Placer County Water Agency
Middle Fork American River Project
(FERC No. 2079)

WORKING DRAFT

AQ 7 - Entrainment - 2007

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1.0 INTRODUCTION

This report describes the entrainment study conducted by the Placer County Water Agency (PCWA) in 2007 in accordance with the AQ 7 - Entrainment Technical Study Plan (AQ 7 - TSP) for the Middle Fork American River Project (MFP or Project). The stakeholder-approved TSP was included in Supporting Document (SD) H of the Pre-Application Document (PAD) filed with the Federal Energy Regulatory Commission (FERC or Commission) on December 13, 2007 (PCWA 2007).

The following sections provide a detailed description of the study objectives, study implementation, extent of the study area, study approach, study results, and literature cited.

2.0 STUDY OBJECTIVES

The objectives of the entrainment studies in the AQ 7 - TSP include the following:

- Characterize Project facilities (diversions, intake structures and intakes, and powerhouse turbines) and operations in relation to factors that may affect entrainment or entrainment-related mortality.
- Develop the information necessary to assess the feasibility of screening intake structures (technical feasibility, feasibility level cost estimates, and maintenance requirements of screens).
- Indirectly estimate the potential for entrainment and entrainment-related mortality using the Project facility characterizations and literature information.
- Determine the need to directly sample entrainment and entrainment-related mortality at Project facilities in coordination with the Aquatic Technical Working Group (TWG).
- If appropriate, directly sample entrainment and entrainment-related mortality at selected Project facilities.

3.0 STUDY IMPLEMENTATION

Figure AQ 7 - 1 shows the AQ 7 -TSP study (PCWA 2007) objectives and the study elements associated with each objective. It also shows how the information developed during the study will be documented and disseminated. The following sections summarize the study elements completed, any deviations from the TSP, outstanding study elements, and proposed modifications to the TSP.

3.1 STUDY ELEMENTS COMPLETED

The following study elements have been completed unless indicated otherwise:

- Characterize Project diversions, intake structures, and powerhouse turbines and operations (**detailed data on some turbines is still being collected**).
- Develop feasibility level estimates of screen installation costs, characterized the technical feasibility of installing the screens (**Pending**), and describe the maintenance requirements of the screens (**Pending**) to assess the feasibility of screening intake structures.
- Indirectly estimate entrainment and mortality potential.
- Summarize fish entrainment and mortality literature.
- Develop fish entrainment threshold calculation approach in collaboration with the Aquatic TWG.

3.2 DEVIATIONS FROM TECHNICAL STUDY PLAN

There are no deviations from the AQ 7 - TSP.

3.3 OUTSTANDING STUDY ELEMENT

The following study element will be completed in 2008 and 2009 and presented in the 2010 Technical Study Report (TSR):

- Collaborate with the Aquatic TWG to determine whether or not direct measurements of entrainment and mortality are warranted.

3.4 PROPOSED MODIFICATION TO TECHNICAL STUDY PLAN

There are no proposed modifications to the AQ 7 - TSP.

4.0 EXTENT OF STUDY AREA

The study area for characterization of the Project diversions, intake structures, and powerhouse turbines includes Duncan Creek Diversion, North Fork Long Canyon Diversion, South Fork Long Canyon Diversion, French Meadows Powerhouse, Hell Hole Powerhouse, French Meadow-Hell Hole Tunnel Intake, Hell Hole-Middle Fork Tunnel Intake, Middle Fork Powerhouse, Middle Fork-Ralston Tunnel Intake, Ralston Powerhouse, Ralston-Oxbow Tunnel Intake, Oxbow Powerhouse, and the low level and instream flow release locations for each of the reservoirs and diversion pools (Map AQ 7-1).

5.0 STUDY APPROACH

This section describes the approach to meet each of the study objectives: (1) characterize the Project facilities and operations in relation to factors that may affect entrainment or mortality; (2) develop information necessary to assess the feasibility of screening intake structures; and (3) indirectly estimate the potential for entrainment and mortality.

5.1 PROJECT FACILITIES

Maps of each of the project diversions facilities are shown in Maps AQ 7-2 to AQ 7-6. The Project diversion structures and intakes where characterized by hydraulic capacity, frequency of use, inlet/outlet type, inlet area, approach velocity over the range of flows, and intake depth (Table AQ 7-1). Pictures of each structure with labels identifying the outlets are provided in Appendix A and a summary of the monthly 10, 20, 50, 80, and 90 percent exceedance flows at each diversion facility for both the inflows and outflows and for the percent of flow diverted is provided in Appendix B. A spreadsheet with the daily flows and a plotting function for each diversion facility will be provided on CD upon request.

5.2 SCREENING FEASIBILITY ASSESSMENT AND COSTS

A screening feasibility assessment was conducted for the Project diversion structures and intakes, diversion operations, and powerhouse turbines. This assessment included: (1) estimates of screen installation costs; (2) characterization of the technical feasibility of installing screens at each location (**Pending**); and (3) maintenance requirements of the screens (**Pending**).

5.2.1 Estimates of Screen Installation Costs

The estimates of screen design and construction costs were based on 35 California screening projects completed from 1983 to 2005. The data were obtained from the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Fish and Wildlife Service (USFWS). Screening costs were compiled for screens within four flow categories (50-100, 100-500, 500-1000, >1000 cfs). The historic screen costs were converted to approximately 2008 dollars using a 3% inflation rate. The current cost of these screens is uncertain due to recent large increases in steel and materials prices. The potential cost of installation of screens at each diversion intakes was estimated using the appropriate per cfs screening cost and the maximum volume of the diversion. Further detailed analysis or site specific cost estimates would be required to refine the estimates.

It should be noted that the cost of screens based on data available on Washington State screen costs was also compiled; however, the costs were significantly lower than California screen costs. The California costs were used because they are considered to be more applicable to the MFP.

5.2.2 Technical feasibility of installing screens at each location

(Pending)

5.2.3 Maintenance requirements of screens

(Pending)

5.3 Entrainment Assessment Threshold Calculation Approach

A preliminary draft fish entrainment threshold calculation approach was initiated by California Department of Fish and Game (CDFG 2007) and further developed by PCWA in collaboration with the Aquatic TWG. The threshold calculation approach evaluated the potential amount of entrainment at Project facilities (reservoirs, diversions, and powerhouse facilities) using literature and Project specific data. Approximate fish entrainment calculations were based on the following data:

- Facility characteristics (e.g., location of intake);
- Project operations (hydrology, percent of flow diverted, and the timing and duration of diversions);
- Fish population estimates and qualitative fish data from the AQ 2 - Fish Population TSR (AQ 2 - TSR) (PCWA 2008a); and
- Entrainment and mortality information from the literature.

The approach estimated: (1) the potential number of fish entrained at Project facilities; (2) the fate of entrained fish; and (3) the potential threshold effect on fish populations at the seven MFP locations where entrainment could occur. There are five shallow water and two deep water diversion/water storage facilities where entrainment can occur, including:

<u>**Shallow Water Intakes**</u>

Small Diversion Pools

Duncan Creek Diversion
North Fork Long Canyon Diversion
South Fork Long Canyon Diversion

Medium Diversion Pool

Middle Fork Interbay

Large Diversion Pool

Ralston Afterbay

<u>**Deep Water Intakes**</u>

Large Reservoirs

French Meadows Reservoir
Hell Hole Reservoir

5.3.4 Potential Number of Entrained Fish

The potential number of fish entrained was estimated differently for the small to medium diversion pool sites and the large reservoir sites. The approaches used to estimate the potential numbers of entrained fish at these locations are described below.

Shallow Water Intakes with Small to Medium Diversion Pools

Potential entrainment at the small to medium diversion pools (Duncan, North Fork Long Canyon, South Fork Long Canyon, Middle Fork Interbay) was calculated by estimating:

- Downstream emigration/movement of two size categories: young-of-the-year (YOY) and juvenile/adult; and
- Percent of fish entrained proportional to the percent of flow diverted.

Estimate of Downstream Movement

Three general approaches were used to estimate downstream movement at the small to medium size diversion pools:

- Empirical entrainment data set
  - West Panther Creek (Mokelumne River tributary)
- Literature based mechanistic approach; and
  - Adult movement studies
  - YOY population modeling (in progress)
- Canal entrainment literature.

Empirical Entrainment Data Set—Historic entrainment sampling data from West Panther Creek, a nearby west slope Sierra Nevada stream, was used to provide an estimate of YOY and juvenile/adult fish downstream movement (and entrainment) for the MFP streams. The West Panther Creek diversion was sampled nearly continuously for entrainment for two years (1983-84) (Bozeman et al. 1987). An inclined plane fish trap (1/8 inch slot spacing) was used to sample 100 percent of the diverted flow. Several other small tributary stream diversions were also sampled at the same time, but West Panther Creek had the highest amount of fish entrainment and the fish population was most similar to the MFP streams (Duncan Creek, North Fork and South Fork Long Canyon creeks). West Panther Creek is located approximately 45 miles south of the MFP streams at an elevation of approximately 3,600 feet. The water temperature pattern of West Panther Creek is similar to the MFP streams (see below).

The second year data (1984) from West Panther Creek were selected to estimate downstream fish movement on a weekly basis for an entire year. The 1984 data showed the greatest amount of entrainment (downstream movement) and 1983 was one of the wettest years on record, potentially limiting its applicability. The West Panther Creek data were generalized (i.e., made applicable to the MFP streams of interest) using the following methods:

- Filling in missing data where necessary (extrapolation/interpolation);
- Scaling the fish capture data on a weekly basis by the weekly trap effort (Fish Caught * 168 hr Week / # hrs Week Trap Effort);
- Estimating the total number of fish moving downstream by scaling the data to the percent of stream sampled (Fish Caught / % Flow Diverted); and
- Scaling the number of YOY and juvenile/adult fish moving downstream to the size of the juvenile/adult fish population (number moving downstream * West Panther Creek fish per mile/ target stream fish per mile).

Figure AQ 7-2 shows the West Panther Creek data collected and the estimated number of fish moving downstream and the amount of flow and percent of flow diverted. The timing of YOY fish present in the West Panther Creek entrainment data coincides with the timing of YOY fish present in the small MFP streams (e.g., Duncan Creek) (see discussion below). Figure AQ 7-3 shows the West Panther Creek mean weekly water temperature overlaid with the 2007 water temperature for several MFP streams (Duncan Creek, North Fork Long Canyon Creek, South Fork Long Canyon Creek, and Middle Fork American River above Middle Fork Interbay).

Literature Data—Existing literature regarding trout movement and trout life history were used to estimate downstream movement of juvenile/adult trout and YOY in the vicinity of MFP diversions.

Juvenile/Adult Fish--Studies of resident juvenile/adult trout movement for periods of 9 to 12 months in small streams and nearby rivers (Gowen and Fausch 1996; Jenkins et al. 1999; Hilderbrand and Kershner 2000; Graf 2008) were fit to probability of dispersal distance distributions (dispersal curves) (Rodriguez 2002) (Table AQ 7-2). The dispersal probability distributions were used to predict how many fish would move downstream into the vicinity of diversions based on the population density upstream of the diversion.

For example, Figure AQ 7-4a shows a fitted annual probability distribution of fish distance from home section (Fausch et al. 1995 cited in Rodriquez 2002) based on 500 m home section lengths (HSL). Figure AQ7-4b shows the same dispersal distribution for multiple home sections along the length of a hypothetical river. The summed probabilities downstream of the zero location represent the probability of fish moving downstream into the vicinity of the diversion. The summed probabilities by 500 m home section upstream of the zero location, when multiplied by the original stream density of fish per 500 m, represent the number of fish remaining in the stream after one year in each 500 m home section (Figure AQ 7-5). This assumes all fish moving downstream are removed from the population (either went downstream over the diversion or were entrained). The difference between the original density and the density after one year is the estimated number of fish moving downstream.

YOY Fish—Modeling downstream movement of YOY resident trout was based on YOY behavior, mortality, and several assumptions regarding how these operate in Project streams. Table AQ 7-3 summarizes the assumptions for the YOY downstream movement modeling. A brief discussion of behavior and mortality issues related to the modeling is provided below.

The potential number of YOY present is based on the number of spawning sized adults greater than approximately 120 mm in length (Moyle 2002, Meyer et al 2003, Avery 1985), the fecundity (number of eggs) of the adult female fish, and the fraction of the eggs that actually get placed in the redd. Figure AQ 7-6 shows fecundity for trout in the 120 to 400 mm size range. Van Winkle et al (1988) found that approximately 90 percent of the eggs were actually deposited in redds.

