flow Channel are not expected to differ from flow fluctuations that could potentially occur under the existing conditions described in Section 5.4.1.1. Daily releases into the High Flow Channel under normal operating conditions under the No-Action Alternative would not fluctuate outside the defined minimum and maximum flow ranges. Flood management releases could require release of flows above the maximum flow specified under normal operating conditions, and drought conditions could require flow releases below the minimum flow specified under normal operating conditions, however. Flood management releases could potentially cause flow fluctuations in the High Flow Channel, while during drought conditions, flows likely would be lowered to a constant minimum flow of 900 cfs in October, prior to the onset of steelhead spawning, and further lowered to 750 cfs in March, during the steelhead spawning period. Reduction in flows from 900 cfs to 750 cfs in March could potentially affect steelhead spawning in the High Flow Channel. Potential effects associated with a reduction in flow could result in redd dewatering or a slight increase in overall amount of spawning habitat. PHABSIM results indicate that flows of 900 cfs in the High Flow Channel would result in approximately 98 percent of maximum WUA while a decrease in flow to 750 cfs would result in approximately 100 percent of maximum WUA.

Evaluation of the WUA index generated by the PHABSIM model for the adult spawning life stage of steelhead indicated that the maximum amount of spawning area in the High Flow Channel, given the current channel configuration, would occur at flows around 750 cfs. Figure G-AQUA3.4-35 shows the WUA curve generated by the PHABSIM model for steelhead spawning in the High Flow Channel.

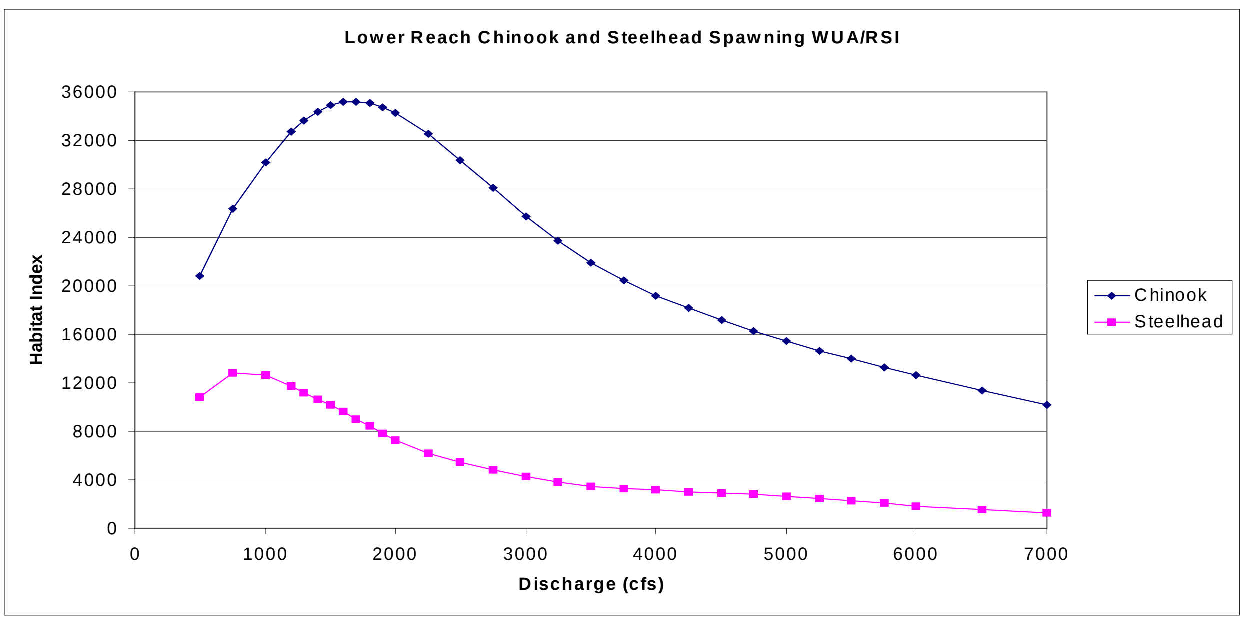


Figure G-AQUA3.4-35. High Flow Channel WUA curves for steelhead and Chinook salmon.

Current minimum flows in the High Flow Channel during the steelhead spawning period are 1,700 cfs, which produce approximately 70 percent of maximum WUA. Average monthly flows under the No-Action Alternative are lower from January through April and from September through December, and higher from May through August. However, minimum flow requirements are not proposed to differ from current conditions. Therefore, minimum flows in the High Flow Channel under the No-Action Alternative also would produce approximately 70 percent of maximum WUA during the steelhead spawning period, representing no change from current conditions.

During extreme drought conditions, total releases from the lower Feather River could be reduced such that releases are no greater than 25 percent of the normal minimum flow requirement below the Thermalito Afterbay Outlet. The 25 percent reduction in flow below the normal minimum flow amounts to a total flow of 750 cfs below the Thermalito Afterbay Outlet from March through September and 900 cfs from October through February. Under the No-Action Alternative, during extreme drought conditions, flow in the Low Flow Channel would be 600 cfs during the beginning of the steelhead spawning period (December through February), while 300 cfs would be released from the Thermalito Afterbay Outlet. During the remainder of the steelhead spawning period flows in the High Flow Channel would be reduced to 750 cfs, 150 cfs of which would come from the Thermalito Afterbay Outlet (600 cfs in the Low Flow Channel). During extreme drought conditions, flow reductions from 900 cfs to 750 cfs in the High Flow Channel could affect spawning adult steelhead by creating the opportunity for redd dewatering during the flow reduction. Additionally, PHABSIM model results indicate that a reduction in flow in the High Flow Channel from 900 cfs to 750 cfs would increase available spawning habitat from approximately 98 percent of maximum WUA to almost 100 percent of maximum WUA.

Based on modeling results, mean monthly flows under the No-Action Alternative during the steelhead spawning period would be lower in the High Flow Channel than under existing conditions. Mean monthly flows under the No-Action Alternative would be 3,575 cfs in December, representing a mean decrease of 88 cfs from existing conditions. In January mean monthly flows would be 4,223 cfs, representing a decrease of 215 cfs. In February mean monthly flows would be 5,214 cfs, representing a decrease of 138 cfs from existing conditions, while mean monthly flows in March would be 5,619 cfs, which represents a 20 cfs decrease from existing conditions. Changes in mean monthly flows during the steelhead spawning period would result in changes in spawning WUA. Due to the generalized nature of the WUA index and the inherent limitations in the methodology associated with IFIM and PHABSIM models, small changes in flow at the flows modeled were not able to determine exact changes in WUA. However, examination of Figure G-AQUA3.4-35 shows that, in December, a decrease in flow of 88 cfs would result in a slight increase in WUA compared to existing conditions. In January, a decrease in flow of 215 cfs would result in a slight increase in WUA. In February, a decrease in flow of 138 cfs would result in a slight increase in WUA, and in March, a decrease in flow of 20 cfs would result in a slight increase in WUA. Overall, the average monthly change in flow under the No-Action Alternative would result in an increase in spawning WUA over the course of the spawning period compared to existing conditions.

Fry and Fingerling Rearing and Downstream Movement

Under the No-Action Alternative, flow fluctuations in the High Flow Channel would be similar to those occurring under existing conditions. Because flow fluctuations under existing conditions have no effect on steelhead fry and fingerling downstream movement, it is likely that flow fluctuations occurring under the No-Action Alternative also would have no effect on this life stage.

Under the No-Action Alternative mean monthly flows would decrease compared to existing conditions from January through April and from September through December, and increase from May through August. Figures G-AQUA3.4-36 and G-AQUA3.4-37 show the WUA curves for steelhead fry (<50mm) and juveniles (>50mm) in the High Flow Channel. The final report for SP-F16 provides detailed description of the differences between the weighting of the no-cover habitat suitability criteria in the PHABSIM model. Due to the generalized nature of the WUA index and the inherent limitations in the methodology associated with IFIM and PHABSIM models, small changes in flow at the flows modeled were not able to determine exact quantitative changes in WUA. However, utilizing the no-cover weighting of 0.17 for fry and 0.40 for juveniles shown in Figures G-AQUA3.4-36 and G-AQUA3.4-37, the mean monthly flow changes compared to existing conditions would result in an overall slight decrease in WUA during July, a slight increase in WUA from October through February and would not change appreciably during the remaining months. Therefore, mean monthly flow changes under the No-Action alternative would have no effect on steelhead fry and fingerling rearing and downstream movement.

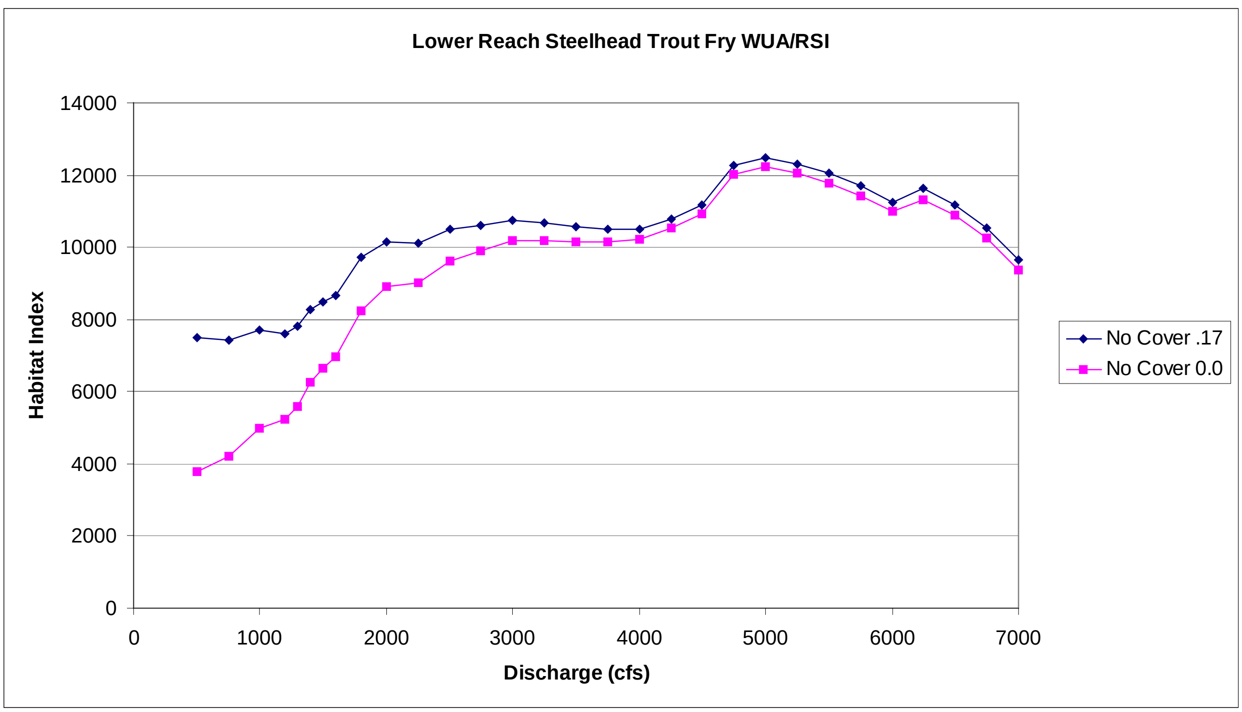


Figure G-AQUA3.4-36. High Flow Channel WUA curves for steelhead fry <50mm.

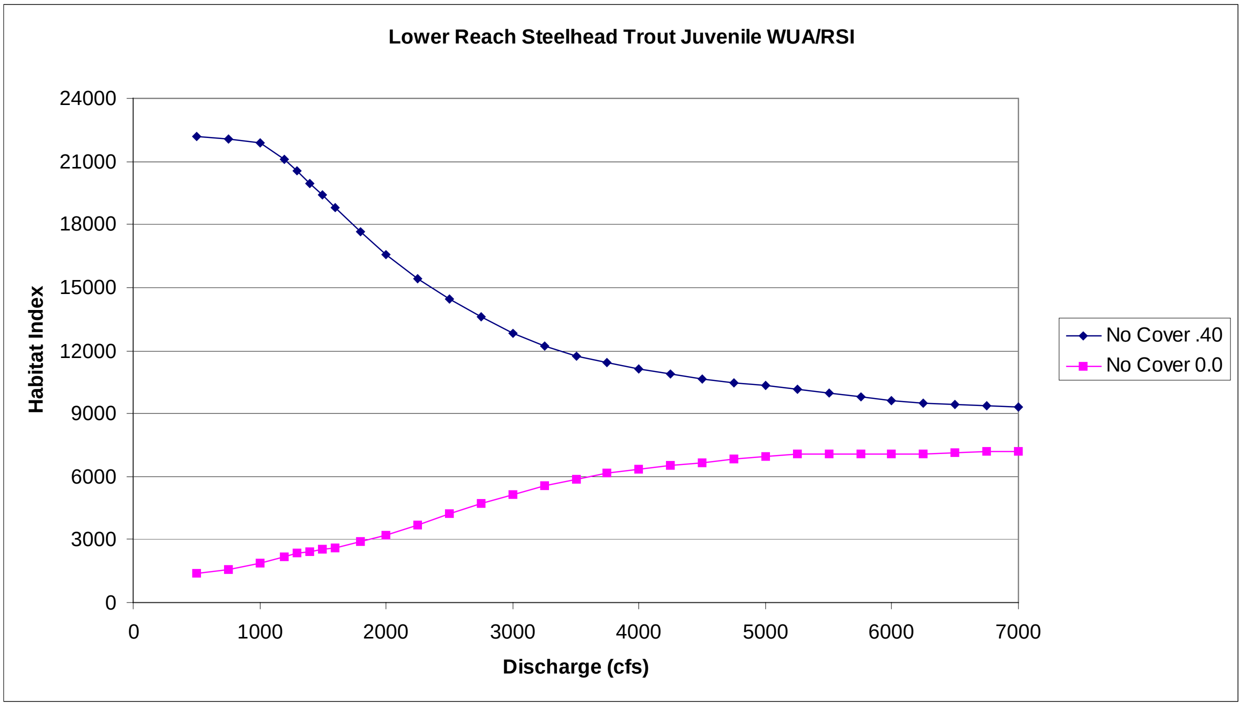


Figure G-AQUA3.4-37. High Flow Channel WUA curves for steelhead salmon 50mm+.

Smolt Emigration

Under the No-Action Alternative, flow fluctuations in the High Flow Channel would be similar to those occurring under existing conditions. Because there is no change in the characteristic of the flow fluctuations from the existing condition to the No-Action Alternative, the No-Action Alternative will not result in a change in the rate of juvenile stranding from flow fluctuations.

Under the No-Action Alternative mean monthly flows would decrease compared to existing conditions from January through April and, and increase from May through June. Figures G-AQUA3.4-36 and G-AQUA3.4-37 show the WUA curves for steelhead fry (<50mm) and juveniles (>50mm) in the High Flow Channel. The final report for SP-F16 provides detailed description of the differences between the weighting of the no-cover habitat suitability criteria in the PHABSIM model. Due to the generalized nature of the WUA index and the inherent limitations in the methodology associated with IFIM and PHABSIM models, small changes in flow at the flows modeled were not able to determine exact quantitative changes in WUA. However, utilizing the no-cover weighting of 0.17 for fry and 0.40 for juveniles shown in Figures G-AQUA3.4-36 and G-AQUA3.4-37, the mean monthly flow changes compared to existing conditions would result in an overall slight decrease in WUA during January and February, and would not change appreciably during the remaining months. Therefore, mean monthly flow changes under the No-Action alternative would have a slight adverse effect on steelhead smolt emigration based on analysis of the WUA index.

G-AQUA3.4.3.2 Water Temperature–related Effects

Effects of water temperature changes associated with the No-Action Alternative are expressed in the quantitative analyses of relative habitat suitability presented below.

The relative habitat suitability analysis includes an evaluation of overall relative habitat suitability based on water temperature index values. The analysis includes a comparison of habitat suitability component metrics between the No-Action Alternative and existing conditions. Detailed descriptions of the methodology used in the derivation and calculation of each metric in the evaluation of relative habitat suitability are presented in Section G-AQUA2.2.3 in Appendix G-AQUA2.

Adult Immigration and Holding

Figures G-AQUA3.4-38, G-AQUA3.4-39, and G-AQUA3.4-40 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA3.4-38, G-AQUA3.4-39, and G-AQUA3.4-40 is equal, which allows for direct comparison of habitat suitability between alternatives.

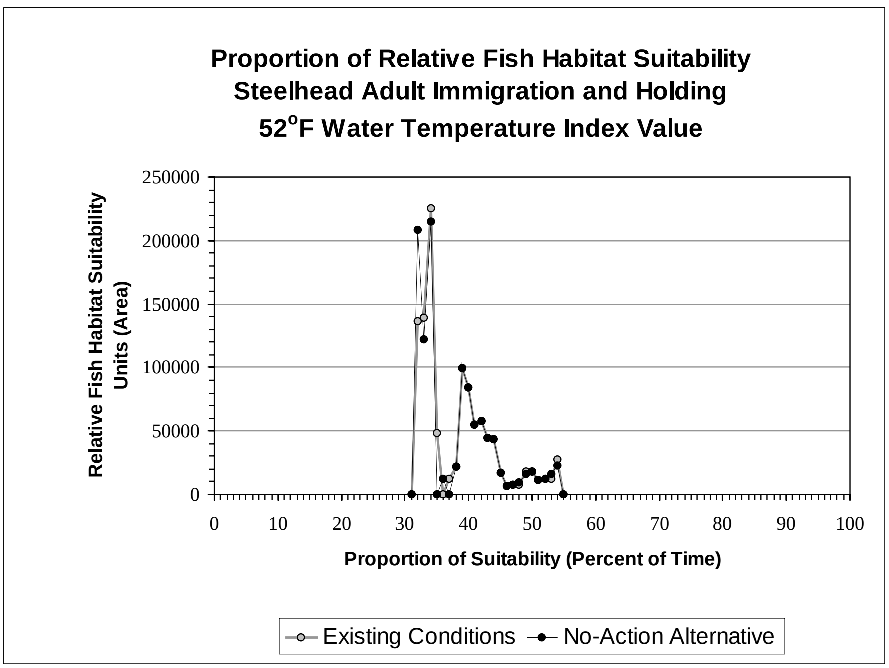


Figure G-AQUA3.4-38. Proportion of relative fish habitat suitability for steelhead adult immigration and holding for the 52°F water temperature index value.

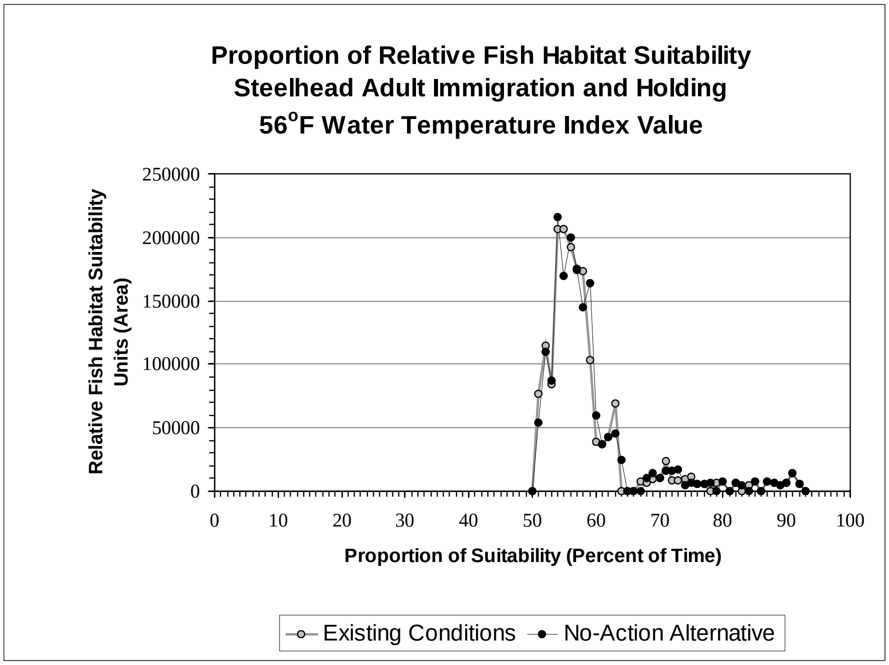


Figure G-AQUA3.4-39. Proportion of relative fish habitat suitability for steelhead adult immigration and holding for the 56°F water temperature index value.

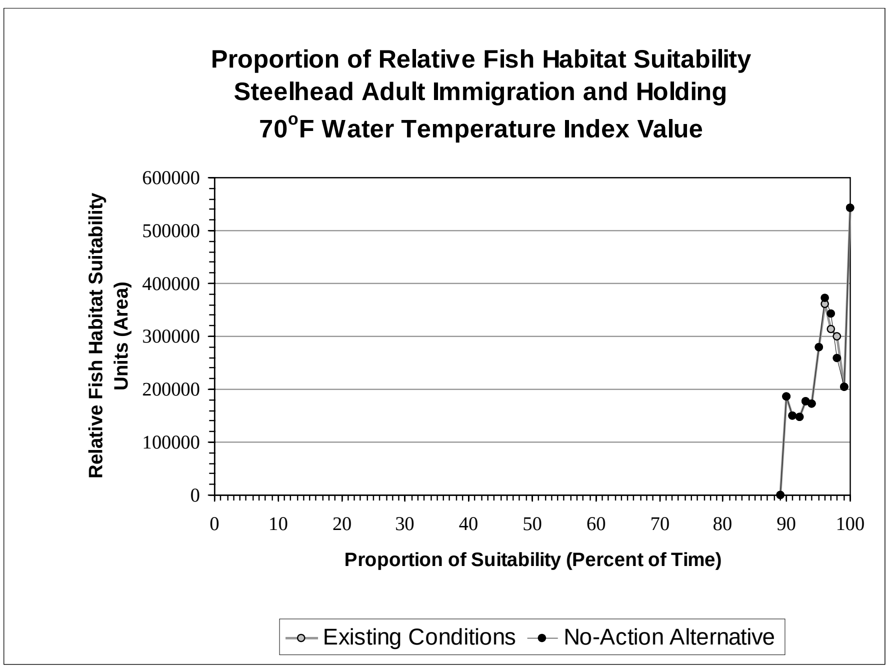


Figure G-AQUA3.4-40. Proportion of relative fish habitat suitability for steelhead adult immigration and holding for the 70°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA3.4-7 for steelhead adult immigration and holding for the 52°F water temperature index value under existing conditions and the No-Action Alternative are 1,106,307 and 1,100,514, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 5,793, which

Table G-AQUA3.4-7. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for steelhead adult immigration and holding.

Water Temperature Index Value	52°F	56°F	70°F
Existing Conditions			
Minimum Percentage of Time Value	32%	51%	90%
Maximum Percentage of Time Value	54%	92%	100%
Habitat Units at 100 Percent of Time	0	0	542,986
Percentage of Time at Maximum Habitat Units	34%	54%	100%
OHSIV	**1,106,307**	**1,705,735**	**2,836,689**
No-Action Alternative			
Minimum Percentage of Time Value	32%	51%	90%
Maximum Percentage of Time Value	54%	92%	100%
Habitat Units at 100 Percent of Time	0	0	542,986
Percentage of Time at Maximum Habitat Units	34%	54%	100%
OHSIV	**1,100,514**	**1,712,352**	**2,836,131**
Percent Change	**-0.52%**	**0.39%**	**-0.02%**

represents a 0.52 percent decrease in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 56°F water temperature index value under existing conditions and the No-Action Alternative are 1,705,735 and 1,712,352, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 6,617, which represents a 0.39 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 70°F water temperature index value under existing conditions and the No-Action Alternative are 2,836,689 and 2,836,131, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 558, which represents a 0.02 percent decrease in OHSIV under the No-Action Alternative compared to existing conditions.

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-7 for the steelhead adult immigration and holding life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.47 for the steelhead adult immigration and holding life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-7 for the steelhead adult immigration and holding life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-7 for the steelhead adult immigration and holding life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

Adult Spawning and Embryo Incubation

Figures G-AQUA3.4-41, G-AQUA3.4-42, G-AQUA3.4-43, and G-AQUA3.4-44 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA3.4-41, G-AQUA3.4-42, G-AQUA3.4-43, and G-AQUA3.4-44 is equal, which allows for direct comparison of habitat suitability between alternatives.

The OHSIV metrics presented in Table G-AQUA3.4-8 for steelhead adult spawning and embryo incubation for the 52°F water temperature index value under existing conditions and the No-Action Alternative are 58,193 and 58,198, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 5, which represents a 0.01 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 54°F water temperature index value under existing conditions and the No-Action Alternative are 71,349 and 71,613, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 264, which represents a 0.37 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 57°F water temperature index

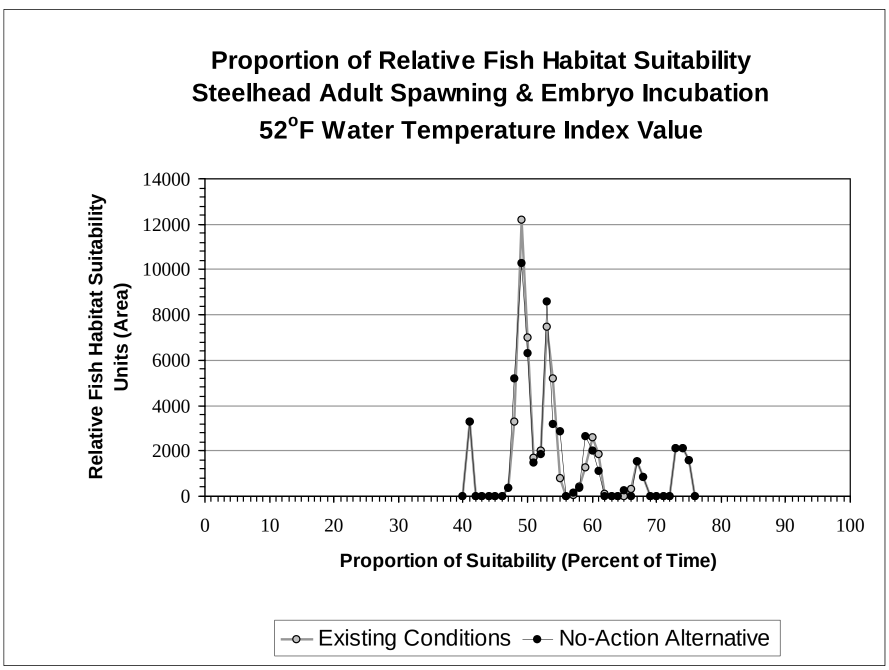


Figure G-AQUA3.4-41. Proportion of relative fish habitat suitability for steelhead adult spawning and embryo incubation for the 52°F water temperature index value.

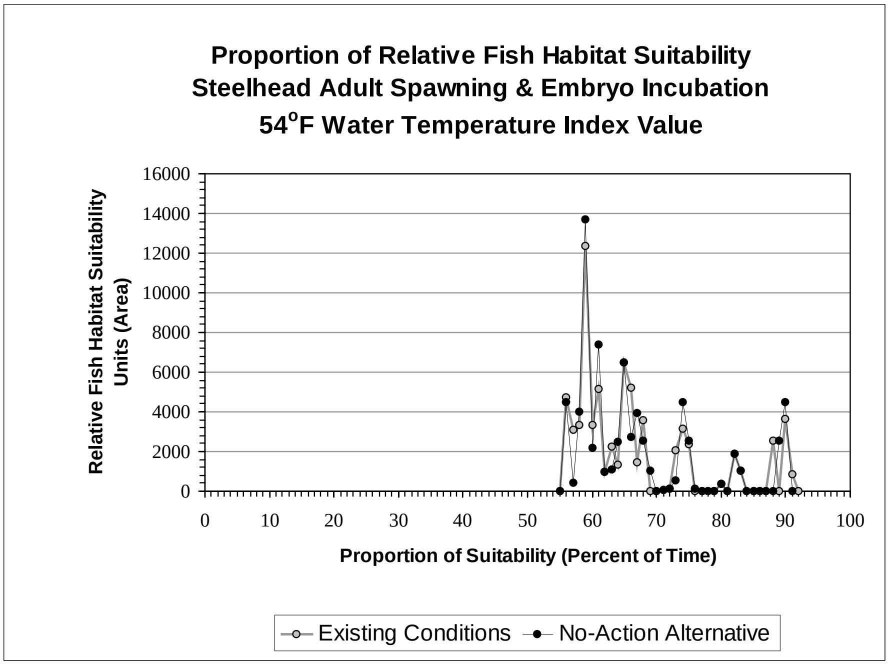


Figure G-AQUA3.4-42. Proportion of relative fish habitat suitability for steelhead adult spawning and embryo incubation for the 54°F water temperature index value.

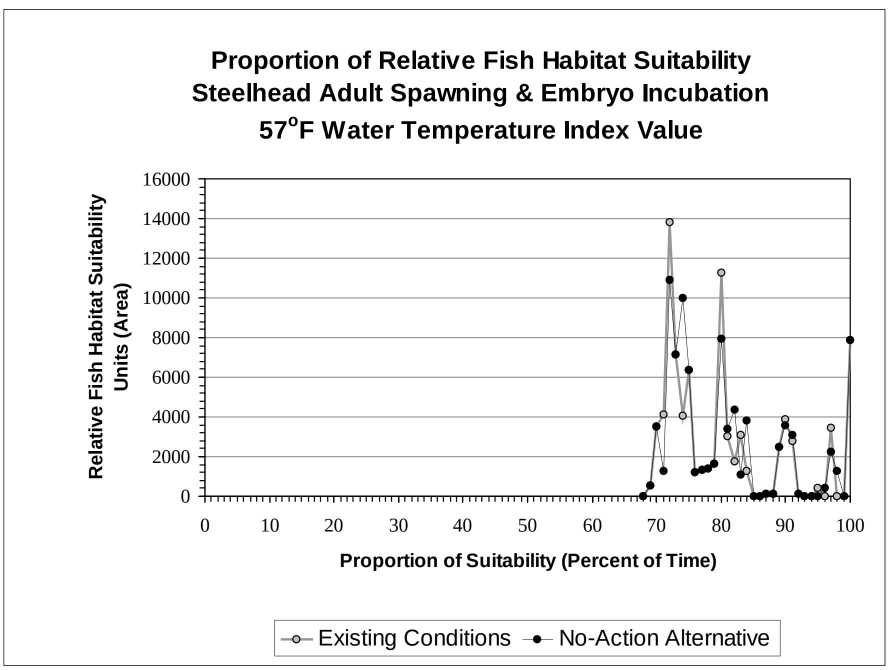


Figure G-AQUA3.4-43. Proportion of relative fish habitat suitability for steelhead adult spawning and embryo incubation for the 57°F water temperature index value.

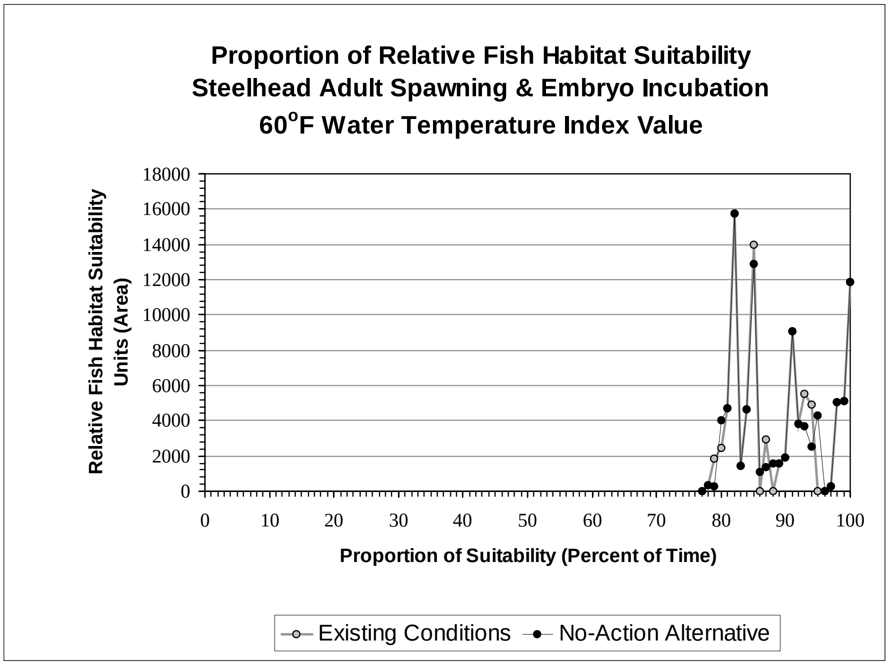


Figure G-AQUA3.4-44. Proportion of relative fish habitat suitability for steelhead adult spawning and embryo incubation for the 60°F water temperature index value.

Table G-AQUA3.4-8. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for steelhead adult spawning and embryo incubation.

Water Temperature Index Value	**52°F**	**54°F**	**57°F**	**60°F**
Existing Conditions				
Minimum Percentage of Time Value	41%	56%	69%	78%
Maximum Percentage of Time Value	75%	91%	100%	100%
Habitat Units at 100 Percent of Time	0	0	7,858	11,890
Percentage of Time at Maximum Habitat Units	49%	59%	72%	82%
OHSIV	**58,193**	**71,349**	**86,835**	**97,065**
No-Action Alternative				
Minimum Percentage of Time Value	41%	56%	69%	78%
Maximum Percentage of Time Value	75%	90%	100%	100%
Habitat Units at 100 Percent of Time	0	0	7,858	11,890
Percentage of Time at Maximum Habitat Units	49%	59%	72%	82%
OHSIV	**58,198**	**71,613**	**87,172**	**97,181**
Percent Change	**0.01%**	**0.37%**	**0.39%**	**0.12%**

value under existing conditions and the No-Action Alternative are 86,835 and 87,172, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 337, which represents a 0.39 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 60°F water temperature index value under existing conditions and the No-Action Alternative are 97,065 and 97,181, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 115, which represents a 0.12 percent increase in OHSIV under the No-Action Alternative compared to existing conditions.

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-8 for the steelhead adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-8 for the steelhead adult spawning and embryo incubation and holding did not change between and the No-Action Alternative for the 52°F, 57°F, and 60°F water temperature index values. The Maximum Percentage of Time Value metric for the 54°F water temperature index value under existing conditions and the No-Action Alternative are 91 percent and 90 percent, respectively. The 1 percent difference in Maximum Percentage of Time Value between existing conditions and the No-Action Alternative represents a small decrease in the number of habitat units with the greatest amount of time and area with water temperatures below 54°F under the No-Action Alternative compared to existing conditions.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-8 for the steelhead adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-8 for the steelhead adult spawning and embryo incubation life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

Fry and Fingerling Rearing and Downstream Movement

Figures G-AQUA3.4-45, G-AQUA3.4-46, G-AQUA3.4-47, and G-AQUA3.4-48 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA3.4-45, G-AQUA3.4-46, G-AQUA3.4-47, and G-AQUA3.4-48 is equal, which allows for direct comparison of habitat suitability between alternatives.

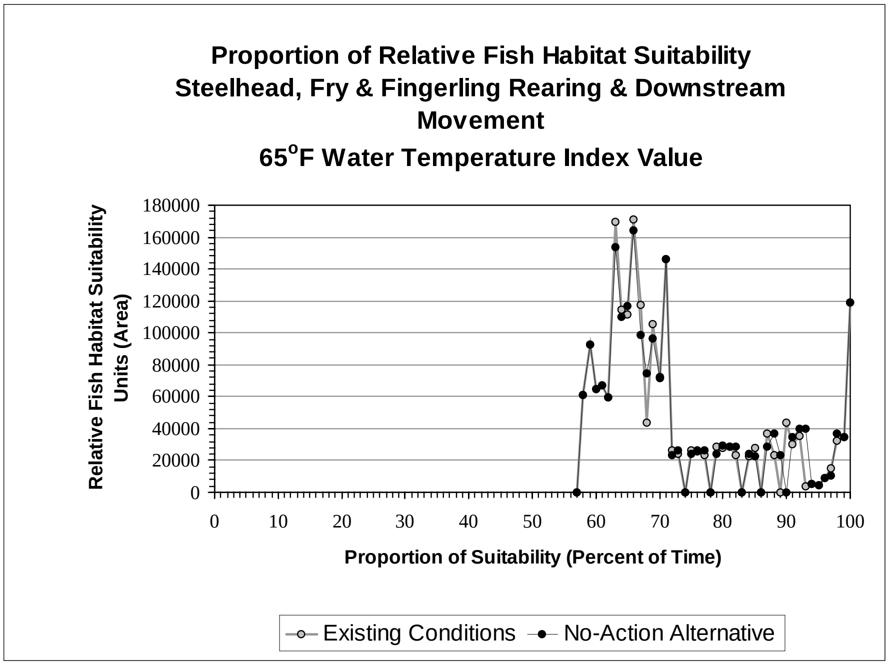


Figure G-AQUA3.4-45. Proportion of relative fish habitat suitability for steelhead fry and fingerling rearing and downstream movement for the 65°F water temperature index value.

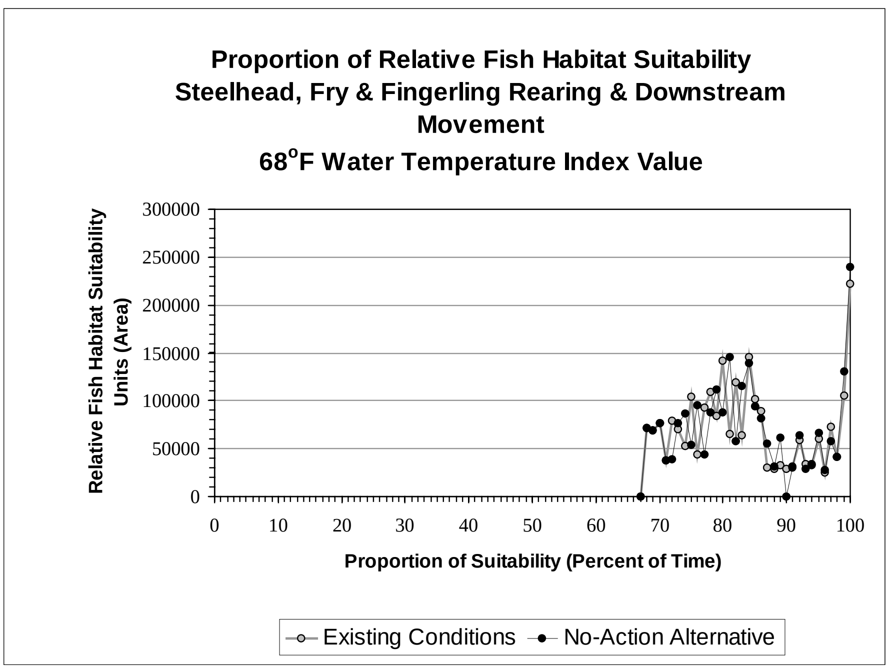


Figure G-AQUA3.4-46. Proportion of relative fish habitat suitability for steelhead fry and fingerling rearing and downstream movement for the 68°F water temperature index value.

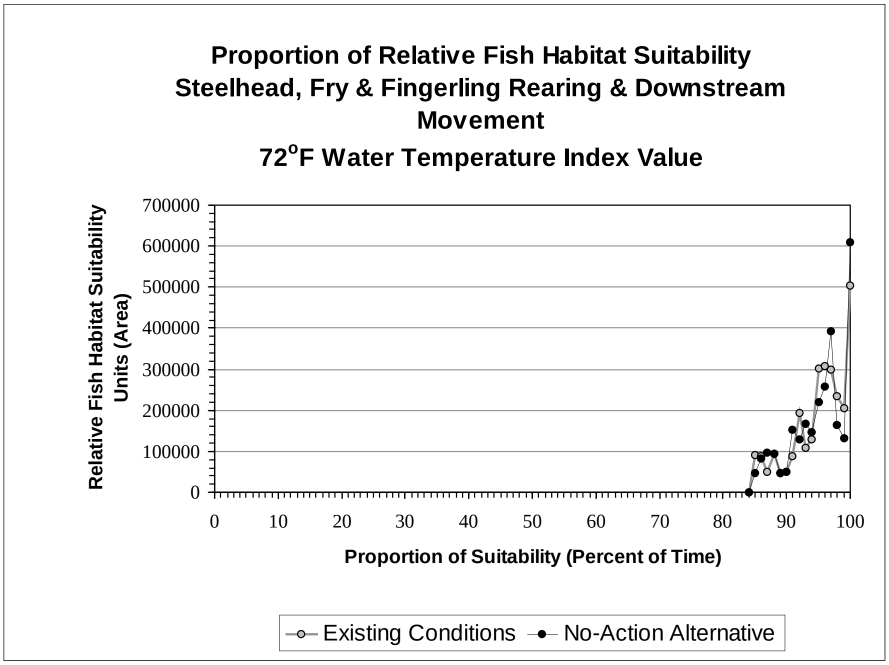


Figure G-AQUA3.4-47. Proportion of relative fish habitat suitability for steelhead fry and fingerling rearing and downstream movement for the 72°F water temperature index value.

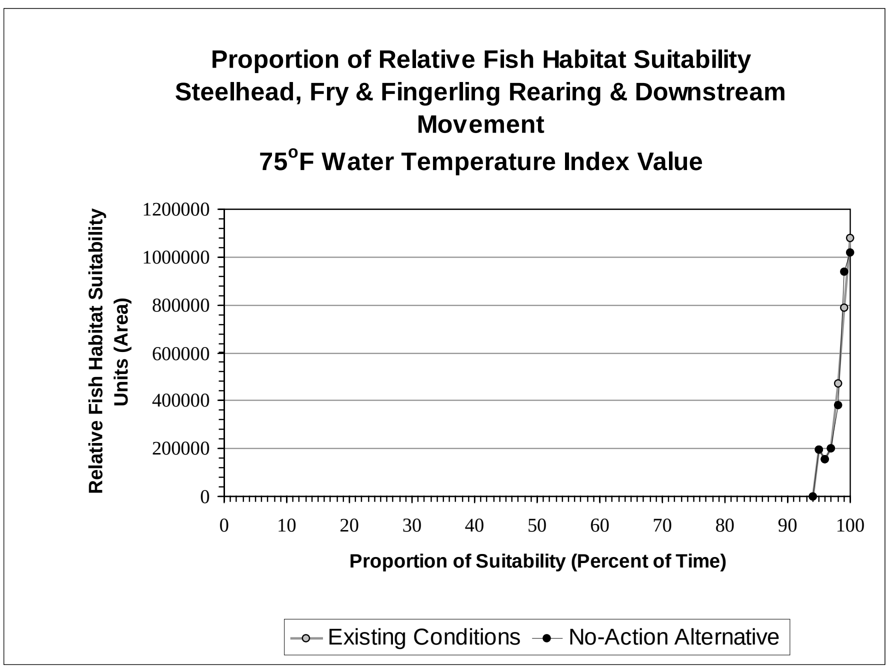


Figure G-AQUA3.4-48. Proportion of relative fish habitat suitability for steelhead fry and fingerling rearing and downstream movement for the 75°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA3.4-9 for steelhead fry and fingerling rearing and downstream movement for the 65°F water temperature index value under existing conditions and the No-Action Alternative are 2,073,387 and 2,083,223, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 9,836, which represents a 0.47 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 68°F water temperature index value under existing conditions and the No-Action Alternative are 2,428,115 and 2,440,326, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 12,211, which represents a 0.50 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 72°F water temperature index value under existing conditions and the No-Action Alternative are 2,785,603 and 2,786,096, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 493, which represents a 0.02 percent increase in OHSIV under No-Action Alternative compared to existing conditions. The OHSIV for the 75°F water temperature index value under existing conditions and the No-Action Alternative are 2,893,159 and 2,893,527, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 378, which represents a 0.01 percent increase in OHSIV under No-Action Alternative compared to existing conditions.

Table G-AQUA3.4-9. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for steelhead fry and fingerling juvenile rearing and downstream movement.

Water Temperature Index Value	65°F	68°F	72°F	75°F
Existing Conditions				
Minimum Percentage of Time Value	58%	68%	85%	95%
Maximum Percentage of Time Value	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	119,042	222,233	502,512	1,078,012
Percentage of Time at Maximum Habitat Units	66%	100%	100%	100%
OHSIV	**2,073,387**	**2,428,115**	**2,785,603**	**2,893,159**
No-Action Alternative				
Minimum Percentage of Time Value	58%	68%	85%	95%
Maximum Percentage of Time Value	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	119,042	240,338	609,003	1,020,829
Percentage of Time at Maximum Habitat Units	66%	100%	100%	100%
OHSIV	**2,083,223**	**2,440,326**	**2,786,096**	**2,893,537**
Percent Change	**0.47%**	**0.50%**	**0.02%**	**0.01%**

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-9 for the steelhead fry and fingerling rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-9 for the steelhead fry and fingerling rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-9 for the steelhead fry and fingerling rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for the 65°F water temperature index value. The Habitat Units at 100 Percent of Time for the 68°F water temperature index value under existing conditions and the No-Action Alternative are 223,233 and 240,338, respectively. The difference in Habitat Units at 100 Percent of Time between the No-Action Alternative and existing conditions is 18,105, which represents an 8.15 percent increase in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are always at or below 68°F. The Habitat Units at 100 Percent of Time for the 72°F water temperature index value under the existing conditions and the No-Action Alternative are 502,512 and 609,003, respectively. The difference in Habitat Units at 100 Percent of Time between the No-Action Alternative and existing conditions is 106,491, which represents a 21.19 percent increase in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are always at or below 72°F. The Habitat Units at 100 Percent of Time for the 75°F water temperature index value under the existing conditions and the No-Action Alternative are 1,078,012 and 1,020,829, respectively. The difference in Habitat Units at 100 Percent of Time between existing conditions and the No-Action Alternative is 57,183, which represents a 5.30 percent decrease in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are always at or below 75°F.

An 8.15 percent increase in the number of habitat units in which water temperatures are always at or below 68°F and above 65°F represents an increase in habitat under the No-Action Alternative that rearing and emigrating steelhead are reported to prefer (Cech and Myrick 1999; Cherry et al. 1977; Kaya et al. 1977). A 21.19 percent increase in the number of habitat units in which water temperatures are always at or below 72°F and above 68°F represents an increase in habitat under the No-Action Alternative in which specific biological effects could potentially occur to rearing and downstream migrating steelhead fry and fingerlings, such as increased physiological stress, increased agnostic activity, and a decrease in forage activity (Nielsen et al. 1994). A 5.30 percent decrease in the number of habitat units in which water temperatures are always at or below 75°F and above 72°F represents an decrease in habitat under the No-Action Alternative in which specific biological effects could potentially occur to rearing and downstream migrating steelhead fry and fingerlings including increased physiological stress, decreased forage activity, and increased mortality (Nielsen et al. 1994; NOAA Fisheries 2001). A detailed description of the potential effects that could occur to rearing and downstream migrating fry and fingerlings steelhead from exposure to water temperatures between above each water temperature index value is presented in Section G-AQUA2.2.3 of Appendix G-AQUA2.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-9 for the steelhead fry and fingerling rearing and downstream movement life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

Smolt Emigration

Figures G-AQUA3.4-49 and G-AQUA3.4-50 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA3.4-49 and G-AQUA3.4-50 is equal, which allows for direct comparison of habitat suitability between alternatives.

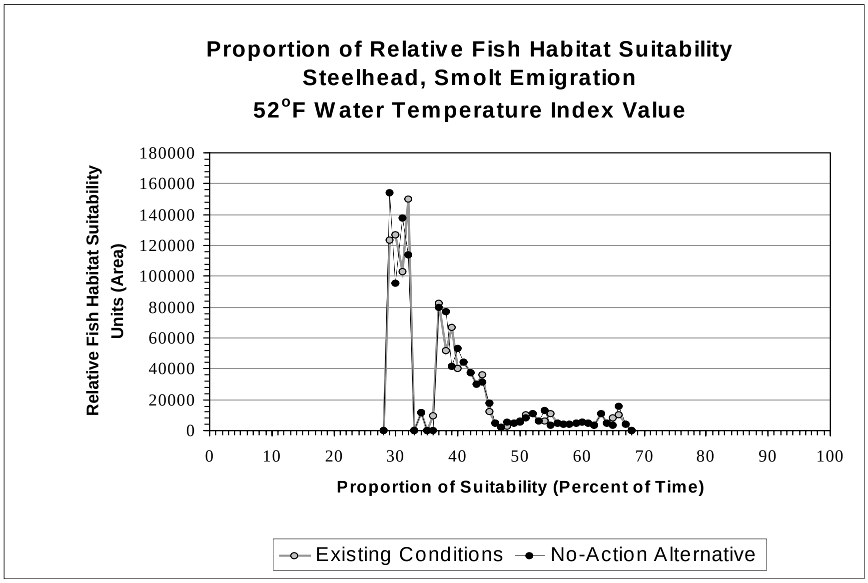


Figure G-AQUA3.4-49. Proportion of relative fish habitat suitability for steelhead smolt emigration for the 52°F water temperature index value.

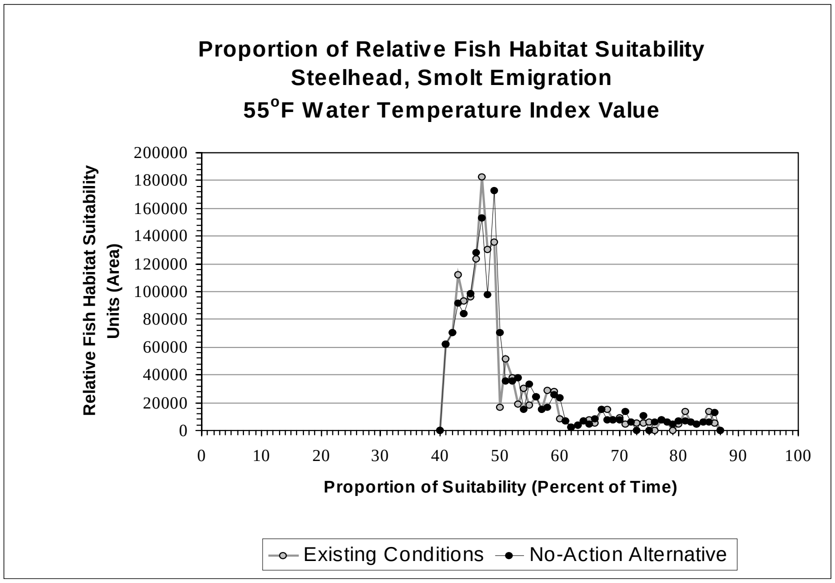


Figure G-AQUA3.4-50. Proportion of relative fish habitat suitability for steelhead smolt emigration for the 55°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA3.4-10 for steelhead smolt emigration for the 52°F water temperature index value under existing conditions and the No-Action Alternative are 1,060,754 and 1,059,104, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 1,650, which represents a 0.16 percent decrease in OHSIV under the No-Action Alternative compared to existing conditions. The OHSIV for the 55°F water temperature index value under existing conditions and the No-Action Alternative are 1,455,067 and 1,463,377, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 8,310, which represents a 0.57 percent increase in OHSIV under the No-Action Alternative compared to existing conditions.

Table G-AQUA3.4-10. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for steelhead smolt emigration.

Water Temperature Index Value	52°F	55°F
Existing Conditions		
Minimum Percentage of Time Value	29%	41%
Maximum Percentage of Time Value	67%	86%
Habitat Units at 100 Percent of Time	0	0
Percentage of Time at Maximum Habitat Units	32%	47%
OHSIV	**1,060,754**	**1,455,067**
No-Action Alternative		
Minimum Percentage of Time Value	29%	41%
Maximum Percentage of Time Value	67%	86%
Habitat Units at 100 Percent of Time	0	0
Percentage of Time at Maximum Habitat Units	29%	49%
OHSIV	**1,059,104**	**1,463,377**
Percent Change	**-0.16%**	**0.57%**

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-10 for the steelhead smolt emigration life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-10 for the steelhead smolt emigration life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-10 for the steelhead smolt emigration life stage did not change between the No-Action Alternative and existing conditions for any of the water temperature index values selected.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-10 for the steelhead smolt emigration life stage for the 52°F water temperature index value under the existing conditions and the No-Action Alternative are 32 percent and 29 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between existing conditions and the No-Action Alternative is three percent, which represents a small decrease in the percentage of time that the habitat is suitable in the greatest area. The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-10 for the steelhead smolt emigration life stage for the 55°F water temperature index value under the existing conditions and the No-Action Alternative are 47 percent and 49 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between existing conditions and the No-Action Alternative is two percent, which represents a small increase in the percentage of time that the habitat is suitable in the greatest area.

G-AQUA3.4.3.3 Predation-related Effects

The slight change in water temperatures resulting from slight changes in seasonal flow patterns in the High Flow Channel under the No-Action Alternative is not anticipated to affect predation rates or the composition of predator species.

G-AQUA3.4.3.4 Fisheries Management–related Effects

Hatchery

No changes to hatchery management are anticipated. Therefore, no hatchery-related effects on steelhead are expected.

Disease

The slight change in water temperatures resulting from slight changes in seasonal flow patterns in the High Flow Channel under the No-Action Alternative is not anticipated to affect the incidence of disease associated with steelhead.

Fishing Regulations, Poaching, and Change in Recreational Access and Visitation

Section 5.10.2, Recreation Resources Environmental Effects, forecasts a one-third increase in recreation and angling activities with the No-Action Alternative. A one-third increase in angling with no other fisheries changes would equate to increased sport fish harvest rates. No changes to fishing regulations are anticipated to occur under the No-Action Alternative.

G-AQUA3.4.3.5 Summary of Potential Effects on Steelhead

Study plan report summaries addressing project effects on steelhead are presented in Section G-AQUA1.5, Fisheries Management; Section G-AQUA1.7, Feather River Fish Hatchery; Section G-AQUA1.8, Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam; Section G-AQUA1.9, Upstream Fish Passage; Section G-AQUA10, Instream Flows and Fish Habitat; and Section G-AQUA1.11, Predation, in

Appendix G-AQUA1, Affected Environment. A description of each steelhead life stage and the time period associated with it is presented in Appendix G-AQUA1.

Adult Immigration and Holding

Changes in mean monthly flows under the No-Action Alternative would have no effect on steelhead adult immigration and holding. Differences in habitat suitability due to decreased water temperatures are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect steelhead juvenile rearing and downstream movement.

Overall, operation of the Oroville Facilities under the No-Action Alternative would have no effect on steelhead immigration and holding.

Adult Spawning and Embryo Incubation

Mean monthly flow changes compared to existing conditions would result in increased WUA, thereby providing a slight beneficial effect on this life stage. Differences in habitat suitability due to decreased water temperatures during the steelhead adult spawning and embryo incubation period are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect steelhead adult spawning and embryo incubation. However, continued degradation of spawning gravel quality in the lower Feather River would result in an adverse effect on steelhead adult spawning and embryo incubation by reducing the quality and quantity of available habitat.

Overall, operation of the Oroville Facilities under the No-Action Alternative would result in an adverse effect on adult spawning and embryo incubation by steelhead.

Fry and Fingerling Rearing and Downstream Movement

Changes in flow under the No-Action Alternative would have no effect on steelhead fry and fingerling rearing and downstream movement. Differences in habitat suitability due to decreased water temperatures are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect steelhead juvenile rearing and downstream movement. However, continued degradation of large woody debris, gravel, and side-channel habitat quality would result in an adverse effect on rearing and downstream movement.

Overall, operation of the Oroville Facilities under the No-Action Alternative would result in an adverse effect on rearing and downstream movement by steelhead fry and fingerlings.

Smolt Emigration

Changes in mean monthly flows under the No-Action Alternative would have a slight adverse effect on steelhead smolt emigration due to the reduction in WUA. Differences in habitat suitability due to decreased water temperatures are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect steelhead smolt emigration.

Overall, operation of the Oroville Facilities under the No-Action Alternative would result in an adverse effect on steelhead smolt emigration.

Conclusions

Based on the above summary of potential effects, it is likely that the No-Action Alternative would have an overall adverse effect on steelhead relative to existing conditions.

G-AQUA3.4.4 American Shad

G-AQUA3.4.4.1 Flow-related Effects

No flow changes are anticipated to occur in the Low Flow Channel under the No-Action Alternative. Changes in mean monthly flow during the American shad adult immigration and spawning period would have no effect due to the small magnitude of flow change during each month of the life stage period.

G-AQUA3.4.4.2 Water Temperature–related Effects

No water temperature changes are anticipated to occur in the Low Flow Channel under the No-Action Alternative.

Figure G-AQUA3.4-51 shows the proportion of time that habitat units are considered suitable for each water temperature range selected. The area under each curve displayed in Figure G-AQUA3.4-51 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA3.4-51 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 46°F to 79°F. Figures depicting the amount of habitat with water temperatures below 46°F or above 79°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of the No-Action Alternative on American shad adult immigration and spawning.

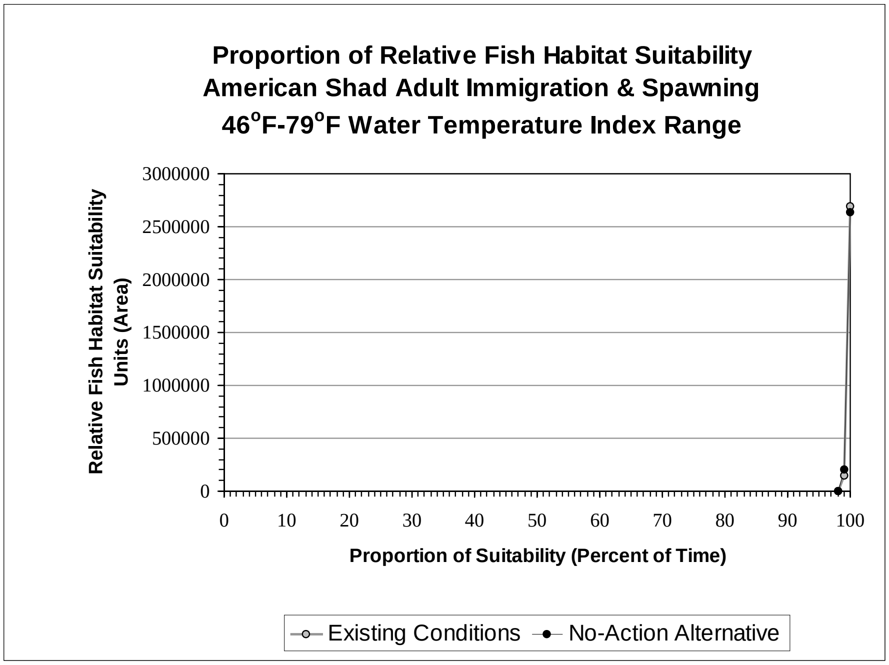


Figure G-AQUA3.4-51. Proportion of relative fish habitat suitability for American shad adult immigration and spawning for the 46°F to 79°F water temperature range.

The OHSIV presented in Table G-AQUA3.4-11 for American shad adult immigration and spawning for the 46°F to 79°F water temperature range under existing conditions and the No-Action Alternative are 2,836,596 and 2,836,030, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 567, which represents a 0.02 percent decrease in OHSIV under the No-Action Alternative compared to existing conditions. Because analysis of the 46°F to 79°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.02 percent decrease in OHSIV for this water temperature range represents a decrease in relative habitat suitability for American shad adult immigration and spawning in the lower Feather River. The decrease in relative habitat suitability under the No-Action Alternative is due to an increase in time and area with water temperatures warmer than the reported thermal tolerance range for American shad adult immigration and spawning, resulting in a decrease in the time and area within the reported thermal tolerance range for the species and life stage. The decrease in relative habitat suitability due to warmer water temperatures generally could result in increased stress response including increased metabolic rates, decreased growth rates, and potentially increased mortality rates (Bond 1996; Moyle 2002; Moyle and Cech 2000).

Table G-AQUA3.4-11. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for American shad adult immigration and spawning.

Water Temperature Index Value	**46°F-79°F**
Existing Conditions	
Minimum Percentage of Time Value	99%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	2,688,520
Percentage of Time at Maximum Habitat Units	100%
OHSIV	**2,836,596**
No-Action Alternative	
Minimum Percentage of Time Value	99%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	2,631,869
Percentage of Time at Maximum Habitat Units	100%
OHSIV	**2,836,030**
Percent Change	**-0.02%**

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-11 for the American shad adult immigration and spawning life stage did not change between the No-Action Alternative and existing conditions for the 46°F to 79°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-11 for the American shad adult immigration and spawning life stage did not change between the No-Action Alternative and existing conditions for the 46°F to 79°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-11 for the American shad adult immigration and spawning life stage for the 46°F to 79°F water temperature range under existing conditions and the No-Action Alternative is 2,688,520 and 2,631,869, respectively. The difference in Habitat Units at 100 Percent of Time between existing conditions and the No-Action Alternative is 56,651, which represents a 2.11 percent decrease in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are between 46°F to 79°F.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-11 for the American shad adult immigration and spawning life stage did not change between the No-Action Alternative and existing conditions for the 46°F to 79°F water temperature range.

G-AQUA3.4.4.3 Summary of Potential Effects on American Shad

Study plan report summaries addressing project effects on American shad are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

No flow or water temperature–related effects are expected to occur in the Low Flow Channel under the No-Action Alternative. Flow changes in the High Flow Channel are not anticipated to alter river stage substantially over potential passage barriers in the lower Feather River, thereby having no effect on American shad adult immigration and spawning. Differences in habitat suitability due to water temperature changes are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect American shad adult spawning.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have no effect on American shad adult immigration and spawning relative to existing conditions.

G-AQUA3.4.5 Black Bass

G-AQUA3.4.5.1 Water Temperature–related Effects

No water temperature changes are anticipated to occur in the Low Flow Channel under the No-Action Alternative.

Figure G-AQUA3.4-52 shows the proportion of time that habitat units are considered suitable for each water temperature range selected. The area under each curve displayed in Figure G-AQUA3.4-52 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA3.4-52 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 54°F to 75°F. Figures depicting the amount of habitat with water temperatures below 54°F or above 75°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of the No-Action Alternative on black bass adult spawning.

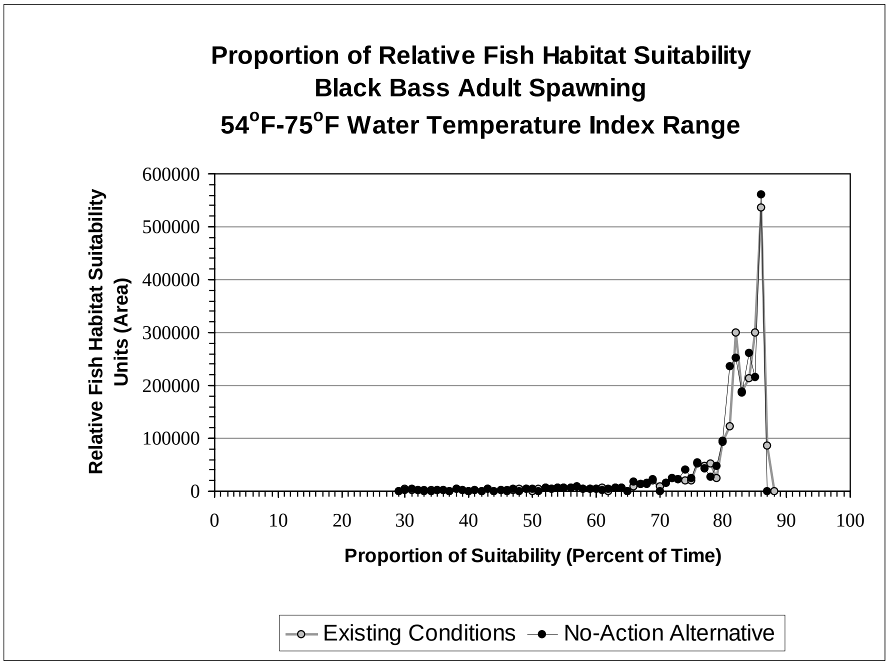


Figure G-AQUA3.4-52. Proportion of relative fish habitat suitability for black bass adult spawning for the 54°F to 75°F water temperature range.

The OHSIV presented in Table G-AQUA3.4-12 for black bass adult spawning for the 54°F to 75°F water temperature range under existing conditions and the No-Action Alternative are 2,310,420 and 2,300,520, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 9,900, which represents a 0.43 percent decrease in OHSIV under the No-Action Alternative compared to existing conditions. Because analysis of the 54°F to 75°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.43 percent decrease in OHSIV for this water temperature range represents a decrease in relative habitat suitability for black bass adult spawning in the lower Feather River. The decrease in relative habitat suitability under the No-Action Alternative is due to an increase in time and area with water temperatures cooler than the reported thermal tolerance range for black bass adult spawning during certain portions of the life stage period and an increase in water temperatures warmer than the reported thermal tolerance range for black bass adult spawning during certain portions of the life stage period, resulting in a decrease in the time and area within the reported thermal tolerance range for the species and life stage. The decrease in relative habitat suitability due to water temperatures outside the reported thermal tolerance range of this species and life stage generally could result in increased stress response including raised or lowered metabolic rates, decreased spawning activity, decreased growth rates, and potentially increased mortality rates (Bond 1996; Moyle 2002; Moyle and Cech 2000).

Table G-AQUA3.4-12. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for black bass adult spawning.

Water Temperature Index Value	54°F-75°F
Existing Conditions	
Minimum Percentage of Time Value	30%
Maximum Percentage of Time Value	87%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	86%
OHSIV	**2,310,420**
No-Action Alternative	
Minimum Percentage of Time Value	30%
Maximum Percentage of Time Value	86%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	86%
OHSIV	**2,300,520**
Percent Change	**-0.43%**

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-12 for the black bass adult spawning life stage did not change between existing conditions and the No-Action Alternative for the 54°F to 75°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-12 for the black bass adult spawning life stage under existing conditions and the No-Action Alternative for the 54°F to 75°F water temperature range is 87 percent and 86 percent, respectively. The 1 percent difference between existing conditions and the No-Action alternative represents a small decrease in the number of habitat units with the greatest amount of time and area with water temperatures in the 54°F to 75°F water temperature range under the No-Action Alternative compared to existing conditions.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-12 for the black bass adult spawning life stage did not change between existing conditions and the No-Action Alternative for the 54°F to 75°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-12 for the black bass adult spawning life stage did not change between existing conditions and the No-Action Alternative for the 54°F to 75°F water temperature range.

G-AQUA3.4.5.2 Summary of Potential Effects on Black Bass

Study plan report summaries addressing project effects on black bass species are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam; Section G-AQUA1.5, Fisheries Management; and Section G-AQUA1.11, Predation, in Appendix G-AQUA1, Affected Environment.

Differences in habitat suitability due to water temperature changes are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect black bass adult spawning.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have no effect on black bass.

G-AQUA3.4.6 Delta Smelt

G-AQUA3.4.6.1 Habitat Components

Adult Spawning

Delta smelt spawn in the upper Sacramento–San Joaquin Delta (Delta) upstream of the mixing zone and use a range of substrates for spawning, including reeds and other submerged vegetation, sandy or hard substrates, and submerged wood. The continued reduced contribution of large woody debris from the lower Feather River under the No-Action Alternative would result in the continued incremental degradation of spawning habitat quality and quantity in the Delta, thereby resulting in slightly adverse effects on delta smelt.

G-AQUA3.4.6.2 Summary of Potential Effects on Delta Smelt

Study plan report summaries addressing project effects on Delta smelt are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

The range of distribution of the delta smelt is outside of the direct and indirect effects area for flows and water temperatures for the Oroville Facilities; therefore, no flow or water temperature effects on delta smelt are anticipated under the No-Action Alternative. Continued reductions in the contribution of large woody debris from the lower Feather River to the Delta for Delta smelt spawning habitat would result in an overall slightly adverse effect on Delta smelt.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have a slight adverse effect on Delta smelt.

G-AQUA3.4.7 Green Sturgeon

G-AQUA3.4.7.1 Flow-related Effects

No flow changes are anticipated to occur in the Low Flow Channel. Changes in mean monthly flow under the No-Action Alternative compared to existing conditions are anticipated to provide a no effect on green sturgeon adult immigration and holding, adult spawning and embryo incubation, juvenile rearing, and juvenile emigration because the changes in river stage associated with changes in flows would be small. Additionally, analytical tools such as PHABSIM were not available for use on this species. Therefore, because of the absence of quantitative analytical tools to determine the effects of flow changes, a qualitative assessment of changes in river stage indicate that it is unlikely that flow changes under the No-Action Alternative would have any effect on green sturgeon.

G-AQUA3.4.7.2 Water Temperature–related Effects

No water temperature changes are anticipated to occur in the Low Flow Channel.

<u>Adult Immigration and Holding</u>

Figure G-AQUA3.4-53 shows the proportion of time that habitat units are considered suitable for each water temperature range selected. The area under each curve displayed in Figure G-AQUA3.4-53 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA3.4-53 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 44°F to 61°F. Figures depicting the amount of habitat with water temperatures below 44°F or above 61°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of the No-Action Alternative on green sturgeon adult immigration and holding.

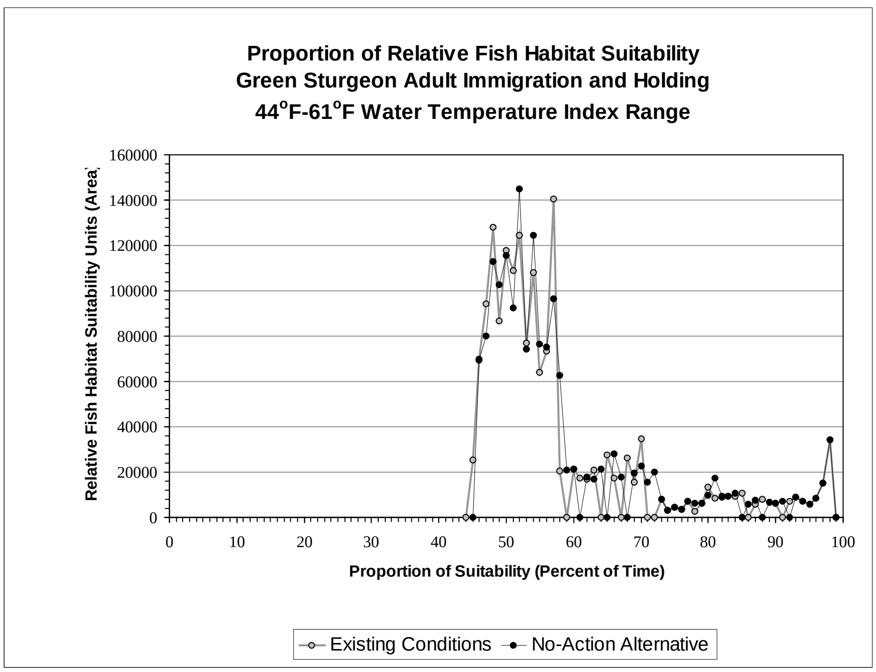


Figure G-AQUA3.4-53. Proportion of relative fish habitat suitability for green sturgeon adult immigration and holding for the 44°F to 61°F water temperature range.

The OHSIV presented in Table G-AQUA3.4-13 for green sturgeon adult immigration and holding for the 44°F to 61°F water temperature range under existing conditions and the No-Action Alternative are 1,644,218 and 1,657,011, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 12,793, which represents a 0.78 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. Because analysis of the 44°F to 61°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.78 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for green sturgeon adult immigration and holding in the lower Feather River. The increase in relative habitat suitability under the No-Action Alternative is due to a decrease in time and area with water temperatures warmer than the reported thermal tolerance range for green sturgeon adult immigration and holding during certain portions of the life stage period. The decrease in OHSIV above the reported thermal tolerance range for green sturgeon adult immigration and holding could result in more habitat defined as suitable and less habitat in which increased stress response including raised metabolic rates, decreased growth rates, and increased mortality rates could potentially occur (Bond 1996; Moyle 2002; Moyle and Cech 2000).

Table G-AQUA3.4-13. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for green sturgeon adult immigration and holding.

Water Temperature Index Value	**44°F-61°F**
Existing Conditions	
Minimum Percentage of Time Value	45%
Maximum Percentage of Time Value	98%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	57%
OHSIV	**1,644,218**
No-Action Alternative	
Minimum Percentage of Time Value	46%
Maximum Percentage of Time Value	98%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	52%
OHSIV	**1,657,011**
Percent Change	**0.78%**

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-13 for the green sturgeon adult immigration and holding life stage under existing conditions and the No-Action Alternative for the 44°F to 61°F water temperature range is 45 percent and 46 percent, respectively. The 1 percent difference between the No-Action alternative and existing conditions represents a small increase in the number of habitat units with the least amount of time and area with water temperatures in the 44°F to 61°F water temperature range under the No-Action Alternative compared to existing conditions.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-13 for the green sturgeon adult immigration and holding life stage did not change between existing conditions and the No-Action Alternative for the 44°F to 61°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-13 for the green sturgeon adult immigration and holding life stage did not change between existing conditions and the No-Action Alternative for the 44°F to 61°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-13 for the green sturgeon adult immigration and holding life stage under existing conditions and the No-Action Alternative for the 44°F to 61°F water temperature range is 57 percent and 52 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between existing conditions and the No-Action Alternative is five percent, which represents a small decrease in the percentage of time that the habitat is suitable in the greatest area.

Adult Spawning and Embryo Incubation

Figure G-AQUA3.4-54 shows the proportion of time that habitat units are considered suitable for each water temperature range selected. The area under each curve displayed in Figure G-AQUA3.4-54 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA3.4-54 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 46°F to 68°F. Figures depicting the amount of habitat with water temperatures below 46°F or above 68°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of the No-Action Alternative on green sturgeon adult spawning and embryo incubation.

The OHSIV presented in Table G-AQUA3.4-14 for green sturgeon adult spawning and embryo incubation for the 46°F to 68°F water temperature range under existing conditions and the No-Action Alternative are 57,213 and 57,858, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 646, which represents a 1.13 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. Because analysis of the 46°F to 68°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 1.13 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for green sturgeon adult spawning and embryo incubation in the lower Feather River. The increase in relative habitat suitability under the No-Action Alternative is due to a decrease in time and area with water temperatures warmer than the reported thermal tolerance range for green sturgeon adult spawning and embryo incubation life stage

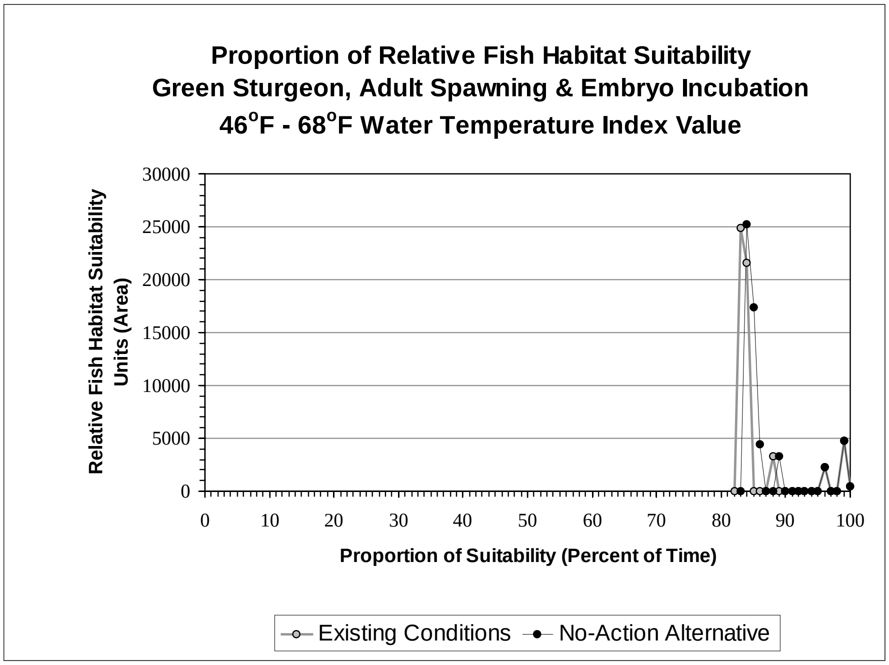


Figure G-AQUA3.4-54. Proportion of relative fish habitat suitability for green sturgeon adult spawning and embryo incubation for the 46°F to 68°F water temperature range.

Table G-AQUA3.4-14. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for green sturgeon adult spawning and embryo incubation.

Water Temperature Index Value	**46°F-68°F**
Existing Conditions	
Minimum Percentage of Time Value	83%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	436
Percentage of Time at Maximum Habitat Units	83%
OHSIV	**57,213**
No-Action Alternative	
Minimum Percentage of Time Value	84%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	436
Percentage of Time at Maximum Habitat Units	84%
OHSIV	**57,858**
Percent Change	**1.13%**

period. The decrease in OHSIV above the reported thermal tolerance range for green sturgeon adult spawning and embryo incubation could result in more habitat defined as suitable and less habitat in which increased stress response including raised metabolic rates, decreased spawning activity, decreased growth rates, and increased mortality rates could potentially occur (Bond 1996; Moyle 2002; Moyle and Cech 2000).

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-14 for the green sturgeon adult spawning and embryo incubation life stage under existing conditions and the No-Action Alternative for the 46°F to 68°F water temperature range is 83 percent and 84 percent, respectively. The 1 percent difference between the No-Action alternative and existing conditions represents a small increase in the number of habitat units with the least amount of time and area with water temperatures in the 46°F to 68°F water temperature range under the No-Action Alternative compared to existing conditions.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-14 for the green sturgeon adult spawning and embryo incubation life stage did not change between existing conditions and the No-Action Alternative for the 46°F to 68°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-14 for the green sturgeon adult spawning and embryo incubation life stage did not change between existing conditions and the No-Action Alternative for the 46°F to 68°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-14 for the green sturgeon adult spawning and embryo incubation life stage under existing conditions and the No-Action Alternative for the 46°F to 68°F water temperature range is 83 percent and 84 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between the No-Action Alternative and existing conditions is 1 percent, which represents a small increase in the percentage of time that the habitat is suitable in the greatest area.

Juvenile Rearing

Figure G-AQUA3.4-55 shows the proportion of time that habitat units are considered suitable for each water temperature range selected. The area under each curve displayed in Figure G-AQUA3.4-55 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA3.4-55 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 50°F to 66°F. Figures depicting the amount of habitat with water temperatures below 50°F or above 66°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of the No-Action Alternative on green sturgeon juvenile rearing.

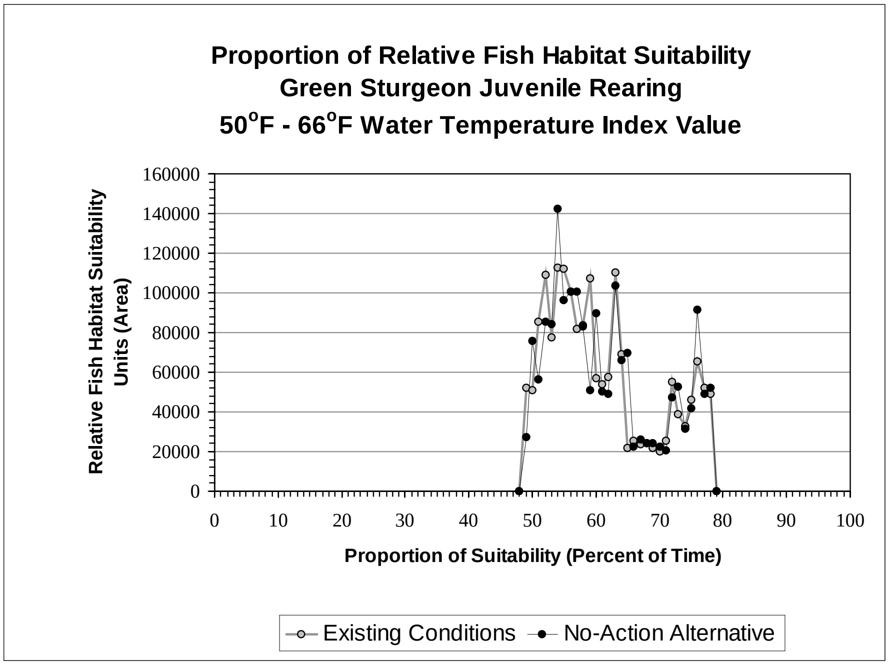


Figure G-AQUA3.4-55. Proportion of relative fish habitat suitability for green sturgeon juvenile rearing for the 50°F to 66°F water temperature range.

The OHSIV presented in Table G-AQUA3.4-15 for green sturgeon juvenile rearing for the 50°F to 66°F water temperature range under existing conditions and the No-Action Alternative are 1,822,244 and 1,837,131, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 14,887, which represents a 0.82 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. Because analysis of the 50°F to 66°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.82 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for green sturgeon juvenile rearing in the lower Feather River. The increase in relative habitat suitability under the No-Action Alternative is due to a decrease in time and area with water temperatures cooler or warmer than the reported thermal tolerance range for green sturgeon juvenile rearing during certain portions of the life stage period. The decrease in OHSIV below or above the reported thermal tolerance range for green sturgeon juvenile rearing could result in more habitat defined as suitable and less habitat in which increased stress response including lowered or raised metabolic rates, decreased forage activity, decreased growth rates, and increased mortality rates could potentially occur (Bond 1996; Moyle 2002; Moyle and Cech 2000).

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-15 for the green sturgeon juvenile rearing life stage did not change between existing conditions and the No-Action Alternative for the 50°F to 66°F water temperature range.

Table G-AQUA3.4-15. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for green sturgeon juvenile rearing.

Water Temperature Index Value	50°F-66°F
Existing Conditions	
Minimum Percentage of Time Value	49%
Maximum Percentage of Time Value	78%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	54%
OHSIV	**1,822,244**
No-Action Alternative	
Minimum Percentage of Time Value	49%
Maximum Percentage of Time Value	78%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	54%
OHSIV	**1,837,131**
Percent Change	**0.82%**

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-15 for the green sturgeon juvenile rearing life stage did not change between existing conditions and the No-Action Alternative for the 50°F to 66°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-15 for the green sturgeon juvenile rearing life stage did not change between existing conditions and the No-Action Alternative for the 50°F to 66°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-15 for the green sturgeon juvenile rearing life stage did not change between existing conditions and the No-Action Alternative for the 50°F to 66°F water temperature range.

Juvenile Emigration

Figure G-AQUA3.4-56 shows the proportion of time that habitat units are considered suitable for each water temperature range selected. The area under each curve displayed in Figure G-AQUA3.4-56 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA3.4-56 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 50°F to 66°F. Figures depicting the amount of habitat with water temperatures below 50°F or above 66°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of the No-Action Alternative on green sturgeon juvenile emigration.

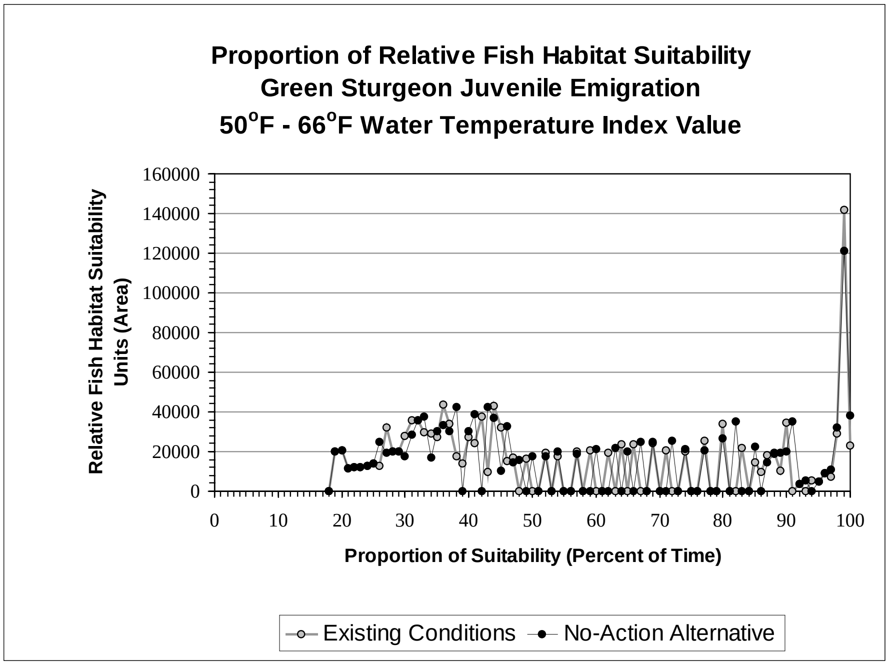


Figure G-AQUA3.4-56. Proportion of relative fish habitat suitability for green sturgeon juvenile emigration for the 50°F to 66°F water temperature range.

The OHSIV presented in Table G-AQUA3.4-16 for green sturgeon juvenile emigration for the 50°F to 66°F water temperature range under existing conditions and the No-Action Alternative are 1,327,349 and 1,354,092, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 26,743, which represents a 2.01 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. Because analysis of the 50°F to 66°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 2.01 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for green sturgeon juvenile emigration in the lower Feather River. The increase in relative habitat suitability under the No-Action Alternative is due to a decrease in time and area with water temperatures warmer than the reported thermal tolerance range for green sturgeon juvenile emigration during certain portions of the life stage period. The decrease in OHSIV above the reported thermal tolerance range for green sturgeon juvenile emigration could result in more habitat defined as suitable and less habitat in which increased stress response could occur. The increase in relative habitat suitability under the No-Action Alternative also is associated with an increase in time and area with water temperatures below the reported thermal tolerance range for green sturgeon juvenile emigration, which also could result in increased incidence of stress response. Generalized stress response includes raised metabolic rates, decreased forage activity, decreased growth rates, and increased mortality rates (Bond 1996; Moyle 2002; Moyle and Cech 2000). However, the decrease in time and area in which water temperatures are above the reported thermal tolerance range for this life stage was 26,814 OHSIV units while the increase in time and area below the reported thermal tolerance range for this life stage was 60 OHSIV units. Therefore, the increase in time and area in which increased incidence of

Table G-AQUA3.4-16. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for green sturgeon juvenile emigration.

Water Temperature Index Value	50°F-66°F
Existing Conditions	
Minimum Percentage of Time Value	19%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	23,284
Percentage of Time at Maximum Habitat Units	99%
OHSIV	**1,327,349**
No-Action Alternative	
Minimum Percentage of Time Value	19%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	37,977
Percentage of Time at Maximum Habitat Units	99%
OHSIV	**1,354,092**
Percent Change	**2.01%**

stress response could occur is negligible compared to the increase in suitable habitat associated with the No-Action Alternative.

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-16 for the green sturgeon juvenile emigration life stage did not change between existing conditions and the No-Action Alternative for the 50°F to 66°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-16 for the green sturgeon juvenile emigration life stage did not change between existing conditions and the No-Action Alternative for the 50°F to 66°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-16 for the green sturgeon juvenile emigration life stage under existing conditions and the No-Action Alternative for the 50°F to 66°F water temperature range is 23,284 and 37,977, respectively. The difference in Habitat Units at 100 Percent of Time between the No-Action Alternative and existing conditions is 14,693, which represents a 63.1 percent increase in the amount of habitat area under the No-Action Alternative compared to Existing Conditions in which water temperatures are always between 50°F and 66°F.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-16 for the green sturgeon juvenile emigration life stage did not change between existing conditions and the No-Action Alternative for the 50°F to 66°F water temperature range.

G-AQUA3.4.7.3 Summary of Potential Effects on Green Sturgeon

Study plan report summaries addressing project effects on green sturgeon are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

No flow or water temperature–related effects are expected to occur in the Low Flow Channel.

Adult Immigration and Holding

Flow changes in the High Flow Channel are not anticipated to appreciably change the river stage over potential passage barriers in the lower Feather River below the Thermalito Afterbay Outlet, thereby having no effect on green sturgeon adult immigration and holding. Differences in habitat suitability due to decreased water temperatures are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect green sturgeon adult immigration and holding.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have no effect on green sturgeon adult immigration and holding.

Adult Spawning and Embryo Incubation

Flow changes in the High Flow Channel are not anticipated to appreciably change the river stage in the lower Feather River below the Thermalito Afterbay Outlet, thereby having no effect on green sturgeon adult spawning and embryo incubation. Differences in habitat suitability due to differences in water temperature between existing conditions and the No-Action Alternative indicate that habitat suitability would increase by approximately 1 percent under the No-Action Alternative. Therefore, changes in water temperature would provide a slight beneficial effect on green sturgeon adult spawning and embryo incubation.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have a slight beneficial effect on green sturgeon adult spawning and embryo incubation.

Juvenile Rearing

Flow changes in the High Flow Channel are not anticipated to affect green sturgeon juvenile rearing because associated changes in river stage likely would result in very small changes in available rearing habitat area. Differences in habitat suitability due to decreased water temperatures are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect green sturgeon juvenile rearing.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have no effect on green sturgeon juvenile rearing.

Juvenile Emigration

Flow changes in the High Flow Channel are not anticipated to affect green sturgeon juvenile emigration because associated changes in river stage likely would result in very small changes in available habitat area. Differences in habitat suitability due to differences in water temperature between existing conditions and the No-Action Alternative indicate that habitat suitability would increase by approximately two percent under the No-Action Alternative. Therefore, changes in water temperature would provide a slight beneficial effect on green sturgeon juvenile emigration.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have a slight beneficial effect on green sturgeon juvenile emigration.

Conclusion

Based on the above summary of potential effects, it is likely that the No-Action Alternative would have an overall slight beneficial effect on green sturgeon relative to existing conditions.

G-AQUA3.4.8 Hardhead

G-AQUA3.4.8.1 Water Temperature–related Effects

No water temperature changes are anticipated to occur in the Low Flow Channel.

Figure G-AQUA3.4-57 shows the proportion of time that habitat units are considered suitable for each water temperature range selected. The area under each curve displayed in Figure G-AQUA3.4-57 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA3.4-57 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 55°F to 75°F. Figures depicting the amount of habitat with water temperatures below 55°F or above 75°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of the No-Action Alternative on hardhead adult spawning.

The OHSIV presented in Table G-AQUA3.4-17 for hardhead adult spawning for the 55°F to 75°F water temperature range under existing conditions and the No-Action Alternative are 2,776,135 and 2,769,601, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 6,534, which represents a 0.24 percent decrease in OHSIV under the No-Action Alternative compared to existing conditions. Because analysis of the 55°F to 75°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.24 percent decrease in OHSIV for this water temperature range represents a

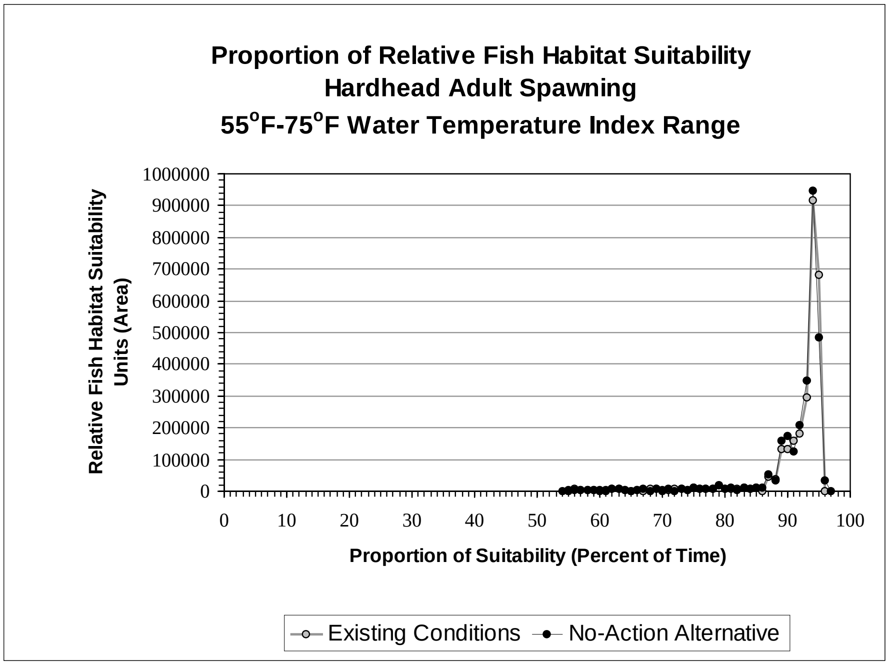


Figure G-AQUA3.4-57. Proportion of relative fish habitat suitability for hardhead adult spawning for the 55°F to 75°F water temperature range.

Table G-AQUA3.4-17. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for hardhead adult spawning.

Water Temperature Index Value	**55°F-75°F**
Existing Conditions	
Minimum Percentage of Time Value	56%
Maximum Percentage of Time Value	95%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	94%
OHSIV	**2,776,135**
No-Action Alternative	
Minimum Percentage of Time Value	55%
Maximum Percentage of Time Value	96%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	94%
OHSIV	**2,769,601**
Percent Change	**-0.24%**

decrease in relative habitat suitability for hardhead adult spawning in the lower Feather River. The decrease in relative habitat suitability under the No-Action Alternative is due to a decrease in time and area with water temperatures warmer than the reported thermal tolerance range for hardhead adult spawning during certain portions of the life stage period and an increase in time and area with water temperatures cooler than the reported thermal tolerance range for hardhead adult spawning. The decrease in OHSIV above the reported thermal tolerance range for hardhead adult spawning could result in more habitat defined as suitable. The increase in time and area with water temperatures below the reported thermal tolerance range for hardhead adult spawning could result in increased incidence of stress response within this species and life stage. Generalized stress response includes raised metabolic rates, decreased forage activity, decreased growth rates, and increased mortality rates (Bond 1996; Moyle 2002; Moyle and Cech 2000).

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-17 for the hardhead adult spawning life stage under existing conditions and the No-Action Alternative for the 55°F to 75°F water temperature range is 56 percent and 55 percent, respectively. The 1 percent difference between the No-Action alternative and existing conditions represents a small decrease in the number of habitat units with the least amount of time and area with water temperatures in the 55°F to 75°F water temperature range under the No-Action Alternative compared to existing conditions.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-17 for the hardhead adult spawning life stage under existing conditions and the No-Action Alternative for the 55°F to 75°F water temperature range is 95 percent and 96 percent, respectively. The 1 percent difference between the No-Action alternative and existing conditions represents a small increase in the number of habitat units with the greatest amount of time and area with water temperatures in the 55°F to 75°F water temperature range under the No-Action Alternative compared to existing conditions.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-17 for the hardhead adult spawning life stage did not change between existing conditions and the No-Action Alternative for the 55°F to 75°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-17 for the hardhead adult spawning life stage did not change between existing conditions and the No-Action Alternative for the 55°F to 75°F water temperature range.

G-AQUA3.4.8.2 Summary of Potential Effects on Hardhead

Study plan report summaries addressing project effects on hardhead are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

Differences in habitat suitability due to water temperature changes are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect hardhead adult spawning.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have no effect on hardhead adult spawning relative to existing conditions.

G-AQUA3.4.9 River Lamprey

G-AQUA3.4.9.1 Water Temperature–related Effects

No water temperature changes are anticipated to occur in the Low Flow Channel.

Figure G-AQUA3.4-58 shows the proportion of time that habitat units are considered suitable for each water temperature range selected. The area under each curve displayed in Figure G-AQUA3.4-58 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA3.4-58 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 43°F to 72°F. Figures depicting the amount of habitat with water temperatures below 43°F or above 72°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of the No-Action Alternative on river lamprey adult spawning.

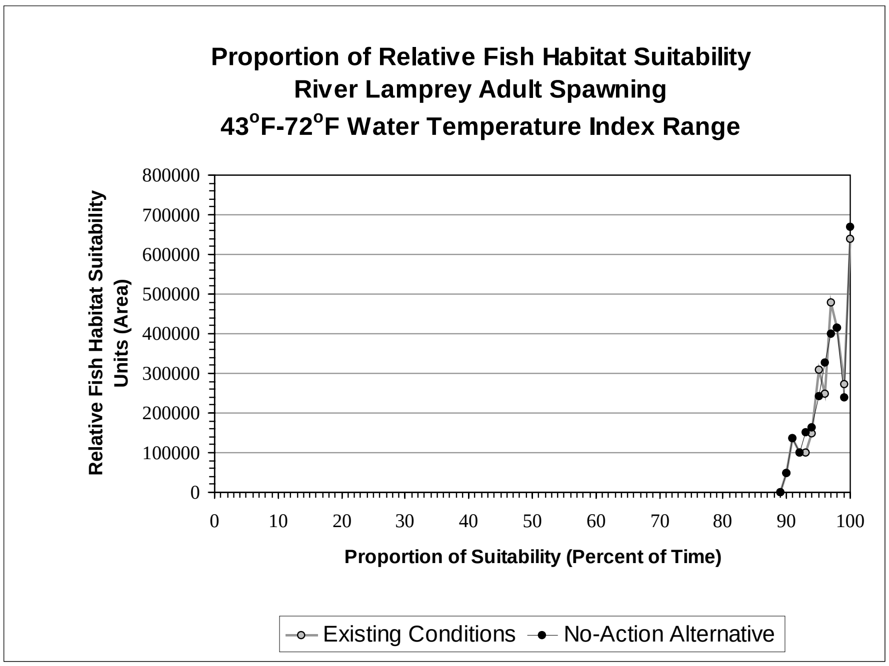


Figure G-AQUA3.4-58. Proportion of relative fish habitat suitability for river lamprey adult spawning for the 43°F to 72°F water temperature range.

The OHSIV presented in Table G-AQUA3.4-18 for river lamprey adult spawning for the 43°F to 72°F water temperature range under existing conditions and the No-Action Alternative are 2,901,102 and 2,899,309, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 1,793, which represents a 0.06 percent decrease in OHSIV under the No-Action Alternative compared to existing conditions. Because analysis of the 43°F to 72°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.06 percent decrease in OHSIV for this water temperature range represents a decrease in relative habitat suitability for river lamprey adult spawning in the lower Feather River. The decrease in relative habitat suitability under the No-Action Alternative is due to an increase in time and area with water temperatures warmer than the reported thermal tolerance range for river lamprey adult spawning in the upper portion of the lower Feather River, resulting in a decrease in the time and area within the reported thermal tolerance range for the species and life stage. The decrease in relative habitat suitability due to warmer water temperatures generally could result in increased incidence of stress response including increased metabolic rate, decreased growth rate, and potentially increased mortality (Bond 1996; Moyle 2002; Moyle and Cech 2000).

Table G-AQUA3.4-18. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for river lamprey adult spawning.

Water Temperature Index Value	**43°F-72°F**
Existing Conditions	
Minimum Percentage of Time Value	90%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	639,158
Percentage of Time at Maximum Habitat Units	100%
OHSIV	**2,901,102**
No-Action Alternative	
Minimum Percentage of Time Value	90%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	670,928
Percentage of Time at Maximum Habitat Units	100%
OHSIV	**2,899,309**
Percent Change	**-0.06%**

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-18 for the river lamprey adult spawning life stage did not change between the No-Action Alternative and existing conditions for the 43°F to 72°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-18 for the river lamprey adult spawning life stage did not change between the No-Action Alternative and existing conditions for the 43°F to 72°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-18 for the river lamprey adult spawning life stage for the 43°F to 72°F water temperature range under existing conditions and the No-Action Alternative is 639,158 and 670,928, respectively. The difference in Habitat Units at 100 Percent of Time between existing conditions and the No-Action Alternative is 31,770, which represents a 4.97 percent decrease in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are between 43°F to 72°F.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-18 for the river lamprey adult spawning life stage did not change between the No-Action Alternative and existing conditions for the 43°F to 72°F water temperature range.

G-AQUA3.4.9.2 Summary of Potential Effects on River Lamprey

Study plan report summaries addressing project effects on river lamprey are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

Differences in habitat suitability due to water temperature changes are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect river lamprey adult spawning. However, continued degradation of spawning gravel quality in the lower Feather River would result in a slightly adverse effect on river lamprey adult spawning by reducing the quality and quantity of available habitat.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have no effect on river lamprey adult spawning relative to existing conditions.

G-AQUA3.4.10 Sacramento Splittail

G-AQUA3.4.10.1 Flow-related Effects

No flow changes are anticipated to occur in the Low Flow Channel. Mean monthly flow changes during the Sacramento splittail spawning period would result in a decrease of 215 cfs in January, 138 cfs in February, and 20 cfs in March. Associated changes in river stage would be less than 0.1 ft, which would result in no change in useable flooded area for Sacramento splittail spawning. Therefore, mean monthly flow changes under the No-Action Alternative would have no effect on Sacramento splittail adult spawning.

G-AQUA3.4.10.2 Water Temperature–related Effects

No water temperature changes are anticipated to occur in the Low Flow Channel.

Figure G-AQUA3.4-59 shows the proportion of time that habitat units are considered suitable for each water temperature range selected. The area under each curve displayed in Figure G-AQUA3.4-59 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA3.4-59 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 45°F to 75°F. Figures depicting the amount of habitat with water temperatures below 45°F or above 75°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of the No-Action Alternative on Sacramento splittail adult spawning.

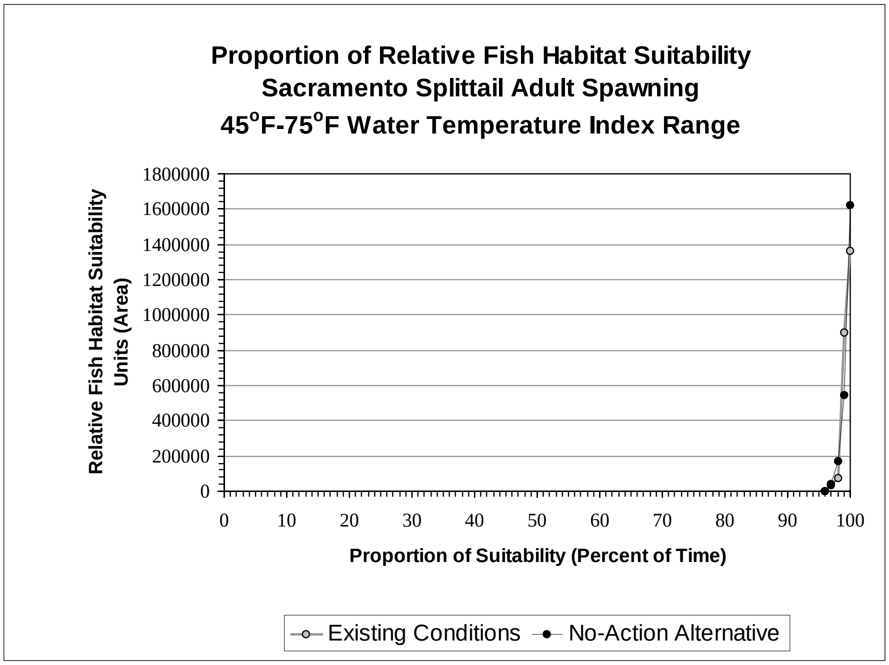


Figure G-AQUA3.4-59. Proportion of relative fish habitat suitability for Sacramento splittail adult spawning for the 45°F to 75°F water temperature range.

The OHSIV presented in Table G-AQUA3.4-19 for Sacramento splittail adult spawning for the 45°F to 75°F water temperature range under existing conditions and the No-Action Alternative are 2,373,553 and 2,375,091, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 1,538, which represents a 0.06 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. Because analysis of the 45°F to 75°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.06 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for Sacramento splittail adult spawning in the lower Feather River. The increase in relative habitat suitability under the No-Action Alternative is due to a decrease in time and area with water temperatures cooler than the reported thermal tolerance range for Sacramento splittail adult spawning, resulting in an increase in the time and area within the reported thermal tolerance range for the species and life stage. The increase in relative habitat suitability could result in decreased incidence of stress response.

Table G-AQUA3.4-19. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for Sacramento splittail adult spawning.

Water Temperature Index Value	**45°F-75°F**
Existing Conditions	
Minimum Percentage of Time Value	97%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	1,361,832
Percentage of Time at Maximum Habitat Units	100%
OHSIV	**2,373,553**
No-Action Alternative	
Minimum Percentage of Time Value	97%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	1,623,755
Percentage of Time at Maximum Habitat Units	100%
OHSIV	**2,375,091**
Percent Change	**0.06%**

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-19 for the Sacramento splittail adult spawning life stage did not change between the No-Action Alternative and existing conditions for the 45°F to 75°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-19 for the Sacramento splittail adult spawning life stage did not change between the No-Action Alternative and existing conditions for the 45°F to 75°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-19 for the Sacramento splittail adult spawning life stage for the 45°F to 75°F water temperature range under existing conditions and the No-Action Alternative is 1,361,832 and 1,623,7558, respectively. The difference in Habitat Units at 100 Percent of Time between existing conditions and the No-Action Alternative is 261,893, which represents a 19.23 percent increase in the amount of habitat area under the No-Action Alternative compared to existing conditions in which water temperatures are between 45°F to 75°F.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-19 for the Sacramento splittail adult spawning life stage did not change between the No-Action Alternative and existing conditions for the 45°F to 75°F water temperature range.

G-AQUA3.4.10.3 Summary of Potential Effects on Sacramento Splittail

Study plan report summaries addressing project effects on Sacramento splittail are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

No flow or water temperature–related effects are expected to occur in the Low Flow Channel. Flow changes in the High Flow Channel are not anticipated to decrease the river stage appreciable over potential spawning benches in the lower Feather River, thereby having no effect on Sacramento splittail adult spawning. Differences in habitat suitability due to water temperature changes are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect Sacramento splittail adult spawning.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have a no effect on Sacramento splittail adult spawning relative to existing conditions.

G-AQUA3.4.11 Striped Bass

G-AQUA3.4.11.1 Flow-related Effects

No flow changes are anticipated to occur in the Low Flow Channel. Mean monthly flow changes during the striped bass adult spawning period are not expected to appreciably change river stage. Therefore, mean monthly flow changes under the No-Action Alternative would have no effect on striped bass adult spawning.

G-AQUA3.4.11.2 Water Temperature-related Effects

No water temperature changes are anticipated to occur in the Low Flow Channel.

Figure G-AQUA3.4-60 shows the proportion of time that habitat units are considered suitable for each water temperature range selected. The area under each curve displayed in Figure G-AQUA3.4-60 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA3.4-60 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 59°F to 68°F. Figures depicting the amount of habitat with water temperatures below 59°F or above 68°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of the No-Action Alternative on striped bass adult spawning.

The OHSIV presented in Table G-AQUA3.4-20 for striped bass adult spawning for the 59°F to 68°F water temperature range under existing conditions and the No-Action Alternative are 46,472 and 46,506, respectively. The difference in OHSIV between existing conditions and the No-Action Alternative is 33, which represents a 0.07 percent increase in OHSIV under the No-Action Alternative compared to existing conditions. Because analysis of the 59°F to 68°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.07 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for striped bass adult spawning in the lower Feather River. The increase in relative habitat suitability under the No-Action Alternative is due to a

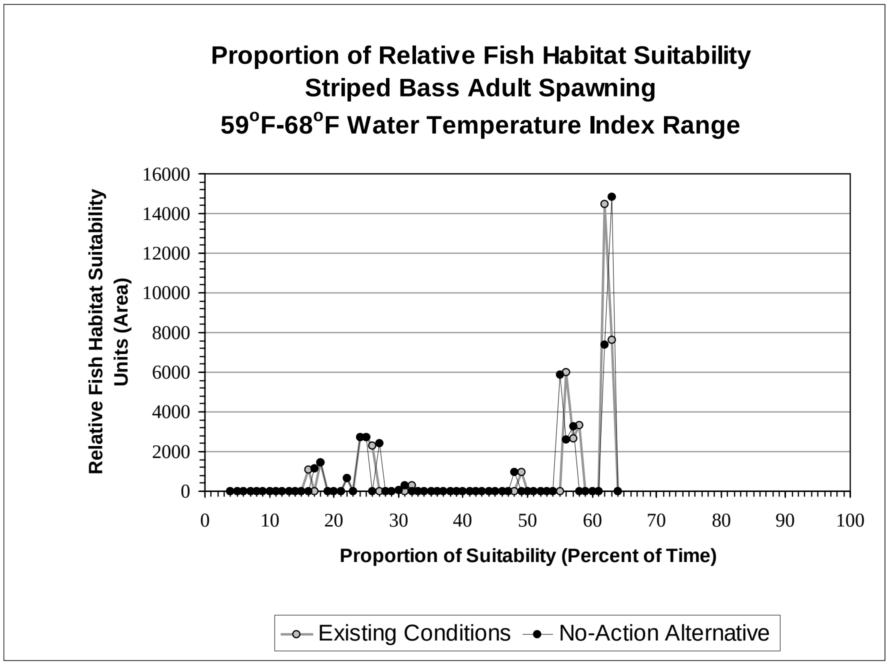


Figure G-AQUA3.4-60. Proportion of relative fish habitat suitability for striped bass adult spawning for the 59°F to 68°F water temperature range.

Table G-AQUA3.4-20. Overall habitat suitability index value comparison between Existing Conditions and the No-Action Alternative for striped bass adult spawning.

Water Temperature Index Value	**59°F-68°F**
Existing Conditions	
Minimum Percentage of Time Value	5%
Maximum Percentage of Time Value	63%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	62%
OHSIV	**46,472**
No-Action Alternative	
Minimum Percentage of Time Value	5%
Maximum Percentage of Time Value	63%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	63%
OHSIV	**46,596**
Percent Change	**0.07%**

decrease in time and area with water temperatures warmer than the reported thermal tolerance range for striped bass adult spawning during certain portions of the life stage period and an increase in time and area with water temperatures cooler than the reported thermal tolerance range for striped bass adult spawning during certain portions of the life stage period. The increase in OHSIV below the reported thermal tolerance range for striped bass adult spawning could result in more habitat during some portion of the life stage period in which increased incidence of stress response including lowered metabolic rates, decreased forage activity, decreased growth rates, and increased mortality rates could potentially occur (Bond 1996; Moyle 2002; Moyle and Cech 2000). However, the decrease in OHSIV above the reported thermal tolerance range for striped bass adult spawning during some portion of the life stage period would result in a decreased incidence of stress response during that period. The combination of decreased time and area above the reported thermal tolerance range and increased time and area below the thermal tolerance range for striped bass adult spawning under the No-Action Alternative results in an overall increase in time and area within the water temperature range defined as suitable.

The Minimum Percentage of Time Value metric presented in Table G-AQUA3.4-20 for the striped bass adult spawning life stage did not change between existing conditions and the No-Action Alternative for the 59°F to 68°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA3.4-20 for the striped bass adult spawning life stage did not change between existing conditions and the No-Action Alternative for the 59°F to 68°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA3.4-20 for the striped bass adult spawning life stage did not change between existing conditions and the No-Action Alternative for the 59°F to 68°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA3.4-20 for the striped bass adult spawning life stage under existing conditions and the No-Action Alternative for the 59°F to 68°F water temperature range is 62 percent and 63 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between existing conditions and the No-Action Alternative is 1 percent, which represents a small decrease in the percentage of time that the habitat is suitable in the greatest area.

G-AQUA3.4.11.3 Summary of Potential Effects on Striped Bass

Study plan report summaries addressing project effects on striped bass are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

No flow or water temperature–related effects are expected to occur in the Low Flow Channel. Flow changes in the High Flow Channel are not anticipated to appreciably alter river stage in the lower Feather River, thereby having no effect on striped bass spawning. Differences in habitat suitability due to water temperature changes are less than 1 percent between existing conditions and the No-Action Alternative and, as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect striped bass adult spawning.

