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
consistently and repeatedly evaluate 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.
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)

Background Summary

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 through 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.

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

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 “drier” 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°F (14.6°C) and 65.4°F (18.6°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)**

**Background Summary**

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)**

**Background Summary**

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

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

<table>
<thead>
<tr>
<th>Species</th>
<th>Source(s)</th>
<th>Origin</th>
<th>Preferred</th>
<th>Optimum</th>
<th>CTM</th>
<th>LT10</th>
<th>UIL (LT50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steelhead (no age given)</td>
<td>Bell 1973, 1986, 1991 in Bjornn and Reiser 1979; Reiser and Bjornn 1979; McEwan and Jackson 1996; Barnhart 1986</td>
<td>Unknown</td>
<td>45°F–58°F</td>
<td>50°F–55°F</td>
<td>75°F</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Steelhead (fry)</td>
<td>DWR and USBR 2000 (cites McEwan and Jackson 1996)</td>
<td>Unknown</td>
<td>45°F–60°F</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Steelhead</td>
<td>Sullivan et al. 2000</td>
<td>Unknown</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>80.6°F at 1 hour</td>
<td>84.4 at 0.1 hour</td>
</tr>
<tr>
<td>Rainbow trout (juvenile)</td>
<td>Threader and Houston 1983 in McCullough 1999</td>
<td>Ontario</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>76.8°F acclimated at 53.6°F</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>77.72°F acclimated at 60.8°F</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>78.62°F acclimated at 68°F</td>
</tr>
<tr>
<td>Steelhead (juvenile)</td>
<td>Grabowski 1973 in McCullough 1999</td>
<td>Dworshak National Fish Hatchery, Idaho</td>
<td>*</td>
<td>59°F</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rainbow trout (unknown)</td>
<td>Charlon et al. 1970 in McCullough 1999</td>
<td>France</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>79.52°F acclimated at 75.2°F</td>
</tr>
<tr>
<td>Rainbow trout (unknown)</td>
<td>Bidgood and Berst 1969 in McCullough 1999</td>
<td>Great Lakes</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>77°F–78.8°F acclimated at 59°F</td>
</tr>
<tr>
<td>Rainbow trout (unknown)</td>
<td>Cherry et al. 1977 in McCullough 1999</td>
<td>Great Lakes</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>77°F acclimated at 75.2°F</td>
</tr>
<tr>
<td>Rainbow trout (unknown)</td>
<td>Stauffer et al. 1984 in McCullough 1999</td>
<td>Great Lakes</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>78.8°F acclimated at 75.2°F</td>
</tr>
</tbody>
</table>
### Table G-AQUA1.8-1. Preferred, optimum, critical thermal maximum, and upper incipient lethal water temperatures for steelhead.

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

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.
Appendix G
Resource Area–Specific Appendices

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 below the defined index value of 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; Schuld 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


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