Timing of spawning depends on photoperiod and water temperature (Lam 1988, cited in Van Winkle et al. 1998). Once the eggs are laid about 330 Celsius degree days is required for the eggs to hatch and another 300 Celsius degree days for emergence (Behnke 1992).

Qualitative sampling (seines and electrofishing) on Duncan, South Fork Long Canyon, and North Fork Long Canyon creeks above their respective diversions on May 17, June 6, and June 26, 2007 found the following: no rainbow trout fry were collected during the first sampling; 3 rainbow trout fry were collected on June 6 in North Fork Long Canyon Creek (23 mm FL) and no fry were found in the other streams; and a combined total of 51 rainbow trout fry were collected on June 26 in the three streams (28-43 mm FL) (PCWA 2008a). Based on this data and the data from West Panther Creek that show rainbow trout YOY entrainment did not start until the first week of June, we assume that emerged YOY fish typically are present and can potentially be entrained no sooner that approximately June 1.

Upon emergence from redds, YOY begin to disperse from the vicinity of the redd. Voluntary dispersal direction is genetically controlled and dispersing fish typically establish and defend group territories (e.g., 1-6 fish) in suitable unoccupied stream habitat (e.g., Elliott 1990). In some situations dispersal is adapted for resident stream rearing and some situations it is directed into lake or reservoir rearing habitats (e.g., Hayes 1988a and 1988b). For example, fish populations spawning in inlet or outlets of reservoirs or above waterfalls (barriers), potentially have hereditary adaptations (genetics) that control the direction of dispersal (Benke 1992). This happens because, over a long period of time, fish with the genetic disposition for dispersal in the wrong direction can be lost from the gene pool. Depending on the river system, dispersal can be directed upstream (e.g., lake outlet spawning fish), downstream, or both directions (Hunt 1965; Raleigh and Chapman 1971; Benke 1992; Lentsch 1985; Elliott 1986; Hayes 1988a and 1988b; Kahler et al. 2001), but it should be noted that rapid downstream dispersal in resident stream fish is potentially maladaptive (see examples of failed attempts to establish resident stream fish using downstream migrating lake inlet spawning fish in Ralegh and Chapman (1971)).

Dispersal of YOY from high density locations near redds to lower density locations potentially "seeds" sections of streams without YOY or spawning habitat (Crisp 1993; Close and Anderson 1992). Not all downstream dispersing YOY, however, are viable. Elliott (1993; 1986) found that for fry in his study stream, 22% emigrated downstream and that most of the emigrating fish, 93.7%, were moribund and that 87% of the older 0+ (parr) that emigrated downstream were moribund. These fish were dying and could not be revived with feeding in the laboratory.

Limited information exists on the distance resident YOY disperse. Kahler et al. (2001) found that rearing juvenile anadromous salmonids moved a maximum of 234 m over the summer. Close and Anderson (1992) and Hunt (1965) found that YOY steelhead and brook trout, respectively, moved as much as about 3 miles over the summer (approximately 1 mile/month) at lower densities. Both studies showed that more fish moved at high densities (e.g., greater than 1 fish per m^2) and Close and Anderson (1992) found that YOY steelhead emigrated farther downstream at very high stocking densities.

High levels of natural mortality occur during the first 2-3 months for newly emerging YOY. Many of the YOY potentially die within close proximity to the spawning location (Elliott 1986) and it appears that many of the fish that are either emigrating or that die are YOY fish that did not or were prevented from establishing territories in suitable habitat (see Figure 1 in Elliott 1990). Mortality during the early 2-3 month "critical period" is as high as 96% (4% survivorship) and then declines (i.e., survivorship improves) (Elliott 1993, Allen 1951). One of the lowest percentages of mortality (highest survivorship values) we found in the literature was 77% (23% survivorship) (Mortenson 1977).

Few moribund or dead fry are observed in streams because they decompose quickly and are scavenged by invertebrates (e.g., caddis larvae and predatory stoneflies) (Elliott 1997) and are likely scavenged by numerous vertebrate predators (fish, birds, mammals).

Canal Entrainment Empirical Data Sets—Data from canal or power tunnel entrainment studies provides another source of information on downstream moving fish. Post et al. (2006) studied entrainment of rainbow and brown trout on the Bow River in Canada, Carlson and Rahel (2007) estimated cutthroat trout entrainment on the Smith Fork River in Wyoming, and some data exists on the entrainment of rainbow and brown trout for the Stanislaus Power Tunnel (PG&E 2002) and canals on the DeSabla Project (PG&E 2007). A summary of the canal entrainment data is provided in Table AQ 7-4.

Description of the rivers for each of the canal entrainment data sets and their applicability to the MFP streams (**to be completed**).

Percent of Fish Entrained Proportional to the Percent of Flow Diverted

After estimating the downstream movement, the number of juvenile/adult fish and YOY entrained was calculated proportional to the amount of flow diverted. For example, if 75% of the flow was diverted, 75% of the fish were assumed to be entrained.

Shallow Water Intakes with Large Diversion Pools

Ralston Afterbay is a relatively large diversion pool with a shallow diversion intake (powerhouse tunnel). Estimation of entrainment at Ralston Afterbay is pending discussions with the Aquatic TWG and collection of fish population data on Ralston Afterbay (June and September 2008).

Deep Water Intakes, Large Reservoirs

Potential entrainment and potential effects on the fishery at the deep water intakes of the large reservoirs will be estimated by:

- Estimating the abundance of fish in the water column near the intake structure; and
- Reviewing stocking and fish sampling data.

French Meadows Reservoir and Hell Hole Reservoir each have dam outlets and tunnel diversion outlets that have deep water intake structures. The dam outlet depths for French Meadows Reservoir average 151 and 169 feet for the instream flow release and low level outlets, respectively (ranges are 92-198 feet and 110-215 feet, respectively) and the tunnel outlet depth averages 102 feet (range is 43-149 feet). The Hell Hole Reservoir dam outlet works depth averages 263 feet (range is 127-347) and the tunnel outlet depth averages 229 feet (range is 93-313). These depths are dependent on the water surface elevations of the reservoirs, which vary seasonally (e.g., higher water surface elevations are associated with deeper depths of intake facilities).

Entrainment is assumed to be low at these facilities because sonar data from other systems with relatively large, deep reservoirs typically shows that the majority of fish in deep water reservoirs reside in depths shallower than the intake structures (e.g., SCE 2007). The Aquatic TWG has agreed that PCWA will use sonar equipment (fish-finder) to estimate the abundance of fish throughout the water column in the vicinity of the reservoir deep water intake structures to assess the potential risk of fish entrainment. This will entail sampling at the structures four times: once during spring, twice during the summer, and once in the fall (road access to the reservoirs is restricted during the winter due to snow).

In addition to the low potential for entrainment at the deep water intakes, no special-status species are present in the reservoirs and annual fish stocking either supplements or supports the reservoir fishery, which may reduce the effect of potential entrainment on the reservoir fisheries. Limited opportunity exists for fish at Hell Hole Reservoir to migrate into tributaries for spawning due to natural barriers in the streams (PCWA 2008b). Most natural spawning would be confined to spawning in a very short segment of stream or within the reservoir itself. It is, therefore, likely that the fishery is primarily supported by stocking. This will be assessed by reviewing stocking records and fish sampling data from the reservoir (PCWA 2008a). At French Meadows Reservoir, the Middle Fork American River provides a potential spawning location for reservoir fish. PCWA will survey upstream of the reservoir to determine the length of river accessible to spawning fish from French Meadows Reservoir and will use this data and stocking records to characterize source of fish for the reservoir fishery.

5.3.5 Fate of Entrained Fish

The fate of entrained fish at a particular diversion depends on the type of facility to which the diversion leads (e.g., reservoir, release outlet, powerhouse, etc.). If the diversion leads to a powerhouse, then the characteristics of the powerhouse also affect mortality. Entrained fish that pass through Pelton turbines are assumed to have very high (nearly 100%) mortality. Fish passing through cone or Howell-Bunger valves are also assumed to have high mortality. Fish entrained and passing through Francis turbines are assumed to have low to moderate mortality depending on the characteristics of the turbine. Table AQ 7-5 shows the immediate and 48-hour fish survival rates for Francis turbines based on data presented in Winchell et al. 2000. Factors that potentially affect fish survival are peripheral runner velocity, blade and or wicket spacing/clearance, and fish size. High survival is assumed for fish passing through minimum flow pipes, over diversion structures, or entrained into other bodies of water (reservoirs).

Table AQ 7-6 shows each potential fish entrainment mortality location (powerhouse, reservoir) by diversion and relative mortality rankings (high, medium, low) for each diversion. Details on mortality are provided in the results section.

5.3.6 Threshold Fish Population Effects

The effect of entrainment on fish populations for the present was assessed conservatively and in a simplistic manner assuming that all mortality was additive (i.e., mortality was not compensatory). Entrainment of adult fish (2+ and older) was assumed to remove an equivalent number of reproductive age adult fish from the population. For potential future mitigation measures, it was assumed removal of two adults from the population was equivalent to the loss of one redd or, vice versa, that the addition of one redd was assumed to compensate for the loss of an adult pair.

Entrainment of YOY and juvenile fish was assumed to remove an equivalent number of YOY fish from the stream population and based on using the survivorship calculated for each stream, the equivalent number of redds or spawning adults lost was also calculated. Plots were developed relating the number of YOY of various ages to the number redds (or adult pairs) required to replace the YOY. The biomass and energy lost to other trophic levels from YOY or juvenile fish potentially lost to entrainment was also estimated.

Mortality based on the threshold analysis, at present, did not consider that mortality could be compensatory; where, removal of some fish from a population is compensated for by freeing up limited resources (food, space) for remaining fish, thereby increasing survivorship, increasing growth, and increasing reproductive capacity for the remaining fish. The concept of sustainable fishery harvest and surplus production is based on the fact that compensatory mortality occurs in fisheries. The implications and evidence for compensatory mortality in Sierra Nevada streams is briefly discussed in the results section.

6.0 STUDY RESULTS

6.1 OVERVIEW

To Be Completed.

6.2 SCREENING FEASIBILITY ASSESSMENT AND COSTS

Potential California screen installation costs by discharge range are shown in Table AQ 7-7. The average cost and the highest cost of the 35 California screens were summarized. The screen cost estimates range from $8,300 to $42,000 per cfs depending on screen size (maximum flow capacity). The data used to create the table are provided in Appendix C. The potential screen costs do not include recent large increases in steel and construction costs.

The potential cost for screen installation at the MFP diversions range from $1 to $21 million dollars. Table AQ 7-8 shows the maximum flow capacity of each of the MFP diversions and the estimated cost of installation based on the average and maximum screen costs in Table AQ 7-7.

6.3 ENTRAINMENT ASSESSMENT THRESHOLD CALCULATION APPROACH

6.3.1 Potential Number of Entrained Fish

The potential number of entrained fish at shallow water intakes with small to medium diversion pools is described below. The results of entrainment analyses at the shallow water intakes at the large diversion pool and deep water intakes are pending additional planned data collection.

Shallow Water Intakes with Small to Medium Diversion Pools

The potential number of entrained fish at the shallow water intakes with small to medium size diversion pools determined by the three approaches is discussed below.

West Panther Creek Empirical Data Set - The fish populations in North Fork Long Canyon Creek, South Fork Long Canyon Creek, Duncan Creek and the Middle Fork American River upstream of Middle Fork Interbay are summarized in Table AQ 7-9. The juvenile/adult fish populations were used to create a scaling factor to scale the data from West Panther Creek to the MPF diversions. The juvenile/adult fish population upstream of the West Panther Creek diversion was 870 fish/ mile (Table AQ 7-9). Weekly estimates of downstream movement of both YOY and juvenile/adult fish were multiplied by both the scale factor and the percent of flow diverted for each MFP diversion to estimate the potential number of fish entrained.

A summary of the daily 50% exceedance percent of flow diverted by month at each MFP diversion is shown in Table AQ 7-10. The calculated monthly YOY and juvenile/adult fish entrainment values, based on the percent of flow diverted, are shown in Table AQ 7-11. The annual YOY entrainment values range from 9 to 525 YOY. The annual juvenile/adult entrainment values range from 63 to 87 fish. Entrainment of YOY was estimated to be very low at both the North and South Fork Long Canyon diversions because the diversions typically do not divert water during the summer time period when YOY were present and entrained at the West Panther Creek Diversion.

Appendix D shows plots of the estimated number fish moving downstream and estimated number entrained by month. The plots also include the amount of flow and the percent of flow diverted.