Overall, operation of the Oroville Facilities under the No-Action Alternative is anticipated to have a no effect on striped bass adult spawning relative to existing conditions.

APPENDIX G-AQUA4
AQUATIC RESOURCES
EFFECTS OF THE PROPOSED ACTION

This appendix provides qualitative analyses of potential effects on aquatic resources with implementation of the Proposed Action, relative to the No-Action Alternative. Although the following topical outline is consistent for analysis of both alternatives, effects on several issue areas are not anticipated to occur under the Proposed Action. From an aquatic resources perspective, there are only a few differences between the No-Action Alternative and the Proposed Action. (See Section 3.1, No-Action Alternative, and Section 3.2, Proposed Action, for a detailed description of the No-Action Alternative and Proposed Action conditions.) Flow releases from the Oroville Facilities, reservoir water surface elevations, and water temperatures with implementation of the Proposed Action are anticipated to be the same as under the No-Action Alternative. Therefore, no quantitative analysis is required or provided to show potential effects on aquatic resources related to changes in flows, reservoir water surface elevations, or water temperature and the resultant effects on the quantity, quality, or distribution of fish habitat.

Actions included in the Proposed Action that are relevant to the assessment of the effects on aquatic resources, and that are not included in the No-Action Alternative, consist of improving existing side-channel fish habitat, a Gravel Supplementation and Improvement Program, and a Large Woody Debris Supplementation and Improvement Program for the lower Feather River. Additionally, the Proposed Action includes fish barrier weirs for the segregation of spring-run Chinook salmon spawning, and adaptive management of the Feather River Fish Hatchery. The actions included in the Proposed Action are evaluated qualitatively in the subsections below. A detailed description of the methodology used to analyze potential effects on aquatic resources is provided in Appendix G-AQUA2, Methodology.

G-AQUA4.1 HABITAT COMPONENTS AFFECTED BY THE OROVILLE FACILITIES

G-AQUA4.1.1 Chinook Salmon Spawning Segregation

Two fish barrier weirs would be installed in the lower Feather River downstream of the Fish Barrier Dam and upstream of the Thermalito Afterbay Outlet with implementation of the Proposed Action. Installation of fish barrier weirs may provide for some level of segregation between spring- and fall-run Chinook salmon and may help alleviate some of the adverse effects of high spawning densities in this reach of the lower Feather River. Appropriately placed weirs could potentially simulate historic spatial segregation of runs by selectively allowing or blocking fish passage on a temporal basis.

In addition to providing a mechanism for segregation of spring- and fall-run Chinook salmon, weirs could reduce redd superimposition and its effects on salmonid productivity in the lower Feather River. (For a discussion of redd superimposition, particularly in the lower Feather River, see Study Plan [SP] F10, Task 2B, *Evaluation of Potential Effects of Facilities Operations on Spawning Chinook Salmon*, in Section G-

AQUA1.8.2 in Appendix G-AQUA1.) By controlling access to spawning habitat on a temporal basis, the adverse effects of redd superimposition, particularly on spring-run Chinook salmon, may be reduced.

Other potential benefits of installing weirs in the lower Feather River include providing a mechanism to allow collection of valuable data on timing, abundance, and movements of Feather River fish species. The installation of fish weirs would provide a flexible management tool for the reach of the Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet.

Two fish weirs are proposed as part of the Proposed Action. The proposed location for the weir furthest upstream is near Bedrock Park at approximately River Mile (RM) 66. The proposed downstream location for the second weir is near Gateway Riffle at approximately RM 60. The installation of weirs in the lower Feather River may create some potential resource conflicts and necessitate some changes to project operations. For example, weirs could conflict with current fishing and boating recreation in this reach of the Feather River. (See Section 5.10.2.2 for additional information on the potential recreational effects of this action.) Additionally, placement of the upper weir at Bedrock Park would inhibit collection of fall-run Chinook salmon brood stock through the existing fish ladder located at the Fish Barrier Dam. The upstream fish barrier weir would include an egg taking station to replace fall-run Chinook salmon access to the Feather River Fish Hatchery fish ladder.

G-AQUA4.1.2 Macroinvertebrate Populations

Macroinvertebrate communities in the lower Feather River would likely benefit from implementation of the Proposed Action. The Large Woody Debris Supplementation and Improvement Program included in the Proposed Action would benefit macroinvertebrates by increasing habitat diversity and contributing nutrients. The Gravel Supplementation and Improvement Program would reduce substrate armoring, improving the quality of macroinvertebrate habitat. The side-channel improvement of Moe’s Ditch and Hatchery Ditch would also offer increased and more diverse habitat for aquatic macroinvertebrates.

G-AQUA4.1.3 Woody Debris Recruitment

Implementation of the Proposed Action would include supplementing large woody debris in the lower Feather River to satisfy fish habitat improvement goals for the duration of the license period. The reach of the Feather River extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet is used intensively as spawning habitat for anadromous salmonids. The Large Woody Debris Supplementation and Improvement Program would contribute to both the geomorphic and ecological functions of the lower Feather River. Additional woody debris would enhance rearing habitat for juvenile salmonids by providing cover and would create scour pools that may serve as holding habitat for anadromous salmonids. Additional large woody debris would also trap sediment, allowing recruitment of riparian vegetation, and decaying large woody debris would provide an additional source of instream nutrients for aquatic organisms. Large woody debris placed or recaptured in backwater mesohabitats below the Thermalito Afterbay Outlet may enhance habitat for warmwater species such as black bass.

The Proposed Action includes the placement of large woody debris in the lower Feather River primarily from the Fish Barrier Dam to the Thermalito Afterbay Outlet, and possibly in other locations downstream of the Afterbay Outlet. In general, single logs, groups of logs, or combinations of logs and boulders that are anchored or cabled together would be placed in the river (Flosi 1998). Anchoring would probably be required for projects that are intended to be site specific, such as riprapped banks or side channels. Wood may also be anchored at banks with cables or between natural or artificial structures.

Placement of large woody debris could create conflicts with landowners adjacent to the channel if bank erosion is inadvertently increased as a result of flow diversion. (See Section 5.8.2.2 for additional information on potential effects of a Large Woody Debris Supplementation and Improvement Program on land use.) Placement of large woody debris could also decrease river navigability in some areas. (See Section 5.10.2.2 for additional information on potential effects of a Large Woody Debris Supplementation and Improvement Program on recreation.)

Under current regulated-flow regimes, placements of large woody debris would provide localized benefits on fish habitat until a high flow event. When that occurs, the magnitude of the flow event would redistribute both naturally recruited and supplemented large woody debris. This redistribution is a normal ecosystem function; however, the large woody debris in the upstream reaches of the Low Flow Channel would need to be replaced following these events. In the event that large woody debris moves out of the Feather River during extreme flow events, it would provide fish habitat benefits downstream on the Sacramento River, perhaps as far as the Sacramento Delta.

G-AQUA4.1.4 Gravel Recruitment

The Proposed Action includes supplementing gravel in the lower Feather River directly below the Fish Barrier Dam and at selected anadromous salmonid spawning riffles between the Fish Barrier Dam and Honcut Creek that would benefit from spawning substrate improvement. The Proposed Action also provides for the ripping and raking of substrate in selected areas of the lower Feather River that are potential salmonid spawning sites, but where the substrate has become armored or sufficiently coarsened in particle size distribution to reduce salmonid spawning habitat quality. (See Section 5.3.1.1 for additional information on gravel conditions.)

Sites that may benefit from gravel supplementation were identified in SP-G2. Depending on the findings of surveys conducted after gravel supplementations, additional supplementations may be conducted in the same areas or certain sites may be abandoned. Likewise, potential sites that may benefit from ripping and raking were identified in SP-G2. Future surveys may determine other areas where ripping and raking of substrate may enhance spawning habitat.

Information gathered from SP-G2 has identified specific sites downstream of the Fish Barrier Dam and upstream of the Thermalito Afterbay Outlet that may benefit from supplementation of spawning gravel. Supplementation of gravel at these locations is intended to increase suitable spawning habitat quality and quantity for anadromous salmonids by restoring habitat substrate. The spawning gravel supplement and improvement program would provide the greatest benefit to the spawning areas in the upstream-most portions of the Low Flow Channel below the Fish Barrier Dam because they currently have the most degraded substrate quality and the least suitability for salmonid spawning. Additionally, gravel supplemented near the base of the Fish Barrier Dam would be mobilized during high flow events and would be redistributed downstream, mimicking normal gravel recruitment that occurred before dam construction. Subsequent gravel placements would be required after future peak-flow events to maintain benefits provided by supplementation of spawning gravel. The improvement of spawning substrate in the upstream reaches of the Low Flow Channel complements the function of the fish barrier weirs—spatial segregation of spring-run Chinook salmon—by providing habitat enhancements in those locations that provide direct benefits to this ESA species.

G-AQUA4.1.5 Channel Complexity

Implementation of the Proposed Action includes enhancement of the existing side-channel habitat in Hatchery Ditch and Moe’s Ditch, both located downstream of the Fish Barrier Dam and adjacent to the Feather River Fish Hatchery. Enhancements to these existing side channels could include reforming the channel for increased water depth and shoreline diversity, placing boulders and woody debris for cover and velocity diversity, and gravel substrate supplementation. The enhancement of these existing side channels would primarily benefit steelhead and spring-run Chinook salmon by increasing the quantity and quality of spawning and rearing habitat.

G-AQUA4.1.6 Water Quality Criteria for Aquatic Life

Water quality conditions for aquatic life are not expected to change with implementation of the Proposed Action, with the exception of any short-term water quality effects associated with instream construction activities such as the fish barrier weirs, enhancement of side-channel habitat, placement of large woody debris, or gravel placement, ripping, or raking. (See Section 5.4.2.2 for the evaluation of construction-related effects on water quality.)

G-AQUA4.2 WARMWATER RESERVOIR FISHERIES

G-AQUA4.2.1 Operations-related Effects

G-AQUA4.2.1.1 Spawning and Initial Rearing

No changes in reservoir water surface elevations, rates of reduction, or surface level fluctuations in Lake Oroville or Thermalito Afterbay are anticipated with implementation of the Proposed Action.

G-AQUA4.2.1.2 Fish Interactions

No changes in fish stocking or in the frequency of sediment wedge exposure from Lake Oroville water surface elevations are anticipated with implementation of the Proposed Action.

G-AQUA4.2.2 Fisheries Management–related Effects

G-AQUA4.2.2.1 Stocking

No changes in warmwater fish stocking or the habitat enhancement program are anticipated with implementation of the Proposed Action.

G-AQUA4.2.2.2 Disease

No changes in the types or rates of warmwater fish diseases are anticipated with implementation of the Proposed Action.

G-AQUA4.2.2.3 Recreational Access or Fishing Regulations

Recreation enhancements included in the Proposed Action are anticipated to increase recreation and angling. Increased angling is expected to result in increased sport fish harvest. Fishing access would be increased through the construction of a fishing pier or platform at the Diversion Pool and South Forebay DUA and increased shoreline access in the north Forebay through the construction of trails. (See Section 5.10.2 for additional information on recreation enhancements.) No changes in regulations for warmwater sport fishing are anticipated with implementation of the Proposed Action.

G-AQUA4.2.3 Summary of Potential Effects on Warmwater Reservoir Fisheries

Implementation of the Proposed Action would not affect the quality or quantity of warmwater fish habitat available in Oroville Facilities reservoirs.

G-AQUA4.3 COLDWATER RESERVOIR FISHERIES

G-AQUA4.3.1 Operations-related Effects

G-AQUA4.3.1.1 Habitat Availability

No changes in reservoir water surface elevations and the associated quality and quantity of effective available coldwater pool habitat in Lake Oroville are anticipated with implementation of the Proposed Action.

G-AQUA4.3.1.2 Fish Interactions

No changes in fish stocking or in the frequency of sediment wedge exposure from Lake Oroville water surface elevations are anticipated with implementation of the Proposed Action.

G-AQUA4.3.2 Fisheries Management–related Effects

G-AQUA4.3.2.1 Stocking

No changes in coldwater fish stocking are anticipated with implementation of the Proposed Action.

G-AQUA4.3.2.2 Disease

No changes in potential exposure to fish diseases is anticipated with implementation of the Proposed Action.

G-AQUA4.3.2.3 Recreational Access or Fishing Regulations

Recreation enhancements included in the Proposed Action are anticipated to increase recreation and angling. Increased angling is expected to result in increased sport fish harvest. Fishing access would be increased through the construction of a fishing pier or platform at the Diversion Pool and South Forebay DUA and increased shoreline access in the north Forebay through the construction of trails. (See Section 5.10.2 for additional information on recreation enhancements.) No changes in regulations for coldwater sport fishing are anticipated with implementation of the Proposed Action.

G-AQUA4.3.3 Summary of Potential Effects on Coldwater Reservoir Fisheries

Implementation of the Proposed Action would not affect the quality or quantity of coldwater fish habitat available in Oroville Facilities reservoirs.

G-AQUA4.4 LOWER FEATHER RIVER FISH SPECIES

The overall determination of effects on each species of primary management concern in the lower Feather River with implementation of the Proposed Action incorporates all of the types of effects associated with each PM&E measure included in the alternative for each life stage of the species. Qualitative and quantitative analyses were performed on various potential effects resulting from implementation of the Proposed Action to determine the incremental effects associated with each PM&E measure included in the alternative. The results of the effects analysis of each PM&E measure on each life stage were synthesized to determine the overall effects of the alternative on the species.

G-AQUA4.4.1 Fall-run Chinook Salmon

G-AQUA4.4.1.1 Flow-related Effects

No flow changes are included in the Proposed Action; therefore, no flow-related effects on adult immigration, adult spawning and embryo incubation, or juvenile rearing and downstream movement by fall-run Chinook salmon are anticipated.

G-AQUA4.4.1.2 Water Temperature–related Effects

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related effects on adult immigration, adult spawning and embryo incubation, or juvenile rearing and downstream movement by fall-run Chinook salmon are anticipated.

G-AQUA4.4.1.3 Predation-related Effects

No flow or water temperature changes are included in the Proposed Action; therefore, no changes are anticipated in the composition of predator species, or in distribution or consumption rates. Adaptive-management changes in steelhead hatchery release practices may reduce predation of juvenile salmonids.

G-AQUA4.4.1.4 Fisheries Management–related Effects

Hatchery

The Hatchery Adaptive Management Program included in the Proposed Action considers a range of potential changes in Feather River Fish Hatchery practices designed to reduce adverse effects of the hatchery on wild fish stocks and to improve the benefits to the Chinook salmon produced by the hatchery. Changes in hatchery practices intended to more successfully separate the breeding of spring-run vs. fall-run Chinook salmon would reduce the amount of genetic introgression between these two runs that may have previously occurred in the hatchery. Other potential adaptive management elements may include changes in steelhead size and timing of release to reduce potential steelhead predation on juvenile Chinook salmon. Other adaptive management elements could include changes to raceways at the Feather River Fish Hatchery to improve conditioning of rearing fish to wild behavior for predator avoidance and preference for cover. An enhanced fish marking program included in the adaptive management options would improve the ability to measure hatchery performance and increase the understanding of the fisheries resources in the lower Feather River.

Disease

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related interactions with the incidence of disease are anticipated.

Fishing Regulations, Poaching, and Change in Recreational Access and Visitation

Recreation enhancements included in the Proposed Action are anticipated to increase recreation and angling. Increased angling is expected to result in increased sport fish harvest. Fishing access in the lower Feather River is anticipated to increase with the implementation of the Proposed Action through the implementation of the fish barrier weirs and other recreation enhancements included in the Proposed Action. (See Section 5.10.2 for additional information on recreation enhancements.)

Installation of fish barrier weirs in the Lower Feather River would require no-fishing zones in the immediate proximity of the installations. Although the fish barrier weirs would be navigable by boats, the presence of the weirs may affect boating recreation activities to some degree. (See Section 5.10.2.2 for additional information about effects of fish barrier weirs on recreation.) Increased densities of fish below the fish barriers and river access on the weirs may potentially contribute to fish poaching opportunities with implementation of the Proposed Action.

G-AQUA4.4.1.5 Summary of Potential Effects on Fall-run Chinook Salmon

Study plan report summaries addressing project effects on fall-run Chinook salmon are presented in Section G-AQUA1.3, Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area; Section G-AQUA1.5, Fisheries Management; Section G-AQUA1.8, Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam; and Section G-AQUA1.11, Predation, in Appendix G-AQUA1. A description of each life stage for fall-run Chinook salmon and the time period associated with it is presented in Appendix G-AQUA1, Affected Environment.

Implementation of the Proposed Action would not alter flows or water temperatures in the lower Feather River compared to the No-Action Alternative. Specifically, there would be no changes in immigration, spawning, or rearing habitat quantity and quality caused by water temperature or stage elevation changes. Additionally, there would be no changes in predation rates or disease incidence as a result of changes in water temperatures. Therefore, no water temperature or flow-related effects on any fall-run Chinook salmon life stage would occur with implementation of the Proposed Action.

Adult Immigration and Holding

Actions potentially affecting adult immigration and holding by fall-run Chinook salmon include a Hatchery Adaptive Management Program, fish barrier weirs, and a Large Woody Debris Supplementation and Improvement Program. The Hatchery Adaptive Management Program would potentially have a beneficial effect on immigrating adult fall-run Chinook salmon by allowing more accurate identification of returning Feather River Fish Hatchery fish and by increasing genetic isolation between runs, thereby reducing effects on phenotypic separation with respect to immigration timing.

Installation of fish barrier weirs would have a beneficial effect on immigration by adult fall-run Chinook salmon by eliminating fishing pressure in the no-fishing zones in the vicinity of the fish barrier weirs. It would also increase genetic segregation of runs by spatially segregating holding adult spring-run Chinook salmon from immigrating fall-run Chinook salmon. However, the potential for increased poaching of fall-run Chinook salmon in the vicinity of the fish barrier weirs likely would be increased because of higher fish densities and increased access to the lower Feather River in those locations.

The Large Woody Debris Supplementation and Improvement Program would have a beneficial effect on immigrating adult fall-run Chinook salmon by creating potential velocity refuges.

Overall, implementation of the Proposed Action would result in a beneficial effect on fall-run Chinook salmon adult immigration and holding.

Spawning and Embryo Incubation

Actions potentially affecting adult spawning and embryo incubation by fall-run Chinook salmon include a Hatchery Adaptive Management Program, fish barrier weirs, and gravel supplementation. The hatchery adaptive management program would potentially have a beneficial effect by reducing genetic introgression between spring- and fall-run Chinook salmon.

Installation of fish barrier weirs in the lower Feather River likely would benefit adult spawning and embryo incubation by fall-run Chinook salmon by maintaining spatial segregation of spawning spring-run and fall-run Chinook salmon, and by eliminating fishing pressure on fish spawning in the no-fishing zones in the vicinity of the fish barrier weirs. However, the potential for poaching of fall-run Chinook salmon in the vicinity of the fish barrier weirs likely would be increased because of higher fish densities and increased access to the lower Feather River in those areas.

Gravel supplementation benefits fall-run Chinook salmon adult spawning and embryo incubation by increasing the amount of available spawning habitat, thereby reducing competition for available habitat and redd superimposition.

Overall, implementation of the Proposed Action would result in a beneficial effect on fall-run Chinook salmon adult spawning and embryo incubation.

Juvenile Rearing and Downstream Movement

Actions potentially affecting juvenile rearing and downstream movement by fall-run Chinook salmon include a Hatchery Adaptive Management Program, a Gravel Supplementation and Improvement Program, and a Large Woody Debris Supplementation and Improvement Program. The Hatchery Adaptive Management

Program would potentially have a beneficial effect on this life stage by improving genetic segregation between spring- and fall-run Chinook salmon. Additionally, by potentially altering the size and timing of juvenile steelhead released into the lower Feather River, the Hatchery Adaptive Management Program could reduce predation rates on rearing and emigrating fall-run Chinook salmon. By altering raceways at the Feather River Fish Hatchery, the Hatchery Adaptive Management Program could increase post-release survival rates of juvenile fall-run Chinook salmon.

The Gravel Supplementation and Improvement Program and Large Woody Debris Supplementation and Improvement Program would potentially have a beneficial effect on rearing and downstream migrating fall-run Chinook salmon by increasing channel complexity and the amount and quality of rearing habitat. However, placement of large woody debris could potentially have an adverse effect by increasing warmwater predator habitat downstream of the Thermalito Afterbay Outlet.

Overall, implementation of the Proposed Action would result in a beneficial effect on fall-run Chinook salmon juvenile rearing and downstream movement.

Conclusion

Based on the above summary of potential effects, it is likely that the Proposed Action would result in an overall beneficial effect on fall-run Chinook salmon.

G-AQUA4.4.2 Spring-run Chinook Salmon

G-AQUA4.4.2.1 Flow-related Effects

No flow changes are included in the Proposed Action; therefore, no flow-related effects on adult immigration and holding, adult spawning and embryo incubation, or juvenile rearing and downstream movement of spring-run Chinook salmon are anticipated.

G-AQUA4.4.2.2 Water Temperature–related Effects

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related effects on adult immigration and holding, adult spawning and embryo incubation, or juvenile rearing and downstream movement of spring-run Chinook salmon are anticipated.

G-AQUA4.4.2.3 Predation-related Effects

No flow or water temperature changes are included in the Proposed Action; therefore, no changes are anticipated in the composition of predator species, or in distribution or consumption rates. Adaptive management changes in steelhead hatchery release practices may reduce predation of juvenile salmonids with implementation of the Proposed Action.

G-AQUA4.4.2.4 Fisheries Management–related Effects

Hatchery

The Hatchery Adaptive Management Program included in the Proposed Action considers a range of potential changes in hatchery practices designed to reduce adverse effects of the Feather River Fish Hatchery on wild fish stocks and improve the benefits to the Chinook salmon produced by the hatchery. Changes in hatchery practices intended to more successfully separate the breeding of spring-run vs. fall-run Chinook salmon would reduce the amount of genetic introgression between these two runs that may have previously occurred in the hatchery. Other potential adaptive management elements may include changes in steelhead size and timing of release to reduce potential steelhead predation on juvenile Chinook salmon. Other adaptive management elements could include changes to raceways at the Feather River Fish Hatchery to improve conditioning of rearing fish to wild behavior for predator avoidance and preference for cover. An enhanced fish marking program included in the adaptive management options would improve the ability to measure hatchery performance and increase the understanding of the fisheries resources in the lower Feather River.

Disease

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related interactions with the incidence of disease are anticipated.

Fishing Regulations, Poaching, and Change in Recreational Access and Visitation

Recreation enhancements included in the Proposed Action are anticipated to increase recreation and angling. Increased angling is expected to result in increased sport fish harvest. Fishing access in the lower Feather River is anticipated to increase with the implementation of the Proposed Action through the installation of fish barrier weirs and other recreation enhancements included in the Proposed Action. (See Section 5.10.2 for additional information on recreation enhancements.)

Installation of fish barrier weirs in the Lower Feather River would require no-fishing zones in the immediate proximity of the installations. Although the fish barrier weirs would be navigable by boats, the presence of the weirs may affect boating recreation activities to some degree. (See Section 5.10.2.2 for additional information on fish barrier weir effects on recreation.) Increased densities of fish below the fish barriers and river access on the weirs may potentially contribute to fish poaching opportunities with implementation of the Proposed Action.

G-AQUA4.4.2.5 Summary of Potential Effects on Spring-run Chinook Salmon

Study plan report summaries addressing project effects on spring-run Chinook salmon are presented in Section G-AQUA1.3, Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area; Section G-AQUA1.5, Fisheries Management; Section G-AQUA1.8**,** Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam; and Section G-AQUA1.11 Predation, in Appendix G-AQUA1. A description of each spring-run Chinook salmon life stage and the time period associated with it is presented in Appendix G-AQUA1, Affected Environment.

Implementation of the Proposed Action would not alter flows or water temperatures in the lower Feather River compared to the No-Action Alternative. Specifically, there would be no changes in habitat quantity and quality for the immigration and holding, spawning and embryo incubation, or juvenile rearing and downstream movement life stages as a result of water temperature or stage elevation changes. Additionally, there would be no changes in predation rates or disease incidence as a result of changes in water temperatures. Therefore, no water temperature or flow-related effects on any spring-run Chinook salmon life stage would occur with implementation of the Proposed Action.

Adult Immigration and Holding

Actions potentially affecting adult immigration and holding by spring-run Chinook salmon include a Hatchery Adaptive Management Program, fish barrier weirs, and a Large Woody Debris Supplementation and Improvement Program. The Hatchery Adaptive Management Program potentially would provide a beneficial effect by allowing more accurate identification of returning hatchery fish and by increasing genetic isolation between runs, thereby improving phenotypic separation between runs with respect to immigration timing.

Installation of fish barrier weirs would have a beneficial effect on spring-run Chinook salmon adult immigration and holding by eliminating fishing pressure within the no-fishing zones in the vicinity of the fish barrier weirs, and by increasing genetic segregation between runs by spatially segregating holding adult spring-run Chinook salmon from immigrating fall-run Chinook salmon. However, the potential for poaching of spring-run Chinook salmon in the vicinity of the fish barrier weirs likely would be increased because of higher fish densities and increased access to the lower Feather River in those locations.

Large woody debris supplementation upstream of the fish barrier weirs would have a beneficial effect on this life stage by creating potential velocity refuges for holding adult spring-run Chinook salmon.

Overall, implementation of the Proposed Action would result in a beneficial effect on spring-run Chinook salmon adult immigration and holding.

Adult Spawning and Embryo Incubation

Actions potentially affecting adult spawning and embryo incubation by spring-run Chinook salmon include a Hatchery Adaptive Management Program, fish barrier weirs, side-channel habitat enhancement, and a Gravel Supplementation and Improvement Program. The Hatchery Adaptive Management Program would potentially provide a beneficial effect by reducing the rate of genetic introgression between spring- and fall-run Chinook salmon.

Installation of fish barrier weirs in the lower Feather River likely would benefit adult spawning and embryo incubation by spring-run Chinook salmon by maintaining spatial segregation of spawning spring-run and fall-run Chinook salmon, and by eliminating fishing pressure on fish spawning in the no-fishing zones in the vicinity of the fish barrier weirs. Additionally, fish barrier weirs would provide a beneficial effect by reducing competition for spawning habitat, which would reduce redd superimposition, and thereby increase embryo survival. However, the potential for poaching of spring-run Chinook salmon in the vicinity of the fish barrier weirs likely would be increased because of higher fish densities and increased access to the lower Feather River in those areas.

Side-channel habitat enhancement and the Gravel Supplementation and Improvement Program could potentially benefit spring-run Chinook salmon adult spawning and embryo incubation by increasing the amount of available spawning habitat, thereby reducing competition for available habitat and reducing redd superimposition.

Overall, implementation of the Proposed Action would result in a beneficial effect on spring-run Chinook salmon adult spawning and embryo incubation.

Juvenile Rearing and Downstream Movement

Actions potentially affecting juvenile rearing and downstream movement by spring-run Chinook salmon include a Hatchery Adaptive Management Program, side-channel habitat enhancement, a Gravel Supplementation and Improvement Program, and a Large Woody Debris Supplementation and Improvement Program. The Hatchery Adaptive Management Program would potentially have a beneficial effect on this life stage by increasing genetic segregation between spring- and fall-run Chinook salmon. Additionally, by potentially altering the size and timing of juvenile steelhead released into the lower Feather River, the Hatchery Adaptive Management Program could reduce predation on rearing and emigrating spring-run Chinook salmon. By altering raceways at the Feather River Fish Hatchery, the Hatchery Adaptive Management Program could increase post-release survival rates of juvenile spring-run Chinook salmon.

Side-channel habitat enhancement, the Gravel Supplementation and Enhancement Program, and the Large Woody Debris Supplementation and Improvement Program would potentially have a beneficial effect on rearing and downstream migrating spring-run Chinook salmon by increasing channel complexity and increasing the amount and quality of rearing habitat. However, placement of large woody debris could potentially have an adverse effect by increasing warmwater predator habitat downstream of the Thermalito Afterbay Outlet.

Overall, implementation of the Proposed Action would result in a beneficial effect on spring-run Chinook salmon juvenile rearing and downstream movement.

Conclusion

Based on the above summary of potential effects, it is likely that the Proposed Action would result in an overall beneficial effect on spring-run Chinook salmon.

G-AQUA4.4.3 Steelhead

G-AQUA4.4.3.1 Flow-related Effects

No flow changes are included in the Proposed Action; therefore, no flow-related effects on adult immigration and holding, adult spawning and embryo incubation, fry and fingerling rearing and downstream movement, or smolt emigration by steelhead are anticipated.

G-AQUA4.4.3.2 Water Temperature–related Effects

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related effects on adult immigration and holding, adult spawning and embryo incubation, fry and fingerling rearing and downstream movement, or smolt emigration by steelhead are anticipated.

G-AQUA4.4.3.3 Predation-related Effects

No flow or water temperature changes are included in the Proposed Action; therefore, no changes are anticipated in the composition of predator species, or in distribution or consumption rates. Adaptive management changes in steelhead hatchery release practices may reduce predation of wild juvenile steelhead with implementation of the Proposed Action.

G-AQUA4.4.3.4 Fisheries Management-related Effects

Hatchery

A Hatchery Adaptive Management Program included in the Proposed Action considers a range of potential changes in hatchery practices designed to reduce adverse effects of the Feather River Fish Hatchery on wild fish stocks and improve the benefits to steelhead produced by the hatchery. These potential changes include changes in steelhead size and timing of release to reduce potential size advantages of hatchery steelhead over wild steelhead, as well as to reduce potential steelhead predation on wild juvenile steelhead. Other adaptive management elements could include changes to raceways at the Feather River Fish Hatchery to improve rearing fish conditioning to wild behavior for predator avoidance and preference for cover. An enhanced fish marking program included in the adaptive management options would improve the ability to measure hatchery performance and increase the understanding of the fisheries resources in the lower Feather River.

Disease

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related interactions with the incidence of disease are anticipated.

Fishing Regulations, Poaching, and Change in Recreational Access and Visitation

Recreation enhancements included in the Proposed Action are anticipated to increase recreation and angling. Increased angling is expected to result in increased sport fish harvest. Fishing access in the lower Feather River is anticipated to increase with the implementation of the Proposed Action through the installation of fish barrier weirs and other recreation enhancements included in the Proposed Action. (See Section 5.10.2 for additional information on recreation enhancements.)

Installation of fish barrier weirs in the lower Feather River would require no-fishing zones in the immediate proximity of the installations. Although the fish barrier weirs would be navigable by boats, the presence of the weirs may affect boating recreation activities to some degree. (See Section 5.10.2.2 for additional information on fish barrier weir effects on recreation.) Increased densities of fish below the fish barriers and river access on the weirs may potentially contribute to fish poaching opportunities with implementation of the Proposed Action.

G-AQUA4.4.3.5 Summary of Potential Effects on Steelhead

Study plan report summaries addressing project effects on steelhead are presented in Section G-AQUA1.5, Fisheries Management; Section G-AQUA1.8, Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam; and Section G-AQUA1.11, Predation, in Appendix G-AQUA1. A description of each steelhead life stage and the time period associated with it is presented in Appendix G-AQUA1, Affected Environment.

Implementation of the Proposed Action would not alter flows or water temperatures in the lower Feather River compared to the No-Action Alternative. Specifically, there would be no changes in holding, spawning, or rearing habitat quantity and quality as a result of water temperature or stage elevation changes. Additionally, there would be no changes in predation rates or disease incidence as a result of changes in water temperatures. Therefore, no water temperature or flow-related effects on any steelhead life stage would occur with implementation of the Proposed Action.

Adult Immigration and Holding

Actions potentially affecting steelhead adult immigration and holding include a Hatchery Adaptive Management Program, fish barrier weirs, and a large Woody Debris Supplementation and Improvement Program.

Installation of fish barrier weirs would have a beneficial effect on steelhead adult immigration and holding by eliminating fishing pressure within the no-fishing zones in the vicinity of the fish barrier weirs. However, the potential for poaching of steelhead in the vicinity of the fish barrier weirs likely would be increased because of higher fish densities and increased access to the lower Feather River in those locations.

Large woody debris supplementation upstream of the fish barrier weirs would have a beneficial effect on this life stage by creating potential velocity refuges and cover.

Overall, implementation of the Proposed Action would result in a beneficial effect on steelhead adult immigration and holding.

Adult Spawning and Embryo Incubation

Actions potentially affecting steelhead adult spawning and embryo incubation include a Hatchery Adaptive Management Program, fish barrier weirs, side-channel habitat enhancement, and a Gravel Supplementation and Improvement Program. Installation of fish barrier weirs in the lower Feather River likely would benefit spawning and embryo incubation by steelhead by eliminating fishing pressure on fish spawning in the no-fishing zones in the vicinity of the fish barrier weirs. However, the potential for increased poaching of steelhead in the vicinity of the fish barrier weirs likely would be increased because of higher fish densities and increased access to the lower Feather River in those areas.

Side-channel habitat enhancement and the Gravel Supplementation and Improvement Program could potentially benefit steelhead adult spawning and embryo incubation by increasing the amount and quality of available spawning habitat, thereby reducing competition for available habitat and reducing redd superimposition.

Overall, implementation of the Proposed Action would result in a beneficial effect on steelhead adult spawning and embryo incubation.

Fry and Fingerling Rearing and Downstream Movement

Actions potentially affecting steelhead fry and fingerling rearing and downstream movement include a Hatchery Adaptive Management Program, side-channel habitat enhancement, a Gravel Supplementation and Improvement Program, and a Large Woody Debris Supplementation and Improvement Program. The Hatchery Adaptive Management Program would potentially have a beneficial effect on this life stage by altering the size and timing of juvenile steelhead released into the lower Feather River, reducing predation on emigrating steelhead. Other adaptive management elements could include changes to raceways at the Feather River Fish Hatchery to improve conditioning of rearing fish to wild behavior for predator avoidance and preference for cover.

Side-channel habitat enhancement, gravel enhancement, and the Large Woody Debris Supplementation and Improvement Program would all have a beneficial effect on rearing and downstream migrating steelhead by increasing channel complexity and increasing the amount and quality of rearing habitat. However, placement of large woody debris could potentially have an adverse effect by increasing warmwater predator habitat downstream of the Thermalito Afterbay Outlet.

Overall, implementation of the Proposed Action would result in a beneficial effect on steelhead fry and fingerling rearing and downstream movement.

Smolt Emigration

Actions potentially affecting steelhead smolt emigration include a Hatchery Adaptive Management Program and a Large Woody Debris Supplementation and Improvement Program. The Hatchery Adaptive Management Program would have a beneficial effect on this life stage by potentially altering the size and timing of juvenile steelhead released into the lower Feather River, which could reduce predation rates on emigrating steelhead smolts. Additionally, by altering raceways at the Feather River Fish Hatchery, the program could increase post-release survival rates of steelhead smolts.

The Large Woody Debris Supplementation and Improvement Program would potentially have an adverse effect on steelhead smolt emigration by increasing warmwater predator habitat downstream of the Thermalito Afterbay Outlet.

Overall, implementation of the Proposed Action would result in a neutral effect on steelhead smolt emigration.

Conclusion

Based on the above summary of potential effects, it is likely that the Proposed Action would result in an overall beneficial effect on steelhead.

G-AQUA4.4.4 American Shad

G-AQUA4.4.4.1 Flow-related Effects

No flow changes are included in the Proposed Action; therefore, no flow-related effects on adult immigration and spawning by American shad are anticipated.

G-AQUA4.4.4.2 Water Temperature–related Effects

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related effects on adult immigration and spawning by American shad are anticipated.

G-AQUA4.4.4.3 Summary of Potential Effects on American Shad

Study plan report summaries addressing project effects on American shad are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

Implementation of the Proposed Action would not alter flows or water temperatures in the lower Feather River compared to the No-Action Alternative. Specifically, there would be no changes in immigration or spawning habitat quantity and quality as a result of water temperature or stage elevation changes. Therefore, there would be no water temperature or flow-related effects on American shad with implementation of the Proposed Action.

G-AQUA4.4.5 Black Bass

G-AQUA4.4.5.1 Water Temperature–related Effects

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related effects on black bass spawning are anticipated.

G-AQUA4.4.5.2 Summary of Potential Effects on Black Bass

Study plan report summaries addressing project effects on black bass species are presented in Section G-AQUA1.3, Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area; Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam; Section G-AQUA1.5, Fisheries Management; and Section G-AQUA1.11, Predation, in Appendix G-AQUA1.

Implementation of the Proposed Action would not alter flows or water temperatures in the lower Feather River compared to the No-Action Alternative. Specifically, there would be no changes in spawning habitat quantity and quality as a result of water temperature or stage elevation changes. Therefore, there would be no water temperature or flow-related effects on black bass with implementation of the Proposed Action.

G-AQUA4.4.6 Delta Smelt

G-AQUA4.4.6.1 Habitat Components

Adult Spawning

Delta smelt spawn in the upper Delta upstream of the mixing zone and use a range of substrates for spawning including reeds and other submerged vegetation, sandy or hard substrates, and submerged wood. The Large Woody Debris Supplementation and Improvement Program for the lower Feather River included in the Proposed Action is expected to contribute some large woody debris to the Delta and provide some contributions to habitat diversity and spawning substrate availability, benefiting delta smelt.

G-AQUA4.4.6.2 Summary of Potential Effects on Delta Smelt

Study plan report summaries addressing project effects on delta smelt are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

The distribution range of delta smelt is outside of the direct and indirect effects area for flows and water temperatures associated with the Oroville Facilities, therefore no flow or water temperature effects on delta smelt are anticipated with implementation of the Proposed Action. Delta smelt would potentially benefit from the Large Woody Debris Supplementation and Improvement Program for the lower Feather River as a result of its large woody debris contributions to the Delta, resulting in potential improvements in habitat quality and diversity.

G-AQUA4.4.7 Green Sturgeon

G-AQUA4.4.7.1 Flow-related Effects

No flow changes are included in the Proposed Action; therefore, no flow-related effects on adult immigration by green sturgeon are anticipated.

G-AQUA4.4.7.2 Water Temperature–related Effects

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related effects on adult immigration, adult spawning and embryo incubation, juvenile rearing, or juvenile emigration by green sturgeon are anticipated.

G-AQUA4.4.7.3 Summary of Potential Effects on Green Sturgeon

Study plan report summaries addressing project effects on green sturgeon are presented in Section G-AQUA1.3, Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area; and Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

Implementation of the Proposed Action would not alter flows or water temperatures in the lower Feather River compared to the No-Action Alternative. Specifically, there would be no changes in spawning habitat quantity and quality as a result of water temperature or stage elevation changes. Therefore, there would be no water temperature or flow-related effects on green sturgeon with implementation of the Proposed Action.

G-AQUA4.4.8 Hardhead

G-AQUA4.4.8.1 Water Temperature–related Effects

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related effects on hardhead spawning are anticipated.

G-AQUA4.4.8.2 Summary of Potential Effects on Hardhead

Study plan report summaries addressing project effects on hardhead are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

Implementation of the Proposed Action would not alter flows or water temperatures in the lower Feather River compared to the No-Action Alternative. Specifically, with implementation of the Proposed Action, there would be no changes in spawning habitat quantity and quality as a result of water temperature or stage elevation changes. Therefore, no water temperature or flow-related effects on hardhead would occur with implementation of the Proposed Action.

G-AQUA4.4.9 River Lamprey

G-AQUA4.4.9.1 Water Temperature–related Effects

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related effects on river lamprey spawning are anticipated.

G-AQUA4.4.9.2 Summary of Potential Effects on River Lamprey

Study plan report summaries addressing project effects on river lamprey are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

Implementation of the Proposed Action would not alter flows or water temperatures in the lower Feather River compared to the No-Action Alternative. Specifically, there would be no changes in spawning habitat quantity and quality as a result of water temperature or stage elevation changes. Therefore, there would be no water temperature or flow-related effects on river lamprey with implementation of the Proposed Action. River lamprey would benefit from improved spawning substrate conditions resulting from the Gravel Supplementation and Improvement Program with implementation of the Proposed Action.

G-AQUA4.4.10 Sacramento Splittail

G-AQUA4.4.10.1 Flow-related Effects

No flow changes are included in the Proposed Action; therefore, no flow-related effects on Sacramento splittail spawning are anticipated.

G-AQUA4.4.10.2 Water Temperature–related Effects

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related effects on Sacramento splittail spawning are anticipated.

G-AQUA4.4.10.3 Summary of Potential Effects on Sacramento Splittail

Study plan report summaries addressing project effects on Sacramento splittail are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

Implementation of the Proposed Action would not alter flows or water temperatures in the lower Feather River compared to the No-Action Alternative. Specifically, with implementation of the Proposed Action, there would be no changes in spawning habitat quantity and quality as a result of water temperature or stage elevation changes. Therefore, there would be no water temperature or flow-related effects on Sacramento splittail with implementation of the Proposed Action.

G-AQUA4.4.11 Striped Bass

G-AQUA4.4.11.1 Flow-related Effects

No flow changes are included in the Proposed Action; therefore, no flow-related effects on adult spawning, embryo incubation, or initial rearing by striped bass are anticipated.

G-AQUA4.4.11.2 Water Temperature–related Effects

No water temperature changes are included in the Proposed Action; therefore, no water temperature–related effects on adult spawning, embryo incubation, or initial rearing by striped bass are anticipated.

G-AQUA4.4.11.3 Summary of Potential Effects on Striped Bass

Study plan report summaries addressing project effects on striped bass are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, in Appendix G-AQUA1.

Implementation of the Proposed Action would not alter flows or water temperatures in the lower Feather River compared to the No-Action Alternative. Specifically, there would be no changes in spawning habitat quantity and quality as a result of water temperature or stage elevation changes. Therefore, there would be no water temperature or flow-related effects on striped bass with implementation of the Proposed Action.

G-AQUA4.5 REFERENCES

Bilby, R. E., P. A. Fransen, P. A. Bisson, and J. K. Walter. 1998. Response of Juvenile Salmon (*Onchorhynchus kisutch*) and Steelhead (*Onchorhynchus mykiss*) to the Addition of Salmon Carcasses to Two Streams in Southwestern Washington, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 39:426-447.

Cox, W. T., Senior Fish Pathologist, DFG, Sacramento, California; E-mail communication with E.Theis, Fishery Biologist, NOAA, Sacramento, California; DFG Disease Concerns Regarding Upstream Passage, September 12, 2003.

Finney, B. P., I. Gregory-Eaves, J. Sweetnam, M. S. V. Douglas, and J. P. Smol. 2000. Impacts of Climatic Change and Fishing on Pacific Salmon Abundance Over the Past 300 Years. Science 290:795-799.

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 1998. California Salmonid Stream Habitat Restoration Manual - Appendix E: Salmon Spawner Surveys. Fish Document #98. Sacramento, CA: CDFG.

Leary, R. F., F. W. Allendorf, and G. K. Sage. 1995. Hybridization and Introgression between Introduced and Native Fish. American Fisheries Society Symposium 15:91-101.

Minkawa, N., and R. I. Gara. 1999. Ecological Effects of a Chum Salmon (*Oncorhynchus keta*) Spawning Run in a Small Stream of the Pacific Northwest. Journal of Freshwater Ecology 14:327-335.

Minkawa, N., R. I. Gara, and J. M. Honea. 2002. Increase Growth Rate and Community Biomass of Stream Insects Associated With Salmon Carcasses. Journal of the North American Benthological Society 21:651-659.

Schuldt, J. A., and A. E. Hershey. 1995. Effect of Salmon Carcass Decomposition on Lake Superior Tributary Streams. Journal of the North American Benthological Society 14:259-268.

Ward, B. R., and P. A. Slaney. 1988. Life History and Smolt-to-Adult Survival of Keogh River Steelhead Trout (*Salmo gairdneri*) and the Relationship to Smolt Size. Canadian Journal of Fisheries and Aquatic Science 45:1110-1122.

Wipfli, M. S., J. Hudson, and J. Caouette. 1998. Influence of Salmon Carcasses on Stream Productivity: Response of Biofilm and Benthic Macroinvertebrates in Southeastern Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 55:1503-1511.

Withler, I. L. 1966. Variability in Life History Characteristics of Steelhead Trout (*Salmo gairdneri*) Along the Pacific Coast of North America. J.Fish.Res.Board Can. 23(3):365-393.

APPENDIX G-AQUA5
AQUATIC RESOURCES
EFFECTS OF ALTERNATIVE 2

This appendix provides qualitative analyses of potential effects on aquatic resources with implementation of Alternative 2, relative to the No-Action Alternative. Although the following topical outline is consistent for analysis of each alternative, effects on several issue areas are not anticipated to occur under Alternative 2. From an aquatic resources perspective, there are only a few differences between the No-Action Alternative and Alternative 2. (See Section 3.1, No-Action Alternative, and Section 3.3, Alternative 2, for a detailed description of No-Action Alternative and Alternative 2 conditions.) Oroville Facilities net flow releases and reservoir water surface elevations under Alternative 2 are anticipated to be the same as under the No-Action Alternative. Therefore, no quantitative analysis is required or provided to show potential effects on aquatic resources related to changes in flows below the Thermalito Afterbay Outlet in the lower Feather River or reservoir water surface elevations and the resultant effects on the quantity, quality, or distribution of fish habitat.

Actions included in Alternative 2 that are relevant to the quantitative assessment of effects on aquatic resources, and that are not included in the No-Action Alternative, consist of changes in water temperature management targets at Robinson Riffle and increases in minimum flows in the Low Flow Channel. Under Alternative 2, flows in the Low Flow Channel would increase from 600 cubic feet per second (cfs) under the No-Action Alternative to 800 cfs, and from May 1 through June 15 would increase to either 1,200 cfs or the total project release, whichever is less. These flow and temperature changes are evaluated quantitatively in the subsections below. Additional description and analysis of the flow changes are available in Section 5.4.2.1, Water Quantity Environmental Effects.

Actions included in Alternative 2 that are relevant to the qualitative assessment of the effects on aquatic resources, and that are not included in the No-Action Alternative, consist of improvements to existing side-channel fish habitat, creation of new side-channel habitat, and a Gravel Supplementation and Improvement Program and Large Woody Debris Supplementation and Improvement Program for the lower Feather River. Additionally, Alternative 2 includes installation of fish barrier weirs for the segregation of fall-run and spring-run Chinook salmon spawning, and adaptive management of the Feather River Fish Hatchery. These actions are evaluated qualitatively in the subsections below. A detailed description of the methodology used to analyze potential effects on aquatic resources is provided in Appendix G-AQUA2, Methodology.

G-AQUA5.1 HABITAT COMPONENTS AFFECTED BY THE OROVILLE FACILITIES

G-AQUA5.1.1 Chinook Salmon Spawning Segregation

Actions associated with installation of fish barrier weirs to address the spatial segregation of spring-run Chinook salmon under Alternative 2 are identical to those actions included with implementation of the Proposed Action. (See Section G-AQUA4.1

in Appendix G-AQUA4, Effects of the Proposed Action, for an evaluation of these actions relative to the No-Action Alternative.)

G-AQUA5.1.2 Macroinvertebrate Populations

Macroinvertebrate communities in the lower Feather River would likely benefit from implementation of Alternative 2. The Large Woody Debris Supplementation and Improvement Program included in Alternative 2 would benefit macroinvertebrates by increasing habitat diversity and contributing nutrients. Gravel supplementation and improvement would reduce substrate armoring, improving the quality of macroinvertebrate habitat. The improvement of Moe's Ditch and Hatchery Ditch, as well as the creation of additional side-channel habitat and increased flows in the Low Flow Channel included in Alternative 2, would also increase the quantity and diversity of habitat for aquatic macroinvertebrates.

G-AQUA5.1.3 Woody Debris Recruitment

Actions associated with the Large Woody Debris Supplementation and Improvement Program under Alternative 2 are identical to those actions included with implementation of the Proposed Action. (See Section G-AQUA4.1 in Appendix G-AQUA4, Effects of the Proposed Action, for an evaluation of these actions relative to the No-Action Alternative.)

G-AQUA5.1.4 Gravel Recruitment

Actions associated with the Gravel Supplementation and Improvement Program under Alternative 2 are identical to those actions included with implementation of the Proposed Action. (See Section G-AQUA4.1 in Appendix G-AQUA4, Effects of the Proposed Action, for an evaluation of these actions relative to the No-Action Alternative.)

G-AQUA5.1.5 Channel Complexity

Implementation of Alternative 2 would include enhancement of the existing side-channel habitat in Hatchery Ditch and Moe's Ditch, both located downstream of the Fish Barrier Dam and adjacent to the Feather River Fish Hatchery. Enhancements to these existing side channels could include reforming of the channel for increased water depth and shoreline diversity, placement of boulders and woody debris for cover and velocity diversity, and gravel substrate supplementation. The enhancement of these existing side channels would benefit steelhead and spring-run Chinook salmon primarily by increasing the quantity and quality of spawning and rearing habitat.

Alternative 2 also includes construction of new side-channel habitat to benefit spring-run Chinook salmon and steelhead spawning and juvenile rearing. Construction of the side channels would increase the amount and improve the quality of available habitat for these two ESA-listed species during the important spawning and juvenile rearing life stages that occur in the lower Feather River.

G-AQUA5.1.6 Water Quality Criteria for Aquatic Life

Water quality conditions for aquatic life are not expected to change with implementation of Alternative 2, with the exception of any short-term water quality effects associated with instream construction activities such as the fish barrier weirs, structural modification of Shanghai Bench and Sunset Pumps, enhancement or construction of side-channel habitat, the Large Woody Debris Supplementation and Improvement Program, or the Gravel Supplementation and Improvement Program. See Section 5.4.2.2 for an evaluation of construction-related effects on water quality.

G-AQUA5.2 WARMWATER RESERVOIR FISHERIES

G-AQUA5.2.1 Operations-related Effects

G-AQUA5.2.1.1 Spawning and Initial Rearing

No changes in reservoir water surface elevations, rates of reduction, or surface level fluctuations in Lake Oroville or Thermalito Afterbay are anticipated under Alternative 2, relative to the No-Action Alternative.

G-AQUA5.2.1.2 Fish Interactions

No changes in warmwater fish stocking, habitat improvement programs, or the frequency of sediment wedge exposure affecting reservoir and upstream tributary fish interactions are anticipated under Alternative 2, relative to the No-Action Alternative.

G-AQUA5.2.2 Fisheries Management–related Effects

G-AQUA5.2.2.1 Stocking

No changes in warmwater fish stocking or the habitat enhancement program are anticipated with implementation of Alternative 2.

G-AQUA5.2.2.2 Disease

No changes in the types or rates of warmwater fish diseases are anticipated with implementation of Alternative 2.

G-AQUA5.2.2.3 Recreational Access or Fishing Regulations

Section 5.10.2, Recreation Resources Environmental Effects, forecasts a one-third increase in recreation and angling activities with the No-Action Alternative and an approximately 51 percent increase in recreation and angling under Alternative 2, as compared to the existing condition. This would indicate an expected increase of approximately 18 percent in recreation and angling under Alternative 2, relative to the No-Action Alternative. A 18 percent increase in angling, with no other PM&E measures associated with fisheries, would potentially result in increased sport fish harvest rates and reduced catch sizes and catch rates. Fishing access would be increased under

Alternative 2 with the implementation of several recreation facilities. No changes in regulations for warmwater sport fishing are anticipated with implementation of Alternative 2.

G-AQUA5.2.3 Summary of Potential Effects on Warmwater Reservoir Fisheries

No changes to the quality, quantity, or distribution of warmwater fisheries habitat are anticipated. Increased angler sport harvest rates may adversely affect the quality of the warmwater sport fishery with implementation of Alternative 2.

G-AQUA5.3 COLDWATER RESERVOIR FISHERIES

G-AQUA5.3.1 Operations-related Effects

G-AQUA5.3.1.1 Habitat Availability

The reservoir surface elevations and drawdown rates under Alternative 2 are the same as under the No-Action Alternative. Water temperature targets for the lower Feather River are lower in Alternative 2 than in the No-Action Alternative, therefore release of the coldwater pool is somewhat increased under Alternative 2. As a result of increased coldwater releases, the coldwater pool volume is decreased somewhat in Alternative 2 relative to the No-Action Alternative. (See Section 5.4.2 for additional information on changes in coldwater pool volume.) Coldwater fish habitat is defined by the volume of water that meets both water temperature and DO requirements to support coldwater fish species. Suitable coldwater fish habitat meeting both of these criteria tends to exist in the upper portion of the coldwater pool below the thermocline. Because Alternative 2 is not expected to alter the nature of the thermocline or DO in the reservoir, the effective volume of water meeting the coldwater fish habitat criteria is not expected to change with implementation of Alternative 2.

G-AQUA5.3.1.2 Fish Interactions

No changes in fish stocking or in the frequency of sediment wedge exposure from Lake Oroville water surface elevations are anticipated with implementation of Alternative 2.

G-AQUA5.3.2 Fisheries Management–related Effects

G-AQUA5.3.2.1 Stocking

No changes in coldwater fish stocking are anticipated with implementation of Alternative 2.

G-AQUA5.3.2.2 Disease

No changes in potential exposure to fish diseases is anticipated with implementation of the Alternative 2.

G-AQUA5.3.2.3 Recreational Access or Fishing Regulations

Section 5.10.2, Recreation Resources Environmental Effects, forecasts a one-third increase in recreation and angling activities with the No-Action Alternative and an approximately 51 percent increase in recreation and angling under Alternative 2, as compared to the existing condition. This would indicate an expected increase of approximately 18 percent in recreation and angling under Alternative 2 relative to the No-Action Alternative. A 18 percent increase in angling, with no other PM&E measures associated with fisheries, would potentially result in increased sport fish harvest rates and reduced catch sizes and catch rates. Fishing access would be increased under Alternative 2 with the implementation of several recreation facilities. No changes in regulations for coldwater sport fishing are anticipated with implementation of Alternative 2.

G-AQUA5.3.3 Summary of Potential Effects on Coldwater Reservoir Fisheries

No changes to the quality, quantity, or distribution of coldwater fisheries habitat are anticipated under Alternative 2. Increased angler sport harvest rates may adversely affect the quality of the coldwater sport fishery with implementation of Alternative 2.

G-AQUA5.4 LOWER FEATHER RIVER FISH SPECIES

The overall determination of effects on each species of primary management concern in the lower Feather River with implementation of Alternative 2 incorporates all of the types of effects associated with each PM&E measure included in the alternative for each life stage of the species. Qualitative and quantitative analyses were performed on various potential effects resulting from implementation of Alternative 2 to determine the incremental effects associated with each PM&E measure included in the alternative. The results of the effects analysis of each PM&E measure on each life stage were synthesized to determine the overall effects of the alternative on the species.

G-AQUA5.4.1 Fall-run Chinook Salmon

G-AQUA5.4.1.1 Flow-related Effects

Adult Immigration and Holding

An increased instream flow of 800 cfs in the Low Flow Channel under Alternative 2 could potentially have a beneficial effect on immigrating and holding fall-run Chinook salmon by increasing the lower Feather River stage elevation over potential critical riffles. Although stage increases would be small, shallow riffles could potentially become deeper, reducing the effort required by immigrating adult fall-run Chinook salmon to proceed through shallow riffles. In addition, water depth would be increased, creating additional amounts of suitable holding habitat relative to water depths.

In addition to a base flow of 800 cfs in the Low Flow Channel, from May 1 through June 15 flows could increase to 1,200 cfs. Section 5.4.2.1 provides a detailed description of the circumstances under which flow increases to 1,200 cfs would occur in the Low Flow

Channel. It is unlikely that flow increases from May through June 15 would affect fall-run Chinook salmon adult immigration and holding because the fall-run Chinook salmon adult immigration and holding period in the Feather River extends from July 15 through December 31.

No flow changes relative to the No-Action Alternative are expected in the High Flow Channel with implementation of Alternative 2.

Adult Spawning and Embryo Incubation

Under Alternative 2, flow in the Low Flow Channel would be 800 cfs year-round, except from May 1 through June 15 when the total releases of the Oroville Facilities, up to a maximum of 1,200 cfs, would be released down the Low Flow Channel. Flow fluctuations in the Low Flow Channel could potentially occur under Alternative 2 to meet water temperature objectives prescribed to protect fisheries resources, or through change in total releases occurring below 1,200 cfs during the May 1 through June 15 period.

Increased flow releases to meet water temperature objectives during September could potentially affect fall-run Chinook salmon spawning and embryo incubation by causing redd dewatering, which could occur as flows return to normal after water temperature objectives are met. Because increasing flows to meet water temperature objectives increases river stage, spawning individuals could potentially construct redds in areas that could be dewatered as flows are lowered to normal levels (800 cfs). However, based on data available on stage-discharge relationships of Low Flow Channel salmonid spawning riffles and Chinook salmon redd water depth distribution from the SP-F16 report (see Section G-AQUA1.10 of Appendix G-AQUA1, Affected Environment), the first redds would not be dewatered until there was more than a 0.4-foot change in stage elevation. Water temperature control flow changes are at or less than 200 cfs, and from 800 cfs to 1,000 cfs all of the spawning riffle stage elevations change less than 0.4 feet. This analysis indicates that no redds would be dewatered in water temperature control–related flow changes in the Low Flow Channel.

Evaluation of the Weighted Useable Area (WUA) index generated by the PHABSIM model for the adult spawning life stage of Chinook salmon (spring-run and fall-run) indicated that the maximum amount of spawning area in the Low Flow Channel, given the current channel configuration, would occur at flows around 850 cfs. Figure G-AQUA5.4-1 shows the WUA curve generated by the PHABSIM model for Chinook salmon spawning in the Low Flow Channel.

Flows in the Low Flow Channel during the spawning period for fall-run Chinook salmon would be 600 cfs under the No-Action Alternative, resulting in approximately 91 percent of maximum WUA. Flows in the Low Flow Channel during the spawning period for fall-run Chinook salmon would be 800 cfs under Alternative 2; according to PHABSIM model results, this would result in almost 100 percent of maximum WUA, representing an increase in the quantity of available spawning habitat compared to the No-Action Alternative.

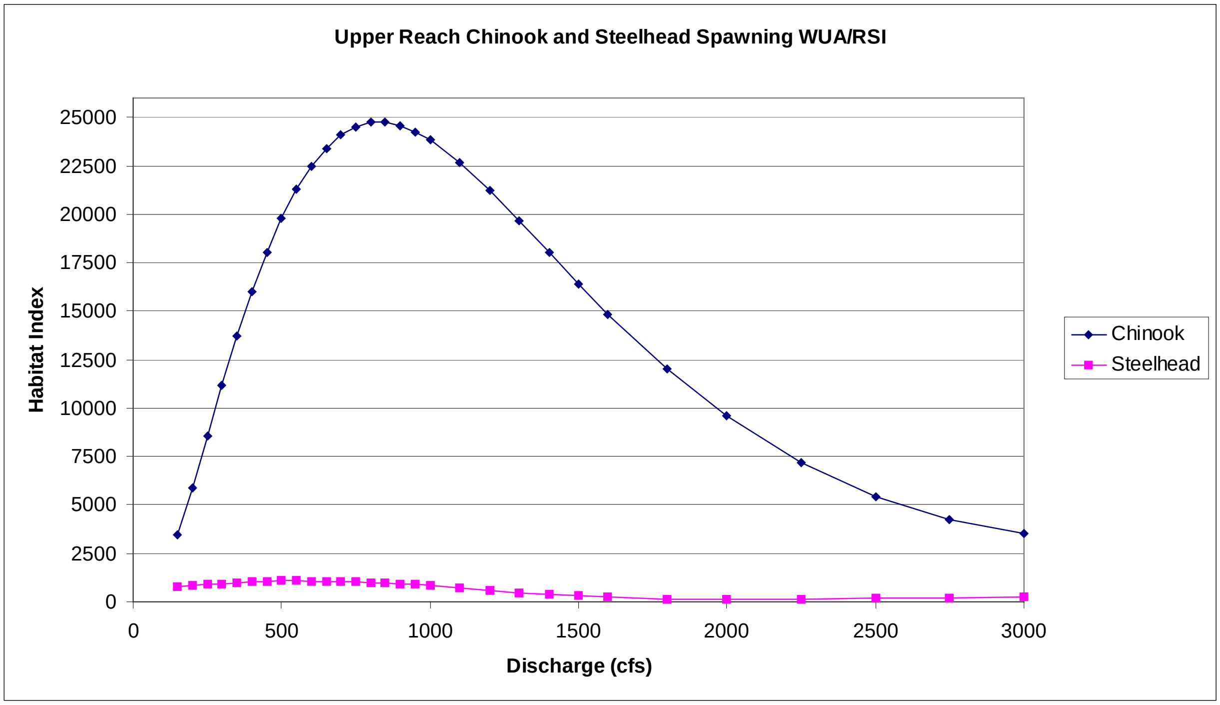


Figure G-AQUA5.4-1. Low Flow Channel WUA curves for steelhead and Chinook salmon.

During extreme drought conditions, total releases from the lower Feather River could be reduced such that releases are no greater than 25 percent of the minimum flow requirement below the Thermalito Afterbay Outlet. The 25 percent reduction in flow below the normal minimum flows amounts to a total flow of 750 cfs below the Thermalito Afterbay Outlet from March through September. The changes in the minimum flow requirements below the Thermalito Afterbay Outlet also could result in reduced flow in the Low Flow Channel. In extreme drought conditions, under Alternative 2, flow in the Low Flow Channel would be 750 cfs at the beginning of the spawning period for fall-run Chinook salmon (September), and no flow would be released from the Thermalito Afterbay Outlet. During the remainder of the spawning period, flows in the Low Flow Channel would increase to 800 cfs (normal conditions under Alternative 2) and 100 cfs would be released from the Thermalito Afterbay Outlet. During extreme drought conditions, flow reductions from 800 cfs to 750 cfs in the Low Flow Channel would occur before the onset of spawning by fall-run Chinook salmon. Therefore, flow reductions during extreme drought conditions likely would not affect spawning by fall-run Chinook salmon in the Low Flow Channel. However, PHABSIM results indicate that a reduction in flow in the Low Flow Channel from 800 cfs to 750 cfs would reduce available spawning habitat from almost 100 percent of maximum WUA to 99 percent of maximum WUA. A 1 percent reduction in available spawning area, as indicated by a 1 percent reduction in WUA, is a small reduction and would be unlikely to affect spawning by fall-run Chinook salmon in the Low Flow Channel.

Under Alternative 2, flows and flow fluctuations occurring in the High Flow Channel are not expected to differ from flows or flow fluctuations that would occur under the No-

Action Alternative as described in Section 5.4.2.1, Water Quantity Environmental Effects. Because there would be no changes in flows or flow fluctuations in the High Flow Channel with implementation of Alternative 2 compared to the No-Action Alternative, Alternative 2 would not result in a change in the amount of spawning habitat available for fall-run Chinook salmon or in rates of redd dewatering occurring in the High Flow Channel.

Juvenile Rearing and Downstream Movement

Increased flows in the Low Flow Channel under Alternative 2 compared to the No-Action Alternative would increase river stage slightly and could potentially increase available rearing habitat for juvenile salmonids including fall-run Chinook salmon. However, the increase in river stage associated with a 200 cfs increase in flow likely would be insufficient to appreciably increase rearing habitat availability. Therefore, increased flows would have no affect on fall-run Chinook salmon juvenile rearing and downstream movement.

Flow fluctuations in the Low Flow Channel could potentially occur under Alternative 2 to meet water temperature objectives prescribed to protect fisheries resources, or through changes in total releases occurring between 800 and 1,200 cfs during the May 1 through June 15 period. Under Alternative 2, the maximum flow fluctuation in the Low Flow Channel would be 400 cfs. Flow fluctuations can result in juvenile salmonid stranding in isolation ponds or beach stranding. Isolation ponds do not occur in the Low Flow Channel below 1,200 cfs; therefore, no isolation pond–type stranding would be anticipated with implementation of Alternative 2. Beach stranding can occur with changes in water surface elevation from changes in flows. Juvenile salmonids tend to select deeper water with increased size and become less susceptible to beach-type stranding as they grow. Flow fluctuations in the Low Flow Channel with implementation of Alternative 2 would occur from May 1 through June 15, with a maximum flow fluctuation of 400 cfs. Typically flow fluctuations for water temperature control in the Low Flow Channel during the summer are 200 cfs or less. A large portion of the juvenile fall-run Chinook population emigrates from the Feather River system before May and therefore would not be subjected to potential beach stranding from flow fluctuations associated with implementation of Alternative 2. Those juvenile fall-run Chinook salmon with prolonged rearing periods would be larger and have deeper water depth rearing preferences before May; therefore, they are less susceptible to beach stranding from flow fluctuations. However, some beach-type stranding could occur due to flow fluctuations occurring under Alternative 2. Water temperature control-related flow changes typically are 200 cfs or less and occur in the summer when rearing juveniles are larger and have preference for deeper water. Therefore rearing juvenile fall-run Chinook salmon would not be susceptible to beach-type stranding resulting from water temperature control-related flow changes.

Implementation of Alternative 2 would not result in any change in the frequency or magnitude of flow fluctuations in the High Flow Channel compared to the No-Action Alternative; therefore, no change in the rate of stranding by juvenile fall-run Chinook salmon would occur in the High Flow Channel.

G-AQUA5.4.1.2 Water Temperature–related Effects

The analysis of relative habitat suitability includes an evaluation of overall relative habitat suitability based on water temperature index values. The analysis includes a comparison of habitat suitability component metrics between the No-Action Alternative and Alternative 2.

The Overall Habitat Suitability Index Value (OHSIV) presented on the bottom row of the habitat suitability analysis table describes the overall relative habitat suitability for each water temperature index value used for the evaluation of each fish species and life stage. This metric represents the total amount of time and area of suitable habitat for each fish species and life stage. Comparison of the OHSIV metric between alternatives indicates which alternative has the greatest amount of suitable habitat with water temperatures equal to or below each water temperature index value.

The “Minimum Percentage of Time Value” and “Maximum Percentage of Time Value” metrics presented in the habitat suitability analysis tables describe the percentage of time that water temperatures within the least and most suitable habitat unit are below each specified index value for each fish species and life stage evaluated, respectively.

In addition, the “Habitat Units at 100 Percent of Time” metric presented in the habitat suitability analysis tables describes the number of habitat units in which water temperatures are always at or below each index value used for each fish species and life stage evaluated.

The “Percentage of Time at Maximum Habitat Units” metric presented in the habitat suitability analysis tables describes the distribution of the population of data, which indicates the percentage of time that water temperatures are equal to or below each water temperature index value selected for each fish species and life stage evaluated in the greatest amount of habitat area. That is, the most area in which water temperatures are below each water temperature index value occurs for some percentage of the total time within the fish species and life stage period. The “Percentage of Time at Maximum Habitat Units” metric describes that peak amount of habitat percentage of time. Detailed descriptions of the methodology used in the derivation and calculation of each of the above metrics is presented in Section G-AQUA2.2.3 of Appendix G-AQUA2, Methodology.

<u>Adult Immigration and Holding</u>

Figures G-AQUA5.4-2, G-AQUA5.4-3, and G-AQUA5.4-4 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA5.4-2, G-AQUA5.4-3, and G-AQUA5.4-4 is equal, which allows for direct comparison of habitat suitability between alternatives.

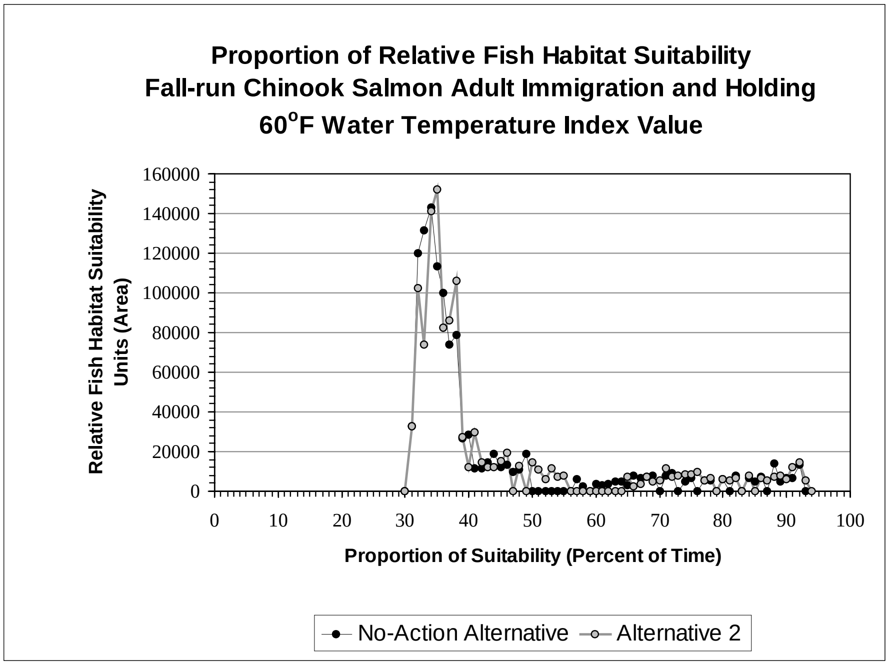


Figure G-AQUA5.4-2. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult immigration and holding for the 60°F water temperature index value.

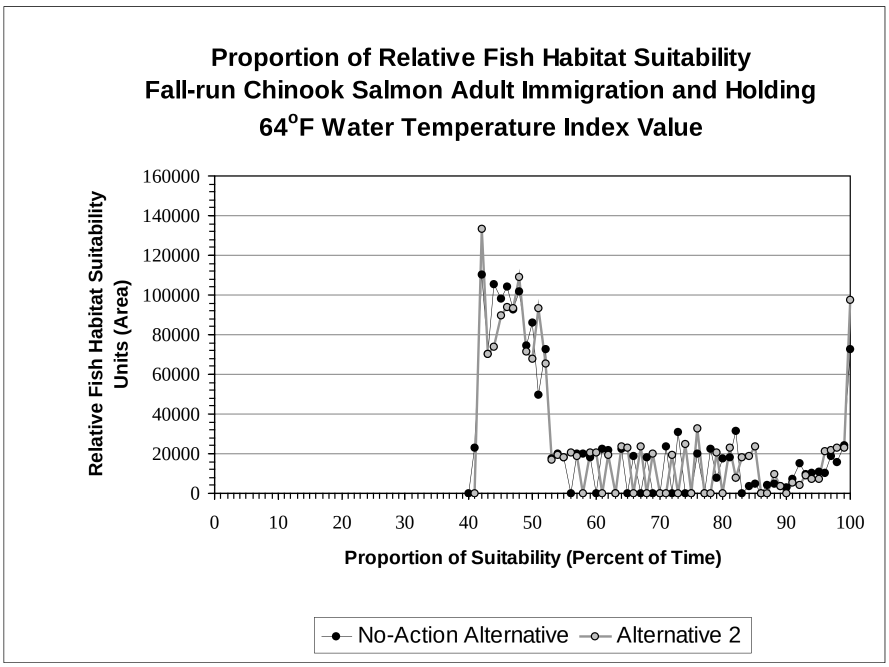


Figure G-AQUA5.4-3. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult immigration and holding for the 64°F water temperature index value.

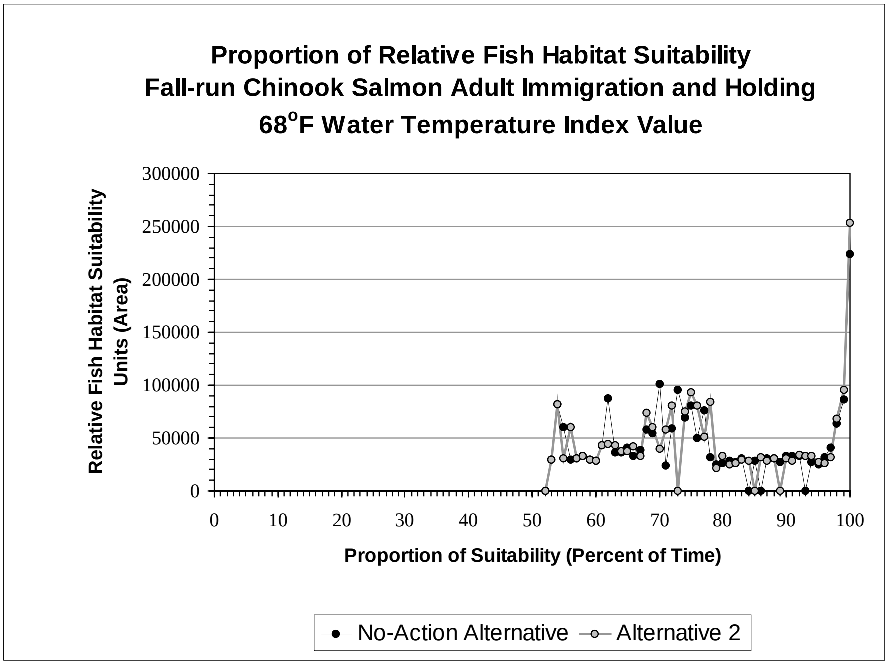


Figure G-AQUA5.4-4. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult immigration and holding for the 68°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA5.4-1 for fall-run Chinook salmon adult immigration and holding for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 1,148,851 and 1,178,538, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 29,687, which represents a 2.58 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 64°F water temperature index value under the No-Action Alternative and Alternative 2 are 1,599,013 and 1,629,108, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 30,095, which represents a 1.88 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,191,674 and 2,216,851, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 25,176, which represents a 1.15 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative.

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-1 for the fall-run Chinook salmon adult immigration and holding life stage did not change between the No-Action Alternative and Alternative 2 for the 60°F, and 68°F water temperature index values. The Minimum Percentage of Time Value metric for the 64°F water temperature index value under the No-Action Alternative and Alternative 2 are 41 and 42 percent, respectively. The 1 percent difference in Minimum Percentage of Time Value between the No-Action Alternative and Alternative 2 represents a small increase in the number of habitat units with the smallest amount of time and area with water temperatures below 64°F under Alternative 2 compared to the No-Action Alternative.

Table G-AQUA5.4-1. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for fall-run Chinook salmon adult immigration and holding.

Water Temperature Index Value	**60°F**	**64°F**	**68°F**
No-Action Alternative			
Minimum Percentage of Time Value	31%	41%	53%
Maximum Percentage of Time Value	92%	100%	100%
Habitat Units at 100 Percent of Time	0	72,837	224,272
Percentage of Time at Maximum Habitat Units	34%	42%	100%
OHSIV	1,148,851	1,599,013	2,191,674
Alternative 2			
Minimum Percentage of Time Value	31%	42%	53%
Maximum Percentage of Time Value	93%	100%	100%
Habitat Units at 100 Percent of Time	0	97,307	253,442
Percentage of Time at Maximum Habitat Units	35%	42%	100%
OHSIV	1,178,538	1,629,108	2,216,851
Percent Change	2.58%	1.88%	1.15%

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-1 for the fall-run Chinook salmon adult immigration and holding did not change between the No-Action Alternative and Alternative 2 for the 64°F and 68°F water temperature index values. The Maximum Percentage of Time Value metric for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 92 percent and 93 percent, respectively. The 1 percent difference in Maximum Percentage of Time Value between the No-Action Alternative and Alternative 2 represents a small increase in the number of habitat units with the greatest amount of time and area with water temperatures below 60°F under Alternative 2 compared to the No-Action Alternative.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-1 for the fall-run Chinook salmon adult immigration and holding life stage did not change between the No-Action Alternative and Alternative 2 for the 60°F water temperature index value. The Habitat Units at 100 Percent of Time for the 64°F water temperature index value under the No-Action Alternative and Alternative 2 are 72,837 and 97,307, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 24,470, which represents approximately a 34 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 64°F. The Habitat Units at 100 Percent of Time for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 224,272 and 253,442, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 29,170, which represents approximately a 13 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 68°F.

A 34 percent increase in the number of habitat units in which water temperatures are always at or below 64°F and above 60°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to immigrating and holding adult fall-run Chinook salmon, such as increased incidence of disease, decreased adult survival, decreased egg viability, and increased latent embryonic abnormalities and mortalities (Berman 1990; EPA 2003; ODEQ 1995; USFWS 1995). A 13 percent increase in the number of habitat units in which water temperatures are always at or below 68°F and above 64°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to immigrating and holding adult fall-run Chinook salmon, such as further increased incidence of disease, additional decreased adult survival, additional decreased egg viability, and additional increased latent embryonic abnormalities and mortalities (Berman 1990; EPA 2003; Marine 1992). A detailed description of the potential effects that could occur to immigrating and holding adult fall-run Chinook salmon from exposure to water temperatures above each water temperature index value is presented in Appendix G-AQUA2.2.3.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-1 for the fall-run Chinook salmon adult immigration and holding life stage did not change between the No -Action Alternative and Alternative 2 for the 64°F or 68°F water temperature index values. The Percentage of Time at Maximum Habitat Units metric presented for the fall-run Chinook salmon adult immigration and holding life stage for the 60°F water temperature index value under the No -Action Alternative and Alternative 2 are 34 percent and 35 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No -Action Alternative is 1 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area.

Adult Spawning and Embryo Incubation

Figures G-AQUA5.4-5, G-AQUA5.4-6, G-AQUA5.4-7, and G-AQUA5.4-8 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA5.4-5, G-AQUA5.4-6, G-AQUA5.4-7, and G-AQUA5.4-8 is equal, which allows for direct comparison of habitat suitability between alternatives.

The OHSIV metrics presented in Table G-AQUA5.4-2 for fall-run Chinook salmon adult spawning and embryo incubation for the 56°F water temperature index value under the No-Action Alternative and Alternative 2 are 91,070 and 93,363, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 2,293, which represents a 2.52 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 58°F water temperature index value under the No-Action Alternative and Alternative 2 are 105,231 and 108,004, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 2,773, which represents a 2.63 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 60°F water temperature index value under the

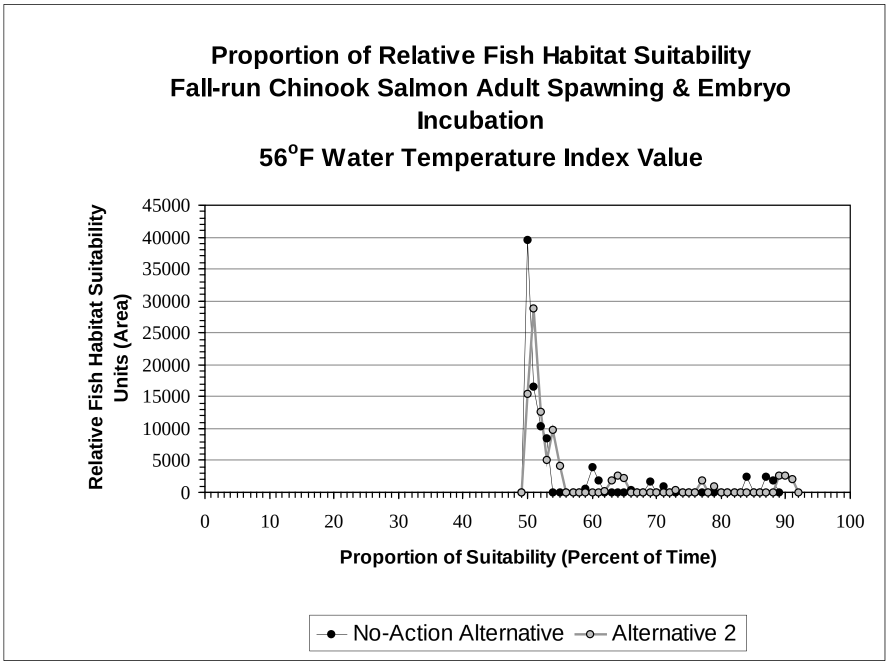


Figure G-AQUA5.4-5. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult spawning and embryo incubation for the 56°F water temperature index value.

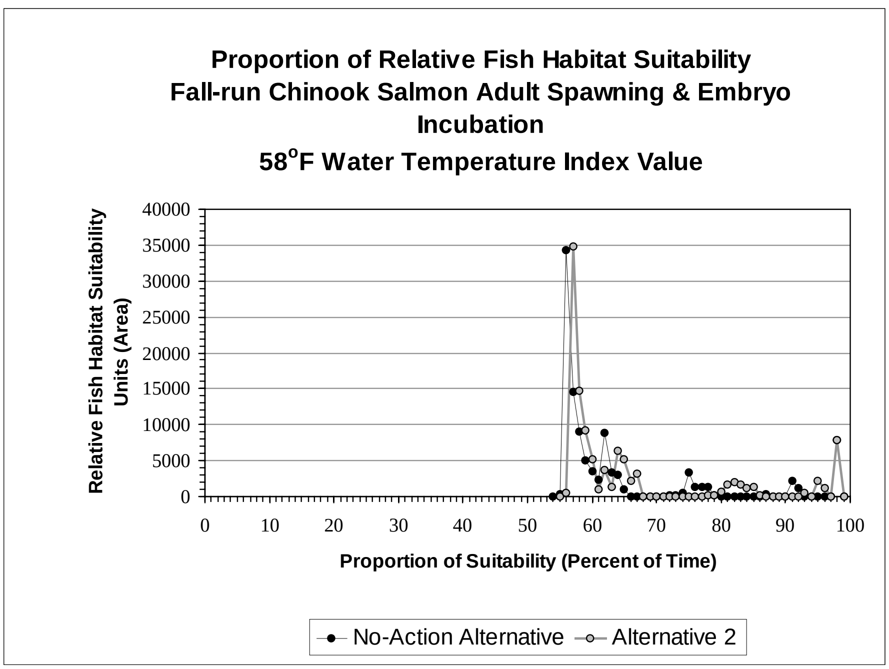


Figure G-AQUA5.4-6. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult spawning and embryo incubation for the 58°F water temperature index value.

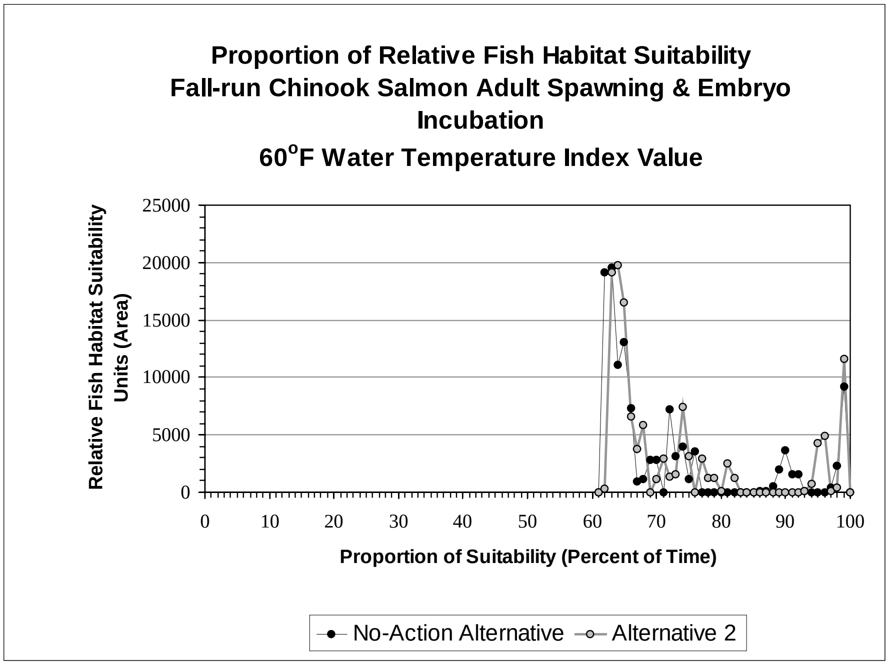


Figure G-AQUA5.4-7. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult spawning and embryo incubation for the 60°F water temperature index value.

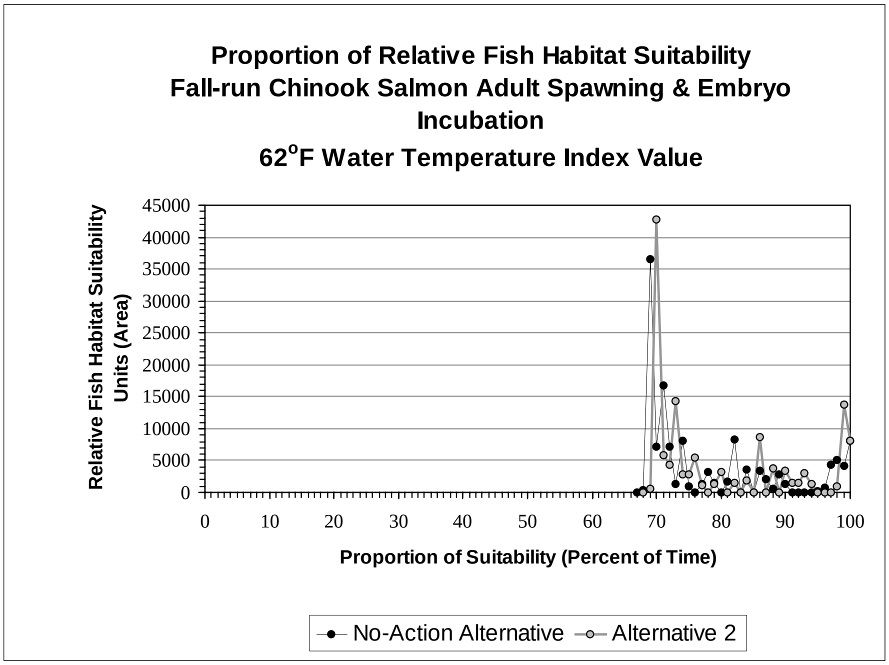


Figure G-AQUA5.4-8. Proportion of relative fish habitat suitability for fall-run Chinook salmon adult spawning and embryo incubation for the 62°F water temperature index value.

Table G-AQUA5.4-2. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for fall-run Chinook salmon adult spawning and embryo incubation.

Water Temperature Index Value	56°F	58°F	60°F	62°F
No-Action Alternative				
Minimum Percentage of Time Value	50%	55%	62%	68%
Maximum Percentage of Time Value	88%	98%	99%	100%
Habitat Units at 100 Percent of Time	0	0	0	8,020
Percentage of Time at Maximum Habitat Units	50%	56%	63%	69%
OHSIV	91,070	105,231	118,429	130,823
Alternative 2				
Minimum Percentage of Time Value	50%	56%	62%	69%
Maximum Percentage of Time Value	91%	98%	99%	100%
Habitat Units at 100 Percent of Time	0	0	0	8,020
Percentage of Time at Maximum Habitat Units	51%	57%	64%	70%
OHSIV	93,363	108,004	121,142	133,455
Percent Change	2.52%	2.63%	2.29%	2.01%

No-Action Alternative and Alternative 2 are 118,429 and 121,142, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 2,713, which represents a 2.29 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 62°F water temperature index value under the No-Action Alternative and Alternative 2 are 130,823 and 133,455, respectively. The difference in OHSIV between the No-Action Alternative and existing conditions is 2,632, which represents a 2.01 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative.

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-2 for the fall-run Chinook salmon adult spawning and embryo incubation life stage did not change between Alternative 2 and the No-Action Alternative for the 56°F and 60°F water temperature index values. The Minimum Percentage of Time Value metric for the 58°F water temperature index value under the No-Action Alternative and Alternative 2 are 55 and 56 percent, respectively. The 1 percent difference in Minimum Percentage of Time Value between Alternative 2 and the No-Action Alternative represents a small increase in the number of habitat units with the smallest amount of time and area with water temperatures below 58°F under Alternative 2 compared to the No-Action Alternative. The Minimum Percentage of Time Value metric for the 62°F water temperature index value under the No-Action Alternative and Alternative 2 are 68 and 69 percent, respectively. The 1 percent difference in Minimum Percentage of Time Value between the No-Action Alternative and Alternative 2 represents a small increase in the number of habitat units with the smallest amount of time and area with water temperatures below 62°F under Alternative 2 compared to the No-Action Alternative.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-2 for the fall-run Chinook salmon adult spawning and embryo incubation life stage did not change between Alternative 2 and the No-Action Alternative for the 58°F, 60°F or 62°F water temperature index values. The Maximum Percentage of Time Value metric for the 56°F water temperature index value under the No-Action Alternative and Alternative 2 are 88 percent and 91 percent, respectively. The three percent difference in Maximum Percentage of Time Value between the No-Action Alternative and Alternative 2 represents an increase in the number of habitat units with the greatest amount of time and area with water temperatures below 56°F under Alternative 2 compared to the No-Action Alternative.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-2 for the fall-run Chinook salmon adult spawning and embryo incubation life stage did not change between Alternative 2 and the No-Action Alternative for any of the water temperature index values selected.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-2 for the fall-run Chinook salmon adult spawning and embryo incubation life stage for the 56°F water temperature index value under the No-Action Alternative and Alternative 2 are 50 and 51 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No -Action Alternative is 1 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area. The Percentage of Time at Maximum Habitat Units metric for the 58°F water temperature index value under the No-Action Alternative and Alternative 2 are 56 and 57 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No -Action Alternative is 1 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area. The Percentage of Time at Maximum Habitat Units metric for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 63 and 64 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No -Action Alternative is 1 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area. The Percentage of Time at Maximum Habitat Units metric for the 62°F water temperature index value under the No-Action Alternative and Alternative 2 are 69 and 70 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No -Action Alternative is 1 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area.

Juvenile Rearing and Downstream Movement

Figures G-AQUA5.4-9, G-AQUA5.4-10, G-AQUA5.4-11, G-AQUA5.4-12, G-AQUA5.4-13, and G-AQUA5.4-14 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA5.4-9, G-AQUA5.4-10, G-AQUA5.4-11, G-AQUA5.4-12, G-AQUA5.4-13, and G-AQUA5.4-14 is equal, which allows for direct comparison of habitat suitability between alternatives.

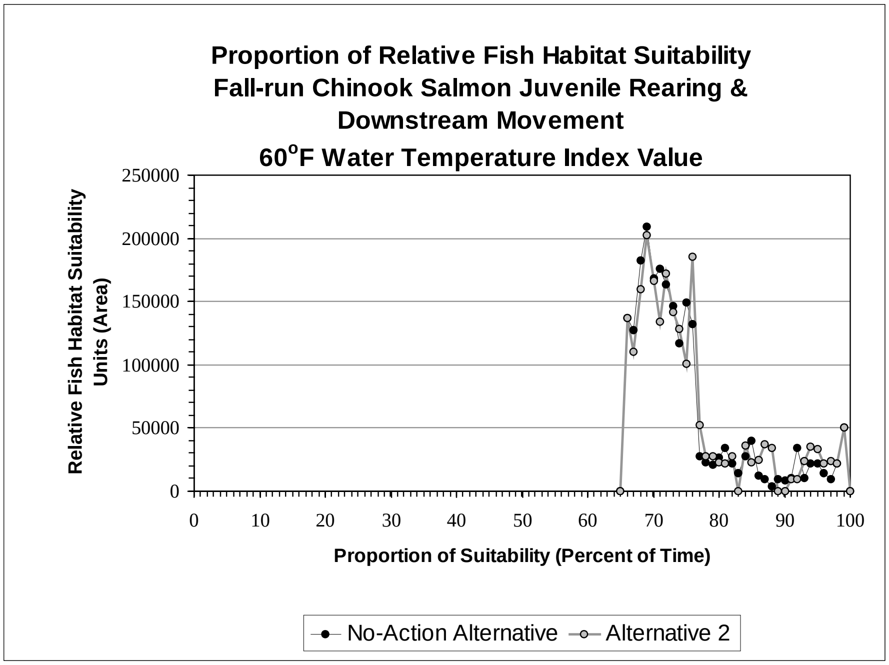


Figure G-AQUA5.4-9. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 60°F water temperature index value.

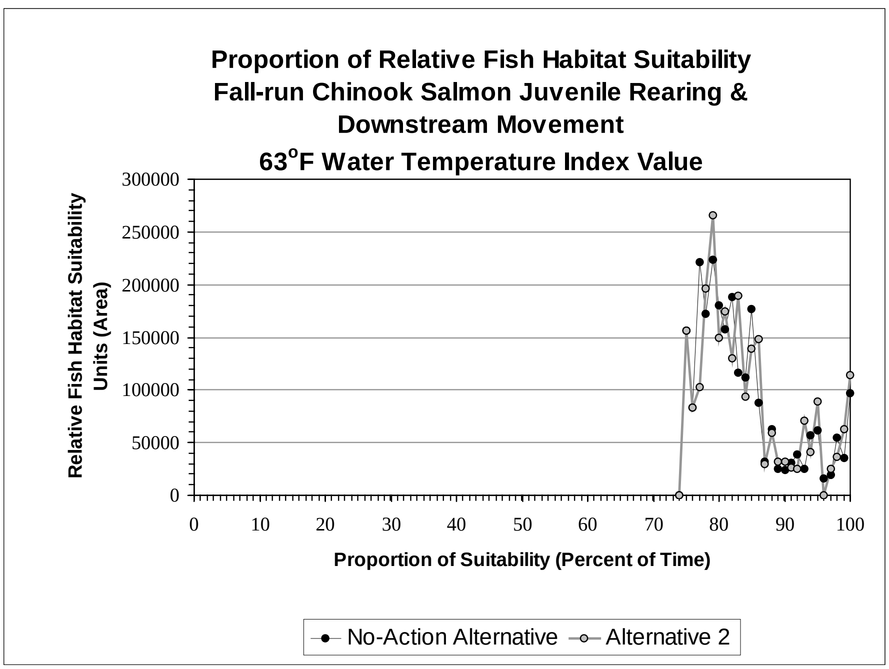


Figure G-AQUA5.4-10. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 63°F water temperature index value.

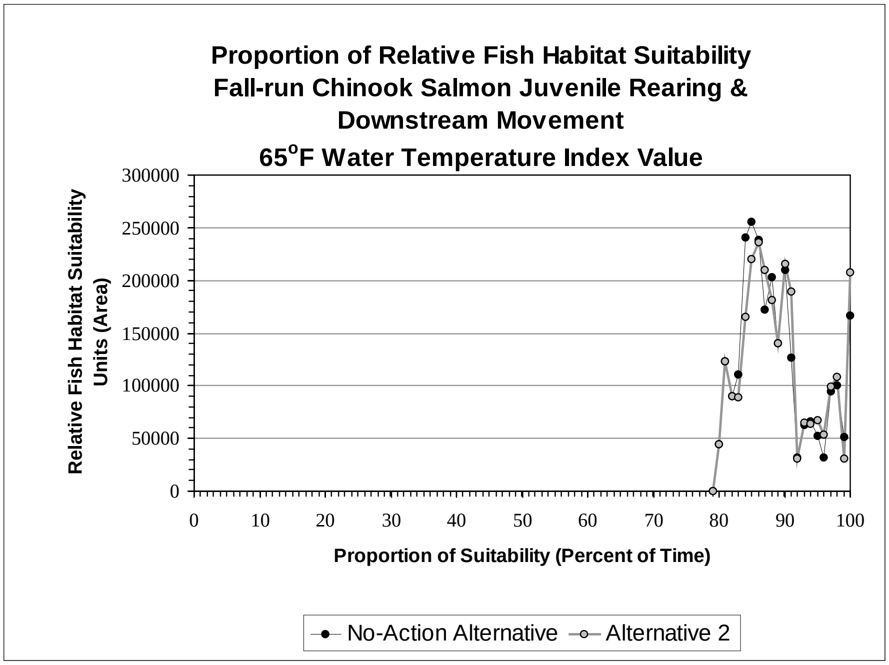


Figure G-AQUA5.4-11. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 65°F water temperature index value.

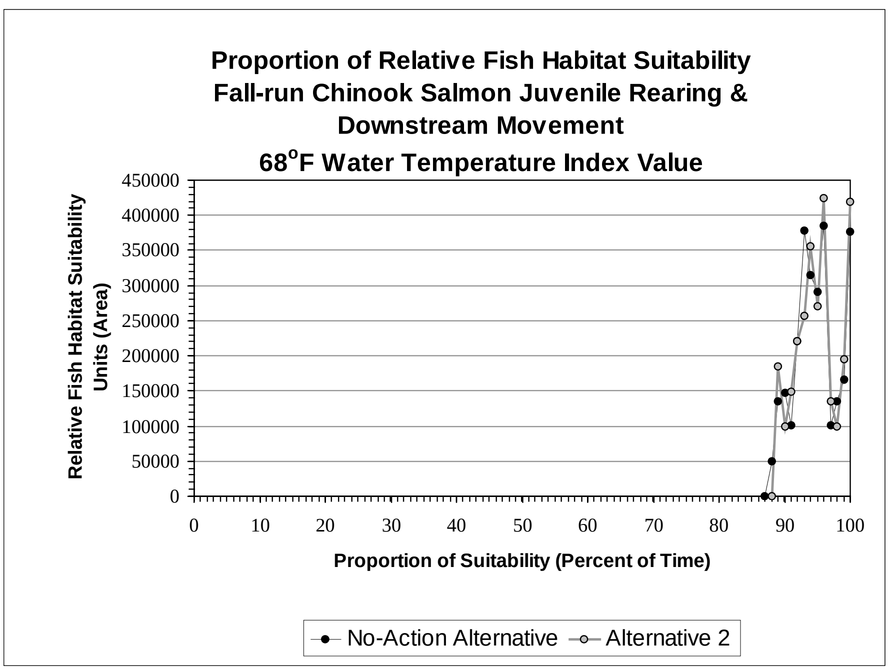


Figure G-AQUA5.4-12. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 68°F water temperature index value.

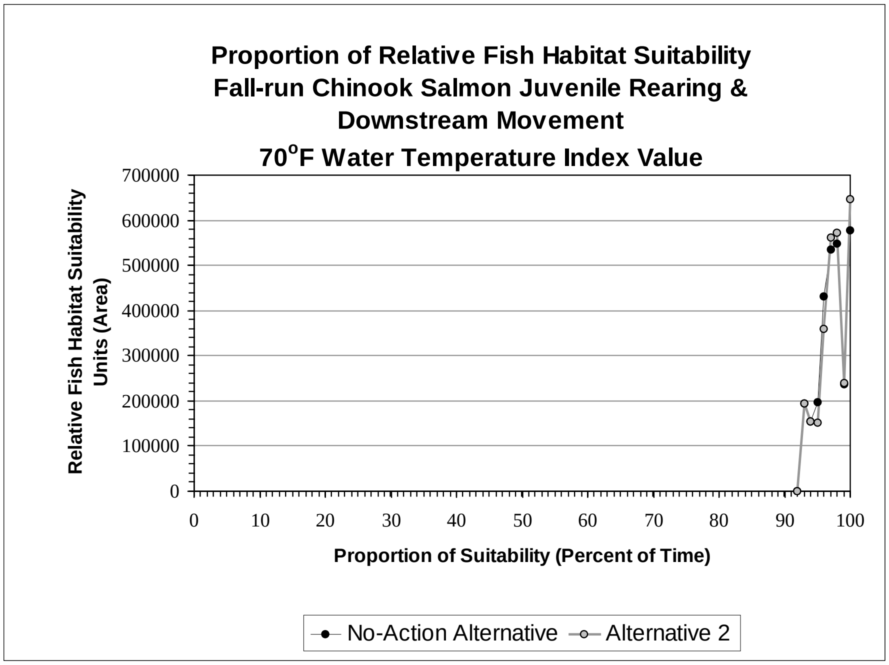


Figure G-AQUA5.4-13. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 70°F water temperature index value.

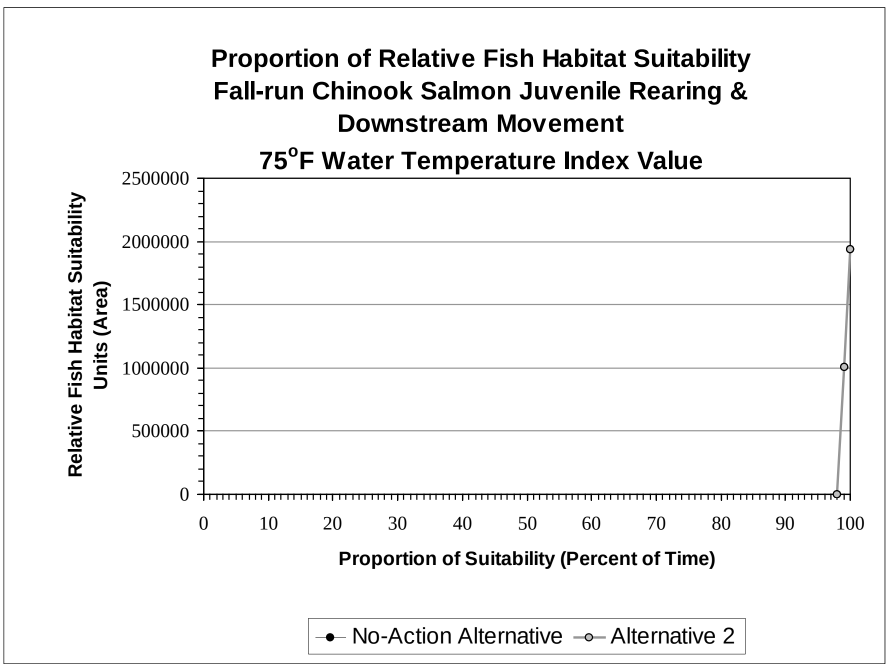


Figure G-AQUA5.4-14. Proportion of relative fish habitat suitability for fall-run Chinook salmon juvenile rearing and downstream movement for the 75°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA5.4-3 for fall-run Chinook salmon juvenile rearing and downstream movement for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,180,180 and 2,200,952, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 20,772, which represents a 0.95 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 63°F water temperature index value under existing conditions and the No-Action Alternative are 2,453,678 and 2,470,311, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 16,633, which represents a 0.68 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 65°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,616,587 and 2,631,166, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 14,578, which represents a 0.56 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,800,642 and 2,807,225, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 6,583, which represents a 0.24 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 70°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,874,312 and 2,878,257, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 3,945, which represents a 0.14 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 75°F water temperature index value the No-Action Alternative and Alternative 2 are 2,946,916 and 2,946,916, respectively, representing no difference in overall habitat suitability between the No-Action Alternative and Alternative 2 for the 75°F water temperature index value.

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-3 for the fall-run Chinook salmon juvenile rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for the 60°F, 63°F, 65°F, 70°F, or 75°F water temperature index values selected. The Minimum Percentage of Time Value metric for the fall-run Chinook salmon juvenile rearing and downstream movement for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 88 percent and 89 percent, respectively. The 1 percent difference in Minimum Percentage of Time Value between Alternative 2 and the No-Action Alternative represents an increase in the number of habitat units with the smallest amount of time and area with water temperatures below 68°F under Alternative 2 compared to the No-Action Alternative.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-3 for the fall-run Chinook salmon juvenile rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for any of the water temperature index values selected.

Table G-AQUA5.4-3. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for fall-run Chinook salmon juvenile rearing and downstream movement.

Water Temperature Index Value	60°F	63°F	65°F	68°F	70°F	75°F
No-Action Alternative						
Minimum Percentage of Time Value	66%	75%	80%	88%	93%	99%
Maximum Percentage of Time Value	99%	100%	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	0	97,307	166,409	376,160	578,584	1,938,161
Percentage of Time at Maximum Habitat Units	69%	79%	85%	96%	100%	100%
OHSIV	2,180,180	2,453,678	2,616,587	2,800,642	2,874,312	2,946,916
Alternative 2						
Minimum Percentage of Time Value	66%	75%	80%	89%	93%	99%
Maximum Percentage of Time Value	99%	100%	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	0	113,590	208,095	418,862	646,443	1,938,161
Percentage of Time at Maximum Habitat Units	69%	79%	86%	96%	100%	100%
OHSIV	2,200,952	2,470,311	2,631,166	2,807,225	2,878,257	2,946,916
Percent Change	0.95%	0.68%	0.56%	0.24%	0.14%	0.00%

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-3 for the fall-run Chinook salmon juvenile rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for the 60°F or 75°F water temperature index values. The Habitat Units at 100 Percent of Time for the 63°F water temperature index value under the No-Action Alternative and Alternative 2 are 97,307 and 113,590, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 16,283, which represents approximately a 17 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 63°F. The Habitat Units at 100 Percent of Time for the 65°F water temperature index value the No-Action Alternative and Alternative 2 are 166,409 and 208,095, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 41,686, which represents approximately a 25 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 65°F. The Habitat Units at 100 Percent of Time for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 376,160 and 418,862, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 42,702, which represents approximately an 11 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 68°F. The Habitat Units at 100 Percent of Time for the 70°F water temperature index value under the No-Action Alternative and Alternative 2 are 578,584 and 646,443, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 67,859, which represents approximately a 12 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 70°F.

A 17 percent increase in the number of habitat units in which water temperatures are always at or below 63°F and above 60°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating juvenile fall-run Chinook salmon, such as acceleration or inhibition of smoltification, and decreased feeding and growth rates, (Clarke and Shelbourn 1985; Marine 1997; Zedonis and Newcomb 1997). A 25 percent increase in the number of habitat units in which water temperatures are always at or below 65°F and above 63°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating juvenile fall-run Chinook salmon, such as acceleration or inhibition of smoltification, decreased growth rates, and increased susceptibility to disease (Clarke and Shelbourn 1985; Marine 1997; Ordal and Pacha 1963; Zedonis and Newcomb 1997). An 11 percent increase in the number of habitat units in which water temperatures are always at or below 68°F and above 65°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating juvenile fall-run Chinook salmon, such as acceleration or inhibition of smoltification, decreased growth rates, increased stress response, decreased metabolic efficiency, and increased mortality rates (Brett et al. 1982; Clarke and Shelbourn 1985; Independent Scientific Group 1996; Marine 1997; Ordal and Pacha 1963; Zedonis and Newcomb 1997). A 12 percent decrease in the number of habitat units in which water temperatures are always at or below 70°F and above 68°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating juvenile fall-run Chinook salmon, such as increased incidence of disease, hyperactivity, decreased appetite, reduced growth rates, and increased mortality rates (McCullough 1999; Rich 1987). A detailed description of the potential effects that could occur to rearing and downstream migrating juvenile fall-run Chinook salmon from exposure to water temperatures above each water temperature index value is presented in Appendix G-AQUA2.2.3.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-3 for the fall-run Chinook salmon juvenile rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for the 60°F, 63°F, 68°F, 70°F or the 75°F water temperature index values. The Percentage of Time at Maximum Habitat Units presented for the fall-run Chinook salmon juvenile rearing and downstream movement life stage for the 65°F water temperature index value under the No-Action Alternative and Alternative 2 are 85 percent and 86 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No-Action Alternative is 1 percent, which represents a small increase in the percentage of time that the habitat is suitable in the greatest area.

G-AQUA5.4.1.3 Predation-related Effects

Changes in minimum flows in the Low Flow Channel are not expected to change the nature or rate of predation with implementation of Alternative 2. Water temperature changes would be very small and are not expected to change the distribution, species composition, consumption rates, or nature of predation in the lower Feather River. Adaptive management changes in steelhead hatchery release practices may reduce predation of juvenile fall-run Chinook salmon. The Large Woody Debris Supplementation and Improvement Program would improve juvenile rearing cover conditions, resulting in a reduction of predation rates on juvenile fall-run Chinook salmon.

G-AQUA5.4.1.4 Fisheries Management–related Effects

<u>Hatchery</u>

The Hatchery Adaptive Management Program included in Alternative 2 is the same as under the Proposed Action, with the exception of the inclusion of a water treatment facility for the hatchery water supply. (See Section G-AQUA4.4 in Appendix G-AQUA4 for an evaluation of the Hatchery Adaptive Management Program relative to the No-Action Alternative.) The hatchery water treatment facility could reduce the rate of incidence and severity of disease occurrences in the hatchery and would result in lower contributions of the accumulated disease pressure in the lower Feather River as a result.

<u>Disease</u>

Water temperature changes with implementation of Alternative 2 would be relatively small; therefore, no changes in water temperature–related interactions with the incidence of fish diseases are anticipated. The proposed hatchery water treatment could reduce the rate of incidence and severity of disease occurrences in the Feather River Fish Hatchery, which, as a result, would lower contributions of the accumulated disease pressure in the lower Feather River.

<u>Fishing Regulations, Poaching, and Change in Recreational Access and Visitation</u>

Section 5.10.2, Recreation Resources Environmental Effects, forecasts a one-third increase in recreation and angling activities with the No-Action Alternative and an approximately 51 percent increase in recreation and angling under Alternative 2 as compared to the existing condition. This would indicate an expected increase of approximately 18 percent in recreation and angling under Alternative 2 relative to the No-Action Alternative. A 18 percent increase in angling, with no other resources actions related to fisheries, would equate to increased angler harvest rates. Fishing access would be increased under Alternative 2 with the implementation of several recreation facilities on the lower Feather River. (See Section 5.10.2.3 for additional information on recreation facilities and changes in visitation under Alternative 2.) No fishing zones in proximity to the fish barrier weirs would require changes in fishing regulations with implementation of Alternative 2.

G-AQUA5.4.1.5 Summary of Potential Effects on Fall-run Chinook Salmon

Study plan report summaries addressing project effects on fall-run Chinook salmon are presented in Section G-AQUA1.5, Fisheries Management; Section G-AQUA1.8, Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam; Section G-AQUA1.10, Instream Flows and Fish Habitat; and Section G-AQUA1.11, Predation; of Appendix G-AQUA1, Affected Environment. A description of each fall-run Chinook salmon life stage and the time period associated with it is presented in Appendix G-AQUA1.

Effects on fall-run Chinook salmon associated with installation of fish barrier weirs, the Large Woody Debris Supplementation and Improvement Program, and the Gravel Supplementation and Improvement Program with implementation of Alternative 2 would not differ from those effects associated with the Proposed Action because the proposed PM&E measures are the same under Alternative 2 and the Proposed Action. Appendix G-AQUA4, Effects of the Proposed Action, describes the effects associated with each PM&E measure proposed for implementation under the Proposed Action. Additionally, water temperature–related effects resulting from changes in flows in the Low Flow Channel under Alternative 2 are not expected to alter disease or predation effects because the changes in water temperature compared to the No-Action Alternative would be small.

<u>**Adult Immigration and Holding**</u>

Actions potentially affecting fall-run Chinook salmon adult immigration and holding include changes to instream flows and water temperatures in the Low Flow Channel. Side-channel habitat creation and enhancement, and a Hatchery Adaptive Management Program, as implemented under Alternative 2 would differ slightly from those PM&E measures as proposed for implementation under the Proposed Action; however, they would have the same types of effects on fall-run Chinook salmon adult immigration and holding compared to the No-Action Alternative. Appendix G-AQUA4, Effects of the Proposed Action, describes the effects associated with each PM&E measure proposed for implementation under the Proposed Action.

An increased instream flow of 800 cfs in the Low Flow Channel under Alternative 2 could potentially have a beneficial effect on immigrating fall-run Chinook salmon by increasing lower Feather River stage elevations. Although stage increases would be small, shallow riffles could potentially become deeper, reducing the effort required by immigrating adult fall-run Chinook salmon to proceed through shallow riffles. Additionally, increased flows would slightly reduce average daily water temperatures, thereby increasing overall habitat suitability for each water temperature index value during the immigration and holding period for adult fall-run Chinook salmon.

Overall, implementation of Alternative 2 would have a beneficial effect on fall-run Chinook salmon adult immigration.

Spawning and Embryo Incubation

Actions potentially affecting fall-run Chinook salmon adult spawning and embryo incubation include a Hatchery Adaptive Management Program, creation and enhancement of side-channel habitat, and changes to instream flows and water temperatures in the Low Flow Channel. Many of the effects of a Hatchery Adaptive Management Program would be the same as those identified for the Proposed Action (see Appendix G-AQUA4), relative to the No-Action Alternative, with one exception. The water treatment program associated with the Hatchery Adaptive Management Program under Alternative 2 would potentially have an additional beneficial effect on incubating fall-run Chinook salmon embryos by minimizing the potential for disease-associated embryonic mortality in the Feather River Fish Hatchery and by reducing the accumulated disease pressure in the lower Feather River.

Creation and enhancement of side-channel habitat under Alternative 2 would provide an additional benefit over the Proposed Action compared to the No-Action Alternative because there would be a greater area of side channel under Alternative 2. The creation of side-channel habitat in Alternative 2 would result in an increase in the amount of spawning area for fall-run Chinook salmon.

An increase in instream flows in the Low Flow Channel from 600 cfs to 800 cfs during the adult spawning and embryo incubation period would increase WUA from 91 percent of maximum to almost 100 percent of maximum. Additionally, during extreme drought years, decreases in flow from 800 cfs to 750 cfs likely would not affect fall-run Chinook salmon adult spawning and embryo incubation because 750 cfs represents approximately 99 percent of maximum WUA, while 800 cfs represents almost 100 percent of maximum WUA. Reduced average daily water temperatures under Alternative 2 result in increased overall habitat suitability for each water temperature index value for fall-run Chinook salmon adult spawning and embryo incubation.

Overall, implementation of Alternative 2 would result in a beneficial effect on fall-run Chinook salmon adult spawning and embryo incubation.

Juvenile Rearing and Downstream Movement

Actions potentially affecting fall-run Chinook salmon juvenile rearing and downstream movement include a Hatchery Adaptive Management Program, side-channel habitat creation, and changes to instream flows and water temperatures in the Low Flow Channel. Many of the effects of a Hatchery Adaptive Management Program would be the same as those identified for the Proposed Action (see Appendix G-AQUA4), relative to the No-Action Alternative, with one exception. The water treatment program associated with the Hatchery Adaptive Management Program under Alternative 2 would potentially have an additional beneficial effect on rearing fall-run Chinook salmon juveniles by minimizing the potential for disease-associated mortality in the hatchery and by reducing the accumulated disease pressure in the lower Feather River.

Creation of side-channel habitat under Alternative 2 would increase the amount of juvenile rearing habitat available compared to the No-Action Alternative. Increased flows and lower water temperature targets at Robinson Riffle with implementation of Alternative 2 would be expected to slightly reduce average daily water temperatures during the juvenile rearing and downstream movement period for fall-run Chinook salmon. However, model results indicate that differences in habitat suitability due to decreased water temperatures are less than 1 percent between the No-Action Alternative and Alternative 2, and as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, changes in water temperature would not affect fall-run Chinook salmon juvenile rearing and downstream movement. However, flow fluctuations ranging from 800 cfs to 1,200 cfs in the Low Flow Channel could occur from May 1 through June 15, when total releases up to 1,200 cfs are routed through the Low Flow Channel. This could result in an adverse effect on fall-run Chinook salmon juvenile rearing and downstream movement by increasing the potential for beach stranding. Based on the emigration timing of most juvenile Chinook salmon in the Feather River, and on the preference for increased water depths as rearing juveniles grow larger later in the rearing season, it is unlikely that any substantial change in the rate of beach stranding would occur as a result of flow fluctuations in the Low Flow Channel from May 1 through June 15. Water temperature control-related changes in flow from 800 cfs to approximately 1,000 cfs later in the summer season also would not be expected to result in beach stranding of juvenile fall-run Chinook salmon.

Overall, implementation of Alternative 2 would result in a beneficial effect on fall-run Chinook salmon juvenile rearing and downstream movement.

Conclusion

Under Alternative 2, flows and flow fluctuations occurring in the High Flow Channel are not expected to differ from those occurring under the No-Action Alternative (described in Section 5.4.2.1). Therefore, implementation of Alternative 2 would not result in a flow-related change in the quantity, quality, or distribution of habitat for fall-run Chinook salmon in the High Flow Channel. Habitat improvement programs including side-channel creation and enhancement and the Gravel Supplementation and Improvement Program and Large Woody Debris Supplementation and Improvement Program also would be beneficial for fall-run Chinook salmon habitat quality and quantity.

Based on the above summary of potential effects, implementation of Alternative 2 would result in an overall beneficial effect on fall-run Chinook salmon.

G-AQUA5.4.2 Spring-run Chinook Salmon

G-AQUA5.4.2.1 Flow-related Effects

Adult Immigration and Holding

An increased instream flow of 800 cfs in the Low Flow Channel under Alternative 2 could potentially have a beneficial effect on immigrating and holding spring-run Chinook salmon by increasing the lower Feather River stage elevation over potential critical riffles. Although stage increases would be small, shallow riffles could potentially become deeper, reducing effort required by immigrating adult spring-run Chinook salmon to proceed through shallow riffles. In addition, water depth would be increased, creating additional amounts of suitable holding habitat relative to water depths.

In addition to a base flow of 800 cfs in the Low Flow Channel, from May 1 through June 15 flows could increase to 1,200 cfs. Section 5.4.2.1, Water Quantity Environmental Effects, provides a detailed description of the circumstances under which flow increases to 1,200 cfs would occur in the Low Flow Channel. Increasing instream flow to 1,200 cfs would further increase river stage, further increasing holding habitat availability in the Low Flow Channel, providing an additional beneficial effect during the period of increased flows.

No flow changes relative to the No-Action Alternative are expected in the High Flow Channel with implementation of Alternative 2.

Adult Spawning and Embryo Incubation

Flow changes in the Low Flow Channel included in Alternative 2 would affect spring-run Chinook salmon adult spawning and embryo incubation in the same way that they would affect this life stage for fall-run Chinook salmon. Refer to the above discussion of adult spawning and embryo incubation by fall-run Chinook salmon for the evaluation of flow-related effects on adult spawning and embryo incubation by spring-run Chinook salmon.

Juvenile Rearing and Downstream Movement

Juvenile rearing and downstream movement is the same for spring-run Chinook salmon as for fall-run Chinook salmon, with the exception that spring-run Chinook salmon can rear in the lower Feather River year round. Flow changes in the Low Flow Channel included in Alternative 2 would affect the early portion of the juvenile rearing and downstream movement period for spring-run Chinook salmon in the same way that they would affect this life stage for fall-run Chinook salmon. Refer to the above discussion of juvenile rearing and downstream movement by fall-run Chinook salmon for the evaluation of flow-related effects on juvenile rearing and downstream movement by spring-run Chinook salmon during the early portion of this period. The later periods of extended juvenile rearing for spring-run Chinook salmon are not susceptible to any additional stranding type losses associated with implementation of Alternative 2 because of the increased size of the fish in the later rearing period and the preference for deeper water habitat as compared to the earlier rearing period.

G-AQUA5.4.2.2 Water Temperature–related Effects

The relative habitat suitability analysis includes an evaluation of overall relative habitat suitability based on water temperature index values. The analysis includes a comparison of habitat suitability component metrics between the No-Action Alternative and Alternative 2. The OHSIV analysis is described in the above discussion of temperature-related effects on fall-run Chinook salmon. Detailed descriptions of the methodology used in the derivation and calculation of each of the above metrics are presented in Section G-AQUA.2.2.3 of Appendix G-AQUA2, Methodology.

Adult Immigration and Holding

Figures G-AQUA5.4-15, G-AQUA5.4-16, and G-AQUA5.4-17 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA5.4-15, G-AQUA5.4-16, and G-AQUA5.4-17 is equal, which allows for direct comparison of habitat suitability between alternatives.

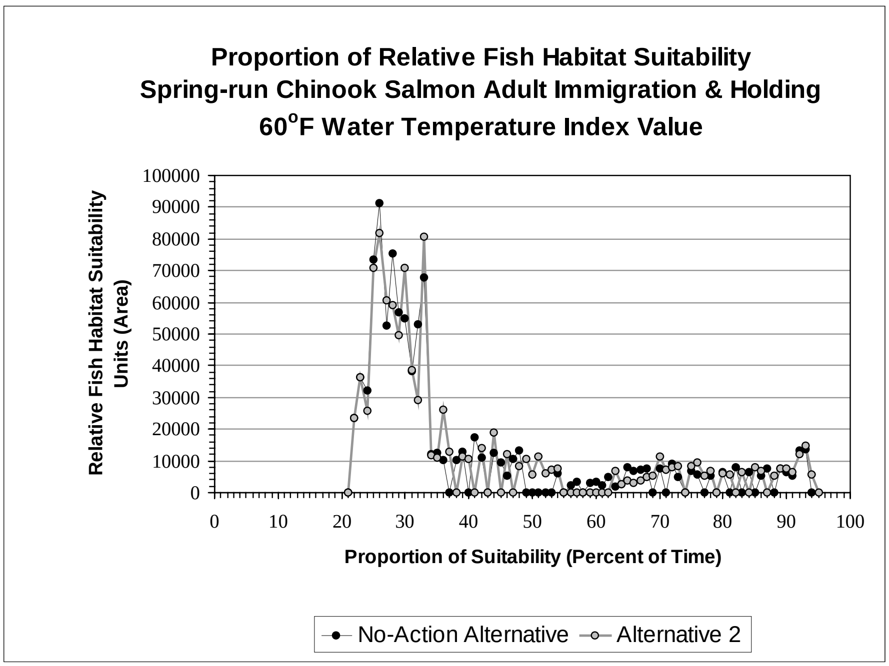


Figure G-AQUA5.4-15. Proportion of relative fish habitat suitability for spring-run Chinook salmon adult immigration and holding for the 60°F water temperature index value.

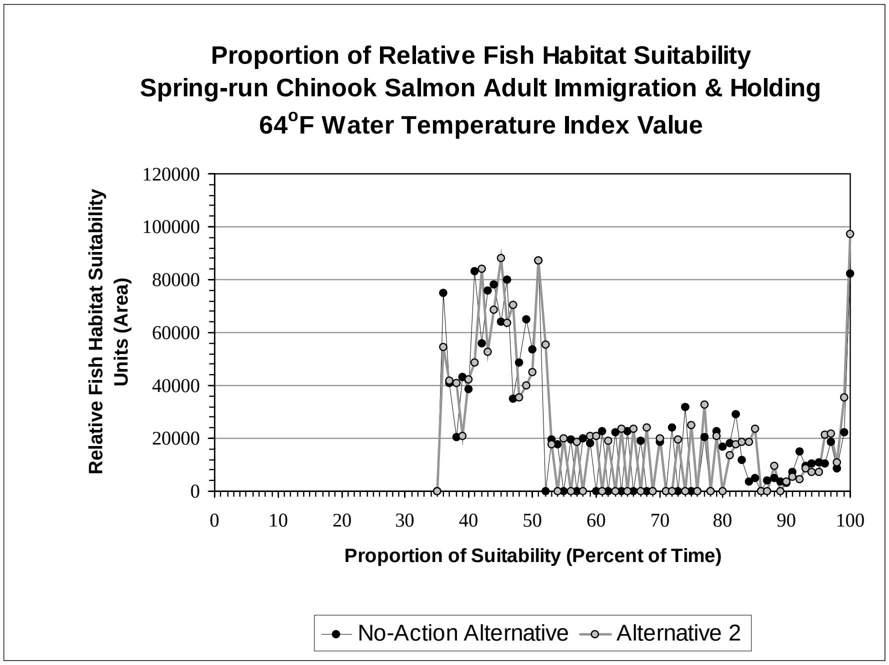


Figure G-AQUA5.4-16. Proportion of relative fish habitat suitability for spring-run Chinook salmon adult immigration and holding for the 64°F water temperature index value.

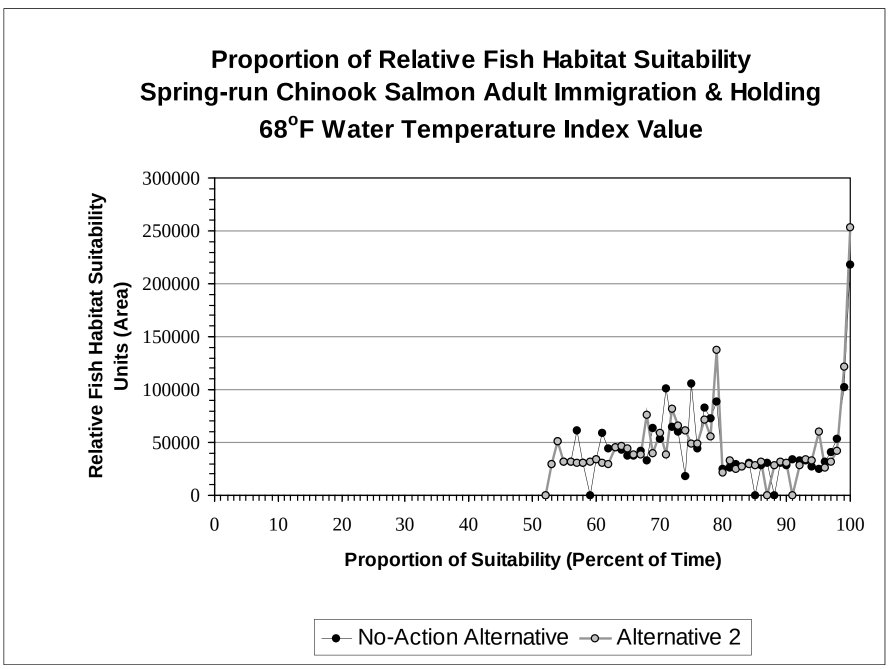


Figure G-AQUA5.4-17. Proportion of relative fish habitat suitability for spring-run Chinook salmon adult immigration and holding for the 68°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA5.4-4 for spring-run Chinook salmon adult immigration and holding for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 970,626 and 1,000,276, respectively. The difference in OHSIV between the No-Action Alternative and Alternative 2 is 29,650, which represents a 3.05 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 64°F water temperature index value under the No-Action Alternative and Alternative 2 are 1,538,763 and 1,572,453, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 33,690, which represents a 2.19 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,225,207 and 2,249,848, respectively. The difference in OHSIV between No-Action Alternative and existing conditions is 24,641, which represents a 1.11 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative.

Table G-AQUA5.4-4. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for spring-run Chinook salmon adult immigration and holding.

Water Temperature Index Value	**60°F**	**64°F**	**68°F**
No-Action Alternative			
Minimum Percentage of Time Value	22%	36%	53%
Maximum Percentage of Time Value	93%	100%	100%
Habitat Units at 100 Percent of Time	0	82,362	218,450
Percentage of Time at Maximum Habitat Units	26%	51%	100%
OHSIV	970,626	1,538,763	2,225,207
Alternative 2			
Minimum Percentage of Time Value	22%	36%	53%
Maximum Percentage of Time Value	94%	100%	100%
Habitat Units at 100 Percent of Time	0	97,307	253,442
Percentage of Time at Maximum Habitat Units	26%	100%	100%
OHSIV	1,000,276	1,572,453	2,249,848
Percent Change	3.05%	2.19%	1.11%

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-4 for the spring-run Chinook salmon adult immigration and holding life stage did not change between the No-Action Alternative and Alternative 2 for any of the water temperature index values selected.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-4 for the spring-run Chinook salmon adult immigration and holding life stage did not change between the No-Action Alternative and Alternative 2 for the 64°F and 68°F water temperature index values. The Maximum Percentage of Time Value for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 93 percent and 94 percent, respectively. The 1 percent difference in Maximum Percentage of Time Value between Alternative 2 and the No-Action Alternative represents a small increase in the number of habitat units with the greatest amount of time and area with water temperatures below 60°F under Alternative 2 compared to the No-Action Alternative.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-4 for the spring-run Chinook salmon adult immigration and holding life stage did not change between the No-Action Alternative and Alternative 2 for the 60°F water temperature index value. The Habitat Units at 100 Percent of Time for the 64°F water temperature index value under the No-Action Alternative and Alternative 2 are 82,362 and 97,307, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 14,945, which represents approximately an 18 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 64°F. The Habitat Units at 100 Percent of Time for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 218,450 and 253,442, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 34,992, which represents approximately a 16 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 68°F.

An 18 percent increase in the number of habitat units in which water temperatures are always at or below 64°F and above 60°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to immigrating and holding adult spring-run Chinook salmon, such as increased incidence of disease, decreased adult survival, decreased egg viability, and increased latent embryonic abnormalities and mortalities (Berman 1990; EPA 2003; ODEQ 1995; USFWS 1995). A 16 percent increase in the number of habitat units in which water temperatures are always at or below 68°F and above 64°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to immigrating and holding adult spring-run Chinook salmon, such as further increased incidence of disease, additional decreased adult survival, additional decreased egg viability, and additional increased latent embryonic abnormalities and mortalities (Berman 1990; EPA 2003; Marine 1992). A detailed description of the potential effects that could occur to immigrating and holding adult spring-run Chinook salmon from exposure to water temperatures above each water temperature index value is presented in Section G-AQUA2.2.3 of Appendix G-AQUA2.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-4 for the spring-run Chinook salmon adult immigration and holding life stage did not change between the No-Action Alternative and Alternative 2 for the 60°F or the 68°F water temperature index values. The Percentage of Time at Maximum Habitat Units for the 64°F water temperature index value under the No-Action Alternative and Alternative 2 are 51 percent and 100 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No-Action Alternative is 49 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area.

Adult Spawning and Embryo Incubation

Adult spawning and embryo incubation by spring-run Chinook salmon has the same life stage period and water temperature requirements as the same life stage for fall-run Chinook salmon. Refer to the above discussion of water temperature–related effects on adult spawning and embryo incubation by fall-run Chinook salmon.

Juvenile Rearing and Downstream Movement

Figures G-AQUA5.4-18, G-AQUA5.4-19, G-AQUA5.4-20, G-AQUA5.4-21, G-AQUA5.4-22, and G-AQUA5.4-23 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA5.4-18, G-AQUA5.4-19, G-AQUA5.4-20, G-AQUA5.4-21, G-AQUA5.4-22, and G-AQUA5.4-23 is equal, which allows for direct comparison of habitat suitability between alternatives.

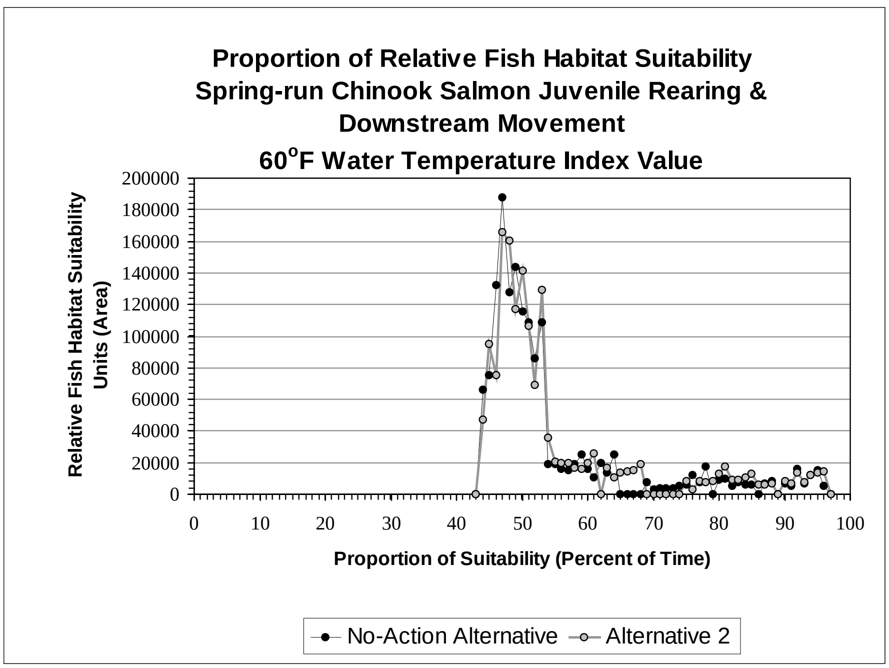


Figure G-AQUA5.4-18. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 60°F water temperature index value.

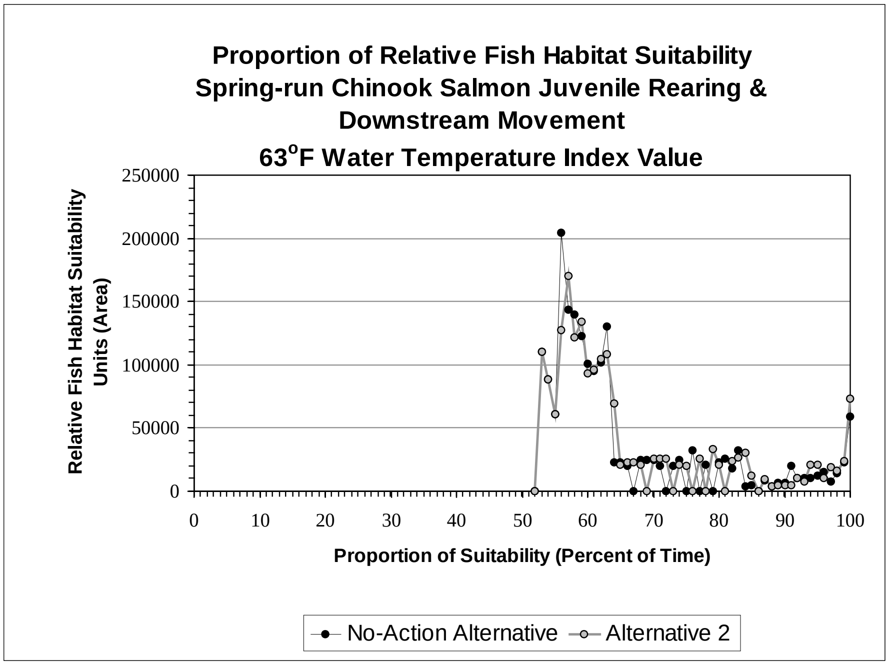


Figure G-AQUA5.4-19. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 63°F water temperature index value.

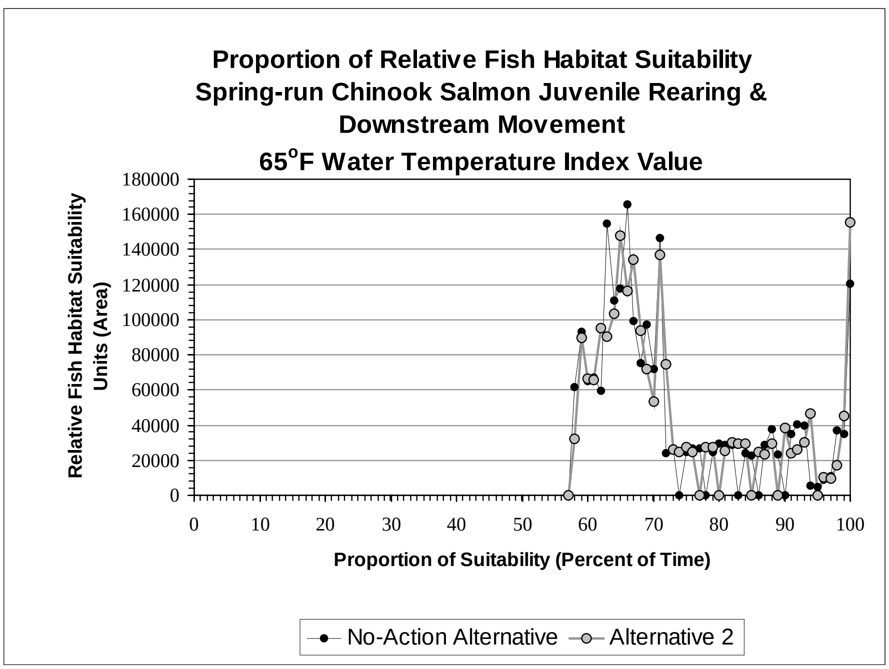


Figure G-AQUA5.4-20. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 65°F water temperature index value.

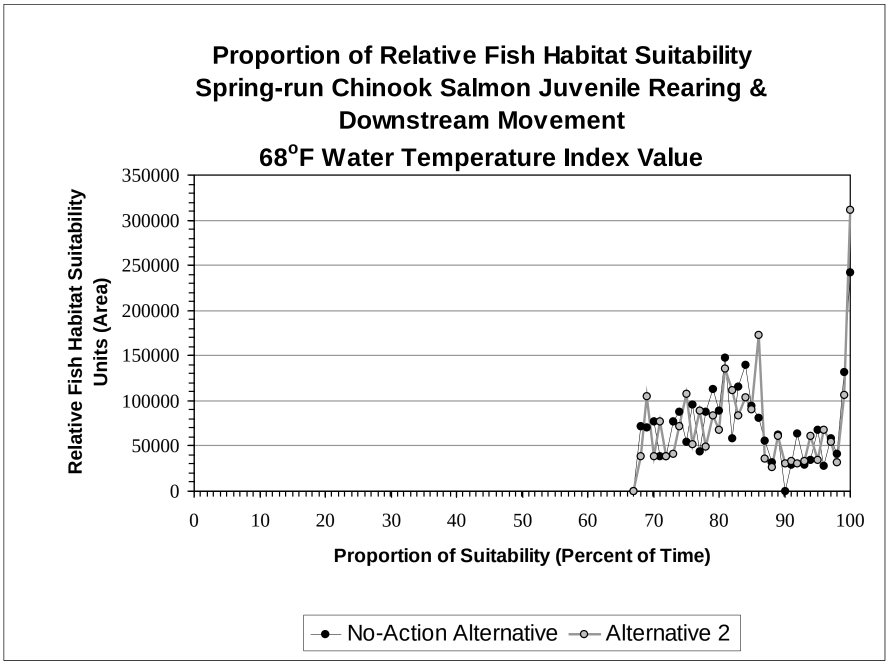


Figure G-AQUA5.4-21. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 68°F water temperature index value.

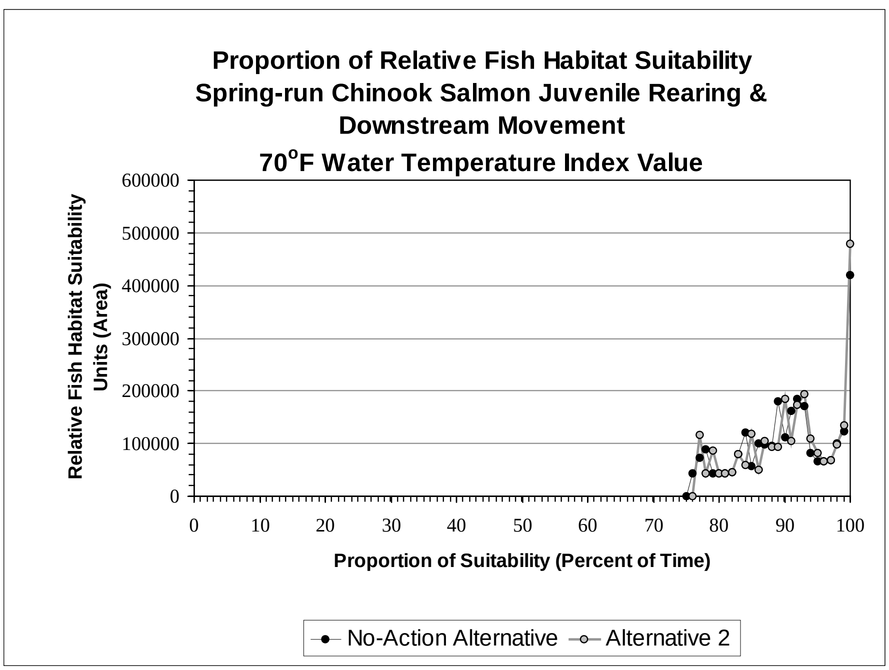


Figure G-AQUA5.4-22. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 70°F water temperature index value.

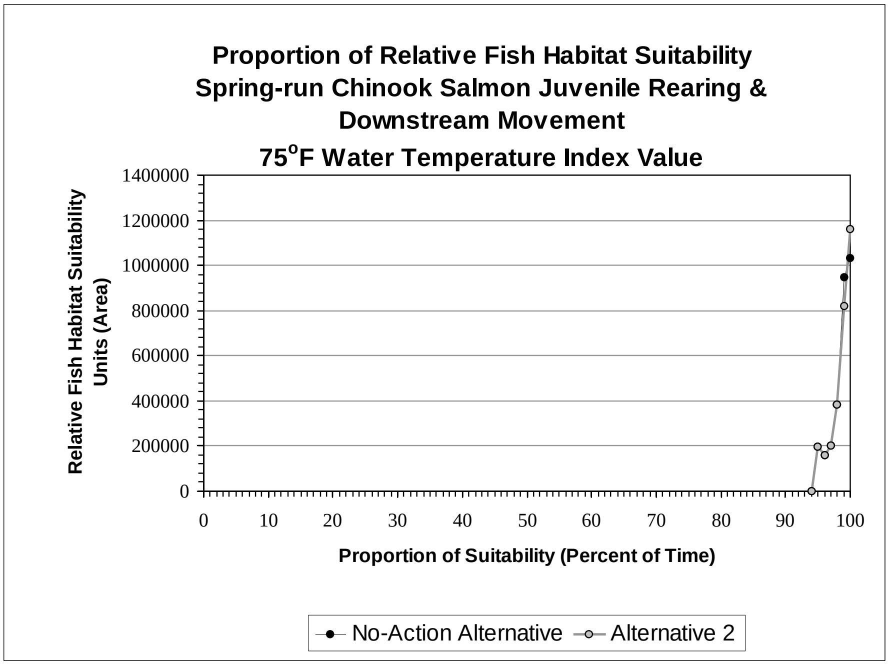


Figure G-AQUA5.4-23. Proportion of relative fish habitat suitability for spring-run Chinook salmon juvenile rearing and downstream movement for the 75°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA5.4-5 for fall-run Chinook salmon juvenile rearing and downstream movement for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 1,549,710 and 1,575,675, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 25,965, which represents a 1.68 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 63°F water temperature index value under the No-Action Alternative and Alternative 2 are 1,870,208 and 1,894,221, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 24,013, which represents a 1.28 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 65°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,100,251 and 2,124,326, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 24,075, which represents a 1.15 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,460,196 and 2,478,520, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 18,324, which represents a 0.74 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 70°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,664,592 and 2,678,338, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 13,746, which represents a 0.52 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 75°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,916,561 and 2,917,860, respectively. The difference in OHSIV

Table G-AQUA5.4-5. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for spring-run Chinook salmon juvenile rearing and downstream movement.

Water Temperature Index Value	60°F	63°F	65°F	68°F	70°F	75°F
No-Action Alternative						
Minimum Percentage of Time Value	44%	53%	58%	68%	76%	95%
Maximum Percentage of Time Value	96%	100%	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	0	59,019	120,339	242,537	418,862	1,030,745
Percentage of Time at Maximum Habitat Units	47%	56%	66%	100%	100%	100%
OHSIV	1,549,710	1,870,208	2,100,251	2,460,196	2,664,592	2,916,561
Alternative 2						
Minimum Percentage of Time Value	44%	53%	58%	68%	77%	95%
Maximum Percentage of Time Value	96%	100%	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	0	72,837	155,395	311,368	479,021	1,160,689
Percentage of Time at Maximum Habitat Units	47%	57%	100%	100%	100%	100%
OHSIV	1,575,675	1,894,221	2,124,326	2,478,520	2,678,338	2,917,860
Percent Change	1.68%	1.28%	1.15%	0.74%	0.52%	0.04%

between Alternative 2 and the No-Action Alternative is 1,299, which represents a 0.04 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative.

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-5 for the spring-run Chinook salmon juvenile rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for the 60°F, 63°F, 65°F, 68°F, or 75°F water temperature index values selected. The Minimum Percentage of Time Value metric for the 70°F water temperature index value under the No-Action Alternative and Alternative 2 are 76 percent and 77 percent, respectively. The 1 percent difference in Minimum Percentage of Time Value between Alternative 2 and the No-Action Alternative represents an increase in the number of habitat units with the smallest amount of time and area with water temperatures below 70°F under Alternative 2 compared to the No-Action Alternative.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-5 for the spring-run Chinook salmon juvenile rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for any of the water temperature index values selected.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-5 for the spring-run Chinook salmon juvenile rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for the 60°F water temperature index value. The Habitat Units at 100 Percent of Time for the 63°F water temperature index value under the No-Action Alternative and Alternative 2 are 59,019 and 72,837, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 13,818, which represents approximately a 23 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 63°F. The Habitat Units at 100 Percent of Time for the 65°F water temperature index value under the No-Action Alternative and Alternative 2 are 120,339 and 155,395, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 35,056, which represents approximately a 29 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 65°F. The Habitat Units at 100 Percent of Time for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 224,537 and 311,368, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 68,831, which represents approximately a 28 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 68°F. The Habitat Units at 100 Percent of Time for the 70°F water temperature index value under the No-Action Alternative and Alternative 2 are 418,862 and 479,021, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 60,159, which represents approximately a 14 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 70°F. The Habitat Units at 100 Percent of Time for the 75°F water temperature index value under the No-Action Alternative and Alternative 2 are 1,030,745 and 1,160,689, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 129,944, which represents approximately a 13 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 75°F.

A 23 percent increase in the number of habitat units in which water temperatures are always at or below 63°F and above 60°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating juvenile spring-run Chinook salmon, such as such as acceleration or inhibition of smoltification, and decreased feeding and growth rates, (Clarke and Shelbourn 1985; Marine 1997; Zedonis and Newcomb 1997). A 29 percent increase in the number of habitat units in which water temperatures are always at or below 65°F and above 63°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating juvenile spring-run Chinook salmon, such as acceleration or inhibition of smoltification, decreased growth rates, and increased susceptibility to disease (Clarke and Shelbourn 1985; Marine 1997; Ordal and Pacha 1963; Zedonis and Newcomb

1997). A 28 percent increase in the number of habitat units in which water temperatures are always at or below 68°F and above 65°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating juvenile spring-run Chinook salmon, such as acceleration or inhibition of smoltification, decreased growth rates, increased stress response, decreased metabolic efficiency, and increased mortality rates (Brett et al. 1982; Clarke and Shelbourn 1985; Independent Scientific Group 1996; Marine 1997; Ordal and Pacha 1963; Zedonis and Newcomb 1997). A 14 percent increase in the number of habitat units in which water temperatures are always at or below 70°F and above 68°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating juvenile spring-run Chinook salmon, such as increased incidence of disease, hyperactivity, decreased appetite, reduced growth rates, and increased mortality rates (McCullough 1999; Rich 1987). A 13 percent increase in the number of habitat units in which water temperatures are always at or below 75°F and above 70°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating juvenile spring-run Chinook salmon, such as substantially increased incidence of disease, hyperactivity, decreased appetite, reduced growth rates, and substantially increased mortality rates (McCullough 1999; Rich 1987). A detailed description of the potential effects that could occur to rearing and downstream migrating juvenile spring-run Chinook salmon from exposure to water temperatures above each water temperature index value is presented in Section G-AQUA2.2.3 of Appendix G-AQUA2.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-5 for the spring-run Chinook salmon juvenile rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for the 60°F, 68°F, 70°F or the 75°F water temperature index values. The Percentage of Time at Maximum Habitat Units presented in Table G-AQUA5.4-5 for the spring-run Chinook salmon juvenile rearing and downstream movement life stage for the 63°F water temperature index value under the No-Action Alternative and Alternative 2 are 56 percent and 57 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No-Action Alternative is 1 percent, which represents a small increase in the percentage of time that the habitat is suitable in the greatest area. The Percentage of Time at Maximum Habitat Units presented in Table G-AQUA5.4-5 for the spring-run Chinook salmon juvenile rearing and downstream movement life stage for the 65°F water temperature index value under the No-Action Alternative and Alternative 2 are 66 percent and 100 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No-Action Alternative is 34 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area.

G-AQUA5.4.2.3 Predation-related Effects

Changes in minimum flows in the Low Flow Channel are not expected to change the nature or rate of predation with implementation of Alternative 2. Water temperature changes would be very small and are not expected to change the distribution, species composition, consumption rates, or nature of predation in the lower Feather River. Adaptive management changes in steelhead hatchery release practices may reduce predation of juvenile spring-run Chinook salmon. The Large Woody Debris Supplementation and Improvement Program would improve juvenile rearing cover conditions and may result in a reduction of predation rates on juvenile spring-run Chinook salmon.

G-AQUA5.4.2.4 Fisheries Management–related Effects

Hatchery

The Hatchery Adaptive Management Program included in Alternative 2 is the same as that included in the Proposed Action, with the exception of the inclusion of a water treatment facility for the hatchery water supply. See Section G-AQUA4.4 of Appendix G-AQUA4, Effects of the Proposed Action, for an evaluation of the Hatchery Adaptive Management Program. The proposed hatchery water treatment could reduce the rate of incidence and severity of disease occurrences in the Feather River Fish Hatchery, which, as a result, would lower contributions of the accumulated disease pressure in the lower Feather River.

Disease

Water temperature changes with implementation of Alternative 2 would be relatively small; therefore, no changes in water temperature–related interactions with the incidence of fish diseases are anticipated. The proposed hatchery water treatment could reduce the rate of incidence and severity of disease occurrences in the Feather River Fish Hatchery, which, as a result, would lower contributions of the accumulated disease pressure in the lower Feather River.

Fishing Regulations, Poaching, and Change in Recreational Access and Visitation

Section 5.10.2, Recreation Resources Environmental Effects, forecasts a one-third increase in recreation and angling activities with the No-Action Alternative and an approximately 51 percent increase in recreation and angling under Alternative 2 as compared to the existing condition. This would indicate an expected increase of approximately 18 percent in recreation and angling under Alternative 2 compared to the No-Action Alternative. A 18 percent increase in angling with no other fisheries changes would equate to increased angler harvest rates. Fishing access would be increased under Alternative 2 with the implementation of several recreation facilities on the lower Feather River. (See Section 5.10.2.3 for additional information on recreation facilities and changes in visitation under Alternative 2.) No fishing zones in proximity to the fish barrier weirs included in Alternative 2 will change the fishing regulations under Alternative 2.

G-AQUA5.4.2.5 Summary of Potential Effects on Spring-run Chinook Salmon

Study plan report summaries addressing project effects on spring-run Chinook salmon are presented in Section G-AQUA1.5, Fisheries Management; Section G-AQUA1.8, Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam; Section G-AQUA1.10, Instream Flows and Fish Habitat and Section G-AQUA1.11, Predation, of Appendix G-AQUA1, Affected Environment. A description of each spring-run Chinook salmon life stage and the time period associated with it is presented in Appendix G-AQUA1.

Effects on spring-run Chinook salmon associated with installation of fish barrier weirs, the Large Woody Debris Supplementation and Improvement Program, and the Gravel Supplementation and Improvement Program with implementation of Alternative 2 would not differ from those effects associated with the Proposed Action; relative to the No-Action Alternative. Appendix G-AQUA4, Effects of the Proposed Action, describes the effects associated with each PM&E measure proposed for implementation under the Proposed Action. Additionally, water temperature–related effects resulting from changes in flows in the Low Flow Channel under Alternative 2 are not expected to alter disease or predation effects because the changes in water temperature compared to the No-Action Alternative would be small.

Adult Immigration and Holding

Actions potentially affecting spring-run Chinook salmon adult immigration and holding include changes to instream flows and water temperatures in the Low Flow Channel. Creation and enhancement of side-channel habitat and a Hatchery Adaptive Management Program implemented under Alternative 2 would differ slightly from those PM&E measures proposed for implementation under the Proposed Action, but would have the same types of effects on spring-run Chinook salmon adult immigration and holding as compared to the No-Action Alternative. Appendix G-AQUA4, Effects of the Proposed Action, describes the effects associated with each PM&E measure proposed for implementation under the Proposed Action.

An increased instream flow of 800 cfs in the Low Flow Channel under Alternative 2 could potentially have a beneficial effect on immigrating and holding spring-run Chinook salmon by increasing lower Feather River stage elevations. Although stage increases would be small, shallow riffles could potentially become deeper, reducing the effort required by immigrating adult spring-run Chinook salmon to proceed through shallow riffles. Water depth also would be increased, creating additional amounts of suitable holding habitat related to water depths. Reduced average daily water temperatures during the spring-run Chinook salmon adult immigration and holding period, result in increased overall habitat suitability for each water temperature index value.

Overall, implementation of Alternative 2 would result in a beneficial effect on spring-run Chinook salmon adult immigration and holding.

Adult Spawning and Embryo Incubation

Actions potentially affecting spring-run Chinook salmon adult spawning and embryo incubation include a Hatchery Adaptive Management Program, creation and enhancement of side-channel habitat, and instream flow and water temperature changes in the Low Flow Channel.

Many of the effects of a Hatchery Adaptive Management Program would be the same as those identified for the Proposed Action (Appendix G-AQUA4), relative to the No-Action Alternative, with one exception. The water treatment program associated with the Hatchery Adaptive Management Program under Alternative 2 would potentially have an additional beneficial effect on incubating spring-run Chinook salmon embryos by minimizing the potential for disease-associated embryonic mortality in the Feather River Fish Hatchery and by reducing the accumulated disease pressure in the lower Feather River.

Creation and enhancement of side-channel habitat under Alternative 2 would provide an additional benefit over the Proposed Action as compared to the No-Action Alternative because there would be a greater area of side-channel habitat under Alternative 2.

An increase in instream flow in the Low Flow Channel from 600 cfs to 800 cfs during the adult spawning and embryo incubation period would increase the amount of available spawning habitat from a PHABSIM WUA from 91 percent of maximum to almost 100 percent of maximum. Additionally, during extreme drought years, decreases in flow from 800 cfs to 750 cfs likely would not affect spring-run Chinook salmon adult spawning and embryo incubation because 750 cfs represents approximately 99 percent of maximum WUA, while 800 cfs represents almost 100 percent of maximum WUA. Reduce average daily water temperatures under Alternative 2 result in increased overall habitat suitability for each water temperature index value for spring-run Chinook salmon adult spawning and embryo incubation.

Overall, implementation of Alternative 2 would result in a beneficial effect on spring-run Chinook salmon adult spawning and embryo incubation.

Juvenile Rearing and Downstream Movement

Actions potentially affecting spring-run Chinook salmon juvenile rearing and downstream movement include a Hatchery Adaptive Management Program, side-channel habitat enhancement and creation, and changes to instream flows and water temperatures in the Low Flow Channel. Many of the effects of a Hatchery Adaptive Management Program would be the same as those identified for the Proposed Action (Appendix G-AQUA4), relative to the No-Action Alternative, with one exception. The water treatment program associated with the Hatchery Adaptive Management Program under Alternative 2 would potentially have an additional beneficial effect on rearing spring-run Chinook salmon juveniles by minimizing the potential for disease-associated mortality in the Feather River Fish Hatchery and by reducing the accumulated disease pressure in the lower Feather River.

Creation and enhancement of side-channel habitat under Alternative 2 would provide an additional benefit over the Proposed Action as compared to the No-Action Alternative because there would be an increased quantity and quality of side-channel habitat under Alternative 2.

Flow fluctuations ranging from 800 cfs to 1,200 cfs in the Low Flow Channel could occur from May 1 through June 15 when total releases up to 1,200 cfs are routed through the Low Flow Channel. This could result in an adverse effect on spring-run Chinook salmon juvenile rearing and downstream movement by increasing the potential for beach stranding. Based on the emigration timing of most juvenile Chinook salmon in the Feather River, and on the preference for increased water depths as rearing juveniles grow larger later in the rearing season, it is unlikely that any substantial change in the rate of beach stranding would occur as a result of flow fluctuations in the Low Flow Channel from May 1 through June 15. Temperature control changes in flow from 800 cfs to approximately 1,000 cfs later in the summer season would also not be expected to result in beach stranding of juvenile spring-run Chinook salmon. Additionally, increased flows would slightly reduce average daily water temperatures during the juvenile rearing and downstream movement period for spring-run Chinook salmon, resulting in increased overall habitat suitability for the 60°F, 63°F, and 65°F water temperature index values. However, model results indicate that differences in habitat suitability due to decreased water temperatures for the remaining water temperature index values are less than 1 percent between the No-Action Alternative and Alternative 2, and as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis.

Overall, implementation of Alternative 2 would result in a beneficial effect on spring-run Chinook salmon juvenile rearing and downstream movement.

Conclusion

Under Alternative 2, flows and flow fluctuations occurring in the High Flow Channel are not expected to differ from those occurring under the No-Action Alternative (described in Section 5.4.2.1). Therefore, Alternative 2 would not result in a flow-related change in the quality, quantity, or distribution of spring-run Chinook salmon habitat occurring in the High Flow Channel. Flow increases in the Low Flow Channel and water temperature reductions also benefit the spring-run Chinook habitat quality and quantity. Habitat improvement programs including side-channel creation and enhancement and the Gravel Supplementation and Improvement Program and Large Woody Debris Supplementation and Improvement Program also would be beneficial for spring-run Chinook salmon habitat quality and quantity.

Based on the above summary of potential effects, it is likely that implementation of Alternative 2 would result in an overall beneficial effect on spring-run Chinook salmon.

G-AQUA5.4.3 Steelhead

G-AQUA5.4.3.1 Flow-related Effects

Adult Immigration and Holding

Flow in the High Flow Channel would not change with implementation of Alternative 2, relative to the No-Action Alternative; therefore, there would be no flow-related effects on steelhead adult immigration and holding in the High Flow Channel. Water depths in the Low Flow Channel would be increased slightly with implementation of Alternative 2, which would be slightly beneficial to steelhead adult immigration and holding because of the increase in amount of habitat that would meet minimum water depth requirements. Increased flows in the Low Flow Channel from May through June 15 would have no effect on steelhead adult immigration and holding because the adult immigration and holding period for adult steelhead migrating to the Feather River begins in September.

Adult Spawning and Embryo Incubation

Under Alternative 2, flow in the Low Flow Channel would be 800 cfs year-round, except from May 1 through June 15, when the total releases from the Oroville Facilities would be released down the Low Flow Channel, up to a maximum flow of 1,200 cfs. Flow fluctuations in the Low Flow Channel from 800 to 1,200 cfs from May 1 through June 15, and from 800 to 1,000 cfs for water temperature control during in the summer, could potentially occur with implementation of Alternative 2.

No flow increases above 800 cfs would occur before the end of steelhead spawning; therefore, there would be no risk of establishing redds at stage elevations that could potentially be dewatered by a subsequent Low Flow Channel flow fluctuation.

Implementation of Alternative 2 would not result in any change in the frequency or magnitude of flow fluctuations in the High Flow Channel relative to the No-Action Alternative; therefore, there would be no change in the rate of steelhead redd dewatering occurring in the High Flow Channel with implementation of Alternative 2.

Evaluation of the WUA index generated by the PHABSIM model for the steelhead adult spawning life stage indicates the maximum amount of spawning area in the Low Flow Channel, given the current channel configuration, occurs at flows around 500 cfs. However, no distinct maximum occurs over the range of flow between 150 cfs and 1,500 cfs. Figure G-AQUA5.4-24 shows the steelhead spawning WUA curve (lower) generated by the PHABSIM model for the Low Flow Channel.

Under the No-Action Alternative, flows in the Low Flow Channel during the steelhead spawning period would be 600 cfs, which would result in approximately 98 percent of maximum WUA. Flows in the Low Flow Channel under Alternative 2 would be 800 cfs during the steelhead spawning period, which would result in approximately 91 percent of maximum WUA, representing a decrease in WUA compared to the No-Action Alternative.

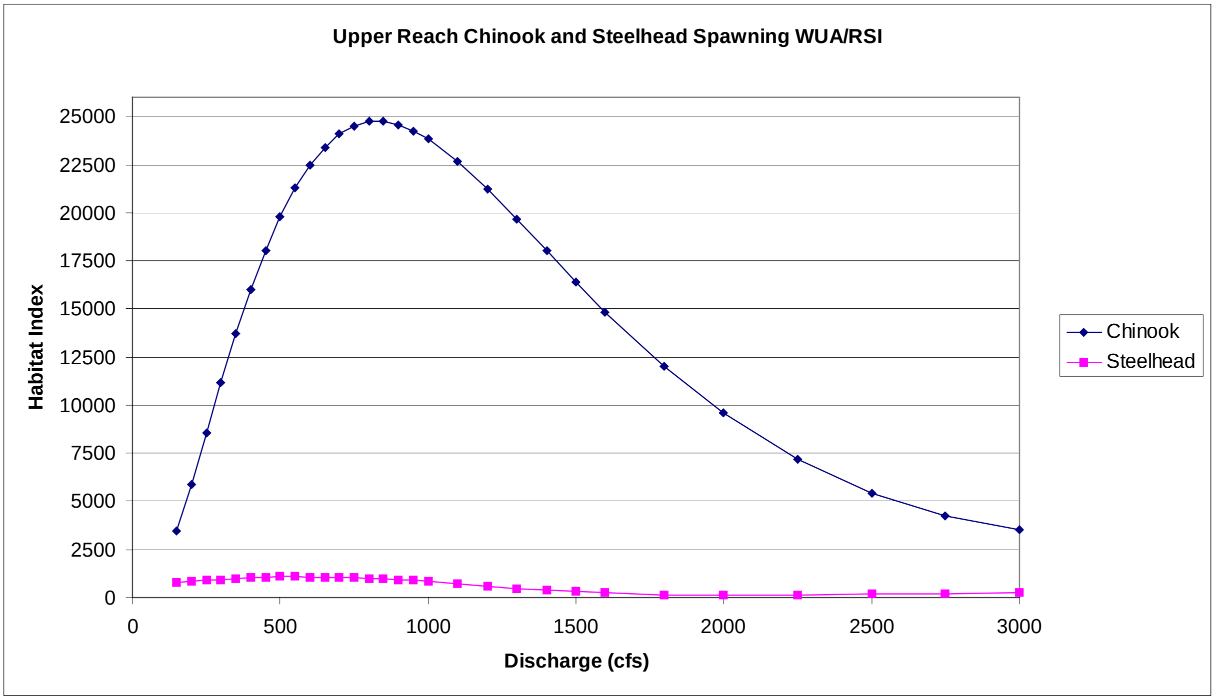


Figure G-AQUA5.4-24. Low Flow Channel WUA curves for steelhead and Chinook salmon.

Under Alternative 2, flows and flow fluctuations occurring in the High Flow Channel are not expected to differ from those occurring under the No-Action Alternative (described in Section 5.4.2.1, Water Quantity Environmental Effects). As a result, implementation of Alternative 2 would not result in a change in the amount of steelhead spawning habitat available or rates of redd dewatering occurring in the High Flow Channel.

Fry and Fingerling Rearing and Downstream Movement

Flow fluctuations in the Low Flow Channel could potentially occur under Alternative 2 to meet water temperature objectives prescribed to protect fisheries resources, or through change in total releases occurring between 800 and 1,200 cfs from May 1 through June 15. Under Alternative 2, the maximum normal operation flow fluctuations in the Low Flow Channel would be 400 cfs. Flow fluctuations can result in juvenile salmonid stranding in isolation ponds or beach stranding. Isolation ponds do not occur in the Low Flow Channel below 1,200 cfs; therefore, no isolation pond–type stranding would be anticipated with implementation of Alternative 2. Beach stranding can occur with changes in water surface elevation from changes in flows. Juvenile steelhead tend to select deeper water with increased size and become less susceptible to beach-type stranding as they grow later in the juvenile rearing period. Flow fluctuations in the Low Flow Channel with implementation of Alternative 2 would occur from May 1 through June 15, with a maximum flow fluctuation of 400 cfs. Flow fluctuations of typically 200 cfs or less also would occur during the summer as a result of temperature control actions. The May 1 through June 15 flow fluctuations of up to 400 cfs likely would result in some occurrences of steelhead beach stranding during this time period. After June

15, water temperature control-related flow changes are typically 200 cfs or less and occur when rearing juveniles are larger and have preference for deeper water, and therefore are not susceptible to beach-type stranding from water temperature control-related flow changes.

Implementation of Alternative 2 would not result in any change in the frequency or magnitude of flow fluctuations in the High Flow Channel compared to the No-Action Alternative; therefore, there would be no change in the rate of juvenile steelhead stranding occurring in the High Flow Channel.

Smolt Emigration

Changes in Low Flow Channel flows with implementation of Alternative 2 are not expected to affect the quality or quantity of habitat for steelhead smolt emigration or the timing behavior of smolt emigration because emigrating smolts spend little time foraging and rearing and the majority of time actively migrating seaward.

G-AQUA5.4.3.2 Temperature-related Effects

The relative habitat suitability analysis includes an evaluation of overall relative habitat suitability based on water temperature index values. The analysis includes a comparison of habitat suitability component metrics between the No-Action Alternative and Alternative 2. The OHSIV analysis is described in the above discussion of temperature-related effects on fall-run Chinook salmon. Detailed descriptions of the methodology used in the derivation and calculation of each of the above metrics are presented in Section G-AQUA.2.2.3 of Appendix G-AQUA2, Methodology.

Adult Immigration and Holding

Figures G-AQUA5.4-25, G-AQUA5.4-26, and G-AQUA5.4-27 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA5.4-25, G-AQUA5.4-26, and G-AQUA5.4-27 is equal, which allows for direct comparison of habitat suitability between alternatives.

The OHSIV metrics presented in Table G-AQUA5.4-6 for steelhead adult immigration and holding for the 52°F water temperature index value under the No-Action Alternative and Alternative 2 are 1,100,514 and 1,098,088, respectively. The difference in OHSIV between the No-Action Alternative and Alternative 2 is 2,425, which represents a 0.22 percent decrease in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 56°F water temperature index value under the No-Action Alternative and Alternative 2 are 1,712,352 and 1,734,439, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 22,087, which represents a 1.29 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 70°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,836,131 and 2,845,249, respectively. The difference in OHSIV

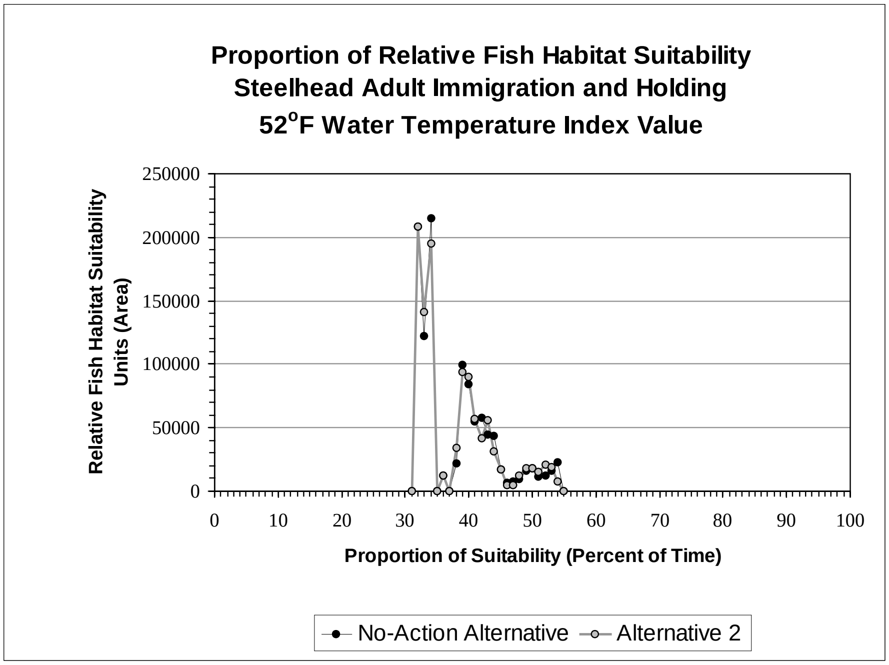


Figure G-AQUA5.4-25. Proportion of relative fish habitat suitability for steelhead adult immigration and holding for the 52°F water temperature index value.

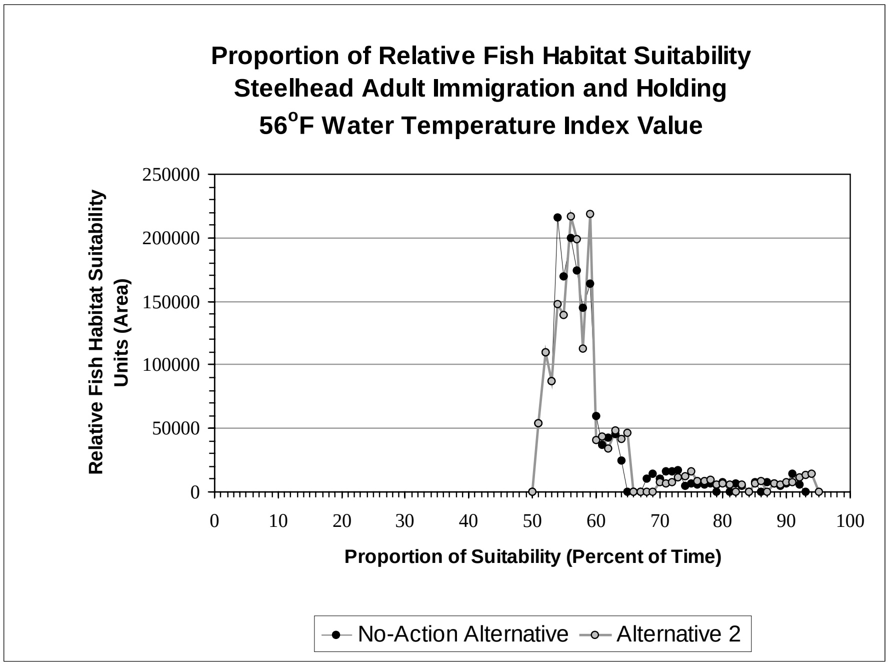


Figure G-AQUA5.4-26. Proportion of relative fish habitat suitability for steelhead adult immigration and holding for the 56°F water temperature index value.

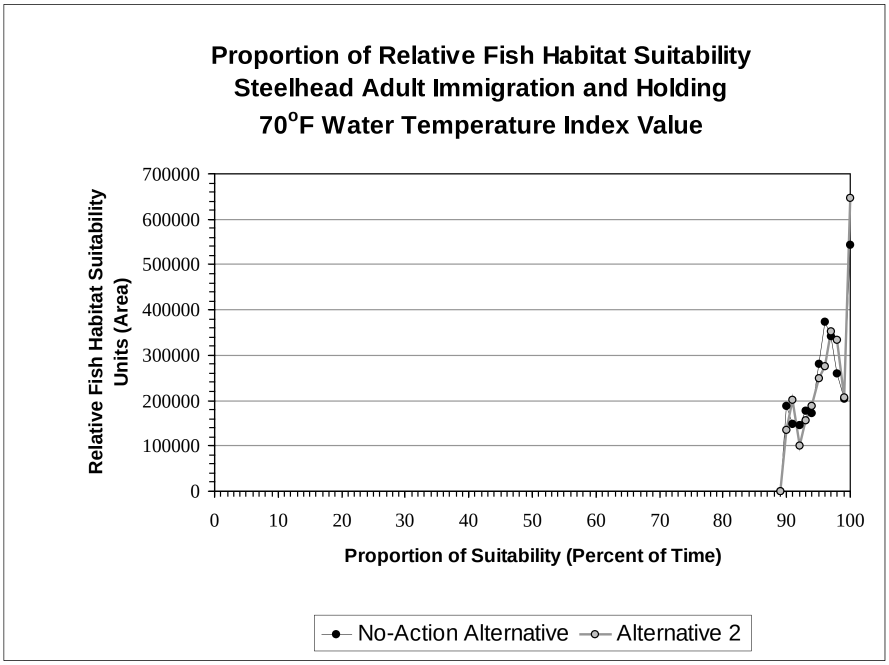


Figure G-AQUA5.4-27. Proportion of relative fish habitat suitability for steelhead adult immigration and holding for the 70°F water temperature index value.

Table G-AQUA5.4-6. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for steelhead adult immigration and holding.

Water Temperature Index Value	**52°F**	**56°F**	**70°F**
No-Action Alternative			
Minimum Percentage of Time Value	32%	51%	90%
Maximum Percentage of Time Value	54%	92%	100%
Habitat Units at 100 Percent of Time	0	0	542,986
Percentage of Time at Maximum Habitat Units	34%	54%	100%
OHSIV	1,100,514	1,712,352	2,836,131
Alternative 2			
Minimum Percentage of Time Value	32%	51%	90%
Maximum Percentage of Time Value	54%	94%	100%
Habitat Units at 100 Percent of Time	0	0	646,443
Percentage of Time at Maximum Habitat Units	32%	59%	100%
OHSIV	1,098,088	1,734,439	2,845,249
Percent Change	**-0.22%**	**1.29%**	**0.32%**

between Alternative 2 and the No-Action Alternative is 9,118, which represents a 0.32 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative.

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-6 for the steelhead adult immigration and holding life stage did not change between Alternative 2 and the No-Action Alternative for any of the water temperature index values selected.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-6 for the steelhead adult immigration and holding life stage did not change between the No -Action Alternative and existing conditions for the 52°F or 70°F water temperature index values. The Maximum Percentage of Time Value metric for the 56°F water temperature index value under the No-Action Alternative and Alternative 2 are 92 percent and 94 percent, respectively. The two percent difference in Maximum Percentage of Time Value between Alternative 2 and the No-Action Alternative represents a small increase in the number of habitat units with the greatest amount of time and area with water temperatures below 56°F under Alternative 2 compared to the No-Action Alternative.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-6 for the steelhead adult immigration and holding life stage did not change between Alternative 2 and the No -Action Alternative for the 52°F or 56°F water temperature index values. The Habitat Units at 100 Percent of Time for the 70°F water temperature index value under the No-Action Alternative and Alternative 2 are 542,986 and 646,443, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 103,457, which represents approximately a 19 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 70°F.

A 19 percent increase in the number of habitat units in which water temperatures are always at or below 70°F and above 56°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to immigrating and holding steelhead, such as cessation of immigration, decreased spawning success, and decreased in vivo egg viability (Bruin and Waldsdorf 1975; McCullough et al. 2001).

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-6 for the steelhead adult immigration and holding life stage did not change between Alternative 2 and the No -Action Alternative for the 70°F water temperature index value. The Percentage of Time at Maximum Habitat Units metric presented for the steelhead adult immigration and holding life stage for the 52°F water temperature index value under the No-Action Alternative and Alternative 2 are 34 percent and 32 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between the No-Action Alternative and Alternative 2 is two percent, which represents a decrease in the percentage of time that the habitat is suitable in the greatest area under Alternative 2. The Percentage of Time at Maximum Habitat Units metric presented for the steelhead adult immigration and holding life stage for the 56°F water temperature index value under the No-Action Alternative and Alternative 2 are 54 percent and 59 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No-Action Alternative is five percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area.

Adult Spawning and Embryo Incubation

Figures G-AQUA5.4-28, G-AQUA5.4-29, G-AQUA5.4-30, and G-AQUA5.4-31 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA5.4-28, G-AQUA5.4-29, G-AQUA5.4-30, and G-AQUA5.4-31 is equal, which allows for direct comparison of habitat suitability between alternatives.

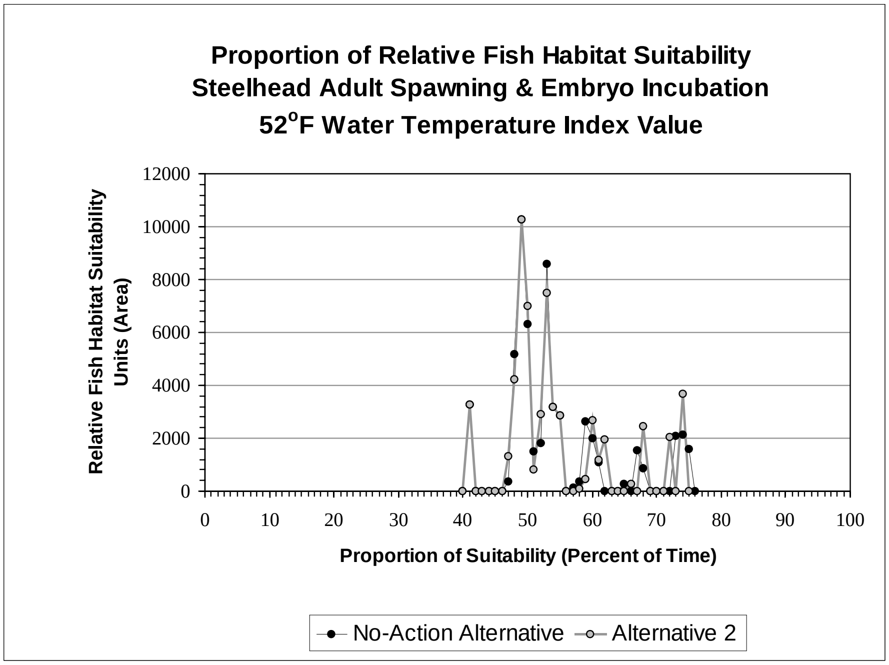


Figure G-AQUA5.4-28. Proportion of relative fish habitat suitability for steelhead adult spawning and embryo incubation for the 52°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA5.4-7 for steelhead adult spawning and embryo incubation for the 52°F water temperature index value under the No-Action Alternative and Alternative 2 are 58,198 and 58,242, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 44, which represents a 0.08 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 54°F water temperature index value under the No-Action Alternative and Alternative 2 are 71,613 and 72,759, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 1,164, which represents a 1.60 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 57°F water temperature index value under the No-Action Alternative and Alternative 2 are 87,172 and 88,550, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 1,378, which represents a 1.58 percent increase in OHSIV under Alternative 2 compared to the

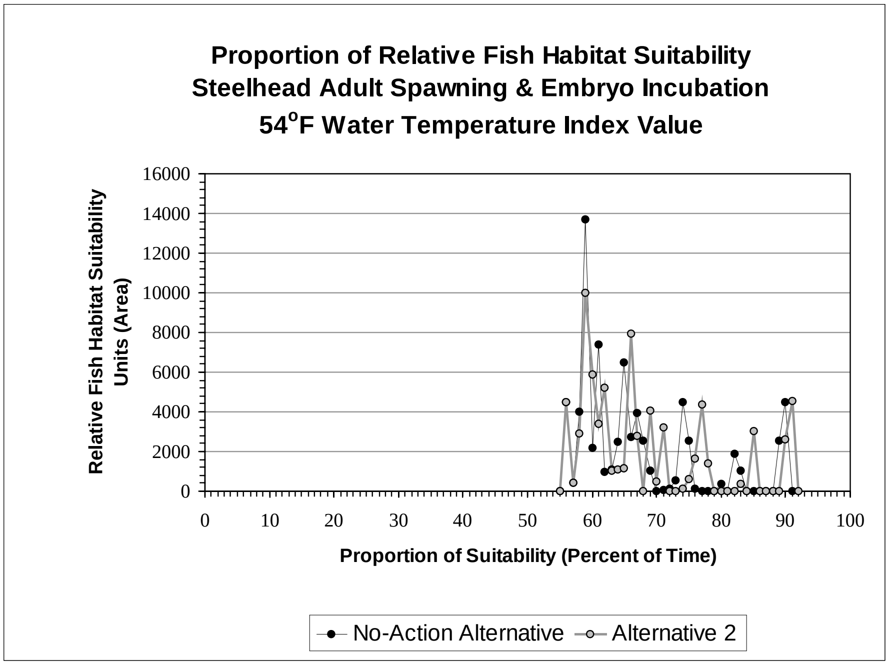


Figure G-AQUA5.4-29. Proportion of relative fish habitat suitability for steelhead adult spawning and embryo incubation for the 54°F water temperature index value.

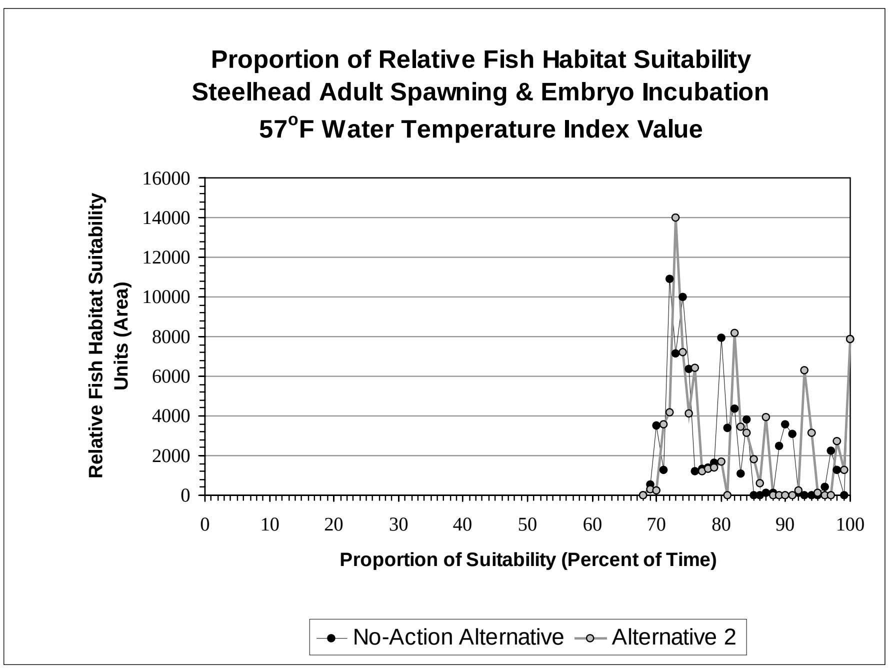


Figure G-AQUA5.4-30. Proportion of relative fish habitat suitability for steelhead adult spawning and embryo incubation for the 57°F water temperature index value.

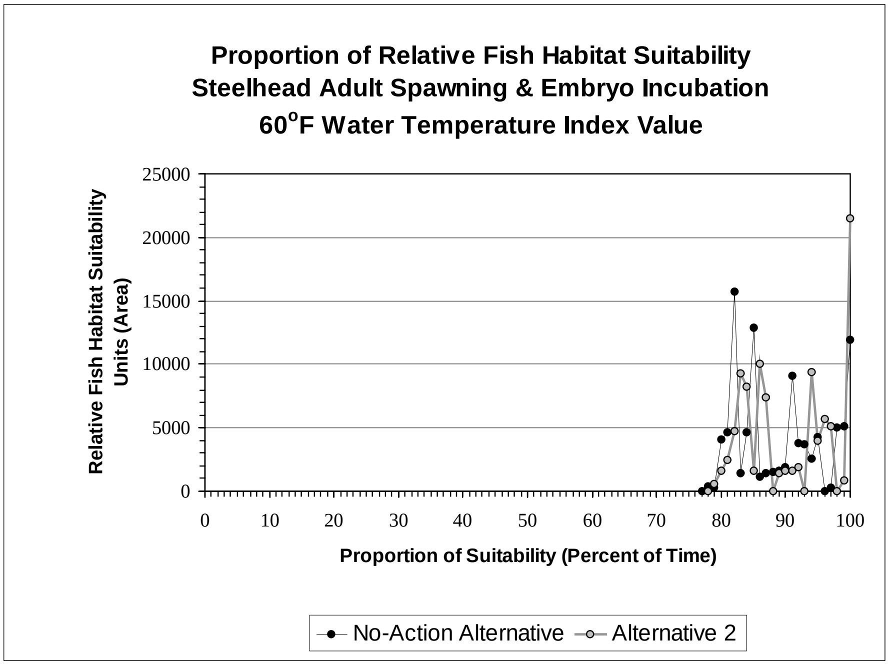


Figure G-AQUA5.4-31. Proportion of relative fish habitat suitability for steelhead adult spawning and embryo incubation for the 60°F water temperature index value.

Table G-AQUA5.4-7. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for steelhead adult spawning and embryo incubation.

Water Temperature Index Value	**52°F**	**54°F**	**57°F**	**60°F**
No-Action Alternative				
Minimum Percentage of Time Value	41%	56%	69%	78%
Maximum Percentage of Time Value	75%	90%	100%	100%
Habitat Units at 100 Percent of Time	0	0	7,858	11,890
Percentage of Time at Maximum Habitat Units	49%	59%	72%	82%
OHSIV	58,198	71,613	87,172	97,181
Alternative 2				
Minimum Percentage of Time Value	41%	56%	69%	79%
Maximum Percentage of Time Value	74%	91%	100%	100%
Habitat Units at 100 Percent of Time	0	0	7,858	21,526
Percentage of Time at Maximum Habitat Units	49%	59%	73%	100%
OHSIV	58,242	72,759	88,550	98,881
Percent Change	0.08%	1.60%	1.58%	1.75%

No-Action Alternative. The OHSIV for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 97,181 and 98,881, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 1,701, which represents a 1.75 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative.

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-7 for the steelhead adult spawning and embryo incubation life stage did not change between Alternative 2 and the No-Action Alternative for the 52°F, 54°F, and 57°F water temperature index values. The Minimum Percentage of Time Value metric for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 78 and 79 percent, respectively. The 1 percent difference in Minimum Percentage of Time Value between Alternative 2 and the No-Action Alternative represents a small increase in the number of habitat units with the smallest amount of time and area with water temperatures below 60°F under Alternative 2 compared to the No-Action Alternative.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-7 for the steelhead adult spawning and embryo incubation and holding did not change between Alternative 2 and the No-Action Alternative for the 57°F and 60°F water temperature index values. The Maximum Percentage of Time Value metric for the 52°F water temperature index value under the No-Action Alternative and Alternative 2 are 75 percent and 74 percent, respectively. The 1 percent difference in Maximum Percentage of Time Value between the No-Action Alternative and Alternative 2 represents a small decrease in the number of habitat units with the greatest amount of time and area with water temperatures below 52°F under Alternative 2 compared to the No-Action Alternative. The Maximum Percentage of Time Value metric for the 54°F water temperature index value under the No-Action Alternative and Alternative 2 are 90 percent and 91 percent, respectively. The 1 percent difference in Maximum Percentage of Time Value between Alternative 2 and the No-Action Alternative represents a small increase in the number of habitat units with the greatest amount of time and area with water temperatures below 54°F under Alternative 2 compared to the No-Action Alternative.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-7 for the steelhead adult spawning and embryo incubation life stage did not change between Alternative 2 and the No-Action Alternative for the 52°F, 54°F, and 57°F water temperature index values. The Habitat Units at 100 Percent of Time for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 11,890 and 21,526, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 9,636, which represents approximately an 81 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 60°F.

An 81.04 percent increase in the number of habitat units in which water temperatures are always at or below 60°F and above 57°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to spawning adult steelhead and steelhead incubating embryos, such as decreased fertilization rates, decreased adult survival, and substantially increased egg and embryo mortality (Kamler and Kato 1983; Kwain 1975; Velsen 1987).

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-7 for the steelhead adult spawning and embryo incubation life stage did not change between Alternative 2 and the No-Action Alternative for the 52°F and 54°F water temperature index values. The Percentage of Time at Maximum Habitat Units metric presented for the steelhead adult spawning and embryo incubation life stage for the 57°F water temperature index value under the No-Action Alternative and Alternative 2 are 72 percent and 73 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 the No-Action Alternative is 1 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area under Alternative 2. The Percentage of Time at Maximum Habitat Units metric presented for the steelhead adult spawning and embryo incubation life stage for the 60°F water temperature index value under the No-Action Alternative and Alternative 2 are 82 percent and 100 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 the No-Action Alternative is 18 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area under Alternative 2.

Fry and Fingerling Rearing and Downstream Movement

Figures G-AQUA5.4-32, G-AQUA5.4-33, G-AQUA5.4-34, and G-AQUA5.4-35 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA5.4-32, G-AQUA5.4-33, G-AQUA5.4-34, and G-AQUA5.4-35 is equal, which allows for direct comparison of habitat suitability between alternatives.

The OHSIV metrics presented in Table G-AQUA5.4-8 for steelhead fry and fingerling rearing and downstream movement for the 65°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,083,223 and 2,107,073, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 23,850, which represents a 1.14 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,440,326 and 2,458,476, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 18,150, which represents a 0.74 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 72°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,786,096 and 2,794,411, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 8,315, which represents a 0.30 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 75°F water temperature index value under the No-Action Alternative and Alternative 2 are 2,893,527 and 2,894,827, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 1,289, which represents a 0.04 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative.

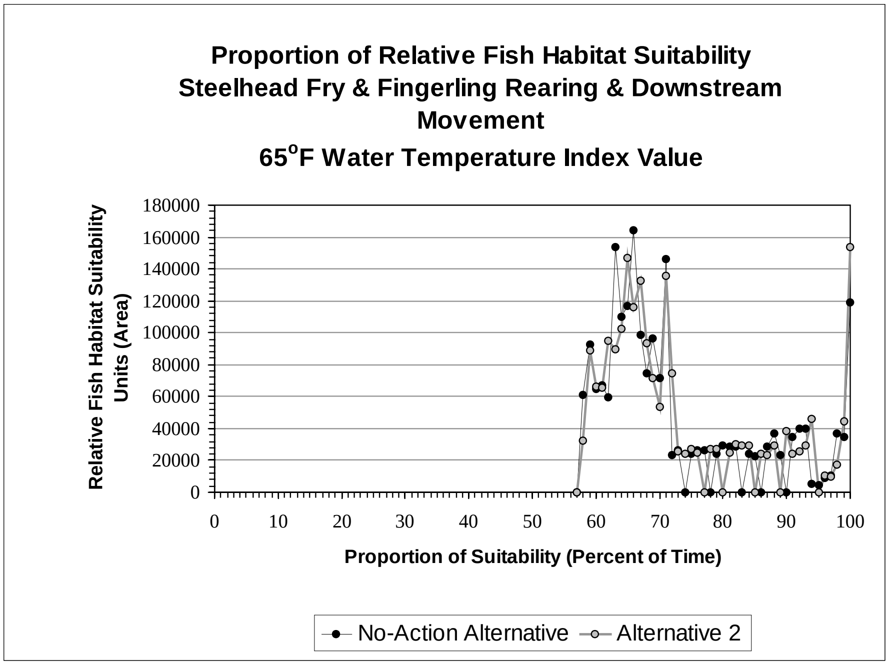


Figure G-AQUA5.4-32. Proportion of relative fish habitat suitability for steelhead fry and fingerling rearing and downstream movement for the 65°F water temperature index value.

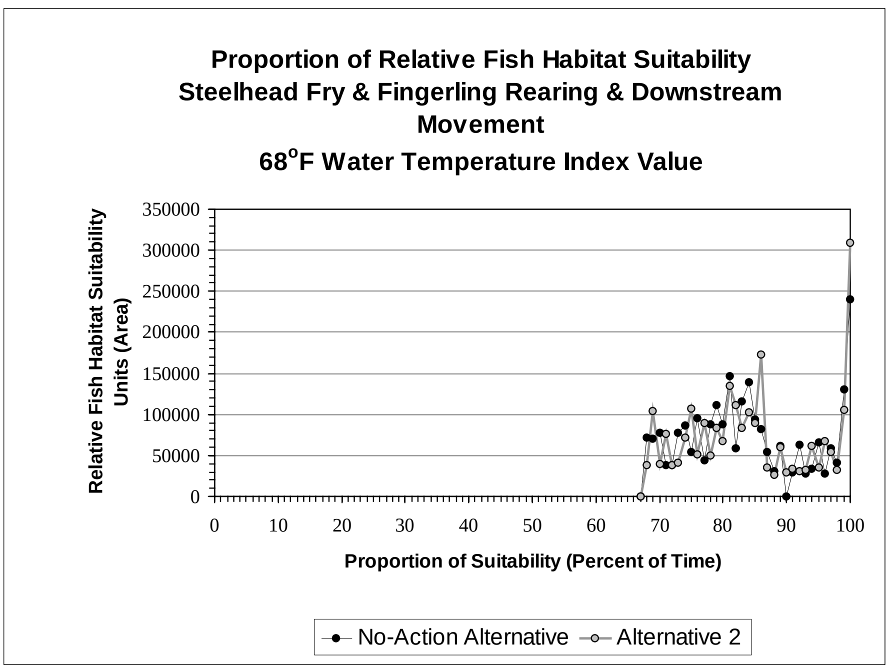


Figure G-AQUA5.4-33. Proportion of relative fish habitat suitability for steelhead fry and fingerling rearing and downstream movement for the 68°F water temperature index value.

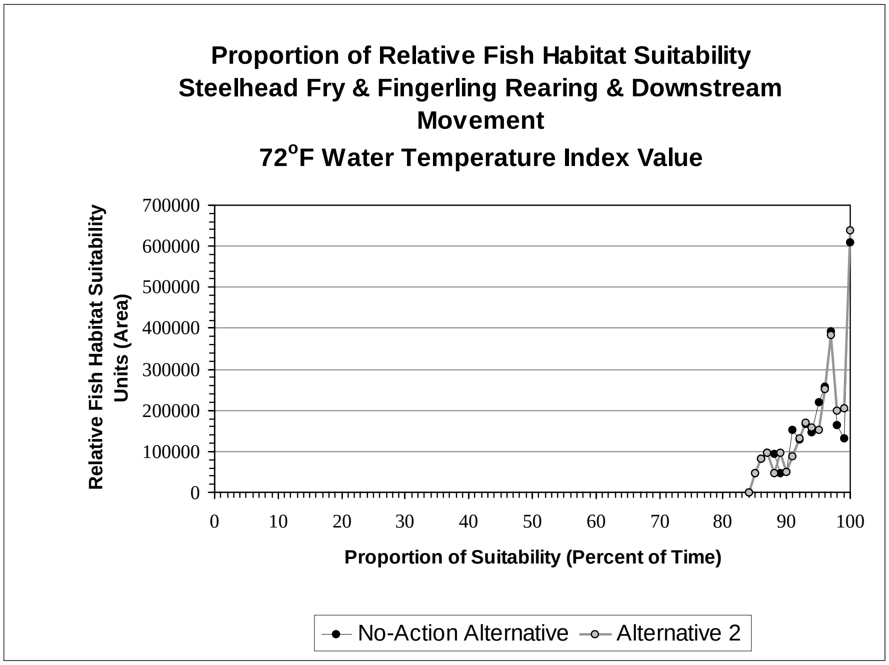


Figure G-AQUA5.4-34. Proportion of relative fish habitat suitability for steelhead fry and fingerling rearing and downstream movement for the 72°F water temperature index value.

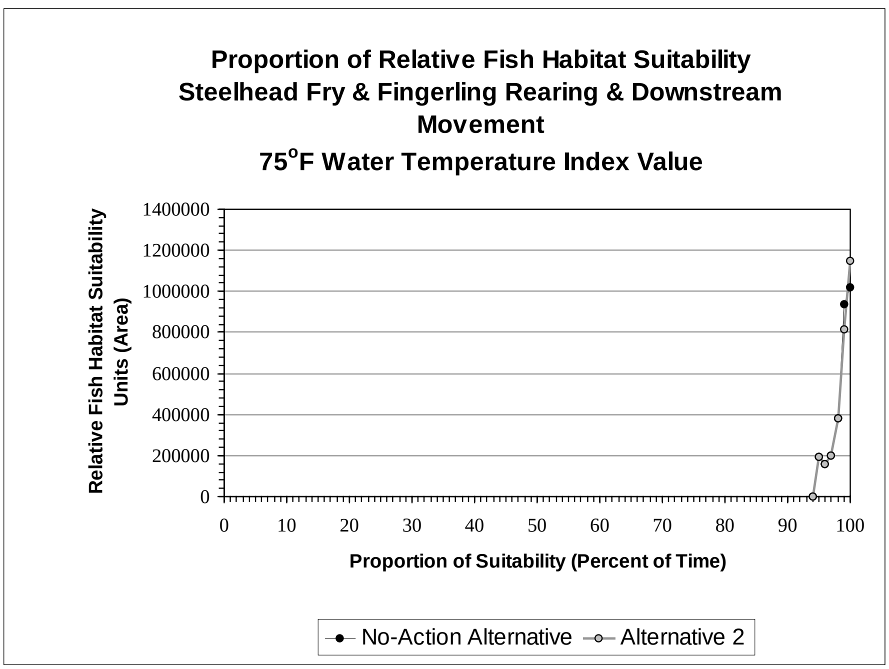


Figure G-AQUA5.4-35. Proportion of relative fish habitat suitability for steelhead fry and fingerling rearing and downstream movement for the 75°F water temperature index value.

Table G-AQUA5.4-8. Overall habitat suitability index value comparison the No-Action Alternative and Alternative 2 for steelhead fry and fingerling juvenile rearing and downstream movement.

Water Temperature Index Value	65°F	68°F	72°F	75°F
No-Action Alternative				
Minimum Percentage of Time Value	58%	68%	85%	95%
Maximum Percentage of Time Value	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	119,042	240,338	609,003	1,020,829
Percentage of Time at Maximum Habitat Units	66%	100%	100%	100%
OHSIV	2,083,223	2,440,326	2,786,096	2,893,537
Alternative 2				
Minimum Percentage of Time Value	58%	68%	85%	95%
Maximum Percentage of Time Value	100%	100%	100%	100%
Habitat Units at 100 Percent of Time	153,953	308,266	639,613	1,149,758
Percentage of Time at Maximum Habitat Units	100%	100%	100%	100%
OHSIV	2,107,073	2,458,476	2,794,411	2,894,827
Percent Change	1.14%	0.74%	0.30%	0.04%

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-8 for the steelhead fry and fingerling rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for any of the water temperature index values selected.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-8 for the steelhead fry and fingerling rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for any of the water temperature index values selected.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-8 for the 65°F water temperature index value for the steelhead fry and fingerling rearing and downstream movement life stage under the No-Action Alternative and Alternative 2 are 119,042 and 153,953, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 34,911, which represents approximately a 29 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 65°F. The Habitat Units at 100 Percent of Time for the 68°F water temperature index value under the No-Action Alternative and Alternative 2 are 240,338 and 308,266, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 67,928, which represents approximately a 28 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 68°F. The Habitat Units at 100 Percent of Time for the 72°F water temperature index value under the No-Action Alternative and Alternative 2 are 609,003 and 639,613, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 30,610, which represents approximately a 5 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 72°F. The Habitat Units at 100 Percent of Time for the 75°F water temperature index value under the No-Action Alternative and Alternative 2 are 1,020,829 and 1,149,758, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 128,929, which represents approximately a 13 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always at or below 75°F.

A 29 percent increase in the number of habitat units in which water temperatures are always at or below 65°F represents an increase in habitat under Alternative 2 that rearing and emigrating juvenile steelhead are reported to prefer (Cech and Myrick 1999; Cherry et al. 1977; Kaya et al. 1977). An 28 percent increase in the number of habitat units in which water temperatures are always at or below 68°F and above 65°F represents an increase in habitat under Alternative 2 that rearing and emigrating juvenile steelhead are reported to prefer (Cech and Myrick 1999; Cherry et al. 1977; Kaya et al. 1977). A 5 percent increase in the number of habitat units in which water temperatures are always at or below 72°F and above 68°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating steelhead fry and fingerlings, such as increased physiological stress, increased agonistic activity, and a decrease in forage activity (Nielsen et al. 1994). A 13 percent increase in the number of habitat units in which water temperatures are always at or below 75°F and above 72°F represents an increase in habitat under Alternative 2 in which specific biological effects could potentially occur to rearing and downstream migrating steelhead fry and fingerlings, including increased physiological stress, decreased forage activity, and increased mortality (Nielsen et al. 1994; NOAA Fisheries 2001). A detailed description of the potential effects that could occur to rearing and downstream migrating fry and fingerlings steelhead from exposure to water temperatures between above each water temperature index value is presented in Section G-AQUA2.2.3 of Appendix G-AQUA2.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-8 for the steelhead fry and fingerling rearing and downstream movement life stage did not change between Alternative 2 and the No-Action Alternative for the 68°F, 70°F, and 72°F water temperature index values. The Percentage of Time at Maximum Habitat Units presented for the steelhead fry and fingerling rearing and downstream movement life stage for the 65°F water temperature index value under the No-Action Alternative and Alternative 2 are 66 percent and 100 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No-Action Alternative is 34 percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area.

<u>Smolt Emigration</u>

Figures G-AQUA5.4-36 and G-AQUA5.4-37 show the proportion of time that habitat units are considered suitable for each water temperature index value selected. The area under each curve displayed in Figures G-AQUA5.4-36 and G-AQUA5.4-37 is equal, which allows for direct comparison of habitat suitability between alternatives.

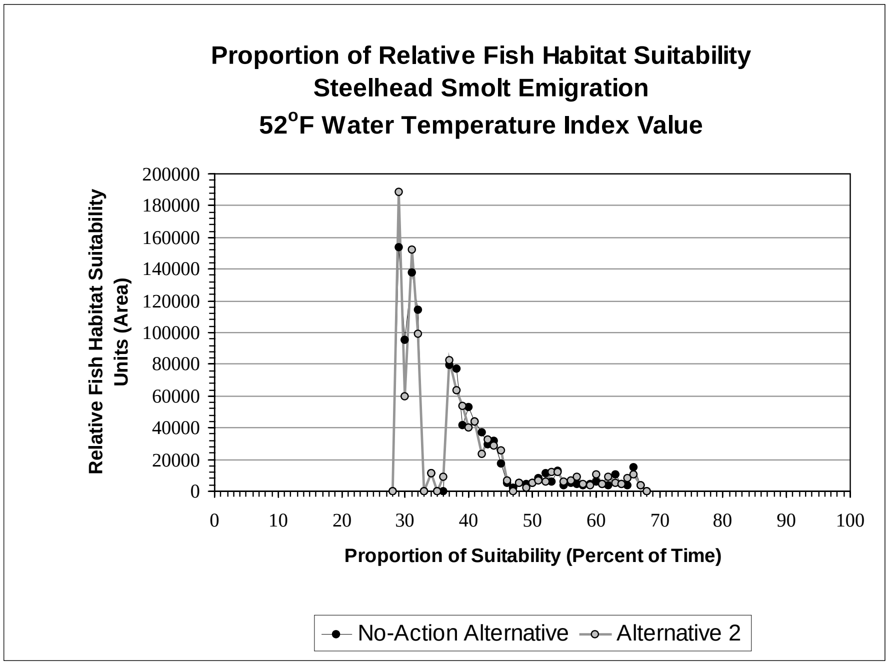


Figure G-AQUA5.4-36. Proportion of relative fish habitat suitability for steelhead smolt emigration for the 52°F water temperature index value.

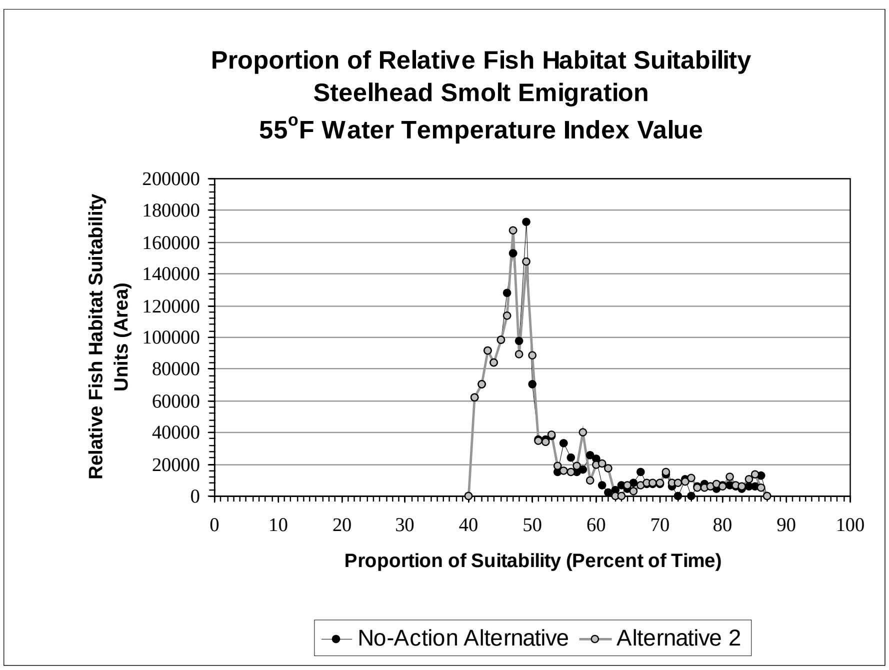


Figure G-AQUA5.4-37. Proportion of relative fish habitat suitability for steelhead smolt emigration for the 55°F water temperature index value.

The OHSIV metrics presented in Table G-AQUA5.4-9 for steelhead smolt emigration for the 52°F water temperature index value under the No-Action Alternative and Alternative 2 are 1,059,104 and 1,059,855, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 751, which represents a 0.07 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. The OHSIV for the 55°F water temperature index value under existing conditions and the No-Action Alternative are 1,463,377 and 1,475,677, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 12,300, which represents a 0.84 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative.

Table G-AQUA5.4-9. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for steelhead smolt emigration.

Water Temperature Index Value	**52°F**	**55°F**
No-Action Alternative		
Minimum Percentage of Time Value	29%	41%
Maximum Percentage of Time Value	67%	86%
Habitat Units at 100 Percent of Time	0	0
Percentage of Time at Maximum Habitat Units	29%	49%
OHSIV	1,059,104	1,463,377
Alternative 2		
Minimum Percentage of Time Value	29%	41%
Maximum Percentage of Time Value	67%	86%
Habitat Units at 100 Percent of Time	0	0
Percentage of Time at Maximum Habitat Units	29%	47%
OHSIV	1,059,855	1,475,677
Percent Change	0.07%	0.84%

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-9 for the steelhead smolt emigration life stage did not change between Alternative 2 and the No-Action Alternative for any of the water temperature index values selected.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-9 for the steelhead smolt emigration life stage did not change between Alternative 2 and the No-Action Alternative for any of the water temperature index values selected.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-9 for the steelhead smolt emigration life stage did not change between Alternative 2 and the No-Action Alternative for any of the water temperature index values selected.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-9 for the steelhead smolt emigration life stage did not change between Alternative 2 and the No-Action Alternative for the 52°F water temperature index value. The Percentage of Time at Maximum Habitat Units metric for the steelhead smolt emigration life stage for the 55°F water temperature index value under the No-Action

Alternative and Alternative 2 are 49 percent and 47 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between the No-Action Alternative and Alternative 2 is two percent, which represents a small decrease in the percentage of time that the habitat is suitable in the greatest area.

G-AQUA5.4.3.3 Predation-related Effects

Changes in minimum flows in the Low Flow Channel with implementation of Alternative 2 are not expected to change the nature or rate of predation relative to the No-Action Alternative. Water temperature changes would be very small and are not expected to change the distribution, species composition, consumption rates, or nature of predation in the lower Feather River. Adaptive management changes in steelhead hatchery release practices may reduce predation of juvenile spring-run Chinook salmon. The Large Woody Debris Supplementation and Improvement Program would improve juvenile rearing cover conditions, resulting in a reduction of predation rates on juvenile steelhead.

G-AQUA5.4.3.4 Fisheries Management–related Effects

Hatchery

The Hatchery Adaptive Management Program included in Alternative 2 is the same as that included in the Proposed Action, with the exception of the inclusion of a water treatment facility for the hatchery water supply. (See Section G-AQUA4.4 of Appendix G-AQUA4, Effects of the Proposed Action, for an evaluation of the Hatchery Adaptive Management Program.) The proposed hatchery water treatment could reduce the rate of incidence and severity of disease occurrences in the Feather River Fish Hatchery, which, as a result, would lower contributions of accumulated disease pressure in the lower Feather River.

Disease

Water temperature changes with implementation of Alternative 2 would be relatively small; therefore, no changes in water temperature–related interactions with the incidence of fish diseases are anticipated. The proposed hatchery water treatment could reduce the rate of incidence and severity of disease occurrences in the Feather River Fish Hatchery, which, as a result, would lower contributions of the accumulated disease pressure in the lower Feather River.

Fishing Regulations, Poaching, and Change in Recreational Access and Visitation

Section 5.10.2, Recreation Resources Environmental Effects, forecasts a one-third increase in recreation and angling activities under the No-Action Alternative and an approximately 51 percent increase in recreation and angling under Alternative 2, as compared to the existing condition. This would indicate an expected increase of approximately 18 percent in recreation and angling under Alternative 2 relative to the No-Action Alternative. A 18 percent increase in angling, with no other PM&E measures related to fisheries, would equate to increased angler harvest rates. Fishing access would be increased under Alternative 2 with the implementation of several recreation facilities on the lower Feather River. (See Section 5.10.2.3 for additional information on recreation facilities and changes in visitation under Alternative 2.) No fishing zones in proximity to the fish barrier weirs would require changes to fishing regulations under Alternative 2.

G-AQUA5.4.3.5 Summary of Potential Effects on Steelhead

Study plan report summaries addressing project effects on steelhead are presented in Section G-AQUA1.5, Fisheries Management; Section G-AQUA1.8, Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam; Section G-AQUA5.10, Instream Flows and Fish Habitat; and Section G-AQUA1.11, Predation, of Appendix G-AQUA1, Affected Environment. A description of each steelhead life stage and the time period associated with it is presented in Appendix G-AQUA1.

Effects on steelhead associated with installation of fish barrier weirs, the Large Woody Debris Supplementation and Improvement Program, and the Gravel Supplementation and Improvement Program with implementation of Alternative 2 would not differ from those effects associated with the Proposed Action; the proposed PM&E measures are the same under Alternative 2 and the Proposed Action as under the No-Action Alternative. Appendix G-AQUA4, Effects of the Proposed Action, describes the effects associated with each PM&E measure proposed for implementation under the Proposed Action. Additionally, water temperature–related effects resulting from changes in flows in the Low Flow Channel under Alternative 2 are not expected to alter disease or predation effects because the changes in water temperature compared to the No-Action Alternative would be small.

Adult Immigration and Holding

Actions potentially affecting steelhead adult immigration and holding include changes to instream flows and water temperatures in the Low Flow Channel. Creation and enhancement of side-channel habitat, and a Hatchery Adaptive Management Program, implemented under Alternative 2 would differ slightly from those PM&E measures proposed for implementation under the Proposed Action, but would have the same effects on steelhead adult immigration and holding compared to the No-Action Alternative. Appendix G-AQUA4, Effects of the Proposed Action, describes the effects associated with each PM&E measure proposed for implementation under the Proposed Action.

An increased instream flow of 800 cfs in the Low Flow Channel under Alternative 2 could potentially have a beneficial effect on immigrating and holding steelhead by increasing lower Feather River stage elevations. Although stage increases would be small, shallow riffles could potentially become deeper, reducing the effort required by immigrating adult steelhead to proceed through shallow riffles. Additional areas of the river would become suitable holding habitat as a result of increased water depths. Reduced average daily water temperatures during the steelhead adult immigration and holding period result in increased overall habitat suitability for the 56°F water temperature index value. However, model results indicate that differences in habitat suitability due to decreased water temperatures for the remaining water temperature index values are less than 1 percent between the No-Action Alternative and Alternative 2, and as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis.

Overall, implementation of Alternative 2 would result in a slight beneficial effect on steelhead adult immigration and holding.

Adult Spawning and Embryo Incubation

Actions potentially affecting steelhead adult spawning and embryo incubation include a Hatchery Adaptive Management Program, creation and enhancement of side-channel habitat, and changes to instream flows and water temperatures in the Low Flow Channel. Many of the effects of a Hatchery Adaptive Management Program would be the same as those identified for the Proposed Action (Appendix G-AQUA4), relative to the No-Action Alternative, with one exception. The water treatment program associated with the Hatchery Adaptive Management Program under Alternative 2 would potentially have an additional beneficial effect on incubating steelhead embryos by reducing accumulated disease pressure in the lower Feather River.

Creation and enhancement of side-channel habitat under Alternative 2 would result in additional quantity and quality of side-channel habitat.

An increase in instream flow in the Low Flow Channel from 600 cfs to 800 cfs during the adult spawning and embryo incubation period would decrease PHABSIM steelhead spawning WUA from 98 percent of maximum to approximately 91 percent of maximum. Potential fluctuations in flow in the Low Flow Channel from May 1 through June 15 would not affect steelhead adult spawning and embryo incubation. Steelhead spawning in the lower Feather River ceases prior to May 1; therefore, no redd dewatering events would occur. Additionally, during extreme drought years, decreases in flow from 800 cfs to 750 cfs likely would have a beneficial effect on steelhead adult spawning and embryo incubation because 750 cfs represents approximately 93 percent of maximum WUA, while 800 cfs represents approximately 91 percent of maximum WUA. Reduced average daily water temperatures during the steelhead adult spawning and embryo incubation period result in increased overall habitat suitability for the 54°F, 57°F, and 60°F water temperature index values. However, model results indicate that differences in habitat suitability due to decreased water temperatures for the 52°F water temperature index value was less than 1 percent between the No-Action Alternative and Alternative 2, and as such, is considered below the detection limits of the analytical tools utilized in the habitat suitability analysis.

Overall, implementation of Alternative 2 would result in a beneficial effect on steelhead adult spawning and embryo incubation.

Juvenile Rearing and Downstream Movement

Actions potentially affecting rearing and downstream movement by steelhead fry and fingerlings include a Hatchery Adaptive Management Program, side-channel habitat enhancement and creation, and changes to instream flows and water temperatures in the Low Flow Channel. Many of the effects of a Hatchery Adaptive Management Program would be the same as those identified for the Proposed Action (Appendix G-AQUA4), relative to the No-Action Alternative, with one exception. The water treatment program associated with the Hatchery Adaptive Management Program under Alternative 2 would potentially have an additional beneficial effect on rearing fry and fingerling steelhead by reducing accumulated disease pressure in the lower Feather River.

Creation and enhancement of side-channel habitat under Alternative 2 would result in additional quantity and quality of side-channel habitat.

Flow fluctuations in the Low Flow Channel from 800 to 1,200 cfs could occur from May 1 through June 15, which could result in an adverse effect on steelhead fry and fingerling rearing and downstream movement by increasing the potential for beach stranding. Reduced average daily water temperatures during the steelhead adult spawning and embryo incubation period result in increased overall habitat suitability for the 65°F water temperature index value. However, model results indicate that differences in habitat suitability due to decreased water temperatures for the remaining water temperature index values were less than 1 percent between the No-Action Alternative and Alternative 2, and as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis.

Overall, implementation of Alternative 2 would result in a beneficial effect on steelhead juvenile rearing and downstream movement.

Smolt Emigration

Actions potentially affecting steelhead smolt emigration include a Hatchery Adaptive Management Program, and changes in instream flows and water temperatures in the Low Flow Channel. Many of the effects of a Hatchery Adaptive Management Program would be the same as identified for the Proposed Action (Appendix G-AQUA4), relative to the No-Action Alternative, with one exception. The water treatment program associated with the Hatchery Adaptive Management Program under Alternative 2 would potentially have an additional beneficial effect on emigrating steelhead smolts by reducing the accumulated disease pressure in the lower Feather River.

Model results indicate that differences in habitat suitability due to decreased water temperatures during the steelhead smolt emigration period were less than 1 percent between the No-Action Alternative and Alternative 2, and as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, water temperature changes in the Low Flow Channel due to increased flows would have no effect on steelhead smolt emigration.

Overall, implementation of Alternative 2 would result in a slight beneficial effect on steelhead smolt emigration.

Conclusion

Under Alternative 2, flows and flow fluctuations occurring in the High Flow Channel are not expected to differ from those occurring under the No-Action Alternative (described in Section 5.4.2.1, Water Quantity Environmental Effects). Therefore, Alternative 2 would not result in a flow-related change in the quality, quantity, or distribution of steelhead habitat occurring in the High Flow Channel. Flow increases in the Low Flow Channel and water temperature reductions also benefit the steelhead habitat quality and quantity. Habitat improvement programs including side-channel creation and enhancement and the Gravel Supplementation and Improvement Program and Large Woody Debris Supplementation and Improvement Program also would be beneficial for steelhead habitat quality and quantity.

Based on the above summary of potential effects, it is likely that implementation of Alternative 2 would result in an overall beneficial effect on steelhead.

G-AQUA5.4.4 American Shad

G-AQUA5.4.4.1 Flow-related Effects

American shad adult immigration occurs in May and June, and spawning occurs in June and July. American shad have been frequently observed in the Feather River from the Thermalito Afterbay Outlet downstream to the confluence with the Sacramento River. American shad are observed only infrequently upstream of the Thermalito Afterbay Outlet to Steep Riffle at River Mile (RM) 61. No changes in flow regimes downstream of the Thermalito Afterbay Outlet are included under Alternative 2, relative to the No-Action Alternative. Under Alternative 2, minimum flows in the river reach extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet would be increased from 600 to 800 cfs. Because American shad are observed only infrequently upstream of the Thermalito Afterbay Outlet, an increase in flow in this reach of the river is not anticipated to have any effect on American shad immigration or spawning.

G-AQUA5.4.4.2 Water Temperature–related Effects

Figure G-AQUA5.4-38 shows the proportion of time that habitat units are considered suitable for the water temperature range selected. The area under each curve displayed in Figure G-AQUA5.4-38 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA5.4-38 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 46°F to 79°F. Figures depicting the amount of habitat with water temperatures below 46°F or above 79°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of Alternative 2 on American shad adult immigration and spawning.

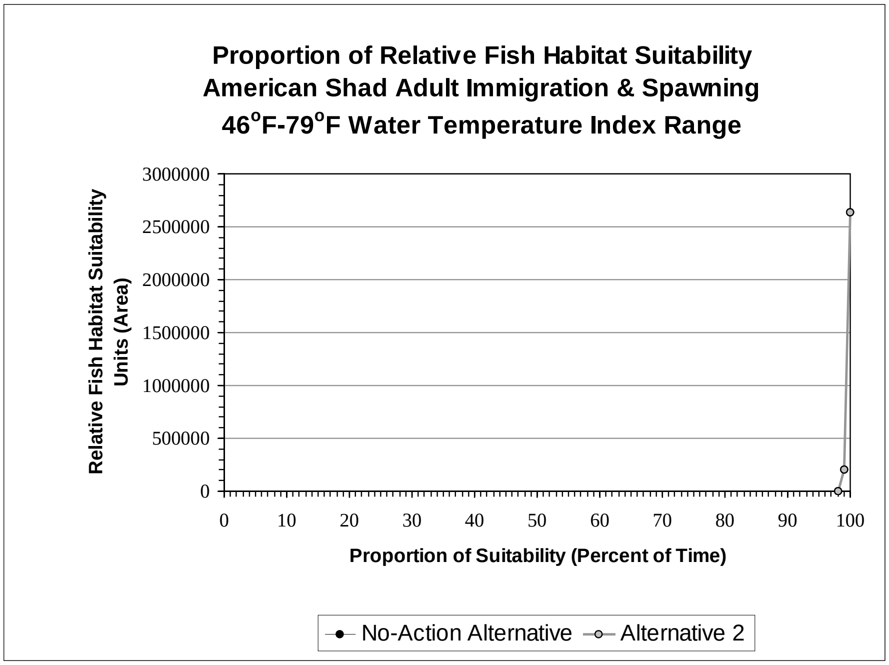


Figure G-AQUA5.4-38. Proportion of relative fish habitat suitability for American shad adult immigration and spawning for the 46°F to 79°F water temperature range.

The OHSIV presented in Table G-AQUA5.4-10 for American shad adult immigration and spawning for the 46°F to 79°F water temperature range under the No-Action Alternative and Alternative 2 are 2,836,030 and 2,836,030, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 0, which represents a no change in OHSIV between Alternative 2 and the No-Action Alternative. Because analysis of the 46°F to 79°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the lack of change in OHSIV for this water temperature range represents no change in relative habitat suitability for American shad adult immigration and spawning in the lower Feather River between the No-Action Alternative and Alternative 2.

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-10 for the American shad adult immigration and spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 46°F to 79°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-10 for the American shad adult immigration and spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 46°F to 79°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-10 for the American shad adult immigration and spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 46°F to 79°F water temperature range.

Table G-AQUA5.4-10. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for American shad adult immigration and spawning.

Water Temperature Index Value	46°F-79°F
No-Action Alternative	
Minimum Percentage of Time Value	99%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	2,631,869
Percentage of Time at Maximum Habitat Units	100%
OHSIV	2,836,030
Alternative 2	
Minimum Percentage of Time Value	99%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	2,631,869
Percentage of Time at Maximum Habitat Units	100%
OHSIV	2,836,030
Percent Change	**0.00%**

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-10 for the American shad adult immigration and spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 46°F to 79°F water temperature range.

G-AQUA5.4.4.3 Summary of Potential Effects on American Shad

Study plan report summaries addressing project effects on American shad are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, of Appendix G-AQUA1.

Implementation of Alternative 2 would increase flows and slightly decrease water temperatures in the Low Flow Channel compared to the No-Action Alternative. However, because American shad are observed infrequently in the Low Flow Channel, an increase in flow would not have an effect on American shad adult immigration and spawning. Model results indicate that differences in habitat suitability due to decreased water temperatures during the American shad spawning period were less than 1 percent between the No-Action Alternative and Alternative 2, and as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, water temperature changes in the Low Flow Channel due to increased flows would have no effect on American shad adult spawning. Additionally, there would be no changes in flows or water temperatures in the High Flow Channel under Alternative 2. Therefore, no water temperature or flow-related effects on American shad would occur.

Based on the above summary of potential effects, it is likely that implementation of Alternative 2 would result in no effect on American shad.

G-AQUA5.4.5 Black Bass

G-AQUA5.4.5.1 Water Temperature–related Effects

Figure G-AQUA5.4-39 shows the proportion of time that habitat units are considered suitable for the water temperature range selected. The area under each curve displayed in Figure G-AQUA5.4-39 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA5.4-39 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 54°F to 75°F. Figures depicting the amount of habitat with water temperatures below 54°F or above 75°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of Alternative 2 on black bass adult spawning.

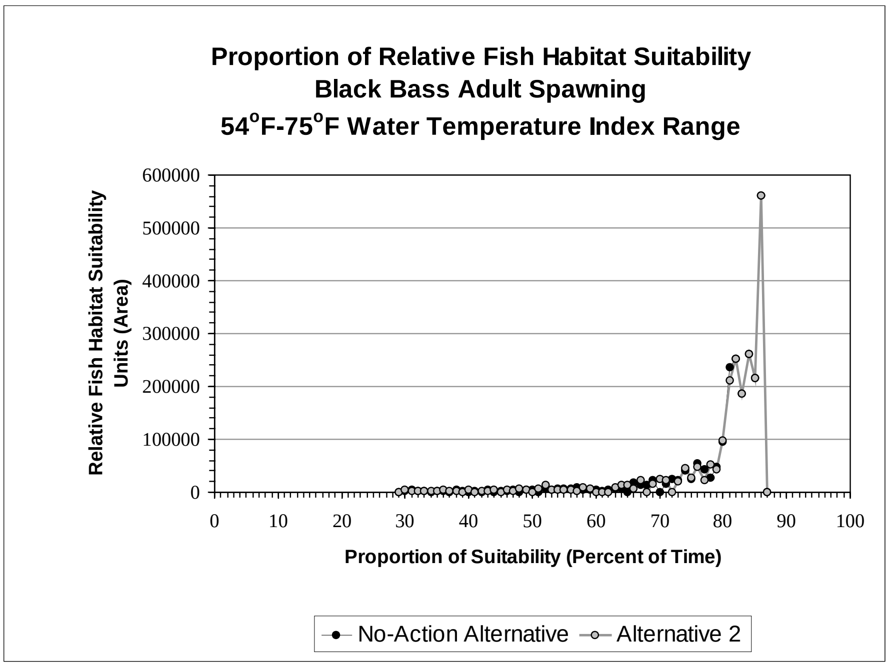


Figure G-AQUA5.4-39. Proportion of relative fish habitat suitability for black bass adult spawning for the 54°F to 75°F water temperature range.