Literature Data Modeling – The estimated downstream movement of juvenile/adult trout and YOY in the vicinity of MFP diversions based on literature data and modeling is presented below.

Juvenile/Adult Fish—The estimated number of fish moving downstream based on four long-term trout movement data sets, scaled to a fish population of 1000 fish/mile, range from 72 to 108 fish annually (Table AQ 7-12). The monthly average was combined with the fish population and 50% exceedance percent of flow diverted at each MFP diversion site to estimate the potential number of entrained juvenile/adult fish (Table AQ 7-13). The annual number of fish potentially entrained at each MFP site ranges from 27 to 59 fish. These values are similar to those estimated by using the West Panther Creek empirical data.

YOY Fish—Survivorship data calculated for each of the fish populations above and below the diversions fall midway between the high and low survivorship data found in the literature for rainbow and brown trout populations. The initial values, beginning the first of June, are based on the estimated number of YOY emerging from redds (estimated from the fecundity and number of the adult females present) and the remaining fish density values are based on the 2007 fall sampling data (AQ 2 TSR PCWA 2008a). Figures AQ 7-7 to 7-10 show the survivorship curves for North Fork Long Canyon Creek, South Fork Long Canyon Creek, Duncan Creek and Middle Fork American River upstream of Middle Fork Interbay. The top figures show all four age classes (0+, 1+, 2+, 3+) and the bottom figures shows only age 0+ fish and indicate when the diversions stops diverting for the year.

The survivorship curves do not provide a direct way to estimate downstream YOY movement. A rough estimate of the potential "excess" number of YOY moving downstream was calculated by making two assumptions: (1) the observed survivorship curve represents equilibrium survivorship (observed numbers of fish are in equilibrium and no excess fish are available for downstream emigration); and (2) the high literature survivorship curve represents the maximum potential survivorship. The difference between the equilibrium and the high literature survivorship curve was used as an estimate of potential "excess" YOY available for downstream emigration. This is viewed as a simple scaling estimate of excess YOY. A potentially more accurate method for estimating excess YOY may be developed based on habitat availability once instream flow modeling is completed.

Table AQ 7-14 shows the difference between the equilibrium number of YOY at the end of the diversion period using the site specific survivorship compared to the number of

YOY assuming the highest literature survivorship (i.e., potential excess YOY emigrating that might be entrained). Included in the table is the number of equivalent adult pairs (or alternatively redds) that are represented by the number of emigrating YOY potentially entrained.

The survivorship curves can be used to estimate the potential population effect of entrainment of different age fish. Figures AQ 7-11 to 7-14 show the number of fish surviving per redd over a period of four years (0+, 1+, 2+, and 3+ age fish) for the fish populations above and below each diversion. Entrainment of an equivalent number of fish of a given age equates to the loss of one redd or alternatively the loss of a pair of adult fish.

It should be noted that, in general, there was little difference between the observed survivorship curves for the above and below diversion data sets.

Canal Entrainment Empirical Data Sets - The canal trout entrainment data sets integrate entrainment over the period of diversion operation. Where the throughput or number of fish actually passing through the canal is accounted for, the estimates represent the total number of fish entrained (Bow River, Smith Fork River). Where the throughput of fish is not accounted for, the canal entrainment data sets should be considered a minimum estimate of entrainment (DeSabla Canal and Stanislaus Tunnel data). As entrainment is integrated over time in these data sets, they do not provide information on the timing of the entrainment (e.g., what time of year YOY were entrained). Consequently, it is difficult to apply the data on a monthly basis to diversions that operate only during selected periods of time (see discussion below).

Entrainment estimates based on canal entrainment data result in higher entrainment than the other two methods used to estimate entrainment (i.e., West Panther Creek empirical data and literature data based modeling). A summary of the canal entrainment data is shown in Table AQ 7-4. The canal data were summarized in a manner that allowed application to downstream movement and entrainment in MFP streams on a monthly average basis (Table AQ 7-15). These data were scaled by the number of months flow was diverted, by the size of the juvenile/adult fish population, and the percent of flow diverted. The juvenile/adult entrainment data are more applicable for analysis and application to MFP diversions than the YOY data. Several of the MFP diversions have limited operations during the summer (North Fork Long Canyon, South Fork Long Canyon, Duncan Creek) when YOY entrainment would be expected to be highest, whereas the canal entrainment data sets all consist of high diversion amounts during the entire summer period.

These data were then used to estimate potential MFP entrainment by multiplying the scaled average canal entrainment data by the juvenile/adult fish population upstream at each MFP diversion and the average amount of flow diverted (50% exceedance value) at the diversion (Table AQ 7-16). The scaled Smith Fork River canal entrainment data for cutthroat trout was excluded from the analysis for the present time because scaling the data based on the low fish population in the Smith Fork River produced average entrainment values that seem unreasonable. This will be revisited in the next revision of this document.

Shallow Water Intakes with Large Diversion Pool

Estimation of entrainment at Ralston Afterbay is pending: (1) discussions with the Aquatic TWG; (2) collection of fish population data on Ralston Afterbay (June and September 2008); and (3) a refined estimate of potential fish mortality at Oxbow Powerhouse.

Deep Water Intakes with Large Reservoirs

Estimates of potential entrainment at French Meadows Reservoir and Hell Hole Reservoir are pending sonar data collection of fish density near intake structures.

6.3.2 Fate of Entrained Fish

Table AQ 7-17 shows the estimated survival for each of the MFP powerhouses. Additional information will be added to this section in a future revision as more detailed information of powerhouse facilities is obtained.

6.3.3 Threshold Fish Population Effects

Table AQ 7-18 shows a summary of potential numbers of YOY and juvenile/adult fish potentially entrained in MFP diversions. The most conservative approach to estimating the effects of the potential number of fish entrained is to assume the mortality is additive. That is, that fish entrained represent a one-to-one loss to the population upstream and/or downstream of the diversion (i.e., one entrained fish equals on lost fish fish to the population). YOY numbers can be back calculated to determine the equivalent number of redds or adult pairs lost from the stream based on the data provided in this report (see Figures AQ 6-11 to AQ 6-14).

Table showing conversion of YOY numbers to equivalent redds and adults (**to be completed**).

There is a high likelihood that some of the mortality based on entrainment would be compensatory. That is, removal of some fish from the population would free up food and space resources for remaining fish and as a result growth would increase, over winter survival might increase, fecundity of the remaining fish would increase because of larger size (see Figure AQ 7-6), and the reproduction of the remaining fish would be enhanced (i.e., compensating for some portion of the lost fish). Jenkins et al. (1999) found a strong inverse relationship between growth and fish density in two Sierra Nevada streams (Convict Creek and Mammoth Creek) at fish densities less than about $1/m^2$ and assumed that the effect would result in compensatory reproductive capacity for fish populations at lower densities.

Discussion of the density of fish in MFP streams compared to Jenkins et al. (1999) and other sources and to reference fish populations (**to be completed**).

Calculations of biomass and energy lost to different trophic levels due to potential entrainment (**to be completed**).

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TABLES

AQ 7-1. Middle Fork Project Facilities – Entrainment Characteristics.

Facility	Hydraulic Capacity (cfs)	Frequency of Use (cfs)	Inlet/Outlet Type	Inlet Area ($ft.^2$)	Approach Velocity (fps)	Intake Depth (ft)	Comments
French Meadows Reservoir							
French Meadows-Hell Hole Tunnel	Existing Project: 400 Betterment: 800	Frequent during spring and summer	Inlet: 10 ft. dia. pipe. Trash rack with 2.6 in. bar spacing. Outlet: vertical Francis turbine	Inlet: 78.5 Trash Rack: 484	Inlet/Exist: 0-5.1 Inlet/Better: 0-10.2 Trash Rack/Exist: 0-0.8 Trash Rack/Better: 0-1.6	145[(1)]	Betterment – French Meadows Powerhouse capacity upgrade. French Meadows Powerhouse discharges into Hell Hole Reservoir.
French Meadows Dam – Low Level Outlet	1,430	Infrequent	Inlet: 60 in. pipe with slide gate. Trash rack with 6 in. bar spacing. Outlet: 60 in. Ring Jet Valve	Inlet: 28 Trash Rack: 52	Inlet: 0-51 Trash Rack: 0 - 28	211.5[(2)]	Energy dissipating valve discharges to a plunge pool
French Meadows Dam – Instream Flow Pipe Intake	4 - 8	Continuous	Inlet: 8 in. pipe. Outlet: 8 in. Howell-Bunger Valve	Inlet: 0.35 Trash Rack: 23	Inlet: 11.4 – 22.86 Trash Rack: 0.2 – 0.4	194[(1)]	Energy dissipating valve discharges to a plunge pool

[1]Maximum reservoir operating surface elevation minus intake surface elevation.
[2]Maximum reservoir operating surface elevation minus curb intake elevation.

AQ 7-1. Middle Fork Project Facilities – Entrainment Characteristics (cont.).

Facility	Hydraulic Capacity (cfs)	Frequency of Use (cfs)	Inlet/Outlet Type	Inlet Area (ft.^{2})	Approach Velocity (fps)	Intake Depth (ft)	Comments
Hell Hole Reservoir							
Hell Hole-Middle Fork Tunnel	800	Frequent	Inlet: 11.5 ft. dia. pipe. Trash rack with 2 in. bar spacing Outlet: Two Pelton Turbines	Inlet: 104 Trash Rack: 705	Inlet: 0-7.8 Trash Rack: 0-1.1	308.1[(1)]	Powerhouse discharges into Middle Fork Interbay
Hell Hole Dam Outlet Works	6-848	Continuous low flow (6-20); Infrequent during outages (approx. 65); Infrequent and would cause facility damage (65-848)	Rectangular inlet (with trash rack) into horizontal 13 ft. horseshoe shaped tunnel (original tunnel opening shut with stop logs).	Inlet: 76 Trash Rack: 300.3	Inlet: 0.08-11.2 Trash Rack: 0.02-2.82	342[(2)]	Outlet works is a tunnel that leads to a 48 in. dia. pipe and 16 in. dia. pipe for the Hell Hole Powerhouse, instream flow pipe, and low level outlet.
Hell Hole Dam Low Level Outlet[(4)]	Calculated maximum capacity 848	Infrequent (would cause facility damage)	Inlet: 48 in. dia. pipe with butterfly valve. Outlet: 48 in. hollow-cone valve	12.6	48 in. pipe opening inlet: 0-67.3[(3)]	342[(2)]	Energy dissipating valve discharges to a plunge pool
Hell Hole Power House[(4)]	Approx 45	Continuous except for maintenance	Inlet: 20 in. dia. pipe with control valve Outlet: horizontal Francis turbine	2.18	20 in. pipe opening inlet: 0-20.6[(3)]	342[(2)]	20 in. dia. penstock for powerhouse "Y's" off of 48 in. dia pipe. Hell Hole Powerhouse discharges to plunge pool
Hell Hole Dam Instream Flow Pipe[(4)]	20	Infrequent (typically Instream flow compliance is provided by Hell Hole Powerhouse) discharge	Inlet: 16 in. dia. pipe with butterfly valve. Outlet: 12 in. hollow-cone valve.	0.8	16 in. pipe opening inlet: 0-25[(3)]	342[(2)]	Energy dissipating valve discharges to a plunge pool

[1]Maximum reservoir operating surface elevation minus intake surface elevation.
[2]Maximum reservoir operating surface elevation minus intake elevation invert of Hell Hole Dam Outlet Works.
[3]Intake velocity calculated at the pipe inlet inside the tunnel. Intake velocity to the tunnel is much lower (see Hell Hole-Middle Fork Tunnel Intake)
[4]Outlet branches off from tunnel. Inlet to tunnel is the Hell Hole Dam Outlet Works.

AQ 7-1. Middle Fork Project Facilities – Entrainment Characteristics (cont.).

Facility	Hydraulic Capacity (cfs)	Frequency of Use (cfs)	Inlet/Outlet Type	Inlet Area (ft.^{2})	Approach Velocity (fps)	Intake Depth (ft)	Comments
Middle Fork Interbay							
Middle Fork – Ralston Tunnel	836	Frequent	Inlet: Tunnel with slide gate and trash rack with 3 in.bar spacing Outlet: Pelton Turbine	Tunnel Inlet: 96 Trash Rack: 680	Inlet: 0-8.71 Trash Rack: 0-1.23	51(1)	Ralston Powerhouse discharges into Ralston Afterbay
Middle Fork Interbay Dam Low Level Outlet	895	Infrequent	Inlet: 60 in. dia. with slide gate and Grizzly (8 in. bar opening) Outlet: Open pipe	Pipe Inlet: 19.6 Grizzly: 62	Inlet: 0-45.7 Trash Rack: 0-14.4	68.5(1)	Discharges to a plunge pool
Middle Fork Interbay Dam Stream Maintenance Pipe	12-23	Continuous	Inlet: 20 in dia. pipe with slide valve and trash rack (3 in. bar opening) Outlet: Open pipe	Pipe Inlet: 2.18 Trash Rack: 6.0	Inlet: 5.5-10.6 Trash Rack: 2.0-3.8	39.84(1)	Outlet discharges to a plunge pool

[1]Maximum reservoir operating surface elevation minus intake elevation invert.

AQ 7-1. Middle Fork Project Facilities – Entrainment Characteristics (cont.).

Facility	Hydraulic Capacity (cfs)	Frequency of Use (cfs)	Inlet/Outlet Type	Inlet Area (ft.^{2})	Approach Velocity (fps)	Intake Depth (ft)	Comments
Ralston Afterbay							
Ralston – Oxbow Tunnel	1,088	Frequent	Inlet: Tunnel with slide gate and trash rack with 3 in. bar spacing Outlet: vertical Francis turbine	Tunnel Inlet: 96 Trash Rack: 590	Inlet: 0-11.3 Trash Rack: 0-1.8	39[(1)]	Oxbow Powerhouse discharges into the Middle Fork American River
Ralston Afterbay Dam Low Level Outlet	1,671	Infrequent	Inlet: 72 in. dia. with slide valve and Grizzly (8" bar opening) Outlet: 72 in. dia. slide gate	Pipe Inlet: 28.3 Grizzly: 82.6	Inlet: 0-59.1 Trash Rack: 0-20.33	74[(1)]	Discharges to a plunge pool
Ralston Afterbay Dam Stream Maintenance Pipe	75	Frequent – 10 cfs Infrequent – 75 cfs	Inlet: 30 in. dia. pipe with slide valve and trash rack (3.88 in. bar opening) Outlet: 30 in. dia. Ring Jet valve	Pipe Inlet: 4.9 Trash Rack: 36.2	Inlet: 2.04-15.31 Trash Rack: 0.3-2.1	41.25[(1)]	Energy dissipating valve discharges to a plunge pool

[1]Maximum reservoir operating surface elevation minus intake elevation invert.

AQ 7-1. Middle Fork Project Facilities – Entrainment Characteristics (cont.).

Facility	Hydraulic Capacity (cfs)	Frequency of Use (cfs)	Inlet/Outlet Type	Inlet Area (ft.^{2})	Approach Velocity (fps)	Intake Depth (ft)	Comments
Duncan Creek Diversion							
Duncan Creek – Middle Fork Tunnel	400	Frequent	Inlet: Tunnel with stop logs. Trash Rack (with 9 in. bar spacing.) Outlet: Open tunnel	Tunnel Inlet: 51 Trash Rack: 51	Inlet: 0-7.84 Trash Rack: 0-7.84	4.25[(1)]	Discharges into French Meadows Reservoir
Duncan Creek Low Level Outlet	304	Infrequent	Inlet: 60 in. dia. pipe w/ slide gate and grizzly with 10 in. bar spacing. Outlet: Open pipe	Pipe Inlet: 19.6 Grizzly: 58.7	Inlet: 0-15.5 Trash Rack: 0-5.2	13.5[(2)]	Discharges to a plunge pool
Duncan Creek Stream Maintenance Pipe	4 - 8	Continuous	Inlet: 10 in. dia. pipe with slide gate and trash screen (with 1.75 in. openings) Outlet: Discharge weir.	Pipe Inlet: 0.55 Trash Screen: 12.2	Inlet: 7.3-14.6 Trash Rack: 0.33-0.66	5[(1)]	Outlet discharges to a plunge pool

[1]Diversion Dam Crest minus top of intake weir.
[2]Diversion Dam Crest minus invert elevation.

AQ 7-1. Middle Fork Project Facilities – Entrainment Characteristics (cont.).

Facility	Hydraulic Capacity (cfs)	Frequency of Use (cfs)	Inlet/Outlet Type	Inlet Area ($ft.^2$)	Approach Velocity (fps)	Intake Depth (ft)	Comments
North Fork Long Canyon							
North Fork Long Canyon Diversion Pipe	100	Frequently during winter and spring. No diversion after July 1.	Inlet: Parshall Flume with slide gate to a 36 in. dia pipe. Trash rack w/ 2 in. bar spacing. Outlet: 403 foot deep drop inlet to the Hell Hole - Middle Fork Tunnel	Inlet: 16 Trash Rack: 68.7	Inlet: 0 – 6.25 Trash Rack: 0 – 1.46	6[(1)]	Discharge to Hell Hole – Middle Fork Tunnel
North Fork Long Canyon Low Level Outlet	104	Infrequent	Inlet: 36 in. dia. pipe with slide gate Outlet: open pipe	Inlet: 7.1	Inlet: 0 – 14.7	5.5[(1)]	Discharge to streambed
North Fork Long Canyon Stream Maintenance Pipe	0 - 2	Continuous	Inlet: 12 in. dia pipe with 12 in. Slide valve Outlet: 25 in. wide concrete channel with weir	Inlet: 0.8	Inlet: 0 - 2.5	6[(1)]	Discharge to streambed

[1]Diversion dam spillway crest minus invert elevation.

AQ 7-1. Middle Fork Project Facilities – Entrainment Characteristics (cont.).

Facility	Hydraulic Capacity (cfs)	Frequency of Use (cfs)	Inlet/Outlet Type	Inlet Area (ft.^{2})	Approach Velocity (fps)	Intake Depth (ft)	Comments
South Fork Long Canyon							
South Fork Long Canyon Diversion Pipe	200	Frequently during winter and spring. No diversion after July 1	Inlet: 42 in. dia. pipe with inlet weir. Trash rack w/2.4 in. bar spacing. Outlet: 387 foot deep drop inlet to Hell Hole-Middle Fork Tunnel	Inlet: 36 Trash Rack: 107	Inlet: 0 – 5.6 Trash Rack: 0 – 1.87	11[(1)]	Discharge to Hell Hole – Middle Fork Tunnel
South Fork Long Canyon Low Level Outlet	136 136	Infrequent	Inlet: 36 in. dia. pipe with slide gate Outlet: open pipe	Inlet: 7.1	Inlet: 0 – 19.5	12.2[(1)]	Discharge to streambed
South Fork Long Canyon Stream Maintenance Pipe	2.5 - 5	Continuous	Inlet: 12 in. dia pipe with 12 in. Slide valve Outlet: 48 in. wide concrete channel with weir	Inlet: 0.8	Inlet: 3.1 – 6.25	6[(1)]	Discharge to streambed

[1]Diversion dam spillway crest minus invert elevation.

AQ 7-2. Dispersal Functions and Derived Parameters for PCWA Juvenile and Adult Trout Modeling[1].

Source	λ_s	λ_m	p	Duration Days	Extent (m)	HSL (m)
Graf 2008	0.000177806	0.002281752	0.099314901	365	6500	500
Jenkins et al. 1999	0.004388637	0.075026033	0.431597998	270	745	13.8
Jenkins et al. 1999	0.000316486	0.006390323	0.317766589	365	4500	500
Fausch et al. (1995; cited in Rodriguez 2002)	0.01767	0.00155	0.46	365	1350	50

1 Dispersal function describing decline in capture probability with distance from the home section:

$$f(x) = p\lambda_s e^{-\lambda_s x} + (1+p)\lambda_m e^{-\lambda_m x}$$

where: p = proportion of stationary individuals; (1 - p) = proportion of mobile individuals; x = distance in meters away from the home section; HSL = home section length (in meters); λ_m and λ_s = displacement parameters (i.e., the inverse of the mean displacement distance; in units of m^{-1}) and subscripts 'm' is mobile and 's' is stationary.

AQ 7-3. Assumptions for YOY Modeling.

Not Yet Completed

AQ 7-4. Summary of Canal Entrainment Data.

River/Project	Bow River, Alberta, CA	Smiths Fork, WY	Stanislaus, CA	DeSabla, CA		
Canal Name	Carseland	Covey, Whites Water, South Branch Irrigation	Stanislaus Power Tunnel and Forebay	Hendricks	Butte	Lower Centerville
Length of Diversion Period (months)	4	5	12	12	12	12
Number of Streams Entering Canal	1	1	1	4	5	4
Approximate % of Flow Diverted	73	32	85	80	76	72
Approximate Amount of Flow Diverted	1018	61[2]	500	125	91	183
Estimate of All Trout Fish Population Main stem	–	–	8233[6]	892	389	1063
Estimate of Adult Fish Population Mainstem	2017	269	3264	892	389	1063
Number of Trout Diverted [1]	4660	404	1872	1420	1102	1174
% RBT	86	65	50	42	65	93
% YOY	62	--	54	43	61	61
Reference	Post et al. 2006	Carlson and Rahel 2007	PG&E 2002	P&GE 2007	P&GE 2007	P&GE 2007

[1]Minimum Entrained
[2]Based on Average annual discharge
[3]Butte Creek - total of 4 tribs, 3 with fish population
[4]3 tribs with no fish population data
[5]Averaged the 3 mainstem Fish Population Sites, above the diversion
[6]Based on 10 years of data

Table AQ 7-5. Immediate and 48-Hour Fish Survival Rates for Francis Turbines by Fish Size.[1]

Runner Speed (rpm)	Hydraulic Capacity (cfs)	Fish Size (mm)	Average Immediate Survival[2] (all species combined)			
			N[3]	Minimum (%)	Maximum (%)	Mean (%)
<250	440-1,600	<100	13	85.9	100[4]	93.9
"	370-1,600	100-199	19	74.8	100.0	91.6
"	370-2,450	200-299	18	59.0	100.0	86.9
"	440-1,600	300+	14	36.1	100.0	73.2
>250	275-695	<100	6	31.0	97.6	70.1
"	"	100-199	7	34.3	82.7	60.0
"	"	200-299	7	22.8	82.9	39.3
"	"	300+	3	3.5	35.4	19.1

Runner Speed (rpm)	Hydraulic Capacity (cfs)	Fish Size (mm)	Average 48-Hour Survival[2] (all species combined)			
			N[3]	Minimum (%)	Maximum (%)	Mean (%)
<250	440-1,600	<100	11	81	101[(4)]	90
"	370-2,450	100-199	17	74	101[(4)]	88
"	440-2,450	200-299	15	47	96	80
"	440-1,600	300+	13	34	94	67
>250	275-695	<100	3	63	86	72
"	275-695	100-199	5	16	78	46
"	275-695	200-299	5	12	65	32
"	275-450	300+	2	4	8	6

[1]From Winchell, F., S. Amaral and D. Dixon. 2000. Hydroelectric Turbine Entrainment and Survival Database: An Alternative to Field Studies. Paper presented at Hydrovision 2000.

[2]Average of all control-adjusted estimates provided in EPRI (1997) including all species and test conditions but excluding tests with less than 90% survival of control groups.

[3]Number of turbines for which survival estimates are available.

[4]Even with high rates of control survival, the true rate of survival may be under- or over-estimated. When the survival of treatment groups is higher than controls, the adjusted survival estimates will exceed 100%.

AQ 7-6. Entrainment Locations by Diversion and Potential Mortality Rankings.

To be completed

[5] Nominal capacity of Hell Hole – Middle Fork Tunnel.

AQ 7-7. Summary of Screen Costs - California.

Flow Range (cfs)	Average Cost Dollars/CFS[1]	Highest Cost Dollars/CFS[2]
50-100	$8,300	$15,000
100-500	$21,000	$42,000
500-1000	$12,000	$23,000
>1000	$12,000	$19,000

Notes

[1]Average capital cost of 35 projects constructed in California between 1983 and 2005. Costs inflated at 3% to 2008 dollars.

[2]Highest capital cost in range (2008 dollars).

AQ 7-8. Estimated Installation Costs to Screen Selected Project Facility Intakes.

Facility	Maximum Flow (CFS)	Average Cost $/CFS[1,4]	Maximum Cost $/CFS[1,4]	Range of Screen Cost (millions)[4]	
Small Facilities					
North Fork Long Canyon Diversion	100	$8,300	$15,000	$1	$2
South Fork Long Canyon Diversion	200	$21,000	$42,000	$4	$8
Large Facilities					
Duncan Creek - Middle Fork Tunnel Intake	400	$21,000	$42,000	$8	$17
French Meadows - Hell Hole Tunnel Intake(2)	400	$21,000	$42,000	$8	$17
French Meadows - Hell Hole Tunnel Intake(3)	800	$12,000	$23,000	$10	$18
Hell Hole - Middle Fork Tunnel Intake	920	$12,000	$23,000	$11	$21
Middle Fork - Ralston Tunnel Intake	836	$12,000	$23,000	$10	$19
Ralston - Oxbow Tunnel Intake	1,088	$12,000	$19,000	$13	$21

[1]Estimated costs per cfs are based on average and maximum costs from 35 previously constructed screening projects in California with a variety of screen designs, sizes, and design criteria.