The OHSIV presented in Table G-AQUA5.4-11 for black bass adult spawning for the 54°F to 75°F water temperature range under the No-Action Alternative and Alternative 2 are 2,300,520 and 2,287,189, respectively. The difference in OHSIV between the No-Action Alternative and Alternative 2 is 13,331, which represents a 0.58 percent decrease in OHSIV under Alternative 2 compared to the No-Action Alternative. Because analysis of the 54°F to 75°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.58 percent decrease in OHSIV for this water temperature range represents a decrease in relative habitat suitability for black bass adult spawning in the lower Feather River. The decrease in relative habitat suitability under Alternative 2 is due to an increase in time and area with water temperatures cooler than the reported thermal tolerance range for black bass adult spawning during certain portions of the life stage period. The increase in the number of habitat units below the reported thermal tolerance range for black bass adult spawning could result in more habitat defined as unsuitable and in which increased stress response could occur. The decrease in relative habitat suitability under Alternative 2 also is associated with an increase in time and area with water temperatures above the reported thermal tolerance range for black bass adult spawning during certain portions of the life stage period. The decrease in relative habitat suitability due to water temperatures outside the reported thermal tolerance range of this species and life stage generally could result in more habitat in which increased stress response including raised or lowered metabolic rates, decreased spawning activity, decreased growth rates, and potentially increased mortality rates could occur (Bond 1996; Moyle 2002; Moyle and Cech 2000).

Table G-AQUA5.4-11. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for black bass adult spawning.

Water Temperature Index Value	54°F-75°F
No-Action Alternative	
Minimum Percentage of Time Value	30%
Maximum Percentage of Time Value	86%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	86%
OHSIV	2,300,520
Alternative 2	
Minimum Percentage of Time Value	30%
Maximum Percentage of Time Value	86%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	86%
OHSIV	2,287,189
Percent Change	-0.58%

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-11 for the black bass adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 54°F to 75°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-11 for the black bass adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 54°F to 75°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-11 for the black bass adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 54°F to 75°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-11 for the black bass adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 54°F to 75°F water temperature range.

G-AQUA5.4.5.2 Summary of Potential Effects on Black Bass

Study plan report summaries addressing project effects on black bass species are presented in Section G-AQUA1.3, Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area; Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam; Section G-AQUA1.5, Fisheries Management, and Section G-AQUA1.11, Predation, of Appendix G-AQUA1, Affected Environment.

Implementation of Alternative 2 would increase flows and decrease water temperatures in the Low Flow Channel compared to the No-Action Alternative. Model results indicate that differences in habitat suitability due to decreased water temperatures during the black bass spawning period were less than 1 percent between the No-Action Alternative and Alternative 2, and as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, water temperature changes in the Low Flow Channel due to increased flows would have no effect on black bass adult spawning. No changes to flows or water temperatures would occur in the High Flow Channel under Alternative 2.

Overall, implementation of Alternative 2 would have no effect on black bass.

G-AQUA5.4.6 Delta Smelt

G-AQUA5.4.6.1 Habitat Components

Adult Spawning

Delta smelt spawn in the upper Sacramento–San Joaquin Delta (Delta) upstream of the mixing zone and use a range of substrates for spawning, including reeds and other submerged vegetation, sandy or hard substrates, and submerged wood. The Large Woody Debris Supplementation and Improvement Program for the lower Feather River included in Alternative 2 is expected to contribute large woody debris to the Delta and provide improvements in habitat diversity and spawning substrate availability, benefiting delta smelt.

G-AQUA5.4.6.2 Summary of Potential Effects on Delta Smelt

Study plan report summaries addressing project effects on delta smelt are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, of Appendix G-AQUA1.

The range of distribution of the delta smelt is outside of the direct and indirect effects area analyzed for changes in flows and temperatures associated with the Oroville Facilities, therefore no flow or water temperature effects on delta smelt are anticipated with implementation of Alternative 2. Delta smelt would benefit from implementation of Alternative 2 as a result of the Large Woody Debris Supplementation and Improvement Program for the lower Feather River because habitat diversity and spawning habitat quantity in the upper Delta areas would increase. Large woody debris supplementation under Alternative 2 would have the same effects on delta smelt spawning as implementation of the Proposed Action, relative to the No-Action Alternative.

G-AQUA5.4.7 Green Sturgeon

G-AQUA5.4.7.1 Flow-related Effects

Flows in the portions of the lower Feather River where sturgeon are distributed would not change with implementation of Alternative 2 relative to the No-Action Alternative; therefore, there would be no flow-related effects on green sturgeon under Alternative 2. Structural modifications of Shanghai Bench and the Sunset Pumps for sturgeon passage enhancement are related to conditions resulting from flows and are included in Alternative 2 (see Section 3.3 for an additional description of this action). During the reporting process for SP-F3.2, Task 3A, two potential sturgeon passage impediments were identified that may block or inhibit upstream migration of sturgeon at some low flows. (See Section G-AQUA1.4.3 of Appendix G-AQUA1 for a summary of the report.) Although there is some lack of certainty as to the benefit of structurally modifying these potential sturgeon passage impediments, it is likely that these structural modifications would increase the range of flows associated with these features, which would provide improved passage for sturgeon.

G-AQUA5.4.7.2 Water Temperature-related Effects

Adult Immigration and Holding

Figure G-AQUA5.4-40 shows the proportion of time that habitat units are considered suitable for the water temperature range selected. The area under each curve displayed in Figure G-AQUA5.4-40 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA5.4-40 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 44°F to 61°F. Figures depicting the amount of habitat with water temperatures below 44°F or above 61°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of Alternative 2 on green sturgeon adult immigration and holding.

The OHSIV presented in Table G-AQUA5.4-12 for green sturgeon adult immigration and holding for the 44°F to 61°F water temperature range under the No-Action Alternative and Alternative 2 are 1,657,011 and 1,683,379, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 26,368, which represents a 1.59 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. Because analysis of the 44°F to 61°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 1.59 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for green sturgeon adult immigration and holding in the lower Feather River. The increase in overall habitat suitability for green sturgeon adult immigration and holding would result in more habitat defined as

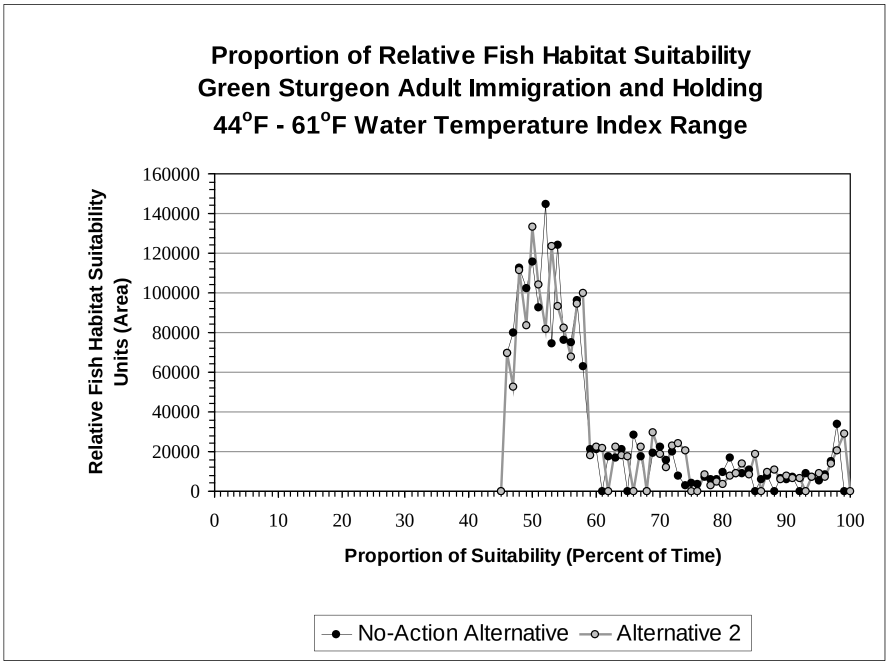


Figure G-AQUA5.4-40. Proportion of relative fish habitat suitability for green sturgeon adult immigration and holding for the 44°F to 61°F water temperature range.

Table G-AQUA5.4-12. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for green sturgeon adult immigration and holding.

Water Temperature Index Value	44°F-61°F
No-Action Alternative	
Minimum Percentage of Time Value	46%
Maximum Percentage of Time Value	98%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	52%
OHSIV	1,657,011
Alternative 2	
Minimum Percentage of Time Value	46%
Maximum Percentage of Time Value	99%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	50%
OHSIV	1,683,379
Percent Change	1.59%

suitable and less habitat in which increased stress response including raised metabolic rates, decreased growth rates, and increased mortality rates could potentially occur (Bond 1996; Moyle 2002; Moyle and Cech 2000).

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-12 for the green sturgeon adult immigration and holding life stage did not change between Alternative 2 and the No-Action Alternative for the 44°F to 61°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-12 for the green sturgeon adult immigration and holding life stage under the No-Action Alternative and Alternative 2 for the 44°F to 61°F water temperature range is 98 percent and 99 percent, respectively. The 1 percent difference between Alternative 2 and the No-Action Alternative represents a small increase in the number of habitat units with the greatest amount of time and area with water temperatures in the 44°F to 61°F water temperature range under Alternative 2 compared to the No-Action Alternative.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-12 for the green sturgeon adult immigration and holding life stage did not change between the No-Action Alternative and Alternative 2 for the 44°F to 61°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-12 for the green sturgeon adult immigration and holding life stage under the No-Action Alternative and Alternative 2 for the 44°F to 61°F water temperature range is 52 percent and 50 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between the No-Action Alternative and Alternative 2 is two percent, which represents a small decrease in the percentage of time that the habitat is suitable in the greatest area.

Adult Spawning and Embryo Incubation

Figure G-AQUA5.4-41 shows the proportion of time that habitat units are considered suitable for the water temperature range selected. The area under each curve displayed in Figure G-AQUA5.4-41 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA5.4-41 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 46°F to 68°F. Figures depicting the amount of habitat with water temperatures below 46°F or above 68°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of Alternative 2 on green sturgeon adult spawning and embryo incubation.

The OHSIV presented in Table G-AQUA5.4-13 for green sturgeon adult spawning and embryo incubation for the 46°F to 68°F water temperature range under the No-Action Alternative and Alternative 2 are 57,858 and 58,816, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 958, which represents a

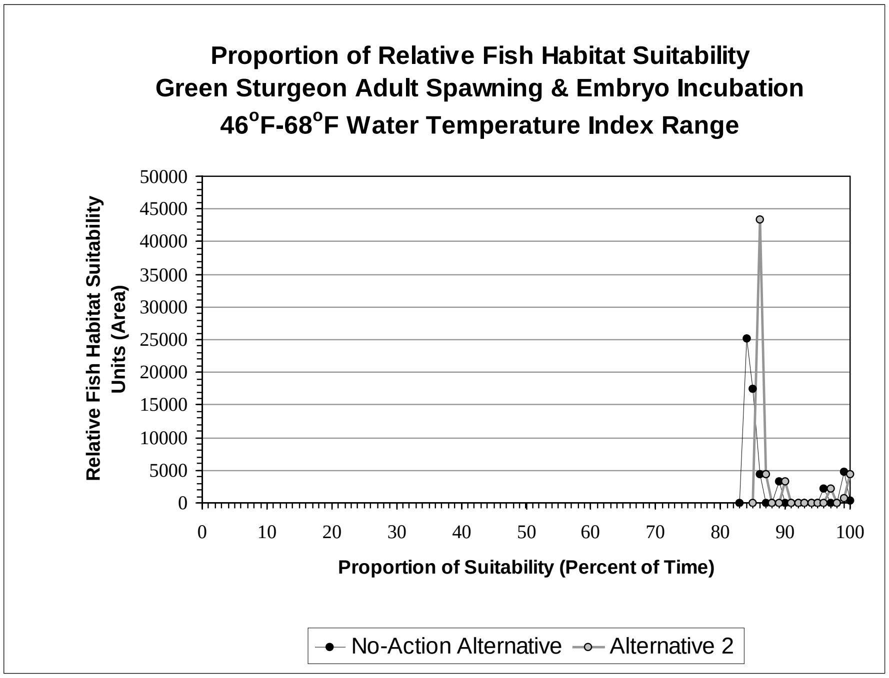


Figure G-AQUA5.4-41. Proportion of relative fish habitat suitability for green sturgeon adult spawning and embryo incubation for the 46°F to 68°F water temperature range.

Table G-AQUA5.4-13. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for green sturgeon adult spawning and embryo incubation.

Water Temperature Index Value	46°F-68°F
No-Action Alternative	
Minimum Percentage of Time Value	84%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	436
Percentage of Time at Maximum Habitat Units	84%
OHSIV	57,858
Alternative 2	
Minimum Percentage of Time Value	86%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	4,472
Percentage of Time at Maximum Habitat Units	86%
OHSIV	58,816
Percent Change	1.66%

1.66 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. Because analysis of the 46°F to 68°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 1.66 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for green sturgeon adult spawning and embryo incubation in the lower Feather River. The increase in overall habitat suitability for green sturgeon adult spawning and embryo incubation would result in more habitat defined as suitable and less habitat in which increased stress response including raised metabolic rates, decreased spawning activity, decreased growth rates, and increased mortality rates could potentially occur (Bond 1996; Moyle 2002; Moyle and Cech 2000).

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.413 for the green sturgeon adult spawning and embryo incubation life stage under the No-Action Alternative and Alternative 2 for the 46°F to 68°F water temperature range is 84 percent and 86 percent, respectively. The two percent difference between Alternative 2 and the No-Action Alternative represents a small increase in the number of habitat units with the least amount of time and area with water temperatures in the 46°F to 68°F water temperature range under Alternative 2 compared to the No-Action Alternative.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-13 for the green sturgeon adult spawning and embryo incubation life stage did not change between Alternative 2 and the No-Action Alternative for the 46°F to 68°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-13 for the green sturgeon adult spawning and embryo incubation life stage for the 46°F to 68°F water temperature range under the No-Action Alternative and Alternative 2 is 436 and 4,472, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 4,036, which represents approximately a 926 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are between 46°F to 68°F.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-13 for the green sturgeon adult spawning and embryo incubation life stage under the No-Action Alternative and Alternative 2 for the 46°F to 68°F water temperature range is 84 percent and 86 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between Alternative 2 and the No-Action Alternative is two percent, which represents a small increase in the percentage of time that the habitat is suitable in the greatest area.

Juvenile Rearing

Figure G-AQUA5.4-42 shows the proportion of time that habitat units are considered suitable for the water temperature range selected. The area under each curve displayed in Figure G-AQUA5.4-42 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA5.4-42 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 50°F to 66°F. Figures depicting the amount of habitat with water temperatures below 50°F or above 66°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of Alternative 2 on green sturgeon juvenile rearing.

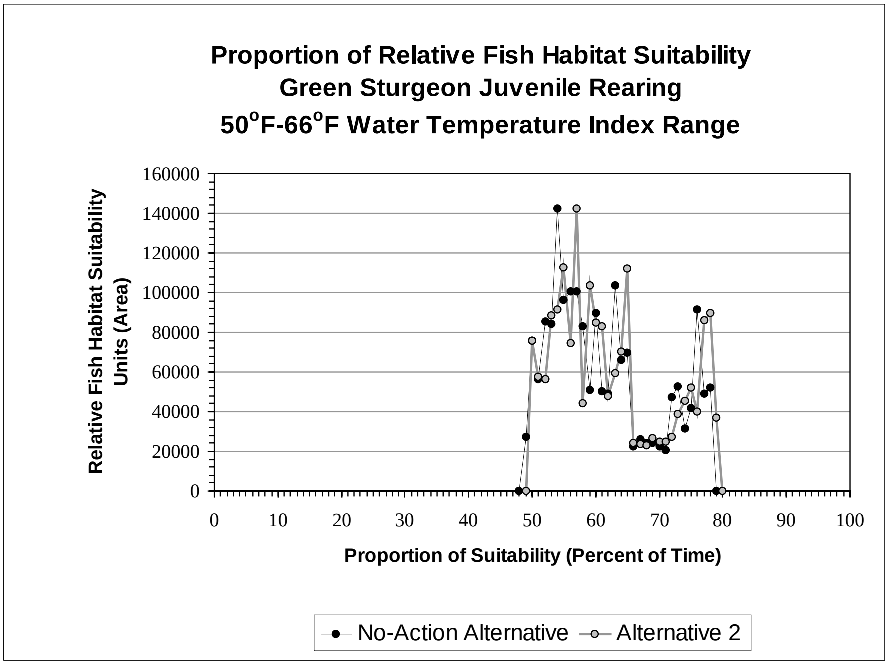


Figure G-AQUA5.4-42. Proportion of relative fish habitat suitability for green sturgeon juvenile rearing for the 50°F to 66°F water temperature range.

The OHSIV presented in Table G-AQUA5.4-14 for green sturgeon juvenile rearing for the 50°F to 66°F water temperature range under the No-Action Alternative and Alternative 2 are 1,837,131 and 1,868,184, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 31,053, which represents a 1.69 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. Because analysis of the 50°F to 66°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 1.69 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for green sturgeon juvenile rearing in the lower Feather River. The increase in overall habitat suitability for green sturgeon juvenile rearing would result in more habitat defined as suitable and less habitat in which increased stress response including lowered or raised metabolic rates, decreased forage activity, decreased growth rates, and increased mortality rates could potentially occur (Bond 1996; Moyle 2002; Moyle and Cech 2000).

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-14 for the green sturgeon juvenile rearing life stage under the No-Action Alternative and Alternative 2 for the 50°F to 66°F water temperature range is 49 percent and 50 percent, respectively. The 1 percent difference in Minimum Percentage of Time Value

Table G-AQUA5.4-14. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for green sturgeon juvenile rearing.

Water Temperature Index Value	50°F-66°F
No-Action Alternative	
Minimum Percentage of Time Value	49%
Maximum Percentage of Time Value	78%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	54%
OHSIV	1,837,131
Alternative 2	
Minimum Percentage of Time Value	50%
Maximum Percentage of Time Value	79%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	57%
OHSIV	1,868,184
Percent Change	1.69%

between Alternative 2 and the No-Action Alternative represents a small increase in the number of habitat units with the smallest amount of time and area with water temperatures in the 50°F to 66°F water temperature range under Alternative 2 compared to the No-Action Alternative.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-14 for the green sturgeon juvenile rearing life stage under the No-Action Alternative and Alternative 2 for the 50°F to 66°F water temperature range is 78 percent and 79 percent, respectively. The 1 percent difference between Alternative 2 and the No-Action Alternative represents a small increase in the number of habitat units with the greatest amount of time and area with water temperatures in the 50°F to 66°F water temperature range under Alternative 2 compared to the No-Action Alternative.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-14 for the green sturgeon juvenile rearing life stage did not change between Alternative 2 and the No-Action Alternative for the 50°F to 66°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-14 for the green sturgeon juvenile rearing life stage under the No-Action Alternative and Alternative 2 for the 50°F to 66°F water temperature range is 54 percent and 57 percent, respectively. The difference in Percentage of Time at Maximum Habitat Units between the No-Action Alternative and Alternative 2 is three percent, which represents an increase in the percentage of time that the habitat is suitable in the greatest area.

Juvenile Emigration

Figure G-AQUA5.4-43 shows the proportion of time that habitat units are considered suitable for the water temperature range selected. The area under each curve displayed in Figure G-AQUA5.4-43 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA5.4-43 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 50°F to 66°F. Figures depicting the amount of habitat with water temperatures below 50°F or above 66°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of Alternative 2 on green sturgeon juvenile emigration.

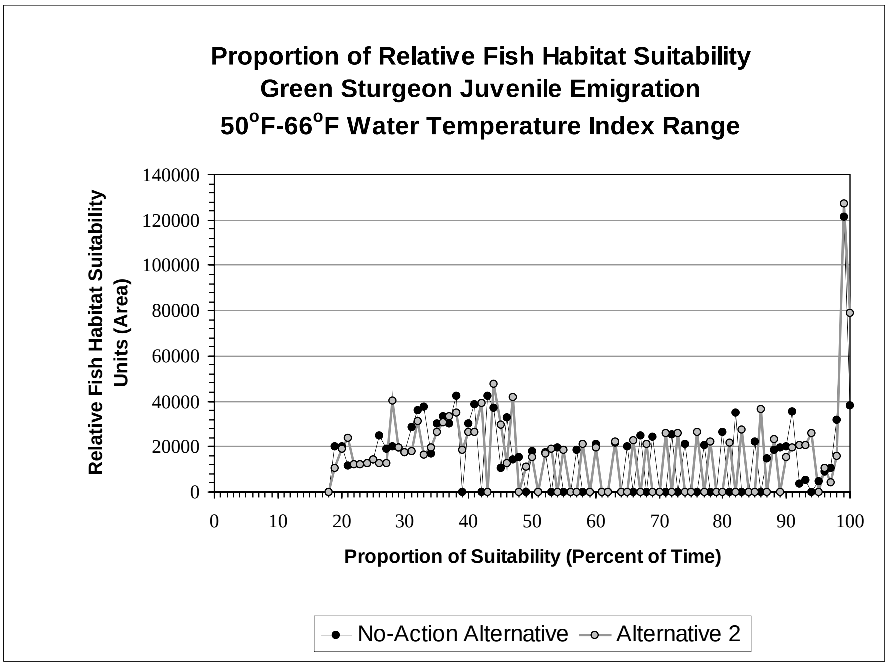


Figure G-AQUA5.4-43. Proportion of relative fish habitat suitability for green sturgeon juvenile emigration for the 50°F to 66°F water temperature range.

The OHSIV presented in Table G-AQUA5.4-15 for green sturgeon juvenile emigration for the 50°F to 66°F water temperature range under the No-Action Alternative and Alternative 2 are 1,354,092 and 1,398,150, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 44,057, which represents a 3.25 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. Because analysis of the 50°F to 66°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 3.25 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for green sturgeon juvenile emigration in the lower Feather River. The increase in overall habitat suitability for green sturgeon juvenile rearing would result in more habitat defined as suitable and less habitat in which increased stress response including lowered or raised metabolic rates, decreased forage activity, decreased growth rates, and increased mortality rates could potentially occur (Bond 1996; Moyle 2002; Moyle and Cech 2000).

Table G-AQUA5.4-15. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for green sturgeon juvenile emigration.

Water Temperature Index Value	50°F-66°F
No-Action Alternative	
Minimum Percentage of Time Value	19%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	37,977
Percentage of Time at Maximum Habitat Units	99%
OHSIV	1,354,092
Alternative 2	
Minimum Percentage of Time Value	19%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	79,272
Percentage of Time at Maximum Habitat Units	99%
OHSIV	1,398,150
Percent Change	3.25%

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-15 for the green sturgeon juvenile emigration life stage did not change between Alternative 2 and the No-Action Alternative for the 50°F to 66°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-15 for the green sturgeon juvenile emigration life stage did not change between Alternative 2 and the No-Action Alternative for the 50°F to 66°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-15 for the green sturgeon juvenile emigration life stage under the No-Action Alternative and Alternative 2 for the 50°F to 66°F water temperature range is 37,977 and 79,272, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 41,295, which represents a 108.74 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are always between 50°F and 66°F.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-15 for the green sturgeon juvenile emigration life stage did not change between the No-Action Alternative and Alternative 2 for the 50°F to 66°F water temperature range.

G-AQUA5.4.7.2 Summary of Potential Effects on Green Sturgeon

Study plan report summaries addressing project effects on green sturgeon are presented in Section G-AQUA1.3, Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area; and Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, of Appendix G-AQUA1.

Implementation of Alternative 2 would increase flows and decrease water temperatures in the Low Flow Channel relative to the No-Action Alternative. However, flows in the portions of the lower Feather River where sturgeon reportedly are distributed would not change with implementation of Alternative 2 relative to the No-Action Alternative. Therefore, there would be no flow-related effects on green sturgeon under Alternative 2. Based on model results, increases in overall habitat suitability for each life stage of green sturgeon due to improvements in water temperature would occur. Therefore, overall green sturgeon habitat suitability would increase under Alternative 2. Additionally, physical alterations to Shanghai Bench and the Sunset Pumps could potentially have a beneficial effect on green sturgeon by increasing the range of flows that are passable by sturgeon under Alternative 2.

Overall, implementation of Alternative 2 would have a beneficial effect on green sturgeon.

G-AQUA5.4.8 Hardhead

G-AQUA5.4.8.1 Temperature-related Effects

Spawning

Figure G-AQUA5.4-44 shows the proportion of time that habitat units are considered suitable for the water temperature range selected. The area under each curve displayed in Figure G-AQUA5.4-44 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA5.4-44 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 55°F to 75°F. Figures depicting the amount of habitat with water temperatures below 55°F or above 75°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determine the effects of the Alternative 2 on hardhead adult spawning.

The OHSIV presented in Table G-AQUA5.4-16 for hardhead adult spawning for the 55°F to 75°F water temperature range under the No-Action Alternative and Alternative 2 are 2,769,601 and 2,759,676, respectively. The difference in OHSIV between the No-Action Alternative and Alternative 2 is 9,925, which represents a 0.36 percent decrease in OHSIV under Alternative 2 compared to the No-Action Alternative. Because analysis of the 55°F to 75°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.36 percent decrease in

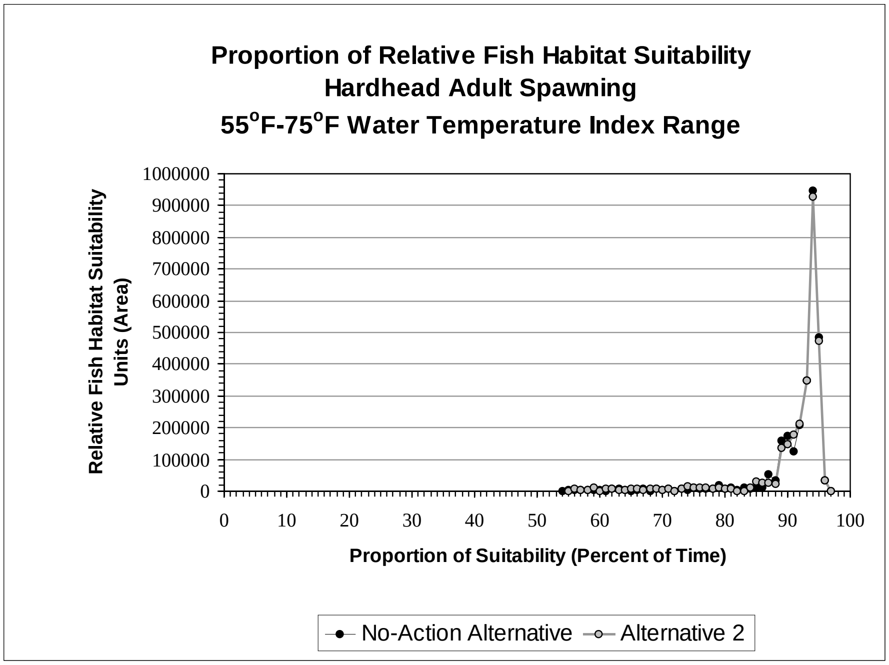


Figure G-AQUA5.4-44. Proportion of relative fish habitat suitability for hardhead adult spawning for the 55°F to 75°F water temperature range.

Table G-AQUA5.4-16. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for hardhead adult spawning.

Water Temperature Index Value	55°F-75°F
No-Action Alternative	
Minimum Percentage of Time Value	55%
Maximum Percentage of Time Value	96%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	94%
OHSIV	2,769,601
Alternative 2	
Minimum Percentage of Time Value	56%
Maximum Percentage of Time Value	96%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	94%
OHSIV	2,759,676
Percent Change	-0.36%

OHSIV for this water temperature range represents a decrease in relative habitat suitability for hardhead adult spawning in the lower Feather River. The decrease in overall habitat suitability for hardhead adult spawning would result in less habitat defined as suitable and more habitat in which increased stress response including raised or lowered metabolic rates, decreased forage activity, decreased growth rates, and increased mortality rates could occur (Bond 1996; Moyle 2002; Moyle and Cech 2000).

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-16 for the hardhead adult spawning life stage under the No-Action Alternative and Alternative 2 for the 55°F to 75°F water temperature range is 55 percent and 56 percent, respectively. The 1 percent difference between Alternative 2 and the No-Action Alternative represents a small increase in the number of habitat units with the least amount of time and area with water temperatures in the 55°F to 75°F water temperature range under Alternative 2 compared to the No-Action Alternative.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-16 for the hardhead adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 55°F to 75°F water temperature.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-16 for the hardhead adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 55°F to 75°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-16 for the hardhead adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 55°F to 75°F water temperature range.

G-AQUA5.4.8.2 Summary of Potential Effects on Hardhead

Study plan report summaries addressing project effects on hardhead are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, of Appendix G-AQUA1.

Implementation of Alternative 2 would increase flows and decrease water temperatures in the Low Flow Channel, relative to the No-Action Alternative. However, there would be no changes to flows or water temperatures in the High Flow Channel under Alternative 2. Model results indicate that differences in habitat suitability due to decreased water temperatures during the hardhead spawning period were less than 1 percent between the No-Action Alternative and Alternative 2, and as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, water temperature changes in the Low Flow Channel due to increased flows would have no effect on hardhead spawning.

Overall, implementation of Alternative 2 would result in no effect on the hardhead.

G-AQUA5.4.9 River Lamprey

G-AQUA5.4.9.1 Temperature-related Effects

Spawning

Figure G-AQUA5.4-45 shows the proportion of time that habitat units are considered suitable for the water temperature range selected. The area under each curve displayed in Figure G-AQUA5.4-45 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA5.4-45 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 43°F to 72°F. Figures depicting the amount of habitat with water temperatures below 43°F or above 72°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of Alternative 2 on river lamprey adult spawning.

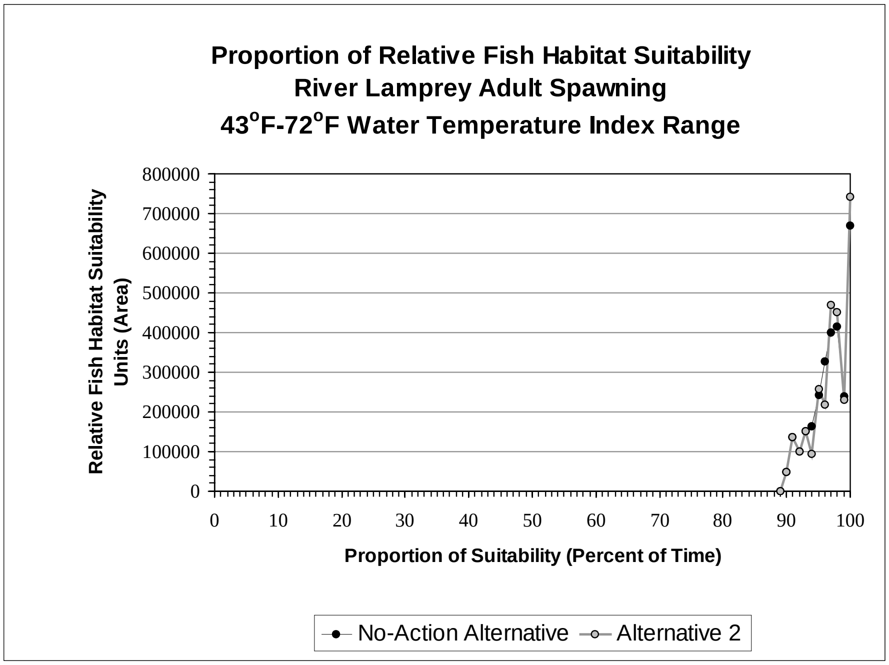


Figure G-AQUA5.4-45. Proportion of relative fish habitat suitability for river lamprey adult spawning for the 43°F to 72°F water temperature range.

The OHSIV presented in Table G-AQUA5.4-17 for river lamprey adult spawning for the 43°F to 72°F water temperature range under the No-Action Alternative and Alternative 2 are 2,899,309 and 2,904,637, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 5,328, which represents a 0.18 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. Because analysis of the 43°F to 72°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.18 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for river lamprey adult spawning in the lower Feather River. The increase in overall habitat suitability for river lamprey adult spawning would result in more habitat defined as suitable and less habitat in which increased stress response including increased metabolic rate, decreased growth rate, and potentially increased mortality (Bond 1996; Moyle 2002; Moyle and Cech 2000).

Table G-AQUA5.4-17. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for river lamprey adult spawning.

Water Temperature Index Value	43°F-72°F
No-Action Alternative	
Minimum Percentage of Time Value	90%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	670,928
Percentage of Time at Maximum Habitat Units	100%
OHSIV	2,899,309
Alternative 2	
Minimum Percentage of Time Value	90%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	742,125
Percentage of Time at Maximum Habitat Units	100%
OHSIV	2,904,637
Percent Change	0.18%

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-17 for the river lamprey adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 43°F to 72°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-17 for the river lamprey adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 43°F to 72°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-17 for the river lamprey adult spawning life stage for the 43°F to 72°F water temperature range under the No-Action Alternative and Alternative 2 is 670,928 and 742,125, respectively. The difference in Habitat Units at 100 Percent of Time between Alternative 2 and the No-Action Alternative is 71,197, which represents approximately an 11 percent increase in the amount of habitat area under Alternative 2 compared to the No-Action Alternative in which water temperatures are between 43°F to 72°F.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-17 for the river lamprey adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 43°F to 72°F water temperature range.

G-AQUA5.4.9.2 Summary of Potential Effects on River Lamprey

Study plan report summaries addressing project effects on river lamprey are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, of Appendix G-AQUA1

Implementation of Alternative 2 would increase flows and decrease water temperatures in the Low Flow Channel, relative to the No-Action Alternative. However, there would be no changes to flows or water temperatures in the High Flow Channel under Alternative 2. Model results indicate that differences in habitat suitability due to decreased water temperatures during the river lamprey spawning period were less than 1 percent between the No-Action Alternative and Alternative 2, and as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, water temperature changes in the Low Flow Channel due to increased flows would have no effect on river lamprey spawning. Additionally, river lamprey would benefit from improved spawning substrate conditions resulting from the Gravel Supplementation and Improvement Program.

Overall, implementation of Alternative 2 would result in a beneficial effect on the river lamprey.

G-AQUA5.4.10 Sacramento Splittail

G-AQUA5.4.10.1 Flow-related Effects

Spawning

Sacramento splittail have only been observed in the Feather River downstream of the Thermalito Afterbay Outlet. No changes in flow regimes are anticipated with implementation of Alternative 2 in this portion of the river; therefore, potential flow-related effects on Sacramento splittail spawning are not included for analysis.

G-AQUA5.4.10.2 Water Temperature–related Effects

Figure G-AQUA5.4-46 shows the proportion of time that habitat units are considered suitable for the water temperature range selected. The area under each curve displayed in Figure G-AQUA5.4-46 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA5.4-46 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 45°F to 75°F. Figures depicting the amount of habitat with water temperatures below 45°F or above 75°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of Alternative 2 on Sacramento splittail adult spawning.

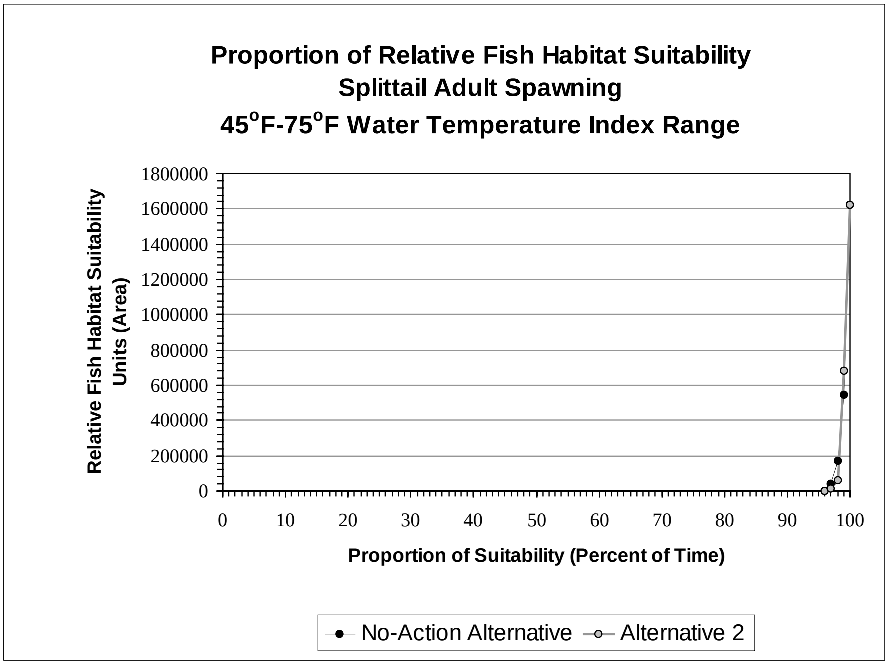


Figure G-AQUA5.4-46. Proportion of relative fish habitat suitability for Sacramento splittail adult spawning for the 45°F to 75°F water temperature range.

The OHSIV presented in Table G-AQUA5.4-18 for Sacramento splittail adult spawning for the 45°F to 75°F water temperature range under the No-Action Alternative and Alternative 2 are 2,375,091 and 2,376,769, respectively. The difference in OHSIV between Alternative 2 and the No-Action Alternative is 1,678, which represents a 0.07 percent increase in OHSIV under Alternative 2 compared to the No-Action Alternative. Because analysis of the 45°F to 75°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 0.07 percent increase in OHSIV for this water temperature range represents an increase in relative habitat suitability for Sacramento splittail adult spawning in the lower Feather River. The increase in overall habitat suitability for river lamprey adult spawning would result in more habitat defined as suitable and less habitat in which increased stress response including increased metabolic rate, decreased growth rate, and potentially increased mortality (Bond 1996; Moyle 2002; Moyle and Cech 2000).

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-18 for the Sacramento splittail adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 45°F to 75°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-18 for the Sacramento splittail adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 45°F to 75°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-18 for the Sacramento splittail adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 45°F to 75°F water temperature range.

Table G-AQUA5.4-18. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for Sacramento splittail adult spawning.

Water Temperature Index Value	45°F-75°F
No-Action Alternative	
Minimum Percentage of Time Value	97%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	1,623,725
Percentage of Time at Maximum Habitat Units	100%
OHSIV	2,375,091
Alternative 2	
Minimum Percentage of Time Value	97%
Maximum Percentage of Time Value	100%
Habitat Units at 100 Percent of Time	1,623,725
Percentage of Time at Maximum Habitat Units	100%
OHSIV	2,376,769
Percent Change	0.07%

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-18 for the Sacramento splittail adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 45°F to 75°F water temperature range.

G-AQUA5.4.10.3 Summary of Potential Effects on Sacramento Splittail

Study plan report summaries addressing project effects on Sacramento splittail are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, of Appendix G-AQUA1.

There would be no changes to flows or water temperatures in the High Flow Channel under Alternative 2. Because no such changes would occur and Sacramento splittail have only been observed in the High Flow Channel within the project study area, no flow–related effects on splittail spawning are expected to occur. Model results indicate that differences in habitat suitability due to decreased water temperatures during the river Sacramento splittail spawning period were less than 1 percent between the No-Action Alternative and Alternative 2, and as such, are considered below the detection limits of the analytical tools utilized in the habitat suitability analysis. Therefore, water temperature changes in the Low Flow Channel due to increased flows would have no effect on river lamprey spawning.

Overall, implementation of Alternative 2 is not anticipated to affect Sacramento splittail.

G-AQUA5.4.11 Striped Bass

G-AQUA5.4.11.1 Flow-related Effects

Adult Spawning

No changes in flows below the Thermalito Afterbay Outlet in the lower Feather River would result from implementation of Alternative 2; therefore, the majority of striped bass habitat would not be affected. Minimum flows in the river reach extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet would increase from 600 cfs to 800 cfs with implementation of Alternative 2. Because striped bass are only infrequently observed upstream of the Thermalito Afterbay Outlet, an increase in flow in this reach of the river is not anticipated to have any effect on the quantity, quality, or distribution of striped bass habitat.

G-AQUA5.4.11.2 Water Temperature–related Effects

Adult Spawning

Figure G-AQUA5.4-47 shows the proportion of time that habitat units are considered suitable for the water temperature range selected. The area under each curve displayed in Figure G-AQUA5.4-47 is equal, which allows for direct comparison of habitat suitability between alternatives. Figure G-AQUA5.4-47 shows the proportion of time during which habitat is suitable as defined by the water temperature range of 59°F to 68°F. Figures depicting the amount of habitat with water temperatures below 59°F or above 68°F were not included because changes in the proportion of time and area defined as suitable rather than changes in the proportion of time and area defined as unsuitable determines the effects of Alternative 2 on striped bass adult spawning.

The OHSIV presented in Table G-AQUA5.4-19 for striped bass adult spawning for the 59°F to 68°F water temperature range under the No-Action Alternative and Alternative 2 are 46,506 and 43,683, respectively. The difference in OHSIV between the No-Action Alternative and Alternative 2 is 2,822, which represents a 6.07 percent decrease in OHSIV under Alternative 2 compared to the No-Action Alternative. Because analysis of the 59°F to 68°F water temperature range represents habitat that is suitable for the species and life stage based on available literature, the 6.07 percent decrease in OHSIV for this water temperature range represents a decrease in relative habitat suitability for striped bass adult spawning in the lower Feather River. The decrease in overall habitat suitability for hardhead adult spawning would result in less habitat defined as suitable and more habitat in which increased stress response including raised or lowered metabolic rates, decreased forage activity, decreased growth rates, and increased mortality rates could occur (Bond 1996; Moyle 2002; Moyle and Cech 2000). Most of the decrease in striped bass adult spawning habitat suitability occurs in the Low Flow Channel where striped bass are infrequently observed.

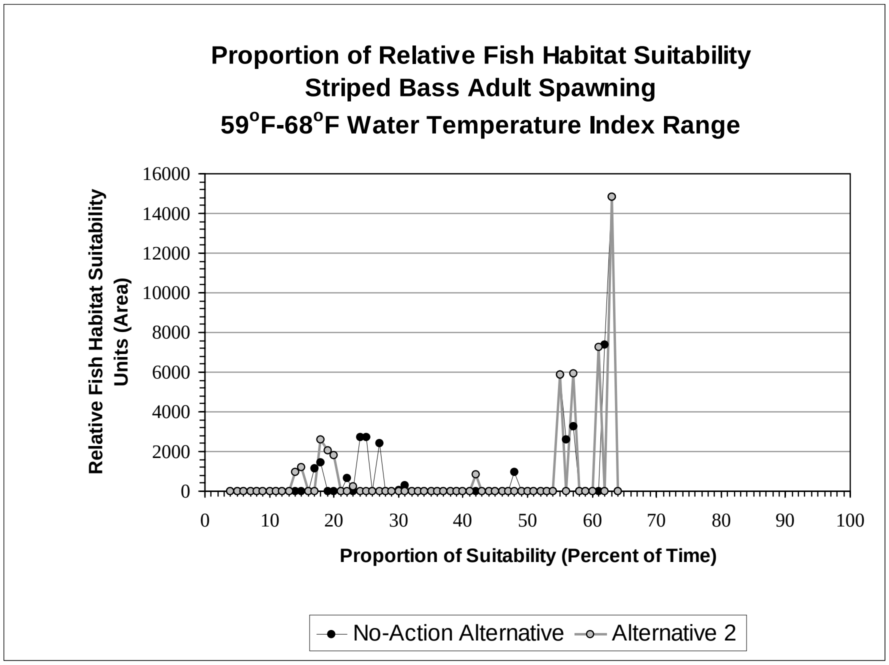


Figure G-AQUA5.4-47. Proportion of relative fish habitat suitability for striped bass adult spawning for the 59°F to 68°F water temperature range.

Table G-AQUA5.4-19. Overall habitat suitability index value comparison between the No-Action Alternative and Alternative 2 for striped bass adult spawning.

Water Temperature Index Value	59°F-68°F
No-Action Alternative	
Minimum Percentage of Time Value	5%
Maximum Percentage of Time Value	63%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	63%
OHSIV	46,506
Alternative 2	
Minimum Percentage of Time Value	5%
Maximum Percentage of Time Value	63%
Habitat Units at 100 Percent of Time	0
Percentage of Time at Maximum Habitat Units	63%
OHSIV	43,683
Percent Change	-6.07%

The Minimum Percentage of Time Value metric presented in Table G-AQUA5.4-19 for the striped bass adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 59°F to 68°F water temperature range.

The Maximum Percentage of Time Value metric presented in Table G-AQUA5.4-19 for the striped bass adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 59°F to 68°F water temperature range.

The Habitat Units at 100 Percent of Time metric presented in Table G-AQUA5.4-19 for the striped bass adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 59°F to 68°F water temperature range.

The Percentage of Time at Maximum Habitat Units metric presented in Table G-AQUA5.4-19 for the striped bass adult spawning life stage did not change between Alternative 2 and the No-Action Alternative for the 59°F to 68°F water temperature range.

G-AQUA5.4.11.3 Summary of Potential Effects on Striped Bass

Study plan report summaries addressing project effects on striped bass are presented in Section G-AQUA1.4, Non-Salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam, of Appendix G-AQUA1.

Implementation of Alternative 2 would increase flows and decrease water temperatures in the Low Flow Channel, relative to the No-Action Alternative. However, there would be no changes to flows in the High Flow Channel under Alternative 2. Because such changes would not occur and striped bass are frequently observed in the High Flow Channel, no flow-related effects on striped bass spawning habitat would occur within most of the areas where striped bass are observed. Because striped bass are only infrequently observed in the Low Flow Channel, reduced water temperatures are not likely to substantially affect striped bass spawning.

Overall, implementation of Alternative 2 would not be expected to have any effect on the quantity, quality, or distribution of striped bass habitat.

G-AQUA5.5 REFERENCES

Cox, W. T., Senior Fish Pathologist, DFG, Sacramento, California; E-mail communication with E.Theis, Fishery Biologist, NOAA, Sacramento, California; DFG Disease Concerns Regarding Upstream Passage, September 12, 2003.

Leary, R. F., F. W. Allendorf, and G. K. Sage. 1995. Hybridization and Introgression between Introduced and Native Fish. American Fisheries Society Symposium 15:91-101.

Ward, B. R., and P. A. Slaney. 1988. Life History and Smolt-to-Adult Survival of Keogh River Steelhead Trout (Salmo gairdneri) and the Relationship to Smolt Size. Canadian Journal of Fisheries and Aquatic Science 45:1110-1122.

Withler, I. L. 1966. Variability in Life History Characteristics of Steelhead Trout (Salmo gairdneri) Along the Pacific Coast of North America. J.Fish.Res.Board Can. 23(3):365-393.

This page intentionally left blank.

APPENDIX G-CUL
CULTURAL RESOURCES

This appendix supplements the information on the cultural resources issues provided in Section 5.9.1. This appendix contains additional information on the:

- Cultural resources overview of the project area;
- Methodologies used for the inventories of archaeological, ethnographic, and historical buildings and structures; and
- Prehistoric, historic, and ethnographic resources documented within the Area of Potential Effects (APE) for the Oroville Facilities.

The cultural resources investigations conducted for the relicensing effort resulted in the production of three technical studies: *Archaeological and Historical Resources Inventory Report* (DWR 2004a), *Ethnographic and Ethnohistoric Inventory of Konkow Maidu Cultural Places* (DWR 2004b), and *Historic Properties Inventory and Evaluation: Oroville Facilities, Butte County, California* (DWR 2004c). Detailed descriptions and analyses of the prehistoric, historic, and ethnographic findings can be found in the respective reports. Because these reports contain sensitive information on the nature and location of cultural resources, they are considered confidential and are intended for limited distribution.

G-CUL.1 CULTURAL RESOURCES OVERVIEW

The following sections provide a more detailed overview of the prehistoric, ethnographic, and historic resources of the region. This information is derived from the technical investigations conducted for the Oroville Facilities.

<u>G-CUL.1.1 Prehistoric Setting</u>

The basic outline of prehistoric cultural chronology in the project area and environs was first developed by Olsen and Riddell (1963) and later expanded and elaborated by Ritter (1968, 1970) and Kowta (1988). Prior to about 5,000 years Before Present (BP), there is little direct evidence of human occupation in the Lake Oroville region, although surrounding areas show indications of human presence.

G-CUL.1.1.1 Oroville Vicinity

Sometime after approximately 5,000 BP, the Lake Oroville locality evinces its first indications of intensive occupation. The earliest securely dated archaeological complex in the Lake Oroville area is the Mesilla Complex, which has been dated between about. 3,000 and 2,000 BP. Kowta (1988) has described this as the Butte County foothills variant of the regional Martis tradition. Use of manos and metates was emphasized for vegetal processing, as they were evidently used to grind and prepare hard seeds; cylindrical pestles and bowl mortars were present but rare. Game was hunted with atlatl and dart points made from basalt, slate, and chert. Among these points were leaf-shaped, stemmed, and side-notched Martis series variants. *Haliotis and Olivella* beads, charm stones, and bone pins and spatulae also are part of Mesilla Complex assemblages. Several burials attributed to this period were flexed on their sides, in some cases marked by milling stones or rock cairns. This complex may represent sporadic, possibly seasonal occupation of the northern Sierra Nevada foothills by primary or local bands and task groups; some exploitation of riverine resources is inferred (Ritter 1970).

The subsequent Bidwell Complex saw the continued use of basalt and slate dart points. This complex is placed from about 2,000 to 1,200 BP. It is inferred that people lived in relatively permanent villages with formal cemetery areas. From these centralized settlements, small task groups went out to hunt; collect freshwater shellfish; fish with nets held in place by grooved, notched sinker stones; and gather acorns processed on milling slabs and also probably in wooden mortars. Bone awls and tubular bone beads were manufactured. Steatite vessels were used for cooking, with their frequency of occurrence increasing as time progressed. Most projectile points were manufactured from basalt, with both large and small variants in stemmed and corner-notched morphologies. Along with a relatively sedentary lifestyle, initial development of tribelets is postulated for this period.

During the Sweetwater Complex, dated from about 1,200 to 500 BP, the advent of the bow and arrow probably occurred. Arrows were tipped with small, lightweight, stemmed and corner-notched projectile points. Mortars (cobble and slab) and pestles (conical, flat-ended) were the principal groundstone tools, though use of the hand stone and milling slab continued at reduced levels. The steatite industry was elaborated, with cups, platters, bowls, and tubular smoking pipes among the items produced. There was a large variety of bone artifacts (tubular beads, spatulate objects, pins, fish gorges, awls, flakers) and an expanded inventory of marine-shell artifacts, including *Olivella* beads and *Haliotis* “banjo” ornaments. The acorn complex appears well-developed, and a tribelet form of political organization probably prevailed.

The Oroville Complex, from about 500 to 150 BP, represents the protohistoric Maidu-Konkow. Acorn processing became increasingly focused at bedrock mortar facilities. Desert series projectile points predominated. Steatite vessels were absent, though the material was still used for ornaments and pipes. Diagnostic artifacts included small, tubular bone beads, incised bird-bone tubes/whistles, bone gorge hooks, gaming bones, metapodial awls, tubular steatite pipes, and clamshell disk beads. Several kinds of structures—including large, circular dance houses—were constructed, and were similar to those occurring historically. Caves and rock shelters continued to be occupied. During this period, the acorn complex reached its greatest development, supplemented by the gathering of other plants, hunting, and fishing. The Kuksu religion was probably present in some form. Political organization was very similar to the ethnographic pattern (i.e., tribelets), and population density reached its highest levels at this time.

G-CUL.1.1.2 Southern Cascades

North of the Lake Oroville region, a more temporally limited cultural chronology has been suggested for ethnographic Yana territory in the southern Cascades. Originally formulated during the 1950s through the work of Baumhoff (1955, 1957), the cultural history of this area subsequently has been elaborated on by the largely unpublished work of Jerald Johnson, summarized by Jangela and White (2001:18-19). The Deadman Complex, placed between about 4,500 and 2,500 BP, appears to largely correspond to the earlier part of the Martis tradition. The use of basalt for manufacture of flaked-stone tools predominates over the use of obsidian and chert. Assemblages are dominated by large, side-notched projectile points. There are also large, unifacially flaked, leaf-shaped points, along with large stemmed forms. Groundstone tools are represented by manos and metates. Marine shell artifacts include *Olivella* shell beads, and large, disk-shaped beads and triangular pendants made from *Haliotis* shell.

The subsequent Kingsley Complex, dated from approximately 2,500 to 1,500 BP, corresponds with the later portion of Martis. A preference for manufacturing flaked-stone tools from basalt continues. Other lithic tools include small, well-shaped scrapers and cobble core tools. Among the wide variety of groundstone tools are rectangular manos, slab metates, hopper mortars, and flat-ended pestles, often shaped from use. Spatulate bone tools, *Olivella* shell beads, and flat *Haliotis* beads also occur. The remains of multifamily houses are present.

The Dry Creek Complex, from about 1,500 to 500 BP, is characterized by a preference for obsidian over basalt and chert for flaked-stone tool manufacture. Introduction of the bow and arrow is indicated by the presence of projectile points morphologically similar to Columbia Plateau corner-notched and Gunther series points, which occur along with medium to large serrated forms. Groundstone artifacts are similar to those typifying the preceding period. Diagnostic shell beads and ornaments include M series and spire-hopped *Olivella* beads, disc-shaped *Haliotis* ornaments, and perforated freshwater shellfish ornaments. Deer ulna awls/flakers are also present. Tightly flexed burials are interred in prepared grave pits.

The Mill Creek Complex, dated from 500 to 150 BP, represents the protohistoric Yana. Use of the bow and arrow is evident, marked by the presence of small, gracile Desert series points, small, serrated corner-notched points, and small, barbed points. Obsidian continues to be favored over basalt and chert as a tool stone. The groundstone assemblage is little different from those typifying the two preceding complexes. Among the diagnostic artifacts are medium-sized clam disk beads, *Glycymeris* shell beads, magnesite cylinders, and twined basketry. Structures include single-family dwelling, 3 to 4 meters (m) in diameter, and larger, earth-covered ceremonial or communal structures. The Mill Creek Complex transitions into the Ethnographic Yana Complex (ca. 150–90 BP), composed of archaeological remains associated with Yana speakers maintaining traditional lifeways during the early part of the historic period.

G-CUL.1.1.3 Northern Sierra Nevada

The prehistoric cultural chronology for the northern Sierra Nevada was initially developed during the 1950s (i.e., Elsasser 1960; Heizer and Elsasser 1953), at which time two complexes were identified. The earlier of these was termed Martis, the later Kings Beach. Traits associated with the Martis Complex included preferred use of basalt for flaked-stone tools; rare use of obsidian and chert; occurrence of large, heavy, roughly flaked, variable-form projectile points; use of manos and metates; presence of cylindrical pestles and possible bowl mortars; atlatl use inferred from the metates; presence of cylindrical pestles and possible bowl mortars; atlatl use inferred from the presence of boat stones; an economic emphasis upon hunting and hard seeks; abundant basalt flake scrapers with pressure-retouched edges; common expanded base, finger-held, flaked-stone drills/punches; common spokeshave-notched tools with concave edge; abundant large bifaces and cores; and “Central Sierra Abstract Style” bedrock petroglyphs (Elsasser and Gortner 1991). Among Kings Beach Complex traits are the following: use of obsidian and chert as the principal toolstones for fabricating flaked-stone tools; rare use of basalt; use of bedrock mortars for grinding acorns and seeds; presence of small, light, side-notched projectile points; inferred use of the bow and arrow; rare occurrence of scrapers and drills; economic emphasis upon fishing, pinyon harvesting, seed grinding, and some hunting; and equation of this complex with the prehistoric ancestors of historic Washoe-speaking peoples (Jackson et al. 1994a, 1994b; Markley and Henton 1985).

The original Martis-Kings Beach dichotomy subsequently has been elaborated and expanded into a Late Pleistocene/Holocene cultural chronology for the northern Sierra and adjacent areas by Elston (1971, 1979) and Elston et al. (1977, 1995). The Washoe Lake phase, dated before 10,000 BP, is the earliest known manifestation of human presence in the broader region. The subsequent Tahoe Reach phase is suggested to have occurred ca. 10,000–8,000/7,500 BP. The Spooner phase dates from 8,000/7,500 to 5,000 BP. The Early Kings Beach phase dates from about 1,300 to 700 BP.

G-CUL.1.1.4 Previous Archaeological Research

Early archaeological efforts within the project area include the 1952 survey of the proposed Lake Oroville for the National Park Service (Treganza 1953). An extensive program of site survey and excavation was undertaken by the California Department of Parks and Recreation (DPR) during the early and mid-1960s. This “salvage archaeology” was focused upon areas destined to be affected by the construction of Oroville Dam and its ancillary facilities, and by the flooding of Lake Oroville. Archaeological surveys, begun in 1960, culminated in 1965 with an intensive survey effort (Chartkoff and Ritter 1966). Excavation efforts were focused on sites located within the relocation route of the Western Pacific Railroad (Olsen and Riddell 1963), the Oroville Dam spillway (Jewell 1964), Bidwell Bar and the Feather River below the damsite (Gebhardt 1964; Olsen 1964), and BUT-84, *Tie Wiah* (Ritter 1968). During the same time, the University of California, Los Angeles, conducted excavations at several sites located adjacent to Lake Oroville (Chartkoff and Chartkoff 1968, 1983; Pritchard et al. 1966).

Ongoing recreational development in areas such as the Lime Saddle and Craig Saddle recreational areas led to extensive archaeological survey and testing efforts in the 1970s, 1980s, and 1990s (Furnis and Young 1976; Hood 1988; Hunter and Orlins 2000; Jensen and Associates 1990; Woodward 1984; Hines 1996; Rivers 1991; Steidl et al. 1999). Inventories of artifact collections associated with human remains from the project area have been conducted by DPR (1992), and Kautz and Taugher (1987).

G-CUL.1.2 Ethnographic Setting

The Feather River region has been occupied by the Konkow-Maidu for at least 3,000 years. Many natural and cultural factors influenced how these prehistoric people used the area in which they lived. The Maidu adjusted their way of life to match the seasonal availability of food and other natural cycles. Over time, the subsistence adaptations they developed increasingly focused upon the gathering and use of fish, large mammals (e.g., elk, deer, pronghorn), and acorns. These were supplemented by a host of other plants and animals. Various technological innovations were directly tied to subsistence. Milling stones, for example, which were used to grind seeds, roots, and acorns, were used during a much earlier time period, and eventually gave way to the use of mortars and pestles. Other technological innovations included changes in weaponry (e.g., the introduction of the bow and arrow) and textile arts (e.g., the development of basketry). Prehistoric people’s responses to annual events are evident in the types of places prehistoric sites are found and the kind of artifacts they contain. For instance, hunting camps are situated along what were once major game trails, and often contain arrow and dart points. By studying the differences in the types and styles of these and other tools, archaeologists are able to reconstruct local innovations as well as cultural influences between the ancestral Konkow-Maidu and their neighbors.

Certain areas of the Feather River basin were more conducive to occupation than others to the indigenous population. Konkow settlement locations depended primarily on elevation, exposure, and proximity to water and other resources. Permanent villages were usually located on low rises along major watercourses. A major village with a large, semi-subterranean lodge often provided the central ceremonial and political focus for several nearby affiliated villages. These communities incorporated 3 to 5 smaller villages, with a total population estimated at 200 people. Houses were domed structures covered with earth and tule or grass. Brush shelters were used in the summer and at temporary camps during food-gathering rounds. Several such village communities have been identified in the general Oroville region, with some locations occurring within the project area (Rathbun n.d.).

The Konkow occupied these permanent settlements from which specific task groups set out to harvest the seasonal bounty of flora and fauna that the rich valley environment provided. Like other California Native American peoples, the Konkow practiced a mixed system of gathering, fishing, and hunting. Deer and salmon were the chief sources of animal protein in the aboriginal diet, but many insect and other animal species were taken when available. Acorns were also an important food source that could be stored in anticipation of winter shortfalls in resource abundance. Many other plant foods were also dried and stored for later use. Konkow families moved to strategic locations at appropriate harvest times to gather these desired foods. Trade with neighboring tribes was also used to supplement the locally available resource base, and to foster intertribal relationships. Resource planning also allowed the Konkow to provide for ceremonial meals to which families or settlements invited many others to partake of their generosity. Traditional competitive games also provided an important opportunity for social interactions with teams from neighboring communities.

Significant changes for California Native Americans began with the Spanish occupation of the coastal regions of the state in the 1800s. This change continued and worsened with the influx of trappers, early settlers, and miners. Disruption of the environment, disease, and conflict decimated Native American communities. The Gold Rush in 1849 was particularly devastating for the Konkow-Maidu. The Feather River and surrounding hills contained rich gold deposits, which enticed thousands of miners to the area. The landscape was destroyed by their mining techniques, and the indigenous people were ultimately driven off their land in numerous violent encounters. The Maidu, along with other tribes, were officially driven off their land in 1853 and removed to the Nome Lackee reservation in Tehama County. Many, however, returned to their original homes due to a structure at this reservation. In 1863, after continuing conflicts, the Konkow were again forcibly removed and marched across the Coast Range to the Round Valley Reservation in northern Mendocino County.

Thereafter, Konkow communities survived by keeping a low profile in areas that were considered less desirable by Euroamerican farmers. Some adopted Western technologies and economic strategies that integrated well into their traditional lifestyles. Many men worked for cash in the lumber companies or worked as ranch hands. Women continued to gather wild foods, but also planted fruit trees, and gardens with beans, potatoes, squash, and other vegetables. A secure land base eluded the Konkow until around the turn of the 20th century, when several small rancherias were created, finally establishing a legal land base for them and formalizing their tribal status with the federal government.

G-CUL.1.3 Historic Setting

The Feather River–Lake Oroville region is an area with a rich and varied history, reflecting myriad human activities and trends. This region of Butte County reflects many of the themes and events observed in California history. The major historical themes pertinent to the area include early settlement, mining, railroad industry, agriculture, and hydroelectric power.

G-CUL.1.3.1 Early Settlement

The first direct contacts between the local indigenous population of the Sacramento Valley and the northern Sierra Nevada foothills and the Spanish did not occur until the early years of the 19th century. The earliest Spanish exploration of the Feather River area came in 1808 with the military expedition of Gabriel Moraga, which set out from Mission San Jose in late September to find a suitable site for a new mission in the interior (Cutter 1950:121-130). There were no further Spanish expeditions into the area until Luis Arguello's explorations of the northern part of the Great Valley in 1820 and 1821. According to lore, the Feather River acquired its modern name during the first of these Spanish military expeditions. Arguello is said to have named the river *Rio de las Plumas*, or Feather River, after seeing a large number of feathers floating on its waters. In the two decades that followed, both the Spanish and English names for the river appear on various maps (Gudde 1998:130; McGie 1982, I:30).

In later years under Mexican rule, foreign immigration and trade were encouraged. Furthermore, if a foreigner was willing to become a Mexican citizen and a Catholic, he was welcomed into Californio society with all the rights of the native-born to participate in trade and to own land (Rice et al. 1996:149-151). Between 1844 and 1846, Governors Manuel Micheltorena and Pio Pico named a number of grants in the area of modern Butte County, including one in the project area. In 1846, Governor Pico granted four leagues along the west side of the Feather River to Dionisio and Maximo Fernandez, the sons of a former alcalde of Monterey who was of Mexican birth. Most of the other ranchos in the area were granted to Americans who had become naturalized Mexican citizens rather than to Californios, and were located to the west and northwest, along the Sacramento River and its tributary creeks (Beck and Haase 1974:26; Cowan 1956:36; Mansfield 1918:38-40).

Most of the early American and European immigrants had come by sea, with the exception of the fur traders who had traveled overland. With the development of overland routes, several immigrant parties that included families began to arrive. Many of these new immigrants were unwilling to become part of the Californio society, remaining United States citizens and resisting Mexican law and conversion to Catholicism (Hass 1998:336). They settled on the western edges of the lower Sacramento Valley. It was from this group, as well as from settlers in the nearby Napa Valley, that the participants in the Bear Flag revolt emerged, striving for independence from Mexico. Their small rebellion was quickly subsumed into the larger war between Mexico and the United States, which ended in the U.S. acquisition of California in 1848.

G-CUL.1.3.2 Mining

The Feather River was a major gold-producing area, with all the social, economic, and environmental consequences found elsewhere in the mining West. The discovery of gold at Sutter's Mill on the American River in January 1848 led ultimately to one of the largest voluntary migrations of people in modern history. The first recorded gold discovery on the Feather River was made by John Bidwell in March 1848. Bidwell arrived in California in 1841 with the Bidwell-Bartleson party, the first to come overland. He later worked for John Sutter and explored the Sacramento Valley and the Feather River area. Visiting the site of the gold find at Sutter's Mill, he recognized the similarity of the Feather River to the American River. On his return trip to Arroyo Chico, where he had bought land and made his home, he stopped at what would be known as the Hamilton Bend of the Feather River and panned for gold, finding some flakes. Encouraged by these finds, he organized a group, including several other ranchers and a sizable number of Konkow-Maidu, to investigate further up the Feather River. Before long, Bidwell made a substantial find in April 1848 at what became known as Bidwell

Bar (aka Bidwell's Bar) on the south side of the Middle Fork of the Feather River, which he proceeded to work using indigenous labor (Mansfield 1918:42-43). Other settlers in the area who made substantial finds on the Feather River included John Potter at Potter's Bar on the North Fork and Sam Neal at what became known as Adamstown, on the south side of the river across from what became known as Long's Bar.

Potential miners who arrived at the Feather River in the fall of 1849 discovered that many had come before them. Charles Parks and his companions traveled north from Sacramento; they first went to Bidwell Bar on the Middle Fork, which had developed into a substantial mining camp, and then 5 miles up the river to locate a claim near what they called Oregon Bar (Parke 1989:85-88). Delano established a store at the lower end of Bidwell Bar, known as Dawlytown (Delano 1853:112). For those who came the northerly route from Lassen's Cutoff, Long's Bar on the main Feather River was usually the first mining camp reached. By November, there were more than 2,000 people at Long's Bar, living in a variety of dwellings on both sides of the river. The camp, a major source of supplies for miners on the Feather River, boasted 15–20 stores and a hotel (Holliday 1981:312).

The Feather River was largely a placer-mining area, being rich in gold-bearing gravels and lacking the large veins of gold found in the Mother Lode. Over the years, the simple early placer-mining techniques were replaced by river mining, drift mining, hydraulic mining, and dredging. Quartz mining, also known as hard-rock mining, occurred, but was not as widespread as the various forms of placer mining. By the end of 1850, there were 214 mining camps on the Feather River, its branches and tributaries (Talbitzer 1987:29). For the next 70 years, gold mining in its various forms remained a significant economic activity in the project area, subject to the boom-and-bust nature of the extractive industries throughout the West.

G-CUL.1.3.3 Railroads

The arrival of the railroad in the 1860s improved the Feather River area's connection to the larger state and national transportation network. The California Northern Railroad, the first in the area, was completed from Marysville to Oroville in 1864. The county subscribed $200,000 in bonds for its construction (Mansfield 1918:245-246). The coming of the railroad increased interest in roads leading to Oroville. The Oroville-Forbestown road was completed in 1865 (McGie 1982, I:97); a smaller road led off it to Stringtown. North of the bridge at Stringtown, a road led to Mooretown. The 1877 and 1886 Butte County maps show roads leading from Oroville to Bidwell Bar. Despite the development of roads in Oroville, in 1870, the California and Oregon Railroad was built north through the valley lands west of the Feather River from Marysville to Chico, rather than through Oroville. The railroad was given "twenty alternate sections of public land" making it a substantial landholder in the area (Robinson 1948:154). The 1886 Butte County map shows that some of this land was within and adjacent to the project area. The California and Oregon, along with its land grants, was later acquired by the Central Pacific, and ultimately the Southern Pacific.

The railroad's presence encouraged the establishment of new agricultural towns along the route (Talbitzer 1987:66-68). It opened up the wheat market for farmers and also benefited the lumber industry. In 1889, after considerable financial troubles, the California Northern was acquired by the Southern Pacific (McGie 1982, I:144-145). The acquisition of these smaller railroads by the larger Central Pacific and Southern Pacific in the upper Sacramento Valley was typical of what was happening elsewhere in California.

The first decade of the 20th century saw the construction of the Northern Electric (later the Sacramento Northern). This interurban electric railway ran between Chico and Oroville in 1906. Oroville was not on the main line but was served by a spur that ran from the Oroville depot northwest through Thermalito to Tres Vias, where passengers and freight would transfer to or from the main line. Later the interurban was completed to Marysville and Sacramento (McGie 1982, I:188). The most ambitious project was the Western Pacific's construction of a route from Salt Lake City to San Francisco through Beckwourth Pass and the steep-sided canyon of the North Fork Feather River (Vance 1995:225-230). It was a massive undertaking that involved large numbers of laborers and poured large sums into Oroville's economy. Construction began in Oroville in 1905, and construction camps were established along the route, while supplies had to be hauled into the canyon by wagons. The route was opened in the fall of 1910 (Mansfield 1918:344; Talbitzer 1987:80-81). Sections of the railroad were relocated when Oroville Dam was built.

G-CUL.1.3.4 Ranching, Farming, and Settlement

Agriculture played an increasingly important role to early settlers in the 1850s and 1860s. Some who originally came to mine turned their attention to farming and stock raising. Many of the miners had been farmers before they came to California, so it was natural that some of those who decided to stay in the Feather River area rather than return east took up their former occupations. The demand for food to supply the miners gave them an eager market in the early years. During the first few years of the Gold Rush, most foodstuffs had been freighted into the area.

Livestock raising on the ranchos had been the earliest form of agriculture in the area, predating the Gold Rush, but with the increase in population, the emphasis shifted from the hide-and-tallow trade to meat production. The first cultivated area within the project area was around Hamilton, where by 1854 there were 2,000 acres planted in wheat and barley, as well as numerous vegetable gardens (Mansfield 1918:168). There was a 2-acre Chinese truck garden in Oroville by the mid-1850s that continued to be cultivated for the next 50 years (Chan 1986:96).

Settlers were attracted to land in the foothills and in the valley, where they raised wheat, vegetables, and livestock and cultivated orchards. Given the topography of the project area, much of which is in the foothills, farms here were usually small operations that marketed any excess products but focused on subsistence agriculture. Wheat became the dominant crop in the 1850s and 1860s as the flatlands to the west of the project area were put under cultivation. As early as 1853, Bidwell had built the first flour mill in the county on his rancho. Oroville had its first such mill in 1853 (Wells and Chambers 1882:206, 243). The arrival of the railroads in the 1860s and 1870s made it easier and less expensive to get the crops to market and led to a great increase in the acreage devoted to wheat. Butte County agriculture was no longer simply local in nature but had become part of the larger national and world market. For most of the 19th century, wheat production continued to dominate the agriculture market in Butte County, as it did that of California. At the end of the 19th century, wheat production fell as a result of soil exhaustion and the general decline of wheat-growing in California (USBC 1883:179; 1896:358; 1902:155).

By the 1880s, agriculture in Butte County and in the project area was diversifying with the increased planting of orchards and other crops. Homestead proofs provided some clarity on the type of agriculture being grown within the project area; these included grains, fruit trees, hay, green vegetables, grapevines, blackberries, as well as cattle, goats, chickens, hogs, and milk cows. Many homesteaders listed orchards on their proofs as evidence of cultivations. The deciduous trees were among the first planted in the project area. Fruit was particularly popular among the miners, so maintaining an orchard was a way for the early farmers and ranchers to make some money while supplying their own needs.

It had been established early on that citrus, especially oranges, would grow in the area, as would a number of other orchard fruits. The first citrus tree in Butte County—what came to be known as the Mother Orange Tree—was planted at Bidwell Bar in 1856. Its seeds are said to have produced successful orange trees throughout the area before it was transplanted to park headquarters (McGie 1982, I:84). In 1887 four businessmen combined land in the foothill thermal belt, which is generally located between the 300- and 1,200-foot elevations, across the river from Oroville with the water from the Miocene Ditch to form the Thermalito Colony. It was a real-estate development patterned after successful citrus colonies in Southern California. The colony was designed to sell small plots for citrus groves and other orchards with the hope of attracting new residents from southern California and the East and Midwest.

In the 20th century, the landholding pattern within Butte County underwent changes. The number of small holdings increased during this time. Between 1900 and 1930, the number of farms increased from 1,179 to 2,603, while the average size of a farm decreased from 574.3 acres to 238 acres (USBC 1902, I:62, 1932, II Part 3:518, 523). This trend was observed for the county as a whole. Additional research would be needed to determine whether this trend applied to the project area.

G-CUL.1.3.5 Water Supply and Hydroelectric Power

With the end of hydraulic mining, a number of the existing ditch systems in the region were allowed to go derelict or were converted to irrigation ditches. Frank McLaughlin's Golden Feather river-mining project of the 1890s involved the repair of the Miocene Ditch, which also became the water-supply system for the Thermalito agricultural colony, another of McLaughlin's projects. While there were purported to be 25 irrigating ditches aggregating 200 miles in 1881 (Wells and Chambers 1882:209), no locations or names were provided. The Miocene Ditch was purchased by the Oroville Light Water and Power Company in 1901; in 1918, it was acquired by Pacific Gas and Electric Company (PG&E), which renovated and repaired the system.

With the passage of the Wright Act in 1887, the establishment of irrigation districts was permitted. In 1922, the Thermalito and Table Mountain irrigation districts were established. They purchased water from PG&E, which was to be delivered by the Miocene and Power ditches (Adams 1929:10-115; Hundley 2001:100). Additional irrigation projects were established to provide water to the valley lands west of the Feather River. In 1905, the Butte County Canal, later known as the Sutter-Butte Canal, was built from the Feather River at Hazelbusch near Hamilton. The dredging firms that controlled the rights to the river closer to Oroville refused to allow the canal to be constructed there, as it would have interfered with their operations. In 1915, the Western Canal was built west from the Hamilton Slough area, where the dredgers had finished working. It was built by the Great Western Power Company, which was searching for a market for its water from Lake Almanor (McGie 1982 I:189). Both of these canals originate in the project area.

During the first decade of the 20th century there was considerable interest in the rights to the waters of the Feather River, especially the North Fork, for use in the generation of power. Mines had been among the first users of hydroelectric power. Frank McLaughlin’s Big Bend Tunnel project of the 1880s used a water-generating plant to provide electric power for the pumps and hoist. The Spring Valley Mine used electric power to provide light for its around-the-clock operations. The dredges also used electricity to power operations. Great Western Power, made up of a powerful group of California and New York investors, was engaged in developing hydroelectric power in the area, having acquired the rights to Big Meadow in Plumas County on the North Fork, which they would flood to produce Lake Almanor. Great Western Power remained the dominant hydroelectric company in Northern California until it was acquired by PG&E in 1930, which then took over the Big Bend Powerhouse and Las Plumas. Both the powerhouse and the community of Las Plumas were razed for the creation of Lake Oroville.

In 1951, the construction of a dam across the Feather River above Oroville was proposed by the State. This dam was needed in order to “control floods and collect runoff for delivery along a 750-mile route” (Hundley 2001:279). The generation of hydroelectric power was also part of the plan. Construction on Oroville Dam as part of the State Water Project (SWP) began in 1962 and was completed in 1967, creating Lake Oroville. Oroville Dam, at 770 feet, is the highest dam in the United States. It generates hydroelectric power and provides flood protection. In addition, it provides water for the southern part of the state. The construction brought an economic boom to the area, and the reservoir created a recreational area out of a great deal of the project area (McGie 1982 II:145-148).

G-CUL.2 INVENTORY AND EVALUATION METHODOLOGY

The three cultural resource inventories (archaeology, ethnography, and historical buildings and structures) for this project were conducted from 2002 to 2004. Methods employed for these endeavors consisted of background research and field work. The pre-field efforts included visiting a number of repositories and libraries to review available published and unpublished literature, maps, and historical documents, as well as conducting oral interviews. The methods employed for each of the three studies are described below.

G-CUL.2.1 Archaeological and Historical Inventory

G-CUL.2.1.1 Background Research

Work began with background research on the natural environment, prehistoric past, and historical development of the area. Project historians found maps of Butte County from the 1850s to the present that showed towns, roads, some of the larger mining areas, and, in some cases, the names of landowners. They also consulted other primary sources, such as census records, photographic archives, homestead proofs, and mining claims. Secondary sources—the results of historians' interpretations—helped provide a general picture of the history of the area.

One of the first tasks of the primary research effort was to identify project-area homesteads. Homesteads of 160 acres were permitted to U.S. citizens and as well as those in the process of naturalization. These records provided researchers with information about who owned the land and what improvements were made to it over time. Historic maps also provided valuable information, sometimes listing landowners' names and the presence of buildings and structures.

Background research for prehistoric archaeology included reviewing information on the natural environment prior to the Gold Rush. Information about Native American lifeways in the late 19th and early 20th centuries was also researched to assess how the Maidu people used the land before contact with settlers disrupted both the local ecosystem and the traditional way of life. Tribal members on the archaeological inventory team provided information about prehistoric Native American sites in the project area.

A records search with the California Historical Resources Information System was conducted to determine the number, locations, and types of sites that had been previously discovered and recorded within the survey area. This work also helped archaeologists design their survey strategy and ensure that the team did not unwittingly record sites that had already been identified. This extensive background research was followed by re-visits to previously recorded sites to update site information.

G-CUL.2.1.2 Field Work

The field work phase of the archaeological and historical resources inventory involved five elements:

- Re-visits to 276 previously recorded resources;
- Inventory of the 9,554-acre fluctuation zone;
- Probabilistic sample survey of about 4,800 acres above maximum pool elevations;
- Survey of 58 historical sensitive areas; and
- Inventory of about 2,000 acres associated with existing and proposed developed recreation facilities.

Archaeologists surveyed as much of the accessible fluctuation zone as possible. In 2002 and 2003, the reservoir level reached about 680 feet above mean sea level (msl), allowing for the intensive inventory of most of this land. A total of almost 7,500 acres were inventoried within the fluctuation zone.

The remaining portions of the project area (i.e., the 21,400 acres that are not inundated) were sampled to gather information that could be used to portray the area as a whole. Sample transects outside of the reservoir pool were chosen randomly to represent the area's topographic and environmental zones. These zones included grassland (2,096 acres surveyed), oak woodland (1,793 acres surveyed), and coniferous forests (918 acres surveyed). The total area inventoried in association with the probabilistic inventory (4,807 acres) represents approximately 22 percent of the available acreage.

Eventually, almost 15,500 acres of land within the APE established for the Oroville Facilities were inventoried for archaeological and historical resources.

G-CUL.2.2 Ethnographic and Ethnohistoric Inventory

The ethnographic and ethnohistoric inventory effort was undertaken using two main research strategies. The first strategy involved interviewing knowledgeable, local Konkow-Maidu elders. Historical information from these elders was critical for developing a representative ethnohistoric perspective because many published sources do not take Maidu views into account. The second strategy consisted of the examination and review of published materials and unpublished archival resources.

Published and unpublished documents were examined to glean relevant data pertaining to the project area. General histories of Butte County and the Oroville area were used, as well as ethnographic documents, census records, and historic photos and maps. The Butte County Public Library, Meriam Library at California State University, Chico, and the California State Archives proved to be valuable sources of information during the research effort.

The ethnographic team, which consisted of anthropologists accompanied by Maidu assistants, conducted interviews with Maidu Tribes regarding information about culturally important and/or sensitive locations in the Oroville Facilities project area. The interviews were designed to directly address locations about which contemporary Maidu have concerns. Many consultants, who included members from Berry Creek, Enterprise, and Mooretown rancherias, participated in multiple interviews. The interview sessions were open-ended, with the goal of encouraging the consultant to have a free flow of memory. Additionally, the ethnographers and elders made a number of field trips, many of them day-long, into the project area and its surroundings to identify important places and discuss cultural values and concerns. A total of 88 oral interviews were conducted and documented in association with the inventory of ethnographic and ethnohistoric resources.

G-CUL.2.2.1 Area of Potential Effects for Ethnographic and Ethnohistoric Resources

As noted in Section 5.9.1.3, the APE for ethnographic and ethnohistoric resources was expanded beyond the FERC project boundary to include Stringtown Mountain, and was extended up the Middle Fork Feather River and Bald Rock Canyon to the base of Bald Rock Dome (see Figure G-CUL.2-1). Bald Rock Canyon is a focus of mythological importance to the Konkow-Maidu people. The APE was extended to include this significant cultural area, including the 25-foot-high falls at the head of the canyon. These falls were the terminus of the salmon run along the Middle Fork. Bald Rock Dome is significant mythological site that is associated with a number of stories told by the Konkow-Maidu.

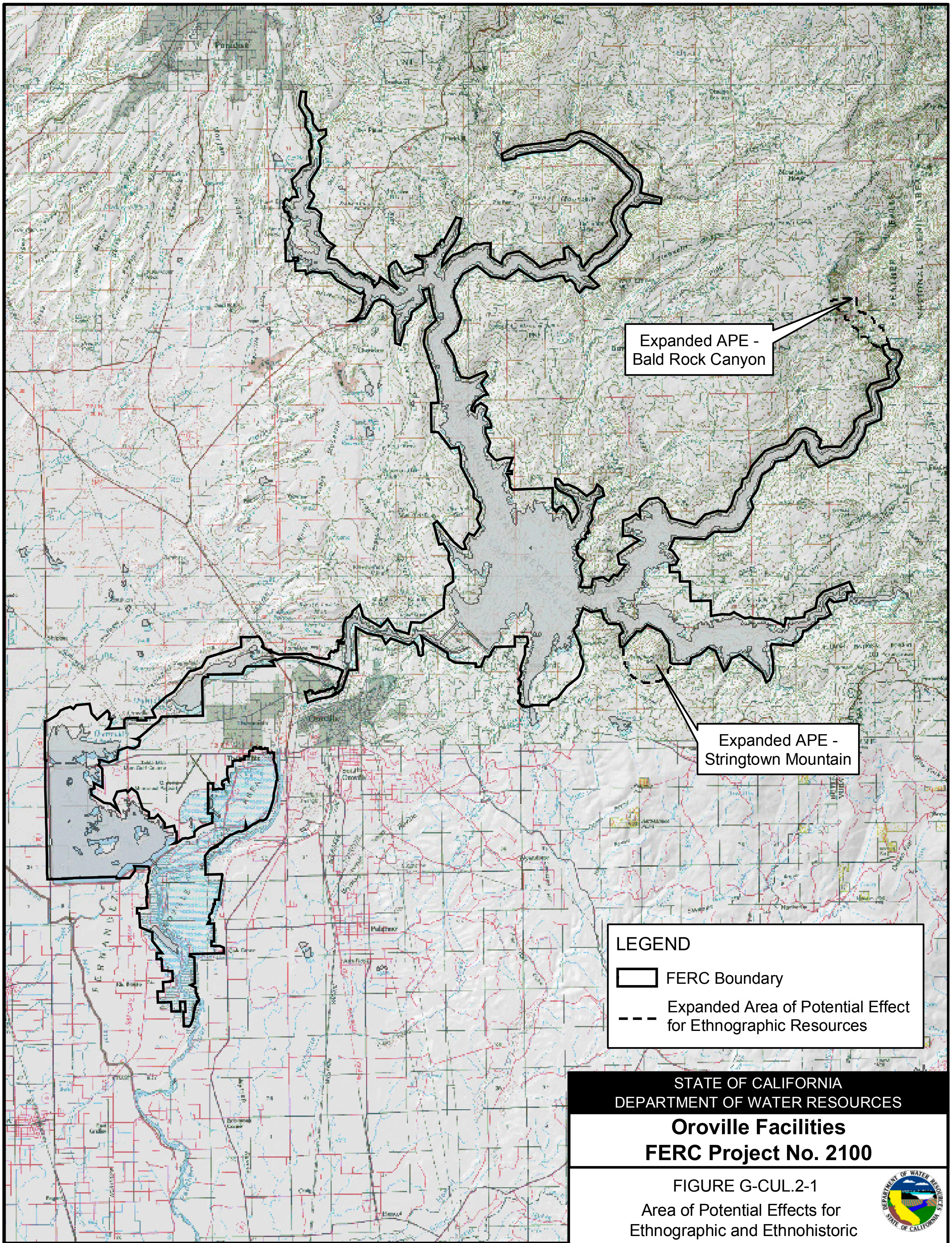
Stringtown Mountain, located just south of the former town of Enterprise, is adjacent to the south bank of the South Fork Feather River. Stringtown Mountain is a mythological site. The town of Enterprise was inundated when Lake Oroville was filled. Also in this area is Enterprise Rancheria No. 2, which was the site for many traditional gatherings and ceremonies. The town was also a major draw for shopping and socializing. The trails from Enterprise connect to many other parts of Maidu territory.

G-CUL.2.2.2 Historical Buildings and Structures Inventory and Evaluation

The historical buildings and structures associated with the Oroville Facilities consist of 16 discrete elements; of these,14 are considered contributors to a proposed National Register district, and 2 are noncontributors. The elements were divided into three main categories: water resource infrastructure (both water storage and conveyance facilities), power facilities, and supplemental facilities. These resources were built by the California Department of Water Resources (DWR) between 1961 and 1974 as part of the Oroville Division of the SWP. The SWP is operated by DWR, with the exception of one facility that is jointly operated by DWR and DPR. The proposed National Register district includes seven dams, three power plants, two operations-maintenance complexes or annexes, and numerous gauging stations and communication posts spread throughout the APE.

G-CUL.2.2.2.1 Water Storage and Conveyance Facilities

The most numerous and massive elements of the proposed district are the seven dams associated with the Oroville Facilities. These resources include Oroville Dam, Bidwell



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

Oroville Facilities
FERC Project No. 2100

FIGURE G-CUL.2-1
Area of Potential Effects for Ethnographic and Ethnohistoric Resources

Sources: Helen McCarthy, Ethnographer, 2004, DWR 2004

17,000 8,500 0 17,000 Feet

Original Scale 1 : 204,000
1" = 17,000 feet

Prepared by LC -- EDAW	Date 11/23/04	x:/Projects/2000/0S016.88/ OroPDEA_G-CUL.2-1.mxd

Bar Canyon Saddle Dam, Parish Camp Saddle Dam, Thermalito Diversion Dam, Fish Barrier Dam, Thermalito Forebay Dam, and Thermalito Afterbay Dam.

Oroville Dam is the key storage facility in the SWP. Construction of this structure began in 1961 and ended in 1968. It is 770 feet tall from excavated streambed to crest, which sits at an elevation of 922 feet above msl. The crest is 50.6 feet wide with a slight upstream curve, and spans 5,600 feet between the gated spillway and the left abutment. In profile, the dam is of a triangular shape with a massive concrete core block, and is divided into five different zones of earth and rockfill totaling 80 million cubic yards. Oroville Dam has the capacity to impound 3,538,000 acre-feet (af) of Feather River water in the reservoir. This structure was determined to be individually eligible for listing in the National Register of Historic Places (NRHP) and to represent a contributing element of the proposed historic district.

Bidwell Bar Canyon Saddle Dam, built between 1966 and 1968, is actually two separate rock-and-earth embankments that encompass the former Miners Ranch Dike built by the Oroville-Wyandotte Irrigation District (now known as the South Feather Water and Power Agency) as part of its South Fork Project. The west dam is 24 feet tall with an upstream slope of 2.5 to 1 and the downstream slope of 2.0 to 1. The fill for the dam was homogenous with the exception of a horizontal blanket drain on the downstream side, a compact rockfill upstream toe, and rock slope projection. Three zones were used to construct the main dam, and riprap lines the upstream slope.

Parish Camp Saddle Dam was also constructed between 1966 and 1968. This dam is located 12 miles northwest of Oroville Dam, in the Parish Camp Saddle Recreation Area. The dam is an earth-and-rockfill embankment, extending 260 feet across Lime Saddle. Reaching 27 feet in height with a 30-foot-wide crest, the dam has a main impervious core that makes up most of the embankment.

Thermalito Forebay Dam and Thermalito Afterbay Dam were both constructed between 1965 and 1968. Both dams are located offstream and impound bodies of water that are used in conjunction with the project. Thermalito Forebay Dam is 15,900 feet long, running from the terminus of the Thermalito Power Canal to the headworks of the Thermalito Power Plant. The dam varies in height from 91 feet to 25 feet depending on the terrain it crosses. The dam is composed of two high sections, often referred to as the main dam and Ruddy Creek Dam. Thermalito Afterbay Dam is 42,000 feet long and is roughly L-shaped in plan, with a triangular profile. Varying in height from 39 feet to 24 feet, the crest is 30 feet wide, is unpaved, and sits at an elevation of 142 feet above msl. Incorporated into the overall design of Thermalito Afterbay Dam is a small saddle dam that is 1,000 feet long and 12 feet high. Except for its lower height, it is virtually indistinguishable from the main Thermalito Afterbay Dam.

The two diversion dams located in the APE are Thermalito Diversion Dam and the Fish Barrier Dam. These resources sit in close proximity to each other, located approximately 0.25 mile apart on the Feather River. Thermalito Diversion Dam was constructed between 1962 and 1968 of reinforced concrete. The dam is approximately 1,300 feet long, extends 143 feet above the foundation, and incorporates a gated spillway, a canal-regulating headworks structure, an earth embankment at the right of the canal headworks, and a small power plant at the dam's left abutment. The Fish Barrier Dam is approximately 600 feet long and varies in height from 148 to 181 feet above the river bed. Sited on bedrock, the dam is constructed of 18 reinforced concrete monoliths ranging from 25 to 35 feet in length. The purpose of the Fish Barrier Dam is to prevent fish from swimming upstream. The designs of both diversion dams allow them to be overtopped during high flows, so they do not have separate spillways.

G-CUL.2.2.2.2 Power Facilities

The power facilities consist of three hydroelectric power plants that use water stored in Lake Oroville, Thermalito Forebay, and Thermalito Afterbay. These plants produce an output of 725 megawatts (MW) of power. Only two of the plants, the Hyatt Pumping-Generating Plant and the Thermalito Pumping-Generating Plant, are contributors to the proposed historic district. The third power plant, located in the left abutment of the Thermalito Diversion Dam, was constructed in 1989 and is a noncontributor to the proposed district.

The Hyatt Pumping-Generating Plant was constructed between 1963 and 1969. It is located in and beneath the left abutment of Oroville Dam. The Thermalito Pumping-Generating Plant was constructed between 1964 and 1969. This power plant is located above ground at the terminus of the Thermalito Power Canal and Thermalito Forebay. Both plants operate on the pumped-storage principle. They generate power during the high-demand hours, and then pump back water from the forebay to the reservoir during the off-peak hours.

G-CUL.2.2.2.3 Supplemental Facilities

The category of supplemental facilities is broad and includes several buildings. These facilities include the Oroville Operations and Maintenance Complex, the Oroville Area Control Center and Switchyard, the Feather River Fish Hatchery, and the visitor centers.

The Oroville Operations and Maintenance Complex, constructed between 1968 and 1969, hosts a range of capabilities including administration, maintenance, engineering, plant maintenance, civil maintenance, and water operation facilities. This facility is classed by function to include maintenance building complexes, subcenters, and single-function maintenance centers. Structures within the subcenter category include the Thermalito Operation and Maintenance Annex at the Thermalito Pumping-Generating Plant site. The last category of buildings is the small, single-use buildings confined to one purpose with limited capability, such as the Thermalito Afterbay Outlet facility on Thermalito Afterbay Dam.

The Oroville Area Control Center and Switchyard, the only control center located within the Oroville Facilities, is set at the base of the left abutment of Oroville Dam. This facility is the primary operating and dispatch center for both the Hyatt and Thermalito Pumping-Generating Plants and all of the hydraulic appurtenances in the Oroville Facilities.

The Feather River Fish Hatchery is considered the most unique of the supplemental facilities. Constructed from 1962 to 1967, this facility is located on the north side of the Feather River, on both the east and west side of Table Mountain Road. DWR constructed the facilities to provide a complete fish hatchery with the ability to trap, hold, and use for spawning the approximately 9,000 Chinook salmon and 1,000 adult steelhead trout that annually migrate upstream in the Oroville area. This facility includes administration, operation, and maintenance buildings; a gathering tank; four holding tanks; a spawning-hatchery building; an aerator; rearing channels; and a rest pool.

Three visitor centers are incorporated into the design of other facilities and consist of a center in the Hyatt Pumping-Generating Plant powerhouse, one in the Oroville Area Control Center, and the last at the Feather River Fish Hatchery. The centers at Hyatt Pumping-Generating Plant and the Oroville Area Control Center are no longer open to the public because of security concerns.

The remaining visitor center is at Kelly Ridge. This center was constructed between 1972 and 1974. It is composed of two buildings and one structure, and is located east of Oroville Dam on Kelly Ridge Road. The facility is jointly owned and operated by DWR and DPR, and serves a dual purpose as the main visitor center for the Oroville Facilities of the SWP and the Lake Oroville State Recreation Area. Unlike other DWR facilities in the SWP, this building does not conform to the architectural guidelines developed for buildings and structures in the project, although it is contemporary in style. The complex is arranged in a radial plan around a central courtyard, with the main visitor facility located on the southwest portion of the complex, an observation tower on the east side, and a former restaurant/gift shop on the northeast.

G-CUL.2.2.2.4 Evaluation of Buildings and Structures

The eligibility criteria for listing in the NRHP are codified in 36 Code of Federal Regulations Part 60.4. Eligibility rests upon twin factors of significance and integrity. A property must have both to be considered eligible for listing in the NRHP. Loss of integrity, if sufficiently great, will overwhelm the historical significance of a resource and render it ineligible. Likewise, a resource can have complete integrity, but if it lacks significance, it must also be considered ineligible.

Historical significance is judged by the application of four criteria:

- Criterion A: Association with “events that have made a significant contribution to the broad patters of our history”;

- Criterion B: Association with the “lives of persons significant in our past”;

- Criterion C: Resources “that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction”; and

- Criterion D: Resources "that have yielded, or may be likely to yield, information important to history or prehistory."

Integrity is defined as the retention of the physical identity that existed during the resource's period of significance. Integrity is evaluated with regard to retention of location, design, setting, materials, workmanship, feeling and association.

The eligibility criteria for listing a property in the California Register of Historical Resources (CRHR) closely parallel those of the NRHP. Each resource must be determined to be significant under the local, State, or national level under one of four criteria to be determined eligible. These criteria are paraphrased below:

- Criterion 1: Resources associated with important events that have made a significant contribution to the broad patterns of our history;
- Criterion 2: Resources associated with the lives of persons important to our past;
- Criterion 3: Resources that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master; and
- Criterion 4: Resources that have yielded, or may be likely to yield, information important in prehistory or history.

Assessing the significance of a complex such as the proposed Oroville Division Historic District involves consideration of a number of special factors that are not often found with single buildings, structures, sites, or objects. The historic significance of the facilities is best understood when the resources are treated as a district, because the significance rests on the group of resources as a whole. The sheer scale of the district places it in a special category, as does the history of its planning and construction, and its place in the history of water development in the State of California. Moreover, it is a rare example of a resource that was directly and specifically approved by a statewide vote of the people.

The Oroville Facilities were determined to be eligible for listing under NRHP Criteria A and C and the CRHR counterpart Criteria 1 and 3. While the facility is not yet 50 years old, its place in California's history and the importance of its engineering achievement make its eligibility possible under Criterion Consideration G, which provides an opportunity for more recent resources with exceptional significance to be included in the NRHP.

G-CUL.3 RESOURCE CATEGORIES

The archaeological and ethnographic inventories conducted in 2002 and 2003 resulted in the identification of 897 prehistoric and historic-era sites and 144 ethnographic and ethnohistoric locations. The following subsections describe the resource categories identified during these inventory efforts.

G-CUL.3.1 Types of Prehistoric Archaeological Sites

Seven categories of prehistoric archaeological sites were expected to occur within the APE for the Oroville Facilities:

- Open-air residential sites;
- Caves and rock shelters;
- Limited lithic scatters;
- Rock art;
- Quarries and workshops;
- Bedrock milling sites; and
- Cemetery areas.

Open-air residential sites are also sometimes referred to as villages or base camps. The larger versions are more commonly called villages, smaller ones temporary camps. Typically, these sites may include communal ceremonial structures, midden deposits, house or storage pits, cooking features, ground stone, and a generally wide variety of artifacts. These sites tend to be located near creeks and streams; many open-air residential sites are presumed to lie within the inundated portions of Lake Oroville. Approximately 33 percent of the prehistoric sites recorded in 2002 and 2003 are assigned to this site category.

Cave and rock shelter sites are those occupation sites that are protected by a cave or rock overhang. Preservation of organic materials is more likely at these sites than at open-air residential sites where deposits are more commonly buried. These types of sites also lend themselves to the creation of rock art—a separate site category. Less than 1 percent of the sites within the APE are located within caves or rock shelters.

Limited lithic scatter sites are those sites that contain a sparse deposit of flakes that may be from one or more parent material. Frequently, these have been identified as temporary camps or secondary workshop areas. Because of their nature (i.e., small and sparse), these sites can be overlooked during archaeological field surveys. Approximately 30 percent of the prehistoric sites are considered to be limited lithic scatters.

Rock art sites are locations where a suitable outcrop surface has been decorated with one or more petroglyphs. These sites are frequently associated with larger occupation areas and/or are near watercourses. Less than 1 percent of the documented prehistoric sites contain rock art elements.

Quarry and workshop sites are locations where raw lithic materials such as chert, basalt, rhyolite, or obsidian have been extracted and, frequently, processed to some degree before transportation to another location. Quarries are located at the stone source, and these initial reduction areas are generally nearby. Similarly, groundstone workshops tend to be found near raw material sources such as granite or steatite outcrops. As with the other miscellaneous site types, less than 1 percent of the documented prehistoric resources match this site category.

Bedrock milling sites are generally associated with oaks or other seed-producing trees, both in association with occupation sites and in isolation. These sites are ubiquitous throughout Northern California and can occur as single cupules or outcrops with 50 mortar holes or more. Sites assigned to this category represent approximately 36 percent of the prehistoric site total.

Cemetery areas are those locations containing evidence of multiple human burials. These sites are generally located within or in proximity to residential sites, but can occur as isolated resources. Native American cemeteries are unmarked and therefore are difficult to locate unless they are exposed during planned excavation, by erosional forces, or by the activities of looters. Less than 1 percent of the 325 documented prehistoric sites are considered cemetery areas.

Occasionally, sites are found that were clearly used by Maidu people in the 19th century, after settlers had moved into the area. Glass trade beads and fragments of bottle glass mark these places, which are especially important as they hold invaluable information on this brief episode in Maidu history.

Because of the excellent visibility within the fluctuation zone, where vegetative cover was virtually nonexistent, most of the prehistoric-era resources were found within this area, which is also generally situated closer to the major watercourses. Based on the inventory results within the fluctuation zone, six prehistoric site classes have been defined. These classes take into consideration site size, archaeological assemblages, and other attributes:

- Class 1 sites represent substantial prehistoric settlements. These are generally large sites containing a diverse assortment of flaked and ground stone items. More than 50 percent of these sites contain steatite sherds and evidence of midden soils.

- Class 2 sites are slightly smaller than Class 1 resources, always include bedrock mortars, and contain slightly less diverse artifact assemblages than the preceding class. Structural depressions, found commonly in Class 1 sites, are less frequently found at Class 2 sites, again suggesting less intensive occupation.

- Class 3 sites are similar to the preceding classes, but lack bedrock mortars. Other differences between these sites and Class 2 sites include the fact that milling stones are twice as common while pestles are far less common. These sites may represent a period of use that is different from the preceding site classes.

- Class 4 sites are relatively small sites that always include bedrock mortars. Artifact assemblages are less complex than at the preceding site classes, with hand tools fairly common but flaked stone tools and debris comparatively rare. These sites are believed to represent more ephemeral use, although structural remains and midden deposits can occur at Class 4 sites.

- Class 5 sites are defined as relatively large sites that never contain bedrock mortars or evidence of house features, and rarely include midden deposits. These sites may have served as camps used for the procurement of various plant and animal resources.

- Class 6 sites are relatively small, and contain only one or two artifact types. Most of these sites contain bedrock mortars, and appear to have served as limited activity or procurement locations associated with larger residential sites.

More intensive archaeological investigations are needed to clarify and refine the nature and relevance of site categories, and gather more specific data on the number, nature, age, and distribution of these diverse site types.

G-CUL.3.2 Types of Historic-Era Archaeological Sites

The historic archaeological sites identified within the APE are associated with one or more of the following historic themes:

- Transportation;
- Settlement;
- Mining;
- Water systems;
- Industry and commerce;
- Agricultural development; and
- Other.

Transportation properties such as trail systems, road systems, and railroads have all left marks on the landscape. More ephemeral locations, such as ferry crossings, may be identified through documentary sources, but stone walls, tracks, watering troughs, bridges, trestles, tunnels, etc., may all mark portions of a transportation system. Approximately 32 percent of the documented historic-era sites are primarily transportation properties.

Settlement properties are those sites containing the remains of residences, shelters, other structures, or refuse deposits containing domestic debris. Other evidence of settlement can include features such as fences or landscaped elements such as gardens and orchards. Approximately 28 percent of the historic resources were associated primarily with the settlement theme.

Mining properties include a wide range of features and structures left behind by exploration, extraction, or processing activities. Physical indications of mining activity might include exploration pits, trenches, claim markers, historic artifact deposits, camp remains, adits, shafts, waste material piles, mining tools, ditches or flumes, or milling equipment. Twenty-two percent of the recorded historic-era sites are related primarily to mining.

Water systems were established by miners and settlers moving into the area. Collection, storage, and transportation of water began on a small scale to meet the needs of individuals, were enlarged for subsequent mining and agricultural operations, and grew to become the hydroelectric generation facilities that are a large part of the landscape today. Wells, pumps, cisterns, ponds, reservoirs, ditches, flumes, gates, dams, and transmission lines are all features associated with the collection and use of water. Approximately 13 percent of the historic-era resources are related primarily to the use, storage, or transport of water.

Industrial/commercial properties might include commercial quarries, mills, kilns, smithies, or other processing structures. Sites containing evidence of commercial timber harvesting are also within this category. Telephone and telegraph lines might be found connecting these locations. About 2 percent of the historic sites are consistent with industrial or commercial activities.

Agricultural properties were operated on a small scale in the project area until the 1880s, after which more developed commercial practices were instituted. Examples of agricultural properties include houses (or their remains) and outbuildings, harvesting machinery, storage buildings, walls or fences, orchards, corrals, water systems, and refuse dumps. Approximately 1 percent of the documented sites in the APE were assigned primarily to this theme.

Other historic-era resources include two contact-period resources and six commemorative monuments.

Because of the substantial overlap in historic themes that may be represented at any given location, different percentages are derived when all themes, not just the primary theme, are considered at each site. When assessing the range of themes represented at each resource, the following percentages are derived:

- Transportation—31 percent;
- Settlement—26 percent;
- Mining—19 percent;
- Water systems—18 percent;

- Industry and commerce—2 percent;
- Agricultural development—2 percent; and
- Other—1 percent.

G-CUL.3.3 Types of Ethnographic and Ethnohistoric Resources

The ethnographic and ethnohistoric inventory resulted in the identification of 144 locations of cultural importance in or near the APE. These locations were divided into 14 categories or site types:

- Villages;
- Cemeteries;
- Camps;
- Fishing grounds;
- Spawning grounds;
- Hunting grounds;
- Gathering areas;
- Swimming holes/picnic sites;
- Ceremonial sites;
- Mythological sites;
- Petroglyphs;
- Historic event/battle sites;
- Trails; and
- Place names.

Villages are residential locations where people lived for substantial periods of the year. Food and other materials were stored and used at these locations. Usually there is a traditional Maidu name associated with these places. Archaeological sites may be found in conjunction with these locations.

Cemeteries are those places where the Maidu buried their dead. Some of these sensitive places have been used for many generations, up to and including the present.

Camps are places to which people customarily moved on a seasonal basis for the gathering of specific resources. Some of these places have Maidu names.

Fishing grounds are locations that the Maidu found to be especially favorable for fishing. They returned to these locations on a regular basis to catch fish—an important component of both the Maidu diet and Maidu life.

Spawning grounds are locations along the main forks and branches of the Feather River where salmon or other fish spawned. As locations of renewal of essential resources, these places are particularly important to the Maidu.

Hunting grounds are where animals were hunted or trapped for food, furs, and other materials.

Gathering areas are locations where people carried out plant gathering activities. These locations were used for a specific purpose, and were not generally used for residential purposes. There may be Maidu names for these places.

Swimming holes/picnic sites are places that families would go to enjoy recreational pastimes. These locations and casual activities provided opportunities to pass on Maidu culture to younger generations.

Ceremonial sites are locations where individual Maidu or Maidu groups practiced traditional ceremonies.

Mythological sites are elements of the landscape that are associated with myths, legends, or cosmological events important to the Maidu. These places often have Maidu names, and are sometimes perceived as dangerous places because of the powerful spirits that may occupy these locations.

Petroglyphs are locations where figures or shapes are incised into rock. They are generally thought to relate to the spiritual world.

Historic event/battle sites are places where a historic event involving the Maidu occurred. Many of these locations are the sites of battles or other conflicts with Euroamericans occurred.

Trails connect people with the larger community and resources scattered across the landscape. Connections between people and places were central to Maidu life, making trails a critical component of the cultural landscape.

Place names are the names associated with important geographic features such as river forks, mountains, and prominent outcrops. They help people associate with the natural world, identify where they are, and navigate from place to place.

The locations of these various resource types are not evenly distributed across the landscape. To enable assessment of the geographic distribution of these categories, the project area was divided into six zones. The distribution of site categories across these six geographic zones is indicated in Table G-CUL.3-1.

Table G-CUL.3-1. Geographic distribution of ethnographic site types.

Site Category	Zone 1—West Branch	Zone 2—North Fork	Zone 3—Main Reservoir	Zone 4—Middle Fork	Zone 5—South Fork	Zone 6—Downstream of Dam	Total
Village	4	5	9	1	3	8	30
Cemetery	-	-	1	-	2	-	3
Camp	-	2	-	-	-	1	3
Fishing Ground	3	7	2	9	6	2	29
Spawning Ground	1	6	2	3	-	-	13
Hunting Ground	1	-	-	1	-	-	2
Gathering Area	-	-	-	3	4	-	7
Swimming Hole/Picnic Area	2	-	1	-	4	-	7
Ceremonial Site	-	-	2	-	-	-	2
Mythological Site	-	1	2	5	3	1	12
Petroglyph	-	-	1	-	1	-	2
Historic Event	-	-	2	-	-	-	2
Trail	-	1	2	3	5	-	11
Placename	7	5	2	3	2	2	21
Total	**18**						**144**

Source: DWR 2004b

G-CUL.4 REFERENCES CITED

Adams, F. 1929. Irrigation Districts of California. Reports of the Division of Engineering and Irrigation, Bulletin No. 21. California Department of Public Works, Sacramento, California.

Baumhoff, M. A. 1955. Excavation of The-1 [Kingsley Cave]. Reports of the University of California Archaeological Survey 30:40-73. Berkeley, California.

Baumhoff, M. A. 1957. An Introduction to Yana Archaeology. University of California Archaeological Survey Reports 40. Berkeley, California.

Beck, W., and Y. D. Haase. 1974. Historical Atlas of California. University of Oklahoma Press, Norman, Oklahoma.

Chan, S. 1986. This Bittersweet Soil: The Chinese in California Agriculture, 1860-1910. University of California Press, Berkeley, California.

Chartkoff, J. L., and K. K. Chartkoff. 1968. Excavations at the Finch Site: Research Strategy and Procedures. In University of California, Los Angeles, Department of Anthropology, Los Angeles, Archaeological Survey Annual Report, Volume 10, edited by T. F. King, J. P. Carpenter, and N. N. Leonard III, pp. 315-370. Department of Anthropology, University of California, Los Angeles, California.

Chartkoff, J. L., and K. K. Chartkoff. 1983. Excavations at the Patrick Site (4-Butte-1): In the Archaeology of Two Northern California Sites, edited by E. S. El.ster, pp. 1-51. Institute of Archaeology Monograph No. 22. University of California, Los Angeles, California.

Chartkoff, J. L., and E. W. Ritter. 1966. A Preliminary Report on Archaeological Survey Work done in the Oroville Reservoir Area, 1966. Report on file, California Department of Parks and Recreation, Cultural Heritage Section, Sacramento, California.

Cowan, R. G. 1956. Ranchos of California: A List of Spanish Concessions, 1775-1822, and Mexican Grants, 1822-1846. Academy Library Guild, Fresno, California.

Cutter, D. C. 1918. Spanish Exploration of California's Central Valley. Doctoral dissertation, Department of History, University of California, Berkeley. Berkeley, California.

Delano, A. 1854. Across the Plains and among the Diggings. Miller, Orton and Mulligan, Auburn, New York. Reprinted 1936 by Wilson-Erickson, Inc. New York.

DPR (California Department of Parks and Recreation). 1992. Summary of Burial Collections. Report on file, California Department of Parks and Recreation, Cultural Heritage Section, Sacramento, California.

DWR (California Department of Water Resources). 2004a. Archaeological and Historical Resources Inventory Report. Oroville Facilities, FERC Project No. 2100. Sacramento, California.

DWR (California Department of Water Resources). 2004b. Ethnographic and Ethnohistoric Inventory of Konkow Maidu Cultural Places. Oroville Facilities, FERC Project No. 2100. Sacramento, California.

DWR (California Department of Water Resources). 2004c. Historic Properties Inventory and Evaluation: Oroville Facilities, Butte County, California. Oroville Facilities, FERC Project No. 2100. Sacramento, California.

Elsasser, A. B. 1960. The Archaeology of the Sierra Nevada in California and Nevada. Reports of the University of California Archaeological Survey 51. Berkeley, California.

Elsasser, A. B., and W. A. Gortner. 1991. The Martis Complex Revisited. North American Archaeologist 12:361-376.

Elston, R. G. 1971. A Contribution to Washo Archaeology. Nevada Archaeological Survey Research Papers No. 2. University of Nevada, Reno.

Elston, R. G. 1979. The Archaeology of U.S. 395 Right-of-Way Corridor between Stead, Nevada and Hallelujah Junction, California. Report on file, California Department of Transportation, Sacramento, California.

Elston, R. G., J. O. Davis, A. Leventhal, and C. Covington. 1977. The Archaeology of the Tahoe Reach of the Truckee River. Northern Division of the Nevada Archaeological Survey, University of Nevada, Reno.

Elston, R. G., K. Ataman, and D. P. Dugas. 1995. A Research Design for the Southern Truckee Meadows Prehistoric Archaeological District. Report on file, American Land Conservancy, on behalf of Humboldt and Toiyabe National Forests, Nevada.

Furnis, C. L., and C. Young. 1976. Statewide Survey Project: Cultural Resources Project Survey, Lime Saddle, Lake Oroville. Report on file, California Department of Parks and Recreation, Cultural Heritage Section, Sacramento, California.