[2]Current operations

[3]Utilizing maximum tunnel capacity

[4]Capital cost in 2008 dollars (3% annual inflation)

AQ 7-9. Fish Population Scaling Factors Versus West Panther Creek Population.

River Site	Juvenile/Adult Trout (#/mile)	Population Scaling Factor
West Panther Creek	870	-
Duncan Creek above Diversion (DC9.0)	1021	1.17
South Fork Long Canyon Creek above Diversion (SFLC4.2)	1380	1.59
North Fork Long Canyon Creek aboveDiversion (NFLC3.8)	1577	1.81
Middle Fork American River above Middle Fork Interbay (MF36.2)	696	0.80

AQ 7-10. Fifty Percent Exceedance Diversion Percent.

	% Flow Diverted			
Month	**NF Long Canyon Creek**	**SF Long Canyon Creek**	**Duncan Creek**	**Middle Fork Interbay**
Jan	0%	0%	21%	89%
Feb	40%	51%	41%	92%
Mar	72%	67%	62%	86%
Apr	77%	81%	82%	84%
May	54%	74%	85%	89%
Jun	0%	0%	46%	95%
Jul	0%	0%	0%	97%
Aug	0%	0%	0%	97%
Sep	0%	0%	0%	97%
Oct	0%	0%	0%	86%
Nov	0%	0%	4%	97%
Dec	0%	0%	7%	93%
Average	**20%**	**23%**	**29%**	**92%**

AQ 7-10. Fifty Percent Exceedance Diversion Percent.

Month	NFLC 3.8	SFLC 4.2	DC 9.0	MF 36.2
Jan	0	0	21	89
Feb	40	51	41	92
Mar	72	67	62	86
Apr	77	81	82	84
May	54	74	85	89
Jun	0	0	46	95
Jul	0	0	0	97
Aug	0	0	0	97
Sep	0	0	0	97
Oct	0	0	0	86
Nov	0	0	4	97
Dec	0	0	7	93
Aerage	20	23	29	92

AQ 7-11. Summary of Potential Fish Diverted using the West Panther Creek Data and the 50% Exceedance Percent Flow Diversion.

	NF Long Canyon Creek		SF Long Canyon Creek		Duncan Creek		Middle Fork Interbay	
Month	# YOY[1]	# Juv/Ad[1]	# YOY	# Juv/Ad	# YOY	# Juv/Ad	# YOY	# Juv/Ad
Jan	0	0	0	0	0	6	0	16
Feb	0	9	0	10	0	6	0	9
Mar	0	60	0	49	0	34	0	32
Apr	0	6	0	5	0	4	0	3
May	5	12	6	14	7	12	7	9
Jun	4	0	5	0	176	1	257	1
Jul	0	0	0	0	8	0	80	0
Aug	0	0	0	0	0	0	47	2
Sep	0	0	0	0	0	0	40	5
Oct	0	0	0	0	0	0	36	5
Nov	0	0	0	0	0	0	39	5
Dec	0	0	0	0	0	0	38	5
Total	**9**	**87**	**11**	**79**	**192**	**63**	**544**	**91**

[1]YOY - young-of-the-year; Juv/Ad = juvenile/ adult

AQ 7-12. Total Potential Number of Fish Moving Downstream by Year and by Month Scaled to a Population of 1,000 Fish/Mile.

Author	Species	Juv/Adult Total	Per Month
Fausch et al. (1995; cited in Rodriguez 2002)	Brook Trout	108	9.00
Hilderbrand and Kershner (2000)	Cutthroat Trout	100	8.33
Jenkins et al (1999)[1]	Brown Trout	72	6.00
Graf (2008)	Rainbow Trout	89	7.42
Average		**92**	**7.69**
Minimum		**72**	**6.00**
Maximum		**108**	**9.00**

[1]Based on 9 months of data.

AQ 7-13. Potential Number of Fish Moving Downstream and Entrained per Month Based on the Literature Movement Data and the 50% Exceedan

	NFLC 3.8		SFLC 4.2		DC 9.0		MF 36.2	
Fish Moving or entrained	**Average**	**(Min-Max)**	**Average**	**(Min-Max)**	**Average**	**(Min-Max)**	**Average**	**(Min-Max)**
Fish Moving / Month	12.1	(9.5 - 14.2)	10.6	(8.3 - 12.4)	7.8	(6.1 - 9.2)	5.3	(4.2 - 6.3)
Jan (entrained)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**1.7**	(1.3 - 2.0)	**4.7**	(3.7 - 5.6)
Feb (entrained)	**4.9**	(3.8 - 5.7)	**5.4**	(4.2 - 6.3)	**3.2**	(2.5 - 3.8)	**4.9**	(3.8 - 5.7)
Mar (entrained)	**8.7**	(6.8 - 10.2)	**7.1**	(5.5 - 8.3)	**4.9**	(3.8 - 5.7)	**4.6**	(3.6 - 5.4)
Apr (entrained)	**9.4**	(7.3 - 11.0)	**8.6**	(6.7 - 10.0)	**6.4**	(5.0 - 7.5)	**4.5**	(3.5 - 5.2)
May (entrained)	**6.5**	(5.1 - 7.6)	**7.8**	(6.1 - 9.1)	**6.7**	(5.2 - 7.8)	**4.8**	(3.7 - 5.6)
Jun (entrained)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**3.6**	(2.8 - 4.2)	**5.1**	(4.0 - 6.0)
Jul (entrained)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**5.2**	(4.0 - 6.1)
Aug (entrained)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**5.2**	(4.1 - 6.1)
Sep (entrained)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**5.2**	(4.1 - 6.1)
Oct (entrained)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**4.6**	(3.6 - 5.4)
Nov (entrained)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**0.3**	(0.2 - 0.3)	**5.2**	(4.1 - 6.1)
Dec (entrained)	**0.0**	(0.0 - 0.0)	**0.0**	(0.0 - 0.0)	**0.6**	(0.4 - 0.7)	**5.0**	(3.9 - 5.8)
Year Total (entrained)	**29.4**	(23.0 - 34.5)	**28.9**	(22.5 - 33.8)	**27.3**	(21.3 - 32.0)	**58.9**	(46.0 - 69.0)

AQ 7-14. Number of Surviving YOY Fish Entrained and the Equivalent Number of Adult Fish Pairs Based (

Site	End of diversion period (days from June 1 emergence)	Difference Between Excess YOY[1]	Equivalent Number of Adult Pairs (Redds)
North Fork Long Canyon	3	67-244	0-2
South Fork Long Canyon	3	90-456	1-3
Duncan Creek	30	382-2789	4-28
Middle Fork American River Abv Interbay	365	2-28	3-43

[1]Note the number of excess YOY potentially entrained at the end of the diversion period cannot be compared directly between sites unless the end of the diversion period is the same (natural mortality is operative over the period of diversion).

AQ 7-15. Summary of Canal Data used for Entrainment Calculations.

River/Project	Bow River, Alberta, CA	Smiths Fork, WY	Stanislaus, CA	DeSabla, CA			Average[1]	Minimum[1]	Maximum[1]
				Hendricks	Butte	Lower Centerville			
Number Diverted per Month	1165	81	156	118	92	98	326	92	1165
Number Diverted per Month Scaled to 1000 AdultFish Pop	578	300	48	336	503	162	325	48	578
Number Diverted per Month Scaled by % Diverted	791	939	56	420	661	225	431	56	791
Number YOY per Month Moving Downstream	487	--	30	181	403	137	248	30	487
Number Juvenile/Adult per Month Moving Downstream	304	939	26	240	258	88	183	26	304

[1]Average, minimum, and maximum calculated with including Smiths Fork River

Table AQ 7-16. Summary of the Potential Number of Fish Entrained Annually Based on the Canal Entrainment Data and the 50% Exceedance Percent of Flow Diverted at each MFP Diversion.

		SF Long Canyon		Duncan Creek		Middle Fork Interbay	
# YOY[1]	# Juv/Ad	# YOY[1]	# Juv/Ad	# YOY[1]	# Juv/Ad	# YOY	# Juv/Ad
332	245	426	314	735	543	3411	2520

[1]Note: The YOY potential entraimnet numbers may be biased by applying the YOY entrainment data for the canals in months when YOY are low in abundance (e.g., winter).

AQ 7-17. Turbine Characteristics and Associated Estimated Mortality for Middle Fork American River Project.

Name	Max. Hydraulic	Turbine Type	Runner Speed	Maximum Blade	Static Head	Fish Size (mm)	Approx. % Survival[2]	
							Immediate	48-Hour
h Meadow	400[3]	Vertical Francis	450	150 - 170	654 - 517	<100	70 (31-98)	72 (63-86)
						100 - 199	60 (34-83)	46 (16-78)
						200 - 299	39 (23-83)	32 (12-65)
						300+	19 (4-35)	6 (4-8)
ell Hole P.I	65[4]	Horizonta l Francis	1200	62 - 94	391 - 101	<100	70 (31-98)	72 (63-86)
						100 - 199	60 (34-83)	46 (16-78)
						200 - 299	39 (23-83)	32 (12-65)
						300+	19 (4-35)	6 (4-8)
Dxbow P.H	1025	Vertical Francis	200	66 - 76	90	<100	94 (86-100)	90 (81-101)
						100 - 199	92 (75-100)	88 (74-101)
						200 - 299	87 (59-100)	80 (47-96)
						300+	73 (36-100)	67 (34-94)
Middle Fo	920[5]	Pelton	400	NA	,096 - 1,80	All	~ 0	
Ralston P.	924	Pelton	240	NA	1,344	All	~ 0	

[1]Approximate range based in diameter of scroll case and allowance for wicket gate assembly.

[2]Mean approximate mortality for all fish species combined. See Winchell et al. 2000 table.

[3]Nominal tunnel capacity.

[4]Maximum flow capacity when supporting instream flow requirements below Oxbow PH during fall maintenance outage.

[5]Nominal capacity of Hell Hole – Middle Fork Tunnel.

Table AQ 7-18. Summary of Potential Number of Fish Entrained Using Each Estimation Method.

Method	NF Long Canyon		SF Long Canyon		Duncan Creek		Middle Fork Interbay	
	# YOY	# Juv/Ad	# YOY	# Juv/Ad	# YOY	# Juv/Ad	# YOY	# Juv/Ad
West Panther Calculations	9	87	11	79	192	63	544	91
Literature Based Modeling	67-244	23-35	90-456	23-34	382-2789	21-32	2-28[1]	46-69
Canal Based Calculations	332	245	426	314	735	543	3411	2520
Range	9-332	23-245	11-456	23-314	192-2789	21-543	2-3411	46-2520

Note that these values are numbers of YOY at the end of one year. They cannot be directly related to the other YOY values except by calculating an equivalent number of redds or adults

FIGURES

Figure AQ 7-1. Entrainment Objectives, Related Study Elements, and Reports.