Gebhardt, C. 1964. Archaeological Field Notes, Oroville Reservoir. Report on file, California Department of Parks and Recreation, Cultural Heritage Section, Sacramento, California.

Gudde, E. G. 1998. California Place Names: The Origin and Etymology of Current Geographical Names. Fourth edition, revised and enlarged by William Bright. Originally published 1949. University of California Press, Berkeley, California.

Haas, L. 1998. War in California, 1846-1848. In: Contested Eden: California before the Gold Rush, edited by Ramon A. Gutierrez and Richard J. Orsi, pp. 331-356. University of California Press, Berkeley and Los Angeles. Originally published as California History 76(2&3).

Heizer, R. F., and A. B. Elsasser. 1953. Some Archaeological Sites and Cultures of the Central Sierra Nevada. Reports of the University of California Archaeological Survey 21. Berkeley, California.

Hines, P. W. 1996. A Partial Cultural Resource Survey of the Craig Saddle Area of Oroville State Recreation Area. Report on file, California Department of Parks and Recreation, Cultural Heritage Section, Sacramento, California.

Hood, J. D. 1988. The World Rushed In: The California Gold Rush Experience. Simon and Schuster, New York.

Hundley, N., Jr. 2001. The Great Thirst: Californians and Water, A History. Revised edition. University of California Press, Berkeley, California.

Hunter, C. A., R. I. Orlins, and S. M. Atchley. 2000. Cultural Resource Survey for the Department of Water Resources Construction Debris Removal at the Feather River Fish Barrier Dam, Butte County, California. California Department of Water Resources, Division of Environmental Services, Sacramento, California.

Jackson, R. J., T. L. Jackson, C. Miksicek, K. Roper, and D. Simons. 1994a. Framework for Archaeological Research and Management, National Forests of the North-Central Sierra Nevada. Unit I: The Framework and Its Context, Volume B, Archaeological Background. Biosystems Analysis, Sacramento. Prepared for USDA Forest Service, Eldorado National Forest, Placerville, California.

Jackson, R. J., T. L. Jackson, C. Miksicek, K. Roper, and D. Simons. 1994b. Framework for Archaeological Research and Management, National Forests of the North-Central Sierra Nevada. Unit II: Forest Overviews, Volume A, Overview of the Prehistory of the Eldorado National Forest. Biosystems Analysis, Sacramento. Prepared for USDA Forest Service, Eldorado National Forest, Placerville, California.

Jangela, J., and G. White. 2001. Archaeological Context. In: Archaeological, Geoarchaeological, and Palynological Investigations in Lassen Volcanic National Park, California, by G. G. White, pp. 15-21. Report on file, Lassen Volcanic National Park, Redwood National and State Parks, Arcata, California.

Jensen and Associates. 1990. Archaeological Inventory Survey of Gold Beach Aviation’s Proposed Land Split Project Involving Approximately 28 Acres near Lime Saddle, Butte County, California. Jensen and Associates, Chico. Report on file, Northeast Information Center, California State University, Chico.

Jewell, D. P. 1964. Archaeology of the Oroville Dam Spillway. Archaeological Report No. 10, Part 1, State of California, Resources Agency, Department of Parks and Recreation, Division of Beaches and Parks, Interpretative Services Section, Sacramento.

Kautz, R. R., and W. Taugher. 1987. Burial Inventory Project Final Report of Phase I Activities. Report on file, California Department of Parks and Recreation, Cultural Heritage Section, Sacramento.

Kowta, M. 1988. The Archaeology and Prehistory of Plumas and Butte Counties California: An Introduction and Interpretative Model. California Archaeological Site Inventory, Northeast Information Center, California State University, Chico. Chico, California.

Mansfield, G. C. 1918. History of Butte County, California, with Biographical Sketches. Historic Record Company, Los Angeles, California.

Markley, R., and G. Henton. 1985. Tahoe National Forest Cultural Resources Overview, Part I: Prehistory. Cultural Resources Report No. 20, Tahoe National Forest, Nevada City, California.

McGie, J. F. 1982. History of Butte County. Two volumes. Butte County Board of Education, Oroville, California.

Olsen, W. H. 1964. Archaeological Survey Program for the Oroville Reservoir. Report on file, California Department of Parks and Recreation, Cultural Heritage Section, Sacramento, California.

Olsen, W. H., and F.A. Riddell. 1963. The Archaeology of the Western Pacific Railroad Relocation. Archaeological Report No. 7, California Department of Parks and Recreation, Division of Beaches and Parks, Interpretative Services Section, Sacramento, California.

Parke, C. R. 1989. Dreams to Dust: A Diary of the California Gold Rush, 1849-1850. University of Nebraska Press, Lincoln, Nebraska.

Pritchard, W. E., D. M. Hill, S. R. Purcell, and R. Purcell. 1966. The Porter Rock Shelter Site (But-S177), Butte County, California. In: University of California, Los Angeles, Department of Anthropology, Los Angeles, Archaeological Survey Annual Report, Volume 8, edited by D. S. Miller, pp. 290-315. Department of Anthropology, University of California, Los Angeles, California.

Rathbun, R. n.d. Ethnographic Field Notes (1960s): Box, Folder, and Map: A Guide to the Heart of the Concow's Land; Special Collections, Meriam Library, California State University, Chico, California.

Rice, R. B., W. A. Bullough, and R. J. Orsi. 1996. The Elusive Eden: A New History of California. The McGraw-Hill Companies, New York.

Ritter, E. W. 1968. Culture History of Tie Wiah (4-BUT-S84), Oroville Locality, California. Master's thesis, Department of Anthropology, University of California, Davis, California.

Ritter, E. W. 1970. Northern Sierra Foothill Archaeology: Culture History and Culture Process. In: Papers on California and Great Basin Prehistory, edited by E.W. Ritter, P.D. Schulz, and R. Kautz, pp. 171-184. Center for Archaeological Research at Davis, Publication Number 2. University of California, Davis, California.

Rivers, B. 1991. CA-BUT-20/H, -21/H, -1261, -1267, -1272, -1273, and -1300. Archaeological Site Records. On file, Northeast Information Center, California State University, Chico, California.

Robinson, W. W. 1948. Land in California: The Story of Mission Lands, Ranchos, Squatters, Mining Claims, Railroad Grants, Land Scrip, Homesteads. University of California Press, Berkeley and Los Angeles, California.

Steidl, L., B. Walsh, and R. Benson. 1999. A Partial Archaeological Reconnaissance of the Craig Area, Lake Oroville State Recreation Area. Report on file, California Department of Parks and Recreation, Cultural Heritage Section, Sacramento, California.

Talbizer, B. 1987. Butte County: An Illustrated History. Windsor Publications, Northridge, California.

Treganza, A. E. 1953. The Archaeological Resources of Seven Reservoir Sites in Central and Northern California. Report on file, National Park Service, San Francisco.

USBC (U.S. Bureau of the Census). 1883. Tenth Census of the United States, 1880, Agriculture, Government Printing Office, Washington, D.C.

USBC (U.S. Bureau of the Census). 1896. Eleventh Census of the United States, 1890, Agriculture. Government Printing Office, Washington, D.C.

USBC (U.S. Bureau of the Census). 1902. Twelfth Census of the United States, 1900. Agriculture. Government Printing Office, Washington, D.C.

Vance, J. E., Jr. 1995. The North American Railroad: Its Origin, Evolution and Geography. The Johns Hopkins University Press, Baltimore, Maryland.

Wells, H. L., and W. L. Chambers. 1882. History of Butte County in Two Volumes. Harry L. Wells, San Francisco, California. Reprinted 1973 by Howell-North Books, Berkeley, California.

Woodward, J. 1984. Archaeological Survey Report, Parish Camp Property Exchange. Report on file, California Department of Parks and Recreation, Cultural Heritage Section, Sacramento, California.

This page intentionally left blank.

APPENDIX G-GS1
GEOLOGY, SOILS, AND PALEONTOLOGICAL RESOURCES

This appendix provides a summary of the results of the following detailed geologic study plan reports prepared for the Oroville Facilities relicensing: SP-G1, *Effects of Project Operations on Geomorphic Processes Upstream of Oroville Dam*; and SP-G2, *Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam*. The study plan reports provide a basis for the definition of the affected environment as described in Section 5.3.1 of the Preliminary Draft Environmental Assessment (PDEA). The completed study plan reports are provided in their entirety in an informational supplement and are also available on the Oroville Facilities website at http://orovillerelicensing.water.ca.gov/wg_plans_envir.html.

This appendix also describes the processes and bases used to evaluate the No-Action Alternative, the Proposed Action, and Alternative 2 and their potential effects on geologic resources. Implementation of any of the alternatives is anticipated to produce two distinct types of effects: (1) direct effects related to construction activities or changes in Oroville Facilities operations; and (2) indirect effects related to changes in hydrologic conditions. The potential effects related to changes in hydrologic conditions may affect environmental resources beyond the project study area and are addressed under the cumulative analysis (see Section 5.7.4, Cumulative Effects).

G-GS1.1 FLUVIAL-12, METHODOLOGY

Modeling results from a 50-year FLUVIAL-12 model run predict the sediment yield for the next 50 years in the lower Feather River with the assumption that the sediment inflow into the study reach is cut off by Oroville Dam. The amount of bed material load in the Feather River passing the Thermalito Afterbay Outlet (in the Low Flow Channel reach) was modeled at 0.3 million tons, or about 6,000 tons per year, or 16 tons per day. This is about 3 percent of the pre-dam bedload of 485 tons per day estimated by the U.S. Geological Survey (USGS). The yield is primarily a result of channel erosion because Oroville Dam traps nearly all of the incoming bed material. Finer sediments are more easily removed from the channel boundary, leaving the coarser sediment behind. The selective sediment transport has resulted in the gradual coarsening and armoring of the bed material. The modeling also showed that much of the sediment delivered from the channel above River Mile 61 is trapped in gravel mining pits excavated immediately adjacent, and connected to the river channel.

The modeled pattern of sediment delivery shows a sharp rise in delivery in the High Flow Channel reach just below the Thermalito Afterbay Outlet. This is likely related to the increase in flow just below the Thermalito Afterbay and therefore an increase in erosion from the channel boundary. The total yield of the Low Flow and High Flow Channels is 2.9 million tons for 50 years.

The model run shows a large increase in the sediment size after 50 years. The largest increase in size was directly below the Fish Barrier Dam, showing a D50 increase from

120 millimeters (mm) to 150 mm, and at River Mile 56, showing an increase from 60 mm to 110 mm.

The modeled channel geometry changed because of scour and fill, which is not generally distributed uniformly across the channel width. Furthermore, scour of the bed may be accompanied by scour or fill in the overbank area, or vice versa. These changes in channel morphology in turn directly affect the hydraulics of flow and sediment transport.

Changes in channel geometry are depicted in the model by changes in thalweg profile and changes in channel cross section. Modeled water surface and channel thalweg profiles show that channel bed degradation is predicted at most cross sections, with aggradation at some locations. Cross section measurements showed average post-dam thalweg decreases of 1 to 5 feet in the Low Flow Channel, 1 to 4 feet between the Thermalito Afterbay Outlet and the Gridley Bridge, and 2 to 5 feet from Gridley Bridge to Honcut Creek. Channel degradation is consistent with the continued erosion. Future changes are limited by bed armoring, which in turn will reduce future bed erosion and sediment yield.

Those reaches near mining areas are subject to greater changes than other areas. This is because of the disruption in channel profile and cross section, resulting in sediment deposition within the mining areas and scour in the areas immediately above and below.

G-GS1.2 EFFECTS OF THE NO-ACTION ALTERNATIVE

This section provides quantitative and qualitative analyses of potential effects on geologic, soils, and paleontological resources with implementation of the No-Action Alternative, relative to existing conditions. Because no potential effects were identified for paleontological resources, there is no further discussion regarding this topic. Although the following topical outline is consistent for analysis of all alternatives, effects in several issue areas are not anticipated to occur under the No-Action Alternative. From a geologic/soils resources perspective, there are only a few differences between existing conditions and the No-Action Alternative. (See Section 3.1, No-Action Alternative, for a detailed description of the No-Action Alternative.)

Quantitative and qualitative analyses were performed using the methodology described in FLUVIAL-12, Methodology. This analysis predicts sediment yield, sediment delivery patterns, and changes to channel geometry over the next 50 years. Although future operations of the Oroville Facilities are expected to differ from existing conditions, the effects of the No-Action Alternative on geology and soils resources—gravel recruitment (sediment transport), woody debris recruitment, and channel complexity—are not expected to differ from those that would occur under existing conditions.

G-GS1.2.1 Geologic/Soils Components Affected by the Oroville Facilities

Currently, more than 97 percent of the sediment from the upstream watershed is trapped in the upstream reservoirs, including Lake Oroville, resulting in sediment deprivation downstream. Virtually the entire gravel component of the former sediment load has been eliminated from the river downstream of the various Oroville Facilities. Currently, only very fine sediment is discharged from Lake Oroville to the stream below.

G-GS1.2.1.1 Sediment Transport/Gravel Recruitment

Under the No-Action Alternative, Oroville Dam, the Thermalito Diversion Dam, and the Fish Barrier Dam would continue to block significant transport of all sediment sizes from the upper Feather River to the lower Feather River that is not initially blocked by the upper watershed reservoirs. High Oroville Facilities releases, such as those implemented for flood management purposes, would mobilize existing sediments within the lower Feather River, particularly the smaller substrate particle sizes. Removal of these smaller substrate sizes, which would not be replaced by upstream sediment/gravel contributions, would result in a gradual relative coarsening of the particle size distribution of the substrate in the upper portions of the lower Feather River. Currently, the highest proportion of coarse substrate components is present in the upstream-most portion of the lower Feather River, that reach below the Fish Barrier Dam but above the Thermalito Afterbay Outlet. Under the No-Action Alternative, this reach would likely become more armored over time. However, the 1983 Operating Agreement between DFG and DWR provides for an annual recommendation to DWR for mutual agreement on spawning gravel maintenance activities.

Continued deprivation of the sediment load in the lower Feather River would result in the continued reduction in the formation of sediment benches, which affects riparian vegetation colonization and succession. (See Section 5.6, Terrestrial Resources, for additional information on riparian vegetation.) Riparian vegetation provides overhanging cover for rearing fish, riparian shade, invertebrate contributions to the fish food base, and future large woody debris site contributions. Additionally, soft sediment substrates also contribute to the function of capture and retention of large woody debris. Therefore, under the No-Action Alternative, a continued lack of sediment recruitment to the lower Feather River would result in the incremental degradation of geomorphic processes, contributing to a decrease in the quality and diversity of habitat for aquatic resources in the lower Feather River.

G-GS1.2.1.2 Woody Debris Recruitment

Under the No-Action Alternative, the Oroville Facilities would continue to block the upstream contribution of large woody debris to the lower Feather River. The lowest proportion of large woody debris availability likely would continue to occur in the upstream-most reach of the lower Feather River, from the Fish Barrier Dam to the Thermalito Afterbay Outlet. Downstream of the Thermalito Afterbay Outlet, the river likely would continue to support a greater availability of large woody debris cover than the reach upstream of the outlet because opportunities for large woody debris recruitment likely would remain higher in the High Flow Channel. The continued lack of large woody debris recruitment to the lower Feather River would result in an incremental degradation of the quantity and quality of large woody debris present in the lower

Feather River and would reduce the quality and diversity of habitat for aquatic resources.

G-GS1.2.1.3 Channel Complexity

Under the No-Action Alternative, channel complexity would be reduced through continued riverbed incision and channel confinement. Continued operation of the Oroville Facilities with relatively static and moderated flow regimes in the Low Flow Channel under the No-Action Alternative likely would continue to limit the geomorphic processes that result in channel complexity, resulting in the ongoing incremental degradation of the quality and diversity of aquatic resource habitat relative to existing conditions.

G-GS1.3 EFFECTS OF THE PROPOSED ACTION

This section provides qualitative analyses of potential effects on geologic, soils, and paleontological resources with implementation of the Proposed Action, relative to the No-Action Alternative. Because no potential effects were identified for paleontological resources, there is no further discussion regarding this topic. From a geology and soils resources perspective, there are only a few differences between the No-Action Alternative and the Proposed Action. (See Section 3.1, No-Action Alternative, and Section 3.2, Proposed Action, for a detailed description of No-Action Alternative and Proposed Action conditions.) While future operations of the Oroville Facilities are expected to differ from existing conditions, the effects of the Proposed Action are anticipated to be essentially the same as under the No-Action Alternative. Therefore, no quantitative analysis is required or provided to show that potential effects on geology and soils resources—gravel recruitment (sediment transport), woody debris recruitment, and channel complexity—are not expected to differ from those that would occur under existing conditions.

Actions included in the Proposed Action that are relevant to the assessment of the effects on aquatic resources, and that are not included in the No-Action Alternative, consist of programs for gravel supplementation and improvement, large woody debris supplementation and improvement, and side channel enhancements. The actions included in the Proposed Action are evaluated qualitatively in the subsections below. A detailed description of the methodology used to analyze potential effects on geology and soils resources is provided in SP-G2, *Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam*.

G-GS1.3.1 Geologic/Soils Components Affected by the Oroville Facilities

G-GS1.3.1.1 Sediment Transport/Gravel Recruitment

The Proposed Action includes supplementing gravel in the lower Feather River directly below the Fish Barrier Dam and at selected riffles between the Fish Barrier Dam and Honcut Creek that are considered to have high potential for anadromous salmonid spawning. The Proposed Action also provides for the ripping and raking of the riverbed substrate in selected areas of the lower Feather River that are potential salmonid spawning sites, but where the substrate has become armored.

Specific locations that may benefit from gravel supplementation were identified in SP-G2. Additional information would be needed to identify the appropriate volume and methodology for gravel placement (riffle supplementation, riffle creation, etc.). Surveys would also be needed after the gravels are introduced in the channel to determine their effectiveness to benefit spawning salmonids. Depending on the findings of surveys conducted after gravel supplementations, additional supplementations may be conducted in the same areas or certain sites may be abandoned. Likewise, potential sites that may benefit from ripping and raking were identified in SP-G2. In general, to avoid the potential for additional channel incision in the Low Flow Channel, the majority of the ripping and raking would be done in the lower portions of the Low Flow Channel near the Thermalito Afterbay Outlet. Future surveys may determine other areas where ripping and raking of substrate may enhance spawning habitat.

Information gathered from SP-G2 has identified specific sites downstream of the Fish Barrier Dam and upstream of the Thermalito Afterbay Outlet that may benefit from supplementation of spawning gravel. Supplementation of gravel at these locations is intended to increase suitable spawning habitat quality and quantity for anadromous salmonids by restoring habitat substrate that has become armored. (See Section 5.5, Aquatic Resources, for additional information on salmonid habitat.)

The spawning gravel supplementation and improvement program would provide the greatest benefit to the spawning areas in the upstream-most portions of the Low Flow Channel below the Fish Barrier Dam because they currently have the most degraded substrate quality and the least suitability for salmonid spawning. Additionally, gravel supplemented near the base of the Fish Barrier Dam would be mobilized during flood management events and would be redistributed downstream, mimicking normal gravel recruitment that occurred before dam construction. Subsequent gravel placement would be required after future peak-flow events to maintain benefits provided by supplementation of spawning gravel.

G-GS1.3.1.2 Woody Debris Recruitment

Implementation of the Proposed Action would include supplementing large woody debris in the lower Feather River, particularly in the Low Flow Channel below the Fish Barrier Dam, to satisfy fish habitat improvement goals for the duration of the license period. Large woody debris supplementation would:

- Contribute to both the geomorphic and ecological functions of the lower Feather River;
- Enhance rearing habitat for juvenile salmonids by providing cover;
- Create scour pools that may serve as holding habitat for anadromous salmonids;

- Trap and organize sediment, allowing recruitment of riparian vegetation, and decaying large woody debris; and
- Provide an additional source of instream nutrients for aquatic organisms.

Large woody debris placed at certain locations below the Thermalito Afterbay Outlet may also enhance habitat for warmwater species such as black bass.

The Proposed Action includes the placement of large woody debris in the lower Feather River primarily from the Fish Barrier Dam to the Thermalito Afterbay Outlet, and possibly in other locations downstream of the Thermalito Afterbay Outlet. The results of SP-G2 indicated that the lower Feather River below the Thermalito Afterbay Outlet has a fairly healthy abundance of large woody debris. In general, single logs, groups of logs, or combinations of logs and boulders or gravel would be placed in the river and anchored or cabled together (Flosi et al. 1998). Anchoring would probably be required for projects that are intended to be site specific, such as riprapped banks or side channels. Wood may also be anchored at banks with cables or between natural or artificial structures.

Under current regulated flow regimes, large woody debris placement would provide localized benefits on fish habitat. When a flood management flow event occurs, the magnitude of the event would redistribute both naturally recruited and supplemented large woody debris. While this redistribution is considered a normal ecosystem function, the large woody debris in the upstream reaches of the Low Flow Channel would need to be replaced following these events. In the event that large woody debris moves out of the Feather River during extreme flow events, it would provide fish habitat benefits downstream on the Sacramento River, perhaps as far as the Sacramento–San Joaquin Delta.

Placement of large woody debris could create conflicts with landowners adjacent to the channel if bank erosion were inadvertently increased as a result of flow diversion. Placement of large woody debris could also decrease river navigability in some areas.

G-GS1.3.1.3 Channel Complexity

Implementation of the Proposed Action includes enhancement of the existing side-channel habitat in Hatchery Ditch and Moe’s Ditch, both downstream of the Fish Barrier Dam and adjacent to the Feather River Fish Hatchery. Enhancements to these existing side channels could include reforming the channel for increased water depth and channel complexity, placing boulders and woody debris for cover and velocity diversity, and gravel substrate supplementation. The enhancement of these existing side channels would primarily benefit steelhead and spring-run Chinook salmon by increasing the quantity and quality of spawning and rearing habitat.

G-GS1.4 EFFECTS OF ALTERNATIVE 2

This section provides qualitative analyses of potential effects on geologic, soils, and paleontological resources with implementation of Alternative 2, relative to the No-Action Alternative. Because no potential effects were identified for paleontological resources, there is no further discussion regarding this topic. Although the following topical outline is consistent for analysis of each alternative, effects on several issue areas are not anticipated to occur under Alternative 2. From a geology and soils resources perspective, there are only a few differences between the No-Action Alternative and Alternative 2. (See Section 3.1, No-Action Alternative, and Section 3.3, Alternative 2, for a detailed description of No-Action Alternative and Alternative 2 conditions.) Oroville Facilities operations under Alternative 2 are anticipated to be the same as under the No-Action Alternative. Therefore, no quantitative analysis is required or provided to show potential effects on geology and soils.

Actions included in Alternative 2 that are relevant to the qualitative assessment of the effects on geology and soils resources, and that are not included in the No-Action Alternative, consist of gravel and large woody debris supplementation and improvement programs in the lower Feather River and improvements to existing side-channel fish habitat and creation of new side-channel habitat. These actions are evaluated qualitatively in the subsections below. A detailed description of the methodology used to analyze potential effects on geology and soils resources is provided in SP-G2, *Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam*.

G-GS1.4.1 Geologic/Soils Components Affected by the Oroville Facilities

G-GS1.4.1.1 Sediment Transport/Gravel Recruitment

Actions associated with gravel supplementation and improvements under Alternative 2 are identical to those actions included with implementation of the Proposed Action. See Effects of the Proposed Action above for an evaluation of these actions relative to the No-Action Alternative.

G-GS1.4.1.2 Woody Debris Recruitment

Actions associated with large woody debris supplementation and improvements under Alternative 2 are identical to those actions included with implementation of the Proposed Action. See Effects of the Proposed Action above for an evaluation of these actions relative to the No-Action Alternative.

G-GS1.4.1.3 Channel Complexity

Implementation of Alternative 2 would include enhancement of the existing side-channel habitat in Hatchery Ditch and Moe's Ditch, both located adjacent to the Feather River Fish Hatchery, downstream of the Fish Barrier Dam. Alternative 2 would also include the creation of additional side channels in the Low Flow Channel. It is assumed that the flows required to maintain these additional side channels are provided for in the Alternative 2 flow increases, and discussed in Section 5.4.2.1.

Creation of new and enhancements of the existing side channels could be coordinated with the proposed supplementation of large woody debris and gravel, and include reforming and reshaping the channel for increased water depth and channel complexity. The creation of new and enhancement of these existing side channels would primarily benefit steelhead and spring-run Chinook salmon by increasing the quantity and quality of spawning and rearing habitat.

G-GS1.5 REFERENCES

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 1998. California Salmonid Stream Habitat Restoration Manual, State of California, The Resources Agency, California Department of Fish and Game, Inland Fisheries Division, Sacramento, CA. Third Edition.

APPENDIX G-GS2
HAZARDOUS MATERIALS AND WASTES

Within the project area there may be existing hazardous waste sites that could adversely affect public health and safety. Such sites should be identified, where possible, within the project area boundary. A computerized database search was conducted for the project area. This database search was then augmented where necessary by review of files and discussions with staff members of the Butte County Department of Environmental Health, the California Department of Toxic Substances Control, and the U.S. Environmental Protection Agency (USEPA).

Continued operations of the Oroville Facilities will necessitate the transport, use, storage, and disposal of hazardous materials, such as petroleum and cleaning products. Accidental release and/or improper handling of hazardous materials can affect public health and safety. Hazardous materials used and stored within the project area were determined by review of Hazardous Materials Management Plan(s) (HMMP) maintained by the California Department of Water Resources (DWR) and others that use and store hazardous materials within the project area. Under California law, if threshold amounts of hazardous materials are used and stored at a site, there must be an HMMP at the site, generally with copies given to local agencies that might conduct emergency response activities. In addition, facilities within the project area that need to legally dispose of spent hazardous materials that become a hazardous waste must ship such waste via the Uniform Waste Manifest system. Thus, there is generally a sufficient record, either through HMMPs or waste manifests, to ascertain the type and amount of hazardous materials entering and leaving the project area. This knowledge can then be used to determine any potentially significant effects on public health and safety.

G-GS2.1 HAZARDOUS MATERIALS

The definition of hazardous materials included in Section 66260.10, Title 22 of the California Code of Regulations (CCR) is provided in Section 5.3.1.6 of Section 5.3, Geology, Soils, and Paleontological Resources, of this Preliminary Draft Environmental Assessment (PDEA). In addition to this definition, hazardous materials have been defined as substances with certain chemical and physical properties that could pose a substantial present or future hazard to human health if improperly handled, used, stored, or disposed. Public health hazards from hazardous materials may occur through contamination of soils or groundwater (and potentially surface water) or through airborne releases of dust or vapors. Exposure to hazardous materials and wastes could cause various short-term or long-term health effects.

G-GS2.1.1 Hazardous Materials Regulatory/Statutory Framework

California Health and Safety Code Section 25531 incorporates the federal law as it pertains to hazardous materials. This includes development of a Risk Management Plan (RMP) for facilities that store or handle acutely hazardous materials in reportable quantities. CCR Title 8 requires facility owners to prepare and implement safety management plans where large quantities of hazardous materials are handled. The

Uniform Fire Code has requirements for the storage and handling of hazardous materials. California has regulations and statutes controlling both aboveground and underground storage tanks for petroleum fuels, a common hazardous material in the project area.

The Hazardous Materials Program within the Butte County Department of Public Health, Environmental Health Division, is the local agency responsible for oversight in the use and storage of hazardous materials within Butte County. The program's major oversight responsibilities include:

- Reviewing, approving, and monitoring Hazardous Material Management Plans (also known as "Business Plans"), as required by State law. These plans are required of all county businesses, including government agencies, that store or handle hazardous materials in amounts equal to or exceeding 55 gallons, 500 pounds, or 200 cubic feet of gas (at standard temperature and pressure).

- Monitoring the installation, removal, and leakage of underground and aboveground petroleum fuel storage tanks.

In regard to hazardous materials incidents (such as spills and accidents involving hazardous materials), Butte County has an interagency hazardous materials team organized through the use of a Joint Powers Agreement (JPA). Members of the hazmat team are provided by the Cities of Chico, Oroville, Paradise, Biggs, and Gridley; and Butte County and the California Department of Forestry and Fire Protection (CDF). It is reported that hazardous materials incidents requiring team responses number about 120 a year. Drug labs and associated wastes are the main cause of incidents. Other significant incidents include train derailments, tanker overturns, and agriculture-related incidents.

In addition to the Butte County Hazardous Materials Program, large cases of hazardous materials contamination and violations are referred to the Central Valley Regional Water Quality Control Board and/or the California Department of Toxic Substances Control (DTSC). In some cases, USEPA Region IX may also be involved.

The Butte County Air Quality Management District regulates air emissions in Butte County.

G-GS2.1.2 Hazardous Materials in the Oroville Facilities Vicinity

To research hazardous waste considerations and incidents in the vicinity of the Oroville Facilities, a computer database search was conducted. This database search examined numerous federal and State databases such as:

- National Priorities List (NPL)—National Superfund List;

- Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS);

- Resource Conservation and Recovery Information System—USEPA regulation of generators of hazardous material;
- Hazardous Waste Information System—DTSC database of the movement and disposal of hazardous waste;
- Emergency Response Notification System—national database on unauthorized releases of oil and hazardous substances;
- Cal-Sites (Bond Expenditure Plan [BEP], Annual Workplan [AWP])—State equivalent to the NPL (California State Superfund);
- Cal-Sites Abandoned Sites Program Information System (ASPIS)—State equivalent to CERCLIS (historical abandoned site survey program);
- Cortese List—list of potential and confirmed hazardous waste or substances sites in California;
- Solid Waste Information System—California Waste Management Board list of certain facilities including active solid waste disposal sites, inactive or closed solid waste disposal sites, and transfer facilities;
- Leaking Underground Storage Tank Information System—database maintained by the State Water Resources Control Board (SWRCB); and
- Registered Underground Storage Tanks—underground storage tanks registered with the SWRCB.

The database search was conducted for a target area within or on the Federal Energy Regulatory Commission (FERC) project boundary line. The search yielded 36 locations (some incidents or facilities are at the same numbered site) where there is some type of hazardous materials information, whether it relates to underground storage tanks, aboveground storage tanks, hazardous materials handling, hazardous waste generation, or hazardous materials spill incidents. Table G-GS2.1-1 illustrates the sites found on the environmental databases.

In addition to these sites within the FERC boundary, the DWR Oroville Field Division facility is located at 460 Glen Drive, approximately 2 miles southwest of Oroville Dam. This facility was included in the database search because, although it is not within the FERC boundary, it does control the use and movement of hazardous materials and associated hazardous waste in and out of the FERC project boundary area. The California Department of Parks and Recreation (DPR) maintenance facility at 400 Glen Drive also controls the use and movement of hazardous materials and waste in and out of the FERC project boundary area. DPR uses such hazardous materials as herbicides and pesticides on lands it manages within the FERC boundary.

Table G-GS2.1-1. Summary of hazardous materials/waste sites within or at project boundaries.

Facility	Address	Materials/Issues
Cherokee Mine	250 Cherokee Road	Mining activities contamination
Pentz Gravel Pit	Cherokee Road	Abandoned gravel pit
Transfer Station	592 Table Mountain Road	Halogenated solvents
Hazardous materials spill site	5413 High Rocks Court	Small spill incident—1/29/03
Illegal drug lab at residence	37 Thompson Flat Road	Drug lab wastes
Thermalito Irrigation District	535 Table Mountain Blvd.	Air quality permit
Bidwell Canyon Marina	801 Bidwell Canyon Road	Formerly had underground storage tanks (UST); currently has aboveground storage tanks (AST) for fuel; facility has Hazardous Material Management Plan (HMMP); wastewater treatment plant (National Pollutant Discharge Elimination System [NPDES] permit)
Hazardous materials spill site	85 Ranch Vista Road	Small diesel spill—12/19/00
Hazardous materials spill site	79 Grand Ave	Small oil spill site—12/31/03
Sprint Communications building	2405 Bird Street	Small hazardous waste generator, leaking UST (some minor groundwater contamination, case closed 8/7/03)
California Water District	2450 Bird Street	Air quality permit, AST
Butte Co. Dept. of Public Works	Butte County Right of Way	Small hazardous waste generator
B&N Mini Mart	1355 Washington Ave	Leaking UST
California Department of Fish and Game (DFG), Feather River Fish Hatchery	5 Table Mountain Road	Small hazardous waste generator (lab waste chemicals, organic chemicals, pesticides); facility has wastewater treatment plant (NPDES permit); leaking diesel UST (case closed—USTs removed)
Bonus (gas station)	1355 Washington Ave	Operating USTs (unleaded gasoline and diesel)
River Road utility poles	South of Fell Street	Minor spill of polychlorinated biphenyl (PCB) containing oil. Cleaned up

Table G-GS2.1-1. Summary of hazardous materials/waste sites within or at project boundaries.

Facility	Address	Materials/Issues
Drug lab waste	7th St. and Feather Ave	Unknown amount of drug lab wastes abandoned; cleaned up by Butte County Dept. of Health
Robert S. Taylor Fram	1086 State Route 70	Gasoline USTs (agricultural)
H.B. Orchard Company	1061 State Route 70	Gasoline UST (agricultural)
Lamalfa & Sons	35 La Malfa Lane	
Kiewit Pacific Co.	831 Oroville Dam Road	Small hazardous waste generator (oil containing wastes)
DFG, Oroville Wildlife Area	945 Oroville Dam Road West	Small hazardous waste generator; no HMMP needed per Butte County; gasoline and diesel USTs previously removed
Buck Animal Hospital	750 Oroville Dam Road	Small hazardous waste generator
Oroville Hospital Urgent Care	900 Oroville Dam Road	
Caltrans Oroville Maintenance Station	350 Oroville Dam Blvd	Leaking UST (diesel, contaminated soil only, cleaned up, case closed); facility no longer present
Feather River Orchard Company	1313 State Route 70	Diesel and gasoline USTs (agricultural)
Robinson Corner (gas station)	1617 State Route 70	Gasoline USTs
Gold Nugget Oil Company (gas station)	2970 Feather River Blvd.	Leaking UST (gasoline, groundwater contamination); small hazardous waste generator
SR 70 Fuel/Scales	2970 Feather River Blvd.	Gasoline and diesel USTs
Rice Experiment Station	SR 162, 3 miles west of Biggs	Gasoline UST (agricultural)
Dane Andres Ranch	3730 Larkin Road	
John Coleman	3828 Larkin Road	
Ames Glaviano	3962 Larkin Road	
John Perkins	9 Oakwood Lane	

Table G-GS2.1-1. Summary of hazardous materials/waste sites within or at project boundaries.

Facility	Address	Materials/Issues
Lime Saddle Marina	P.O. Box 1088 Pentz Magalia Highway Paradise	Formerly had UST; currently has ASTs for fuel; facility has HMMP
Outside FERC Boundary*		
DWR Oroville Field Division Facility	460 Glen Drive	Hazardous materials associated with Oroville Facilities operations and maintenance, facility has HMMP, past leaking USTs and active fuel ASTs
California Department of Parks and Recreation	400 Glen Drive	

** The DWR Oroville Operations Facility, although not within the FERC boundary, does control the use and movement of hazardous materials and associated hazardous waste in and out of the FERC project boundary area.*

G-GS2.1.3 Hazardous Materials Management Plans

As mentioned above, there are regulatory requirements for the preparation and maintenance of HMMPs when facility operations store or handle hazardous materials in amounts equal to or exceeding 55 gallons, 500 pounds, or 200 cubic feet of gas (at standard temperature and pressure). These HMMPs must be submitted to local agencies, particularly the environmental health and emergency response agencies, ostensibly so that emergency responders know what to expect in a facility when an emergency entrance is needed. Also, the HMMP allows the local environmental health agency to know what a facility is storing and handling, and to know that it is doing so in a manner protective of human health and worker safety.

Both private and public sector facilities must have an HMMP if they meet the threshold levels of hazardous materials. Within the FERC boundary, DWR, DPR, and DFG have HMMPs (per the Butte County Department of Health). Hazardous materials present are those related to operations of the hydroelectric facilities, fish hatchery facilities, and recreational facilities. Fuel facilities (containing petroleum hydrocarbon compounds such as diesel and gasoline) are located at these facilities as well. Table G-GS2.1-1 lists those facilities within the FERC boundary confirmed by Butte County as having HMMPs. Bidwell Marina also maintains an HMMP in regard to the hazardous materials generally associated with marina activities (principally fueling and marine vessel maintenance).

There appear to be no significant hazardous materials or waste issues within the FERC project boundary. DWR conducts its hazardous materials and wastes management activities within the requirements of local, State, and federal laws and regulations.

This page intentionally left blank.

APPENDIX G-LU1
AGRICULTURAL RESOURCES

G-LU1.1 INTRODUCTION

This appendix provides additional information regarding the methodology used to assess potential effects on agricultural resources, along with a more-detailed description of the affected environment. Most of the material included in this appendix, and all of the environmental consequences information contained below, focuses on the issue assessed in the Preliminary Draft Environmental Assessment (PDEA): potential effects on water temperatures at Thermalito Afterbay and related agricultural diversion points. Such temperature impacts could in turn affect rice yields and production. Rice yields and production are affected by many factors, with water temperature being one.

G-LU1.2 METHODOLOGY

The original intent was to evaluate the Proposed Action and Alternative 2 compared to the number of accumulated hours below each rice production water temperature index value during the period of the analysis to the accumulated hours below the same rice production water temperature index values that would occur under the No-Action Alternative. However, hourly water temperature model data were not available. Daily mean water temperatures available at the agricultural diversion locations were not adequate to support the analyses; therefore, a qualitative analysis of water temperature changes at the agricultural diversions was conducted.

Qualitative effects assessments were completed to evaluate the potential effects of the alternatives on agricultural production in the vicinity of the Oroville Facilities. Qualitative effects evaluations of the alternatives included potential effects of operations-induced water temperature changes on rice production, the potential for conversion of prime farmland due to construction or project-related erosion, and conflicts in land use due to adjacent changes in land use. Both the land use changes and land use conflicts were based on qualitative evaluations of the type of change or conflict and the amount of area affected. Changes in water quality or groundwater tables were evaluated based on their suitability for agricultural production associated with groundwater quality and depth, as well as crop drainage effects on agricultural resources. Other qualitative analyses included the evaluation of changes in the rate and type of contribution of aquatic weeds into the agricultural diversions and distribution systems from Thermalito Afterbay. This evaluation included effects on irrigation district operations, as well as effects on aquatic weed management practices for rice production.

G-LU1.3 AFFECTED ENVIRONMENT

The Oroville Facilities provide water for agricultural diversions to senior water rights holders in Butte and Sutter Counties. Agricultural operations in these counties enjoy major benefits from the Oroville Facilities through improved water supply reliability for agricultural diversions and flood management that makes much of their agricultural production possible. The Oroville Facilities also have the potential to affect agricultural resources in several ways, including influencing water temperatures at agricultural diversions, changing the groundwater table, changing water quality, converting farmland through project-related construction or from erosion attributable to Oroville Facilities releases, and contributing aquatic weeds and weed seeds from Thermalito Afterbay into the agricultural irrigation distribution and conveyance system.

California is the number one agricultural producer in the United States, earning $27.6 billion in agricultural markets in 2001. The total land acreage dedicated to farming in California is 27.7 million acres, and 13 percent of the national gross cash receipts from farming can be attributed to California farming products (California Department of Food and Agriculture 2002). Rice ranks as the 32nd most valuable agricultural commodity produced in California. In 2001, rice production accounted for $209 million of the agricultural production value in California, or approximately 1 percent of California's total gross cash income from farming (California Department of Food and Agriculture 2002). The top three counties for rice production in California are Colusa (25.3 percent of the total value), Sutter (19.1 percent), and Butte (18.7 percent) (CASS Website).

Historically, Butte County has been an agriculturally based county, and commercial agriculture continues to be the county's principal economic base (see Section 5.12, Socioeconomics, for additional information on agricultural economics in Butte and Sutter counties). The Feather River and groundwater are the largest sources used to meet the county's water demands. Butte County had approximately 381,532 acres of farmland in 2002 (NASS 2004), and farming accounted for 41.6 percent of the county's total inventoried land area of 917,909 acres (Farmland Mapping and Monitoring Program 2004a). The region supported approximately 256,519 acres of total cropland, of which 222,735 acres were irrigated land (NASS 2004). Rice is the highest total value crop grown in Butte County. Approximately 94,700 acres of rice were harvested in Butte County, which constituted approximately 18.7 percent ($101.2 million) of the value of California's rice production in 2002 (CASS Website). Other major crops in the county are almonds, walnuts, and plums. Figure G-LU1.3-1 shows rice yields over time for Butte and Sutter Counties.

It is apparent that the yield has increased over time. Sutter County has a highly agricultural economy. Sutter County's water supply includes surface water from the Feather and Sacramento Rivers, other surface water, surface water reuse, and groundwater wells (USBR et al. 2004). In 2002, there were 1,391 farms occupying 371,964 acres (NASS 2004) of the 389,439 total acres inventoried in the county (Farmland Mapping and Monitoring Program 2004b). The main agricultural commodities in 2002 were rice, dried plums, peaches, and walnuts. Sutter County accounted for 19.1 percent ($103.1 million) of California's total rice production value in 2002 with more than 96,000 acres of rice having been harvested (CASS Website).

Rice is cultivated in the majority of the area of agricultural production in the Feather River Service Area (FRSA) (see Figure G-LU1.3-2). Heavy red and gray clay soils and their associated low-water infiltration rate characteristics make much of the areas to the northwest, west, and southwest of the Oroville Facilities ideal for rice production. These

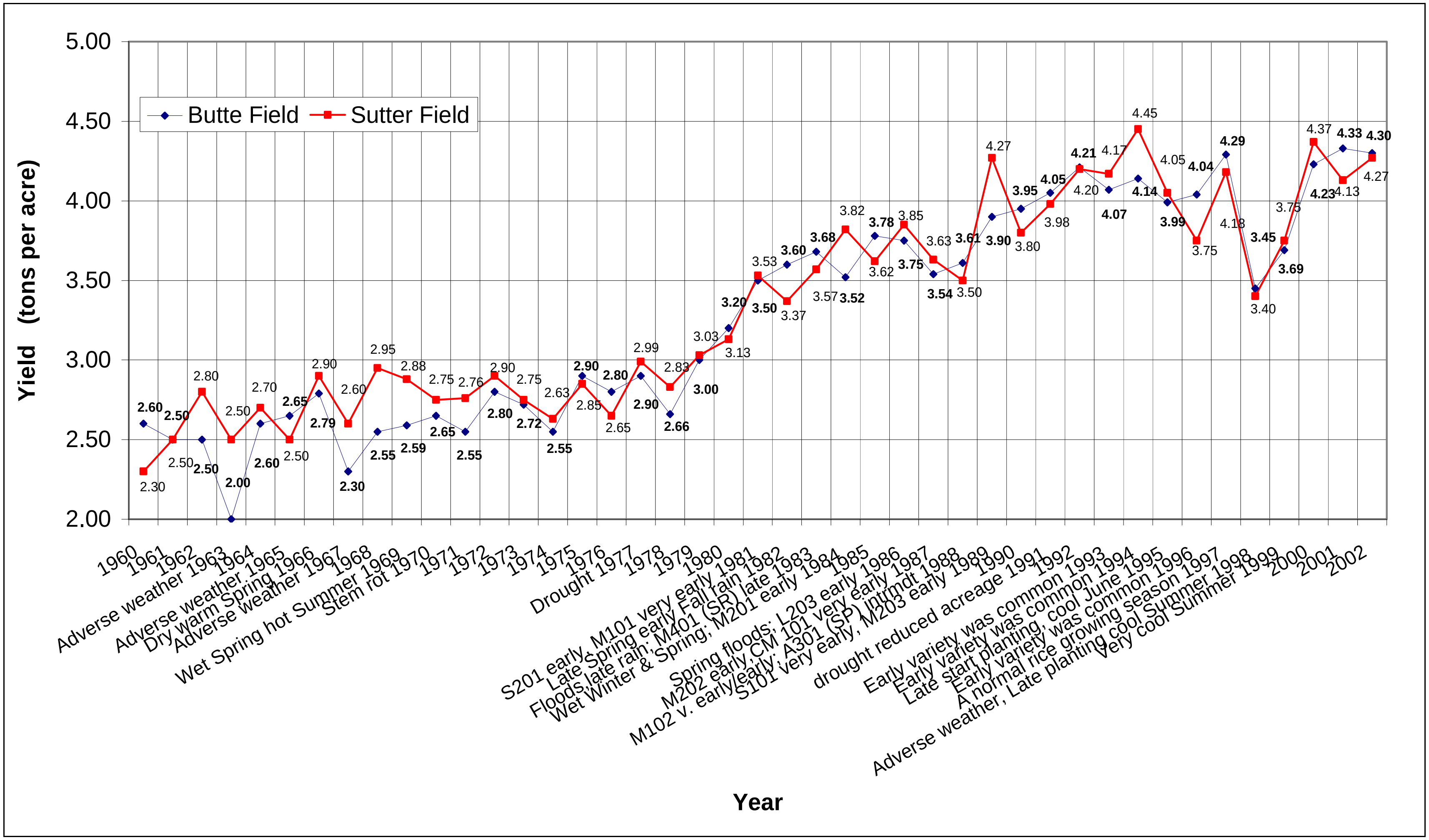


Figure G-LU1.3-1. Butte and Sutter County Rice Yield.

soil types also limit crop selection alternatives and account for the general monoculture of rice production in these areas. (See Section 5.3, Geology and Soils, for additional information on soil types.) Crop types that occur downstream of Thermalito Afterbay along the Feather River include field crops, pasture, deciduous fruit, and nuts. Other agricultural land uses occur adjacent to the Oroville Facilities, including dryland grain farming, grazing, truck crops, nurseries, ranchettes, and forestry upland of the Oroville Facilities.

As part of the Land Inventory and Monitoring (LIM) system developed by the U.S. Department of Agriculture (USDA), definitions were established for designations of Prime Farmland, Farmland of Statewide Importance, Unique Farmland, and Farmland of Local Importance. Farmland maps are created by the Farmland Mapping and Monitoring Program (FMMP), under the direction of the USDA. The FRSA farmland designations are provided in Figure G-LU1.3-3.

Prime Farmland is land that has been deemed to encompass the best combination of physical and chemical characteristics for the production of crops. If treated and managed according to current farming methods, Prime Farmland has the soil quality, growing season, and moisture supply to produce sustained high yields of crops. Criteria for ten factors have been established, and for farmland to be designated, it must meet the criteria for all ten aspects. Established criteria include those for water, soil temperature range, acid-alkali balance, water table, soil sodium content, flooding, erodibility, permeability, rock fragment content, and rooting depth.

Farmland of Statewide Importance includes lands not designated as Prime Farmland that have a good combination of physical and chemical characteristics for the production of crops. Eight of the above listed criteria for Prime Farmland must be met to allow for a designation of Farmland of Statewide Importance. Criteria for permeability and rooting depth are not restrictive of designation for this categorization of farmland.

Unique Farmland cannot be either Prime Farmland or Farmland of Statewide Importance, as it is land that does not meet the criteria for either land designation. However, Unique Farmland exhibits a particular combination of soil quality, location, growing season, and moisture supply such that the land produces a sustained high quality and/or high yield of a specific crop (e.g., oranges, avocados, rice) when managed according to current farming methods. Unique Farmland tends to be used for specific high-value crops, of which favorable conditions exist for the growth of the specific crop on the particular parcel of land. High-value crops are determined by the California Department of Food and Agriculture and are listed in its annual publication *California Agriculture* (California Department of Food and Agriculture 2002).

The total acreage of each type of farmland designation in each water district, as determined by the FMMP, is provided in Tables G-LU1.3-1 and G-LU1.3-2. Approximately 6,300 acres of Prime Farmland within Sutter County are located in the FRSA. An interim mapping study has been conducted for Butte County. Where no farmland mapping study is conducted, an interim mapping study is conducted, and designations of land are made as either Irrigated Farmland or Non-irrigated Farmland.

Table G-LU1.3-1. Farmland Mapping and Monitoring Program summary for Butte County by water district service area.

	Other		Irrigated Farmland*		Non-irrigated Farmland*		Unique Farmland		Farmland of Statewide Importance		Prime Farmland		Total	
	Acres	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**
Western Canal WD	4,828	7	61,210	93	33	0	0	0	0	0	0	0	66,038	100
Richvale ID	5,079	14	32,287	86	0	0	0	0	0	0	0	0	37,366	100
Butte WD	2,215	12	15,617	88	60	0	0	0	0	0	0	0	17,832	100
Biggs-West Gridley WD	5,770	17	27,984	83	0	0	0	0	0	0	0	0	33,754	100

Notes: ID = Irrigation District; WD = Water District. Butte County contains only Interim Farmland map categories.
** Two categories of Interim Farmland, Irrigated Farmland and Non-irrigated Farmland, are mapped in lieu of Prime Farmland, Farmland of Statewide Importance, Unique Farmland, and Farmland of Local Importance. No Farmland of Local Importance occurs within the water district service areas of concern in Butte County. The "Other" category represents Grazing Land, Urban and Built-up Land, Other Land, Water, and Areas Not Mapped.*

Source: Farmland Mapping and Monitoring Program 2004a

Table G-LU1.3-2. Farmland mapping and monitoring summary for Sutter County by water district service area.

	Other		Irrigated Farmland*		Non-irrigated Farmland*		Unique Farmland		Farmland of Statewide Importance		Prime Farmland		Total	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Butte WD	3,126	8	0	0	0	0	130	0	27,262	74	6,278	17	36,796	100
Biggs-West Gridley WD	283	7	0	0	0	0	1,817	45	1,892	47	26	1	4,018	100

Notes: ID = Irrigation District; WD = Water District. Sutter County utilizes an Important Farmland Mapping system compiled by the FMMP.
** The categories “Irrigated Farmland” and “Non-irrigated Farmland” are only used for Interim Farmland Maps. Therefore, no lands within the water district service areas of concern in Sutter County are designated as either Irrigated Farmland or Non-irrigated Farmland. No Farmland of Local Importance occurs within the water district service areas of concern in Sutter County. The “Other” category represents Grazing Land, Urban and Built-up Land, Other Land, Water, and Areas Not Mapped.*

Source: Farmland Mapping and Monitoring Program 2004b

The interim designations collectively represent the four categories of farmland and are intended to be renamed once advanced soil surveys are conducted. The total number of acres of farmland within the FRSA, as listed in Tables G-LU1.3-1 and G-LU1.3-2, represents the agricultural resource area potentially affected by Oroville Facilities operations.

Under existing environmental commitments, the California Department of Water Resources (DWR) operates the Oroville Facilities to meet water temperature objectives in the Feather River for aquatic species survival and to meet salinity requirements in the Sacramento–San Joaquin Delta.

Several water districts in the Feather River watershed diverted water from the Feather River prior to construction of Oroville Dam. DWR entered into agreements with certain water districts to provide them with water based upon these prior rights (DWR 1969). The agreement among Richvale Irrigation District, Biggs–West Gridley Water District, Butte Water District, Sutter Extension Water District (i.e., the Joint Water District), and DWR includes terms describing the amounts of water that the State shall make available to the districts. This May 1969 agreement states that the “Districts shall have the right to divert from the Feather River at the Afterbay Diversion Structures each Irrigation Season, five hundred sixty thousand (560,000) acre-feet of water of the Feather River up to and including the year 1980 and five hundred fifty-five thousand (555,000) acre-feet each Irrigation Season thereafter” (DWR 1969). The May 1969 agreement between DWR and the Joint Water District does not contain any specific water temperature or water quality goals or criteria. The primary water use of FRSA-diverted water is for agricultural irrigation, although some water is allocated for habitat production (USBR et al. 2004). The irrigation districts in the FRSA deliver water from the Oroville Facilities to approximately 195,800 acres of farmland in Butte and Sutter counties.

Thermalito Afterbay was constructed on permeable geologic material, resulting in seepage of water into the local groundwater basin. Two effects of groundwater table elevation could be of potential concern for agricultural purposes. If the water table in the vicinity of the Oroville Facilities project area were to decrease, then at a certain low level there would be increased costs to agricultural users as a result of increased pumping costs. Another possible effect of groundwater table elevation on agricultural resources would occur if the water table were high enough to affect agricultural drainage systems or crop root zones.

Additionally, the Oroville Facilities could potentially affect surface water or groundwater quality, which could affect agricultural resources. Results from Phases 1 and 2 of Study W-5, *Project Effects on Groundwater*, do not indicate any adverse effects on groundwater levels or quality in the project area from the Thermalito Forebay or Thermalito Afterbay. If there are any subtle effects on groundwater from the Oroville Facilities, the effects would be beneficial because groundwater levels would be recharged from the Oroville Facilities and the high mineral content of the groundwater would be diluted with surface water containing much lower mineral levels, resulting in better suitability for all beneficial uses.

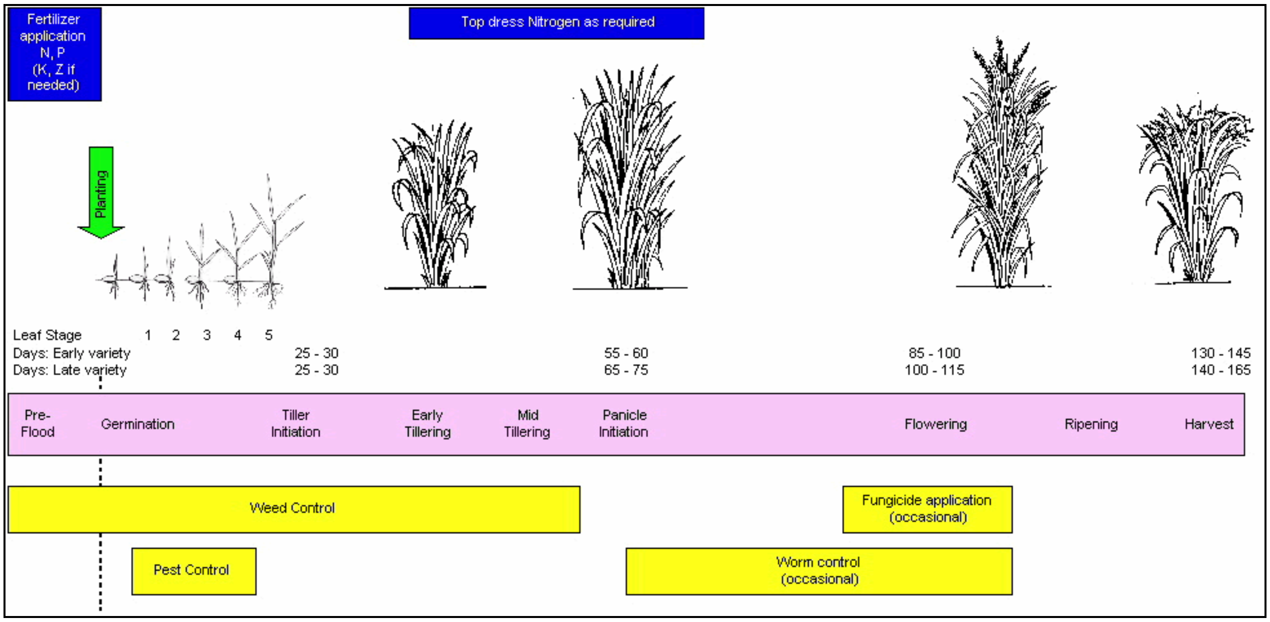
DWR conducts aquatic weed management in Thermalito Afterbay for water primrose and other native and exotic plant species present in the afterbay. The possibility exists that aquatic weeds from Thermalito Afterbay could become entangled in irrigation district diversions or block water turnouts. The occurrence of such entwinements could potentially require maintenance or other operational activities and service in the irrigation district diversion structures and conveyance system. In addition to aquatic weeds, several control/eradication projects in the vicinity of Lake Oroville for exotic or invasive weed species are currently conducted. These include chemical treatment of parrot's feather by the California Department of Fish and Game (DFG) and local irrigation districts and general weed control using chemical and mechanical efforts by the irrigation districts. (See Section 5.6, Terrestrial Resources, for additional information about weed management efforts.)

G-LU1.3.1 Agricultural Production and Cultural Practices

Irrigation water is an essential component of high-value agricultural crop production. Agricultural cropland is often irrigated before crop planting in the spring to leach accumulated salts out of the crop root zone and to recharge the moisture availability of the soil profile. Crops are irrigated at frequent intervals during the growing season; in the case of rice production, irrigation is nearly continuous, with the exception of some periods of water holding and recirculation for specific cultural practices related to herbicide and insecticide applications. In the case of rice production, the field is often flooded after harvest to facilitate rice straw decomposition and provide waterfowl habitat. Because rice is the dominant crop type grown in the FRSA and is potentially affected by FRSA water temperatures, the remainder of this section focuses on rice production practices as they relate to the effects of water temperatures.

Rice production typically occurs on clays or other poorly drained soils with impervious layers. These soil types are fairly impermeable to water, which increases their water use efficiency. Rice is an aquatic crop requiring almost continuous flooding until the time of harvest. Fields intended for rice crop seeding are typically initially flooded in April and May, which accounts for the peak in agricultural water diversion volumes during this time period. Planting is done primarily in April and May.

Rice plants go through five growth stages: germination, tiller initiation, panicle initiation, flowering, and harvest (see Figure G-LU1.3-4). Germination occurs very shortly after planting and lasts about 5 days. In both early and late varieties of rice, tiller initiation occurs 25–30 days after planting. The timing of panicle initiation is different for early and late varieties of rice. For early varieties of rice, panicle initiation occurs within 55–60 days of germination. Late varieties reach the panicle initiation stage 65–75 days after germination. The flowering stage is reached at 85–100 days in early varieties of rice and 100–115 days in late varieties of rice. Harvest occurs between 130 and 145 days for early rice varieties and between 140 days and 165 days for late rice varieties.



Source: California Rice Research Board Website 2004

Figure G-LU1.3-4. Rice growth and cultural practice timeline.

Continually flowing water is needed for rice production. The total water use for growing rice is similar to that used to grow alfalfa or cotton, even though the rice fields are flooded most of the season. Water is reused and pumped back through a rice paddy several times before it is released back into the main water channel. Rice paddies are laser-leveled or contoured so that there is a slight slope within the field to aid in the flow of water. Berms or checks are constructed to control the flow of water over the growing rice and to ensure that there is an equal water depth within each basin (UC Cooperative Extension Rice Project Website). Water depth management in the rice paddy is important for weed control, rigorous rice crop growth, and management of potential plant diseases. Pest management during rice cultivation often requires the use of pesticide applications. Under State regulations, treated waters are required to be held within fields to facilitate the breakdown of pesticides before draining. Holding water for the extended period of time required for decomposition of chemical pesticides can cause stress to rice if tailwater is not managed properly (UC Cooperative Extension Rice Project Website).

After the panicle initiation, the water level in the rice paddy is often raised to protect the reproductive organs of the plant from colder air temperatures at night. Sterility may occur if the panicle is exposed to air temperatures below 55 degrees Fahrenheit (°F) 10–15 days before heading (UC Cooperative Extension Rice Project Website). Fields are not drained until the panicle is fully tipped and brown. Early drainage can result in low milling yields from breaking or cracking at harvest if the kernels are not completely filled (UC Cooperative Extension Rice Project Website).

To avoid the losses associated with coldwater effects, some growers use “warming checks,” which are areas of the field at the turnout dedicated to a water warming basin where either: (1) there are no crop inputs, or (2) increased yield losses associated with the cold water are expected. Warming checks can vary in size from approximately 1 to 5 acres depending on the inlet water temperatures and the volume of water flowing into the field, which is determined in part by the size of the field. Another strategy used for water temperature management in the field is the use of tailwater recirculation to blend warm water from the tail end of the field with the cooler water at the field inlet.

Qualitative effects assessments were completed to evaluate potential effects on agricultural resources with implementation of the alternatives. Qualitative effects evaluated included: (1) conversion of Prime Farmland resulting from construction or erosion attributable to Oroville Facilities project releases; (2) changes in cultural practices due to noxious weeds, conflicts with recreational uses, or restrictions to the application of agricultural inputs due to changes in adjacent land uses or recreation; and (3) changes in agricultural production due to groundwater table elevations, water quality, or potential effects of changes in water temperature on rice production.

G-LU1.4 NO-ACTION ALTERNATIVE

G-LU1.4.1 Prime and Other Farmland

The qualitative effects evaluation of the No-Action Alternative included the potential for conversion of Prime Farmland due to construction activities or project-related erosion, as well as conflicts due to adjacent changes in land use. No construction activities that result in conversion of Prime or other farmland are included under the No-Action Alternative; therefore, no change in the status of Prime Farmland or other land use designations of lands surrounding the project area is anticipated. In addition, erosion rates and conversion of Prime Farmland due to erosion in the lower Feather River are not expected to increase above existing condition levels as a result of future project operations under the No-Action Alternative. (See Section 5.3.1, Geology and Soils, for additional information on lower Feather River erosion effects.) Prime and other farmland designations under the No-Action Alternative are unlikely to change from current land use designations. Therefore, no loss of Prime Farmland or other farmland is anticipated under the No-Action Alternative.

G-LU1.4.2 Agricultural Cultural Practices

Potential changes in the rate and type of contribution of aquatic weeds into the agricultural diversions and distribution systems from Thermalito Afterbay were qualitatively evaluated. This evaluation included effects on irrigation district operations, as well as effects on aquatic weed management practices for rice production. No changes in Thermalito Afterbay operations are anticipated to occur under the No-Action Alternative; therefore, it is anticipated that the rate and type of weed contribution from the afterbay into the agricultural diversion system under the No-Action Alternative would not differ from the rate and type of weed contribution under existing conditions. Under the No-Action Alternative, it is anticipated that more visitors to the area would result in some increased traffic flows in the vicinity of agricultural fields. (See Section 5.10, Recreation Resources, for additional information on changes in recreation visitation under the No-Action Alternative.) However, the patterns and seasonality of the potential increased traffic in proximity to agricultural areas would be limited and are anticipated to have no effect on agricultural practices and equipment transit.

No new recreation facilities development is included in the No-Action Alternative; therefore, no changes in restrictions on agricultural spraying activities would occur under the No-Action Alternative. Therefore, no effects are anticipated on agricultural cultural practices due to improvement or development of recreational facilities such as picnic areas, campsites, or boat ramps under the No-Action Alternative relative to existing conditions.

G-LU1.4.3 Agricultural Production

Changes in water quality or groundwater tables were qualitatively evaluated based on their suitability for agricultural production associated with groundwater quality and depth, as well as crop drainage effects on agricultural resources. Currently, groundwater quality and water table depth do not adversely influence agricultural production in the project vicinity. No changes in project operations are anticipated to occur at Thermalito Afterbay under the No-Action Alternative; therefore, no changes in water quality or water table elevations influencing agricultural resources are expected to occur.

Under the No-Action Alternative, operations in Thermalito Afterbay would not differ appreciably from the operations under existing conditions during the May 1 through June 30 period of rice production yield sensitivity to irrigation water temperatures. Therefore, the Thermalito Afterbay water temperature regime is not expected to significantly change under the No-Action Alternative from the water temperature regime observed under existing conditions. Some changes in future water demand patterns occur in the No-Action Alternative as compared to the existing conditions, which alter the seasonal pattern of flow releases from the project. (See Section 5.4.1.2, Water Quantity, for additional information on flow changes associated with the primary project alternatives.) Because changes to the effective reside time of water in Thermalito Afterbay and afterbay release changes are small, these potential changes from the existing condition to the No-Action Alternative conditions likely would not effect affect water temperatures at the agricultural diversions as compared to the existing conditions.

Under the No-Action Alternative, Thermalito Afterbay operations would not differ from existing operational procedures. Water temperatures in Thermalito Afterbay at the agricultural diversion points under the No-Action Alternative were therefore expected to be similar to those observed under existing conditions. Agricultural production under the No-Action Alternative, according to the above qualitative analyses, is therefore not expected to change relative to existing conditions.

G-LU1.5 PROPOSED ACTION

G-LU1.5.1 Prime and Other Farmland

The qualitative effects evaluation of the Proposed Action included the potential for conversion of Prime Farmland due to construction activities or project-related erosion, as well as conflicts due to changes in adjacent land use. No construction activities are included with implementation of the Proposed Action that would affect Prime or other farmland; therefore, no change in the status of Prime Farmland or other land use designations of lands surrounding the project area is anticipated. In addition, the erosion rates and conversion of Prime Farmland due to erosion are not expected to change from No-Action Alternative conditions, as no changes in flow are included in the Proposed Action. Prime and other farmland designations with implementation of the Proposed Action are unlikely to change from current land use designations. Therefore, no loss of Prime Farmland or other farmland is anticipated with the implementation of the Proposed Action.

G-LU1.5.2 Agricultural Cultural Practices

Potential changes in the rate and type of contribution of aquatic weeds into the agricultural diversions and distribution systems from Thermalito Afterbay were qualitatively evaluated. An invasive species management plan to reduce noxious non-native plant species is included in the Proposed Action. (See Section 3.2.3 for an additional description of this program.) The invasive species management plan included in the Proposed Action is anticipated to reduce the rate and type of weed contribution from the afterbay into the agricultural diversion system. Terrestrial and noxious weed management programs, as well as exotic and invasive weed management programs, should decrease the occurrence of weeds and weed seed in Thermalito Afterbay. Potentially, management actions could reduce the quantity of weeds in the agricultural diversion facilities contributed by Thermalito Afterbay. (See Section 5.6, Terrestrial Resources, for additional information on weed management programs in Thermalito Afterbay.)

Increased recreation facilities and visitation included with implementation of the Proposed Action could conflict with agricultural cultural practices. (See Section 5.10, Recreation Resources, for additional information on proposed recreational improvements.) Additional opportunities to recreate would result in increased visitation to the area, thereby increasing traffic flows in the vicinity of agricultural fields. However, the patterns and seasonality of the potential increased traffic in proximity to agricultural areas are anticipated to have no effect on agricultural practices and equipment transit.

Facility development, including new and/or improved campsites, could cause restrictions on agricultural spraying activities. Recreational development and associated activities adjacent to Oroville Facilities are anticipated to be consistent with and in proximity to current recreation projects in place at Lake Oroville and the Thermalito Complex. Therefore, no effects are anticipated on agricultural cultural practices with implementation of the Proposed Action due to improvement or development of recreational facilities such as picnic areas, campsites, or boat ramps.

G-LU1.5.3 Agricultural Production

Changes in water quality or groundwater tables were evaluated based on their suitability for agricultural production associated with groundwater quality and depth, as well as crop drainage effects on agricultural resources. Currently, groundwater quality and water table depth do not adversely influence agricultural production in the project vicinity. No changes in project operations are anticipated to occur at Thermalito Afterbay with implementation of the Proposed Action; therefore, no changes in water quality or water table elevations influencing agricultural resources are expected to occur.

Oroville Facilities operations affect water temperatures and their distribution in Thermalito Afterbay, which affect water temperatures at the agricultural diversions. (See Section 5.4.2.1, Water Quality, Environmental Effects, for additional information on water temperature effects in Thermalito Afterbay.) Project operations that affect Thermalito Afterbay water temperatures include Oroville Dam release water temperatures, and those operational variables that determine the effective reside time of water in the afterbay. Oroville Facilities operations that determine the effective reside time of water in the afterbay include the volume of inflows compared to the total releases from the afterbay (at both the Thermalito Afterbay Outlet and the agricultural diversions), afterbay stage elevations, and the amount of peaking and pumpback. Under the Proposed Action, operations in Thermalito Afterbay would not differ from the operational procedures under the No-Action Alternative. Therefore, Thermalito Afterbay water temperature regime, flows, and effective reside time of water are not expected to change with implementation of the Proposed Action, relative to the No-Action Alternative. In addition, temperatures of water released into Thermalito Afterbay, as well as resulting water temperatures at the agricultural diversion points, are not expected to change with implementation of the Proposed Action. Agricultural production, according to the above qualitative analyses, is therefore not expected to differ with implementation of the Proposed Action from the agricultural production anticipated under No-Action Alternative conditions.

G-LU1.6 ALTERNATIVE 2

G-LU1.6.1 Prime and Other Farmland

The qualitative effects evaluation of Alternative 2 included the potential for conversion of Prime Farmland due to construction activities or project-related erosion, as well as conflicts due to changes in adjacent land use. No construction activities are included with implementation of Alternative 2 that affect Prime or other farmland; therefore, no change in the status of Prime Farmland or other land use designations of lands surrounding the project area are anticipated. Although flows in the Low Flow Channel would be increased under Alternative 2, no net changes in total releases to the lower Feather River would occur with implementation of Alternative 2; therefore, the rate of erosion and conversion of Prime and other farmland is not expected to change from No-Action Alternative conditions. Therefore, no loss of Prime Farmland or other farmland is anticipated with implementation of Alternative 2.

G-LU1.6.2 Agricultural Cultural Practices

With respect to potential effects on agricultural cultural practices, actions associated with implementation of Alternative 2 would be identical to those actions included under the Proposed Action. (See Section 5.8.2.2 for an evaluation of these actions relative to the No-Action Alternative.)

G-LU1.6.3 Agricultural Production

Changes in water quality or groundwater tables were evaluated based on their suitability for agricultural production associated with groundwater quality and depth, as well as crop drainage effects on agricultural resources. Currently, groundwater quality and water table depth do not adversely influence agricultural production in the project vicinity. No changes in project operations are anticipated to occur at Thermalito Afterbay with implementation of Alternative 2; therefore, no changes in water quality or water table elevations influencing agricultural resources are expected to occur.

Under Alternative 2, operations in Thermalito Afterbay would differ from the No-Action Alternative. Alternative 2 includes reduced Thermalito Afterbay releases due to the increase in minimum Low Flow Channel flows (from 600 cubic feet per second [cfs] to 800 cfs), and the increase in Low Flow Channel flows of up to 1,200 cfs from May 1 through June 15. Changes in water temperature targets included in Alternative 2 also would alter the water temperature of project releases. Both of these operational changes associated with implementation of Alternative 2 would change water temperatures in Thermalito Afterbay and therefore at the agricultural diversions.

Under Alternative 2, 200 cfs more project water would be released downstream into the Feather River during most periods of the year. Although the change in project operations is small and does not involve a change to Thermalito Afterbay operations per se, the action has the potential to increase the effective reside time of water in Thermalito Afterbay, providing for an increased duration of opportunity for water to warm in Thermalito Afterbay prior to agricultural diversions. During the May 1 through June 15 period when of flows up to 1,200 cfs would be released through the Low Flow Channel, encompassing the majority of the May 1 through June 30 critical period of rice yield water temperature sensitivity, there would be an additional increase in the effective reside time of water in Thermalito Afterbay prior to agricultural diversions. This increased effective reside time should result in some water temperature increases at the agricultural diversions under Alternative 2 when the ambient air temperatures are above the water temperatures in Thermalito Afterbay. Mean daily water temperature modeling data available for the agricultural diversions were not successful in quantifying this increase, but it is expected that there would be some improvement in increased water temperatures for rice production under Alternative 2.

G-LU1.7 REFERENCES

Boles, J. 2004. Evaluation of Effects from the Oroville Facilities to Water Temperatures for Irrigation. Memorandum Report. California Department of Water Resources, Division of Planning and Local Assistance, Northern District. Red Bluff, California.

California Department of Food and Agriculture. 2002. California Agriculture: A Tradition of Innovation - Agricultural Resource Directory. URL = http://www.cdfa.ca.gov.

California Rice Research Board Website. Rice Growth Timeline. Site accessed on August 15, 2003. URL = http://syix.com/rrb/Facts/RiceGrow.htm.

CASS (California Agricultural Statistics Service). 2003. County Agricultural Commissioners' Data, 2002. California Agricultural Statistics Service.

DWR (California Department of Water Resources). 1969. Agreement on Diversion of Water From the Feather River.

DWR (California Department of Water Resources). 2001. Initial Information Package, Relicensing of the Oroville Facilities. FERC License Project No. 2100.

Farmland Mapping and Monitoring Program. 2004a. Butte County, 2000-2002 Land Use Conversion. California Department of Conservation, Division of Land Resource Protection.

Farmland Mapping and Monitoring Program. 2004b. Sutter County, 2000-2002 Land Use Conversion. California Department of Conservation, Division of Land Resource Protection.

NASS (U.S. Department of Agriculture, National Agricultural Statistics Service). 2004. 2002 Census of Agriculture. USDA, National Agricultural Statistics Service.

University of California, Davis. UC Cooperative Extension Rice Project. Site accessed on September 15, 2003. URL = http://agronomy.ucdavis.edu/uccerice.

USBR, DWR, USFWS, NOAA Fisheries, and DFG (U.S. Bureau of Reclamation, California Department of Water Resources, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration Fisheries, and California Department of Fish and Game). 2004. Environmental Water Account. Final Environmental Impact Statement/Environmental Impact Report. January 2004.

This page intentionally left blank.

APPENDIX G-LU2
PUBLIC HEALTH AND SAFETY

G-LU2.1 METHODS USED TO ASSESS PUBLIC HEALTH AND SAFETY EFFECTS

G-LU2.1.1 Water Quality Effects on Human Health

The water quality of the project area has been affected by past activities, particularly past gold mining activities in the region. Effects on water quality will continue to occur with the continued operation of the Oroville Facilities. Recreational facilities and operations have the potential to introduce nutrients, bacterial contamination at swim areas, sewage and wastewater spills into surface waters in the project area, and contamination (such as petroleum hydrocarbons and additives like methyl tertiary butyl ether [MTBE]) from boat operations, maintenance, and cleaning operations.

Water quality studies currently under way by the California Department of Water Resources (DWR) were analyzed and appropriate information used concerning potential effects on public health and safety from contaminants found in Lake Oroville and the Feather River. Constituents exceeding specific thresholds as identified by the following standards are the focal point of the analysis of effects on public health and safety. These standards include but are not necessarily limited to:

- Drinking water standards and health advisories;
- Drinking water quality criteria;
- Agricultural water quality criteria;
- Bacterial limit guidelines; and
- Contaminant action levels as established by the U.S. Environmental Protection Agency (USEPA) and California Environmental Protection Agency (Cal/EPA).

Lake Oroville and the Feather River are considered in the Central Valley Regional Water Quality Control Board (RWQCB) Basin Plan to have beneficial use for municipal and domestic supply, agricultural supply, recreation use, and freshwater fish habitat. There are several lists of public health criteria for pollutant constituents and parameter levels in water with potential beneficial use for municipal and domestic supply. These lists have been compiled by the Central Valley RWQCB in its August 2003 *Compilation of Water Quality Goals* (Central Valley RWQCB 2003). The comprehensive list of Water Quality Limits for Constituents and Parameters forms the basis of the analysis of project effects on public health.

G-LU2.1.2 Accumulation of Contaminants through the Food Chain

Related to water quality above, contaminant accumulation in fish, sediment, and the aquatic food chain can ultimately adversely affect human health. Contamination of fish from mercury, other heavy metals, and bioaccumulative organic constituents such as polychlorinated biphenyls (PCBs) have been noted as a potential concern in the project area.

The specific thresholds for a potential contaminant of bioaccumulation concern were selected from a variety of sources, such as those contained in the Central Valley RWQCB list of Water Quality Limits for Constituents and Parameters (Central Valley RWQCB 2003). Contained within that list are human health criteria, such as those under the California and National Toxics Rules, that take into account the consumption of contaminated fish—the principal pathway of bioaccumulation of constituents of concern to human beings. Other potential thresholds of potential human health effects from bioaccumulation were examined, with consideration of U.S. Food and Drug Administration action levels and the median international standards for trace elements established by the Food and Agriculture Organization of the United Nations.

G-LU2.1.3 Wildfire Potential in the Project Area

There is stakeholder concern that historic fuel management and fire prevention and suppression activities have increased biomass fuel loads in the project area. An increased fuel load can lead to an increased risk of destructive wildfires and their concomitant effects on public health and safety, which is manifested in the potential loss of property and structures, injury, and even death.

To address this potential significant effect on public health and safety, information gathered and presented in SP-L5, *Fuel Load Management Evaluation*, was used.

G-LU2.2 PUBLIC HEALTH AND SAFETY

G-LU2.2.1 Fuel Loading

G-LU2.2.1.1 Overview

This appendix summarizes fuel load management in the project area. This summary is based on SP-L5, *Fuel Load Management Evaluation*, which contains detailed information pertinent to fuel loading issues in the project area. The definition of fuel loading varies among land management and fire prevention organizations. For this Preliminary Draft Environmental Assessment (PDEA), fuel loading refers to a buildup of fuels, particularly vegetation, that can burn and contribute to wildfires.

Buildup of vegetation (fuel loading) throughout California and the West is of great concern because of the potential for damage associated with wildfires. Fire is a natural evolutionary force that has influenced Sierra Nevada ecosystems for millennia. It has influenced biodiversity, plant reproduction, vegetation development, insect outbreak and disease cycles, wildlife habitat relationships, soil functions and nutrient cycling, gene flow, selection, and, ultimately, sustainability (SNEP 1996).

Changes in fire patterns over the last 100 years in the Sierra Nevada have led to larger and more severe fires than occurred historically. Many factors have influenced changes in fire patterns in the Sierra Nevada over the last century (McKelvey et al. 1996; Skinner and Chang 1996). These factors include population decline among native peoples (who ignited fires to improve hunting and gathering conditions), settlement by Euroamericans, grazing, mining, logging, recreation, and changes in fire management philosophy. The expansion of Euroamerican settlement in the Sierra Nevada since the mid-1800s initiated profound changes in the role of fire in Sierra Nevada ecosystems (SNEP 1996). Settlement in the Sierra Nevada resulted in an emphasis on extinguishing any and all fires to protect property, homes, and natural resources such as timber. Fire suppression activities together with the loss of ignitions by Native Americans significantly reduced the areas burned by wildfires during the last century (SNEP 1996).

The virtual exclusion of widespread low- to moderate-severity fires has affected the structure and composition of most Sierra Nevada vegetation, especially in low- to middle-elevation forests. Conifer stands generally have become denser and consist of mainly small and medium size classes of shade-tolerant and fire-sensitive tree species. In combination with the removal of large trees for timber, conditions have promoted the establishment of dense, young forests. As a result, stands in many areas have experienced increased mortality recently from the cumulative effects of competition (primarily for water and light), drought, insects, disease, and in some cases, air pollution (SNEP 1996). Dead, dying, and dry vegetative material accumulates on trees and falls to the ground surface. In addition, without regular fire events, understory vegetation is left to flourish and provides a connection between ground fuels and the canopy of trees. Because forests are denser, they have intertwined canopies, which allows fire to spread easily from one tree to the next. As a result of the accumulation of fuel and increase in stand density, today’s forest conditions more readily support severe fires than did historic conditions (McKelvey et al. 1996), and severe fires are more likely to be large in size because they are more difficult to suppress (SNEP 1996).

G-LU2.2.1.2 Fire History in the Project Area

As with most lands in and near the Sierra Nevada, the project area has a history of fire events. Information regarding the fire history of the project area is available from the California Department of Forestry and Fire Protection (CDF) and was used extensively for SP-L5 and this appendix. CDF maintains detailed and up-to-date Geographic Information Systems (GIS) databases for fire history, ignition locations, fuel type, and other information to allow for comprehensive analysis of fire hazards, assets at risk, and level of service and to develop fire management plans. Figure G-LU2.2-1 depicts the location and approximate configuration of large fires (more than 50 acres) that have occurred in the project area since the early 1900s. In recent years (between 1990 and June 2003), there have been 13 fires that have burned more than 50 acres within the FERC project boundary. These fires have been located in the northern portion of the Lake Oroville area (between the Upper North Fork and West Branch), the Middle Fork, Loafer Creek, Thermalito Forebay, and the Oroville Wildlife Area (OWA) (Table G-LU2.2-1). The size of these fires has ranged from 58 to 8,055 acres. These fires have been caused by lightning, equipment use, arson, power lines, debris burning, and unknown sources.

Table G-LU2.2-1. Size and cause of recent fires (since 1990) in the project area.

Fire Name	Location	Year	Acres Burned	Cause
Wild	OWA	1990	257	Equipment Use
Dry	West Branch	1992	820	Miscellaneous
Nelson	Thermalito Forebay	1993	743	Equipment Use
Union	Middle Fork	1999	736	Lightning
Bloomer	Northern Lake Oroville	1999	2,610	Lightning
South	Loafer Creek	1999	1,572	Lightning
Bean Creek	Middle Fork	1999	1,785	Lightning
Concow	Northern Lake Oroville	2000	1,835	Equipment Use
Larkin	OWA (two fires)	2001	487	Arson
Poe	Northern Lake Oroville	2001	8,333	Powerline
Larkin	OWA	2001	627	Unknown/Undetermined
Poe	West Branch–Upper North Fork	2001	8,055	Arson
Union	Middle Fork	2002	58	Debris Burning

Source: CDF 2002a

CDF has also kept records for all known “fire ignitions” in Butte County, regardless of size, since 1990. The locations of the ignitions are not recorded precisely but are plotted as the center of 160-acre quarter sections. The frequency of ignitions for each quarter section was calculated by CDF and the data classified into ranges. Figure G-LU2.2-2 displays the locations of fire ignitions in the general project area between 1990 and June 2003. Because almost every quarter section in the project area and beyond has experienced at least one ignition since 1990, the sections containing between one and six ignitions are not displayed in the figure; these data were excluded to highlight the areas with more frequent (greater than seven) ignitions. The most frequent ignitions have occurred in the urbanized areas around City of Oroville, Thermalito, other communities, in the Clay Pit State Vehicular Recreation Area (SVRA), and along roadways. Although not all of these areas are within the FERC project boundary, fires that start in the general project region could potentially move into the FERC project boundary and vice versa.

G-LU2.2.1.3 Fuel Hazard Ranking in the Project Area

The severity of a wildfire depends upon a number of factors such as available fuel to burn, vegetation types and conditions, topography, wind patterns, humidity, and moisture content. Fuel is one of the factors that can be measured and predicted in advance, so assessing fuel loading (the condition of fuels) is an important part of fire planning. CDF has developed a fuel assessment methodology that uses models to describe current fuel load conditions and rank fuel hazard situations. This information assists CDF and other entities in targeting critical areas for fuel treatment. The fuel ranking methodology assigns ranks based on current flammability of a particular fuel model and includes variables such as slope, ladder fuels (fuel that connects ground fire with tree crowns), and crown density. The models use GIS technology to build and analyze the data.

The first step in developing a fuel hazard ranking for an area is to determine fuel types. Grass, brush, and timber are the most common fuel types within the project area. Each has its own burning characteristics based on several factors, including moisture content, volume, live-to-dead vegetation ratio, size, structure, and inherent species characteristics such as volatility. For the CDF fuel hazard ranking methodology, fuel types are initially determined from aerial photograph interpretation and validated, where necessary, with on-the-ground assessments. The model takes into account vegetation type and other fuel characteristics. Fire history is added to the model to create a more accurate and current representation of fuel hazard. The fire history layer shows where vegetation has burned over a fire area, and computer modeling is used to predict the regrowth of native vegetation over the area based on principles of ecological succession. Once the fuel model is determined, one of the six slope classes along with indices for crown and ladder fuels is integrated into the model to arrive at a surface fuel hazard rank. Overall hazard scores of “Moderate,” “High,” or “Very High” are assigned to 450-acre “quads.” Figure G-LU2.2-3 shows the CDF fuel hazard ranking for all of Butte County using the 450-acre quads.

The results of the fuel hazard ranking model for lands in the project area are depicted in Figure G-LU2.2-4. Approximately 53 percent of the project area was classified with a hazard score of Moderate, 23 percent High, and 15 percent Very High (Table G-LU2.2-2). The highest concentration of lands classified as Very High is along the South Fork and Middle Fork, with other areas scattered along the Upper North Fork and West Branch.

G-LU2.2.1.4 Fuel Load Management Policies, Plans, Programs, and Organizations

Because wildfires are a concern in the project area, land management entities have developed policies, plans, and programs to address the threat of wildfire and deal with fuel loading. The U.S. Forest Service (USFS), U.S. Bureau of Land Management (BLM), CDF, and California Department of Parks and Recreation (DPR), along with Butte County and the City of Oroville, have developed policies, plans, and programs for fire management/suppression and/or for fuel loading. Table G-LU2.2-3 lists the policies and plans that were reviewed for SP-L5 (see SP-L5 for detailed descriptions of the policies, plans, and programs).

Table G-LU2.2-2. Fuel hazard ranking classification within the project area.

Area	Fuel Hazard Classification Approximate percent of area (acres)		
	Very High	**High**	**Moderate**
Lake Oroville and Thermalito Diversion Pool	15 (10,765)	32 (22,493)	22 (15,549)
Thermalito Forebay and Thermalito Afterbay	-	0 (4)	18 (12,744)
OWA	-	-	13 (8,977)
Total	**15 (10,765)**	**32 (22,497)**	**53 (37,270)**

Source: CDF 2002b

Table G-LU2.2-3. Relevant fire management policies and plans in the study area by agency.

	Document Title	Date
FEDERAL		
U.S. Department of Agriculture	Healthy Forest Initiative	2002
USFS	Sierra Nevada Forest Plan Amendment, Record of Decision (ROD)	2001
USFS	Plumas and Lassen National Forests, Proposed Administrative Study	2002
BLM	Redding Resource Management Plan	1993
STATE		
CDF and State Board of Forestry (SBF)	The California Fire Plan	1996
CDF	Butte Unit Fire Management Plan	2002
DPR	Wildfire Management Planning: Guidelines and Policy	2002
DPR	Loafer Creek Prescribed Fire Management Plan	1999
CDFG	Oroville Wildlife Area Management Plan	1978
LOCAL		
City of Oroville	General Plan	1995
Butte County	General Plan	1996

Source: Compiled by EDAW 2003

In addition to plans, policies, and programs that address fuel loading, the Butte County Fire Safe Council and the Oroville Community Association focus on wildfire-related issues. The main function of these organizations is to provide education to local residents relating to issues associated with wildfires such as reducing fuel loading. These organizations work closely with CDF's local unit, the Butte Unit, in outreach and educational programs.

G-LU2.2.1.5 Fuel Loading Reduction Measures

Many researchers and professionals have concluded that, overall, pretreatment and fuel load management reduce the intensity and severity of wildfires as well as reduce effects on private property and other resources. Benefits of fuel treatments are assessed by examining subsequent fire behavior, physical effects on resources, economic losses, enhanced forest health, and increased firefighter safety (FRAP Website). Numerous field accounts yield evidence that fires were reduced in severity when they burned into areas previously burned or treated (Agee et al. 2000; FRAP Website). CDF has compiled 26 reports documenting the benefits of the Vegetation Management Program (VMP) associated with reduced fire size and increased resource protection during wildfire events (FRAP Website).

There are a number of ways to reduce fuel loading. Some of the more common ones include prescribed burning, pile burning, mastication, thinning, chipping and multicutting, disking and mowing, grazing, and herbicide application. These techniques are described in SP-L5.

G-LU2.3 REFERENCES

Agee, J. K., B. Bahro, M. A. Finney, P. N. Omi, D. B. Sapsis, C. N. Skinner, J. W. Van Wagtendonk, and C. P. Weatherspoon. 2000. The Use of Shaded Fuelbreaks in Landscape Fire Management. Forest Ecology and Management 127: 55-66.

CDF (California Department of Forestry and Fire Protection). 2002a. Fire Perimeter Database.

CDF (California Department of Forestry and Fire Protection). 2002b. Q81 Database.

Central Valley RWQCB (Central Valley Regional Water Quality Control Board). 2003. A Compilation of Water Quality Goals. Rancho Cordova, California. August 2003.

FRAP (California Fire Resource Assessment Program). Website. The Effectiveness of Fuels Management. Site accessed June 18, 2003. URL=http://frap.cdf.ca.gov/projects/ prefire_mgmt/prefire.html.

McKelvey, K. S., C. N. Skinner, C. Chang, D. C. Erman, S. J. Husari, D. J. Parsons, J. W. van Wagtendonk, and C. P. Weatherspoon. 1996. An Overview of Fire in the Sierra Nevada. In: Status of the Sierra Nevada, Sierra Nevada Ecosystem Project, Final Report to Congress, Vol. II, Assessments and Scientific Basis for Management Options, pp. 1033-1041. University of California, Centers for Water and Wildland Resources, Davis, California.

Skinner, C. N., and C. Chang. 1996. Fire Regimes, Past and Present. In: Status of the Sierra Nevada, Sierra Nevada Ecosystem Project, Final Report to Congress, Vol. II, Assessments and Scientific Basis for Management Options, pp. 1041-1069. University of California, Centers for Water and Wildland Resources, Davis, California.

SNEP (Sierra Nevada Ecosystem Program). 1996. Fire and Fuels. Chapter 4 In: Status of the Sierra Nevada. Final Report to Congress, vol. I, Assessment Summaries and Management Strategies. University of California, Centers for Water and Wildland Resources, Davis, California.

This page intentionally left blank.

APPENDIX G-WQ1
WATER QUANTITY
CALSIM II MODELING RESULTS

G-WQ1.1 INTRODUCTION

Appendix G-WQ1 contains selected results of the CALSIM II modeling performed for the Oroville Facilities.

These tables include data on the modeled total release from Lake Oroville. They include flows in the Feather River and at various points, including the Low Flow Channel below Thermalito Diversion Dam, the High Flow Channel below the Thermalito Afterbay Outlet, and at Verona downstream, using the synthetic hydrology data developed for the period from 1922 through 1993. The tables also include modeled Lake Oroville pool elevations and storage volumes over the same period. Lastly, the tables provide information on both local Feather River Service Area (FRSA) water deliveries and south-of-Delta deliveries.

Data are presented for both the “Existing Conditions,” which for the modeling is year 2001 level of development, and “Future Conditions,” which for the modeling is year 2020 level of development.

G-WQ1.2 LIST OF TABLES AND FIGURES INCLUDED

The following tables of output data are included in this appendix:

The following figures representing output data are included in this appendix:

- Figure G-WQ1.2-1. Modeled FRSA and SWP South-of-Delta Water Supply Delivery, Existing Conditions
- Figure G-WQ1.2-2. Total Modeled FRSA and SWP South-of-Delta Water Supply Delivery, Existing Conditions
- Figure G-WQ1.2-3. Modeled FRSA and SWP South-of-Delta Water Supply Delivery, Future (2020) No-Action, Proposed Action, and Alternative 2 Conditions
- Figure G-WQ1.2-4. Total Modeled FRSA and SWP South-of-Delta Water Supply Delivery, Future (2020) No-Action, Proposed Action, and Alternative 2 Conditions
- Figure G-WQ1.2-5. End of Month Lake Oroville Elevation, Existing Conditions
- Figure G-WQ1.2-6. End of Month Lake Oroville Elevation Exceedance, Existing Conditions
- Figure G-WQ1.2-7. End of Month Lake Oroville Elevation, Future (2020) No-Action, Proposed Action, and Alternative 2 Conditions
- Figure G-WQ1.2-8. End of Month Lake Oroville Elevation Exceedance, Future (2020) No-Action, Proposed Action, and Alternative 2 Conditions
- Figure G-WQ1.2-9. Lake Oroville Total Release, Existing Conditions
- Figure G-WQ1.2-10. Lake Oroville Total Release, Future (2020) No-Action, Proposed Action, and Alternative 2 Conditions
- Figure G-WQ1.2-11. Low Flow Channel Flow, Existing Conditions
- Figure G-WQ1.2-12. Low Flow Channel Flow, Future (2020) No-Action and Proposed Action Conditions
- Figure G-WQ1.2-13. Low Flow Channel Flow, Future (2020) Alternative 2 Conditions
- Figure G-WQ1.2-14. Feather River Below Thermalito Afterbay, Existing Conditions
- Figure G-WQ1.2-15. Feather River Below Thermalito Afterbay, Future (2020) No-Action, Proposed Action, and Alternative 2 Conditions
- Figure G-WQ1.2-16. Feather River Flow at Verona, Existing Conditions
- Figure G-WQ1.2-17. Feather River Flow at Verona, Future (2020) No-Action, Proposed Action, and Alternative 2 Conditions

Table G-WQ1.2-1. Modeled FRSA water supply deliveries, existing conditions, 1922-1993 monthly flow (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	37	8	2	1	1	1	161	167	196	188	154	140	1,057
1923	14	6	2	1	1	17	125	195	204	208	170	101	1,046
1924	43	11	2	0	0	2	118	103	115	116	88	36	633
1925	2	1	0	0	0	1	105	167	205	216	171	119	988
1926	46	2	1	0	1	12	65	176	213	204	164	145	1,028
1927	16	4	1	1	1	1	135	177	195	203	166	146	1,046
1928	14	6	2	1	1	1	127	196	199	192	158	143	1,039
1929	47	4	1	0	0	1	177	186	163	207	157	62	1,007
1930	28	6	0	0	1	1	115	179	207	196	161	130	1,025
1931	49	7	1	0	0	7	123	87	105	121	93	38	632
1932	15	1	0	0	0	7	166	139	196	186	151	135	998
1933	51	4	1	0	0	3	198	149	195	197	150	60	1,009
1934	19	6	1	0	0	3	105	98	121	128	98	40	619
1935	11	2	1	0	0	1	70	192	222	211	173	139	1,023
1936	34	10	2	0	0	1	126	174	184	202	166	146	1,045
1937	52	14	2	0	0	1	123	193	179	190	156	145	1,054
1938	15	6	2	1	1	1	94	194	223	211	173	112	1,034
1939	16	8	2	1	5	34	203	143	190	182	149	116	1,048
1940	43	12	1	0	0	1	127	160	203	197	161	147	1,053
1941	15	8	2	1	1	1	70	164	224	217	176	139	1,018
1942	14	6	2	1	1	1	59	157	229	219	175	141	1,005
1943	50	8	2	1	1	1	86	186	204	196	161	146	1,042
1944	49	5	2	1	1	5	134	163	195	190	156	144	1,045
1945	17	6	2	0	1	1	150	162	200	196	161	147	1,042
1946	10	6	2	1	1	3	176	180	197	182	152	134	1,042
1947	50	6	2	0	0	1	132	178	183	193	145	143	1,033
1948	6	4	1	0	0	0	42	126	205	215	172	134	906
1949	44	5	1	0	0	0	144	165	195	184	149	135	1,024
1950	52	4	1	0	0	1	134	176	194	186	148	132	1,028
1951	9	5	1	1	1	8	172	153	201	189	154	142	1,038
1952	8	6	2	1	1	1	115	199	195	199	162	146	1,035
1953	59	8	2	1	1	7	117	169	193	196	149	147	1,047
1954	33	8	2	1	1	1	81	192	210	203	156	146	1,034
1955	51	6	2	0	1	14	134	180	189	179	145	120	1,019
1956	32	2	1	1	1	12	160	156	196	190	154	127	1,033
1957	18	10	2	1	1	1	158	168	221	209	169	65	1,024
1958	6	5	1	1	1	1	68	164	187	211	172	133	951
1959	50	13	2	1	1	6	175	187	198	186	151	71	1,043
1960	57	13	1	0	0	0	107	166	201	188	153	138	1,025
1961	46	3	1	0	0	1	129	184	183	189	152	134	1,022
1962	49	4	1	0	0	1	145	181	189	181	147	135	1,034
1963	7	5	2	1	1	1	55	176	226	219	175	136	1,005
1964	11	6	2	1	1	11	188	176	182	184	150	123	1,035
1965	16	5	1	1	1	9	125	200	206	194	130	143	1,032

Table G-WQ1.2-1. Modeled FRSA water supply deliveries, existing conditions, 1922-1993 monthly flow (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1966	52	6	1	1	1	8	170	177	184	173	141	130	1,045
1967	57	6	2	1	1	1	55	198	183	210	170	141	1,026
1968	54	8	2	1	1	1	142	184	184	188	141	139	1,044
1969	16	5	1	1	1	1	129	199	193	191	156	143	1,037
1970	26	9	2	1	1	1	153	193	181	186	151	139	1,043
1971	25	6	2	1	1	5	188	158	193	184	149	132	1,044
1972	50	6	2	1	1	16	179	172	182	179	145	106	1,036
1973	11	4	1	1	1	1	148	190	203	190	154	133	1,037
1974	9	7	2	1	1	1	119	206	211	169	164	145	1,038
1975	19	8	2	1	1	1	127	198	206	190	151	142	1,047
1976	11	8	2	1	3	53	185	183	201	202	130	57	1,037
1977	34	8	1	0	1	20	124	73	119	119	90	24	613
1978	13	0	0	0	1	1	79	205	226	214	172	95	1,007
1979	57	6	2	1	1	1	109	191	205	192	147	134	1,046
1980	12	6	2	1	1	1	152	189	196	192	154	138	1,044
1981	48	9	2	1	1	1	115	185	206	195	156	121	1,039
1982	7	5	1	1	1	1	91	204	211	219	174	98	1,015
1983	11	8	2	1	1	1	69	190	209	218	171	101	982
1984	40	7	2	1	1	3	159	192	194	186	135	131	1,051
1985	11	6	2	1	1	1	162	206	211	198	157	86	1,043
1986	47	7	2	0	0	1	128	194	207	197	159	103	1,045
1987	47	9	2	1	1	1	139	187	191	182	145	132	1,036
1988	38	5	1	0	0	10	90	89	111	108	87	77	617
1989	30	1	0	0	0	0	139	208	210	208	167	39	1,003
1990	14	10	2	0	0	1	190	117	201	192	154	133	1,013
1991	39	2	0	0	1	0	79	107	104	112	90	81	616
1992	17	3	0	0	0	0	109	197	180	194	157	141	998
1993	9	5	1	0	1	1	112	150	190	220	175	144	1,008
Avg =	29	6	1	1	1	4	127	171	192	190	152	119	994
Max =	59	14	2	1	5	53	203	208	229	220	176	147	1,057
Min =	2	0	0	0	0	0	42	73	104	108	87	24	613

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-2. Modeled FRSA water supply deliveries, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993 monthly flow (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	37	8	2	1	1	1	160	166	196	189	155	141	1,057
1923	15	6	2	1	1	18	123	194	203	208	170	103	1,044
1924	43	11	2	0	0	1	117	102	114	115	87	35	628
1925	1	1	0	0	0	1	104	168	205	216	173	122	991
1926	47	2	1	0	1	12	64	175	211	203	164	148	1,026
1927	16	4	1	1	1	1	133	176	195	203	166	149	1,046
1928	14	6	2	1	1	1	125	195	199	192	158	145	1,039
1929	49	4	1	0	0	2	176	186	163	207	158	63	1,009
1930	28	6	0	0	1	1	114	178	206	196	161	133	1,025
1931	50	4	1	0	0	7	122	87	106	121	93	39	631
1932	16	2	0	0	1	8	165	138	196	187	153	138	1,004
1933	53	4	1	0	0	3	196	149	195	197	151	61	1,012
1934	19	6	1	0	0	4	104	97	121	128	99	40	620
1935	11	2	1	0	1	1	69	191	221	211	173	143	1,024
1936	35	10	2	0	0	1	125	173	184	202	166	149	1,046
1937	53	14	2	0	0	1	121	191	177	189	155	144	1,046
1938	14	4	1	1	1	1	93	193	222	212	174	115	1,032
1939	16	6	2	1	4	34	201	142	189	181	149	117	1,044
1940	38	12	1	0	0	1	126	159	202	197	161	149	1,047
1941	18	8	2	1	1	1	70	164	224	217	178	142	1,025
1942	14	6	2	1	1	1	59	157	230	220	177	145	1,012
1943	51	8	2	1	1	1	85	184	203	195	161	149	1,041
1944	50	5	1	1	1	5	132	162	194	190	156	145	1,041
1945	17	5	2	1	1	1	149	161	199	195	160	150	1,040
1946	10	5	2	1	1	3	174	178	196	182	152	134	1,038
1947	51	5	2	0	0	0	130	177	182	192	145	143	1,028
1948	5	4	1	0	0	0	42	127	206	217	174	137	915
1949	46	10	2	0	0	0	143	164	195	184	150	137	1,031
1950	53	5	1	0	0	1	133	175	193	186	148	134	1,029
1951	9	5	2	1	1	8	170	152	201	189	154	144	1,038
1952	8	6	2	1	1	1	113	198	195	199	163	149	1,036
1953	57	8	2	1	1	7	115	168	192	196	149	149	1,044
1954	34	6	2	1	1	1	80	191	209	203	157	149	1,033
1955	51	6	2	0	1	14	133	180	189	179	145	122	1,021
1956	32	2	1	1	1	12	158	155	196	190	155	129	1,033
1957	18	10	2	1	1	1	157	168	221	209	170	67	1,024
1958	7	5	1	1	1	1	68	164	188	213	174	136	959
1959	51	10	2	1	1	7	173	186	198	187	151	72	1,039
1960	58	13	1	0	0	0	106	165	201	189	154	141	1,028
1961	47	3	1	0	0	1	128	183	183	189	152	135	1,023
1962	50	4	1	0	0	1	144	180	189	182	147	137	1,035
1963	8	5	2	1	1	1	55	176	227	219	177	140	1,012
1964	11	6	2	1	1	11	186	175	181	184	150	124	1,031

Table G-WQ1.2-2. Modeled FRSA water supply deliveries, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993 monthly flow (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1965	15	4	1	1	1	9	124	199	206	194	131	144	1,029
1966	52	4	1	1	1	8	168	176	183	173	141	131	1,040
1967	58	5	2	1	1	1	55	197	183	210	170	145	1,028
1968	55	8	2	1	1	1	141	183	183	188	142	141	1,045
1969	16	5	1	1	1	1	128	198	193	191	156	145	1,037
1970	26	9	2	1	1	1	151	193	181	187	152	141	1,043
1971	26	6	2	1	1	5	186	157	192	184	150	133	1,044
1972	50	6	2	1	1	16	177	171	181	179	145	107	1,035
1973	11	4	1	1	1	1	146	188	202	190	154	134	1,034
1974	9	7	2	1	1	1	118	205	210	169	165	149	1,038
1975	16	6	2	1	1	1	126	197	206	190	152	144	1,042
1976	11	6	2	1	2	54	184	183	200	202	131	58	1,033
1977	35	5	1	0	1	21	123	73	119	119	90	25	611
1978	13	0	0	0	1	1	79	206	225	215	173	97	1,010
1979	58	6	2	1	1	1	108	189	203	192	147	135	1,041
1980	12	5	2	1	1	1	150	187	195	192	154	139	1,040
1981	48	9	2	1	1	1	113	184	206	195	157	123	1,039
1982	7	5	1	1	1	1	91	205	212	219	176	100	1,021
1983	8	8	2	1	1	1	69	191	210	220	173	103	987
1984	40	7	2	1	1	3	158	192	194	186	135	133	1,051
1985	11	6	2	1	1	1	161	205	210	198	157	86	1,039
1986	44	5	2	0	1	1	127	193	206	197	159	104	1,038
1987	47	9	2	1	1	1	138	186	191	182	145	135	1,038
1988	39	6	1	0	0	10	90	89	112	109	88	79	624
1989	33	1	0	0	0	0	138	207	210	209	167	40	1,005
1990	14	10	2	0	0	1	188	116	201	192	155	136	1,014
1991	40	3	0	0	1	0	78	106	104	112	90	82	616
1992	18	3	0	0	0	0	108	196	179	194	158	144	1,000
1993	10	4	1	0	1	1	112	150	189	221	177	147	1,014
Avg =	30	6	1	1	1	5	126	170	191	190	152	121	994
Max =	58	14	2	1	4	54	201	207	230	221	178	150	1,057
Min =	1	0	0	0	0	0	42	73	104	109	87	25	611

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-3. Modeled south-of-Delta water supply deliveries existing conditions, 1922–1993 monthly flow (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	272	236	218	118	154	206	267	353	456	477	467	346	3,571
1923	245	214	201	168	193	225	283	376	482	504	492	370	3,755
1924	270	235	217	34	43	69	68	91	116	122	117	91	1,472
1925	67	58	53	26	38	113	133	179	228	238	230	177	1,539
1926	132	115	107	54	105	176	185	331	422	440	426	327	2,820
1927	244	213	199	82	159	218	280	371	476	498	488	364	3,592
1928	260	227	213	154	188	210	244	325	415	431	419	323	3,408
1929	240	209	193	33	47	63	85	113	144	151	146	113	1,539
1930	84	73	67	51	118	148	239	318	405	421	410	316	2,651
1931	235	204	191	28	50	55	84	113	143	150	145	113	1,510
1932	83	71	66	41	82	93	110	146	187	195	189	146	1,408
1933	109	95	87	52	83	84	110	147	187	195	189	146	1,485
1934	108	94	86	53	75	105	139	185	236	246	238	185	1,752
1935	138	119	110	20	84	116	270	418	533	557	548	421	3,334
1936	307	268	250	11	68	239	311	411	522	545	535	412	3,880
1937	304	265	244	29	59	143	280	371	474	494	484	368	3,515
1938	267	232	217	153	177	204	263	348	447	466	456	342	3,571
1939	247	214	199	166	192	214	259	344	442	458	445	341	3,521
1940	252	220	201	8	54	227	309	408	519	542	531	407	3,678
1941	299	262	245	125	157	183	235	308	395	410	400	304	3,323
1942	224	193	179	161	186	214	275	363	467	485	476	359	3,580
1943	263	225	210	165	189	216	265	351	450	466	453	346	3,599
1944	258	222	205	84	128	203	280	370	473	492	483	366	3,565
1945	268	232	217	72	88	206	295	388	496	516	507	386	3,672
1946	279	246	230	168	193	220	284	376	480	499	490	371	3,837
1947	273	235	220	63	67	102	241	320	407	422	410	318	3,079
1948	236	208	194	10	32	23	100	372	472	490	476	369	2,982
1949	282	243	226	47	51	67	174	232	294	306	297	230	2,448
1950	174	151	139	19	78	165	277	371	470	487	473	368	3,172
1951	276	242	225	167	197	228	287	383	488	507	496	378	3,874
1952	274	242	227	140	155	186	237	314	400	416	404	309	3,304
1953	233	199	184	173	198	220	288	385	489	508	497	380	3,754
1954	281	243	227	152	193	224	294	392	498	517	506	388	3,914
1955	288	248	232	58	96	101	123	168	213	221	214	166	2,128
1956	124	107	99	163	182	220	277	370	472	490	480	364	3,349
1957	268	235	216	160	193	204	247	330	420	435	421	325	3,455
1958	241	214	198	136	182	210	269	356	455	473	463	349	3,546
1959	258	224	205	170	188	223	259	345	439	454	441	341	3,548
1960	256	224	205	8	12	73	183	244	309	321	311	243	2,388
1961	184	159	148	51	65	102	226	301	382	396	384	299	2,697
1962	226	195	182	10	13	149	285	379	480	499	484	375	3,278
1963	279	246	230	137	186	203	282	374	477	496	486	368	3,765
1964	267	233	218	151	199	209	259	346	439	454	441	341	3,557
1965	257	223	208	141	185	198	243	323	412	426	413	317	3,345

Table G-WQ1.2-3. Modeled south-of-Delta water supply deliveries existing conditions, 1922–1993 monthly flow (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1966	236	204	190	169	194	226	284	378	481	499	488	371	3,721
1967	273	236	221	94	181	209	270	358	455	473	463	349	3,583
1968	255	219	205	173	191	211	263	351	446	461	447	345	3,567
1969	259	225	208	91	168	194	248	326	416	431	418	320	3,305
1970	242	209	192	168	193	215	285	377	483	499	488	370	3,723
1971	274	237	222	172	201	218	295	390	497	514	502	383	3,905
1972	284	246	230	148	170	199	224	297	379	390	378	291	3,236
1973	219	190	176	126	187	218	282	371	476	491	481	363	3,580
1974	265	233	218	165	189	218	281	370	475	491	480	363	3,748
1975	266	232	217	169	190	222	286	377	483	499	488	370	3,801
1976	271	238	221	164	168	199	232	307	392	405	391	302	3,288
1977	227	198	182	9	10	11	14	19	24	25	23	19	761
1978	14	12	10	11	145	199	256	336	424	442	426	326	2,601
1979	246	215	198	137	175	208	276	364	465	484	471	353	3,592
1980	256	224	210	117	160	196	251	330	417	434	419	320	3,334
1981	244	214	194	136	190	208	266	353	448	464	448	346	3,511
1982	259	228	213	155	179	206	267	353	451	469	456	341	3,577
1983	248	220	205	136	156	181	233	309	395	410	395	298	3,186
1984	221	192	178	167	185	222	282	376	480	498	485	365	3,652
1985	270	237	222	147	160	192	283	378	481	499	485	367	3,722
1986	273	238	223	18	63	220	251	336	427	442	427	328	3,246
1987	247	218	200	86	112	142	220	294	374	387	374	288	2,943
1988	216	189	176	11	57	36	34	46	59	62	58	46	991
1989	34	29	27	51	59	62	294	391	496	520	503	387	2,854
1990	292	256	237	11	42	53	80	106	135	142	136	106	1,597
1991	79	69	63	9	10	11	73	98	124	130	125	98	889
1992	73	64	58	23	24	74	119	159	203	212	204	158	1,373
1993	119	104	96	51	190	219	281	372	477	499	487	365	3,260
Avg =	226	197	183	96	130	167	230	310	396	411	400	306	3,051
Max =	307	268	250	173	201	239	311	418	533	557	548	421	3,914
Min =	14	12	10	8	10	11	14	19	24	25	23	19	761

Source: DWR, 2004 CALSIM II Modeling Results

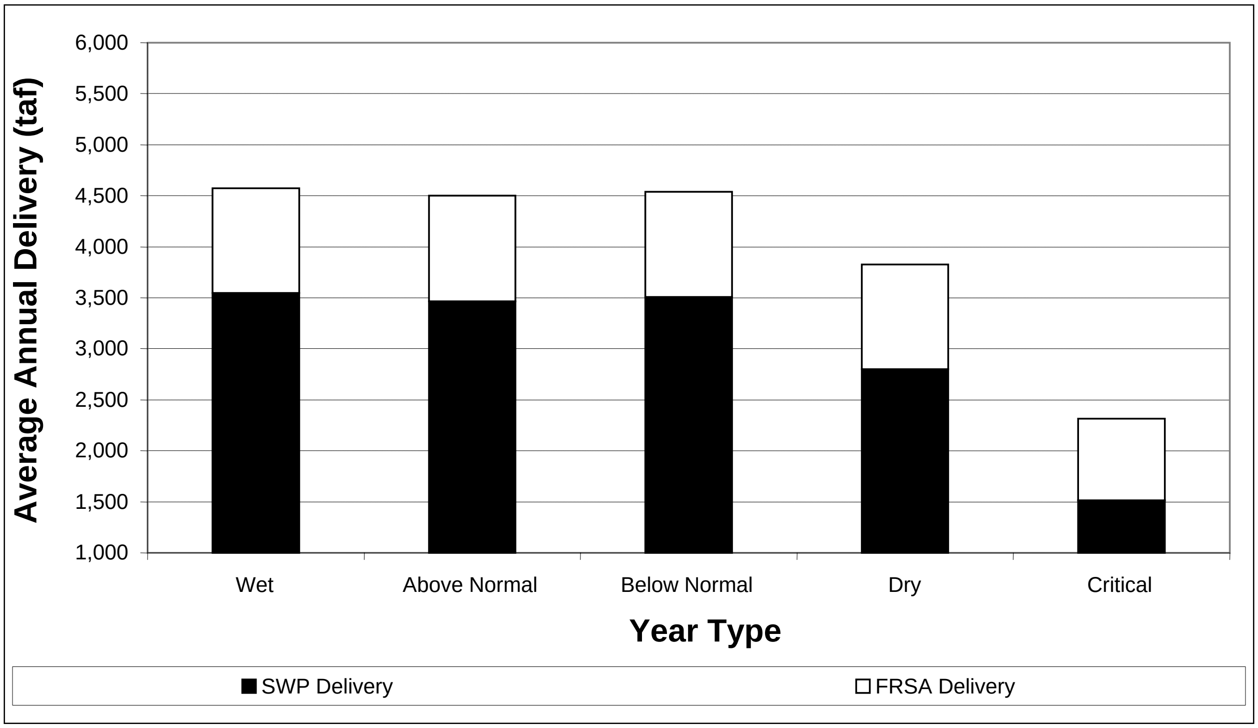
Table G-WQ1.2-4. Modeled south-of-Delta water supply deliveries, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993 monthly flow (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	296	252	252	141	184	320	372	403	475	548	543	395	4,181
1923	308	266	273	235	257	307	325	359	429	491	484	351	4,086
1924	275	236	234	26	33	60	52	58	70	79	77	57	1,258
1925	44	37	37	32	45	132	146	164	196	225	220	161	1,438
1926	126	108	110	68	108	179	176	287	342	392	385	280	2,564
1927	221	190	195	130	195	320	372	403	475	548	543	395	3,987
1928	306	264	271	157	206	238	283	307	367	419	413	301	3,531
1929	238	202	206	56	70	86	107	117	140	160	157	115	1,655
1930	90	77	77	64	141	174	260	282	335	384	379	276	2,538
1931	217	185	190	45	72	85	110	120	143	164	161	118	1,610
1932	91	77	78	65	124	145	161	175	210	239	236	173	1,775
1933	136	116	116	67	102	106	136	149	178	203	200	146	1,655
1934	114	98	98	65	97	132	159	173	207	236	232	170	1,781
1935	134	113	115	30	114	155	318	422	499	573	564	422	3,460
1936	329	282	289	20	89	311	391	421	492	566	554	421	4,165
1937	335	259	319	27	56	155	307	331	391	449	442	326	3,397
1938	257	220	226	221	258	306	357	388	459	526	522	381	4,121
1939	298	255	258	220	236	268	299	325	389	442	436	319	3,747
1940	251	214	86	13	57	282	404	433	506	577	556	432	3,812
1941	352	222	391	128	220	261	308	334	396	450	444	328	3,835
1942	260	222	225	219	237	281	334	366	438	497	494	357	3,932
1943	279	235	239	225	257	272	307	332	397	451	445	325	3,766
1944	258	217	217	102	134	249	320	349	418	475	470	341	3,551
1945	267	228	233	107	118	251	355	382	451	517	513	375	3,795
1946	294	254	260	222	240	263	326	353	420	480	474	345	3,931
1947	273	231	237	75	76	121	249	268	317	363	358	262	2,829
1948	205	179	183	22	61	48	158	396	462	534	526	390	3,163
1949	316	269	275	57	63	86	218	235	278	318	313	230	2,657
1950	184	157	159	25	100	193	335	362	426	488	481	354	3,264
1951	281	243	248	229	254	302	352	385	454	518	514	375	4,156
1952	289	252	258	203	210	258	302	331	391	444	437	323	3,699
1953	261	222	225	234	252	277	350	383	453	517	513	374	4,060
1954	293	251	257	171	230	286	360	392	461	527	523	383	4,134
1955	303	259	265	76	122	133	147	175	208	237	232	171	2,328
1956	133	114	116	218	250	308	357	389	458	524	520	380	3,765
1957	302	262	263	169	209	247	287	313	372	423	417	304	3,568
1958	237	208	211	165	227	287	346	380	451	513	509	370	3,904
1959	290	250	251	219	228	280	297	323	385	437	431	314	3,705
1960	249	213	210	14	28	113	239	258	303	347	342	252	2,569
1961	203	172	176	67	89	147	264	285	336	384	378	278	2,780
1962	222	189	193	21	31	198	352	379	444	510	503	370	3,413
1963	293	255	261	184	247	252	349	402	472	540	536	394	4,186
1964	307	265	271	152	223	224	263	287	341	387	381	278	3,380

Table G-WQ1.2-4. Modeled south-of-Delta water supply deliveries, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993 monthly flow (taf).

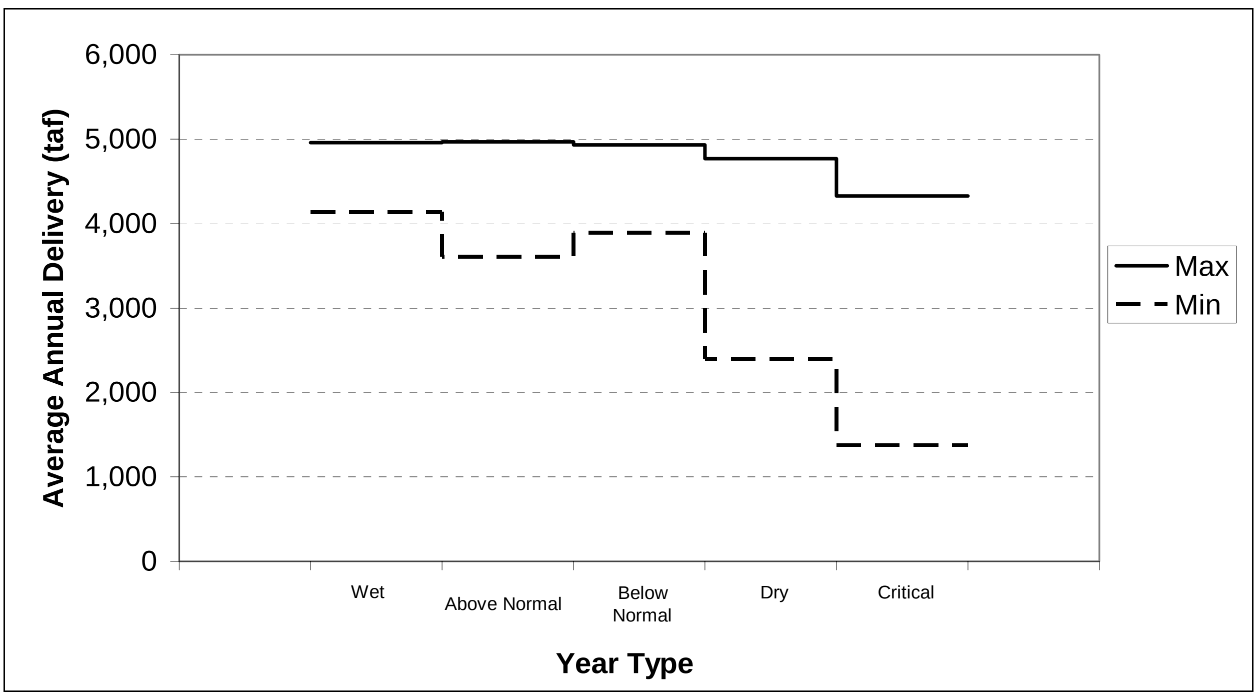
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1965	307	265	271	152	223	224	263	287	341	387	381	278	3,380
1966	230	196	195	233	250	299	337	367	434	495	488	356	3,880
1967	281	239	238	125	257	304	357	390	459	523	519	380	4,073
1968	296	252	258	237	248	264	306	334	397	450	443	324	3,808
1969	255	217	216	133	229	271	317	343	404	460	452	335	3,632
1970	271	232	233	229	247	271	347	378	452	511	506	368	4,046
1971	289	248	253	240	257	279	361	389	461	524	520	379	4,199
1972	297	254	260	172	204	235	246	267	320	361	355	259	3,231
1973	204	174	173	169	235	300	334	360	429	487	480	349	3,696
1974	275	239	244	236	254	300	354	383	455	517	512	372	4,141
1975	293	252	258	218	234	284	363	392	463	527	522	381	4,186
1976	297	257	262	203	200	243	252	273	327	371	364	265	3,314
1977	210	179	178	17	19	20	21	25	30	34	32	25	788
1978	19	16	15	22	174	267	375	396	452	525	505	390	3,155
1979	324	279	284	114	172	270	332	358	423	484	474	345	3,858
1980	272	235	241	141	190	271	314	337	395	453	443	326	3,618
1981	264	230	231	152	230	260	312	338	401	456	447	325	3,645
1982	256	223	228	230	247	293	347	378	448	511	505	365	4,030
1983	283	246	252	189	204	243	288	319	381	429	420	306	3,562
1984	242	206	209	234	243	298	349	383	454	517	510	369	4,013
1985	291	252	258	173	183	232	325	353	419	477	468	340	3,770
1986	270	233	238	29	87	307	282	307	364	414	406	295	3,230
1987	235	204	205	118	146	194	278	302	359	408	400	291	3,140
1988	229	198	202	37	95	82	80	89	106	120	117	86	1,440
1989	68	57	56	67	79	83	348	374	441	510	500	365	2,947
1990	292	252	257	18	56	75	101	110	131	151	147	108	1,697
1991	85	73	73	13	14	17	86	94	111	128	124	92	910
1992	73	63	62	32	32	104	156	169	200	230	225	165	1,512
1993	131	114	114	65	240	322	374	404	476	550	543	396	3,728
Avg =	240	204	209	125	164	218	279	309	366	418	412	302	3,247
Max =	352	282	391	240	258	322	404	433	506	577	564	432	4,199
Min =	19	16	15	13	14	17	21	25	30	34	32	25	788

Source: DWR, 2004 CALSIM II Modeling Results



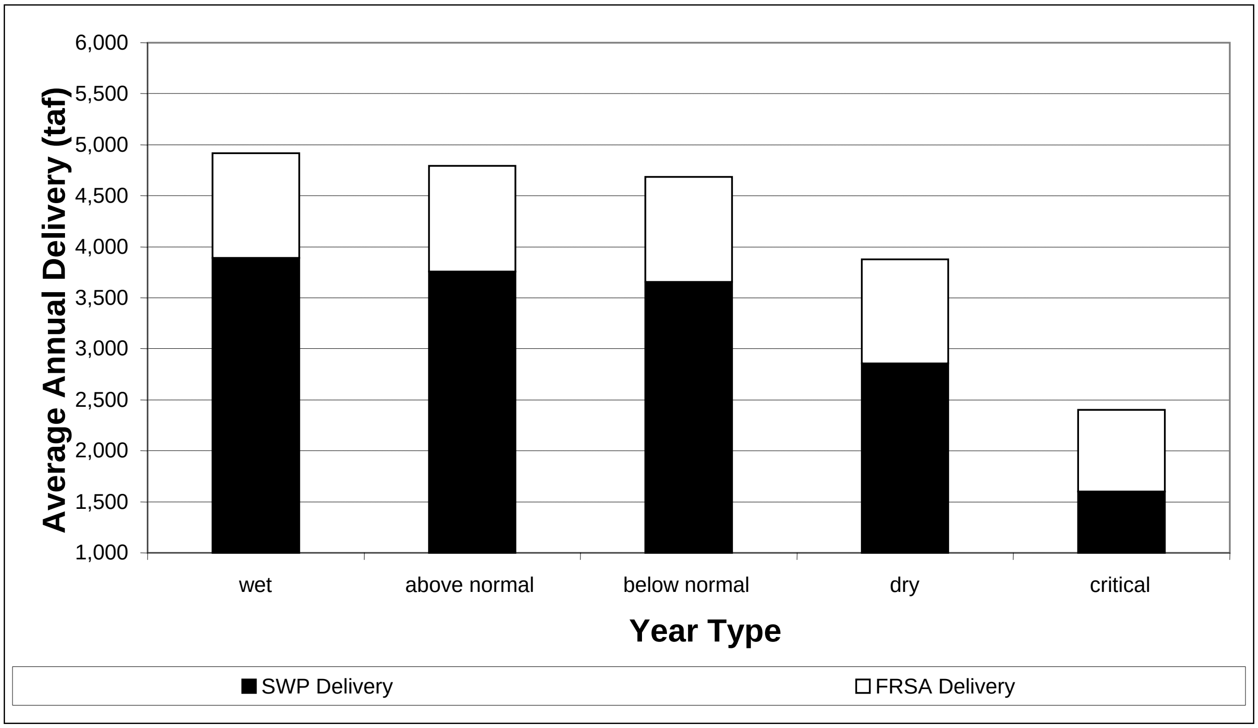
Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-1. Modeled FRSA and SWP south-of-Delta water supply delivery, existing conditions.



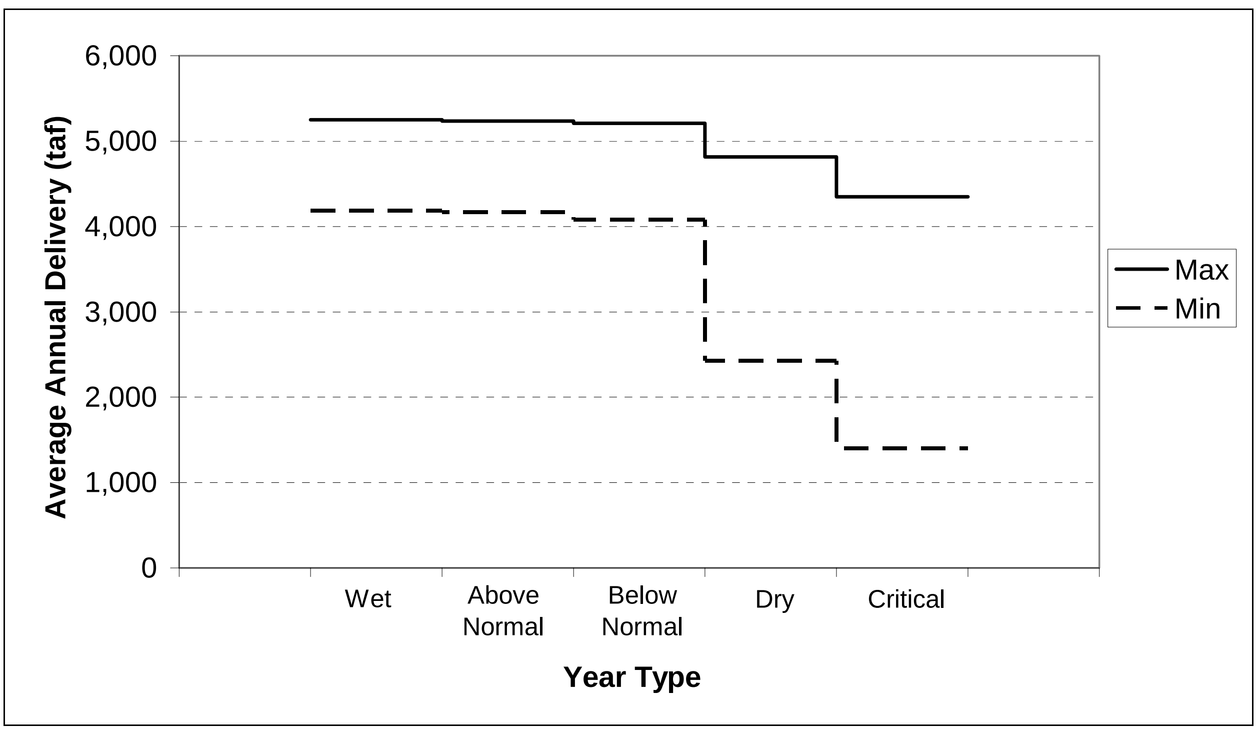
Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-2. Total modeled FRSA and SWP south-of-Delta water supply delivery, existing conditions.



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-3. Modeled FRSA and SWP south-of-Delta water supply delivery, future (2020) No-Action, Proposed Action, and Alternative 2 conditions.



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-4. Total modeled FRSA and SWP south-of-Delta water supply delivery, future (2020) No-Action, Proposed Action, and Alternative 2 conditions.

Table G-WQ1.2-5. End-of-month Lake Oroville storage, existing conditions, 1922–1993 (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	2,479	2,485	2,483	2,616	2,813	2,922	3,446	3,538	3,538	3,006	2,945	2,906
1923	2,947	2,998	2,922	2,976	3,089	3,163	3,459	3,538	3,326	2,868	2,432	2,366
1924	2,286	2,174	2,008	2,061	2,245	2,207	2,076	1,978	1,782	1,486	1,360	1,271
1925	1,278	1,323	1,369	1,507	2,123	2,274	2,564	2,693	2,414	1,988	1,874	1,811
1926	1,774	1,801	1,801	1,941	2,441	2,733	3,348	3,163	2,811	2,342	1,935	1,837
1927	1,725	2,040	2,028	2,330	2,788	2,999	3,396	3,538	3,538	3,212	2,794	2,706
1928	2,654	2,811	2,804	2,979	3,108	2,797	3,223	3,131	2,838	2,471	2,162	1,931
1929	1,766	1,733	1,728	1,778	1,894	2,031	2,070	2,051	1,905	1,711	1,555	1,457
1930	1,416	1,397	2,020	2,300	2,523	2,989	3,291	3,400	3,048	2,546	2,166	2,020
1931	1,974	1,901	1,761	1,895	2,021	2,222	2,144	2,101	1,871	1,443	1,210	1,097
1932	961	944	907	1,110	1,295	1,619	1,896	2,225	1,993	1,845	1,750	1,666
1933	1,569	1,544	1,567	1,668	1,756	1,718	1,783	1,878	1,828	1,652	1,521	1,465
1934	1,424	1,423	1,435	1,662	1,812	2,086	2,065	1,995	1,819	1,631	1,455	1,267
1935	1,165	1,213	1,277	1,511	1,706	1,982	2,991	3,338	2,987	2,430	1,987	1,728
1936	1,537	1,446	1,243	1,754	2,531	2,934	3,324	3,504	3,345	2,762	2,313	2,210
1937	2,089	1,985	1,738	1,779	1,950	2,302	2,683	3,020	2,763	2,377	1,991	1,880
1938	1,825	2,004	2,867	2,924	2,788	2,788	3,277	3,538	3,538	3,261	3,233	3,241
1939	3,163	3,163	3,163	3,134	3,163	3,133	2,978	2,892	2,526	2,072	1,549	1,310
1940	1,082	980	896	1,401	2,392	2,788	3,238	3,293	2,956	2,363	1,938	1,896
1941	1,894	1,866	2,378	2,788	2,788	2,918	3,334	3,538	3,396	2,962	2,924	2,901
1942	2,955	3,045	2,788	2,788	2,806	3,058	3,281	3,538	3,538	3,134	2,997	2,971
1943	2,993	3,085	2,966	2,788	2,890	2,937	3,350	3,506	3,374	3,014	2,616	2,573
1944	2,587	2,629	2,628	2,730	2,898	3,069	3,086	3,310	3,024	2,511	2,090	1,820
1945	1,650	1,723	1,891	2,053	2,657	2,951	3,185	3,440	3,123	2,552	2,131	2,032
1946	2,023	2,111	2,758	3,007	3,064	3,063	3,372	3,509	3,153	2,608	2,185	2,062
1947	1,901	1,958	2,048	2,113	2,390	2,719	2,806	2,716	2,475	1,954	1,510	1,291
1948	1,240	1,239	1,170	1,483	1,542	1,739	2,396	2,858	2,971	2,455	2,034	1,941
1949	1,864	1,847	1,861	1,914	1,996	2,283	2,590	2,788	2,466	2,134	1,803	1,709
1950	1,642	1,650	1,672	1,954	2,415	2,859	3,350	3,538	3,263	2,709	2,270	2,204
1951	2,253	2,788	2,866	2,846	2,925	3,105	3,332	3,538	3,225	2,735	2,323	2,278
1952	2,279	2,336	2,788	2,788	2,832	2,988	3,452	3,538	3,538	3,538	3,535	3,350
1953	3,163	3,163	2,918	2,809	3,059	3,059	3,284	3,538	3,538	3,227	3,151	3,117
1954	3,146	3,115	3,163	2,918	2,903	2,943	3,292	3,045	2,812	2,319	1,978	1,781
1955	1,770	1,793	1,886	2,014	2,102	2,229	2,335	2,514	2,234	1,953	1,837	1,756
1956	1,680	1,661	2,788	2,788	2,788	3,018	3,427	3,538	3,453	3,015	2,893	2,882
1957	2,956	3,041	3,136	3,116	2,847	2,990	2,950	3,234	2,986	2,637	2,289	2,280
1958	2,297	2,342	2,563	2,860	2,788	2,788	3,235	3,538	3,538	3,303	3,277	3,256
1959	3,163	3,163	3,163	2,978	2,839	3,054	3,115	3,086	2,651	2,166	1,713	1,625
1960	1,417	1,315	1,085	1,211	1,810	2,375	2,459	2,557	2,282	1,959	1,829	1,674
1961	1,573	1,609	1,703	1,817	2,116	2,376	2,436	2,500	2,385	1,863	1,402	1,200
1962	994	921	1,008	1,131	1,702	2,050	2,506	2,676	2,448	1,965	1,468	1,219
1963	1,889	2,016	2,382	2,682	3,057	2,927	3,180	3,538	3,335	2,993	2,626	2,595
1964	2,600	2,775	2,823	2,975	3,108	3,163	3,012	2,942	2,720	2,145	1,666	1,438
1965	1,264	1,278	2,788	2,788	2,997	3,096	3,354	3,416	3,473	3,118	2,828	2,799
1966	2,852	2,943	2,946	3,015	3,100	3,163	3,459	3,314	2,974	2,439	2,021	1,759

Table G-WQ1.2-5. End-of-month Lake Oroville storage, existing conditions, 1922–1993 (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1967	1,569	1,679	2,048	2,684	2,951	2,847	3,236	3,538	3,538	3,538	3,505	3,350
1968	3,162	3,162	3,141	2,922	2,962	3,036	3,006	3,096	2,724	2,311	1,984	1,778
1969	1,714	1,774	1,996	2,788	2,788	3,027	3,470	3,538	3,538	3,140	3,119	3,122
1970	3,162	3,162	2,806	2,787	2,787	3,163	3,057	3,101	2,836	2,282	1,942	1,751
1971	1,725	1,990	2,406	2,780	3,077	3,162	3,433	3,538	3,538	3,048	2,967	2,942
1972	3,008	3,101	3,029	3,088	3,058	3,163	3,321	3,364	3,011	2,659	2,315	2,249
1973	2,203	2,364	2,642	2,788	2,788	2,951	3,262	3,538	3,179	2,661	2,281	2,190
1974	2,217	2,788	2,800	2,870	3,009	2,788	3,292	3,538	3,466	3,390	3,395	3,338
1975	3,163	3,163	3,163	3,163	2,884	2,833	3,270	3,538	3,522	3,155	3,152	3,119
1976	3,140	3,163	3,163	3,163	3,162	3,163	3,076	2,944	2,679	2,136	1,818	1,627
1977	1,496	1,410	1,235	1,217	1,201	1,196	1,062	1,006	796	514	391	374
1978	314	339	544	1,451	1,966	2,859	3,218	3,520	3,468	2,905	2,856	2,878
1979	2,909	2,968	3,025	3,111	2,843	3,001	3,143	3,426	3,018	2,633	2,286	2,155
1980	2,209	2,266	2,389	2,813	2,788	3,028	3,282	3,465	3,264	2,755	2,668	2,599
1981	2,575	2,599	2,728	2,875	3,075	3,024	3,187	3,118	2,769	2,310	1,962	1,766
1982	1,755	2,685	2,788	2,943	2,987	2,936	3,303	3,538	3,538	3,178	3,154	3,189
1983	3,149	2,981	2,930	2,854	2,788	2,788	3,208	3,538	3,538	3,538	3,538	3,351
1984	3,163	2,950	2,788	3,091	3,078	3,120	3,286	3,430	3,135	2,639	2,393	2,202
1985	2,253	2,460	2,622	2,714	2,905	3,117	3,271	3,045	2,699	2,115	1,607	1,437
1986	1,269	1,197	1,265	1,590	2,790	2,788	3,135	3,213	3,050	2,516	2,057	2,120
1987	2,151	2,241	2,259	2,274	2,435	2,758	2,598	2,454	2,218	1,830	1,377	1,156
1988	1,016	1,046	1,381	1,631	1,704	1,796	1,827	1,751	1,575	1,360	1,210	1,134
1989	1,125	1,288	1,384	1,450	1,590	2,785	3,167	3,016	2,652	2,115	1,641	1,509
1990	1,475	1,488	1,257	1,391	1,468	1,727	1,684	1,698	1,614	1,395	1,281	1,202
1991	1,168	1,159	1,160	1,158	1,173	1,562	1,759	1,888	1,829	1,680	1,595	1,568
1992	1,565	1,548	1,572	1,611	1,872	2,116	2,252	2,135	1,922	1,702	1,478	1,277
1993	1,271	1,206	1,370	1,951	2,462	2,964	3,456	3,538	3,538	2,997	2,616	2,558
Avg =	2,043	2,097	2,195	2,345	2,520	2,699	2,946	3,050	2,859	2,464	2,197	2,091
Max =	3,163	3,163	3,163	3,163	3,163	3,163	3,470	3,538	3,538	3,538	3,538	3,351
Min =	314	339	544	1,110	1,173	1,196	1,062	1,006	796	514	391	374

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-6. End-of-month Lake Oroville storage, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993 (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	2,463	2,468	2,490	2,624	2,813	2,922	3,446	3,538	3,538	2,978	2,953	2,913
1923	2,954	3,005	2,922	2,976	3,089	3,163	3,459	3,500	3,267	2,729	2,338	2,145
1924	2,016	1,905	1,686	1,738	1,923	1,896	1,826	1,678	1,461	1,185	1,064	991
1925	999	1,044	1,112	1,250	1,865	2,004	2,293	2,422	2,147	1,765	1,677	1,611
1926	1,558	1,585	1,592	1,731	2,231	2,523	3,148	3,000	2,686	2,226	1,794	1,676
1927	1,666	1,981	1,970	2,271	2,788	2,999	3,396	3,538	3,538	3,130	2,677	2,586
1928	2,443	2,600	2,596	2,771	2,950	2,797	3,224	3,141	2,831	2,485	2,139	1,925
1929	1,834	1,801	1,795	1,845	1,961	2,098	2,138	2,119	1,955	1,756	1,592	1,522
1930	1,455	1,435	1,952	2,233	2,453	2,919	3,236	3,350	3,069	2,556	2,136	1,967
1931	1,926	1,951	1,944	2,078	2,204	2,405	2,317	2,240	1,955	1,579	1,337	1,219
1932	1,163	1,163	1,149	1,353	1,538	1,868	2,150	2,479	2,234	1,859	1,761	1,674
1933	1,583	1,497	1,520	1,621	1,709	1,723	1,789	1,925	1,868	1,684	1,541	1,472
1934	1,432	1,395	1,384	1,611	1,762	2,036	2,018	1,950	1,771	1,575	1,416	1,252
1935	1,176	1,225	1,289	1,522	1,718	1,993	3,003	3,120	2,826	2,260	1,811	1,701
1936	1,537	1,446	1,231	1,742	2,520	2,922	3,314	3,495	3,298	2,706	2,245	2,139
1937	1,930	1,826	1,552	1,593	1,764	2,116	2,498	2,838	2,581	2,244	1,907	1,796
1938	1,743	1,923	2,819	2,924	2,788	2,788	3,277	3,538	3,538	3,009	2,989	2,995
1939	3,057	3,132	3,163	3,134	3,163	3,133	3,037	2,817	2,562	2,090	1,613	1,395
1940	1,213	1,111	930	1,435	2,426	2,788	3,238	3,268	2,818	2,278	1,814	1,770
1941	1,626	1,597	2,109	2,679	2,788	2,918	3,334	3,538	3,349	2,795	2,757	2,731
1942	2,785	2,875	2,788	2,788	2,806	3,058	3,281	3,538	3,538	3,330	2,997	2,968
1943	2,989	3,085	2,966	2,788	2,890	2,937	3,350	3,518	3,377	3,042	2,601	2,555
1944	2,569	2,611	2,604	2,706	2,875	3,069	3,133	3,360	2,991	2,452	2,041	1,777
1945	1,599	1,672	1,840	2,002	2,606	2,899	3,135	3,386	3,081	2,517	2,087	1,984
1946	1,976	2,064	2,711	3,007	3,060	3,063	3,373	3,488	3,128	2,576	2,119	1,885
1947	1,754	1,780	1,869	1,935	2,211	2,540	2,659	2,582	2,468	1,959	1,589	1,427
1948	1,441	1,461	1,426	1,739	1,822	2,019	2,676	3,137	3,287	2,697	2,302	2,154
1949	1,956	1,887	1,848	1,900	1,982	2,269	2,577	2,777	2,477	2,177	1,877	1,781
1950	1,730	1,689	1,631	1,913	2,374	2,817	3,310	3,513	3,246	2,652	2,195	2,127
1951	2,176	2,744	2,866	2,846	2,925	3,105	3,323	3,538	3,363	2,763	2,310	2,138
1952	2,094	2,151	2,629	2,788	2,832	2,988	3,452	3,538	3,538	3,299	3,297	3,261
1953	3,163	3,163	2,918	2,809	3,059	3,059	3,284	3,538	3,538	3,199	2,857	2,820
1954	2,849	2,981	3,111	2,918	2,903	2,943	3,292	3,032	2,789	2,301	2,024	1,782
1955	1,688	1,711	1,804	1,932	2,020	2,146	2,243	2,423	2,165	1,907	1,764	1,681
1956	1,605	1,585	2,788	2,788	2,788	3,018	3,427	3,538	3,453	2,937	2,632	2,620
1957	2,694	2,779	2,874	2,984	2,847	2,990	2,968	3,252	2,989	2,596	2,203	2,193
1958	2,210	2,255	2,475	2,776	2,788	2,788	3,235	3,538	3,538	3,144	3,117	3,093
1959	3,107	3,163	3,163	2,978	2,839	3,054	3,139	3,101	2,658	2,186	1,815	1,769
1960	1,572	1,470	1,292	1,418	2,017	2,582	2,702	2,801	2,522	2,143	1,764	1,649
1961	1,597	1,632	1,729	1,843	2,142	2,407	2,490	2,535	2,322	1,949	1,553	1,365
1962	1,165	1,146	1,234	1,357	1,928	2,276	2,734	2,886	2,601	1,990	1,539	1,294
1963	1,965	2,091	2,457	2,758	3,057	2,927	3,180	3,538	3,315	2,926	2,555	2,521
1964	2,526	2,701	2,748	2,901	3,033	3,145	2,906	3,001	2,766	2,186	1,744	1,556
1965	1,419	1,433	2,788	2,788	2,997	3,096	3,354	3,429	3,326	3,033	2,687	2,658
1966	2,711	2,876	2,946	3,015	3,100	3,163	3,459	3,314	2,937	2,412	2,076	1,797

Table G-WQ1.2-6. End-of-month Lake Oroville storage, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993 (taf).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1967	1,607	1,718	2,087	2,723	2,951	2,847	3,236	3,538	3,538	3,514	3,481	3,350
1968	3,162	3,162	3,141	2,922	2,962	3,036	3,017	3,107	2,725	2,329	2,077	1,871
1969	1,818	1,877	2,100	2,788	2,788	3,027	3,470	3,538	3,538	3,061	3,044	3,045
1970	3,148	3,162	2,806	2,787	2,787	3,163	3,063	3,109	2,784	2,236	1,949	1,737
1971	1,692	1,957	2,373	2,746	3,028	3,162	3,433	3,538	3,538	3,055	2,696	2,669
1972	2,736	2,828	2,951	3,088	3,058	3,163	3,322	3,401	3,039	2,637	2,236	2,169
1973	2,123	2,284	2,561	2,788	2,788	2,951	3,254	3,538	3,159	2,634	2,218	2,126
1974	2,155	2,788	2,800	2,870	3,009	2,788	3,292	3,538	3,475	3,072	2,940	2,902
1975	2,926	3,022	3,093	3,163	2,884	2,833	3,271	3,538	3,445	2,947	2,769	2,735
1976	2,779	2,936	3,077	3,163	3,162	3,163	3,077	2,946	2,676	2,160	1,883	1,728
1977	1,630	1,570	1,434	1,416	1,400	1,396	1,258	1,168	959	668	541	517
1978	456	481	686	1,594	2,108	2,944	3,218	3,519	3,422	2,772	2,724	2,744
1979	2,775	2,833	2,644	2,850	2,843	3,001	3,182	3,466	3,063	2,659	2,289	2,176
1980	2,225	2,283	2,407	2,813	2,788	3,028	3,284	3,468	3,428	2,828	2,740	2,670
1981	2,645	2,670	2,799	2,946	3,075	3,024	3,188	3,168	2,803	2,310	2,027	1,835
1982	1,799	2,730	2,788	2,943	2,987	2,936	3,303	3,538	3,538	3,013	2,987	3,020
1983	3,137	2,981	2,930	2,854	2,788	2,788	3,208	3,538	3,538	3,538	3,538	3,351
1984	3,163	2,950	2,788	3,091	3,078	3,120	3,274	3,419	3,086	2,561	2,339	2,173
1985	2,118	2,325	2,487	2,579	2,770	3,005	3,209	2,985	2,632	1,995	1,524	1,384
1986	1,266	1,244	1,313	1,638	2,836	2,788	3,136	3,216	2,994	2,394	2,336	2,397
1987	2,428	2,518	2,536	2,552	2,712	3,035	2,880	2,750	2,487	2,024	1,588	1,377
1988	1,235	1,264	1,600	1,850	1,923	2,031	2,063	2,065	1,846	1,631	1,475	1,412
1989	1,365	1,528	1,624	1,690	1,830	2,788	3,171	3,007	2,612	2,056	1,601	1,552
1990	1,471	1,485	1,234	1,368	1,445	1,704	1,662	1,677	1,592	1,308	1,187	1,092
1991	1,072	1,073	1,075	1,072	1,087	1,476	1,673	1,803	1,732	1,573	1,489	1,455
1992	1,458	1,442	1,466	1,505	1,766	2,009	2,146	2,030	1,830	1,607	1,439	1,222
1993	1,224	1,207	1,371	1,952	2,463	2,964	3,456	3,538	3,538	2,945	2,612	2,549
Avg =	2,010	2,075	2,179	2,341	2,523	2,702	2,952	3,055	2,857	2,428	2,153	2,050
Max =	3,163	3,163	3,163	3,163	3,163	3,163	3,470	3,538	3,538	3,538	3,538	3,351
Min =	456	481	686	1,072	1,087	1,396	1,258	1,168	959	668	541	517

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-7. End-of-month Lake Oroville elevation, existing conditions, 1922–1993 (feet msl).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	824	825	825	835	850	858	894	900	900	864	860	857
1923	860	864	858	862	870	875	895	900	886	854	821	815
1924	808	798	783	788	805	801	790	780	761	729	713	702
1925	703	709	715	731	794	807	831	841	819	781	770	764
1926	760	763	763	777	821	844	888	875	850	813	776	767
1927	755	786	785	812	848	864	891	900	900	879	849	842
1928	838	850	850	862	872	849	879	873	852	824	797	776
1929	759	756	755	761	772	785	789	787	773	754	736	725
1930	720	718	784	809	828	863	884	891	867	830	798	784
1931	780	773	759	772	784	803	796	792	770	724	694	678
1932	658	655	643	680	705	744	772	803	782	767	758	749
1933	738	735	738	749	758	754	761	771	766	747	733	726
1934	721	721	723	748	764	790	789	782	765	745	725	702
1935	688	694	703	731	753	781	863	887	863	820	781	755
1936	734	724	698	758	829	859	886	898	888	847	811	802
1937	791	781	756	761	778	810	840	865	847	816	782	771
1938	765	783	854	859	848	848	883	900	900	882	880	881
1939	875	875	875	873	875	873	862	856	828	789	736	707
1940	676	661	646	718	817	848	880	884	861	815	776	772
1941	772	769	816	848	848	858	887	900	891	861	859	857
1942	861	867	848	848	850	868	883	900	900	873	864	862
1943	863	870	862	848	856	859	888	898	889	865	835	832
1944	833	836	836	844	857	869	870	885	866	827	791	765
1945	747	755	772	787	839	860	877	894	873	830	795	785
1946	785	793	846	864	868	868	889	898	875	835	799	788
1947	773	778	787	793	817	843	850	843	824	778	731	705
1948	698	698	689	728	735	757	818	854	862	822	786	777
1949	769	768	769	774	782	808	833	849	823	795	763	753
1950	746	747	749	778	819	854	888	900	882	842	807	801
1951	805	848	854	853	859	871	887	900	880	845	811	808
1952	808	813	848	848	852	863	895	900	900	900	900	888
1953	875	875	858	850	868	868	884	900	900	880	875	872
1954	874	872	875	858	857	860	884	867	850	811	780	761
1955	760	762	771	784	792	803	812	827	804	778	767	758
1956	750	748	848	848	848	865	893	900	895	865	856	855
1957	861	867	873	872	853	863	860	880	863	837	808	808
1958	809	813	831	854	848	848	880	900	900	885	883	882
1959	875	875	875	862	852	868	872	870	838	798	754	744
1960	720	708	677	694	764	816	823	831	808	779	766	750
1961	739	743	753	765	793	816	821	826	817	769	719	693
1962	663	639	665	683	753	787	827	840	822	779	726	695
1963	772	784	816	840	868	859	877	900	887	863	836	834
1964	834	848	851	862	872	875	865	860	843	796	749	723
1965	701	703	848	848	864	871	888	892	896	872	851	849

Table G-WQ1.2-7. End-of-month Lake Oroville elevation, existing conditions, 1922–1993 (feet msl).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1966	853	860	860	865	871	875	895	886	862	821	784	759
1967	738	750	787	841	860	853	880	900	900	900	898	888
1968	875	875	874	858	861	867	864	871	844	810	781	761
1969	754	760	782	848	848	866	896	900	900	874	872	873
1970	875	875	850	848	848	875	868	871	852	808	777	758
1971	755	782	818	848	869	875	893	900	900	867	862	860
1972	865	871	866	870	868	875	886	889	865	839	811	805
1973	801	815	837	848	848	860	882	900	876	839	808	800
1974	802	848	849	855	865	848	884	900	895	891	891	887
1975	875	875	875	875	856	852	883	900	899	875	875	872
1976	874	875	875	875	875	875	869	860	840	795	765	744
1977	730	720	697	695	693	692	673	665	630	572	539	534
1978	511	523	579	724	779	854	879	899	896	857	854	855
1979	857	862	866	872	853	864	874	893	865	837	808	797
1980	802	807	817	850	848	866	883	895	882	846	839	834
1981	832	834	844	855	869	866	877	872	847	810	779	759
1982	758	841	848	860	863	859	885	900	900	876	875	877
1983	874	863	859	853	848	848	878	900	900	900	900	888
1984	875	860	848	870	869	872	884	893	873	837	817	801
1985	805	823	836	843	857	872	883	867	842	793	742	723
1986	702	692	701	740	849	848	873	879	867	827	788	794
1987	796	804	806	807	821	846	834	822	802	766	716	687
1988	666	671	716	745	753	762	766	758	739	713	694	684
1989	682	704	716	724	740	848	876	865	838	793	746	731
1990	727	729	700	717	726	755	751	752	743	718	703	693
1991	688	687	687	687	689	737	759	772	766	750	741	738
1992	738	736	738	743	770	793	805	795	775	753	728	703
1993	702	694	715	778	823	861	895	900	900	864	835	831
Avg =	777	782	791	807	824	839	857	864	849	818	794	783
Max =	875	875	875	875	875	875	896	900	900	900	900	888
Min =	511	523	579	680	689	692	673	665	630	572	539	534

Source: DWR, 2004 CALSIM II Modeling Results

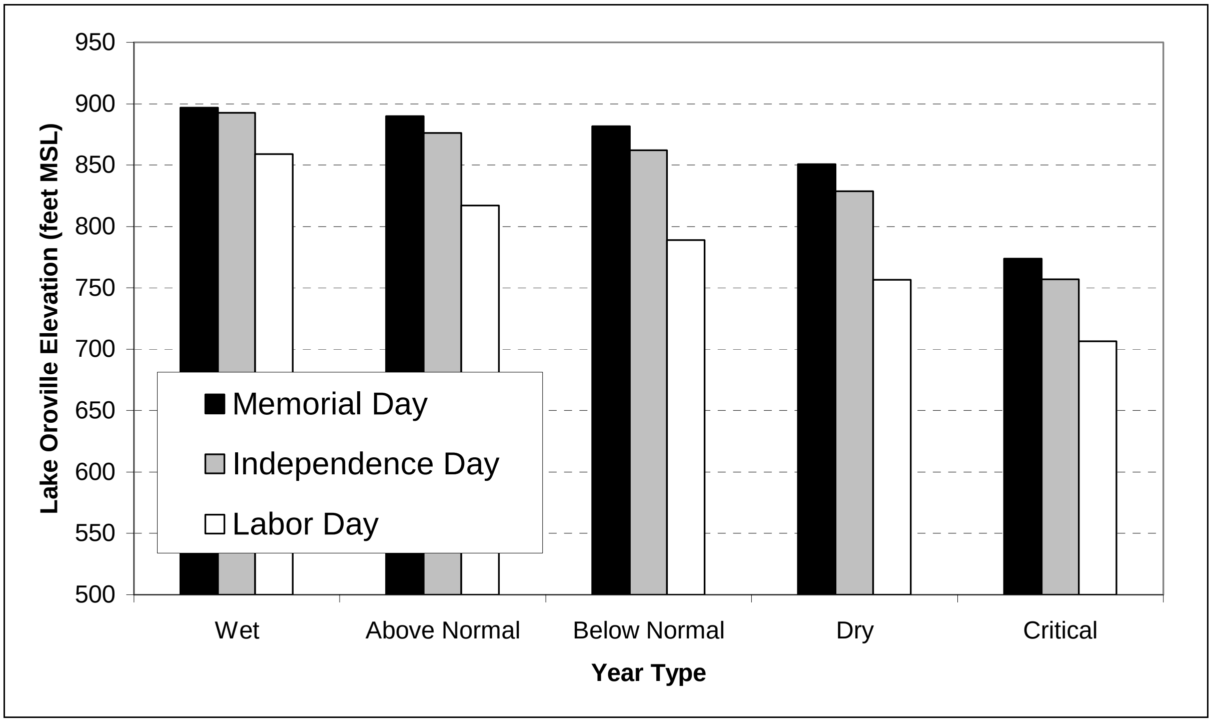
Table G-WQ1.2-8. End-of-month Lake Oroville elevation, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993 (feet msl).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1922	823	824	825	836	850	858	894	900	900	862	861	858
1923	861	864	858	862	870	875	895	898	882	844	813	796
1924	784	773	751	756	775	772	765	750	726	691	674	663
1925	664	671	681	699	769	783	809	820	796	759	750	743
1926	737	740	741	756	803	828	874	864	841	803	762	750
1927	749	781	780	807	848	864	891	900	900	873	840	833
1928	821	834	834	847	860	849	879	874	852	825	795	775
1929	766	763	762	767	779	792	795	793	778	758	741	733
1930	725	723	778	804	822	858	880	888	869	831	795	779
1931	775	778	777	790	801	818	811	804	778	739	711	695
1932	688	688	686	713	735	770	796	824	804	769	759	750
1933	740	730	733	744	753	755	762	775	770	751	735	727
1934	722	718	716	743	759	786	784	778	760	739	720	700
1935	690	696	704	733	754	782	864	872	851	806	764	753
1936	734	724	697	757	828	858	886	897	884	842	805	795
1937	776	765	736	741	759	793	826	852	833	805	773	762
1938	757	775	851	859	848	848	883	900	900	865	863	864
1939	868	873	875	873	875	873	867	851	831	791	743	718
1940	694	680	637	723	820	848	880	882	851	808	764	760
1941	744	741	793	840	848	858	887	900	888	849	846	844
1942	848	855	848	848	850	868	883	900	900	887	864	862
1943	863	870	862	848	856	859	888	899	890	867	834	830
1944	832	835	834	842	855	869	873	889	863	822	786	760
1945	741	749	767	783	835	857	873	890	870	827	791	781
1946	780	788	843	864	868	868	889	897	873	832	793	771
1947	758	761	770	776	802	829	839	833	823	778	740	722
1948	723	726	721	757	765	784	840	874	884	842	810	797
1949	778	772	768	773	781	807	832	848	824	799	771	761
1950	756	751	745	774	816	851	885	898	881	838	800	794
1951	799	845	854	853	859	871	886	900	889	847	810	795
1952	791	796	836	848	852	863	895	900	900	885	884	882
1953	875	875	858	850	868	868	884	900	900	878	854	851
1954	853	863	872	858	857	860	884	866	849	810	785	761
1955	751	754	763	776	784	796	805	820	798	773	759	750
1956	742	740	848	848	848	865	893	900	895	859	837	836
1957	841	848	855	863	853	863	862	881	863	834	801	800
1958	802	806	824	848	848	848	880	900	900	874	872	870
1959	871	875	875	862	852	868	874	871	839	800	764	760
1960	738	727	705	720	784	833	842	849	828	796	759	747
1961	741	745	756	767	796	818	825	829	811	778	736	714
1962	688	685	697	713	776	807	844	856	834	781	735	705
1963	779	791	823	846	868	859	877	900	886	859	830	828
1964	828	842	845	857	866	874	857	864	847	799	757	737

Table G-WQ1.2-8. End-of-month Lake Oroville elevation, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993 (feet msl).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1965	721	722	848	848	864	871	888	893	886	866	841	839
1966	843	855	860	865	871	875	895	885	859	819	789	762
1967	742	754	791	844	860	853	880	900	900	898	896	888
1968	875	875	874	858	861	867	865	871	844	812	790	770
1969	765	771	792	848	848	866	896	900	900	868	867	867
1970	874	875	850	848	848	875	868	872	848	804	778	756
1971	752	778	816	845	866	875	893	900	900	868	841	839
1972	845	851	860	870	868	875	886	891	867	837	804	798
1973	794	808	831	848	848	860	882	900	875	837	802	794
1974	797	848	849	855	865	848	884	900	896	869	860	857
1975	859	866	871	875	856	852	883	900	894	860	847	844
1976	848	859	869	875	875	875	869	860	840	797	771	755
1977	745	738	722	720	718	718	700	688	658	606	578	572
1978	557	564	609	741	793	860	879	899	893	847	844	845
1979	847	852	837	853	853	864	877	895	868	839	809	799
1980	803	808	818	850	848	866	884	896	893	851	845	839
1981	838	839	849	860	869	866	877	876	850	810	785	766
1982	763	844	848	860	863	859	885	900	900	865	863	865
1983	874	863	859	853	848	848	878	900	900	900	900	888
1984	875	860	848	870	869	872	883	892	870	831	813	798
1985	793	812	825	832	847	864	878	863	837	782	733	716
1986	702	699	707	746	852	848	873	879	864	817	812	818
1987	820	828	829	830	843	866	855	846	825	785	740	715
1988	697	701	742	768	775	785	788	789	767	745	727	720
1989	714	733	744	751	766	848	876	864	835	788	742	736
1990	727	729	697	714	724	753	748	750	741	707	691	678
1991	675	675	675	675	677	727	750	763	756	739	729	725
1992	725	723	726	731	759	783	796	785	766	742	723	696
1993	696	694	715	778	823	861	895	900	900	860	835	830
Avg =	776	781	791	808	824	839	858	865	850	816	791	780
Max =	875	875	875	875	875	875	896	900	900	900	900	888
Min =	557	564	609	675	677	718	700	688	658	606	578	572

Source: DWR, 2004 CALSIM II Modeling Results

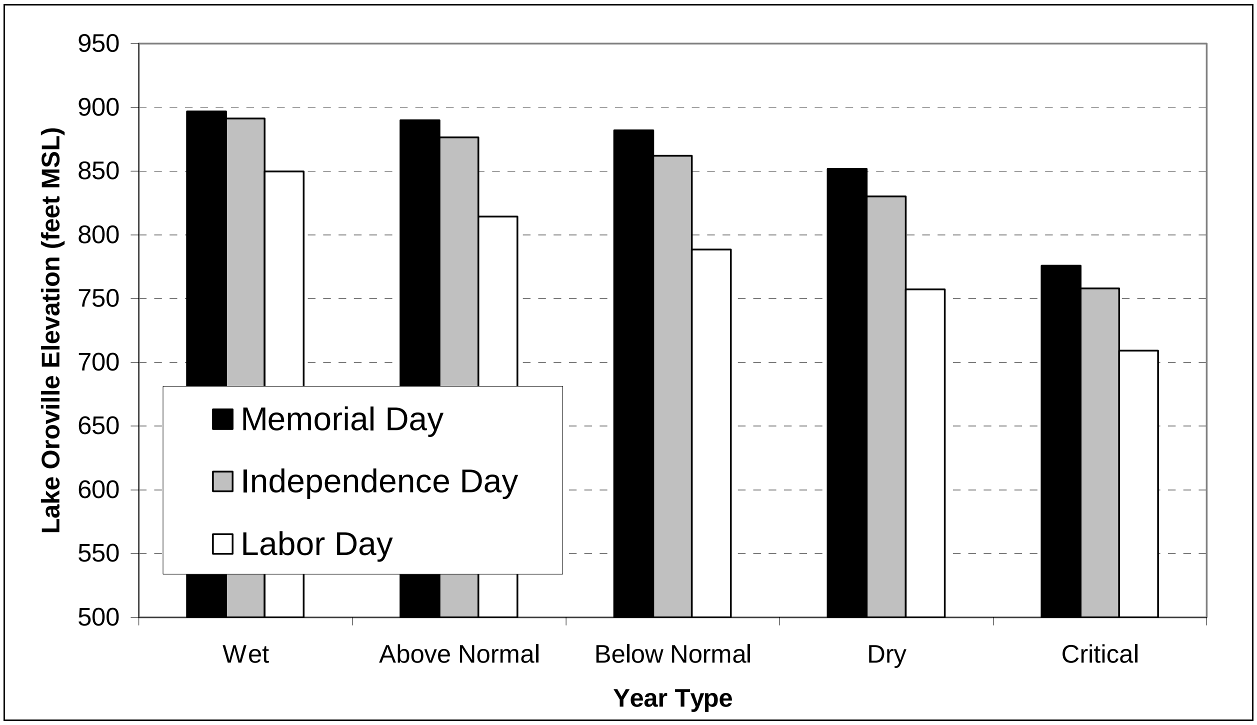


Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-5. End of month Lake Oroville elevation, existing conditions.

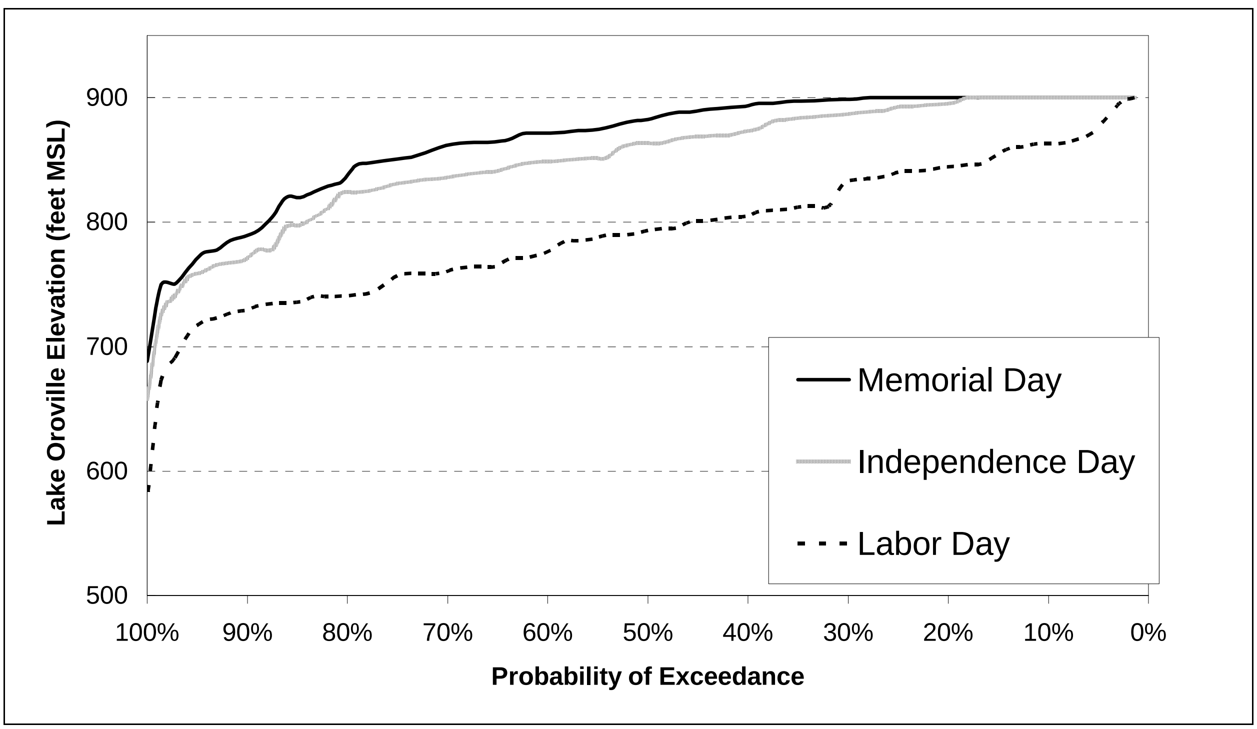
Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-6. End of month Lake Oroville elevation exceedance, existing conditions.



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-7. End of month Lake Oroville elevation, future (2020) No-Action, Proposed Action, and Alternative 2 conditions.



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-8. End of month Lake Oroville elevation exceedance, future (2020) No-Action, Proposed Action, and Alternative 2 conditions.

Table G-WQ1.2-9. Lake Oroville elevation, existing conditions Memorial Day 1922–1993.

Probability of Exceedance	Elevation (feet msl)	Probability of Exceedance	Elevation (feet msl)
1%	900	51%	884
3%	900	53%	880
4%	900	54%	879
6%	900	56%	875
7%	900	57%	873
8%	900	58%	872
10%	900	60%	871
11%	900	61%	871
13%	900	63%	870
14%	900	64%	867
15%	900	65%	867
17%	900	67%	865
18%	900	68%	865
19%	900	69%	860
21%	900	71%	860
22%	900	72%	856
24%	900	74%	854
25%	900	75%	849
26%	900	76%	843
28%	900	78%	841
29%	900	79%	840
31%	900	81%	831
32%	899	82%	827
33%	898	83%	826
35%	898	85%	822
36%	898	86%	803
38%	895	88%	795
39%	894	89%	792
40%	893	90%	787
42%	893	92%	782
43%	892	93%	780
44%	891	94%	772
46%	889	96%	771
47%	887	97%	758
49%	886	99%	752
50%	885	100%	665

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-10. Lake Oroville elevation, existing conditions Independence Day 1922–1993.

Probability of Exceedance	Elevation (feet msl)
1%	900
3%	900
4%	900
6%	900
7%	900
8%	900
10%	900
11%	900
13%	900
14%	900
15%	900
17%	900
18%	900
19%	899
21%	896
22%	896
24%	895
25%	895
26%	891
28%	889
29%	888
31%	887
32%	886
33%	882
35%	882
36%	880
38%	876
39%	875
40%	873
42%	873
43%	867
44%	867
46%	866
47%	865
49%	865
50%	863

Probability of Exceedance	Elevation (feet msl)
51%	863
53%	862
54%	862
56%	861
57%	852
58%	852
60%	850
61%	850
63%	847
64%	847
65%	844
67%	843
68%	842
69%	840
71%	838
72%	838
74%	828
75%	824
76%	823
78%	822
79%	819
81%	817
82%	808
83%	804
85%	802
86%	782
88%	775
89%	773
90%	770
92%	766
93%	766
94%	765
96%	761
97%	743
99%	739
100%	630

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-11. Lake Oroville elevation, existing conditions Labor Day 1922–1993.

Probability of Exceedance	Elevation (feet msl)	Probability of Exceedance	Elevation (feet msl)
1%	900	51%	788
3%	900	53%	786
4%	898	54%	784
6%	891	56%	782
7%	883	57%	781
8%	880	58%	781
10%	875	60%	780
11%	875	61%	779
13%	875	63%	777
14%	872	64%	776
15%	864	65%	776
17%	862	67%	770
18%	860	68%	767
19%	859	69%	766
21%	856	71%	765
22%	854	72%	763
24%	851	74%	758
25%	849	75%	754
26%	839	76%	749
28%	836	78%	746
29%	835	79%	742
31%	835	81%	741
32%	821	82%	736
33%	817	83%	736
35%	811	85%	733
36%	811	86%	731
38%	811	88%	728
39%	808	89%	726
40%	808	90%	725
42%	808	92%	719
43%	807	93%	716
44%	799	94%	713
46%	798	96%	703
47%	797	97%	694
49%	795	99%	694
50%	791	100%	539

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-12. Lake Oroville elevation, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, Memorial Day, 1922-1993.

Probability of Exceedance	Elevation (feet msl)	Probability of Exceedance	Elevation (feet msl)
1%	900	51%	881
3%	900	53%	879
4%	900	54%	876
6%	900	56%	874
7%	900	57%	874
8%	900	58%	872
10%	900	60%	872
11%	900	61%	871
13%	900	63%	871
14%	900	64%	866
15%	900	65%	864
17%	900	67%	864
18%	900	68%	864
19%	900	69%	863
21%	900	71%	860
22%	900	72%	856
24%	900	74%	852
25%	900	75%	851
26%	900	76%	849
28%	900	78%	848
29%	899	79%	846
31%	899	81%	833
32%	898	82%	829
33%	898	83%	824
35%	897	85%	820
36%	897	86%	820
38%	896	88%	804
39%	895	89%	793
40%	893	90%	789
42%	892	92%	785
43%	891	93%	778
44%	890	94%	775
46%	889	96%	763
47%	888	97%	750
49%	885	99%	750
50%	882	100%	688

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-13. Lake Oroville elevation, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, Independence Day, 1922-1993.

Probability of Exceedance	Elevation (feet msl)	Probability of Exceedance	Elevation (feet msl)
1%	900	51%	835
3%	900	53%	834
4%	900	54%	833
6%	900	56%	831
7%	900	57%	828
8%	900	58%	825
10%	900	60%	824
11%	900	61%	823
13%	900	63%	811
14%	900	64%	804
15%	900	65%	798
17%	900	67%	796
18%	900	68%	778
19%	896	69%	778
21%	895	71%	770
22%	894	72%	767
24%	893	74%	766
25%	893	75%	760
26%	890	76%	756
28%	889	78%	741
29%	888	79%	726
31%	886	81%	658
32%	886	82%	0
33%	884	83%	0
35%	884	85%	0
36%	882	86%	0
38%	881	88%	0
39%	875	89%	0
40%	873	90%	0
42%	870	92%	0
43%	870	93%	0
44%	869	94%	0
46%	868	96%	0
47%	867	97%	0
49%	864	99%	0
50%	863	100%	0

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-14. Lake Oroville elevation, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, Labor Day, 1922-1993.

Probability of Exceedance	Elevation (feet msl)
1%	900
3%	896
4%	884
6%	872
7%	867
8%	864
10%	863
11%	863
13%	861
14%	860
15%	854
17%	847
18%	846
19%	845
21%	844
22%	841
24%	841
25%	840
26%	837
28%	835
29%	834
31%	830
32%	813
33%	813
35%	812
36%	810
38%	810
39%	809
40%	805
42%	804
43%	802
44%	801
46%	800
47%	795
49%	795
50%	793

Probability of Exceedance	Elevation (feet msl)
51%	791
53%	790
54%	789
56%	786
57%	785
58%	785
60%	778
61%	773
63%	771
64%	771
65%	764
67%	764
68%	764
69%	762
71%	759
72%	759
74%	759
75%	757
76%	750
78%	743
79%	742
81%	741
82%	740
83%	740
85%	736
86%	735
88%	735
89%	733
90%	729
92%	727
93%	723
94%	720
96%	711
97%	691
99%	674
100%	578

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-15. Lake Oroville total release, existing conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	3,493	2,565	3,448	1,518	4,040	4,626	3,495	18,978	9,295	12,135	3,667	3,001
1923	1,843	1,728	6,326	4,750	1,515	3,676	3,613	4,418	6,856	9,170	8,587	2,410
1924	2,270	2,623	3,524	1,603	1,528	2,996	5,031	3,687	5,205	6,085	3,432	2,578
1925	833	841	1,097	759	754	2,532	2,165	3,057	7,738	8,579	3,543	2,453
1926	1,571	884	1,790	697	710	727	1,692	7,047	8,213	9,202	8,159	2,904
1927	2,779	918	4,077	700	12,147	6,935	6,543	6,337	4,735	8,279	9,257	3,095
1928	1,832	1,728	2,725	1,521	3,919	24,816	2,758	7,124	7,819	8,317	6,812	5,122
1929	3,535	1,693	1,640	1,612	1,560	1,585	3,373	4,874	5,389	4,706	3,921	2,693
1930	1,435	1,058	1,908	697	2,643	561	2,908	3,731	8,891	9,751	7,736	3,680
1931	1,632	2,543	3,546	789	796	713	4,459	3,267	5,935	8,226	5,093	2,900
1932	3,054	1,404	4,231	761	729	1,915	3,175	2,627	8,301	4,003	3,142	2,693
1933	2,467	1,418	837	806	814	4,687	3,695	3,530	4,801	4,504	3,517	1,992
1934	1,481	925	2,383	743	2,421	611	4,244	3,810	5,032	4,371	4,195	4,174
1935	2,431	852	804	742	775	600	1,884	5,647	10,912	10,793	8,845	5,542
1936	4,037	2,595	4,759	1,506	1,440	1,529	2,751	3,400	6,771	11,076	8,886	3,069
1937	2,808	2,655	5,186	1,630	1,514	1,529	2,731	3,686	8,671	7,880	7,900	3,059
1938	1,826	1,595	2,076	5,144	14,359	19,226	14,276	19,855	11,317	8,731	3,504	2,542
1939	4,038	2,967	3,255	3,661	2,655	5,199	7,273	4,261	8,366	8,822	9,915	5,133
1940	4,539	2,623	2,900	1,001	969	14,487	5,525	5,106	9,258	12,366	9,275	3,126
1941	1,864	2,543	1,537	4,131	17,461	11,296	4,619	10,666	8,613	10,810	3,441	2,985
1942	1,804	1,695	16,888	14,192	17,466	2,630	11,198	7,823	9,162	10,560	5,223	3,016
1943	2,252	2,762	8,564	18,602	7,325	15,925	5,252	3,754	7,239	8,903	8,994	3,117
1944	2,274	1,705	1,643	1,584	1,478	2,738	5,513	3,700	8,589	10,024	8,562	5,868
1945	3,682	1,673	1,537	1,512	1,501	1,526	3,133	3,211	9,484	11,392	8,721	3,137
1946	1,765	1,604	1,537	4,012	4,194	6,325	3,525	4,459	9,568	11,480	9,084	3,514
1947	3,658	1,837	1,537	1,612	1,499	1,517	4,000	4,475	6,829	10,011	8,821	4,947
1948	2,400	1,522	2,495	1,001	1,696	845	1,449	2,679	4,654	11,710	8,926	2,937
1949	2,240	1,701	1,574	1,622	1,600	1,559	2,783	3,006	8,286	7,102	6,957	2,716
1950	1,868	898	846	693	707	562	2,878	5,227	9,452	11,743	9,414	2,925
1951	1,680	2,134	14,612	11,507	10,677	4,466	3,815	3,216	8,967	10,592	9,062	3,083
1952	2,440	1,656	1,964	8,749	11,978	6,936	18,980	22,848	11,668	4,969	3,235	5,678
1953	5,619	2,890	8,938	20,841	1,515	6,091	6,072	5,485	8,277	9,177	4,168	3,143
1954	2,075	4,431	2,865	9,623	8,410	9,982	7,182	10,511	7,908	10,748	8,000	5,693
1955	2,567	1,701	1,537	1,545	1,595	1,772	2,958	3,554	8,025	6,255	3,510	2,720
1956	2,108	1,666	8,198	20,823	11,184	6,426	5,421	12,858	8,589	11,394	4,722	2,841
1957	1,840	1,763	1,617	3,728	15,755	6,766	6,766	3,311	8,729	8,384	7,613	1,871
1958	1,679	1,688	1,531	1,587	23,504	11,763	8,490	12,679	9,337	8,029	3,380	2,927
1959	4,115	2,988	3,307	9,770	9,361	2,116	4,636	5,140	9,862	9,683	8,947	2,944
1960	4,296	2,644	5,083	1,094	930	755	5,268	3,266	7,598	7,073	3,620	3,866
1961	2,609	1,159	1,164	1,084	969	887	4,027	3,862	5,120	10,181	9,159	4,632
1962	4,287	2,480	755	806	657	517	3,543	4,101	8,727	9,818	9,723	5,532
1963	1,103	1,039	986	1,688	11,544	8,109	13,696	5,457	8,564	8,726	8,350	2,945
1964	1,725	1,570	1,493	1,477	1,421	2,781	8,144	6,166	6,884	10,838	9,339	5,075
1965	3,686	1,635	3,427	18,949	4,652	5,152	9,336	7,983	4,057	8,806	7,450	3,028
1966	2,282	2,781	3,427	3,302	1,661	4,252	3,425	6,946	7,669	11,047	8,727	5,530
1967	3,923	1,609	1,539	1,504	4,666	14,247	2,768	11,876	11,057	4,360	3,380	5,148
1968	5,897	2,713	3,473	7,933	11,573	6,449	6,833	3,594	9,061	9,048	7,778	5,629
1969	2,926	1,583	1,528	11,496	12,367	6,318	9,203	15,399	6,408	9,345	3,212	3,052
1970	2,943	3,770	16,215	35,711	10,502	3,980	6,596	3,686	6,487	10,769	7,904	5,607
1971	2,654	1,599	1,534	1,516	1,484	12,218	6,304	10,579	8,197	11,636	4,416	2,881

Table G-WQ1.2-15. Lake Oroville total release, existing conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1972	2,313	1,555	4,690	3,767	6,366	6,831	3,531	3,946	7,567	7,017	7,264	2,616
1973	1,730	1,572	1,511	9,005	9,946	5,948	3,434	4,572	8,664	9,681	7,782	2,948
1974	1,653	5,103	10,038	20,369	5,602	26,162	9,959	8,484	8,478	5,391	3,274	3,440
1975	4,977	3,413	2,728	2,882	13,054	12,729	2,726	10,847	9,267	9,080	3,065	3,015
1976	2,029	3,832	3,814	3,414	3,904	4,190	3,832	4,014	5,325	9,246	5,818	4,662
1977	2,929	2,508	3,547	1,190	1,213	1,285	3,193	2,006	4,188	5,173	3,508	1,934
1978	1,958	902	809	678	693	577	4,740	3,886	5,589	10,897	3,477	2,376
1979	1,932	1,130	1,199	3,112	11,575	4,304	3,876	3,693	9,643	8,491	7,703	3,718
1980	1,681	1,767	1,677	13,646	17,951	5,136	3,095	3,575	6,539	10,639	3,091	2,942
1981	2,427	1,749	1,534	1,601	2,219	6,762	2,646	4,354	7,996	8,612	6,874	5,133
1982	2,493	1,082	17,222	8,118	17,776	13,216	20,115	10,723	6,636	9,622	3,379	2,400
1983	4,208	8,583	10,782	12,469	21,512	31,803	9,605	14,416	14,608	5,785	3,742	6,485
1984	5,550	14,494	24,126	5,383	8,392	8,843	4,315	3,643	8,926	10,890	6,099	5,544
1985	1,650	1,545	1,486	1,648	1,527	1,871	4,664	7,432	7,417	11,483	9,412	4,265
1986	4,644	2,526	1,499	1,460	20,960	21,700	2,751	3,717	6,345	11,039	9,661	2,471
1987	2,423	1,428	1,378	1,667	1,577	1,497	5,843	3,920	4,534	6,607	7,713	5,216
1988	4,380	2,342	975	956	961	1,387	2,109	3,493	4,071	4,291	3,335	2,681
1989	2,070	799	682	655	668	513	2,676	5,900	8,180	10,231	9,401	3,613
1990	3,054	2,525	6,128	775	781	644	4,069	2,351	3,711	4,681	3,226	2,803
1991	2,358	1,464	1,488	866	885	541	1,725	2,102	2,747	3,972	2,712	2,517
1992	1,238	1,352	865	767	692	500	2,195	3,611	4,335	4,522	4,763	5,067
1993	1,937	2,442	732	650	665	11,596	4,954	9,631	6,980	12,204	8,897	3,229
Avg =	2,692	2,238	3,872	4,853	5,771	6,026	5,215	6,198	7,615	8,766	6,353	3,614
Max =	5,897	14,494	24,126	35,711	23,504	31,803	20,115	22,848	14,608	12,366	9,915	6,485
Min =	833	799	682	650	657	500	1,449	2,006	2,747	3,972	2,712	1,871

Source: DWR, 2004 CALSIM II Modeling Results

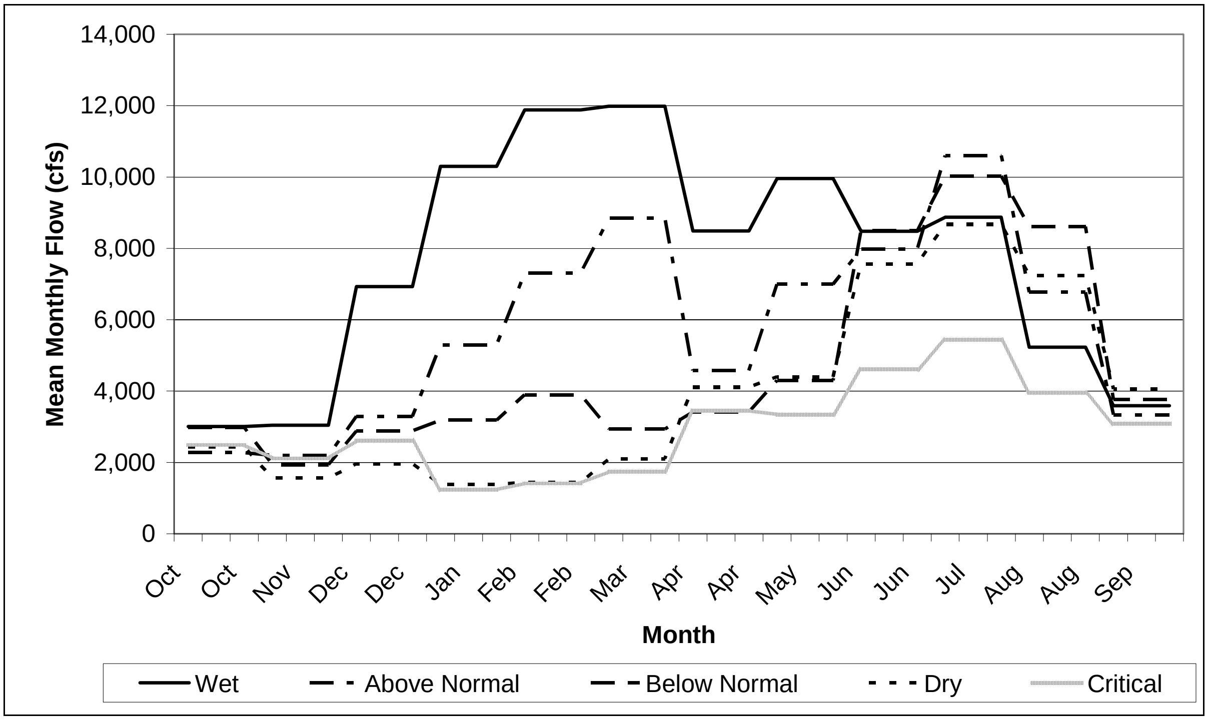
Table G-WQ1.2-16. Lake Oroville total release, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	3,759	2,565	3,059	1,517	4,177	4,626	3,496	18,979	9,295	12,590	3,077	3,030
1923	1,847	1,728	6,430	4,750	1,515	3,676	3,613	5,045	7,212	10,470	7,864	4,544
1924	3,057	2,613	4,379	1,601	1,527	2,808	4,015	4,499	5,576	5,771	3,371	2,310
1925	823	834	735	759	754	2,743	2,157	3,065	7,687	7,881	3,142	2,496
1926	1,834	882	1,677	697	709	730	1,530	6,445	7,569	9,074	8,558	3,251
1927	1,129	912	4,060	703	11,097	6,935	6,543	6,337	4,735	9,619	9,823	3,148
1928	3,314	1,728	2,669	1,518	3,053	22,241	2,740	6,981	8,100	7,981	7,413	4,828
1929	2,349	1,694	1,640	1,614	1,561	1,587	3,351	4,892	5,682	4,790	4,046	2,221
1930	1,863	1,058	3,633	697	2,673	561	2,667	3,637	7,716	9,919	8,395	4,056
1931	1,552	896	1,394	790	798	718	4,619	3,810	6,877	7,375	5,213	2,997
1932	1,754	1,119	3,843	762	731	1,808	3,101	2,621	8,519	7,675	3,183	2,744
1933	2,371	2,452	840	806	815	3,842	3,672	2,856	4,931	4,627	3,714	2,204
1934	1,454	1,545	2,756	743	2,390	613	4,204	3,772	5,083	4,513	3,921	3,762
1935	2,000	852	804	743	776	601	1,868	9,396	9,961	10,948	8,951	3,033
1936	3,606	2,595	4,943	1,506	1,441	1,529	2,730	3,384	7,416	11,223	9,073	3,123
1937	4,237	2,659	5,617	1,629	1,513	1,527	2,702	3,657	8,670	7,094	7,113	3,047
1938	1,807	1,577	1,532	4,368	14,359	19,226	14,276	19,855	11,318	12,831	3,391	2,581
1939	1,756	1,711	2,749	3,661	2,655	5,199	6,276	6,447	6,494	9,116	9,172	4,775
1940	3,793	2,620	4,482	1,002	969	15,041	5,526	5,523	11,157	11,503	9,916	3,161
1941	4,182	2,543	1,537	1,519	15,506	11,296	4,619	10,666	9,404	12,755	3,465	3,036
1942	1,808	1,695	14,115	14,192	17,466	2,630	11,198	7,823	9,161	7,354	8,420	3,068
1943	2,269	2,692	8,564	18,602	7,325	15,925	5,252	3,549	7,407	8,479	9,706	3,159
1944	2,280	1,710	1,727	1,583	1,476	2,354	4,724	3,655	9,975	10,455	8,408	5,748
1945	3,828	1,668	1,535	1,514	1,502	1,525	3,106	3,287	9,282	11,280	8,881	3,180
1946	1,763	1,601	1,536	3,247	4,272	6,255	3,495	4,828	9,643	11,582	9,645	5,394
1947	3,163	2,360	1,535	1,612	1,498	1,517	3,476	4,254	4,707	9,821	7,595	3,989
1948	1,347	1,172	1,950	1,002	1,291	846	1,448	2,689	4,014	12,919	8,483	3,855
1949	4,193	2,578	2,454	1,622	1,600	1,560	2,765	2,995	7,912	6,580	6,434	2,752
1950	1,606	1,733	2,141	694	708	561	2,858	4,987	9,323	12,389	9,711	2,956
1951	1,684	1,585	13,890	11,507	10,677	4,466	3,970	3,073	6,652	12,372	9,735	5,211
1952	3,175	1,656	1,537	6,155	11,978	6,936	18,981	22,848	11,668	8,854	3,240	3,177
1953	4,167	2,890	8,938	20,841	1,515	6,091	6,073	5,486	8,277	9,648	8,500	3,175
1954	2,086	1,688	1,537	8,775	8,410	9,982	7,182	10,716	8,080	10,680	6,965	6,442
1955	3,903	1,701	1,537	1,545	1,596	1,778	3,121	3,544	7,643	5,885	3,958	2,755
1956	2,123	1,670	6,960	20,823	11,184	6,426	5,421	12,859	8,588	12,655	7,705	2,867
1957	1,846	1,766	1,617	1,609	13,373	6,766	6,468	3,299	8,989	9,110	8,341	1,896
1958	1,680	1,689	1,531	1,519	21,997	11,763	8,490	12,678	9,337	10,613	3,410	2,975
1959	2,375	2,052	3,307	9,770	9,361	2,116	4,228	5,292	9,993	9,463	7,627	2,233
1960	4,111	2,647	4,241	1,094	931	756	4,661	3,256	7,638	7,978	7,672	3,192
1961	1,824	1,165	1,108	1,084	970	804	3,648	4,178	6,764	7,749	8,107	4,399
1962	4,178	1,569	754	807	659	517	3,506	4,392	9,673	11,903	8,972	5,453
1963	1,105	1,041	987	1,676	12,914	8,109	13,696	5,457	8,886	9,517	8,408	2,995
1964	1,727	1,570	1,493	1,474	1,418	1,863	9,634	3,472	7,105	10,930	8,711	4,426
1965	3,071	1,626	5,960	18,949	4,652	5,152	9,337	7,768	6,753	7,798	8,356	3,051
1966	2,284	1,531	2,335	3,302	1,661	4,252	3,426	6,957	8,284	10,884	7,398	5,804
1967	3,914	1,604	1,537	1,504	5,371	14,247	2,768	11,876	11,057	4,753	3,383	4,740
1968	5,897	2,713	3,473	7,933	11,573	6,449	6,652	3,581	9,233	8,779	6,562	5,621
1969	2,747	1,584	1,528	13,184	12,367	6,318	9,203	15,399	6,408	10,622	3,159	3,082
1970	1,932	3,526	16,215	35,711	10,502	3,980	6,481	3,674	7,494	10,679	7,030	5,963

Table G-WQ1.2-16. Lake Oroville total release, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993, mean monthly flow (cfs).

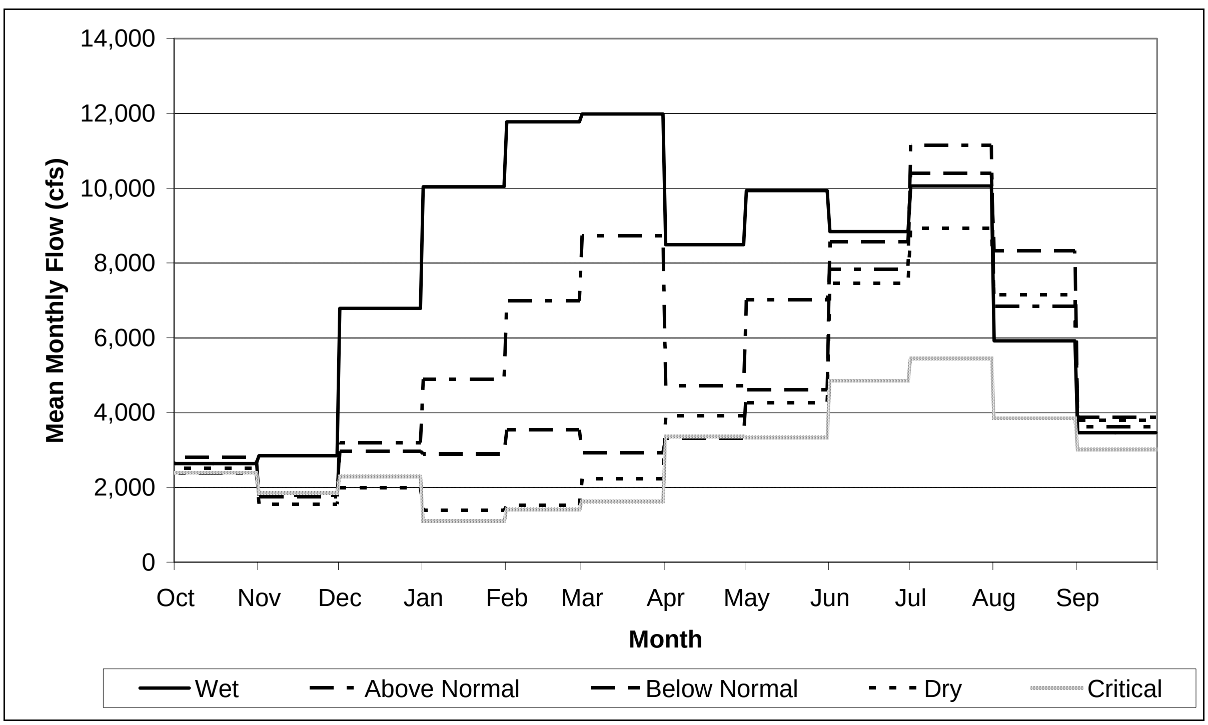
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1971	2,967	1,599	1,534	1,517	1,765	11,419	6,304	10,579	8,197	11,528	8,944	2,909
1972	2,321	1,555	1,512	2,500	6,366	6,831	3,506	3,359	7,729	7,822	8,198	2,643
1973	1,729	1,569	1,510	7,698	9,946	5,948	3,569	4,442	8,997	9,793	8,370	2,962
1974	1,645	4,046	10,038	20,369	5,602	26,162	9,959	8,484	8,332	10,715	5,509	3,133
1975	1,750	1,793	1,573	1,744	13,054	12,729	2,708	10,866	10,557	11,221	5,918	3,046
1976	1,668	1,570	1,517	2,013	3,904	4,190	3,808	4,013	5,401	8,805	5,154	4,053
1977	2,388	2,085	2,908	1,191	1,213	1,287	3,248	2,553	4,159	5,313	3,570	2,041
1978	1,967	903	810	679	693	1,508	6,176	3,896	6,350	12,316	3,465	2,409
1979	1,942	1,130	5,211	1,147	6,876	4,304	3,230	3,671	9,553	8,792	8,078	3,423
1980	1,752	1,757	1,674	13,926	17,951	5,136	3,070	3,560	3,811	12,129	3,093	2,968
1981	2,430	1,751	1,534	1,599	3,494	6,762	2,629	3,564	8,252	9,168	5,816	5,073
1982	2,881	1,084	17,946	8,118	17,776	13,216	20,115	10,723	6,636	12,316	3,408	2,435
1983	1,655	8,387	10,782	12,469	21,512	31,803	9,606	14,416	14,607	5,785	3,741	6,485
1984	5,549	14,494	24,126	5,383	8,392	8,843	4,516	3,631	9,552	11,377	5,700	5,138
1985	3,367	1,545	1,486	1,647	1,526	1,488	3,828	7,411	7,529	12,348	8,813	3,760
1986	3,834	1,683	1,496	1,461	20,981	22,454	2,732	3,701	7,320	12,124	3,143	2,487
1987	2,425	1,428	1,377	1,668	1,579	1,499	5,764	3,681	4,976	7,816	7,441	5,045
1988	4,400	2,350	977	958	963	1,117	2,100	2,215	4,783	4,286	3,421	2,458
1989	2,672	810	686	655	669	4,365	2,657	6,122	8,710	10,530	9,099	2,210
1990	3,812	2,525	6,446	776	782	644	4,058	2,340	3,732	5,718	3,357	3,079
1991	2,136	1,289	1,480	867	885	541	1,713	2,094	2,965	4,131	2,709	2,632
1992	1,149	1,325	865	767	692	501	2,179	3,597	4,138	4,571	3,849	5,341
1993	1,805	1,649	733	650	663	11,603	4,954	9,631	6,981	13,045	8,122	3,311
Avg =	2,567	2,047	3,792	4,646	5,647	6,022	5,158	6,226	7,731	9,321	6,476	3,569
Max =	5,897	14,494	24,126	35,711	21,997	31,803	20,115	22,848	14,607	13,045	9,916	6,485
Min =	823	810	686	650	659	501	1,448	2,094	2,965	4,131	2,709	1,896

Source: DWR, 2004 CALSIM II Modeling Results



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-9. Lake Oroville total release, existing conditions.



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-10. Lake Oroville total release, future (2020) No-Action, Proposed Action, and Alternative 2 conditions.

Table G-WQ1.2-17. Low Flow Channel flow, existing conditions, 1922–1993 mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	600	600	600	600	600	600	600	1,793	600	600	600	600
1923	600	600	600	600	600	600	600	600	600	600	600	600
1924	600	600	600	600	600	600	600	600	600	600	600	600
1925	600	600	600	600	600	600	600	600	600	600	600	600
1926	600	600	600	600	600	600	600	600	600	600	600	600
1927	600	600	600	600	600	600	600	600	600	600	600	600
1928	600	600	600	600	600	7,614	600	600	600	600	600	600
1929	600	600	600	600	600	600	600	600	600	600	600	600
1930	600	600	600	600	600	600	600	600	600	600	600	600
1931	600	600	600	600	600	600	600	600	600	600	600	600
1932	600	600	600	600	600	600	600	600	600	600	600	600
1933	600	600	600	600	600	600	600	600	600	600	600	600
1934	600	600	600	600	600	600	600	600	600	600	600	600
1935	600	600	600	600	600	600	600	600	600	600	600	600
1936	600	600	600	600	600	600	600	600	600	600	600	600
1937	600	600	600	600	600	600	600	600	600	600	600	600
1938	600	600	600	600	600	2,025	600	2,669	600	600	600	600
1939	600	600	600	600	600	600	600	600	600	600	600	600
1940	600	600	600	600	600	600	600	600	600	600	600	600
1941	600	600	600	600	600	600	600	600	600	600	600	600
1942	600	600	600	600	600	600	600	600	600	600	600	600
1943	600	600	600	1,400	600	600	600	600	600	600	600	600
1944	600	600	600	600	600	600	600	600	600	600	600	600
1945	600	600	600	600	600	600	600	600	600	600	600	600
1946	600	600	600	600	600	600	600	600	600	600	600	600
1947	600	600	600	600	600	600	600	600	600	600	600	600
1948	600	600	600	600	600	600	600	600	600	600	600	600
1949	600	600	600	600	600	600	600	600	600	600	600	600
1950	600	600	600	600	600	600	600	600	600	600	600	600
1951	600	600	600	600	600	600	600	600	600	600	600	600
1952	600	600	600	600	600	600	1,801	5,671	600	600	600	600
1953	600	600	600	3,639	600	600	600	600	600	600	600	600
1954	600	600	600	600	600	600	600	600	600	600	600	600
1955	600	600	600	600	600	600	600	600	600	600	600	600
1956	600	600	600	3,621	600	600	600	600	600	600	600	600
1957	600	600	600	600	600	600	600	600	600	600	600	600
1958	600	600	600	600	6,303	600	600	600	600	600	600	600
1959	600	600	600	600	600	600	600	600	600	600	600	600
1960	600	600	600	600	600	600	600	600	600	600	600	600
1961	600	600	600	600	600	600	600	600	600	600	600	600
1962	600	600	600	600	600	600	600	600	600	600	600	600
1963	600	600	600	600	600	600	600	600	600	600	600	600
1964	600	600	600	600	600	600	600	600	600	600	600	600

Table G-WQ1.2-17. Low Flow Channel flow, existing conditions, 1922–1993 mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1965	600	600	600	1,792	600	600	600	600	600	600	600	600
1966	600	600	600	600	600	600	600	600	600	600	600	600
1967	600	600	600	600	600	600	600	600	600	600	600	600
1968	600	600	600	600	600	600	600	600	600	600	600	600
1969	600	600	600	600	600	600	600	600	600	600	600	600
1970	600	600	600	18,494	600	600	600	600	600	600	600	600
1971	600	600	600	600	600	600	600	600	600	600	600	600
1972	600	600	600	600	600	600	600	600	600	600	600	600
1973	600	600	600	600	600	600	600	600	600	600	600	600
1974	600	600	600	3,187	600	8,913	600	600	600	600	600	600
1975	600	600	600	600	600	600	600	600	600	600	600	600
1976	600	600	600	600	600	600	600	600	600	600	600	600
1977	600	600	600	600	600	600	600	600	600	600	600	600
1978	600	600	600	600	600	600	600	600	600	600	600	600
1979	600	600	600	600	600	600	600	600	600	600	600	600
1980	600	600	600	600	772	600	600	600	600	600	600	600
1981	600	600	600	600	600	600	600	600	600	600	600	600
1982	600	600	600	600	617	600	2,954	600	600	600	600	600
1983	600	600	600	600	4,357	14,465	600	600	600	600	600	600
1984	600	600	6,970	600	600	600	600	600	600	600	600	600
1985	600	600	600	600	600	600	600	600	600	600	600	600
1986	600	600	600	600	3,783	4,539	600	600	600	600	600	600
1987	600	600	600	600	600	600	600	600	600	600	600	600
1988	600	600	600	600	600	600	600	600	600	600	600	600
1989	600	600	600	600	600	600	600	600	600	600	600	600
1990	600	600	600	600	600	600	600	600	600	600	600	600
1991	600	600	600	600	600	600	600	600	600	600	600	600
1992	600	600	600	600	600	600	600	600	600	600	600	600
1993	600	600	600	600	600	600	600	600	600	600	600	600
Avg =	600	600	688	996	778	1,080	649	716	600	600	600	600
Max =	600	600	6,970	18,494	6,303	14,465	2,954	5,671	600	600	600	600
Min =	600	600	600	600	600	600	600	600	600	600	600	600

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-18. Low Flow Channel flow, future (2020) No-Action and Proposed Action conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	600	600	600	600	600	600	600	1,793	600	600	600	600
1923	600	600	600	600	600	600	600	600	600	600	600	600
1924	600	600	600	600	600	600	600	600	600	600	600	600
1925	600	600	600	600	600	600	600	600	600	600	600	600
1926	600	600	600	600	600	600	600	600	600	600	600	600
1927	600	600	600	600	600	600	600	600	600	600	600	600
1928	600	600	600	600	600	5,039	600	600	600	600	600	600
1929	600	600	600	600	600	600	600	600	600	600	600	600
1930	600	600	600	600	600	600	600	600	600	600	600	600
1931	600	600	600	600	600	600	600	600	600	600	600	600
1932	600	600	600	600	600	600	600	600	600	600	600	600
1933	600	600	600	600	600	600	600	600	600	600	600	600
1934	600	600	600	600	600	600	600	600	600	600	600	600
1935	600	600	600	600	600	600	600	600	600	600	600	600
1936	600	600	600	600	600	600	600	600	600	600	600	600
1937	600	600	600	600	600	600	600	600	600	600	600	600
1938	600	600	600	600	600	2,025	600	2,670	600	600	600	600
1939	600	600	600	600	600	600	600	600	600	600	600	600
1940	600	600	600	600	600	600	600	600	600	600	600	600
1941	600	600	600	600	600	600	600	600	600	600	600	600
1942	600	600	600	600	600	600	600	600	600	600	600	600
1943	600	600	600	1,400	600	600	600	600	600	600	600	600
1944	600	600	600	600	600	600	600	600	600	600	600	600
1945	600	600	600	600	600	600	600	600	600	600	600	600
1946	600	600	600	600	600	600	600	600	600	600	600	600
1947	600	600	600	600	600	600	600	600	600	600	600	600
1948	600	600	600	600	600	600	600	600	600	600	600	600
1949	600	600	600	600	600	600	600	600	600	600	600	600
1950	600	600	600	600	600	600	600	600	600	600	600	600
1951	600	600	600	600	600	600	600	600	600	600	600	600
1952	600	600	600	600	600	600	1,801	5,671	600	600	600	600
1953	600	600	600	3,639	600	600	600	600	600	600	600	600
1954	600	600	600	600	600	600	600	600	600	600	600	600
1955	600	600	600	600	600	600	600	600	600	600	600	600
1956	600	600	600	3,621	600	600	600	600	600	600	600	600
1957	600	600	600	600	600	600	600	600	600	600	600	600
1958	600	600	600	600	4,795	600	600	600	600	600	600	600
1959	600	600	600	600	600	600	600	600	600	600	600	600
1960	600	600	600	600	600	600	600	600	600	600	600	600
1961	600	600	600	600	600	600	600	600	600	600	600	600
1962	600	600	600	600	600	600	600	600	600	600	600	600
1963	600	600	600	600	600	600	600	600	600	600	600	600
1964	600	600	600	600	600	600	600	600	600	600	600	600

Table G-WQ1.2-18. Low Flow Channel flow, future (2020) No-Action and Proposed Action conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1965	600	600	600	1,792	600	600	600	600	600	600	600	600
1966	600	600	600	600	600	600	600	600	600	600	600	600
1967	600	600	600	600	600	600	600	600	600	600	600	600
1968	600	600	600	600	600	600	600	600	600	600	600	600
1969	600	600	600	600	600	600	600	600	600	600	600	600
1970	600	600	600	18,494	600	600	600	600	600	600	600	600
1971	600	600	600	600	600	600	600	600	600	600	600	600
1972	600	600	600	600	600	600	600	600	600	600	600	600
1973	600	600	600	600	600	600	600	600	600	600	600	600
1974	600	600	600	3,187	600	8,913	600	600	600	600	600	600
1975	600	600	600	600	600	600	600	600	600	600	600	600
1976	600	600	600	600	600	600	600	600	600	600	600	600
1977	600	600	600	600	600	600	600	600	600	600	600	600
1978	600	600	600	600	600	600	600	600	600	600	600	600
1979	600	600	600	600	600	600	600	600	600	600	600	600
1980	600	600	600	600	772	600	600	600	600	600	600	600
1981	600	600	600	600	600	600	600	600	600	600	600	600
1982	600	600	787	600	617	600	2,954	600	600	600	600	600
1983	600	600	600	600	4,357	14,465	600	600	600	600	600	600
1984	600	600	6,970	600	600	600	600	600	600	600	600	600
1985	600	600	600	600	600	600	600	600	600	600	600	600
1986	600	600	600	600	3,804	5,293	600	600	600	600	600	600
1987	600	600	600	600	600	600	600	600	600	600	600	600
1988	600	600	600	600	600	600	600	600	600	600	600	600
1989	600	600	600	600	600	600	600	600	600	600	600	600
1990	600	600	600	600	600	600	600	600	600	600	600	600
1991	600	600	600	600	600	600	600	600	600	600	600	600
1992	600	600	600	600	600	600	600	600	600	600	600	600
1993	600	600	600	600	600	600	600	600	600	600	600	600
Avg =	600	600	691	996	758	1,055	649	716	600	600	600	600
Max =	600	600	6,970	18,494	4,795	14,465	2,954	5,671	600	600	600	600
Min =	600	600	600	600	600	600	600	600	600	600	600	600

Source: DWR, 2004 CALSIM II Modeling Results

Table G-WQ1.2-19. Low Flow Channel flow, future (2020) Alternative 2 conditions, 1922-1993, mean monthly flow (cfs).

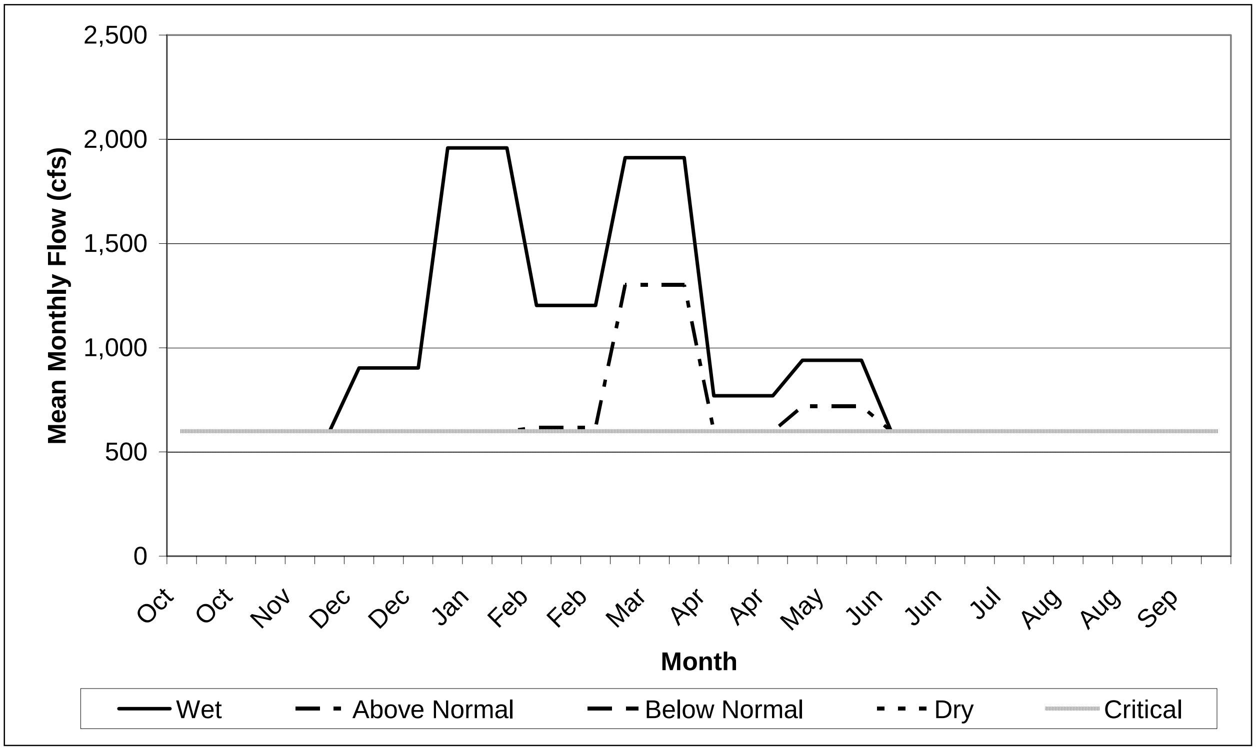
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun*	Jul	Aug	Sep
1922	800	800	800	800	800	800	800	1,793	1,000	800	800	800
1923	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1924	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1925	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1926	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1927	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1928	800	800	800	800	800	5,039	800	1,200	1,000	800	800	800
1929	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1930	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1931	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1932	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1933	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1934	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1935	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1936	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1937	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1938	800	800	800	800	800	2,025	800	2,670	1,000	800	800	800
1939	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1940	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1941	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1942	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1943	800	800	800	1,400	800	800	800	1,200	1,000	800	800	800
1944	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1945	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1946	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1947	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1948	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1949	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1950	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1951	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1952	800	800	800	800	800	800	1,801	5,671	1,000	800	800	800
1953	800	800	800	3,639	800	800	800	1,200	1,000	800	800	800
1954	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1955	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1956	800	800	800	3,621	800	800	800	1,200	1,000	800	800	800
1957	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1958	800	800	800	800	4,795	800	800	1,200	1,000	800	800	800
1959	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1960	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1961	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1962	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1963	800	800	800	800	800	800	800	1,200	1,000	800	800	800

' Minimum flow is 1,200 cfs May 1 through June 15 and 800 cfs from June 16 through June 30.*

Table G-WQ1.2-19. Low Flow Channel flow, future (2020) Alternative 2 conditions, 1922-1993, mean monthly flow (cfs).

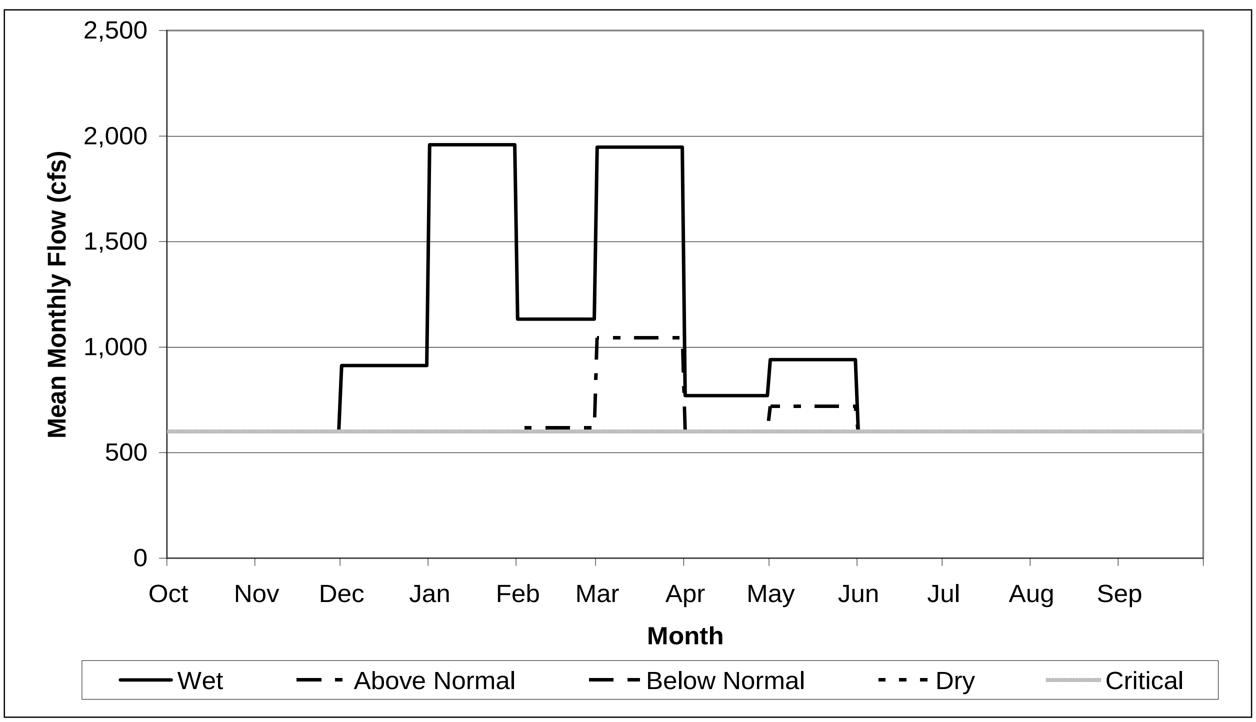
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun*	Jul	Aug	Sep
1964	800	800	800	1,792	800	800	800	1,200	1,000	800	800	800
1965	800	800	800	1,792	800	800	800	1,200	1,000	800	800	800
1966	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1967	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1968	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1969	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1970	800	800	800	18,494	800	800	800	1,200	1,000	800	800	800
1971	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1972	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1973	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1974	800	800	800	3,187	800	8,913	800	1,200	1,000	800	800	800
1975	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1976	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1977	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1978	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1979	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1980	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1981	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1982	800	800	800	800	800	800	2,954	1,200	1,000	800	800	800
1983	800	800	800	800	4,357	14,465	800	1,200	1,000	800	800	800
1984	800	800	6,970	800	800	800	800	1,200	1,000	800	800	800
1985	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1986	800	800	800	800	3,804	5,293	800	1,200	1,000	800	800	800
1987	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1988	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1989	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1990	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1991	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1992	800	800	800	800	800	800	800	1,200	1,000	800	800	800
1993	800	800	800	800	800	800	800	1,200	1,000	800	800	800
Avg =	800	800	886	1,193	947	1,241	844	1,291	1,000	800	800	800
Max =	800	800	6,970	18,494	4,795	14,465	2,954	5,671	1,000	800	800	800
Min =	800	800	800	800	800	800	800	1,200	1,000	800	800	800

' Minimum flow is 1,200 cfs May 1 through June 15 and 800 cfs from June 16 through June 30.*
Source: DWR, 2004 CALSIM II Modeling Results



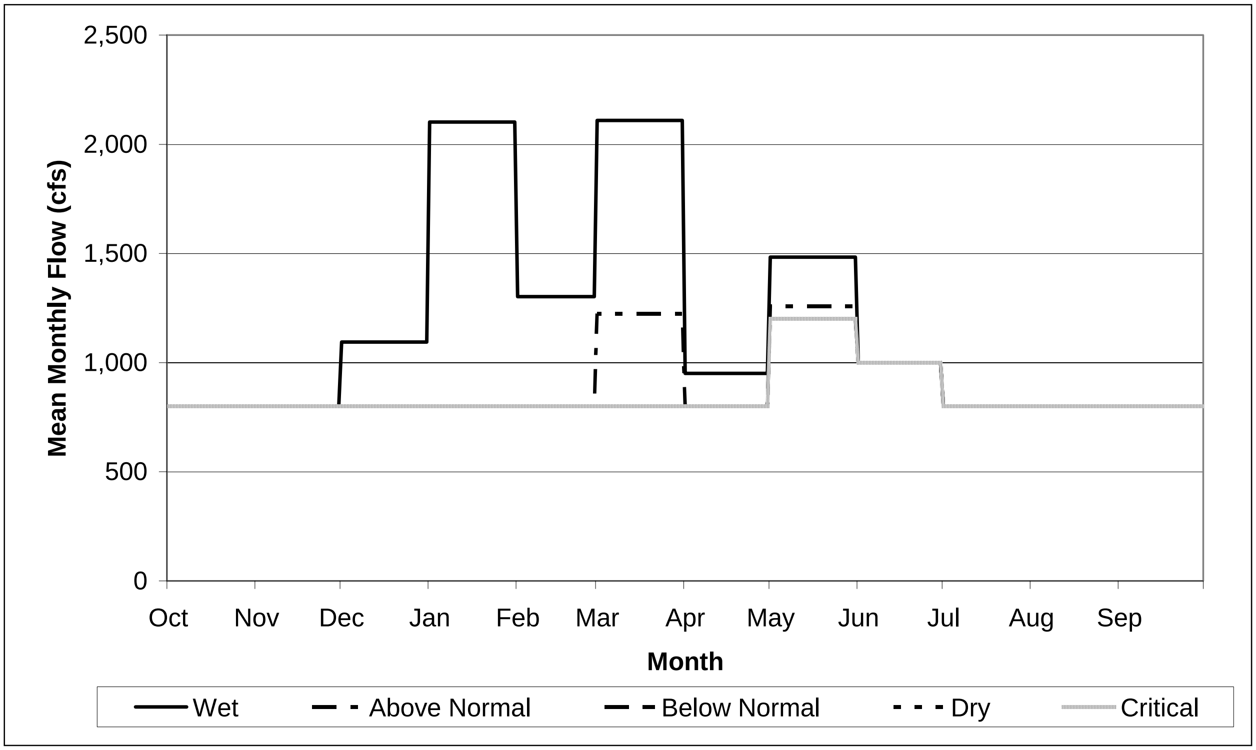
Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-11. Low Flow Channel flow, existing conditions.



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-12. Low Flow Channel flow, future (2020) No-Action and Proposed Action conditions.



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-13. Low Flow Channel flow, future (2020) Alternative 2 conditions.