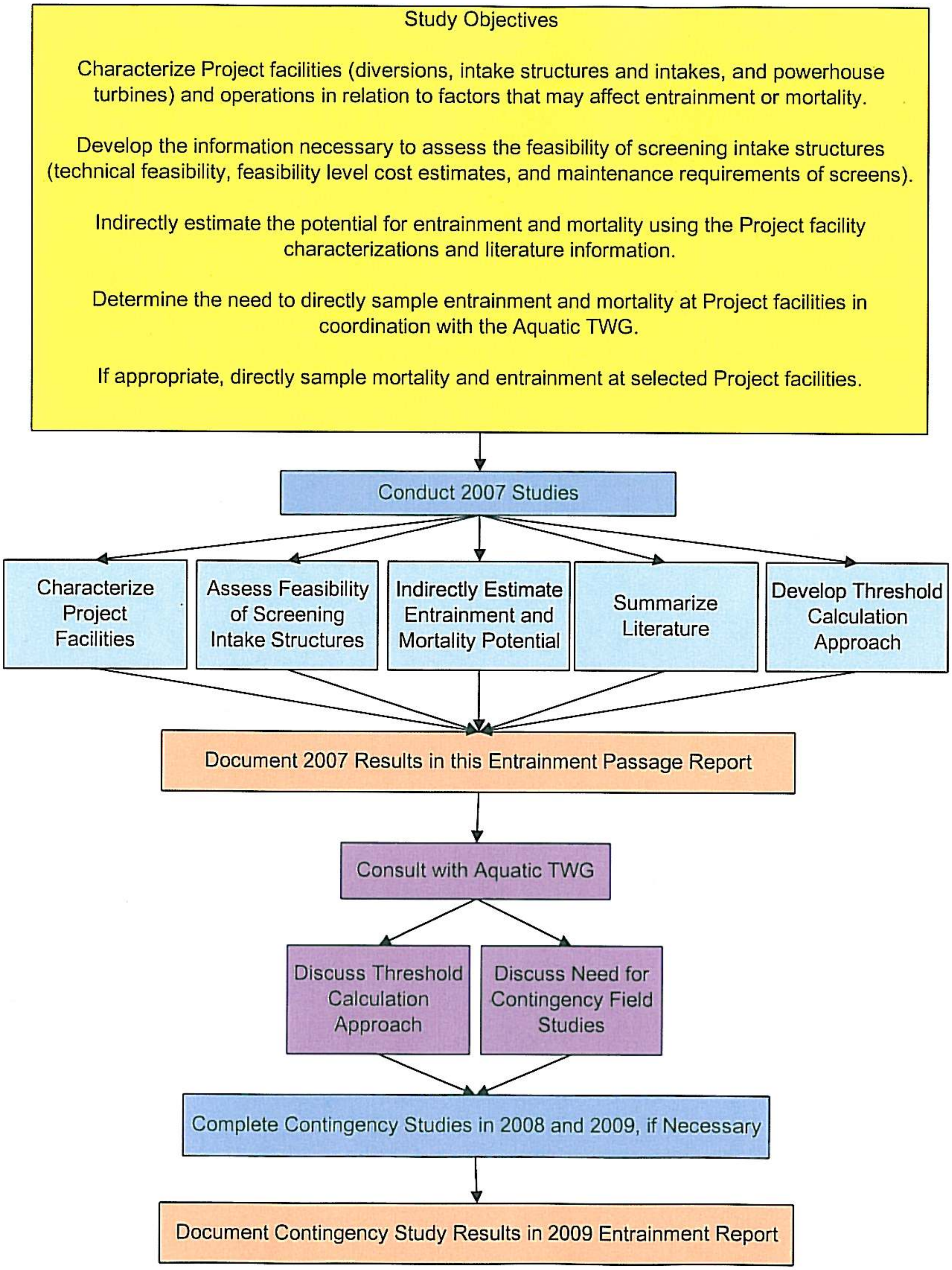
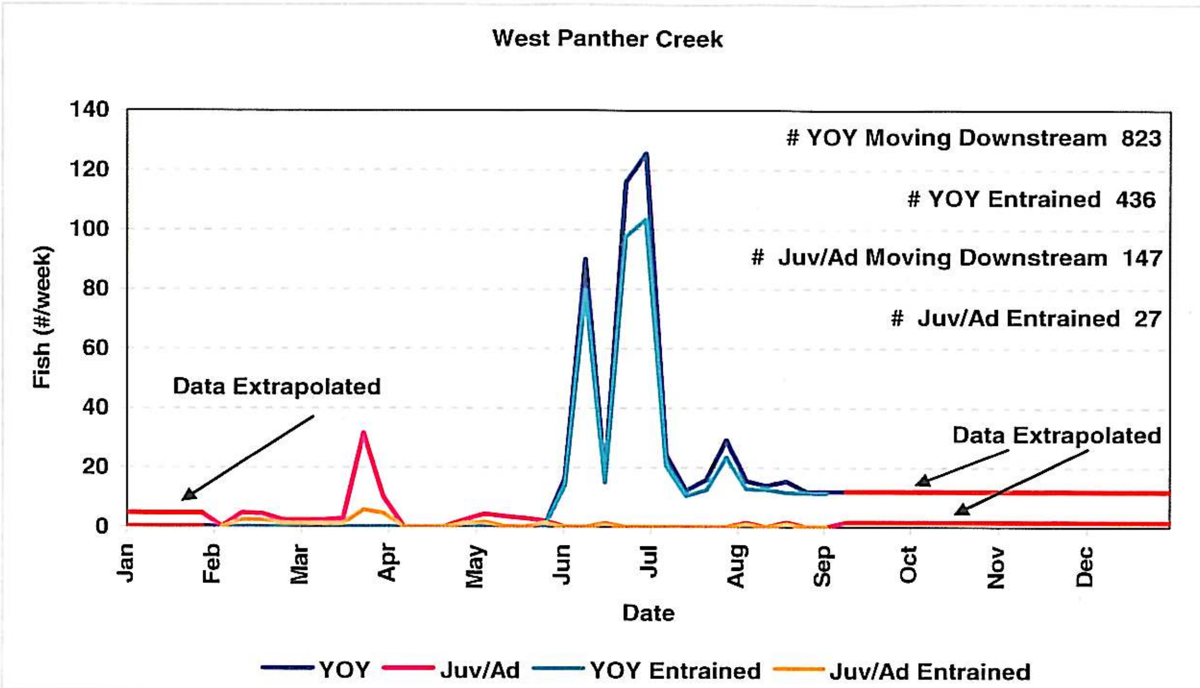


Figure AQ 7-2. Relationship between Number of Fish Moving Downstream, Number of Fish Entrained, the Amount of Flow and Percent of Flow Diverted on West Panther Creek.



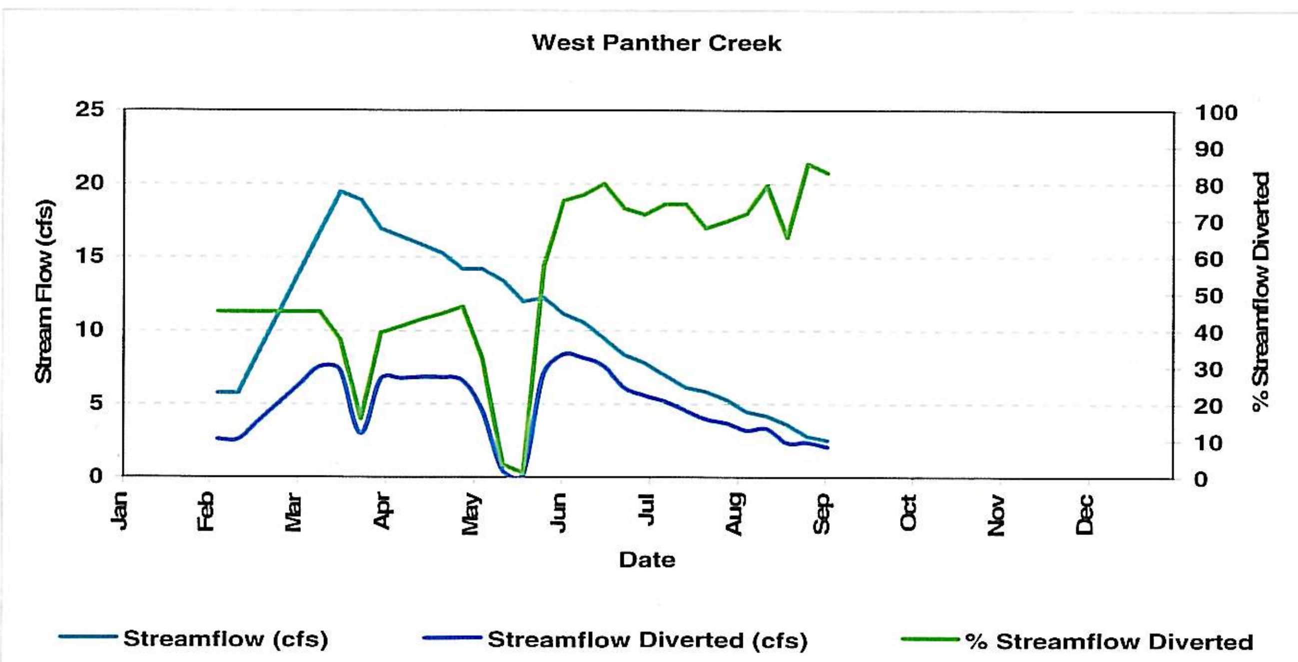


Figure AQ 7-3. Comparison of Mean Weekly Water Temperatures on West Panther Creek and Middle Fork Project Streams.

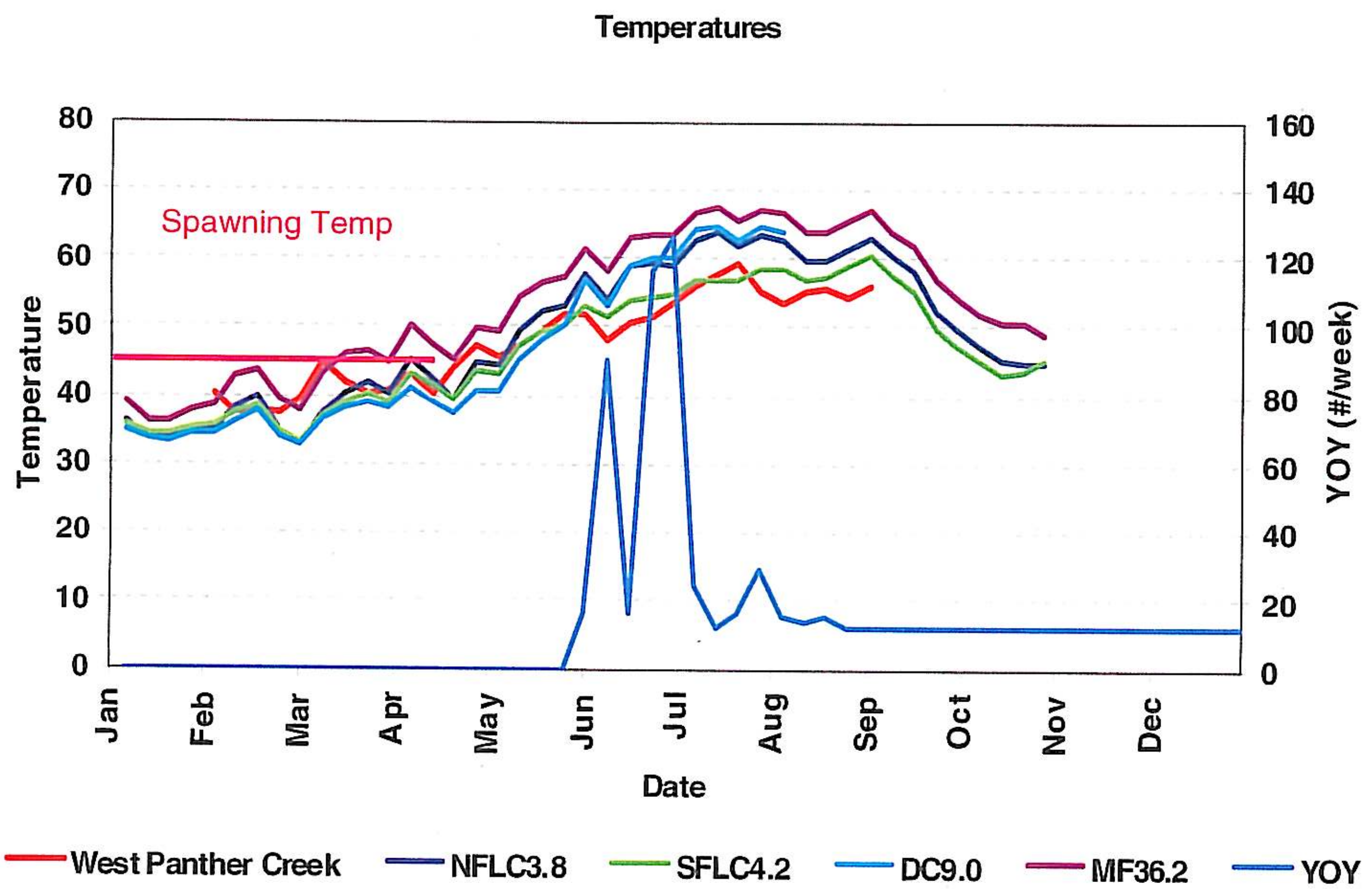
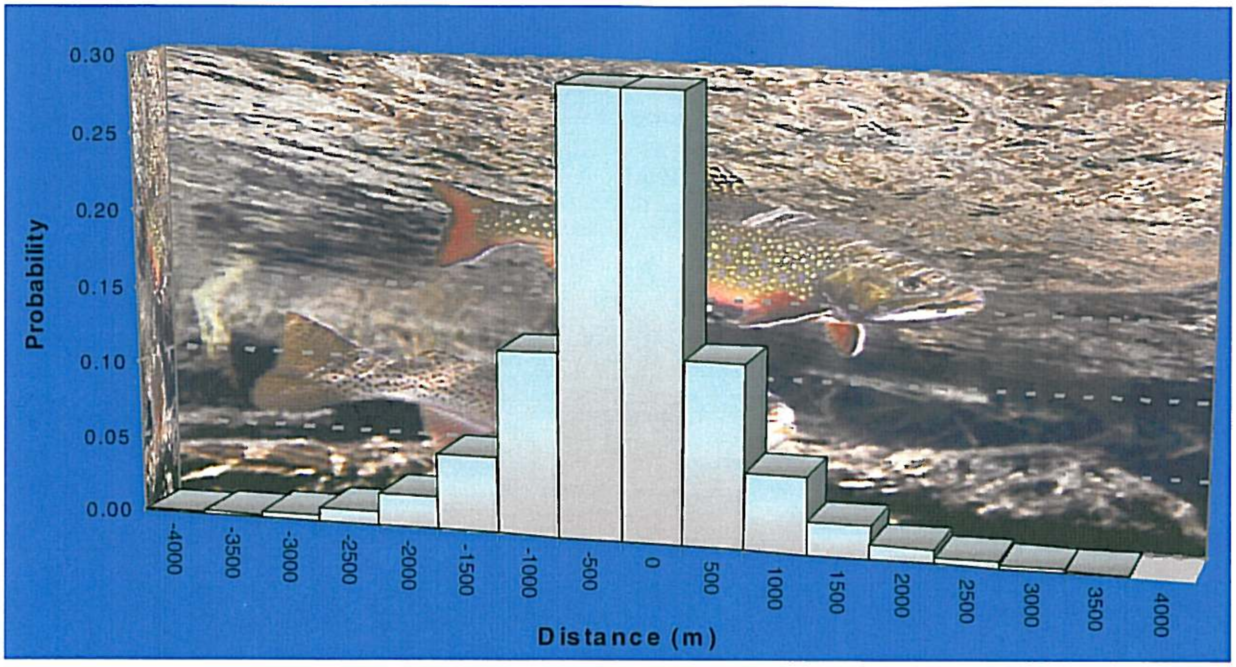


Figure AQ 7-4. Example Fitted Annual Probability Distribution of Fish Distance from Home Section.



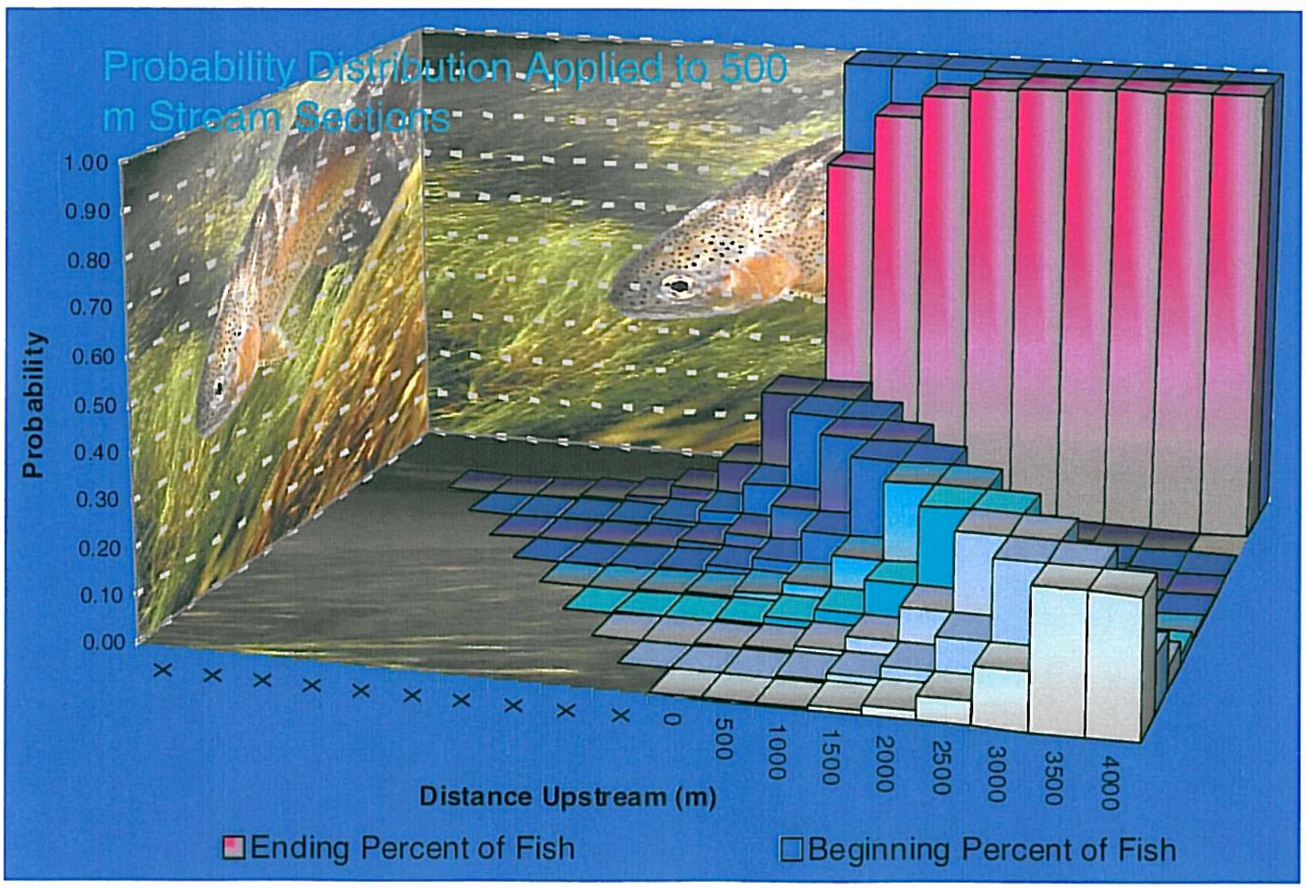


Figure AQ 7-5. Example Number of Fish Remaining in Stream After One Year.

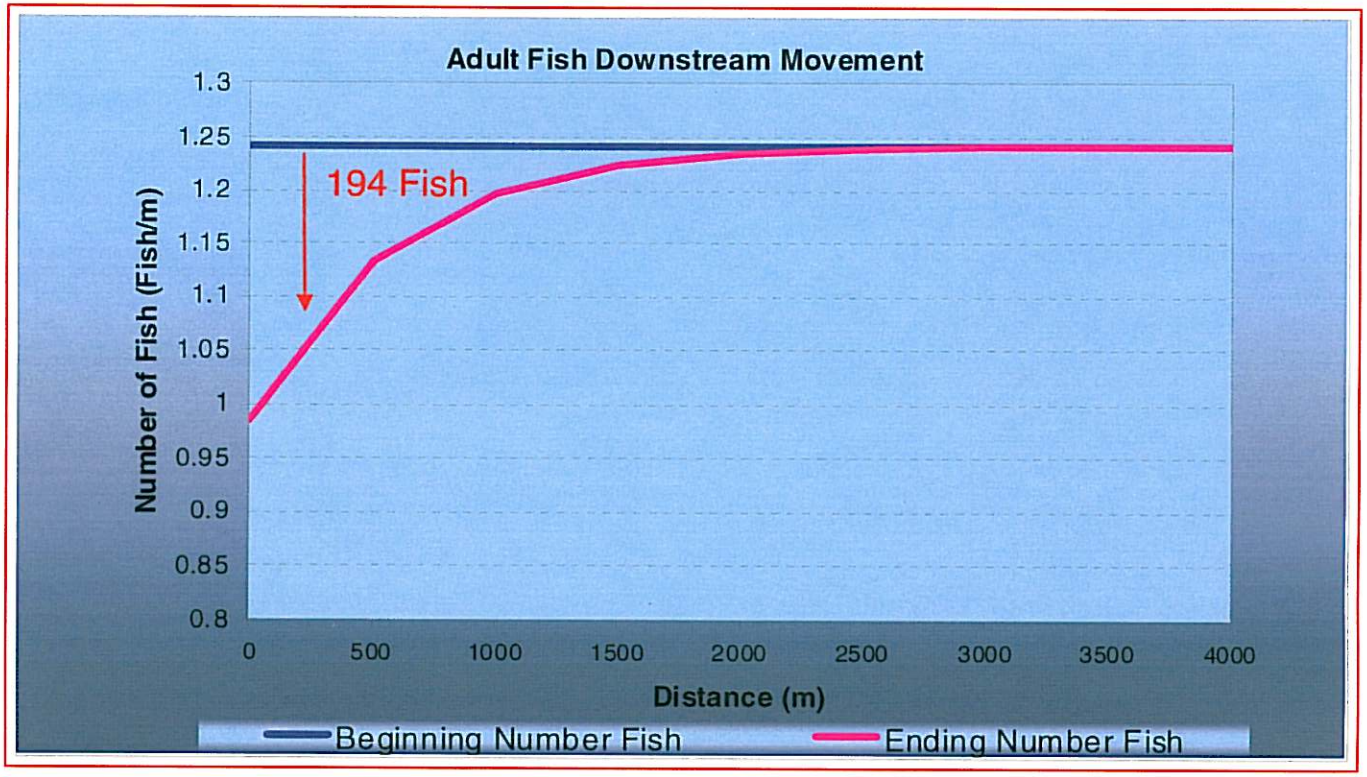


Figure AQ 7-6. Fecundity for Trout in the 120 to 400 mm Size Range.

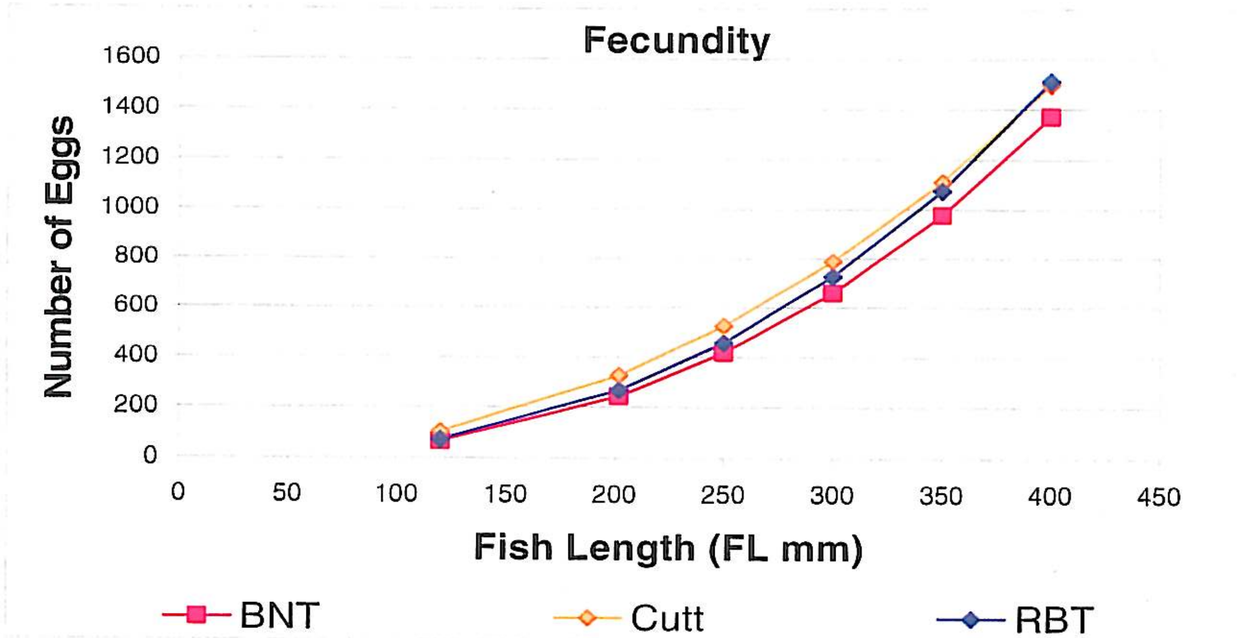
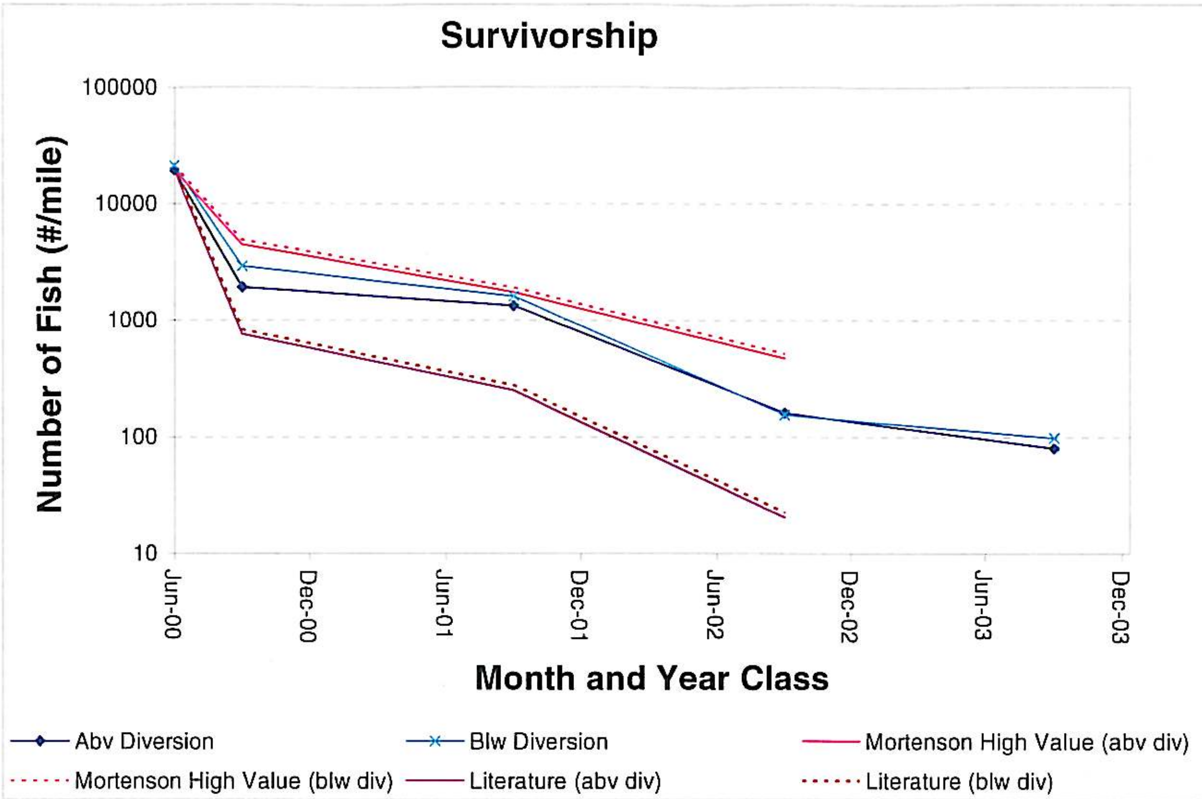