Table G-WQ1.2-20. Feather River below Thermalito Afterbay, existing conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	3,026	2,500	3,487	1,708	4,223	4,801	1,204	16,669	6,460	9,545	1,586	1,008
1923	1,708	1,697	6,365	4,932	1,693	3,608	1,888	1,688	3,900	6,284	6,269	1,008
1924	1,708	2,500	3,563	1,708	1,634	3,105	3,318	2,243	3,560	4,564	2,329	2,171
1925	894	908	1,254	894	900	2,705	756	748	4,697	5,551	1,186	756
1926	964	908	1,845	894	900	748	895	4,605	5,122	6,378	5,921	825
1927	2,622	908	4,122	894	12,332	7,113	4,666	3,879	1,916	5,477	7,005	1,008
1928	1,708	1,697	2,764	1,708	4,099	24,997	1,008	4,317	4,846	5,638	4,663	3,087
1929	2,912	1,697	1,708	1,708	1,693	1,708	756	2,176	2,973	1,794	1,758	1,892
1930	1,104	1,036	2,099	894	2,831	748	1,292	1,172	5,809	7,010	5,534	1,838
1931	985	2,500	3,600	894	900	748	2,667	2,053	4,424	6,621	3,919	2,478
1932	2,925	1,467	4,388	894	869	1,987	810	748	5,409	1,408	1,077	756
1933	1,783	1,425	894	894	900	4,792	756	1,414	1,908	1,739	1,461	1,217
1934	1,291	908	2,491	894	2,597	748	2,764	2,442	3,272	2,654	2,927	3,725
1935	2,360	908	894	894	900	748	1,008	2,971	7,610	7,821	6,445	3,569
1936	3,636	2,500	4,811	1,708	1,634	1,708	1,008	992	4,105	8,238	6,604	1,008
1937	2,141	2,500	5,225	1,708	1,693	1,708	1,008	992	6,095	5,223	5,763	1,008
1938	1,708	1,697	2,247	5,326	14,537	19,405	13,027	17,147	8,059	5,750	1,111	1,008
1939	3,995	2,920	3,347	3,743	2,675	4,831	4,280	2,199	5,519	6,276	7,873	3,518
1940	4,000	2,500	2,965	1,203	1,165	14,667	3,765	2,839	6,220	9,598	7,025	1,008
1941	1,734	2,500	1,708	4,314	17,639	11,474	3,745	8,413	5,326	7,750	998	1,008
1942	1,708	1,697	17,059	14,374	17,643	2,809	10,495	5,682	5,811	7,464	2,787	1,008
1943	1,708	2,829	8,734	18,784	7,503	16,104	4,126	1,174	4,270	6,159	6,774	1,008
1944	1,708	1,697	1,708	1,708	1,634	2,863	3,583	1,459	5,755	7,363	6,404	3,777
1945	3,593	1,697	1,708	1,708	1,693	1,708	1,008	992	6,574	8,651	6,505	1,008
1946	1,708	1,697	1,708	4,194	4,372	6,481	1,008	1,974	6,714	8,938	6,997	1,577
1947	2,985	1,848	1,708	1,708	1,693	1,708	2,101	1,878	4,108	7,319	6,820	2,861
1948	2,393	1,535	2,553	1,203	1,815	992	1,008	992	1,671	8,677	6,544	1,008
1949	1,708	1,697	1,708	1,708	1,693	1,708	756	748	5,372	4,542	4,911	756
1950	1,172	907	894	894	900	748	1,008	2,796	6,612	9,154	7,379	1,008
1951	1,708	2,248	14,786	11,691	10,855	4,548	1,362	1,123	6,026	7,948	6,936	1,008
1952	2,460	1,697	2,135	8,931	12,157	7,114	17,416	20,073	8,835	2,179	992	3,562
1953	4,882	2,843	9,108	21,023	1,693	6,197	4,477	3,162	5,480	6,437	2,132	1,008
1954	1,708	4,407	3,036	9,810	8,590	10,162	6,136	7,836	4,814	7,897	5,844	3,570
1955	1,930	1,697	1,708	1,708	1,693	1,708	1,008	992	5,226	3,753	1,522	1,008
1956	1,708	1,697	8,385	21,005	11,356	6,456	3,155	10,718	5,743	8,740	2,598	1,008
1957	1,708	1,697	1,708	3,824	15,934	6,948	4,521	992	5,488	5,449	5,258	1,008
1958	1,708	1,697	1,708	1,774	23,682	11,941	7,656	10,426	6,632	5,059	992	1,008
1959	3,462	2,832	3,368	9,999	9,585	2,278	2,121	2,517	6,883	7,067	6,860	1,974
1960	3,521	2,500	5,131	1,203	1,165	992	3,847	992	4,646	4,443	1,500	1,859
1961	2,009	1,193	1,318	1,203	1,206	1,077	2,149	1,298	2,422	7,548	7,065	2,703
1962	3,629	2,483	894	894	900	748	1,533	1,595	5,985	7,291	7,713	3,593
1963	1,203	1,193	1,203	1,920	11,766	8,334	13,084	3,028	5,254	5,640	5,915	1,008
1964	1,708	1,697	1,708	1,708	1,634	2,864	5,331	3,666	4,218	8,239	7,256	3,337
1965	3,621	1,697	3,646	19,181	4,874	5,289	7,642	5,201	1,008	6,047	5,650	1,008
1966	1,708	2,917	3,647	3,528	1,802	4,332	1,041	4,510	4,964	8,606	6,739	3,653

Table G-WQ1.2-20. Feather River below Thermalito Afterbay, existing conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1967	3,244	1,697	1,708	1,708	4,860	14,438	2,135	9,064	8,415	1,399	992	3,111
1968	5,202	2,786	3,654	8,143	11,793	6,664	4,869	992	6,366	6,384	5,809	3,617
1969	2,843	1,697	1,708	11,678	12,487	6,492	7,440	12,633	3,593	6,657	1,050	1,008
1970	2,727	3,827	16,401	35,878	10,669	4,153	4,457	992	3,875	8,150	5,833	3,643
1971	2,394	1,697	1,708	1,708	1,693	12,371	3,624	8,386	5,417	9,068	2,374	1,008
1972	1,708	1,697	4,885	3,975	6,577	6,851	1,008	1,565	4,946	4,511	5,273	1,008
1973	1,708	1,697	1,708	9,197	10,124	6,138	1,408	1,929	5,698	7,005	5,610	1,008
1974	1,708	5,179	10,226	20,570	5,792	26,293	8,329	5,576	5,415	3,037	992	1,368
1975	4,890	3,505	2,863	2,965	13,236	12,932	1,008	8,077	6,270	6,431	992	1,008
1976	2,070	3,926	4,004	3,626	3,988	3,513	1,008	1,303	2,238	6,249	3,863	3,962
1977	2,561	2,500	3,537	1,203	1,206	992	1,301	921	2,371	3,413	2,174	1,568
1978	1,773	908	894	894	900	748	3,590	992	2,221	7,810	1,011	1,008
1979	1,203	1,193	1,203	3,163	11,708	4,448	2,355	992	6,606	5,738	5,616	1,748
1980	1,708	1,697	1,708	13,844	18,152	5,342	1,008	992	3,729	7,980	992	1,008
1981	1,708	1,697	1,708	1,708	2,419	6,986	1,008	1,814	5,021	5,870	4,730	3,235
1982	2,487	1,193	17,443	8,343	17,997	13,436	18,983	7,930	3,609	6,567	992	1,008
1983	4,212	8,703	11,001	12,697	21,736	31,845	8,745	11,832	11,636	2,756	1,416	5,080
1984	5,077	14,569	24,345	5,612	8,609	9,047	2,095	992	6,159	8,345	4,314	3,696
1985	1,708	1,697	1,708	1,708	1,693	2,091	2,404	4,530	4,245	8,647	7,271	3,026
1986	4,000	2,500	1,708	1,708	21,178	21,919	1,008	992	3,355	8,320	7,513	1,008
1987	1,708	1,697	1,708	1,708	1,693	1,708	3,937	1,250	1,671	4,038	5,765	3,287
1988	4,000	2,500	1,203	1,203	1,165	1,270	756	2,384	2,552	2,889	2,268	1,582
1989	1,714	908	894	894	900	748	756	3,016	5,163	7,367	7,159	3,163
1990	3,051	2,500	6,345	894	900	748	1,327	748	828	2,040	1,150	883
1991	1,787	1,672	1,560	894	900	748	756	748	1,386	2,553	1,615	1,344
1992	986	1,559	894	894	869	748	756	899	1,791	1,867	2,577	2,883
1993	1,806	2,500	894	894	900	11,831	3,466	7,620	4,283	9,179	6,555	1,064
Avg =	2,369	2,271	4,009	5,017	5,942	6,152	3,441	3,815	4,814	6,114	4,270	1,911
Max =	5,202	14,569	24,345	35,878	23,682	31,845	18,983	20,073	11,636	9,598	7,873	5,080
Min =	894	907	894	894	869	748	756	748	828	1,399	992	756

Source: DWR, 2004 CALSIM II Modeling Results

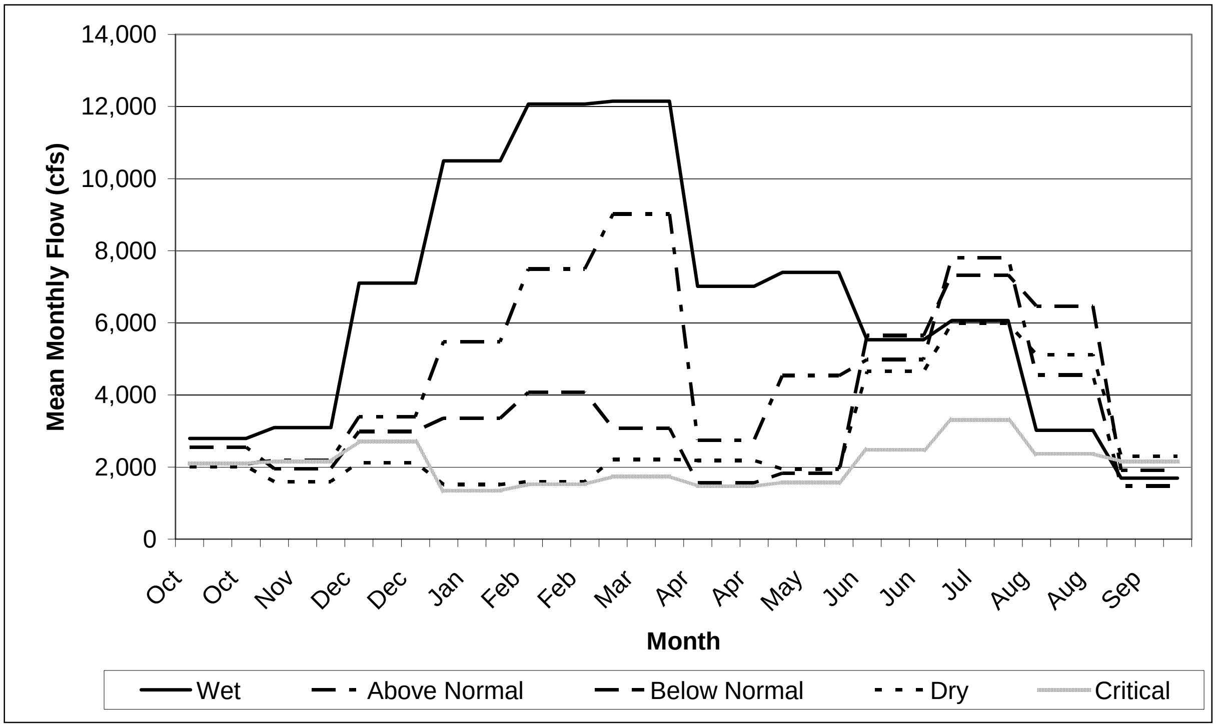
Table G-WQ1.2-21. Feather River below Thermalito Afterbay, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	3,285	2,500	3,098	1,708	4,362	4,802	1,227	16,682	6,466	10,000	992	1,008
1923	1,708	1,697	6,469	4,933	1,693	3,600	1,912	2,335	4,270	7,590	5,547	3,115
1924	2,490	2,500	4,420	1,708	1,634	2,921	2,318	3,065	3,940	4,256	2,272	1,918
1925	894	908	894	894	900	2,916	756	748	4,656	4,851	760	756
1926	1,215	908	1,733	894	900	748	756	4,027	4,496	6,260	6,326	1,128
1927	976	907	4,107	894	11,280	7,113	4,687	3,894	1,924	6,817	7,568	1,008
1928	3,186	1,697	2,708	1,708	3,235	22,423	1,008	4,188	5,134	5,300	5,258	2,761
1929	1,708	1,697	1,708	1,708	1,693	1,708	756	2,200	3,269	1,871	1,873	1,400
1930	1,522	1,030	3,824	894	2,861	748	1,072	1,097	4,646	7,184	6,195	2,174
1931	894	907	1,449	894	900	748	2,840	2,599	5,366	5,764	4,031	2,555
1932	1,617	1,178	3,999	894	869	1,870	756	748	5,623	5,069	1,100	756
1933	1,659	2,449	894	894	900	3,945	756	748	2,039	1,855	1,648	1,410
1934	1,254	1,523	2,863	894	2,566	748	2,738	2,409	3,326	2,794	2,649	3,306
1935	1,928	908	894	894	900	748	1,008	6,737	6,669	7,976	6,546	1,008
1936	3,194	2,500	4,995	1,708	1,634	1,708	1,008	992	4,760	8,387	6,788	1,008
1937	3,553	2,500	5,656	1,708	1,693	1,708	1,008	992	6,124	4,459	4,996	1,008
1938	1,708	1,697	1,708	4,551	14,537	19,405	13,043	17,162	8,066	9,848	992	1,008
1939	1,708	1,697	2,841	3,745	2,682	4,830	3,307	4,400	3,656	6,571	7,128	3,142
1940	3,330	2,500	4,548	1,203	1,165	15,222	3,784	3,272	8,128	8,736	7,662	1,008
1941	4,000	2,500	1,708	1,708	15,684	11,474	3,750	8,405	6,129	9,695	992	1,008
1942	1,708	1,697	14,286	14,374	17,643	2,809	10,501	5,674	5,789	4,254	5,955	1,008
1943	1,708	2,760	8,734	18,785	7,503	16,106	4,147	992	4,455	5,742	7,489	1,008
1944	1,708	1,711	1,794	1,708	1,634	2,479	2,822	1,434	7,157	7,800	6,255	3,643
1945	3,740	1,697	1,708	1,708	1,693	1,708	1,008	1,085	6,386	8,544	6,668	1,008
1946	1,708	1,697	1,708	3,430	4,450	6,411	1,008	2,361	6,803	9,046	7,564	3,449
1947	2,484	2,380	1,708	1,708	1,693	1,708	1,604	1,679	2,003	7,136	5,601	1,894
1948	1,353	1,193	2,010	1,203	1,408	992	1,008	992	1,008	9,851	6,066	1,863
1949	3,634	2,500	2,586	1,708	1,693	1,708	756	748	5,003	4,017	4,380	756
1950	894	1,738	2,188	894	900	748	1,008	2,567	6,488	9,798	7,671	1,008
1951	1,708	1,697	14,064	11,690	10,855	4,543	1,542	992	3,717	9,727	7,603	3,107
1952	3,195	1,697	1,708	6,337	12,157	7,114	17,434	20,089	8,842	6,063	992	1,008
1953	3,460	2,843	9,108	21,023	1,693	6,193	4,500	3,178	5,489	6,909	6,461	1,008
1954	1,708	1,697	1,708	8,963	8,591	10,162	6,153	8,059	4,995	7,830	4,806	4,266
1955	3,260	1,697	1,708	1,708	1,693	1,708	1,194	992	4,847	3,381	1,962	1,008
1956	1,708	1,697	7,146	21,007	11,356	6,450	3,182	10,731	5,749	10,000	5,576	1,008
1957	1,708	1,697	1,708	1,708	13,556	6,948	4,242	992	5,752	6,170	5,976	1,008
1958	1,708	1,697	1,708	1,708	22,177	11,942	7,663	10,418	6,616	7,613	992	1,008
1959	1,708	1,960	3,368	9,998	9,585	2,274	1,738	2,679	7,018	6,844	5,534	1,246
1960	3,326	2,500	4,290	1,203	1,165	992	3,257	992	4,690	5,345	5,544	1,144
1961	1,203	1,193	1,260	1,203	1,206	992	1,791	1,629	4,074	5,116	6,009	2,443
1962	3,512	1,573	894	894	900	748	1,517	1,897	6,938	9,375	6,957	3,483
1963	1,203	1,193	1,203	1,907	13,136	8,335	13,090	3,018	5,557	6,431	5,944	1,008
1964	1,708	1,697	1,708	1,708	1,634	1,940	6,850	992	4,453	8,336	6,630	2,681
1965	3,013	1,697	6,182	19,180	4,875	5,284	7,667	5,004	3,715	5,040	6,556	1,008

Table G-WQ1.2-21. Feather River below Thermalito Afterbay, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993, mean monthly flow (cfs).

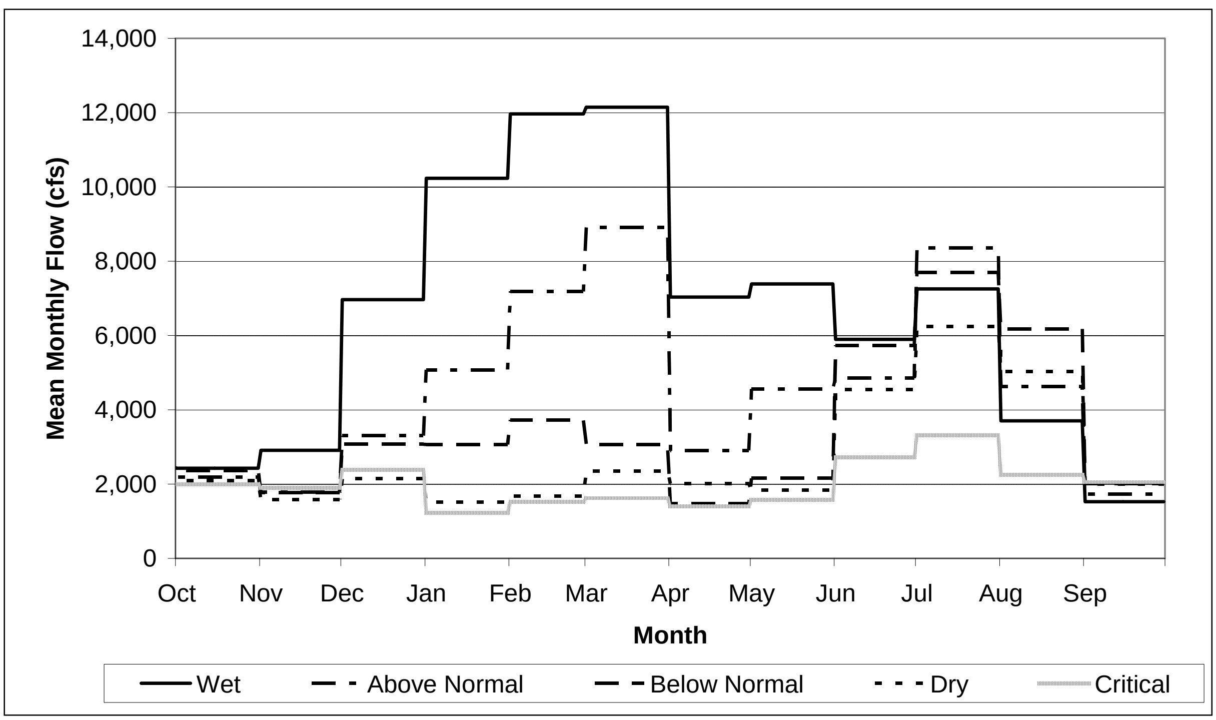
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1966	1,708	1,697	2,556	3,528	1,802	4,328	1,070	4,538	5,591	8,447	5,411	3,911
1967	3,223	1,697	1,708	1,708	5,565	14,438	2,140	9,083	8,426	1,794	992	2,652
1968	5,186	2,786	3,654	8,143	11,793	6,664	4,710	992	6,544	6,114	4,588	3,578
1969	2,658	1,697	1,708	13,365	12,487	6,492	7,461	12,648	3,601	7,934	992	1,008
1970	1,708	3,583	16,401	35,878	10,669	4,154	4,365	992	4,889	8,059	4,954	3,970
1971	2,699	1,697	1,708	1,708	1,973	11,570	3,650	8,399	5,423	8,959	6,897	1,008
1972	1,708	1,697	1,708	2,709	6,577	6,847	1,008	992	5,118	5,317	6,204	1,017
1973	1,708	1,697	1,708	7,889	10,126	6,139	1,567	1,816	6,047	7,122	6,198	1,008
1974	1,708	4,131	10,228	20,570	5,792	26,293	8,347	5,591	5,277	8,361	3,221	1,008
1975	1,708	1,919	1,708	1,829	13,237	12,934	1,008	8,108	7,566	8,570	3,841	1,008
1976	1,708	1,697	1,708	2,226	3,990	3,507	1,008	1,312	2,321	5,805	3,196	3,347
1977	2,016	2,130	2,898	1,203	1,206	992	1,368	1,472	2,341	3,547	2,227	1,664
1978	1,776	908	894	894	900	1,679	5,031	992	2,988	9,227	992	1,008
1979	1,203	1,193	5,215	1,203	7,015	4,450	1,732	992	6,533	6,049	5,997	1,442
1980	1,791	1,697	1,708	14,125	18,154	5,342	1,008	992	1,008	9,474	992	1,008
1981	1,708	1,697	1,708	1,708	3,694	6,986	1,008	1,039	5,283	6,424	3,666	3,147
1982	2,872	1,193	18,166	8,343	17,997	13,436	18,988	7,919	3,592	9,257	992	1,008
1983	1,708	8,507	11,001	12,697	21,736	31,845	8,751	11,822	11,615	2,725	1,386	5,044
1984	5,071	14,569	24,345	5,612	8,609	9,045	2,319	992	6,790	8,831	3,912	3,262
1985	3,423	1,697	1,708	1,708	1,693	1,708	1,592	4,524	4,368	9,515	6,671	2,514
1986	3,238	1,697	1,708	1,708	21,198	22,673	1,008	992	4,340	9,406	992	1,008
1987	1,708	1,697	1,708	1,708	1,693	1,708	3,876	1,020	2,115	5,240	5,483	3,077
1988	4,000	2,500	1,203	1,203	1,165	992	756	1,105	3,259	2,871	2,341	1,322
1989	2,278	908	894	894	900	4,600	756	3,250	5,697	7,662	6,850	1,746
1990	3,804	2,500	6,663	894	900	748	1,337	748	854	3,073	1,272	1,121
1991	1,552	1,494	1,551	894	900	748	756	748	1,609	2,713	1,610	1,441
1992	894	1,530	894	894	869	748	756	898	1,599	1,913	1,653	3,115
1993	1,665	1,726	894	894	900	11,838	3,470	7,613	4,294	10,000	5,751	1,093
Avg =	2,240	2,084	3,930	4,810	5,817	6,147	3,403	3,854	4,935	6,667	4,386	1,835
Max =	5,186	14,569	24,345	35,878	22,177	31,845	18,988	20,089	11,615	10,000	7,671	5,044
Min =	894	907	894	894	869	748	756	748	854	1,794	760	756

Source: DWR, 2004 CALSIM II Modeling Results



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-14. Feather River below Thermalito Afterbay, existing conditions.



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-15. Feather River below Thermalito Afterbay, future (2020) No-Action, Proposed Action, and Alternative 2 conditions.

Table G-WQ1.2-22. Feather River flow at Verona, existing conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	4,119	2,771	1,708	5,279	7,451	13,302	10,519	28,355	20,704	11,801	1,808	3,380
1923	2,069	1,892	4,965	12,123	3,114	5,174	9,436	5,680	6,434	6,137	6,152	2,622
1924	2,461	2,763	3,373	4,525	3,606	2,749	4,798	2,260	3,263	4,227	2,092	2,030
1925	1,261	1,167	894	4,174	12,104	8,951	4,441	3,276	6,126	5,313	1,432	2,590
1926	1,808	1,244	894	5,669	5,966	5,237	5,401	6,414	5,145	5,778	5,500	2,493
1927	3,021	6,985	894	9,875	32,721	18,440	14,467	11,303	7,030	7,355	7,439	2,896
1928	2,432	2,686	1,708	8,858	2,502	44,279	7,880	7,750	5,155	5,331	4,898	4,962
1929	4,012	2,411	1,815	4,821	3,005	3,480	1,760	2,487	3,180	1,559	1,511	1,826
1930	1,348	908	894	8,299	900	10,301	5,332	4,266	7,235	6,871	5,929	4,185
1931	1,670	3,260	4,242	1,778	2,369	1,005	3,906	2,274	4,525	6,208	3,372	2,329
1932	2,985	1,328	894	9,657	5,746	748	3,158	5,129	8,826	1,576	1,648	2,778
1933	2,506	908	1,623	2,226	3,881	748	3,211	1,779	2,999	1,551	1,569	1,804
1934	1,708	1,271	894	7,001	900	2,609	5,233	2,186	3,179	2,087	2,360	3,462
1935	2,182	1,042	1,602	8,841	1,486	6,888	9,572	11,311	12,397	8,506	6,880	5,659
1936	4,638	3,032	4,860	9,708	14,738	14,181	8,965	5,292	7,429	8,342	6,954	2,813
1937	2,810	2,522	5,703	3,503	13,046	13,832	7,607	6,060	8,581	5,362	6,214	2,745
1938	2,332	3,247	12,967	11,972	25,881	36,190	27,149	27,307	19,458	8,654	1,891	2,684
1939	4,368	3,382	4,023	4,940	3,176	5,764	5,011	2,616	5,722	5,717	7,485	5,034
1940	4,174	2,450	3,011	6,623	5,489	37,497	32,571	8,599	8,637	9,623	7,284	3,036
1941	2,206	4,408	5,667	13,399	28,485	23,500	6,517	15,622	9,379	10,066	1,598	2,987
1942	1,976	2,564	19,172	18,619	34,500	10,437	22,412	14,344	12,995	9,647	3,127	2,839
1943	2,579	4,016	11,536	25,553	16,724	25,928	11,919	7,340	6,717	6,367	7,157	2,638
1944	2,750	2,000	2,415	4,122	7,004	7,472	4,536	2,467	6,927	7,084	6,690	5,562
1945	3,796	3,891	3,979	3,584	11,309	7,316	3,339	2,812	8,249	8,353	6,789	2,734
1946	1,932	3,418	5,515	16,100	8,851	9,488	3,885	4,212	7,471	8,478	7,163	3,521
1947	3,925	2,858	3,727	2,964	4,449	5,488	4,545	2,161	4,472	6,599	6,522	4,638
1948	2,868	2,085	2,852	3,267	2,380	2,067	7,709	9,728	5,989	9,505	7,415	3,534
1949	2,880	1,851	2,680	2,878	2,778	7,720	3,276	2,391	5,784	3,878	5,028	2,806
1950	1,942	1,236	1,131	4,997	8,196	4,624	5,464	6,215	9,525	9,118	7,860	3,331
1951	2,063	11,970	32,207	26,089	20,920	11,681	5,868	4,675	6,395	7,341	7,238	3,287
1952	3,452	3,539	3,753	25,085	21,893	16,556	27,794	35,000	17,891	5,188	2,547	5,510
1953	5,989	3,189	10,716	21,817	8,627	9,467	6,003	8,254	9,988	7,779	2,328	3,363
1954	2,670	5,295	3,714	9,497	15,615	17,389	13,174	10,111	5,269	7,139	5,750	5,732
1955	3,033	2,238	4,354	5,287	2,632	2,229	2,131	2,070	5,147	2,533	1,028	2,883
1956	2,110	1,845	8,145	43,052	19,058	16,964	7,882	17,699	10,082	9,385	2,249	2,969
1957	2,100	2,211	1,712	5,466	14,704	18,277	7,037	4,955	7,787	4,966	5,441	2,604
1958	2,756	1,699	3,445	4,431	28,447	31,100	25,301	20,259	12,264	7,127	1,414	3,212
1959	4,600	3,050	3,328	12,289	17,999	5,337	3,455	3,506	7,146	6,161	6,197	3,082
1960	3,845	2,535	5,406	2,540	6,183	4,539	4,599	1,659	4,825	3,932	1,545	3,596
1961	2,938	2,353	1,203	2,262	5,545	992	3,781	2,336	2,630	6,739	6,312	4,599
1962	4,128	2,497	1,114	1,942	12,201	6,972	3,873	2,755	6,954	6,499	7,822	5,394
1963	10,584	4,061	6,085	1,203	25,839	12,802	26,599	12,647	8,976	5,986	6,571	3,257
1964	2,745	5,435	1,978	7,068	2,935	3,363	7,396	4,769	4,911	8,020	7,780	5,164
1965	4,013	3,214	5,559	43,834	12,624	9,095	12,753	10,652	4,645	6,641	7,070	3,555
1966	2,967	4,827	5,651	7,814	5,736	6,473	4,535	6,316	5,361	8,186	6,706	5,347
1967	3,958	2,829	7,983	4,898	21,745	20,559	9,089	15,192	17,277	5,158	3,039	4,793
1968	5,969	2,844	4,364	11,212	15,801	16,953	5,810	1,848	6,617	6,038	4,969	4,502

Table G-WQ1.2-22. Feather River flow at Verona, existing conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1969	3,162	2,313	3,618	30,911	31,280	19,424	15,574	23,379	7,877	7,383	1,728	3,131
1970	3,169	3,919	23,248	62,903	40,240	13,855	5,753	1,652	4,420	8,133	6,386	5,403
1971	2,807	2,115	14,866	9,075	7,301	16,084	11,782	12,547	9,471	11,482	3,751	3,911
1972	3,167	2,207	6,982	6,855	11,156	10,325	3,912	3,543	6,029	5,177	6,664	3,978
1973	2,953	5,359	5,986	23,627	25,471	20,362	6,582	5,794	8,097	7,560	7,336	3,867
1974	2,885	11,342	19,674	36,532	15,687	36,109	31,037	9,711	10,192	5,562	2,475	4,415
1975	5,096	3,327	4,061	4,923	25,350	20,546	6,970	12,790	11,198	8,688	2,807	4,175
1976	3,574	4,594	5,463	5,217	5,075	4,694	4,098	992	2,073	6,283	4,518	4,719
1977	2,933	2,707	4,129	2,665	1,393	1,614	2,252	911	1,745	2,872	1,197	1,419
1978	1,696	1,332	2,468	12,354	8,551	9,468	8,459	5,608	6,062	8,981	2,485	3,682
1979	2,347	2,091	1,921	8,716	19,126	11,662	4,817	5,046	7,556	6,051	7,118	4,622
1980	2,780	2,855	3,732	32,785	37,360	22,218	8,353	5,994	6,806	9,092	1,727	3,024
1981	2,818	1,947	2,270	2,739	8,341	10,226	4,931	3,870	5,440	5,535	5,728	5,312
1982	3,003	5,810	32,292	31,638	36,910	28,441	52,039	16,194	9,923	9,901	2,436	3,642
1983	6,273	12,930	20,778	16,771	36,641	53,958	23,786	22,617	24,020	6,938	5,005	7,215
1984	6,682	22,679	46,695	23,812	16,327	15,454	7,371	5,366	8,371	8,930	5,855	5,249
1985	1,788	3,372	3,937	3,295	4,997	3,972	4,961	6,030	4,915	9,229	8,700	6,229
1986	4,892	3,676	5,356	7,499	41,458	52,969	7,603	3,053	4,649	8,792	8,795	3,852
1987	3,125	1,853	2,173	3,877	5,902	4,552	5,278	3,024	1,571	3,427	5,654	5,004
1988	4,474	2,864	2,250	4,636	2,309	992	3,692	3,614	2,262	1,838	2,292	2,973
1989	2,025	1,486	1,635	2,590	2,409	13,614	9,798	5,860	5,318	6,987	8,106	4,945
1990	3,801	2,883	6,172	5,736	4,733	3,422	4,993	1,196	1,841	2,381	2,288	2,413
1991	1,528	1,504	894	1,538	1,513	8,805	4,222	2,820	2,998	3,288	2,656	2,718
1992	2,012	1,203	1,303	3,182	9,956	3,373	3,683	2,096	2,590	1,025	1,667	2,502
1993	1,745	2,679	1,885	13,378	12,949	17,161	14,628	11,541	7,920	9,500	6,480	2,501
Avg =	3,186	3,448	6,252	11,367	13,107	13,187	9,412	7,661	7,376	6,541	4,745	3,718
Max =	10,584	22,679	46,695	62,903	41,458	53,958	52,039	35,000	24,020	11,801	8,795	7,215
Min =	1,261	908	894	1,203	900	748	1,760	911	1,571	1,025	1,028	1,419

Source: DWR, 2004 CALSIM II Modeling Results

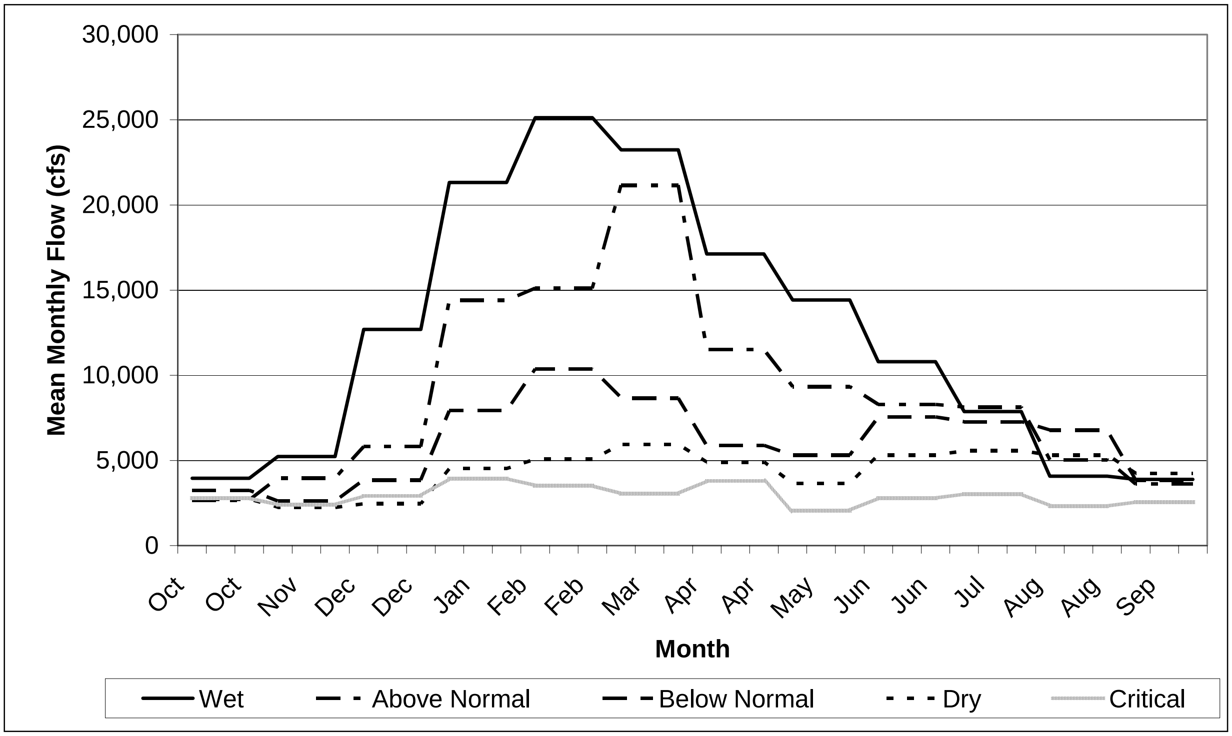
Table G-WQ1.2-23. Feather River flow at Verona, future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993, mean monthly flow (cfs).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	4,643	2,903	1,708	5,271	7,495	13,022	10,271	28,469	20,677	12,230	1,237	3,381
1923	2,098	1,955	5,106	12,143	3,319	6,084	9,249	5,454	6,786	7,420	5,469	4,762
1924	3,221	2,848	4,339	4,632	3,727	2,854	3,133	3,019	3,435	3,733	2,023	1,985
1925	1,705	1,261	918	4,618	12,127	8,197	4,368	3,392	6,075	4,592	986	2,584
1926	2,032	1,268	894	5,655	5,960	5,171	5,435	5,945	4,194	5,432	5,844	2,549
1927	1,829	7,322	894	9,883	31,677	18,479	14,412	11,360	7,036	8,669	8,026	2,888
1928	3,940	2,747	1,708	8,894	1,634	41,771	7,794	7,632	5,424	4,965	5,462	4,637
1929	2,821	2,494	2,002	4,891	3,494	4,244	1,968	2,484	3,461	1,365	1,564	1,507
1930	2,157	908	894	8,069	900	10,330	5,660	4,363	5,839	6,860	6,195	4,486
1931	1,773	1,621	2,109	2,178	3,138	1,579	3,328	2,910	5,321	5,090	3,441	2,620
1932	2,071	1,142	894	10,275	5,221	748	3,362	3,265	8,567	5,201	1,612	2,786
1933	2,426	1,959	1,695	2,737	4,701	748	3,389	1,306	2,685	1,365	1,311	1,614
1934	1,587	1,799	894	6,099	900	2,811	4,828	2,204	2,994	1,940	2,013	3,260
1935	2,156	1,266	1,768	9,619	1,599	7,777	8,709	14,545	11,255	8,108	6,953	3,081
1936	4,218	3,059	5,159	9,737	14,689	14,210	8,859	5,362	8,083	8,458	7,106	2,817
1937	4,255	2,517	6,210	3,982	12,653	14,147	7,324	5,969	8,430	4,571	5,418	2,754
1938	2,338	3,320	12,434	11,215	25,915	36,246	27,105	27,365	19,423	12,743	1,718	2,696
1939	2,098	2,176	3,600	4,908	3,930	6,014	3,667	5,041	3,660	5,907	6,745	4,654
1940	3,935	2,496	4,619	5,568	5,472	38,108	32,447	9,089	10,509	8,720	7,893	3,032
1941	4,480	4,424	5,772	10,784	26,578	23,567	6,642	15,727	10,110	11,960	1,554	2,959
1942	1,993	2,601	16,443	18,656	34,531	10,485	22,569	14,480	12,894	6,395	6,339	2,801
1943	2,536	3,996	11,550	25,578	16,757	25,988	11,930	7,173	6,876	5,924	7,901	2,625
1944	2,713	2,068	2,620	4,118	7,091	7,811	4,718	2,546	7,511	7,149	5,965	5,168
1945	3,982	3,948	4,029	3,602	11,323	7,372	3,794	2,397	8,051	8,216	6,917	2,725
1946	1,967	3,474	5,567	15,352	8,965	9,452	3,711	4,657	7,532	8,553	7,693	5,404
1947	3,387	3,430	3,795	2,964	4,503	5,513	4,802	1,969	2,340	6,241	5,325	3,462
1948	2,170	1,870	2,379	2,321	2,580	3,062	7,430	8,905	5,282	10,603	6,963	4,373
1949	4,819	2,641	3,690	2,957	3,490	8,486	3,032	2,099	4,936	3,032	4,137	2,818
1950	1,722	2,117	2,463	4,879	8,186	4,666	5,350	6,032	9,349	9,731	8,170	3,328
1951	2,095	11,455	31,556	26,106	20,950	11,665	5,901	4,675	4,054	9,100	7,915	5,396
1952	4,230	3,594	3,360	22,511	21,933	16,610	27,696	35,052	17,897	9,045	2,489	2,965
1953	4,534	3,257	10,728	21,832	8,622	9,465	5,982	8,338	9,991	8,220	6,625	3,335
1954	2,654	2,627	2,406	8,689	15,689	17,452	13,187	10,535	5,231	7,042	4,721	6,424
1955	4,358	2,258	4,405	5,299	3,147	3,092	3,096	2,727	4,678	1,820	992	2,534
1956	2,196	1,831	6,884	40,758	19,284	17,058	8,304	17,840	10,061	10,630	5,242	2,974
1957	2,139	2,184	1,768	3,349	12,389	18,328	7,345	4,491	7,984	5,632	6,181	2,636
1958	2,805	1,697	3,491	4,407	26,974	31,166	25,441	20,315	12,241	9,639	1,378	3,207
1959	2,859	2,165	3,400	12,266	17,992	6,242	3,273	3,697	7,145	5,785	4,851	2,595
1960	3,945	2,575	4,644	3,395	5,381	3,340	4,858	2,068	4,752	4,529	5,060	2,551
1961	2,195	2,369	1,203	2,446	5,469	1,749	3,866	2,677	4,137	4,130	5,242	4,102
1962	4,339	1,648	1,092	1,604	12,453	5,842	3,237	3,069	7,868	8,542	7,020	5,284
1963	10,687	4,085	6,102	1,203	27,239	12,851	26,720	12,706	9,198	6,718	6,625	3,243
1964	2,782	5,522	1,983	7,088	3,194	3,407	9,524	2,465	5,239	7,970	6,981	4,143

Table G-WQ1.2-23. Feather River flow at Verona—future (2020) No-Action, Proposed Action, and Alternative 2 conditions, 1922-1993 mean monthly flow (cfs).

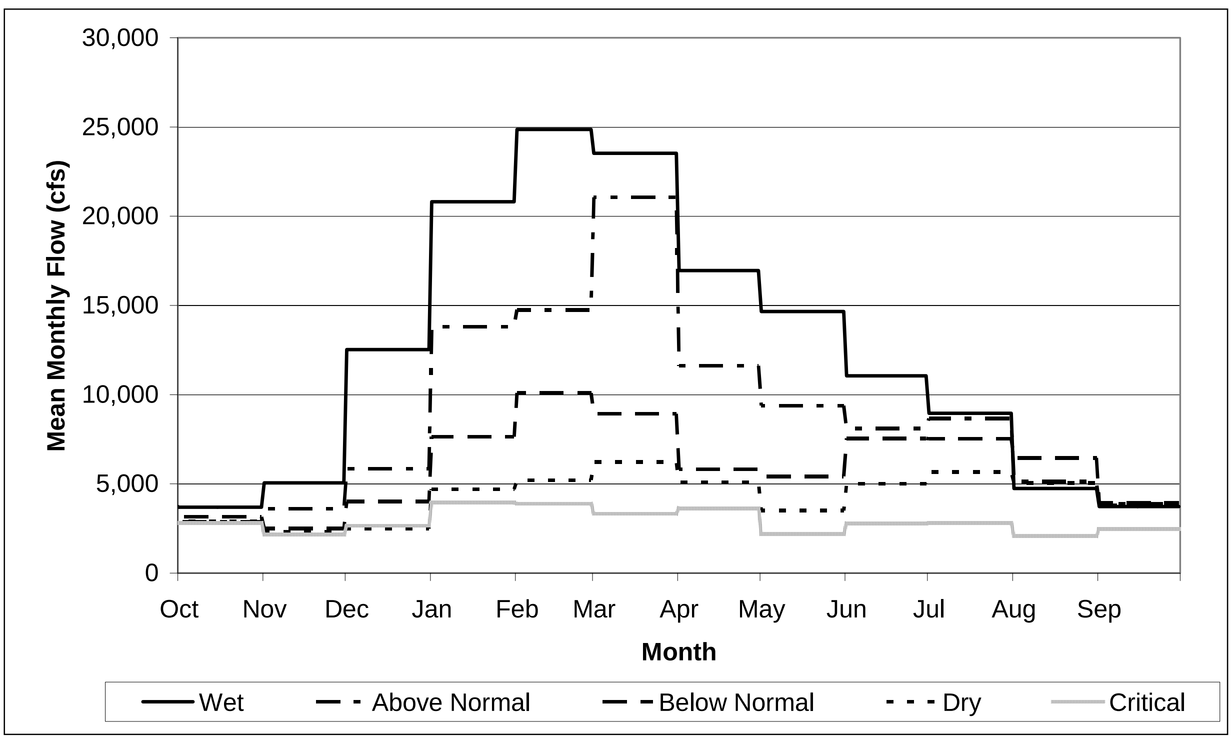
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1965	3,462	3,073	8,038	42,289	12,639	9,079	12,784	10,466	7,315	5,588	8,018	3,546
1966	2,920	3,687	4,603	7,795	6,083	7,129	4,418	6,520	5,892	7,944	5,239	5,317
1967	4,009	2,220	7,978	4,837	22,456	20,624	9,243	15,213	17,314	5,496	3,006	4,311
1968	5,911	2,870	4,382	11,278	15,830	17,006	6,134	1,955	6,740	5,606	3,790	4,287
1969	3,297	2,519	3,207	32,522	31,297	19,458	15,485	22,811	8,128	8,645	1,689	3,129
1970	2,151	3,686	23,323	62,916	40,273	13,897	5,928	2,021	5,218	7,606	5,275	5,737
1971	3,367	1,971	14,847	9,087	7,578	15,310	11,926	12,635	9,458	11,101	8,295	3,896
1972	3,137	2,225	3,867	5,594	11,191	10,268	4,610	3,168	5,882	5,509	7,329	3,998
1973	2,987	5,453	6,000	22,332	25,510	20,417	6,586	5,689	8,413	7,640	7,886	3,874
1974	2,926	10,385	19,693	36,544	15,714	36,165	30,970	9,716	10,007	10,948	4,641	4,037
1975	2,002	1,697	3,012	3,767	25,424	20,599	7,805	12,465	11,982	10,732	5,614	4,156
1976	3,243	2,372	3,200	3,831	5,689	5,151	3,676	992	1,921	5,610	3,953	4,329
1977	2,790	2,352	3,494	2,843	1,771	1,837	1,892	1,799	1,717	2,889	748	1,415
1978	1,390	1,275	2,614	12,060	8,557	10,434	9,932	5,556	6,635	10,442	2,481	3,709
1979	2,346	2,108	5,993	6,706	14,483	11,737	5,221	3,987	7,433	6,323	7,459	4,293
1980	2,899	2,889	3,809	33,063	37,386	22,254	8,293	6,017	4,069	10,567	1,738	3,021
1981	2,776	1,951	2,291	2,795	9,616	10,909	5,867	3,127	5,487	5,899	4,608	5,149
1982	3,682	5,844	32,806	31,634	32,629	33,774	46,230	20,373	9,032	12,184	2,393	3,685
1983	3,814	12,836	20,820	16,785	36,669	54,012	23,914	22,621	23,946	6,855	4,944	7,201
1984	6,652	22,772	46,707	23,849	16,360	15,408	7,433	5,392	9,001	9,376	5,475	4,821
1985	3,544	3,465	3,949	3,307	5,122	4,696	4,798	5,989	4,848	9,898	8,048	5,832
1986	4,396	3,020	4,995	5,962	41,526	53,776	7,478	3,767	4,998	9,734	2,232	3,918
1987	3,078	1,856	2,216	4,055	5,734	4,936	5,087	2,652	2,019	4,533	5,372	4,667
1988	4,894	2,902	2,661	5,354	2,401	1,242	3,918	2,403	2,794	1,691	2,346	2,558
1989	2,928	1,902	1,766	3,088	2,541	15,020	9,152	5,897	5,724	7,312	7,760	3,568
1990	4,595	2,880	6,480	5,807	4,814	3,727	4,711	2,021	1,589	3,220	2,348	2,467
1991	1,624	1,320	894	1,721	2,034	8,326	4,936	3,024	2,429	3,091	2,277	2,694
1992	1,973	1,134	1,363	3,238	10,018	4,055	4,119	1,876	2,278	927	748	2,558
1993	1,979	1,969	2,299	12,603	12,530	17,212	14,341	11,638	7,984	10,281	5,690	2,557
Avg =	3,162	3,299	6,201	11,114	13,016	13,412	9,370	7,744	7,354	6,967	4,788	3,609
Max =	10,687	22,772	46,707	62,916	41,526	54,012	46,230	35,052	23,946	12,743	8,295	7,201
Min =	1,390	908	894	1,203	900	748	1,892	992	1,589	927	748	1,415

Source: DWR, 2004 CALSIM II Modeling Results



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-16. Feather River flow at Verona, existing conditions.



Source: DWR, 2004 CALSIM II Modeling Results

Figure G-WQ1.2-17. Feather River flow at Verona, future (2020) No-Action, Proposed Action, and Alternative 2 conditions.

APPENDIX G-WQ2
WATER QUALITY

G-WQ2.1 INTRODUCTION

Appendix G-WQ2 contains figures summarizing and comparing the California Department of Water Resources' (DWR) water temperature modeling results for the different project alternative scenarios. The appendix also gives descriptions of the methodologies used in DWR's relicensing studies for water quality and provides tables summarizing the results of these studies. The water quality studies include SP-W6, a water temperature monitoring study. The results of the water temperature modeling and the water quality studies provide the bases for the descriptions of existing conditions and project effects in the main text of the Preliminary Draft Environmental Assessment (PDEA). Finally, the appendix includes several tables that give numerical limits for concentrations of water quality parameters and tissue contaminants. These numerical limits serve as the Central Valley Regional Water Quality Control Board (RWQCB) Basin Plan objectives for water quality.

G-WQ2.2 LIST OF TABLES AND FIGURES INCLUDED

The following tables of output data are included in this appendix:

- Table G-WQ2.4-1. Monitoring Site Number System for Maps
- Table G-WQ2.4-2. Numerical Limits Used to Evaluate Compliance of Surface Waters with Basin Plan Objectives (expressed as mg/L unless otherwise noted)
- Table G-WQ2.4-3. Fish and Crayfish Collected from Project Waters for Analysis of Tissue Contaminants
- Table G-WQ2.4-4. Numerical Limits Used to Evaluate Compliance of Fish and Crayfish Tissue Metals Concentrations with Basin Plan Objectives for Toxicity
- Table G-WQ2.4-5. Numerical Limits Used to Evaluate Compliance of Fish and Crayfish Tissue Organic Concentrations with Basin Plan Objectives for Toxicity
- Table G-WQ2.4-6. Water Quality Limits for Feather River Basin Groundwater
- Table G-WQ2.5-1. Fish (and Crayfish) Tissue Concentrations of Metals
- Table G-WQ2.5-2. Fish (and Crayfish) Tissue Concentrations of Pesticides
- Table G-WQ2.5-3. Ranges of Bacteria Counts at SP-W1 Monitoring Stations and Numbers of Water Quality Standard Exceedances
- Table G-WQ2.5-4. Ranges of Bacteria Counts at Recreation Area Monitoring Stations and Number of Water Quality Standards Exceedances in 2002

- Table G-WQ2.5-5. Ranges of Bacteria Counts at Recreation Area Monitoring Stations and Number of Water Quality Standard Exceedances in 2003
- Table G-WQ2.5-6. Stormwater Sampling Results – Bacteria
- Table G-WQ2.5-7. Water Quality Ranges in Downgradient and Upgradient Wells and Surface Water Samples
- Table G-WQ2.5-8. Exceedances of Basin Plan Water Quality Objectives
- Table G-WQ2.5-9. Water Quality Ranges in Well A11 near Thermalito Forebay, Other Wells, and Surface Water Samples

The following figures representing output data are included in this appendix (or the Figures volume):

- Figure G-WQ2.3-1. Temperature Exceedances from Simulations for Existing Conditions, No-Action, and Alternative 2 Scenarios and for Differences between the Scenarios, at the Thermalito Diversion Dam
- Figure G-WQ2.3-2. Temperature Exceedances from Simulations for Existing Conditions, No-Action, and Alternative 2 Scenarios and for Differences between the Scenarios, in the Feather River at Robinson Riffle
- Figure G-WQ2.3-3. Temperature Exceedances from Simulations for Existing Conditions, No-Action, and Alternative 2 Scenarios and for Differences between the Scenarios, in the Feather River Upstream of the Thermalito Afterbay Outlet
- Figure G-WQ2.3-4. Temperature Exceedances from Simulations for Existing Conditions, No-Action, and Alternative 2 Scenarios and for Differences between the Scenarios, in the Thermalito Afterbay Outlet
- Figure G-WQ2.3-5. Temperature Exceedances from Simulations for Existing Conditions, No-Action, and Alternative 2 Scenarios and for Differences between the Scenarios, in the Feather River Downstream of the Thermalito Afterbay Outlet
- Figure G-WQ2.3-6. Temperature Exceedances from Simulations for Existing Conditions, No-Action, and Alternative 2 Scenarios and for Differences between the Scenarios, in the Feather River Upstream of Honcut Creek
- Figure G-WQ2.3-7. Temperature Exceedances from Simulations for Existing Conditions, No-Action, and Alternative 2 Scenarios and for Differences between the Scenarios, in the Feather River Upstream of the Yuba River
- Figure G-WQ2.3-8. Temperature Exceedances from Simulations for Existing Conditions, No-Action, and Alternative 2 Scenarios and for Differences between

G-WQ2.3 WATER TEMPERATURE MODELING RESULTS

This section provides exceedance plots summarizing water temperature modeling results for several locations in the Low Flow Channel and High Flow Channel of the Feather River and at agricultural diversions in the Thermalito Complex under "Existing Conditions," which for the modeling is year 2001 level of development; "No-Action," which for the modeling is year 2020 level of development with no new project actions; and “Alternative 2,” which for the modeling is year 2020 level of development with the project actions included in Alternative 2. Figures giving results for the Proposed Action are not provided, because project operations under this alternative would be identical to those under the No-Action Alternative and, therefore, the water temperature results for the alternative are identical to those of No-Action.

The following provides 1 figure for each of 12 modeling locations, with 5 plots included per figure. Each plot gives information on water temperature exceedances for each day of the year, based on the 1922-through-1993 simulation period of record. The first 3 plots in each figure show the 50^{th} (median), 80^{th}, and 95^{th} percentile water temperatures for the Existing Conditions, No-Action, and Alternative 2 modeling scenarios, respectively. The last two charts show the differences in the three percentiles between No-Action and Existing Conditions and between Alternative 2 and No-Action. The two charts of differences are useful for evaluating effects of “Future Conditions” (including both No-Action and “Proposed Action”) and Alternative 2.

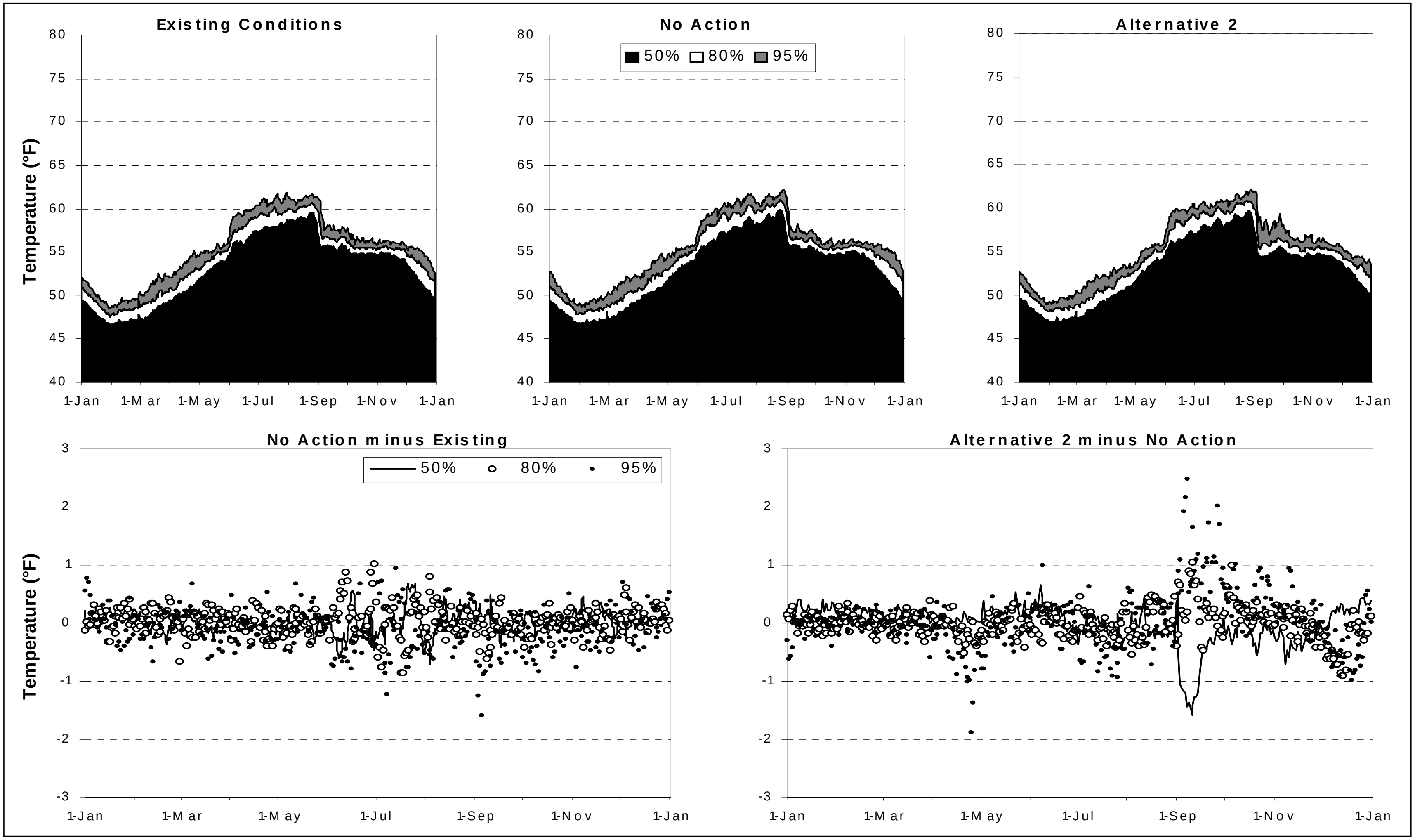


Figure G-WQ2.3-1. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, at the Thermalito Diversion Dam.

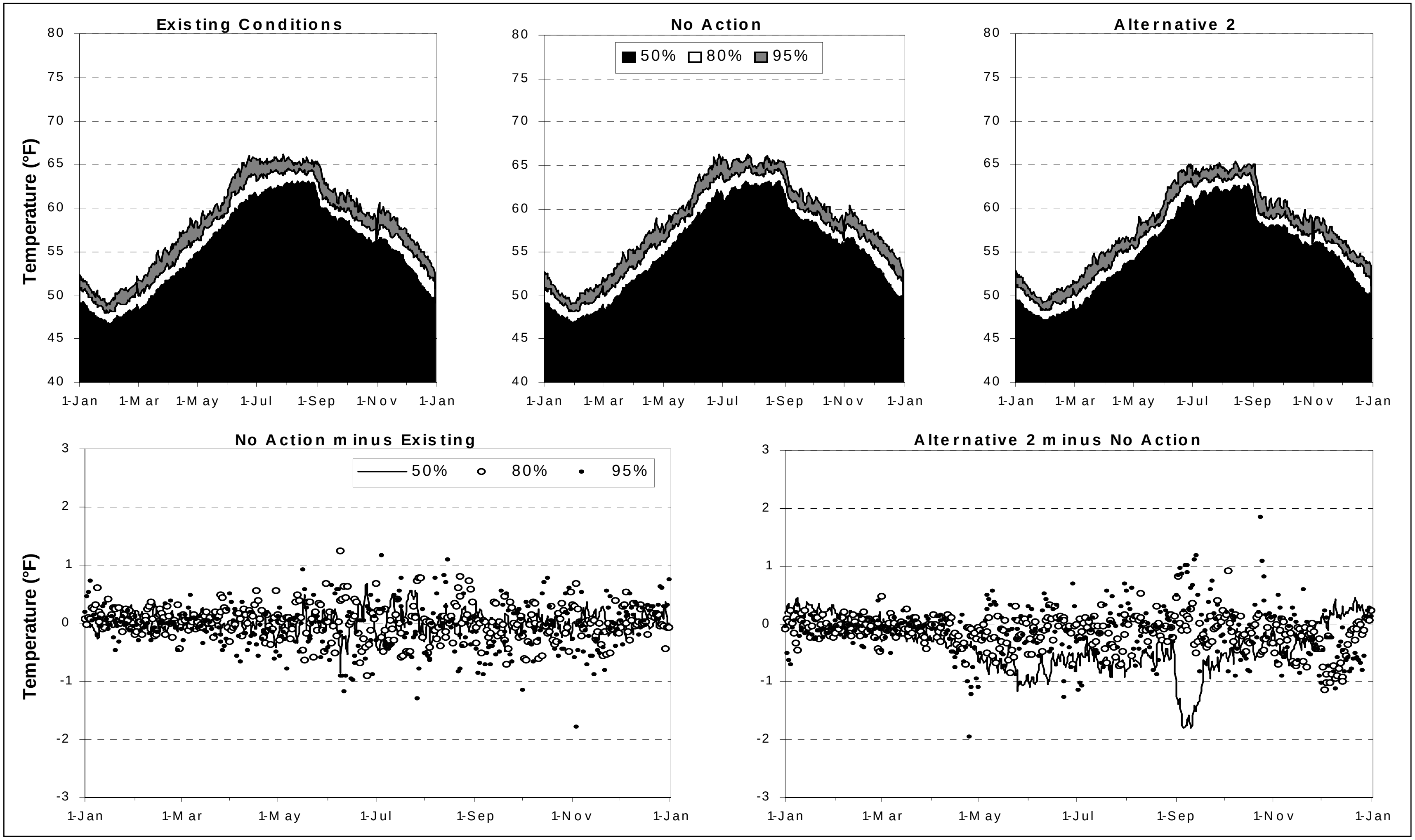


Figure G-WQ2.3-2. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, in the Feather River at Robinson Riffle.

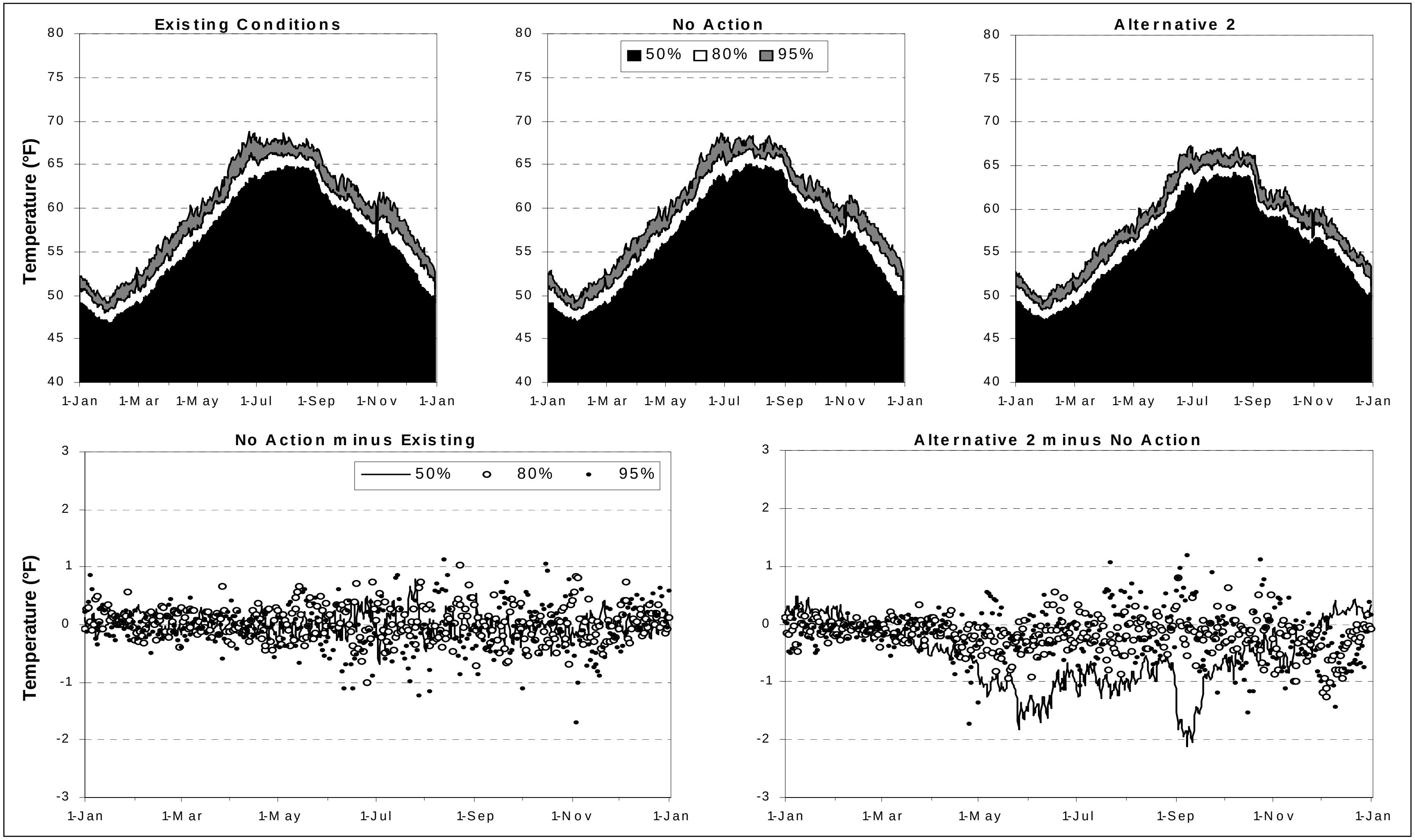


Figure G-WQ2.3-3. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, in the Feather River upstream of the Thermalito Afterbay Outlet.

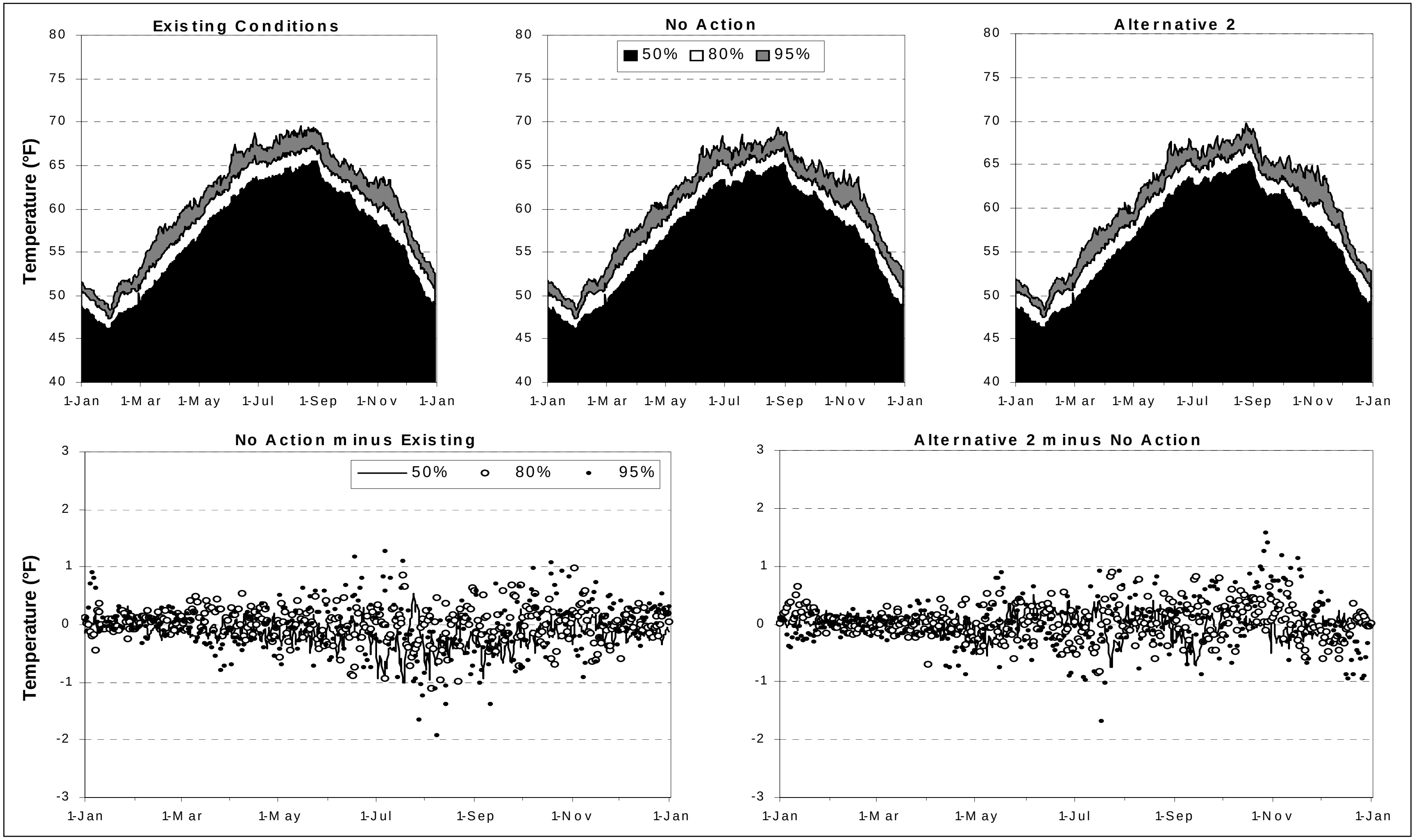


Figure G-WQ2.3-4. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, at the Thermalito Afterbay Outlet.

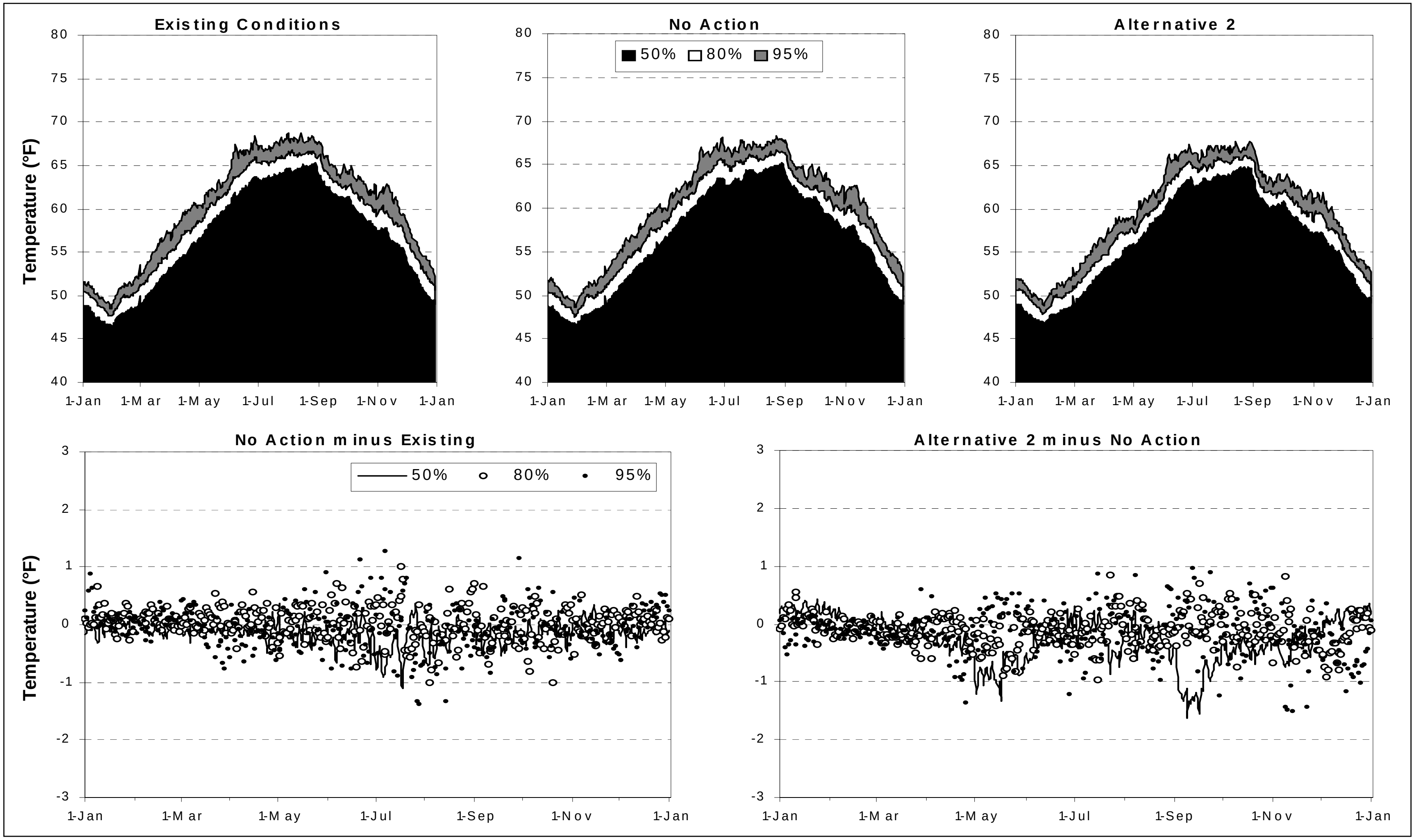


Figure G-WQ2.3-5. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, in the Feather River downstream of the Thermalito Afterbay Outlet.

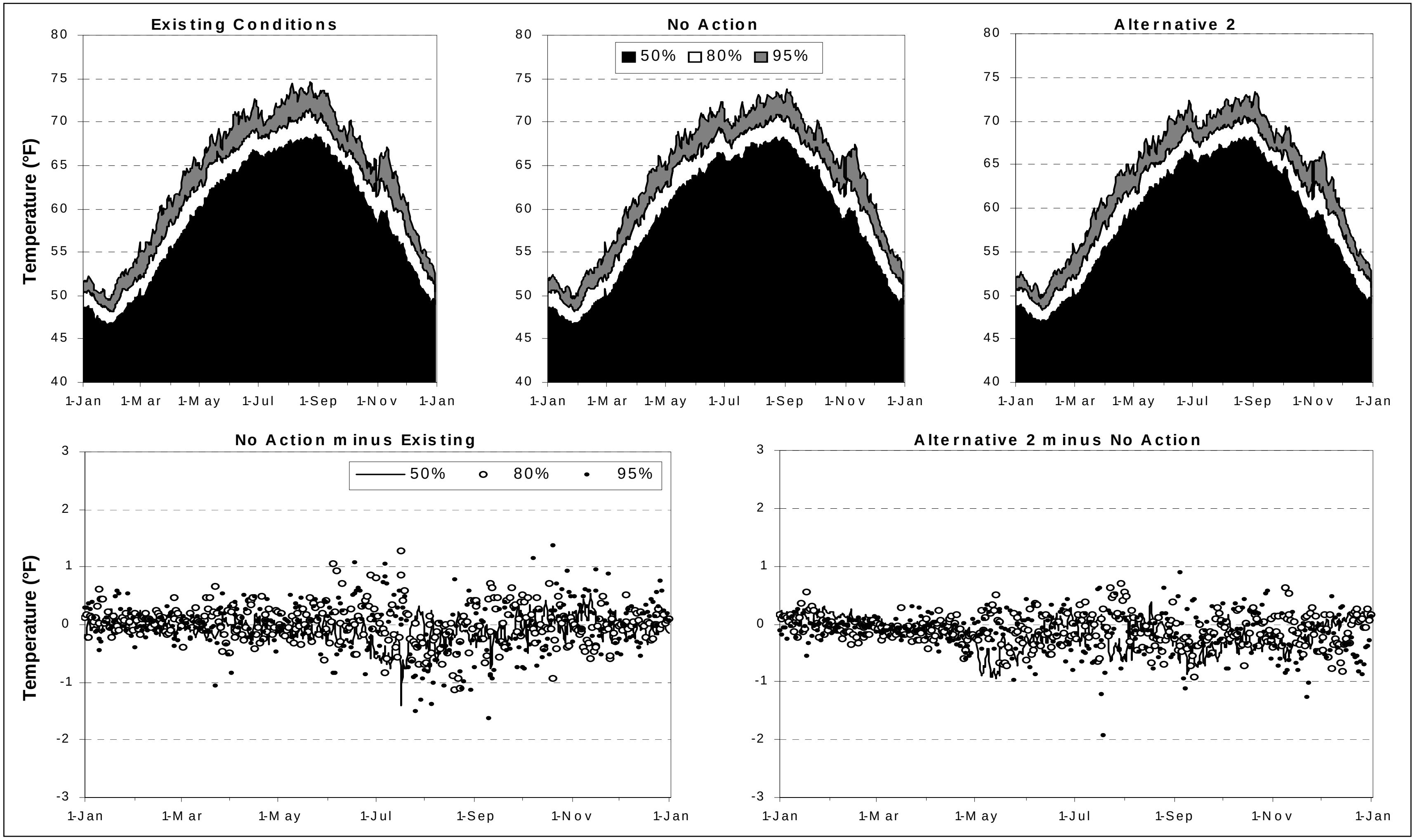


Figure G-WQ2.3-6. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, in the Feather River upstream of Honcut Creek.

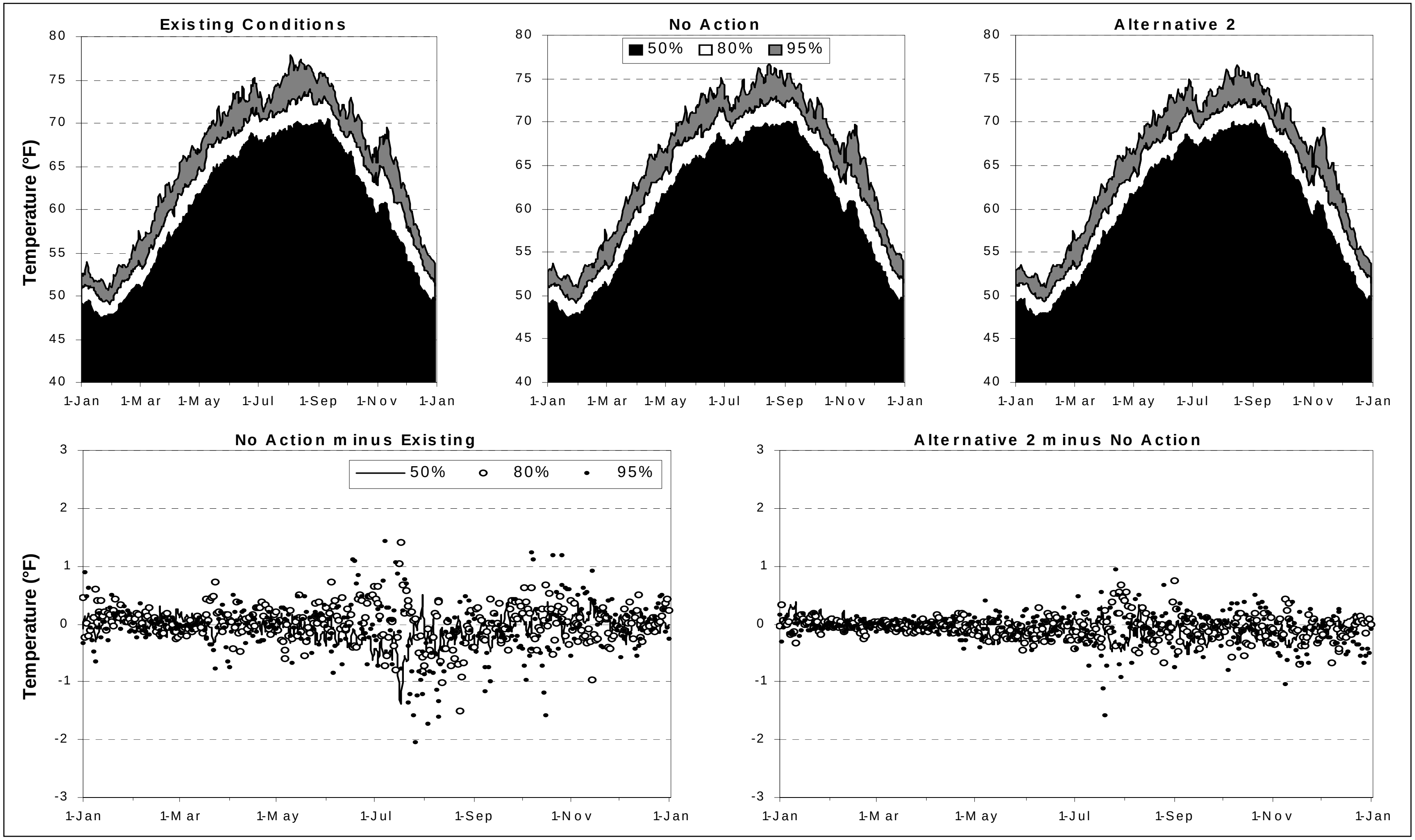


Figure G-WQ2.3-7. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, in the Feather River upstream of the Yuba River.

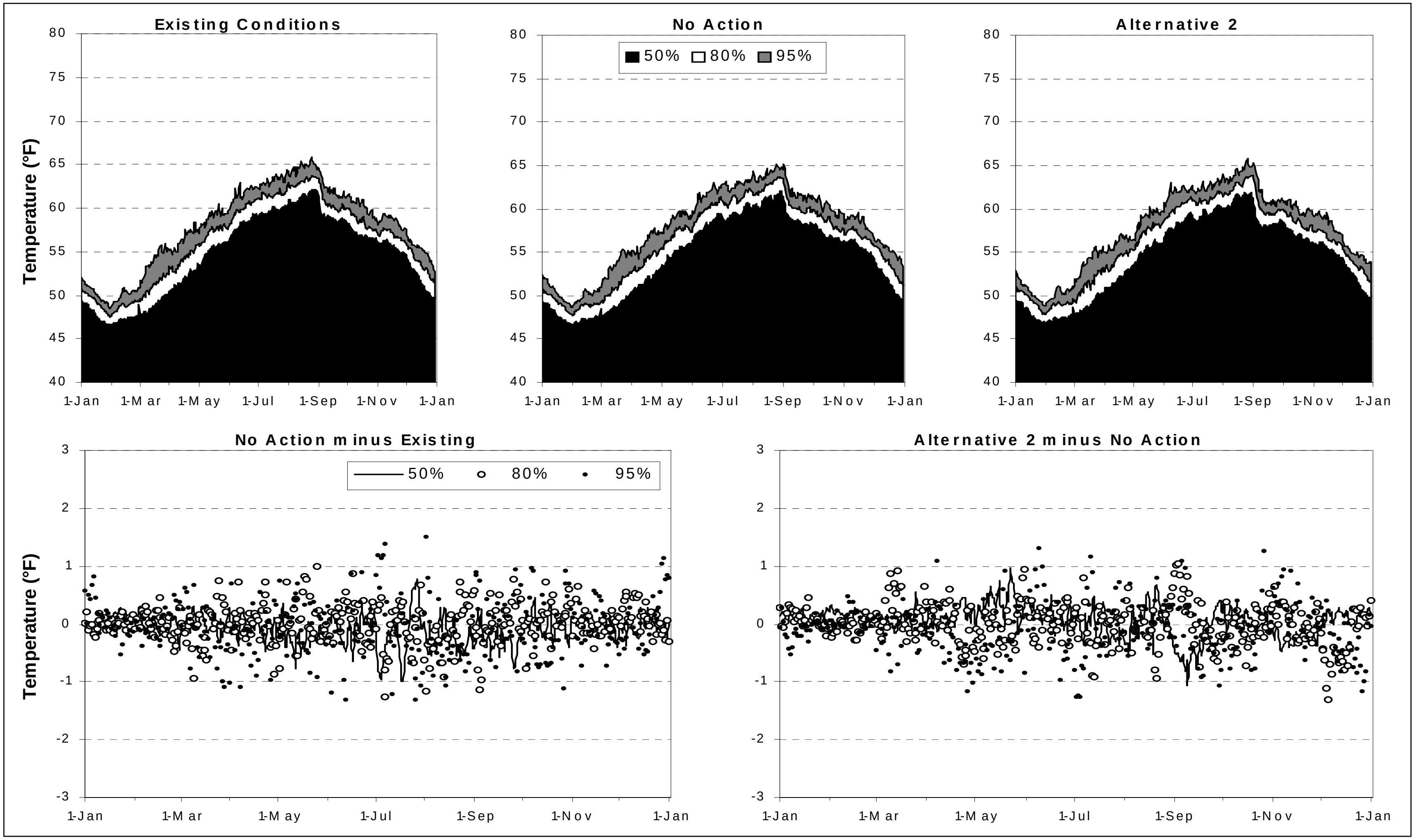


Figure G-WQ2.3-8. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, at the California Water Company Diversion from the Thermalito Complex.

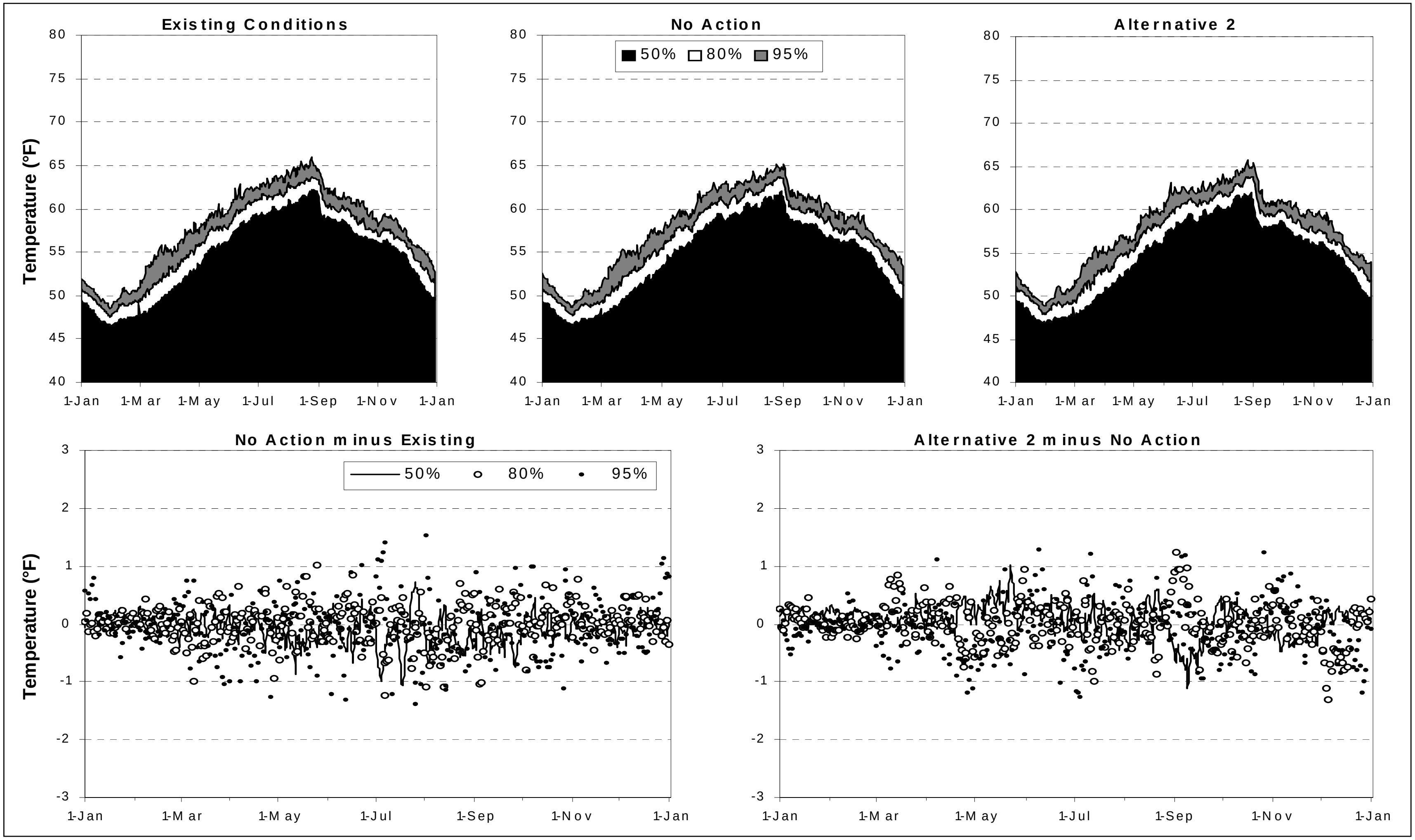


Figure G-WQ2.3-9. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between scenarios, at the Thermalito Irrigation District Diversion from the Thermalito Complex.

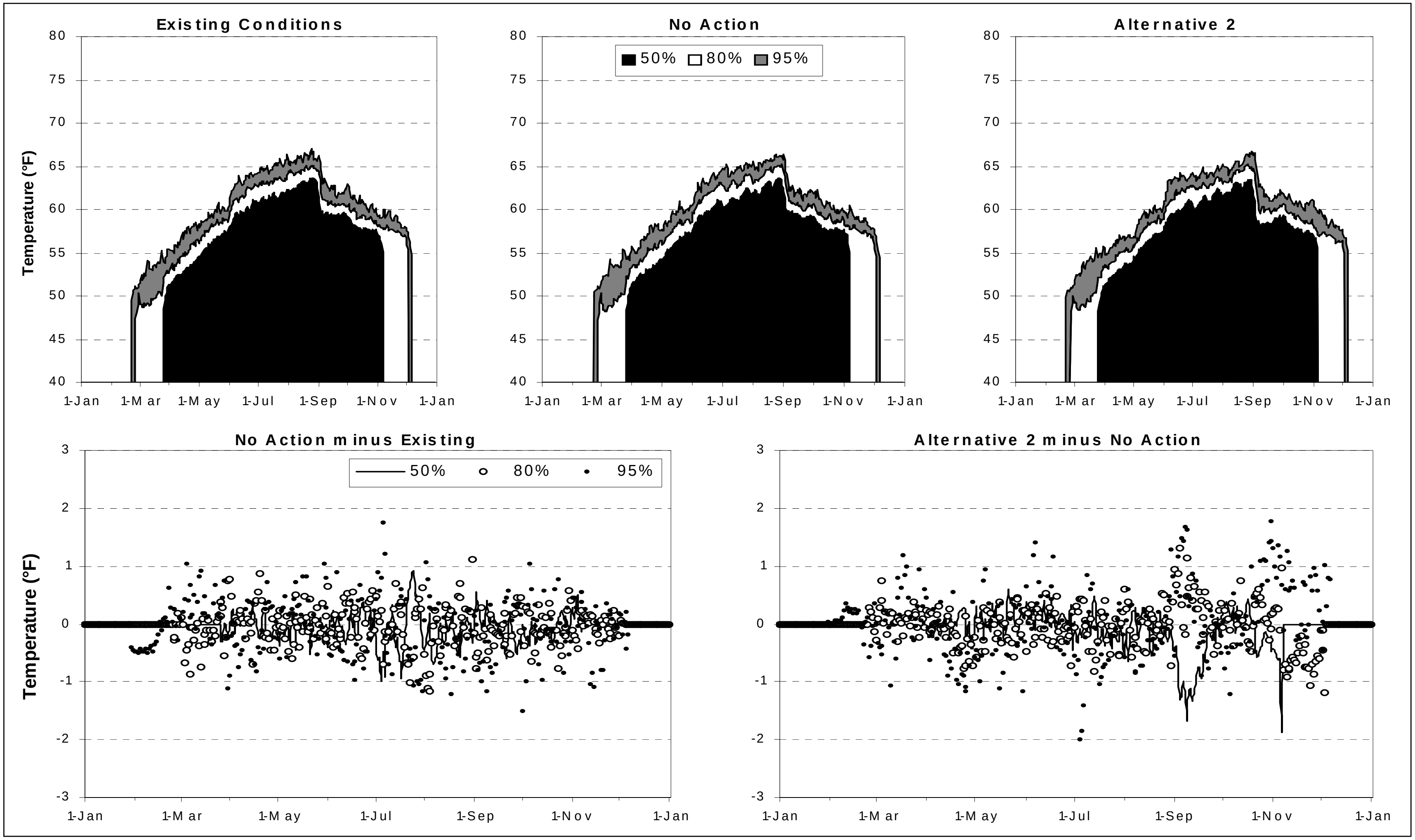


Figure G-WQ2.3-10. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, at the Western Canal Main Diversion from Thermalito Afterbay.

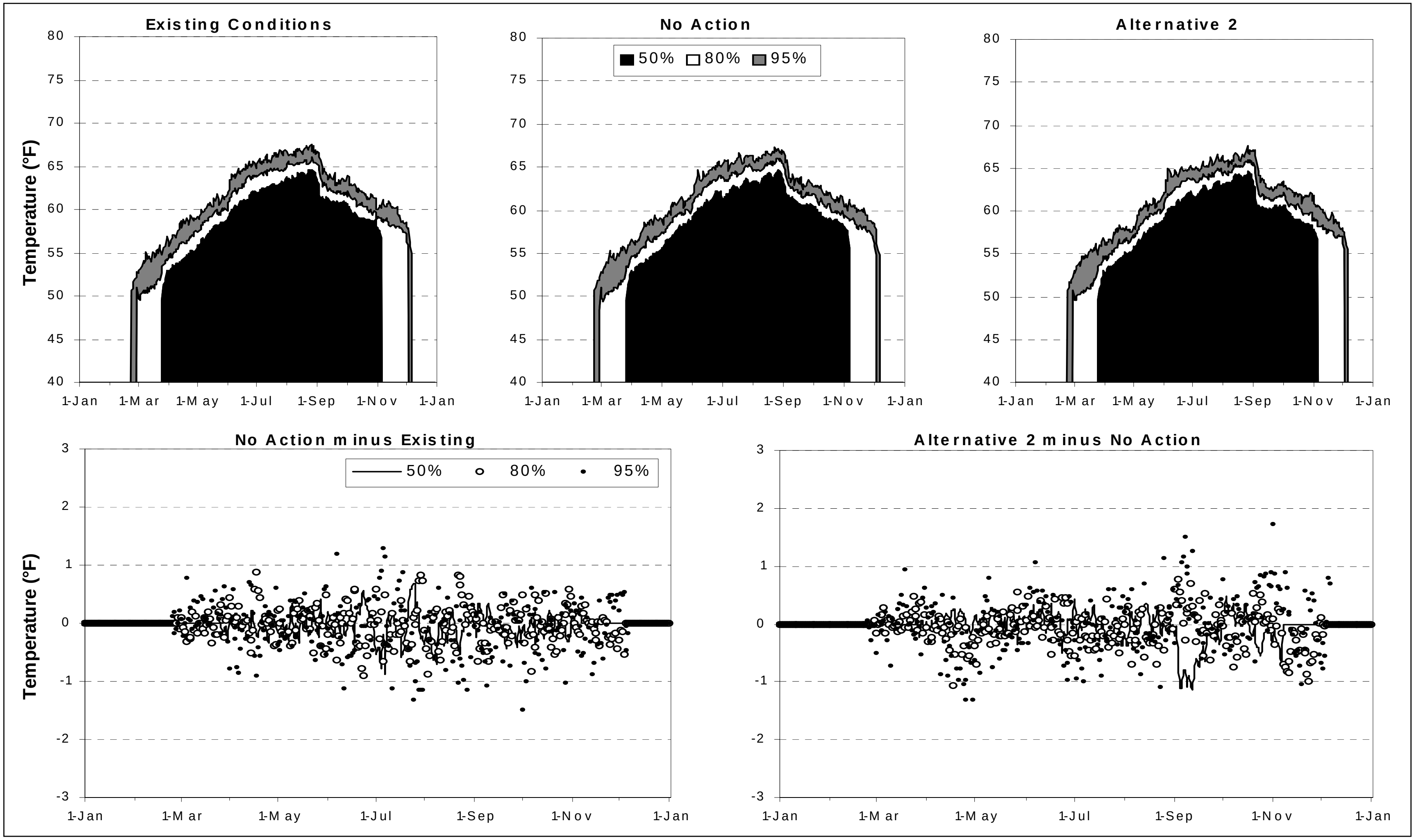


Figure G-WQ2.3-11. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, at the Western Canal Lateral Diversion from Thermalito Afterbay.

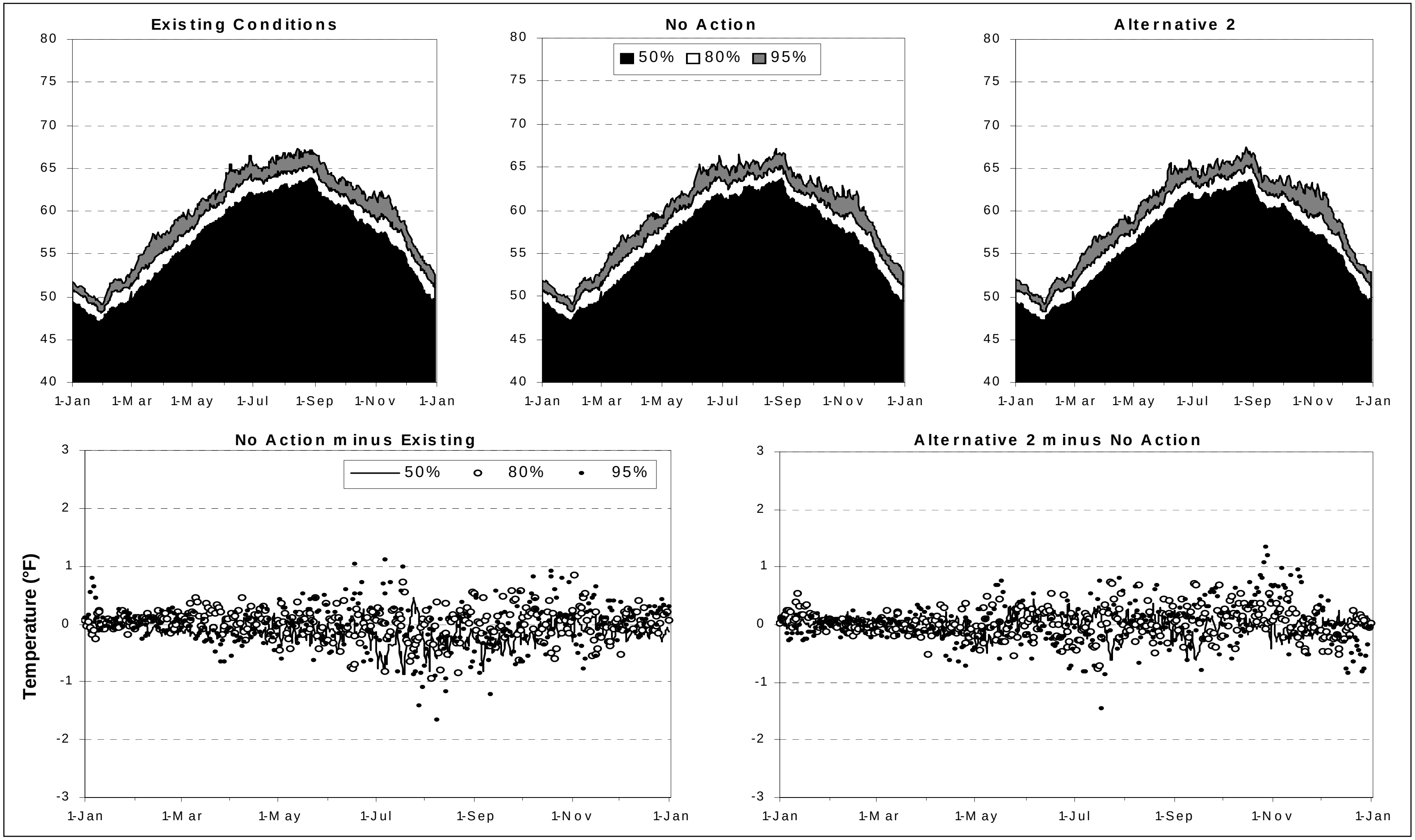


Figure G-WQ2.3-12. Temperature exceedances from simulations for Existing Conditions, No-Action, and Alternative 2 scenarios and for differences between the scenarios, at the Sutter Butte Canal Diversion from Thermalito Afterbay.

G-WQ2.4 WATER QUALITY STUDIES, METHODOLOGY

G-WQ2.4.1 Water Temperature Monitoring Program (SP-W6)

This study obtained water temperature data for empirical analyses of current conditions and to provide data for calibration of the temperature models developed in Engineering and Operations study plans.

Continuously recording loggers (Onset Optic Stowaway) were used to record temperatures at 15-minute intervals at river or discharge (e.g., Feather River Fish Hatchery, Thermalito Afterbay Outlet) monitoring locations (Figures G-WQ2.4-1 and G-WQ2.4-2). Temperature loggers were serviced and data downloaded to laptop computers at intervals not exceeding monthly.

Water temperatures were measured with a thermistor at half-meter intervals in deeper pools in the Feather River downstream of the dam to determine effects of project flows on thermal conditions including stratification. Temperatures were measured biweekly from late spring (May) to fall (October), and monthly from late fall (November) though early spring (April). Additional profiles were obtained at several sites upstream, within, and downstream of the pool formed in the Feather River by discharges from the Thermalito Afterbay Outlet. These additional measurements were obtained monthly from late spring to fall. Both temperature and dissolved oxygen were measured at intervals from the surface to the bottom at these sites.

Water temperatures were also measured at close intervals along the edge of the river upstream and downstream of the Feather River Fish Hatchery from spring through fall to help determine whether water leaches to the river from the hatchery and whether any hatchery leakage affects river temperatures.

Water temperatures were measured from the surface to the bottom at monthly intervals during the winter and biweekly from spring to fall in impounded waters (Lake Oroville, the Diversion Pool, Thermalito Forebay, Thermalito Afterbay, and the Fish Barrier Pool) and ponds in the Oroville Wildlife Area (OWA). Temperature profiles were measured in Lake Oroville with a thermistor at meter intervals when temperature differences are observed between successive depth measurements, and at 3- to 5- meter intervals when temperatures are uniform between depths. Temperature profiles were measured at 0.5- to 1-meter intervals in the other water bodies from the surface to the bottom using a thermistor. Cross section measurements were also conducted at Thermalito Forebay and Thermalito Afterbay to determine variation in temperatures in shallower and deeper areas, arms, and bays.

Existing and newly collected data were evaluated to determine thermal processes in Lake Oroville, the Diversion Pool, Thermalito Forebay, Thermalito Afterbay, the Fish Barrier Pool, and OWA ponds. Temperature data and the depth-capacity curve for the reservoir were used to evaluate the extent of the coldwater pool under existing project operations.

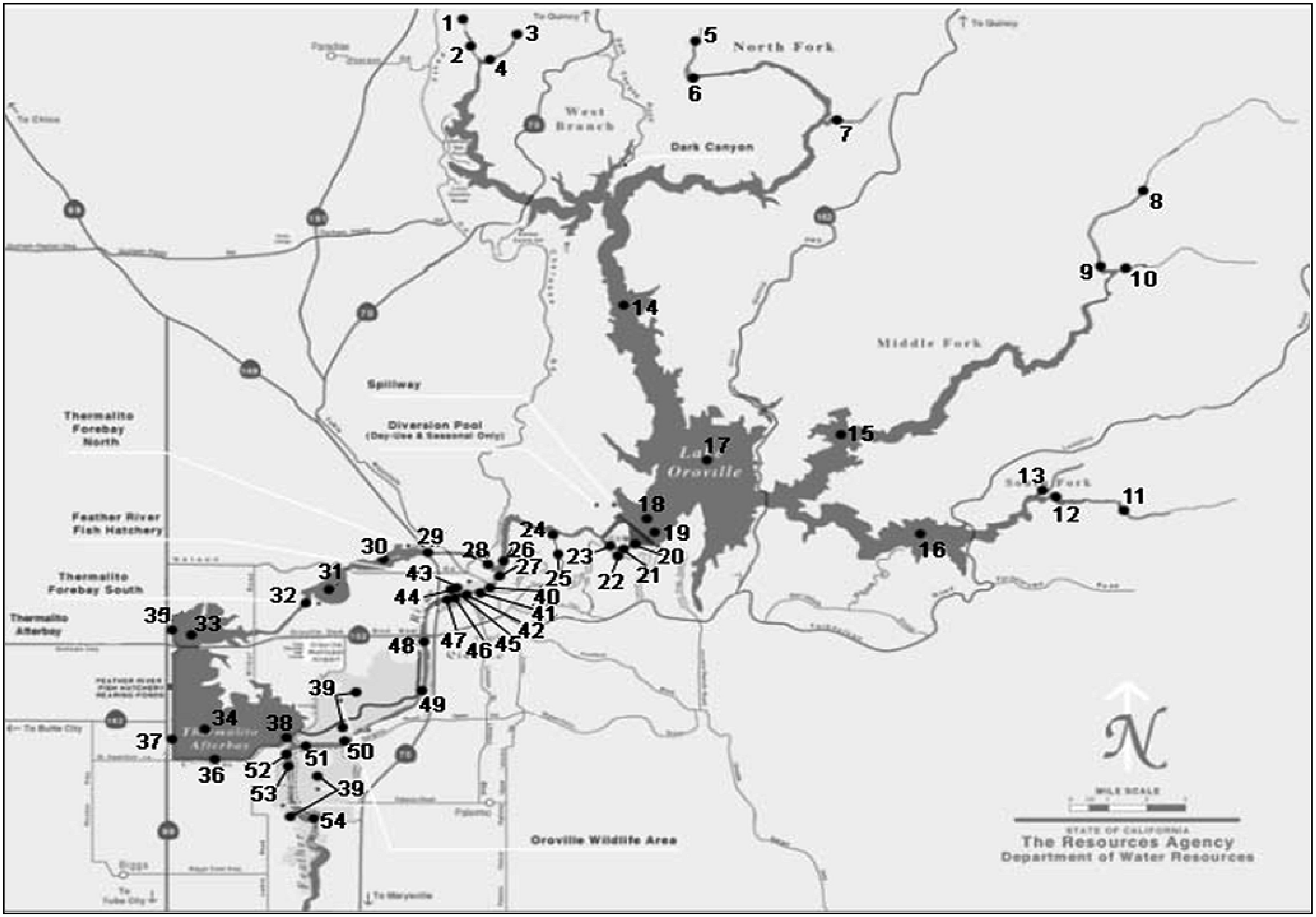


Figure G-WQ2.4-1. Temperature monitoring sites for project waters.

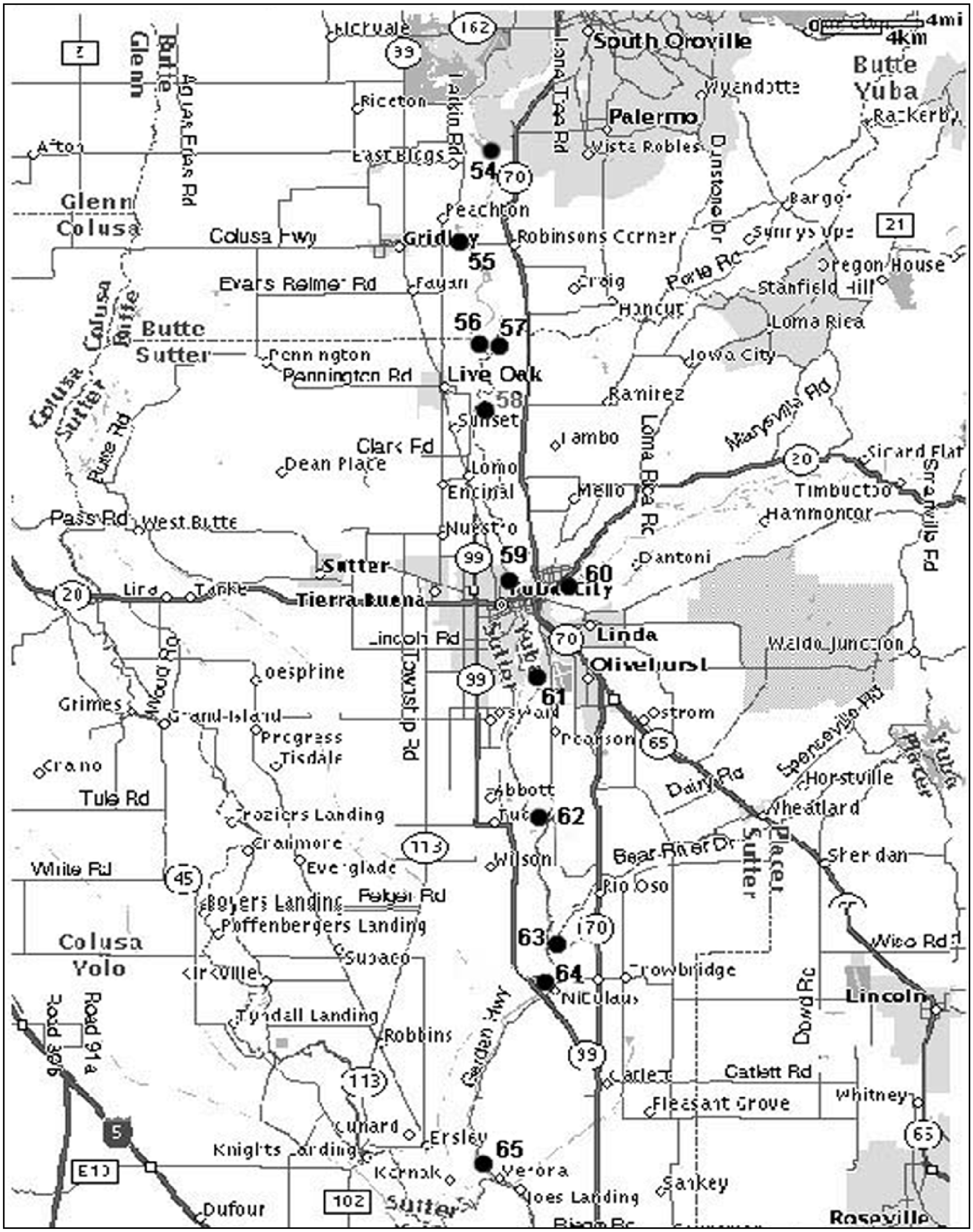
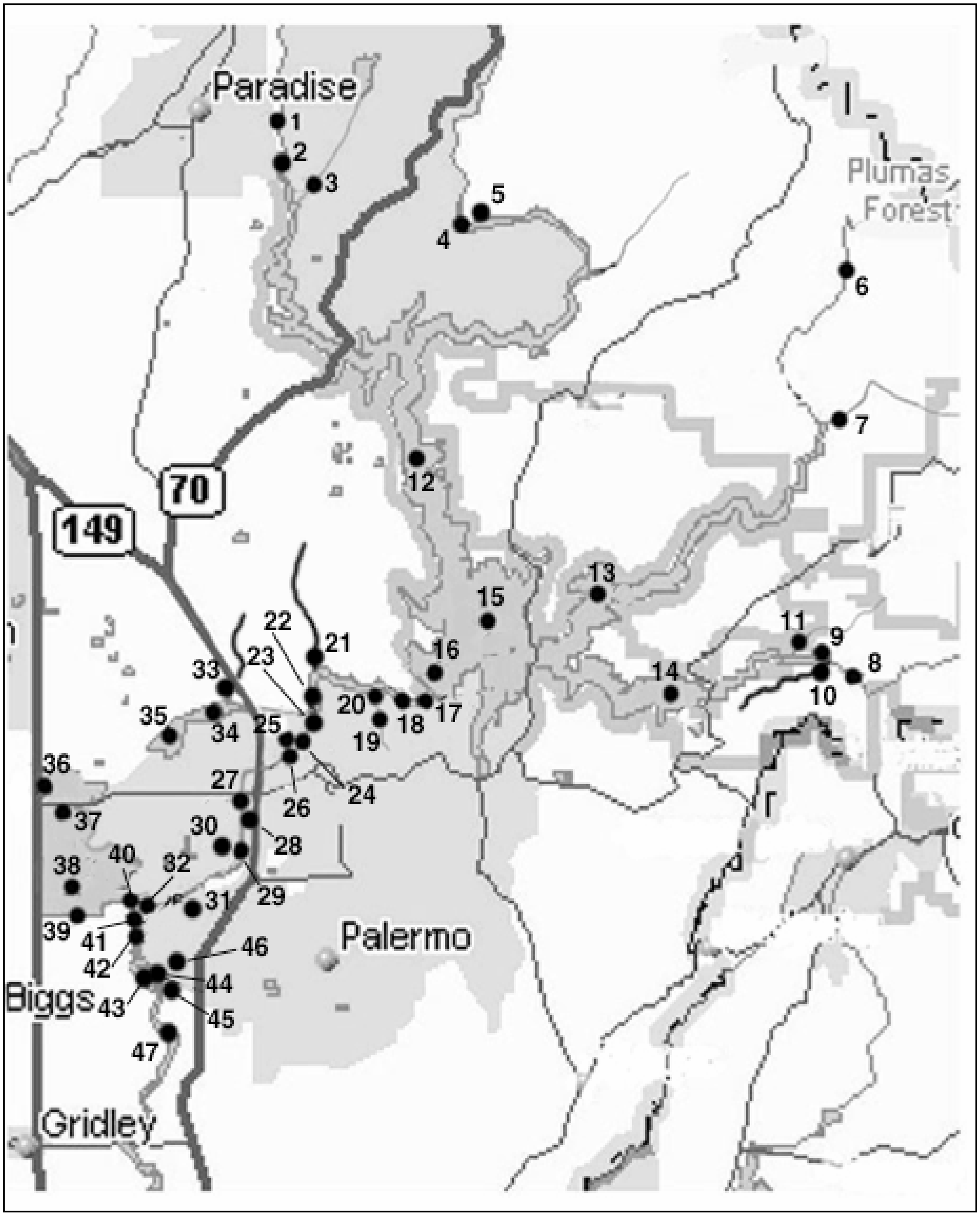


Figure G-WQ2.4-2. Temperature monitoring sites in the lower Feather River.

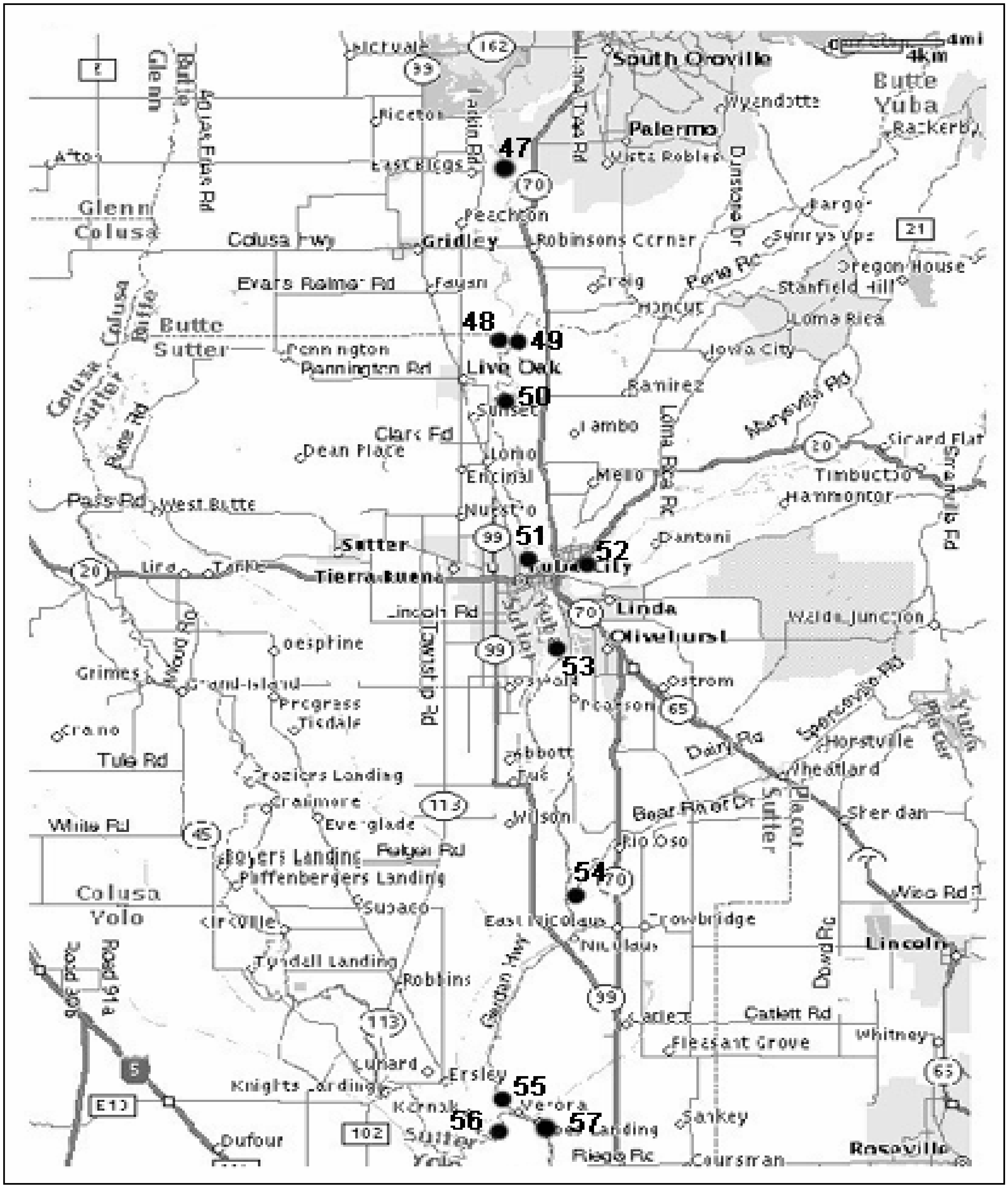
G-WQ2.4.2 General Water Quality Sampling Program (SP-W1)

This study characterized existing water quality conditions at different times of year throughout the project area to provide a basis for understanding effects of potential actions on water quality. The study generally relied on monthly collection of data from spring 2002 through spring 2004, although some parameters were targeted to specific times of the year because of parameter-specific factors. The study evaluated those parameters potentially affected by the project for which the Central Valley Regional Water Quality Control Board (RWQCB) has established water quality objectives in the Water Quality Control Plan (Basin Plan). Monitoring sites were identified in Environmental Work Group Task Force meetings, which included participation by federal and State agencies and other stakeholders. The monitoring sites were divided into three major regions: the Feather River and tributaries upstream of Lake Oroville, Lake Oroville and the Thermalito Complex impoundments, and the lower Feather River, including the OWA ponds (Figures G-WQ2.4-3 and G-WQ2.4-4, Table G-WQ2.4-1). The results of the study were compared to Basin Plan objectives and other water quality criteria for protection of beneficial uses in Table G-WQ2.4-2.



Note: See Table G-WQ2.4-1 for numbers legend.

Figure G-WQ2.4-3. Water quality monitoring sites in the project area.



Note: See Table G-WQ2.4-1 for numbers legend.

Figure G-WQ2.4-4. Water quality monitoring sites in the Lower Feather River.

Table G-WQ2.4-1. Monitoring site number system for maps.

1. West Branch Feather River near Paradise	30. Robinson Riffle Pond
2. West Branch Feather River upstream of Lake Oroville	31. Upper Pacific Heights Pond
3. Concow Creek at Jordan Hill Road	32. Feather River upstream of Thermalito Afterbay Outlet
4. North Fork Feather River upstream of Poe Powerhouse	33. North Thermalito Forebay Creek
5. Poe Powerhouse Discharge	34. Thermalito Forebay (north)
6. Middle Fork Feather River near Merrimac	35. Thermalito Forebay (south)
7. Fall River upstream of Feather Falls	36. Western Canal at Thermalito Afterbay Outlet
8. South Fork Feather River upstream of Ponderosa Reservoir	37. Thermalito Afterbay (north)
9. South Fork Feather River downstream of Ponderosa Reservoir	38. Thermalito Afterbay (south)
10. Miners Ranch Canal	39. Sutter Buttes Canal at Thermalito Afterbay Outlet
11. Sucker Run near Forbestown	40. Thermalito Afterbay Outlet Canal to Feather River
12. North Fork Arm Lake Oroville	41. Feather River downstream of Thermalito Afterbay Outlet
13. Middle Fork Arm Lake Oroville	42. Feather River downstream of SCOR Outlet
14. South Fork Arm Lake Oroville	43. Mile Long Pond
15. Lake Oroville Main Body	44. Feather River near Mile Long Pond
16. Lake Oroville near Dam	45. Lower Pacific Heights Pond
17. Diversion Pool upstream of Kelly Ridge Powerhouse (upstream of power plant)	46. See’s Pond
18. Diversion Pool downstream of Kelly Ridge Powerhouse (downstream of power plant)	47. Feather River downstream of FERC project boundary
19. Glen Creek upstream of Glen Pond	48. Feather River at Singh AB Riviera Road
20. Glen Pond	49. Honcut Creek at Pacific Ranch near Palermo
21. Morris Ravine	50. Feather River at Archer Ave. (near Live Oak)
22. Diversion Pool upstream of Dam	51. Feather River upstream of Yuba River
23. Feather River at Oroville	52. Yuba River at Mouth
24. Feather River upstream of the Feather River Fish Hatchery	53. Feather River at Shanghai Bend
25. Feather River Fish Hatchery Settling Pond	54. Bear River near Mouth
26. Feather River downstream of the Feather River Fish Hatchery	55. Feather River near Verona
27. Feather River downstream of State Route (SR) 162	56. Sacramento River upstream of Feather River
28. Oroville Fishing Pond	57. Sacramento River at Verona
29. Feather River at Robinson Riffle	

Table G-WQ2.4-2. Numerical limits used to evaluate compliance of surface waters with Basin Plan objectives (expressed as mg/L unless otherwise noted).

Criteria	Sedimentation	Turbidity	Suspended Solids	Settleable Matter	Dissolved Oxygen	pH	Alkalinity	Conductivity
Primary MCL[1]	*no criteria*	1 / 5 NTU[8]	*no criteria*	*no criteria*				
Secondary MCL[1]		5 NTU						900 µmhos/cm
Agricultural Goal[2]						6.5 to 8.4		700 µmhos/cm
NAWQC Humans[3]								
NAWQC Aquatic Life[3]								
Chronic (4-day Average)					variable[9]		≥ 20	
Acute (1-hour Average)[4]						6.5 to 9		
Recommended Ecoregional Nutrient Criteria								
Central Valley Rivers and Streams[5]		4.38 NTU						
Sierra Nevada Rivers and Streams[6]		1.3 NTU						
Basin Plan[7]								150 µmhos/cm

[1] California Department of Health Services (DHS), California Code of Regulations, Title 22, Division 4, Chapter 15, Domestic Water Quality and Monitoring.
[2] Food and Agriculture Organization of the United Nations. 1985. Water Quality for Agriculture.
[3] U.S. Environmental Protection Agency (USEPA), Quality Criteria for Water, 1986 (May 1986) [The Gold book] plus updates (various dates).
[4] Sometimes this is an Instantaneous Maximum.
[5] USEPA, Ambient Water Quality Criteria Recommendations for Rivers and Streams in Ecoregion I. 2001. EPA 822-B-01-012.
[6] USEPA, Ambient Water Quality Criteria Recommendations for Rivers and Streams in Ecoregion II. 2000. EPA 822-B-00-015.
[7] The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region, Fourth edition. The Sacramento River Basin and the San Joaquin River Basin. Central Valley Regional Water Quality Control Board. Sacramento, California.
[8] Proposed; applies only to second value if two separate values are listed; applies to range if a range of values is listed.
[9] Central Valley Regional Water Quality Control Board (RWQCB). 2003. A Compilation of Water Quality Goals. See Page 26.

Table G-WQ2.4-2 (Continued). Numerical limits used to evaluate compliance of surface waters with Basin Plan objectives (expressed as mg/L unless otherwise noted).

Criteria	Calcium	Magnesium	Sodium	Potassium	Sulfate	Chloride	Boron	Hardness
USEPA - Taste and Odor Thresholds[10]	*no criteria*	*no criteria*	30 to 60	*no criteria*	250			*no criteria*
Secondary MCL[11]					250/500 [17]	250		
Agricultural Goal[12]			69			106	0.7	
NAWQC Aquatic Life[13]								
Chronic (4-day Average)						230 [18]		
Acute (1-hour Average)						860 [18]		
USEPA IRIS Reference Dose[14]							0.63 [19]	
DHS Action Level for drinking water[15]							1	
USEPA draft Drinking Water Advisory[10]			20 [16]		500		0.6	
USEPA Proposed MCL Goal[10]					500			

[10] USEPA, Office of Water, 2004 Edition of the Drinking Water Standards & Health Advisories. (Winter 2004). EPA 822-R-04-005.
[11] DHS, California Code of Regulations, Title 22, Division 4, Chapter 15, Domestic Water Quality and Monitoring.
[12] Food and Agriculture Organization of the United Nations, 1985. Water Quality for Agriculture.
[13] USEPA, Quality Criteria for Water, 1986 (May 1986) [The Gold book] plus updates (various dates).
[14] USEPA, Integrated Risk Information System [IRIS] database.
[15] DHS, Division of Drinking Water and Environmental Management, Drinking Water Action Levels (6 June 2003), http://www.dhs.cahwnet.gov/ps/ddwem.
[16] Guidance level to protect those individuals restricted to a total sodium intake of 500 mg/day; Reference 33.
[17] First value is ambient level, second is "upper" level.
[18] For dissolved chloride associated with sodium; criterion probably will not be adequately protective when chloride is associated with potassium, calcium, or magnesium, rather than sodium.
[19] Assumes 70 kilograms body weight, 2 liters per day drinking water consumption, and 20 percent relative source contribution. An additional uncertainty factor of 10 is used for Class C carcinogens.

Table G-WQ2.4-2 (Continued). Numerical limits used to evaluate compliance of surface waters with Basin Plan objectives (expressed as mg/L unless otherwise noted).

Criteria	Ammonia		Nitrate	Nitrite (as N)	Nitrate + Nitrite (as N)	Ortho-phosphate (dissolved)	Total Phosphorus	Organic Carbon
	Total	Dissolved						
Tastes and Odors[20]	1.5							
Primary MCL[21]			45 [28]	1				
NAWQC Aquatic Life[22]								
Chronic (4-day Average)	see table 1							
Acute (1-hr Average)	see table 1							
Recommended Ecoregional Nutrient Criteria								
Central Valley Rivers and Streams[23]		*no criteria*			0.15	*no criteria*	0.047	*no criteria*
Sierra Nevada Rivers and Streams[24]					0.014		0.01	
Sierra Nevada Lakes and Reservoirs[25]					0.02		0.00875	
USEPA Draft Drinking Water Health Advisory[26]			10 [29]	1				
Public Health Goal[27]			10 [29]	1	10			

[20] *J. E. Amoore and E. Hautala. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatitilities for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, 3(6):272-290. 1983.*
[21] *DHS, California Code of Regulations, Title 22, Division 4, Chapter 15, Domestic Water Quality and Monitoring.*
[22] *USEPA, Quality Criteria for Water, 1986 (May 1986) [The Gold book] plus updates (various dates).*
[23] *USEPA, Ambient Water Quality Criteria Recommendations for both Rivers and Streams in Ecoregion 1. 2001. EPA 822-B-01-012.*
[24] *USEPA, Ambient Water Quality Criteria Recommendations for Rivers and Streams in Ecoregion II. 2000. EPA 822-B-00-015.*
[25] *USEPA, Ambient Water Quality Criteria Recommendations for Lakes and Reservoirs in Ecoregion II. 2000. EPA 822-B-00-007.*
[26] *USEPA, Office of Water, 2004 Edition of the Drinking Water Standards and Health Advisories. (Winter 2004). EPA 822-R-04-005.*
[27] *California Environmental Protection Agency (Cal/EPA), Office of Environmental Health Hazard Assessment, Public Health Goals for Chemicals in Drinking Water (various dates), http://www.oehha.org/water.phg/.*
[28] *As NO_3.*
[29] *As nitrogen (N).*

Table G-WQ2.4-2 (Continued). Numerical limits used to evaluate compliance of surface waters with Basin Plan objectives (expressed as mg/L unless otherwise noted).

Criteria	Aluminum		Arsenic		Cadmium	Chromium	Copper		Iron	Mercury	
	T	D	T	D	D	T	T	D	D	T	D
Public Health Goal[30]	-	0.6	-	-	-	-	-	0.17	-	-	-
Primary MCL[31]	-	1	-	0.05	0.005	0.05	-	1.3	-	-	-
Secondary MCL[31]	-	0.2	-	-	0.00007	-	-	1	0.3	-	-
Agricultural Goal[32]	-	5	-	-	0.01	-	-	200	5	-	-
Cal/EPA Cancer Potency Factor[33,34]	-	-	-	0.000023	0.000092	-	-	-	-	-	-
CTR Humans[35]	-	-	-	-	-	-	1.3	-	-	0.00005	-
CTR Aquatic Life[35]											
Chronic, 4-day Average	-	-	-	0.15	*variable* [41]	-	-	*variable* [43]	-	-	-
Acute, 1-hour Average	-	-	-	0.34	*variable* [41]	-	-	*Variable* [43]	-	-	-
NAWQC Humans[36]	-	-	.000018 [40]	-	-	-	-	1.3	-	-	-
NAWQC Aquatic Life[36]											
Chronic, 4-day Average	0.087 [39]	-	-	0.15	*variable* [42]	-	-	*variable* [43]	1	-	0.00077
Acute, 1-hour Average	0.75 [39]	-	-	0.34	*variable* [42]	-	-	*Variable* [43]	-	-	0.0014
USEPA IRIS Reference Dose[37,38]	-	-	-	.0021	0.0035	-	-	-	-	-	-

[30] California Environmental Protection Agency (Cal/EPA) Office of Environmental Health Hazard Assessment Public Health Goals for Chemicals in Drinking Water.
[31] DHS, California Code of Regulations, Title 22, Division 4, Chapter 15, Domestic Water Quality and Monitoring.
[32] Food and Agriculture Organization of the United Nations, 1985. Water Quality for Agriculture.
[33] Cal/EPA, Office of Environmental Health Hazard Assessment, Cal/EPA Toxicity Criteria Database.
[34] Assumes 70 kg body weight and 2 liters/day water consumption.
[35] State Water Resources Control Board (SWRCB), Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (2 March 2003).
[36] USEPA, Quality Criteria for Water, 1986 (May 1986) [The Gold book] plus updates (various dates).
[37] USEPA, Integrated Risk Information System [IRIS] database.
[38] Assumes 70 kilograms body weight, 2 liters/day water consumption, and 20 percent relative source contribution from drinking water. An additional uncertainty factor of 10 is used for Class C carcinogens.
[39] For pH between 6.5 and 9.0. Use of Water-Effects Ratios might be appropriate because: (1) aluminum is less toxic at higher pH and hardness but relationship not well quantified; (2) aluminium associated with clay particles may be less toxic than that associated with aluminum hydroxide particles; (3) many high quality waters in U.S. exceed 87 µg/L as total or dissolved.
[40] Criterion refers to the inorganic form only.
[41] Central Valley RWQCB. 2003. A Compilation of Water Quality Goals. See Page 19.
[42] Central Valley RWQCB. 2003. A Compilation of Water Quality Goals. See Page 20.
[43] Central Valley RWQCB. 2003. A Compilation of Water Quality Goals. See Page 23.

Table G-WQ2.4-2 (Continued). Numerical limits used to evaluate compliance of surface waters with Basin Plan objectives (expressed as mg/L unless otherwise noted).

Criteria	Methyl Mercury	Manganese	Nickel		Lead	Selenium		Silver	Zinc	
	T	D	T	D	D	T	D	D	T	D
Public Health Goal[44]	-	-	-	0.012	0.002	-	-	-	-	-
Primary MCL[45]	-	-	-	0.1	0.015	-	0.05	-	-	-
Secondary MCL[45]	-	0.05	-		-	-	-	0.1	-	5
Agricultural Goal[46]	-	0.2	-	0.2	5	-	0.02	-	-	2
Cal/EPA Cancer Potency Factor[47,48]	-	-	-		0.0041	-	-	-	-	-
CTR Humans[49]	-	-	0.61	-	-	-	-	-	-	-
CTR Aquatic Life[49]										
Chronic, 4-day Average	-	-	-	*variable* [53]	*variable* [54]	0.005		-	-	*variable* [57]
Acute, 1-hour Average	-	-	-	*variable* [53]	*variable* [54]	0.02		*variable* [55]	-	*variable* [57]
NAWQC Humans[50]	-	-	0.61	-	-	0.170	-	-	7.4	-
NAWQC Aquatic Life[50]										
Chronic, 4-day Average	-	-	-	*variable* [53]	*variable* [54]	0.005		-	-	*variable* [57]
Acute, 1-hour Average	-	-	-	*variable* [53]	*variable* [54]	0.135		*variable* [56]	-	*variable* [57]
USEPA IRIS Reference Dose[51,52]	0.00007	0.98	-	0.14	-	-	0.035	0.035	-	2.1

[44] Cal/EPA, Office of Environmental Health Hazard Assessment, Public Health Goals for Chemicals in Drinking Water.
[45] DHS, California Code of Regulations, Title 22, Division 4, Chapter 15, Domestic Water Quality and Monitoring.
[46] Food and Agriculture Organization of the United Nations, 1985. Water Quality for Agriculture.
[47] Cal/EPA, Office of Environmental Health Hazard Asssessment, Cal/EPA Toxicity Criteria Database.
[48] Assumes 70 kilograms body weight and 2 liters/day water consumption.
[49] SWRCB, Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (2 March 2003).
[50] USEPA, Quality Criteria for Water, 1986 (May 1986) [The Gold book] plus updates (various dates).
[51] USEPA, Integrated Risk Information System [IRIS] database.
[52] Assumes 70 kilograms body weight, 2 liters/day water consumption, and 20 percent relative source contribution from drinking water. An additional uncertainty factor of 10 is used for Class C carcinogens.
[53] Central Valley RWQCB. 2003. A Compilation of Water Quality Goals. See Page 25.
[54] Central Valley RWQCB. 2003. A Compilation of Water Quality Goals. See Page 24.
[55] Central Valley RWQCB. 2003. A Compilation of Water Quality Goals. See Page 28.
[56] Central Valley RWQCB. 2003. A Compilation of Water Quality Goals. See Page 29.
[57] Central Valley RWQCB. 2003. A Compilation of Water Quality Goals. See Page 30.
Notes: CTR = California Toxics Rule; MCL = Maximum Contaminant Level; mg/L = milligrams per liter; µmhos/cm = micro-mhos per centimeter; NAWQC = National Ambient Water Quality Criteria; NTU = nephelometric turbidity units

G-WQ2.4.2.1 Field Parameters (Water Temperature, Dissolved Oxygen, pH, Electrical Conductivity, and Turbidity)

Basic water quality parameters, including water temperature, dissolved oxygen (DO), pH, electrical conductivity, and turbidity were measured with calibrated field instrumentation during each field visit. Stream samples or measurements were collected about 1 foot below the surface in flowing, well-mixed riffle or run areas. DO was measured in streams by titration (azide modification of the iodometric method). Basic water quality parameters collected in lentic waters (impoundments and ponds) were measured from the surface to the bottom at meter intervals when differences in individual parameters were observed between successive depths, and at 3- to 5- meter intervals when there were no differences in successive values. Conductivity and pH were measured with meters in samples collected at intervals with a van Dorn water bottle. Turbidity was measured with a nephelometer from samples collected using the van Dorn water bottle.

DO was also measured in pools near the sampling stations downstream of the Fish Barrier Dam to the mouth of the Feather River. DO (and temperature in conjunction with SP-W6) profiles were measured at half-meter intervals from the surface to the bottom of pools with meters and probes every other week from May through October, and monthly from November through April.

G-WQ2.4.2.2 Inorganic Chemistry (Minerals, Alkalinity, Metals, Hardness, Nutrients, and Organic Carbon)

Inorganic chemical analyses included minerals (calcium, sodium, potassium, magnesium, sulfate, chloride, boron, and alkalinity); metals (aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, and zinc); nutrients (nitrate plus nitrite, ammonia, dissolved orthophosphate, and total phosphorus); and total and dissolved organic carbon. For all metals except mercury, samples were collected for both total recoverable and dissolved metals. Mercury analyses were conducted by using U.S. Environmental Protection Agency (USEPA) Method 1631, and include both total recoverable and total methyl fractions. Hardness was also analyzed from samples collected at each site.

Samples for chemical analyses from streams were collected by wading into the channel and dipping sample containers to a depth of approximately 1 foot into the well-mixed channel flow. Mineral and nutrient samples were collected into clean polyethylene containers. Samples for trace metals analyses at water quality criteria levels were collected into polyethylene or glass bottles according to USEPA Method 1669 (USEPA 1996). Samples for mineral, nutrient, and metal analyses from lakes and ponds were collected from the surface by dipping an inverted container to approximately 0.5 meter below the surface. Water samples at greater depths were collected with a van Dorn water bottle for minerals and nutrients and Teflon bomb or Kemmerer style bottles for trace metals. Samples were collected from near the surface and bottom of lakes and ponds during periods of stratification or when differences in field parameters occurred between the surface and bottom, but only at mid-depth during those portions of the year when field parameters indicated uniform conditions throughout the water column in the shallower water bodies, such as OWA ponds.

Chemical analyses of minerals, nutrients, and metals were performed at the DWR Bryte Chemical Laboratory in West Sacramento using USEPA approved techniques, equipment, and methods.

G-WQ2.4.2.3 Sedimentation

Stream gravels from riffle areas were analyzed for laboratory determination of particle size distribution in Study Plan SP-G2, Task 2.

G-WQ2.4.2.4 Suspended and Settleable Solids

Water samples were collected for suspended and settleable materials analyses during monthly visits to the sites designated for inorganic chemistry analyses. Settleable materials were determined by settling the water sample in an Imhoff cone, while suspended material was determined by filtration.

G-WQ2.4.2.5 Pesticides

Water samples for determining concentrations of pesticides were collected from the monitoring stations in the fall after rains produced the first significant runoff and again during February or March. Samples were analyzed at the Bryte Chemical Laboratory for chlorinated organic pesticides, organic phosphorus pesticides, chlorinated phenoxy acid herbicides, volatile organic pesticides, carbamate pesticides, and glyphosate.

G-WQ2.4.2.6 Color

Color is defined as either true or apparent color. Water samples were collected for color analyses during monthly visits to the sites designated for inorganic chemistry analyses. Color was determined by first filtering samples to remove apparent color and then comparing the filtered samples against calibrated glass disks (colorimetry). The analyses were conducted by using Standard Method 2120 B.

G-WQ2.4.2.7 Floating Material and Oil and Grease

Floating materials and oil and grease were determined through visual observation during each visit to each monitoring site. Floating materials, if present, were estimated as a percent cover of the water. If oil, grease, or related compounds were sighted, water samples were collected for laboratory determination of the type of compound. The oil and grease analyses were conducted using Standard Method 5520.

G-WQ2.4.2.8 Tastes and Odors

Sampling water for taste requires that a sample be taken into the mouth for sensory analysis. However, raw water is not safe for taste testing because of the potential presence of bacteria, viruses, hazardous chemicals, and other factors. Therefore, water from the project area was not subjected to taste tests.

Water can be analyzed for odor simply by smelling a sample. At least two individuals smelled water samples from each site visit to determine the presence of odors. The samplers described the type of any odor detected to attempt determination of the causative agent.

G-WQ2.4.2.9 Pathogens (Bacteria)

Fecal coliform bacteria in aquatic ecosystems are indicative of fecal contamination. Though these bacteria generally do not pose adverse risks, their presence indicates the possible presence of far more serious microorganisms that may affect human health and potential nutrient loading that may adversely affect the aquatic environment.

Bacteria levels were screened monthly at the monitoring stations using membrane filter procedures for both fecal and total coliform bacteria. In addition, a focused coliform bacteria sampling program was conducted by monitoring selected stations at intensively used recreation areas, such as the North Forebay Recreation Area, during a major holiday event, according to requirements in the Basin Plan (i.e., no fewer than 5 samples for any 30-day period). This list of coliform sampling stations was developed in consultation with State Water Resources Control Board (SWRCB) staff and other members of the Environmental Work Group.

G-WQ2.4.2.10 Aquatic Toxicity

Toxicity tests measured survival and growth for the fathead minnow, and reproduction and survival of *Ceriodaphnia* over a 7-day test period (USEPA 1994). The tests were conducted by using USEPA Method 600-4-91-002. Water samples were analyzed during the high-temperature months of July and September, following the first flush in the fall, following winter dormant spraying in February, and again during the high runoff period in April or May in tributaries to Lake Oroville. Samples were analyzed monthly for toxicity analyses from the monitoring sites downstream from the Fish Barrier Dam to Honcut Creek. Identification of the causative agent for toxicity was attempted through toxicity identification evaluation (TIE) procedures for some sites displaying frequent toxicity. Several OWA ponds were sampled in the spring and again in mid-summer. Toxicity tests were conducted at the Pacific EcoRisk Laboratory.

G-WQ2.4.2.11 Periphyton

Periphyton is attached algae. Taxa and density of periphyton are used as indices of nutrient status of the water. Periphyton was sampled monthly from riffle substrates in the Feather River and upstream tributaries. A cylindrical sampler was used to enclose the periphyton, which was then brushed from the substrate and aspirated into collection jars. Ten samples from each site were composited. Analyses of the periphyton included species identification and counts.

G-WQ2.4.3 Fish Tissues Contaminants Sampling Program (SP-W2)

This study investigated concentrations of metal and pesticide contaminants in fish and crayfish from the Thermalito Complex impoundments and the lower Feather River. Fish tissues were collected from 16 locations and crayfish were collected from four sites. Site selections were based on water quality data from Study Plan SP-W1. The study area included Lake Oroville, the Diversion Pool, Thermalito Forebay, Thermalito Afterbay, the Low Flow Channel of the Feather River, the Feather River immediately downstream of the Thermalito Afterbay Outlet, and two OWA ponds (Table G-WQ2.4-3 and Figure G-WQ2.4-5).

Table G-WQ2.4-3. Fish and crayfish collected from project waters for analysis of tissue contaminants.

Sampling Location	Bass	Pikeminnow	Catfish	Carp	Crayfish
SF Lake Oroville (McCabe Cove)	9 SB		3 CHC		
SF Lake Oroville (Lower)	7 SB		5 CHC		
MF Lake Oroville (Upper)	7 SB		3 CHC		
MF Lake Oroville (Lower)	5 SB		3 CHC		
NF Lake Oroville (Bloomer Canyon)	10 SB		4 CHC	2	
NF Lake Oroville (Foreman Creek)	10 SB		5 CHC, 3WHC		
Lime Saddle Marina (West Branch Arm)	10 SB		4 CHC		
Lake Oroville (Spillway Arm)	7 SB		4 CHC		
Lake Oroville (Bidwell Arm)	7 SB		5 CHC		
Diversion Pool					10
North Thermalito Forebay (Swim Area)		10		5	
North Thermalito Afterbay					10
North Thermalito Afterbay (Potter's Pond)	8 LM			3	
South Thermalito Afterbay	8 LM			5	10
Feather River US of Thermalito Afterbay Outlet	5 LM				
Feather River DS of Thermalito Afterbay Outlet	10 LM				
Feather River DS of SR 70					10
Mile Long Pond	8 LM		4 BRB		
Lower Pacific Heights Pond			5 CHC		

Note: BRB = brown bullhead, CHC = channel catfish, DS = downstream, LM = largemouth bass, MF = Middle Fork, NF = North fork, SB = spotted bass, SF = South Fork, SR = State Route, US = upstream, WHC = white catfish

The fish species selected for sampling were those resident in the water body being investigated. Collection of newly planted fish (i.e., less than 1 year residency) was avoided. Fish were collected beginning in the late spring of 2002 with electroshockers, gill nets, hooks and lines, and seines. Fish were weighed and measured, wrapped in aluminum foil, and immediately frozen for transport to the laboratory. Crayfish were also collected from several sites within the project area at approximately the same time that the fish were collected. Larger (older) crayfish were targeted. Ten crayfish of similar size from each sampled site were composited. Crayfish were collected by hand, nets, and baited traps. Crayfish were wrapped in aluminum foil and frozen for transport to the laboratory.

Analytical procedures generally followed those used in the Toxic Substances Monitoring Program conducted by the SWRCB and California Department of Fish and Game (DFG) (SWRCB 1996). Metals, pesticides, polychlorinated biphenyls, and polynuclear aromatic hydrocarbons were analyzed from fish or crayfish tissues for this study. Methyl mercury is assumed to be the form of mercury available for bioaccumulation in the food web. Most mercury in fish tissues is in the methyl mercury fraction. Total mercury, however, is typically analyzed from fish tissue and is assumed to represent the methyl mercury content of tissues. Fish muscle tissue (filet) is typically analyzed for arsenic, cadmium, nickel, mercury, and selenium, while fish liver is analyzed for copper, zinc, chromium, lead, and silver. The laboratory performed these typical analyses, as well as analyses of all the metals from most filet samples. All organic chemicals in the fish were analyzed from filets. Whole body analyses of metals and organic chemicals were performed on the crayfish. Crayfish were shelled at the laboratory before analysis for methyl mercury. All analyses for organic contaminants were performed at the DFG Water Pollution Control Laboratory in Rancho Cordova, while metals analyses were performed at the DFG Moss Landing Marine Laboratories in Monterey.

Bass obtained from each sampling site were individually analyzed for total mercury contamination. Subsequently, up to five fish from each site were composited following guidelines of the California Environmental Protection Agency Office of Environmental Health Hazard Assessment (OEHHA). The bass and catfish composites were analyzed for organic and metal contaminants. The composites of bass and catfish collected near the Lime Saddle Marina were analyzed for polynuclear aromatic hydrocarbons. The composited crayfish samples were analyzed for organic and metal contaminants.

Criteria and guidance values for protection of human health and wildlife from contaminant accumulation or ingestion were researched and reviewed for those contaminants identified in the fish from this study. Criteria and guidance values reviewed include numerical criteria and guidance values of USEPA, OEHHA, SWRCB, the U.S. Food and Drug Administration, the Food and Agriculture Organization of the United Nations, the U.S. Fish and Wildlife Service (USFWS), Environment Canada, the National Academies of Sciences and Engineering, and the New York Department of Environmental Conservation (see SP-W2). Unfortunately, few criteria or guidelines have been developed for protection of predatory wildlife species from ingestion of prey containing metal or organic contaminants, although USFWS and USEPA are beginning efforts to evaluate toxicity data that may eventually lead to development of protective criteria. The numerical limits used to evaluate compliance with the Basin Plan objective for toxicity are listed in Tables G-WQ2.4-4 and G-WQ2.4-5.

Table G-WQ2.4-4. Numerical limits used to evaluate compliance of fish and crayfish tissue metal concentrations with Basin Plan objectives for toxicity (expressed as ppm [mg/kg] fresh weight).

			Arsenic	Cadmium	Chromium	Copper		Lead	Mercury	Nickel	Selenium	Silver	Zinc
Maximum Tissue Residue Levels (MTRLs) (for Filets or Edible Tissues) [a]	For Carcinogens in Inland Surface Waters		0.2										
	For Non-carcinogens in Inland Surface Waters			0.64					1				
NAS Recommended Guideline for Freshwater Fish [b]	(Whole Fish)								0.5				
FDA Action Level for Freshwater and Marine Fish [c]	(Edible Portion)								1.0 [d]				
OEHHA Screening values and action levels in fish tissues [e]	USEPA Value		3 [f]	10					0.6 [g]		50		
	OEHHA Value		1 [f]	3					0.3 [g,j]		20		
Elevated Data Levels [a]	Fish Type [h]		All	All	All	Non	Salmo	All	All	All	All	All	All
	Fish Livers	EDL 85	0.21	0.36	0.03	12	170	0.1	ID [i]	<0.10 [h]	3.32	0.26	28
		EDL 95	0.68	0.99	0.07	33	230	0.2	ID	0.2	4.74	0.76	38
	Whole Fish	EDL 85	0.41	0.12	0.23	3.3		0.2	0.11	0.21	1.4	0.02	42
		EDL 95	0.88	0.19	0.54	4.3		0.46	0.22	0.56	1.9	0.04	49
	Fish Filets	EDL 85	0.14	<0.01 [h]	<0.02 [h]	0.69		<0.10 [h]	0.8	<0.10 [h]	1	<0.02 [h]	21.4
		EDL 95	0.43	0.01	<0.02 [h]	0.99		<0.10	1.7	<0.10 [h]	1.8	<0.02 [h]	30.2
Median International Standards [a]	(Excludes Liver)		1.5	0.3	1	20		2	0.5		2		45
Canadian Tissue Residue Guidelines									0.033 [k]				
USFWS Contaminant Hazard Reviews			NA [l] (USFWS 1988b)	0.1 (USFWS 1985a)	NA [l] (USFWS 1986b)	NA [l] (USFWS 1998a)		NA [l] (USFWS 1988c)	wildlife: 1.1, avian: 0.1 (USFWS 1987)	wildlife: 500; avian: 200 (USFWS 1998b)	NA [l] (USFWS 1985b)	6 (USFWS 1996)	300 [l] (USFWS 1993)
USFWS Protection of Threatened and Endangered Wildlife									0.3 [m]				

Table G-WQ2.4-4. Numerical limits used to evaluate compliance of fish and crayfish tissue metal concentrations with Basin Plan objectives for toxicity (expressed as ppm [mg/kg] fresh weight).

	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc

[a] *From SWRCB 1995. Toxic Substances Monitoring Program, 1994-95 Data Report. State Water Resources Control Board, Sacramento, California.*
[b] *National Academy of Sciences-National Academy of Engineering. 1973. Water Quality Criteria, 1972 (Blue Book). U.S. Environmental Protection Agency, Ecological Research Series.*
[c] *U.S. Food and Drug Administration (FDA) 2000. Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed. U.S. Food and Drug Administration. Industry Activities Staff Booklet. Washington, D.C.*
[d] *As methyl mercury.*
[e] *OEHHA 1999. Prevalence of Selected Target Chemical Contaminants in Sport Fish from Two California Lakes: Public Health Designed Screening Study. Office of Environmental Health Hazard Assessment, Sacramento, California.*
[f] *Measured as total arsenic.*
[g] *Measured as total mercury.*
[h] *< = elevated data level (EDL) lies below the indicated detection limit.*
[i] *ID = Insufficient data to calculate the EDL.*
[j] *As methyl mercury; from USEPA 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. EPA-823-R-01-001.*
[k] *As methyl mercury.*
[l] *No criteria proposed.*
[m] *USFWS 2003. Evaluation of the Clean Water Act Section 304(a) Human Health Criterion for Methylmercury: Protectiveness for Threatened and Endangered Wildlife in California. U.S. Fish and Wildlife Service. Sacramento, California.*

Table G-WQ2.4-5. Numerical limits used to evaluate compliance of fish and crayfish tissue organic concentrations with Basin Plan objectives for toxicity (expressed as ppb [ng/g] fresh weight).

			Chlor-dane, cis	Chlor-dane, trans	Non-achlor, cis	Non-achlor, trans	Chlor-dane (total) [e]	Chlor-pyrifos	DDD, o,p'	DDD, p,p'	DDE, p,p'	DDMU, p,p'	DDT (total) [f]	Diel-drin	HCB	aroc-lor 1254	aro-clor 1260	PCB [g]	PCB (total) [h]
Maximum Tissue Residue Levels (MTRLs) (for Filets or Edible Tissues) [a]	For Carcinogens in Inland Surface Waters						1.1						32	0.65	6			2.2	
NAS Recommend-ed Guideline for Freshwater Fish [b]	(whole fish)						100						1,000	100				500	
FDA Action Level for Freshwater and Marine Fish [c]	(edible portion)						300						5,000	300				2,000 (i)	
OEHHA Screening values and action levels in fish tissues [d]	USEPA value						80	30,000					300	7	70			10	
	OEHHA value						30	10,000					100	2	20			20	
Elevated Data Levels [a]	Fish type [h]																		
	Whole fresh-water fish calcula-ted using 1978-1995 data (ppb, wet weight)	EDL 85	30.7	20	16.7	44	128.8	25.4	44	254	1,570	46.4	2,393.4	46.4	3.6	120	77.1	219.6	
		EDL 95	57.9	36	27	65.7	195.1	61.9	140	893	3,490	120	5,037.7	379	9.1	358.5	160	472.5	

Table G-WQ2.4-5. Numerical limits used to evaluate compliance of fish and crayfish tissue organic concentrations with Basin Plan objectives for toxicity (expressed as ppb [ng/g] fresh weight).

			Chlor-dane, cis	Chlor-dane, trans	Non-achlor, cis	Non-achlor, trans	Chlor-dane (total) [e]	Chlor-pyrifos	DDD, o,p’	DDD, p,p’	DDE, p,p’	DDMU, p,p’	DDT (total) [f]	Diel-drin	HCB	aroc-lor 1254	aro-clor 1260	PCB [g]	PCB (total) [h]
	Fresh-water fish filets calcula-ted using 1978-1995 data (ppb, wet weight)	EDL 85	12	7.4	5.4	17.2	38.8	<10.0	11	77.6	540	<5.0	667.9	9.4	<2.0	<50.0	54.2	120	
		EDL 95	36.4	21	18	44	117.8	25.7	33.6	232	1,955	36	2,424.4	32.5	5	140.5	180	350	
Median International Standards [a]	(excludes liver)																		
New York DEC Fish Flesh Criteria for fish-eating wildlife							500						200	120	330			110	110
Canadian Tissue Residue Guidelines													14						
USFWS Contaminant Hazard Reviews recommendation							300 (USF-WS 1990)	2,000 (USF-WS 1988a)										Wildlife <100, avian <3,000 (USF-WS 1986a)	Wildlife <100, avian <3,000 (USF-WS 1986a)

Note: HCB = hexachlorobenzene; PCB = polychlorinated biphenyl; ppb = parts per billion

[a] *From SWRCB 1995. Toxic Substances Monitoring Program, 1994-95 Data Report. State Water Resouces Control Board, Sacramento, California.*

[b] *National Academy of Sciences-National Academy of Engineering. 1973. Water Quality Criteria, 1972 (Blue Book). U.S. Environmental Protection Agency, Ecological Research Series.*

[c] *FDA 2000. Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed. U.S. Food and Drug Administration. Industry Activities Staff Booklet. Washington, D.C.*

[d] *OEHHA 1999. Prevalence of selected target chemical contaminants in sport fish from two California Lakes: Public Health Designed Screening Study. Office of Environmental Health Hazard Assessment, Sacramento, California.*

[e] *Sum of alpha and gamma chlordane, cis- and trans-nonachlor and oxychlordane.*

[f] *Sum of ortho and para DDTs, DDDs, and DDEs.*

[g] *Expressed as the sum of Aroclors.*

[h] *Expressed as sum of congeners.*

G-WQ2.4.4 Recreational Facilities Water Quality Sampling Program (SP-W3)

This study focused on evaluating the potential for recreation facilities, operations, and activities to affect water quality. Water quality monitoring was performed to determine the extent of contamination. Data obtained from the study were compared to water quality goals and criteria for protection of beneficial uses (Table G-WQ2.4-4). Several different water quality–sampling programs were implemented to evaluate the effects of different recreational facilities and activities on natural water quality through Resource Area Managers (RAMs). Sampling sites were chosen to reflect the specific type of contaminant from each facility or activity that could potentially affect project waters.

The current Lake Oroville State Recreation Area map was reviewed for completeness and updated to ensure that all recreational facilities and activities have been identified. The potential types of contamination associated with each type of recreational facility and activity were identified. Field surveys were conducted to determine potential sources of contamination from recreation facilities and activities. Operators of recreation facilities were contacted, recreation facilities visited, and recreational activities reviewed to determine potential for contamination of project waters. The interviews and field visits were conducted to identify potential sources of contamination, potential contaminants, source pathways, and operations and management that may contribute to contamination.

Specific monitoring was developed following determination of the potential for each type of recreational facility and activity to contaminate project waters. The contribution of contaminants from wildlife was also investigated where appropriate, such as waterfowl contribution to bacterial levels at swim areas. The monitoring programs were designed to target specific recreational facilities and activities with potential to introduce contaminants into project waters.

Monitoring for effects on water quality from recreational facilities and activities was dependent upon the type of recreational facility or activity and the period of effect. Parameters monitored include bacteria, metals, nutrients, pesticides, petroleum byproducts, and special substances of concern (polybrominated diphenyl ether [PBDE], tetrabutyl titanate [TBT]). Weekly and event-based (e.g., holiday weekends, recreation or fishing tournaments, spills) water quality data collection was performed during the recreation season or event.

G-WQ2.4.5 Stormwater Drainage Sampling Program (SP-W7)

Stormwater runoff water quality within urbanized areas around the Oroville Facilities was monitored at three stormwater discharge outfalls from the City of Oroville to the Feather River and one discharge outfall from Kelly Ridge to Lake Oroville during the first three storm events of the 2003–2004 winter season, November 7 and 14, and December 1. Samples bottles were filled directly from the ends of culverts or pipes and preserved with ice. Discharges were analyzed for bacteria, metals, minerals, nutrients, pesticides, petroleum byproducts, physical parameters, and toxicity through use of toxicity bioassays. Results of the analyses were compared to the numerical limits for the Basin Plan water quality objectives in Table G-WQ2.4-4.

Additionally, three river stations (the Feather River upstream of the Feather River Fish Hatchery, the Feather River downstream of the Feather River Fish Hatchery, and the Feather River downstream of the State Route [SR] 162 bridge) were sampled for toxicity analysis only. Grab samples for toxicity analyses were collected by first rinsing pre-cleaned, 5-gallon polyethylene bottles three times in ambient water at the sampling site. The bottles were then held approximately 6 inches below the water's surface at the river locations and filled with approximately 5 gallons of sample water. The sample bottles were placed into ice chests, and preserved with ice at a temperature of approximately 39 degrees Fahrenheit (ºF). Samples were delivered to the Pacific EcoRisk Laboratory in Martinez, California, within 24 hours of collection. Laboratory staff removed an aliquot from each water sample for analysis of initial water quality characteristics, including temperature, pH, dissolved oxygen, alkalinity, hardness, electrical conductivity, and total ammonia. The remaining sample water was stored at 39ºF until used for the toxicity tests. Toxicity tests measured survival and growth for the fathead minnow, and reproduction and survival of *Ceriodaphnia* over a 7-day test period using USEPA Method 600-4-91-002 (USEPA 1994).

G-WQ2.4.6 Pesticides Treatment Sampling Program (SP-W7)

The Butte County Mosquito and Vector Control District (MVCD) treats the open-water ponds in the OWA with methoprene and malathion for mosquito control. Both chemicals are approved by USEPA for this use.

Water samples were collected monthly for analyses of methoprene and malathion from May 2003 to November 2003 from six persistent ponds that are treated with methoprene or are in the vicinity of malathion treatments, as well as along the bank of the Feather River adjacent to the treated area to determine any leaching to the river. In addition, water temperatures were measured along the bank and compared to pond temperatures to determine if any significant leaching to the river could be occurring. The ponds were also sampled for zooplankton and aquatic invertebrates. Two control ponds in untreated areas were sampled for comparison.

G-WQ2.4.7 Groundwater Sampling Program (SP-W5)

Potential effects of Thermalito Forebay and Thermalito Afterbay on local groundwater water quality were investigated by measuring water quality in 18 wells in the vicinity of these reservoirs (Figure G-WQ2.4-6). Most of the sampled wells were downgradient from Thermalito Afterbay, but two upgradient wells were also sampled to assess water quality of local groundwater unaffected by the Thermalito Complex. One well downgradient from Thermalito Forebay was also sampled. Depth of the groundwater sampled from the wells ranged from 24 to 463 feet below the surface. Water from 4 of the wells was at least 100 feet below ground. These 4 wells were considered deep wells and the remaining 14 wells were considered shallow wells. All of the wells were sampled once in the late spring or early summer and once in fall 2003.

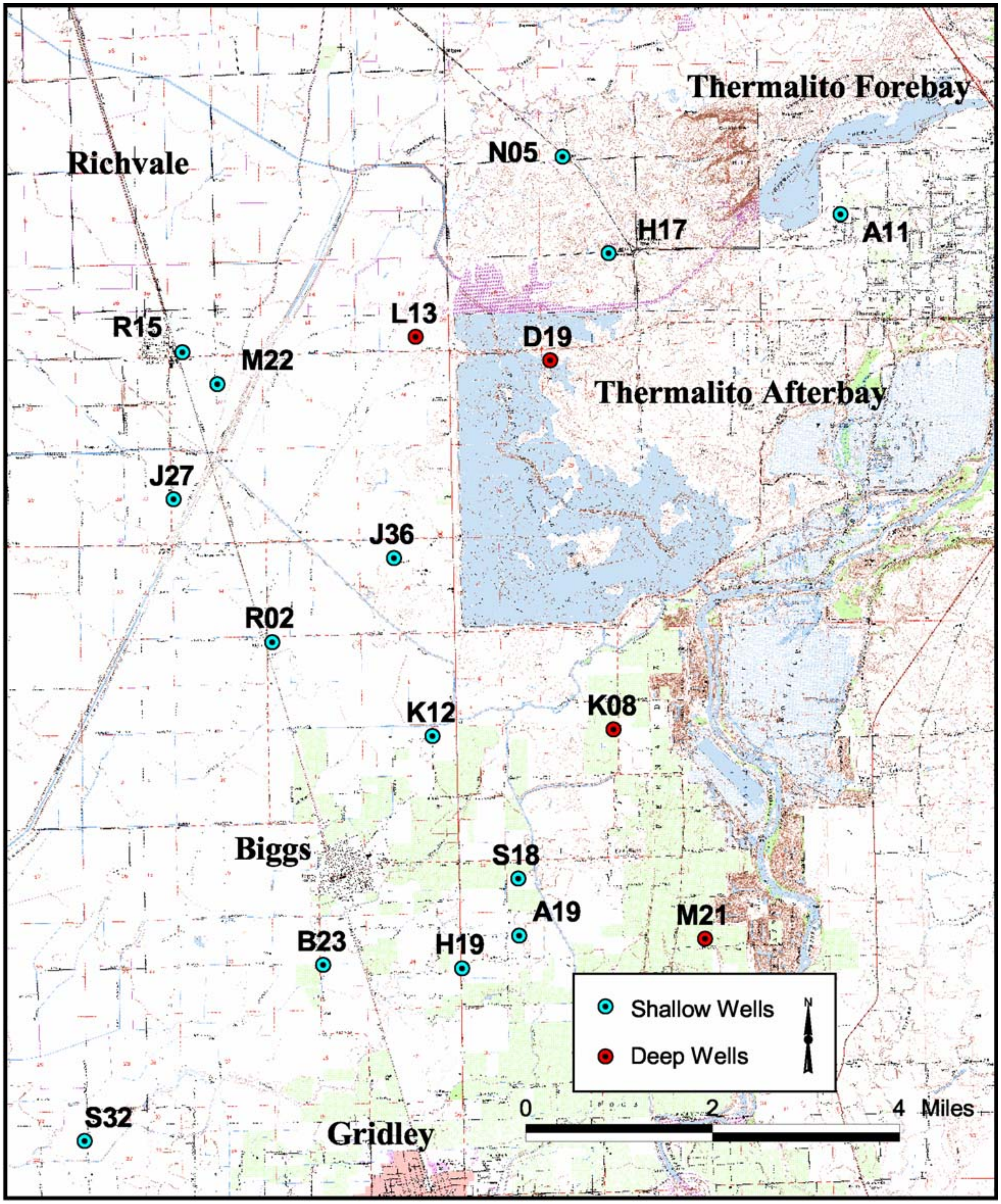


Figure G-WQ2.4-6. Groundwater quality monitoring wells.

The water quality parameters measured in the groundwater were a subset of those measured in surface waters. Temperature, pH, and specific conductance were measured at the time of sampling. Groundwater samples were analyzed for general mineral composition, aluminum, and mercury. Mineral composition and specific conductance measurements are particularly useful for evaluating effects of surface waters on groundwater quality. Aluminum was measured because all surface-water-sampling stations in the project area had aluminum concentrations that at least occasionally exceeded Basin Plan objectives. Mercury was analyzed because of its toxicity and its prevalence in many Central Valley surface waters. No pesticides or petroleum byproducts were detected in surface water samples, so these constituents were assumed to be below detection limits in the groundwater samples.

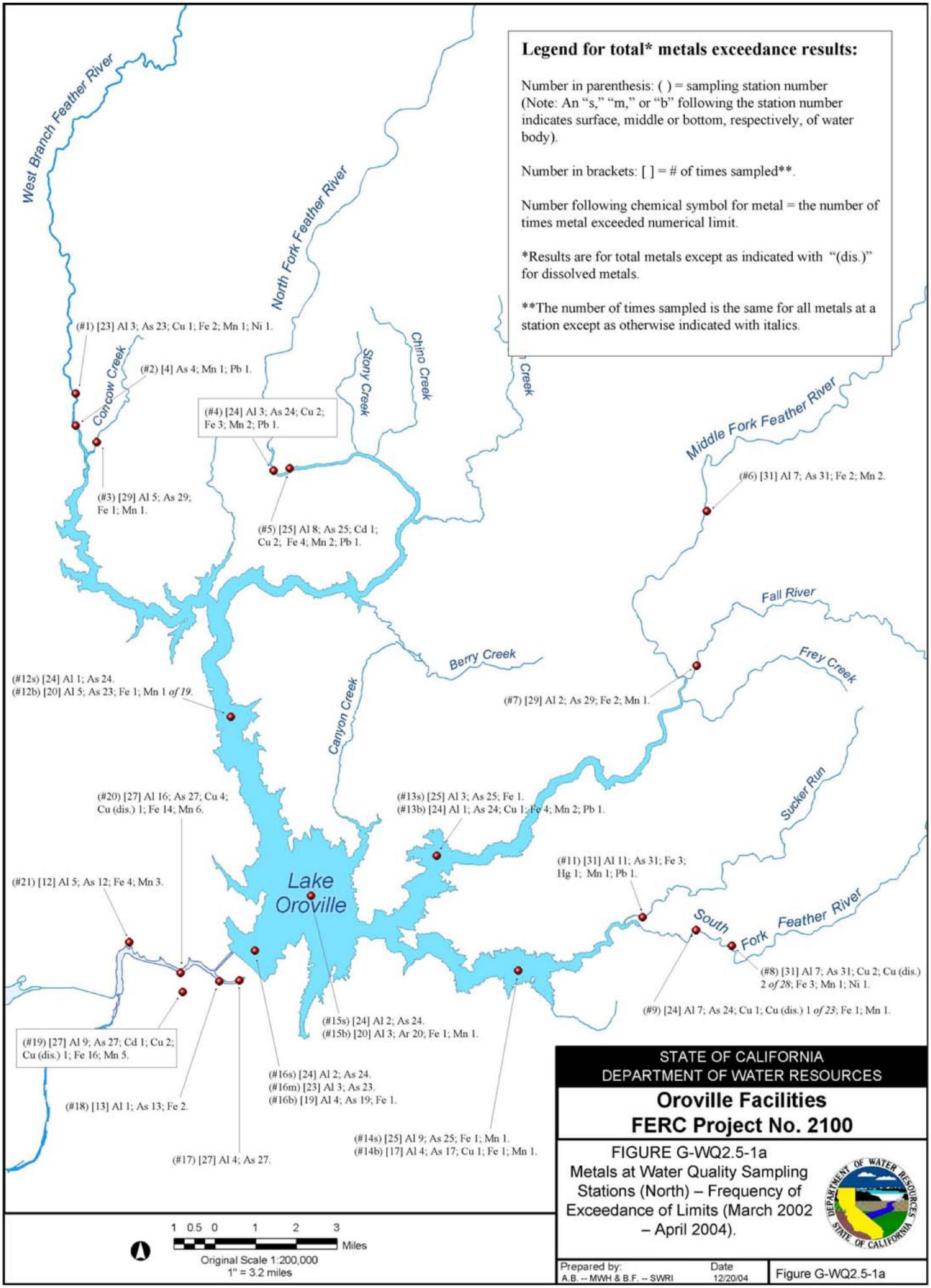
Results of groundwater water quality measurements were compared to Basin Plan objectives. Many of the beneficial uses for surface waters in the Feather River Basin, including recreation, freshwater habitat, and fish migration and spawning, do not apply to groundwater. Therefore, the water quality objectives for groundwater differ somewhat from those for surface waters. The numerical limits for the Basin Plan groundwater quality objectives are given in Table G-WQ2.4-6.

G-WQ2.5 SUPPLEMENTARY TABLES AND FIGURES FOR THE AFFECTED ENVIRONMENT SECTION

This section contains a number of tables and figures that were referenced in the Affected Environment section of Section 5.4, Water Quality, of the Preliminary Draft Environmental Assessment (PDEA).

G-WQ2.5.1 Results of Metals Analyses from Surface Waters

Figures G-WQ2.5-1a and G-WQ2.5-1b give the maximum number of times that each metal exceeded one of the numerical limits listed in Table G-WQ2.4-2 during the March 2002 through April 2004 study period at each of the sampling stations.


Legend for total* metals exceedance results:
Number in parenthesis: ( ) = sampling station number (Note: An "s," "m," or "b" following the station number indicates surface, middle or bottom, respectively, of water body).
Number in brackets: [ ] = # of times sampled**.
Number following chemical symbol for metal = the number of times metal exceeded numerical limit.
*Results are for total metals except as indicated with "(dis.)" for dissolved metals.
**The number of times sampled is the same for all metals at a station except as otherwise indicated with italics.
West Branch Feather River
North Fork Feather River
Concow Creek
Stony Creek
Chino Creek
Creek
Middle Fork Feather River
Fall River
Frey Creek
Berry Creek
Canyon Creek
Sucker Run
South Fork Feather River
Lake Oroville
(#1) [23] Al 3; As 23; Cu 1; Fe 2; Mn 1; Ni 1.
(#2) [4] As 4; Mn 1; Pb 1.
(#3) [29] Al 5; As 29; Fe 1; Mn 1.
(#4) [24] Al 3; As 24; Cu 2; Fe 3; Mn 2; Pb 1.
(#5) [25] Al 8; As 25; Cd 1; Cu 2; Fe 4; Mn 2; Pb 1.
(#6) [31] Al 7; As 31; Fe 2; Mn 2.
(#7) [29] Al 2; As 29; Fe 2; Mn 1.
(#12s) [24] Al 1; As 24.
(#12b) [20] Al 5; As 23; Fe 1; Mn 1 *of 19*.
(#20) [27] Al 16; As 27; Cu 4; Cu (dis.) 1; Fe 14; Mn 6.
(#13s) [25] Al 3; As 25; Fe 1.
(#13b) [24] Al 1; As 24; Cu 1; Fe 4; Mn 2; Pb 1.
(#11) [31] Al 11; As 31; Fe 3; Hg 1; Mn 1; Pb 1.
(#21) [12] Al 5; As 12; Fe 4; Mn 3.
(#8) [31] Al 7; As 31; Cu 2; Cu (dis.) 2 *of 28*; Fe 3; Mn 1; Ni 1.
(#9) [24] Al 7; As 24; Cu 1; Cu (dis.) 1 *of 23*; Fe 1; Mn 1.
(#15s) [24] Al 2; As 24.
(#15b) [20] Al 3; Ar 20; Fe 1; Mn 1.
(#19) [27] Al 9; As 27; Cd 1; Cu 2; Cu (dis.) 1; Fe 16; Mn 5.
(#16s) [24] Al 2; As 24.
(#16m) [23] Al 3; As 23.
(#16b) [19] Al 4; As 19; Fe 1.
(#18) [13] Al 1; As 13; Fe 2.
(#14s) [25] Al 9; As 25; Fe 1; Mn 1.
(#14b) [17] Al 4; As 17; Cu 1; Fe 1; Mn 1.
(#17) [27] Al 4; As 27.
1 0.5 0 1 2 3
Miles
Original Scale 1:200,000
1" = 3.2 miles
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
Oroville Facilities
FERC Project No. 2100
FIGURE G-WQ2.5-1a
Metals at Water Quality Sampling Stations (North) – Frequency of Exceedance of Limits (March 2002 – April 2004).
Prepared by:
A.B. -- MWH & B.F. -- SWRI
Date
12/20/04
Figure G-WQ2.5-1a

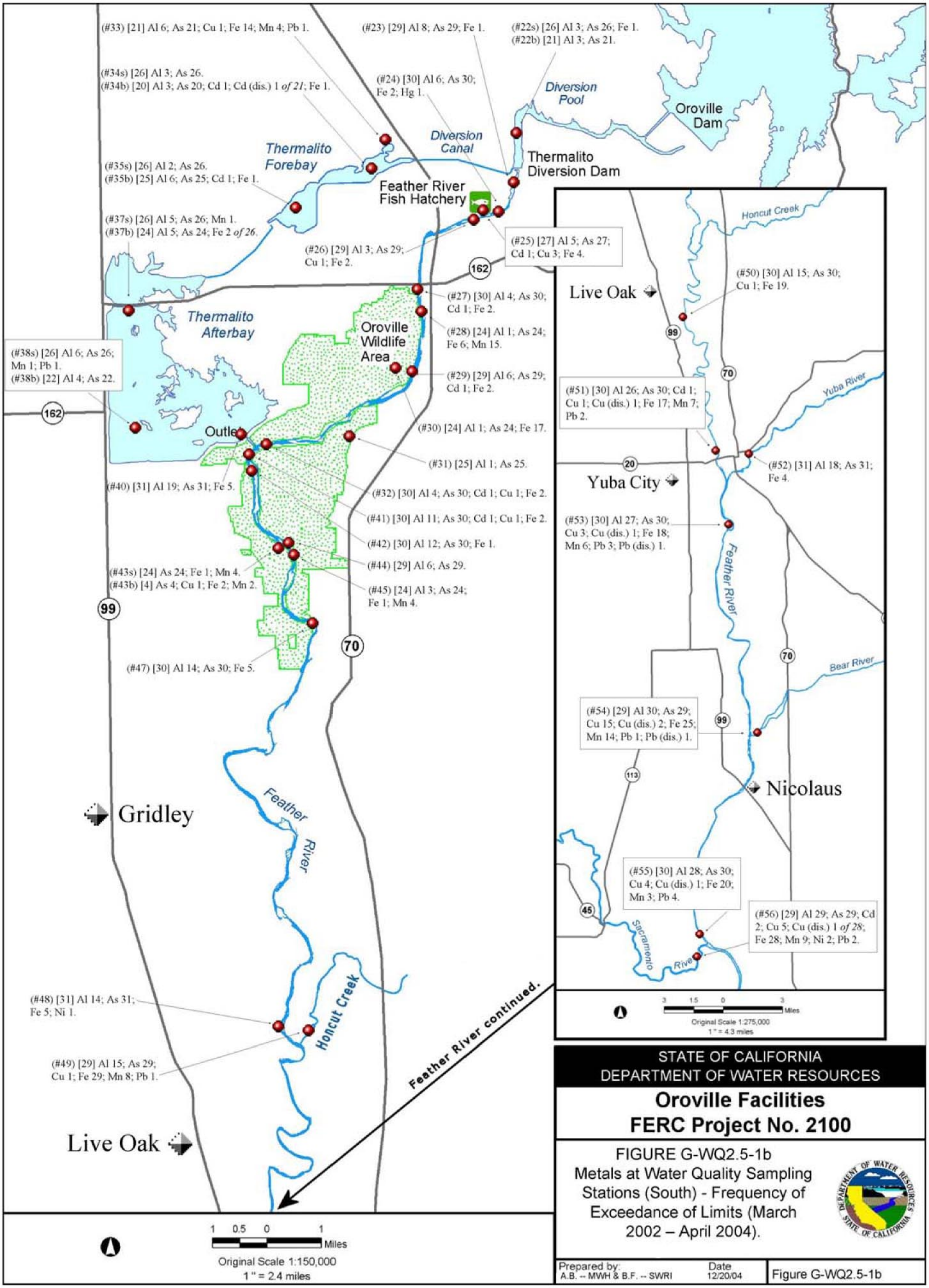

(#33) [21] Al 6; As 21; Cu 1; Fe 14; Mn 4; Pb 1.
(#23) [29] Al 8; As 29; Fe 1.
(#22s) [26] Al 3; As 26; Fe 1.
(#22b) [21] Al 3; As 21.
(#34s) [26] Al 3; As 26.
(#34b) [20] Al 3; As 20; Cd 1; Cd (dis.) 1 of 21; Fe 1.
(#24) [30] Al 6; As 30; Fe 2; Hg 1.
Diversion Pool
Oroville Dam
Thermalito Forebay
Diversion Canal
Thermalito Diversion Dam
(#35s) [26] Al 2; As 26.
(#35b) [25] Al 6; As 25; Cd 1; Fe 1.
Feather River Fish Hatchery
(#37s) [26] Al 5; As 26; Mn 1.
(#37b) [24] Al 5; As 24; Fe 2 of 26.
(#26) [29] Al 3; As 29; Cu 1; Fe 2.
(#25) [27] Al 5; As 27; Cd 1; Cu 3; Fe 4.
162
(#27) [30] Al 4; As 30; Cd 1; Fe 2.
Thermalito Afterbay
Oroville Wildlife Area
(#28) [24] Al 1; As 24; Fe 6; Mn 15.
(#38s) [26] Al 6; As 26; Mn 1; Pb 1.
(#38b) [22] Al 4; As 22.
(#29) [29] Al 6; As 29; Cd 1; Fe 2.
162
(#30) [24] Al 1; As 24; Fe 17.
Outlet
(#31) [25] Al 1; As 25.
(#40) [31] Al 19; As 31; Fe 5.
(#32) [30] Al 4; As 30; Cd 1; Cu 1; Fe 2.
(#41) [30] Al 11; As 30; Cd 1; Cu 1; Fe 2.
(#42) [30] Al 12; As 30; Fe 1.
(#44) [29] Al 6; As 29.
(#43s) [24] As 24; Fe 1; Mn 4.
(#43b) [4] As 4; Cu 1; Fe 2; Mn 2.
(#45) [24] Al 3; As 24; Fe 1; Mn 4.
99
70
(#47) [30] Al 14; As 30; Fe 5.
Gridley
Feather River
Honcut Creek
(#48) [31] Al 14; As 31; Fe 5; Ni 1.
(#49) [29] Al 15; As 29; Cu 1; Fe 29; Mn 8; Pb 1.
Feather River continued.
Live Oak
1 0.5 0 1 Miles
Original Scale 1:150,000
1 " = 2.4 miles
Live Oak
Honcut Creek
(#50) [30] Al 15; As 30; Cu 1; Fe 19.
99
70
Yuba River
(#51) [30] Al 26; As 30; Cd 1; Cu 1; Cu (dis.) 1; Fe 17; Mn 7; Pb 2.
20
(#52) [31] Al 18; As 31; Fe 4.
Yuba City
(#53) [30] Al 27; As 30; Cu 3; Cu (dis.) 1; Fe 18; Mn 6; Pb 3; Pb (dis.) 1.
Feather River
70
Bear River
(#54) [29] Al 30; As 29; Cu 15; Cu (dis.) 2; Fe 25; Mn 14; Pb 1; Pb (dis.) 1.
99
113
Nicolaus
(#55) [30] Al 28; As 30; Cu 4; Cu (dis.) 1; Fe 20; Mn 3; Pb 4.
45
(#56) [29] Al 29; As 29; Cd 2; Cu 5; Cu (dis.) 1 of 28; Fe 28; Mn 9; Ni 2; Pb 2.
Sacramento River
3 1.5 0 3 Miles
Original Scale 1:275,000
1 " = 4.3 miles
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
Oroville Facilities
FERC Project No. 2100
FIGURE G-WQ2.5-1b
Metals at Water Quality Sampling Stations (South) - Frequency of Exceedance of Limits (March 2002 – April 2004).
Prepared by: A.B. -- MWH & B.F. -- SWRI
Date 12/20/04
Figure G-WQ2.5-1b

Table G-WQ2.4-6. Water quality limits for Feather River Basin groundwater.

Agency	pH	EC	TDS (mg/L)	Na* (mg/L)	B* (mg/L)	Cl* (mg/L)	SO^4* (mg/L)	Total Al (µg/L)	Total Hg (µg/L)
California Primary MCL [1]								1,000	2
California Secondary MCL [1]		900	500			500	250	200	
USEPA Primary MCL [2]							500	1,000	2
USEPA Secondary MCL [2]	6.5-8.5		500			250	250	50-200	
Agriculture Goal [3]	6.5-8.4	700	450	69	0.7	106		5,000	
California Public Health Goal [4]								600	1.2
DHS Action Level for Drinking Water [5]					1				
USEPA Drinking Water Taste and Odor Advisory [6]				30-60					
USEPA Drinking Water Health Advisory [6]				20	0.6		500		
NAWQC Humans [7]	5-9		250				250		

Note: DHS = California Department of Health Services; MCL = Maximum Contaminant Level, mg/L = milligrams per liter; NAWQC = National Ambient Water Quality Criteria; SC = Specific Conductance (micro-mhos per centimeter); USEPA = U.S. Environmental Protection Agency.

[1] DHS, California Code of Regulations, Title 22, Division 4, Chapter 15, Domestic Water Quality and Monitoring.
[2] USEPA, Title 40, Code of Federal Regulations, Parts 141 and 143.
[3] Food and Agriculture Organization of the United Nations. 1985. Water Quality for Agriculture.
[4] Cal/EPA, Office of Environmental Health Hazard Assessment, Public Health Goals for Chemicals in Drinking Water (various dates), http://www.oehha.org/water.phg/.
[5] DHS, Division of Drinking Water and Environmental Management, Drinking Water Action Levels (6 June 2003), http://www.dhs.cahwnet.gov/ps/ddwem.
[6] USEPA, Office of Water, 2004 Edition of the Drinking Water Standards & Health Advisories. (Winter 2004). EPA 822-R-04-005.
[7] USEPA, Quality Criteria for Water, 1986 (May 1986) [The Gold book] plus updates (various dates).

G-WQ2.5.2 Results of the Analysis of Fish and Crayfish Tissue Contaminants

Tables G-WQ2.5-1 and G-WQ2.5-2 below provide results of tissue concentrations of metals and pesticides, respectively, in fish and crayfish collected from the Thermalito Complex and the Feather River, as reported in SP-W2. The guidelines used to evaluate compliance of these concentrations with Basin Plan objectives for toxicity are listed in Tables G-WQ2.4-4 and G-WQ2.4-5 above.

Table G-WQ2.5-1. Fish (and crayfish) tissue concentrations of metals (expressed as ppm (mg/kg) fresh weight).

Station Name	Species [a]	Type	Arsenic	Cad-mium	Chromium	Copper	Lead	Mercury	Nickel	Sele-nium	Silver	Zinc
SF Arm Lake Oroville (McCabe Cove)	CHC	flesh	<0.025	<0.002	0.134 [i]	0.29	<0.002	0.876 [f,g,i,k,l,m,n]	<0.002	0.11	<0.002	6.78
SF Arm Lake Oroville (McCabe Cove)	CHC	liver	0.115	0.061	0.477 [h]	4.07	0.038	0.022	0.047	1.72	0.006	18.6
SF Arm Lake Oroville (McCabe Cove)	SPB	flesh	0.188 [i]	<0.002	0.123 [i]	0.24	<0.002	0.722 [f,g,k,l,m,n]	<0.002	0.27	<0.002	5.00
SF Arm Lake Oroville (McCabe Cove)	SPB	liver	0.378 [h]	0.775 [t,l]	0.125 [h]	6.33	0.005	0.556	<0.002	0.77	0.005	22.1
SF Arm Lake Oroville (Lower)	CHC	liver			0.3 [h]	2.13	0.943 [h]				0.003	19.2
SF Arm Lake Oroville (Lower)	CHC	flesh	<0.025	<0.002				1.059 [d,e,f,g,i,k,l,m,n]	0.006	0.16		
SF Arm Lake Oroville (Lower)	SPB	liver			0.27 [h]	2.82	0.070				<0.002	19.0
SF Arm Lake Oroville (Lower)	SPB	flesh	0.21 [c,i]	<0.002				0.677 [r,g,k,l,m,n]	0.007	0.28		
Upper MF Lake Oroville	CHC	liver			0.48 [h]	2.87	2.581 [h]				<0.002	18.4
Upper MF Lake Oroville	CHC	flesh	<0.025	<0.002				0.476 [g,l,m,n]	<0.002	0.12		
Upper MF Lake Oroville	SPB	liver			0.3 [h]	1.91	0.004				<0.002	18.3

Table G-WQ2.5-1. Fish (and crayfish) tissue concentrations of metals (expressed as ppm (mg/kg) fresh weight).

Station Name	Species [a]	Type	Arsenic	Cad-mium	Chromium	Copper	Lead	Mercury	Nickel	Sele-nium	Silver	Zinc
Upper MF Lake Oroville	SPB	flesh	0.17 [i]	<0.002				0.535 [g,k,l,m,n]	0.024	0.3		
Lower MF Lake Oroville	CHC	flesh	<0.025	<0.002	0.076 [i]	0.38	<0.002	1.614 [d,e,f,g,i,k,l,m,n]	<0.002	0.13	0.004	6.43
Lower MF Lake Oroville	CHC	liver	0.164	0.182 [l]	0.449 [h]	3.28	0.048	6.513	0.021	2.23	0.006	18.8
Lower MF Lake Oroville	SPB	flesh	0.189 [i]	<0.002	0.124 [i]	0.24	<0.002	0.587 [g,k,l,m,n]	0.018	0.27	<0.002	4.50
Lower MF Lake Oroville	SPB	liver	0.482 [h]	0.066	0.057 [h]	6.11	0.009	0.591	<0.002	0.94	0.009	22.9
NF Arm Lake Oroville (Bloomer Canyon)	CHC	liver			0.56 [h]	2.87	0.089				<0.002	18.3
NF Arm Lake Oroville (Bloomer Canyon)	CHC	flesh	0.020	0.003				0.402 [g,l,m,n]	0.135 [i]	0.16		
NF Arm Lake Oroville (Bloomer Canyon)	CP	flesh	0.050	0.006				0.231 [l,n]	0.007	0.27		
NF Arm Lake Oroville (Bloomer Canyon)	SPB	flesh	0.242 [c,i]	<0.002	0.096 [i]	0.21	<0.002	0.394 [g,l,m,n]	<0.002	0.27	<0.002	4.36
NF Arm Lake Oroville (Foreman Creek)	CHC	liver			0.48 [h]	2.73	0.015				<0.002	20.7
NF Arm Lake Oroville (Foreman Creek)	CHC	flesh	0.030	<0.002				0.343 [g,l,m,n]	<0.002	0.18		

Table G-WQ2.5-1. Fish (and crayfish) tissue concentrations of metals (expressed as ppm (mg/kg) fresh weight).

Station Name	Species [a]	Type	Arsenic	Cad-mium	Chromium	Copper	Lead	Mercury	Nickel	Sele-nium	Silver	Zinc
NF Arm Lake Oroville (Foreman Creek)	CP	flesh	0.110	0.005				0.721 [f,g,k,l,m,n]	0.007	0.45		
NF Arm Lake Oroville (Foreman Creek)	SPB	liver			0.26 [h]	1.91	<0.002				<0.002	18.4
NF Arm Lake Oroville (Foreman Creek)	SPB	flesh	0.100	<0.002				0.143 [l,n]	<0.002	0.13		
NF Arm Lake Oroville (Foreman Creek)	WHC	liver			0.63 [h]	1.85	0.005				<0.002	19.3
NF Arm Lake Oroville (Foreman Creek)	WHC	flesh	0.030	<0.002				0.38 [g,l,m,n]	<0.002	0.15		
Lake Oroville Spillway arm	CHC	flesh	0.029	<0.002	0.175 [i]	0.10	<0.002	0.154 [l,n]	<0.002	0.06	<0.002	4.14
Lake Oroville Spillway arm	SPB	flesh	0.228 [o,i]	<0.002	0.073 [i]	0.24	<0.002	0.469 [g,l,m,n]	<0.002	0.26	<0.002	4.68
Lake Oroville Spillway arm	SPB	liver	0.772 [h]	0.087	0.169 [h]	4.39	0.006	0.299	<0.002	1.10	<0.002	22.3
Lake Oroville Bidwell Arm	CHC	flesh	<0.025	<0.002	0.094 [i]	0.23	<0.002	0.973 [f,g,i,k,l,m,n]	<0.002	0.13	<0.002	6.28
Lake Oroville Bidwell Arm	CHC	liver	0.108	0.096	0.296 [h]	3.99	0.219 [h]	2.025	<0.002	1.45	0.002	20.4
Lake Oroville Bidwell Arm	SPB	flesh	0.159 [i]	<0.002	0.141 [i]	0.21	<0.002	0.432 [g,l,m,n]	<0.002	0.27	<0.002	4.85
Lake Oroville Bidwell Arm	SPB	liver	0.673 [h]	0.19 [l]	0.024	8.36	0.012	0.845	<0.002	1.03	0.013	25.9

Table G-WQ2.5-1. Fish (and crayfish) tissue concentrations of metals (expressed as ppm (mg/kg) fresh weight).

Station Name	Species [a]	Type	Arsenic	Cad-mium	Chromium	Copper	Lead	Mercury	Nickel	Sele-nium	Silver	Zinc
North Forebay (Swim Area)	CP	flesh	0.060	<0.002				0.146 [l,n]	<0.002	0.27		
North Forebay (Swim Area)	PM	flesh	0.25 [c,i]	<0.002				0.543 [g,k,l,m,n]	<0.002	0.17		
South Thermalito Afterbay (Ski Cove)	LMB	flesh	0.080	<0.002	0.077 [i]	0.19	<0.002	0.475 [g,l,m,n]	0.031	0.23	<0.002	4.78
South Thermalito Afterbay (Ski Cove)	LMB	liver	0.291 [h]	0.293 [l]	0.074 [h]	29.5 [h]	<0.002	0.399	0.025	0.90	0.018	29.6 [h]
South Thermalito Afterbay (Ski Cove)	CP	flesh	0.126	0.007				0.234 [l,n]	0.014	0.18		
Feather River US of Thermalito Afterbay Outlet	LMB	flesh	0.039	<0.002	0.09 [i]	0.26	<0.002	0.475 [g,l,m,n]	0.016	0.16	<0.002	4.45
Feather River US of Thermalito Afterbay Outlet	LMB	liver	0.113	0.058	0.109 [h]	1.68	0.003	0.215	0.022	0.63	<0.002	17.4
Feather River DS of Thermalito Afterbay Outlet	LMB	liver			0.22 [h]	9.23	<0.002				<0.002	18.0

Table G-WQ2.5-1. Fish (and crayfish) tissue concentrations of metals (expressed as ppm (mg/kg) fresh weight).

Station Name	Species [a]	Type	Arsenic	Cad-mium	Chromium	Copper	Lead	Mercury	Nickel	Sele-nium	Silver	Zinc
Feather River DS of Thermalito Afterbay Outlet	LMB	flesh	0.050	<0.002				0.542 [g,k,l,m,n]	<0.002	0.20		
Mile Long Pond	BRB	flesh	<0.025	<0.002	0.126 [i]	0.32	<0.002	0.062	0.004	0.04	<0.002	3.85
Mile Long Pond	BRB	liver	<0.025	<0.002	0.111 [h]	2.08	0.008	0.005	0.14 [h]	0.16	0.005	9.23
Potters Pond	CP	flesh	0.060	0.004				0.133 [l,n]	0.009	0.18		
Potters Pond	LMB	liver			0.19 [h]	3.53	0.008				<0.002	19.0
Potters Pond	LMB	liver			0.23 [h]	3.47	0.004				<0.002	18.2
Potters Pond	LMB	flesh	<0.025	<0.002				0.26 [l,n]	0.123 [i]	0.12		
Lower Pacific Heights Pond	CHC	liver			0.06 [h]	2.05	0.034				0.003	21.0
Lower Pacific Heights Pond	CHC	flesh	<0.025	<0.002				0.355 [g,l,m,n]	0.006	0.10		
Diversion Pool	crayfish [b]	cray-fish			0.25 [j]	20.3 [j,k]	0.012	0.0325 [n]			0.006	19.7
North Afterbay	crayfish [b]	cray-fish			0.25 [j]	34.3 [j,k]	0.023	0.022/0.0249			0.011	19.8
South Afterbay	crayfish [b]	cray-fish			0.32 [j]	27.6 [j,k]	0.035	0.0263			0.010	23.0
Feather River DS of SR 70	crayfish [b]	cray-fish			0.26 [j]	22.2 [j,k]	0.025	0.0416 [n]			0.016	22.5

Table G-WQ2.5-1. Fish (and crayfish) tissue concentrations of metals (expressed as ppm (mg/kg) fresh weight).

Station Name	Species [a]	Type	Arsenic	Cad-mium	Chromium	Copper	Lead	Mercury	Nickel	Sele-nium	Silver	Zinc

Note: DS = downstream; MF = Middle Fork; NF = North Fork; SF = South Fork; US = upstream.
[a] *BRB = brown bullhead; CHC = channel catfish; CP = carp; LMB = large mouth bass; PM = pikeminnow; SPB = spotted bass; WHC = white catfish.*
[b] *Analyzed as composites.*
[c] *Exceeds maximum tissue residue level (MTRL) for carcinogens.*
[d] *Exceeds MTRL for non-carcinogens.*
[e] *Exceeds FDA action level.*
[f] *Exceeds USEPA screening level.*
[g] *Exceeds OEHHA screening level.*
[h] *Exceeds EDL for fish livers.*
[i] *Exceeds EDL for fish filets.*
[j] *Exceeds EDL for whole fish.*
[k] *Exceeds Median International Standards (MIS).*
[l] *Exceeds recommended limit in USFWS Contaminant Hazard Review.*
[m] *Exceeds recommendation of USFWS Evaluation of CWA Section 304(a) for methyl mercury.*
[n] *Exceeds Canadian Tissue Guideline.*

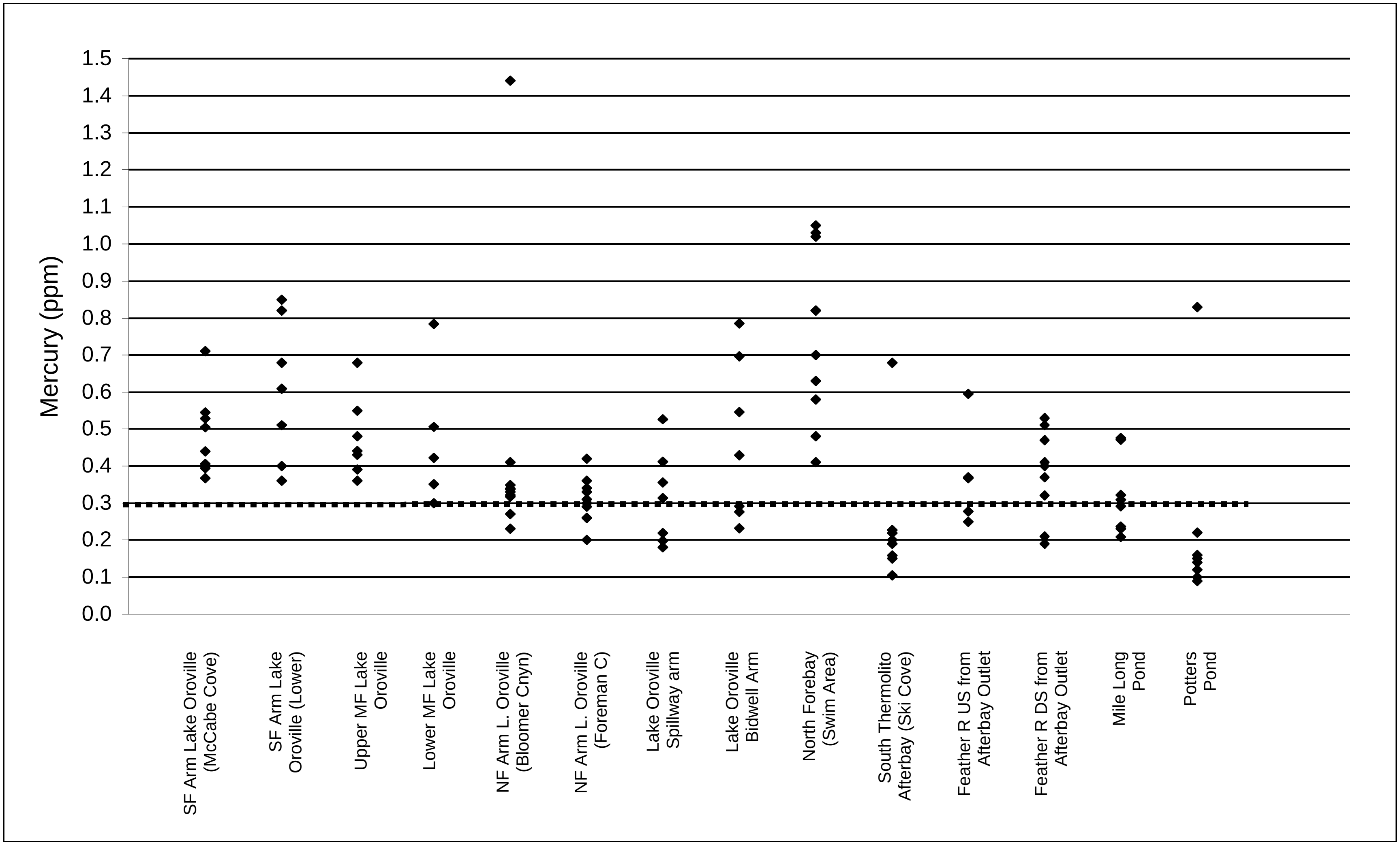


Figure G-WQ2.5-2. Mercury levels in individual fish (spotted bass, largemouth bass, and pikeminnow) from project waters.

Table G-WQ2.5-2. Fish (and crayfish) tissue concentrations of pesticides (expressed as ppb (ng/g) fresh weight).

	Species	chlo-rd-ane, cis	chlo-rd-ane, trans	non-achl-or, cis	non-achl-or, trans	chlor-dane (total) [a]	chlor-pyrifos	DDD, o,p’	DDD, p,p’	DDE, p,p’	DDMU, p,p’	DDT (total) [b]	diel-drin	HCB	Aro-clor 1254	aroc-lor 1260	PCB [c]	PCB (total) [d]
SF Arm Lake Oroville (McCabe Cove)	SPB	ND	<RL	<RL	<RL		ND	ND	1.10	6.40	ND	7.50	<RL	<RL	16	31	47 [e,g,h]	34.991
SF Arm Lake Oroville (McCabe Cove)	CHC	<RL	<RL	<RL	2.26	2.26 [e]	ND	ND	2.59	27.8	<RL	30.39 [i]	ND	0.312	37	97 [f]	134 [e,f,g,h,j,k]	88.777
Lower SF Lake Oroville	CHC	<RL	<RL	<RL	2.31	2.31 [e]	ND	<RL	3.57	24.7	<RL	28.27 [i]	<RL	<RL	37	94 [f]	131 [e,f,g,h,j,k]	85.137
Lower SF Lake Oroville	SPB	<RL	<RL	<RL	<RL		ND	ND	<RL	5.21	ND	5.21	<RL	<RL	18	24	42 [e,g,h]	29.33
Upper MF Lake Oroville	CHC	<RL	<RL	<RL	1.79	1.79 [e]	ND	ND	1.37	15.9	<RL	17.27 [l]	0.522	<RL	20	27	47 [e,g,h]	29.093
Upper MF Lake Oroville	SPB	ND	ND	ND	<RL		ND	ND	<RL	2.16	ND	2.16	<RL	<RL	<RL	<RL		4.664
Lower MF Lake Oroville	SPB	ND	<RL	ND	<RL		ND	ND	<RL	2.05	ND	2.05	<RL	<RL	10	<RL	10 [e,h]	8.655
Lower MF Lake Oroville	CHC	<RL	<RL	<RL	3.43	3.43 [e]	ND	ND	2.21	21.0	<RL	23.21 [i]	<RL	<RL	37	66 [f]	103 [e,g,h,k]	66.772
NF Lake Oroville (Bloomer Canyon)	SPB	ND	ND	ND	<RL		ND	ND	<RL	2.24	ND	2.24	<RL	ND	<RL	<RL		7.078
NF Lake Oroville (Bloomer Canyon)	CHC	<RL	<RL	<RL	1.72	1.72 [e]	ND	ND	1.38	15.3	ND	16.68 [i]	0.732 [e]	<RL	27	24	51 [e,g,h]	30.398
NF Lake Oroville (Bloomer Canyon)	CP	<RL	<RL	<RL	1.51	1.51 [e]	ND	ND	1.16	12.9	<RL	14.06 [i]	0.525	<RL	18	12	30 [e,g,h]	20.327
NF Lake Oroville (Foreman Creek)	CHC	<RL	<RL	<RL	1.88	1.88 [e]	ND	ND	1.76	16.6	<RL	18.36 [i]	0.598	<RL	31	20	51 [e,g,h]	31.332
NF Lake Oroville (Foreman Creek)	SPB	<RL	<RL	ND	<RL		ND	ND	<RL	2.29	ND	2.29	<RL	ND	<RL	<RL		7.299
NF Lake Oroville (Foreman Creek)	WHC	<RL	<RL	ND	<RL		ND	ND	ND	3.3	ND	3.30	<RL	ND	<RL	<RL		7.473
NF Lake Oroville (Foreman Creek)	CP	<RL	<RL	<RL	1.58	1.58 [e]	ND	<RL	1.37	15.2	ND	16.57 [i]	<RL	<RL	16	15	31 [e,g,h]	22.023
Lake Oroville Spillway arm	CHC	<RL	<RL	<RL	2.46	2.46 [e]	<RL	ND	2.72	33.7	<RL	36.42 [e]	0.775 [e]	0.710	34	32	66 [e,g,h]	42.282

Table G-WQ2.5-2. Fish (and crayfish) tissue concentrations of pesticides (expressed as ppb (ng/g) fresh weight).

	Species	chlordane, cis	chlordane, trans	nonachlor, cis	nonachlor, trans	chlordane (total) [a]	chlorpyrifos	DDD, o,p'	DDD, p,p'	DDE, p,p'	DDMU, p,p'	DDT (total) [b]	dieldrin	HCB	Aroclor 1254	aroclor 1260	PCB [c]	PCB (total) [d]
Lake Oroville Spillway arm	SPB	ND	ND	ND	<RL		ND	ND	<RL	2.43	ND	2.43	ND	<RL	<RL	<RL		8.406
Lake Oroville Bidwell arm	CHC	<RL	<RL	<RL	2.37	2.37 [e]	ND	ND	2.23	20.5	<RL	22.73 [i]	0.591	0.355	31	49	80 [e,g,h]	50.938
Lake Oroville Bidwell arm	SPB	ND	<RL	ND	<RL		ND	ND	ND	<RL	ND		<RL	ND	<RL	<RL		5.596
Diversion Pool	SS	<RL	<RL	<RL	2.69	2.69 [e]	ND	<RL	2.13	19.2	<RL	21.33 [i]	<RL	0.832	55 [f]	34	89 [e,g,h]	66.365
Diversion Pool	crayfish	ND	ND	ND	<RL		ND	ND	ND	<RL	ND		<RL	ND	<RL	<RL		3.894
North Thermalito Forebay (swim area)	PM	2.27	1.09	2.61	7.04	13.01 [e]	<RL	<RL	13	86.9	4.71	104.61 [e,g,i]	1.64	1.05	180 [f]	104 [f]	284 [e,f,g,h,j,k]	186.81 [j,k]
North Thermalito Forebay (swim area)	CP	2.86	1.17	2.40	6.64	13.07 [e]	<RL	1.57	11.1	121	3.48	137.15 [e,g,i]	0.738 [e]	0.956	166 [f]	215 [f]	381 [e,f,g,h,j,k]	281.386 [j,k]
North Afterbay	crayfish	ND	ND	ND	<RL		ND	ND	<RL	5.66	ND	5.66	ND	ND	<RL	<RL		7.272
South Thermalito Afterbay (Ski Cove)	LMB	ND	ND	ND	<RL		ND	ND	<RL	4.99	ND	4.99	<RL	ND	<RL	<RL		112.397 [j,k]
South Thermalito Afterbay (Ski Cove)	CP	1.01	<RL	1.26	4.31	6.58 [e]	<RL	1.22	6.31	214	7.82 (f)	229.35 [e,g,i]	0.751 [e]	0.457	81 [f]	68 [f]	149 [e,f,g,h,j,k]	5.59
South Thermalito Afterbay (Ski Cove)	crayfish	ND	ND	ND	ND		ND	ND	ND	2.11	ND	2.11	ND	ND	<RL	<RL		5.933
Potters Pond	LMB	ND	<RL	ND	<RL		ND	ND	ND	<RL	ND		<RL	ND	<RL	ND		3.365
Potters Pond	CP	<RL	<RL	<RL	<RL		ND	ND	<RL	23.7	ND	23.7 [i]	<RL	ND	19	17	36 [e,g,h]	22.537
Potters Pond	LMB	ND	<RL	ND	<RL		ND	ND	ND	<RL	ND		<RL	ND	<RL	<RL		1.937
Feather River DS of SR 70 #2	crayfish	ND	ND	ND	<RL		ND	ND	ND	3.01	ND	3.01	ND	ND	76 [f]	<RL	76 [e,g,h]	55.978
Feather River US of Thermalito Afterbay Outlet	LMB	<RL	<RL	ND	<RL		ND	ND	<RL	4.98	ND	4.98	<RL	ND	22	<RL	22 [e,g,h]	15.629

Table G-WQ2.5-2. Fish (and crayfish) tissue concentrations of pesticides (expressed as ppb (ng/g) fresh weight).

	Species	chlord-ane, cis	chlord-ane, trans	non-achlor, cis	non-achlor, trans	chlordane (total) [a]	chlorpyrifos	DDD, o,p'	DDD, p,p'	DDE, p,p'	DDMU, p,p'	DDT (total) [b]	dieldrin	HCB	Aroclor 1254	aroclor 1260	PCB [c]	PCB (total) [d]
Feather River DS of Thermalito Afterbay Outlet	LMB	ND	ND	ND	<RL		ND	ND	<RL	6.41	ND	6.41	<RL	<RL	24	<RL	24 [e,g,h]	15.008
Feather River DS of Thermalito Afterbay Outlet	LMB	ND	ND	ND	<RL		ND	ND	<RL	5.38	ND	5.38	<RL	<RL	21	<RL	21 [e,g,h]	11.228
Mile Long Pond	LMB	ND	ND	ND	ND		ND	ND	ND	<RL	ND		<RL	ND	<RL	ND		2.379
Mile Long Pond	BRB	ND	<RL	ND	<RL		ND	ND	ND	<RL	ND		1.67 [e]	ND	<RL	<RL		2.366
Lower Pacific Heights Pond	CHC	1.04	<RL	1.02	3.12	5.17 [e]	4.18	ND	2.25	56.2	<RL	58.45 [e,i]	0.836 [e]	<RL	54 [f]	27	81 [e,g,h]	48.893
Lower Pacific Heights Pond	CHC	1.03	<RL	1.01	2.94	4.98 [e]	3.97	ND	2.25	53.2	<RL	55.45 [e,i]	0.627	<RL	52 [f]	27	79 [e,g,h]	46.66

Notes: BRB = brown bullhead; DS = downstream; HCB = hexachlorobenzene; LMB = largemouth bass; MF = Middle Fork; NF = North Fork; PM = pikeminnow; SF = South Fork; SS = Sacramento sucker; US = upstream

[a] *Sum of alpha and gamma chlordane, cis- and trans-nonachlor and oxychlordane.*
[b] *Sum of ortho and para DDTs, DDDs, and DDEs.*
[c] *Expressed as the sum of Aroclors.*
[d] *Expressed as sum of congeners.*
[e] *Exceeds MTRL.*
[f] *Exceeds EDL for fish filets.*
[g] *Exceeds OEHHA screening level.*
[h] *Exceeds USEPA screening level.*
[i] *Exceeds Canadian Tissue Residue guideline.*
[j] *Exceeds New York DEC fish flesh criteria for fish-eating wildlife.*
[k] *Exceeds USFWS Contaminant Hazard Review proposed criteria in diet of wildlife (based on susceptibility of mink).*

G-WQ2.5.3 Results of Bacterial Monitoring

This section provides tables giving results of the relicensing studies' monitoring of bacteria that are used as indicators of the potential presence of pathogens. Table G-WQ2.5-3 gives results from the general water quality monitoring study (SP-W1), while Tables G-WQ2.5-4 and G-WQ2.5-5 show results from monitoring in recreation areas (SP-W1 and SP-W3). Table G-WQ2.5-6 gives the results of stormwater sampling conducted in 2003. Tables G-WQ2.5-3, G-WQ2.5-4, and G-WQ2.5-5 summarize results that are contained in extensive tables in the appendix of SP-W1, while Table G-WQ2.5-6 is taken directly from SP-W7. Table G-WQ2.5-3 gives the ranges of total and fecal coliform bacteria counts for monitoring conducted in 2002, 2003, and 2004 at each of the SP-W1 stations. The table also gives the number of dates on which a water quality standard, the California Department of Health Services' (DHS) draft guidance for bacteria counts at freshwater beaches, was exceeded. Tables G-WQ2.5-4 gives the ranges of total and fecal coliform bacteria counts and numbers of exceedances of the DHS guidelines and Basin Plan objectives for monitoring conducted in 2002 at a number of stations in recreation areas. Table G-WQ2.5-5 provides similar information for 2003, but also includes specific counts for enterococcus and fecal streptococcus.

Table G-WQ2.5-3. Ranges of bacteria counts at SP-W1 monitoring stations and numbers of water quality standard exceedances.

Station	Range				Exceedance	
	Total Coliform		Fecal Coliform		Total Coliform	Fecal Coliform
	Min	Max	Min	Max	DHS[1] Single Sample[2]	
West Branch near Paradise	0	588	0	30	0	0
West Branch US of Lake Oroville	0	252	0	3	0	0
Concow Creek at Jordan Hill Road	0	448	0	24	0	0
NF Feather River US of Poe Powerhouse	0	2,288	0	13	0	0
Poe Powerhouse Outflow	0	TNTC	0	41	1	0
NF Feather River DS of Poe Powerhouse	88	228	0	6	0	0
MF Feather River near Merrimac	0	TNTC	0	40	1	0
Fall River US of Feather Falls	0	TNTC	0	866	1	1
SF Feather River US of Ponderosa Reservoir	0	TNTC	0	30	1	0
Sucker Run near Forbestown	0	TNTC	0	42	3	0
SF Feather River DS of Ponderosa Reservoir	5	TNTC	0	8	1	0
Miner's Ranch Canal	0	111	0	4	0	0
NF arm of Lake Oroville	0	2,252	0	3	0	0
MF arm of Lake Oroville	0	212	0	2	0	0
SF arm of Lake Oroville	0	180	0	4	0	0
Lake Oroville Main Body	0	247	0	0	0	0
Lake Oroville near Dam	0	198	0	1	0	0
Diversion Pool US of Kelly Ridge Powerhouse	0	586	0	1	0	0
Diversion Pool DS of Kelly Ridge Powerhouse	4	TNTC	0	2	1	0
Glen Pond	0	TNTC	0	TNTC	6	3
Glen Creek US of Glen Pond	0	144	0	251	0	0
Glen Creek US of Glen Pond	13	TNTC	0	TNTC	7	1
Morris Ravine	28	TNTC	6	1,190	1	3
Diversion Pool US of Thermalito Diversion Dam	0	TNTC	0	105	1	0
Feather River at Oroville	0	TNTC	0	174	1	0
Feather River US of Feather River Fish Hatchery	0	990	0	46	0	0
Feather River Fish Hatchery Settling Pond	0	TNTC	0	55	2	0
Feather River DS of Feather River FishHatchery	1	TNTC	0	203	4	0
Feather River DS of SR 162	0	TNTC	0	123	4	0
Feather River at Robinson Riffle	0	TNTC	0	111	4	0
Feather River US of Thermalito Afterbay Outlet	0	TNTC	0	66	4	0
Feather River DS of Thermalito Afterbay Outlet	0	TNTC	0	32	2	0
Feather River DS of SCOR Outlet	0	TNTC	0	207	3	0

Table G-WQ2.5-3. Ranges of bacteria counts at SP-W1 monitoring stations and numbers of water quality standard exceedances.

Station	Range				Exceedance	
	Total Coliform		Fecal Coliform		Total Coliform	Fecal Coliform
	Min	Max	Min	Max	DHS[1] Single Sample[2]	
Feather River near Mile Long Pond	0	TNTC	0	39	1	0
Feather River DS of FERC Project Boundary	0	TNTC	0	95	3	0
Oroville Fish Pond	0	TNTC	0	15	2	0
Robinson Riffle Pond	0	TNTC	0	336	2	0
Mile Long Pond	0	TNTC	0	14	1	0
Upper Pacific Heights Pond	0	TNTC	0	TNTC	1	1
Lower Pacific Heights Pond	0	TNTC	0	3	1	0
Thermalito Afterbay at Feather River Outlet	0	TNTC	0	182	2	0
South Afterbay	0	272	0	21	0	0
North Afterbay	1	382	0	61	0	0
South Forebay	0	363	0	86	0	0
North Forebay Creek	19	TNTC	0	TNTC	5	3
North Forebay	0	613	0	146	0	0
Feather River at Singh AB Riviera Road	0	TNTC	0	50	3	0
Honcut Creek at Pacific Ranch near Palermo	0	TNTC	0	1,280	3	2
Feather River at Archer Ave.	0	TNTC	0	297	2	0
Feather River US of Yuba River	0	TNTC	0	TNTC	2	1
Yuba River at Mouth	0	TNTC	0	TNTC	3	1
Feather River at Shanghai Bend	0	TNTC	0	167	2	0
Bear River near Mouth	0	TNTC	0	TNTC	4	1
Feather River near Verona	2	TNTC	0	TNTC	4	2
Sacramento River US of Feather River	0	TNTC	0	TNTC	2	1

Notes: DS = downstream; MF = Middle Fork; NF = North Fork; SF = South Fork; TNTC = Too Numerous to Count; US = upstream.

[1] DHS. Draft Guidance for Fresh Water Beaches. July 24, 2001.

[2] DHS recommends the bacteria in a single sample not to exceed 10,000 per 100 mL for total coliform and 400 per 100 mL for fecal coliform.

Table G-WQ2.5-4. Ranges of bacteria counts at recreation area monitoring stations and number of water quality standards exceedances in 2002.

Station	Range				Exceedance			
	Total Coliform		Fecal Coliform		Total Coliform	Fecal Coliform	Fecal Coliform	
					CDHS[1]		CVRWQCB[3]	
	Min	Max	Min	Max	Single Sample[2]		5/30[4]	10% in 30[5]
Afterbay Outlet	6	88	0	5	0	0	0	0
Bedrock Park (Upstream)	40	368	0	21	0	0	0	0
Bedrock Park (Downstream)	16	432	0	332	0	0	0	0
Bidwell Marina Houseboats at E-36	0	124	0	3	0	0	0	0
Bidwell Marina Houseboats at L-4	0	72	0	2	0	0	0	0
Foreman Creek Boat Access	0	336	0	4	0	0	0	0
Mile Long Pond	26	TNTC	2	71	2	0	0	0
Monument Hill Recreation Area	0	304	0	TNTC	0	1	0	1
North Forebay Recreation Area at Beach	0	TNTC	6	416	1	1	0	1
North Forebay Recreation Area at Footbridge	0	12	0	148	0	0	0	0
North Forebay Recreation Area at Mouth	0	156	0	40	0	0	0	0
Potter Ravine Floating Campsite	0	36	0	10	0	0	0	0
South Forebay Boat Launch	0	334	1	96	0	0	0	0
South Forebay Recreation Area	0	TNTC	1	213	1	0	0	0
Stringtown Cove	0	164	0	0	0	0	0	0
Stringtown Main Body	0	44	0	1	0	0	0	0

Note: TNTC = Too Numerous To Count.
[1] DHS. Draft Guidance for Fresh Water Beaches. July 24, 2001.
[2] DHS recommends the bacteria in a single sample not exceed 10,000 per 100 mL for total coliform and 400 per 100 mL for fecal coliform.
[3] Central Valley RWQCB. Water Quality Control Plan (Basin Plan), Fourth Edition, 1998.
[4] Geometric Mean of 200 bacteria per 100 mL of water sample from not less than 5 samples collected over a 30 days period.
[5] No more than 10 percent of the total samples taken during any 30-day period shall have fecal bacteria in excess of 400 organism per 100 mL.

Table G-WQ2.5-5. Ranges of bacteria counts at recreation area monitoring stations and number of water quality standards exceedances in 2003.

Station	Range								Exceedance						
	Total Coliform		Fecal Coliform		Enterococcus		Fecal Streptococcus		Total Coliform	Fecal Coliform	Enterococcus	Fecal Coliform		Enterococcus	
									DHS[1]			Central Valley RWQCB[3]		USEPA[6]	
	Min	Max	Min	Max	Min	Max	Min	Max	Single Sample[2]			5/30[4]	10% in 30[5]	Single Sample[7]	5/30[8]
Bedrock Park US	23	>1,600	4	300	2	170	7	280	1	0	1	0	0	1	0
Bedrock Park DS	80	900	8	300	4	300	11	500	0	0	1	0	0	1	0
Foreman Creek Boat Access	17	>1,600	<2	>1,600	<2	500	<2	900	2	1	2	0	1	2	0
Loafer Creek Swim Area	14	>1,600	2	1,600	<2	>1,600	2	>1,600	2	2	2	0	2	2	1
Monument Hill Swim Area	60	>1,600	4	500	4	280	7	900	1	1	3	0	1	3	3
North Forebay Swim Area (Beach)	170	50,000	23	5,000	22	>1,600	50	>1,600	4	7	8	6	7	8	6
North Forebay Swim Area (Cove)	80	**>160,000**	22	22,000	2	>1,600	4	>1,600	3	3	9	3	3	9	6
North Forebay Swim Area (Mouth)	140	>1,600	14	>1,600	11	1,600	11	>1,600	3	2	4	0	2	4	3
South Forebay Boat Ramp	17	>1,600	4	>1,600	4	900	4	900	2	3	6	1	3	6	5
South Forebay Swim Area	17	>1,600	7	>1,600	2	>1,600	6	>1,600	2	2	3	0	2	3	3
Stringtown Boat Ramp	2	1,600	<2	1,600	<2	>1,600	2	>1,600	0	1	3	0	1	3	2

Table G-WQ2.5-5. Ranges of bacteria counts at recreation area monitoring stations and number of water quality standards exceedances in 2003.

Station	Range								Exceedance						
	Total Coliform		Fecal Coliform		Enterococcus		Fecal Streptococcus		Total Coliform	Fecal Coliform	Enterococcus	Fecal Coliform		Enterococcus	
	Min	Max	Min	Max	Min	Max	Min	Max	DHS[1]			Central Valley RWQCB[3]		USEPA[6]	
									Single Sample[2]			5/30[4]	10% in 30[5]	Single Sample[7]	5/30[8]

[1] *DHS. Draft Guidance for Fresh Water Beaches. July 24, 2001.*
[2] *DHS recommends the bacteria in a single water sample not to exceed 10,000 per 100 mL for total coliform and 400 per 100 mL for fecal coliform, and 61 per 100 mL for enterococcus.*
[3] *Central Valley RWQCB. Water Quality Control Plan (Basin Plan), Fourth Edition, 1998.*
[4] *Geometric Mean of 200 bacteria per 100 mL of water sample from not less than 5 samples collected over a 30 days period.*
[5] *No more than 10 percent of the total samples taken during any 30-day period shall have fecal bacteria in excess of 400 organism per 100 mL.*
[6] *USEPA. Ambient Water Quality Criteria for Bacteria - 1986. EPA 440/5-84-002.*
[7] *USEPA guideline, the enterococcus in a single sample per 100 mL of water sample shall not exceed 61 organism.*
[8] *Geometric Mean of 33 bacteria per 100 mL of water sample from not less than 5 samples collected over a 30-day period.*

Table G-WQ2.5-6. Stormwater sampling results—bacteria.

Station	Date	Total Coliform #/100 mL	Fecal Coliform #/100 mL	Entero-Coccus [1] #/100 mL	Fecal Strepto-coccus #/100 mL
Kelly Ridge	11/7/03	>1600	**>1600**	**>1600**	>1600
	12/1/03	>1600	**>1600**	**500**	500
Oliver Street	12/1/03	>1600	**>1600**	**>1600**	>1600
Pine Street	11/7/03	>1600	**>1600**	**>1600**	>1600
	12/1/03	>1600	**>1600**	**>1600**	>1600
Robinson Street	11/7/03	>1600	**>1600**	**>1600**	>1600
	12/1/03	>1600	**>1600**	**>1600**	>1600

Note: Bold indicates that values exceed water quality criteria.
[1] USEPA criteria – freshwater designated bathing beach area: Enterococci 61 per 100 mL. DHS recommended freshwater public beach criteria: Total coliform 10,000/100 ml; Fecal coliform 400/100 mL; Enterococcus 33/100 mL.

G-WQ2.5.4 Results of Groundwater Sampling

This section provides tables that contain results for chemical constituents in groundwater from monitoring of wells near Thermalito Afterbay and Thermalito Forebay, as well as results for surface water from Thermalito Afterbay. These results are directly referenced in the groundwater discussion of Section 5.4.1.2, Affected Environment for Water Quality. Table G-WQ2.5-7 compares ranges of water quality parameters in wells downgradient and upgradient from Thermalito Forebay and Thermalito Afterbay with ranges in the surface waters of these impoundments. Table G-WQ2.5-8 provides a record of exceedances of the numerical water quality limits that were provided in Table G-WQ2.4-6 of this appendix. Table G-WQ2.5-9 compares water quality in well A11, which is immediately downgradient of Thermalito Forebay, with the water quality of other groundwater and surface water samples.

Table G-WQ2.5-7. Water quality ranges in downgradient and upgradient wells and surface water samples.

Water Quality Parameter	Downgradient Wells			Upgradient Wells			Surface Water		
	Samples	Maximum	Minimum	Samples	Maximum	Minimum	Samples	Maximum	Minimum
pH	32	8.2	6.9	4	7.3	7.2	81	7.9	7.0
Total Alkalinity (mg/L $CaCO_3$)	32	437	44	4	93	64	76	52	35
Specific Conductance (mmhos/cm)	32	1,220	124	4	261	153	81	94	59
Total Hardness (mg/L $CaCO_3$)	32	609	36	4	93	60	72	41	30
Dissolved Hardness (mg/L $CaCO_3$)	32	610	34	4	93	58	72	41	30
Total Dissolved Solids (mg/L)	32	801	75	4	200	101	79	61	35
Total Calcium (mg/L)	32	125	6	4	14	11	72	10	7
Dissolved Calcium (mg/L)	32	127	7	4	14	10	72	10	7
Dissolved Potassium (mg/L)	32	2.8	<0.5	4	1.7	0.8	72	1.0	0.6
Total Magnesium (mg/L)	32	72	4	4	14	8	72	4	3
Dissolved Magnesium (mg/L)	32	71	4	4	14	8	72	4	3
Dissolved Sodium (mg/L)	32	48	5	4	16	11	72	4	3
Dissolved Boron (mg/L)	32	<0.01	<0.01	4	<0.01	<0.01	72	<0.01	<0.01
Dissolved Chloride (mg/L)	32	29	2	4	9	7	72	1	<1
Dissolved Sulfate (mg/L)	32	195	<1	4	9	2	72	2	2
Total Aluminum (mg/L)	32	54.8	1.32	4	2.14	1.35	80	**479**	11
Dissolved Aluminum (mg/L)	32	54.9*	0.52	4	1.62	0.79	80	38.4	<1.5
Dissolved Mercury (mg/L)	32	0.00156	<0.00015	4	0.00038	<0.00015	80	0.0366	0.00024

** This result may be erroneous. Next highest result for dissolved aluminum was 9.97 µg/L.*

Table G-WQ2.5-8. Exceedances of Basin Plan water quality objectives.

Specific Conductance			
Well ID	**Date**	**Value (µmhos/cm)**	**Water Quality Limit Exceeded***
B23	10/14/2003	714	Agricultural Goal
R15	6/11/2003	755	
M22	7/2/2003	783	
R15	10/15/2003	849	
M22	10/14/2003	1,220	California Secondary MCL
Total Dissolved Solids			
Well ID	**Date**	**Value (mg/L)**	**Water Quality Limit Exceeded***
J36	10/29/2003	268	NAWQC Humans
K12	7/1/2003	273	
K12	10/15/2003	294	
H19	7/7/2003	299	
J27	7/7/2003	300	
S32	7/7/2003	303	
H19	10/14/2003	305	
J36	7/2/2003	309	
S32	10/29/2003	330	
B23	7/7/2003	416	
B23	10/14/2003	417	
R15	10/15/2003	479	Agricultural Goal
M22	7/2/2003	490	
R15	6/11/2003	491	
M22	10/14/2003	801	California and USEPA Secondary MCLs
Dissolved Sodium			
Well ID	**Date**	**Value (mg/L)**	**Water Quality Limit Exceeded***
B23	7/7/2003	22	USEPA Drinking Water Health Advisories
B23	10/14/2003	24	
J36	7/2/2003	21	
M22	7/2/2003	28	
M22	10/14/2003	30	USEPA Drinking Water Taste and Odor Advisory
R15	6/11/2003	48	
R15	10/15/2003	44	
Total Aluminium			
Well ID	**Date**	**Value (µg/L)**	**Water Quality Limit Exceeded***
A11	7/1/2003	54.8	USEPA Primary MCL

** For each parameter, the indicated water quality limit was exceeded for the sample in the same row and all samples listed below it.*

Table G-WQ2.5-9. Water quality ranges in Well A11 near Thermalito Forebay, other wells, and surface water samples.

Water Quality Parameter	Other Wells			A11 Well			Surface Water		
	Samples	Maximum	Minimum	Samples	Maximum	Minimum	Samples	Maximum	Minimum
pH	34	8.2	6.9	2	7.5	7.3	81	7.9	7.0
Total Alkalinity (mg/L $CaCO_3$)	34	437	64	2	76	44	76	52	35
Specific Conductance (μmhos/cm)	34	1,220	137	2	153	124	81	94	59
Total Hardness (mg/L $CaCO_3$)	34	609	55	2	52	36	72	41	30
Dissolved Hardness (mg/L $CaCO_3$)	34	610	58	2	55	34	72	41	30
Total Dissolved Solids (mg/L)	34	801	101	2	109	75	79	61	35
Total Calcium (mg/L)	34	125	9	2	8	6	72	10	7
Dissolved Calcium (mg/L)	34	127	10	2	7	7	72	10	7
Dissolved Potassium (mg/L)	34	2.8	<0.5	2	0.6	<0.5	72	1.0	0.6
Total Magnesium (mg/L)	34	72	8	2	9	4	72	4	3
Dissolved Magnesium (mg/L)	34	71	8	2	9	4	72	4	3
Dissolved Sodium (mg/L)	34	48	11	2	11	5	72	4	3
Dissolved Boron (mg/L)	34	<0.01	<0.01	2	<0.01	<0.01	72	<0.01	<0.01
Dissolved Chloride (mg/L)	34	29	2	2	2	2	72	1	<1
Dissolved Sulfate (mg/L)	34	195	<1	2	6	1	72	2	2
Total Aluminum (µg/L)	34	33.3	1.32	2	54.8	1.93	80	479	11
Dissolved Aluminum (µg/L)	34	9.97	0.52	2	54.9*	1.31	80	38.4	<1.5
Dissolved Mercury (µg/L)	34	0.00156	<0.00015	2	0.00063	0.00033	80	0.0366	0.00024

G-WQ2.5.5 References

USEPA (U.S. Environmental Protection Agency). 1994. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water for Freshwater Organisms. Third edition. EPA-600-4-91-002. U.S. Environmental Protection Agency. Washington, D.C.

USEPA (U.S. Environmental Protection Agency). 1996. Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels. EPA-821-R-96-008. U.S. Environmental Protection Agency. Washington, D.C.

This page intentionally left blank.