Figure AQ 7-7. Survivorship Curves for North Fork Long Canyon Creek Compared to Literature Survivorship Curves.



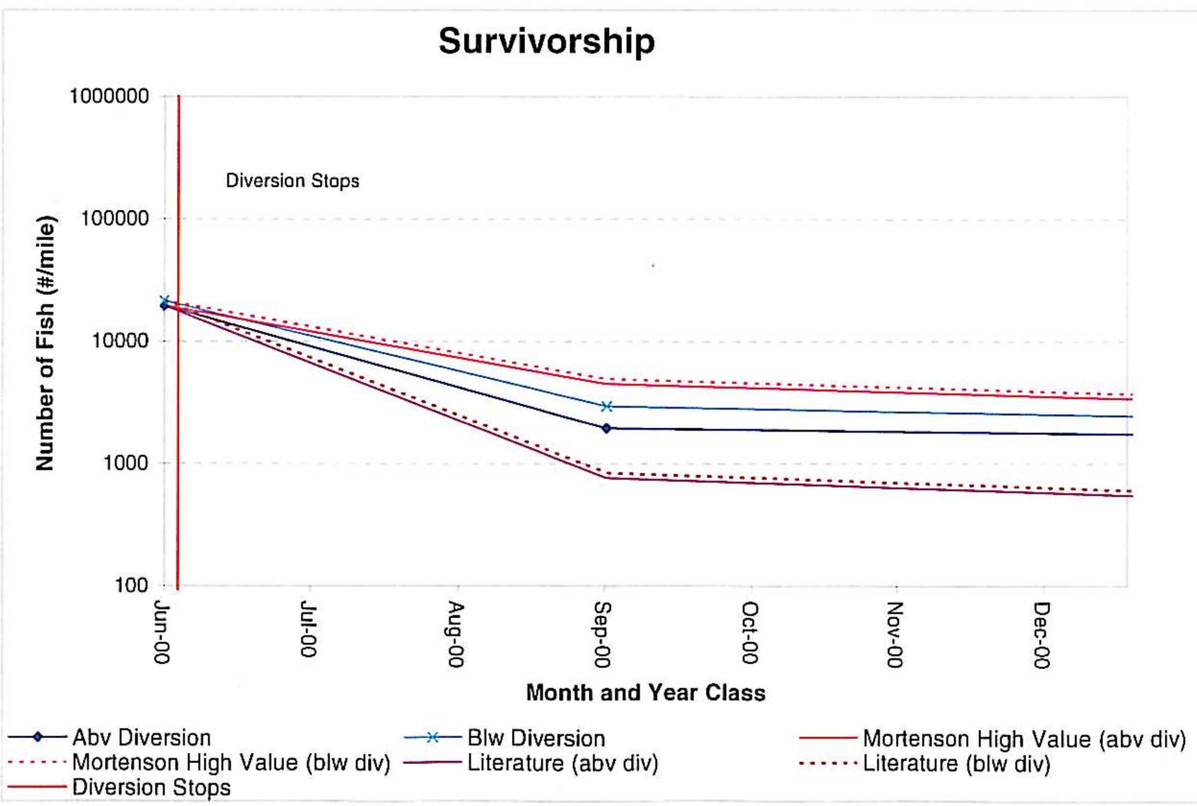
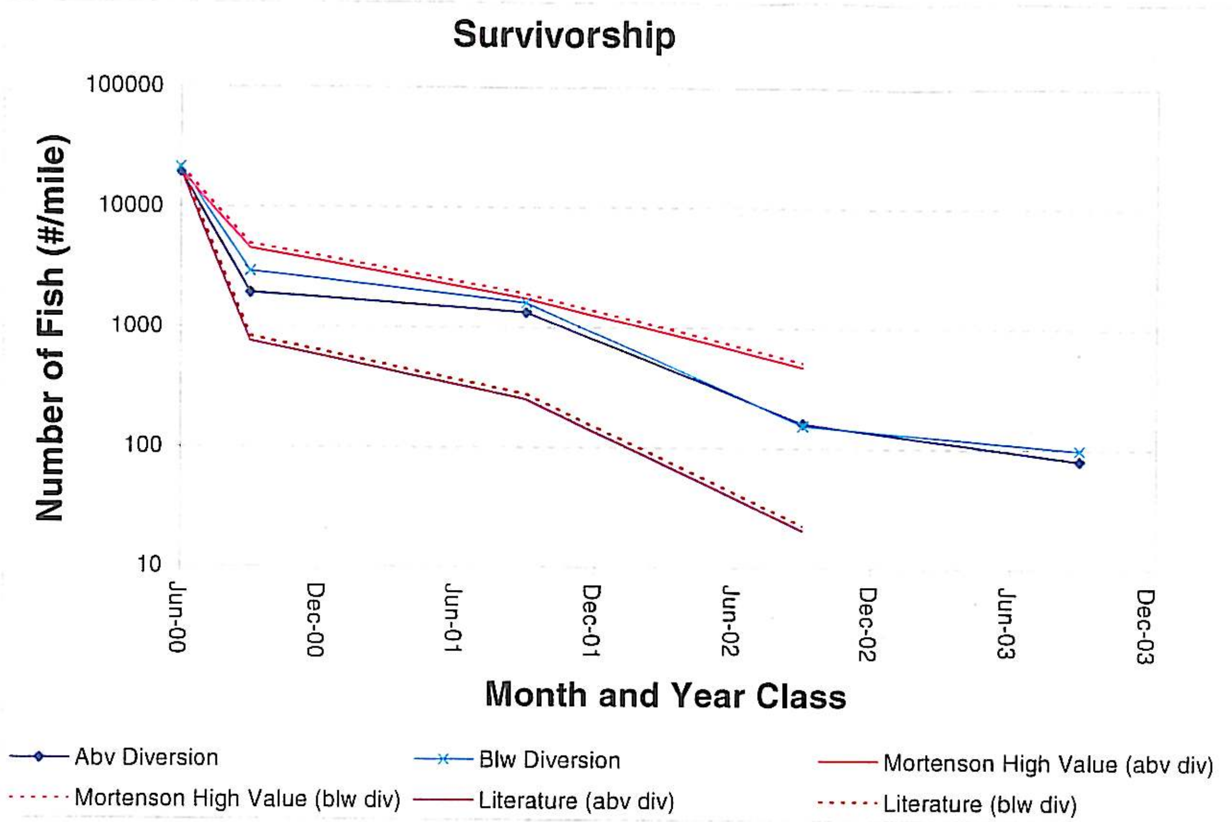


Figure AQ 7-8. Survivorship Curves for South Fork Long Canyon Creek Compared to Literature Survivorship Curves.



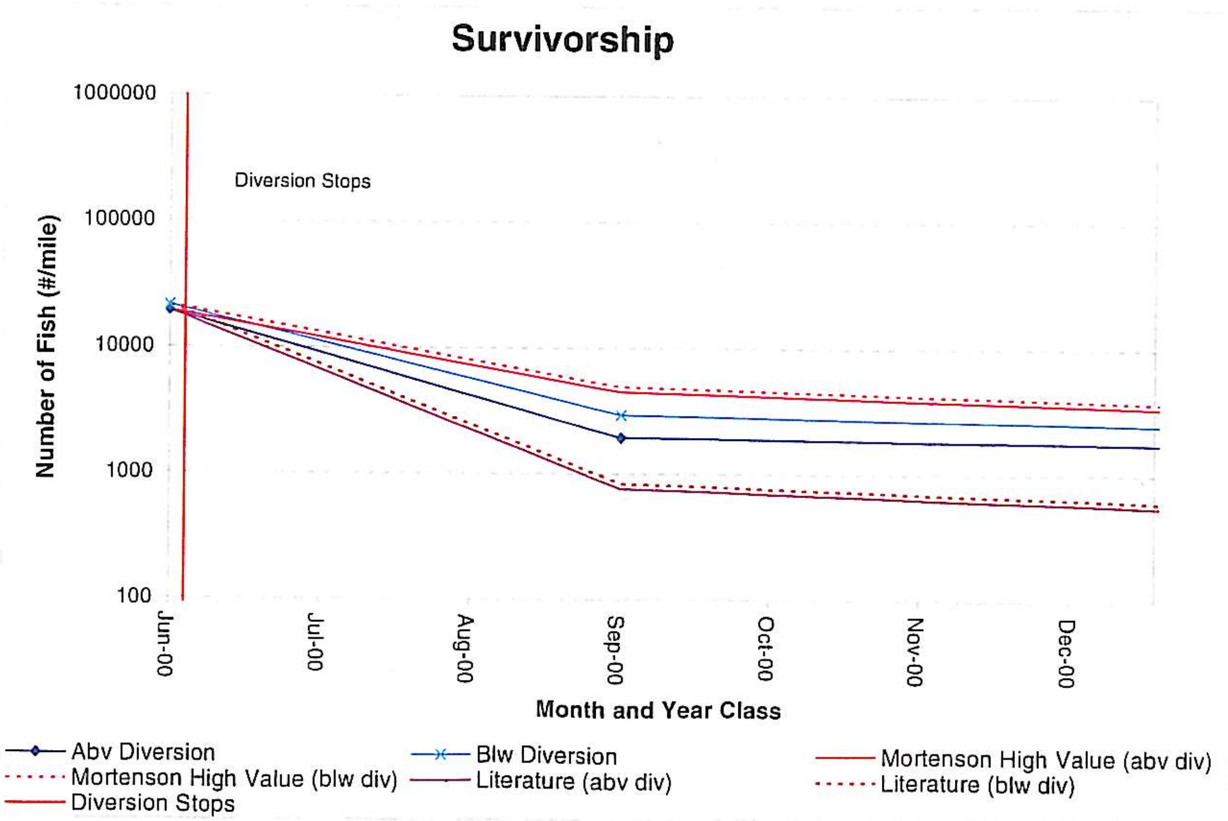
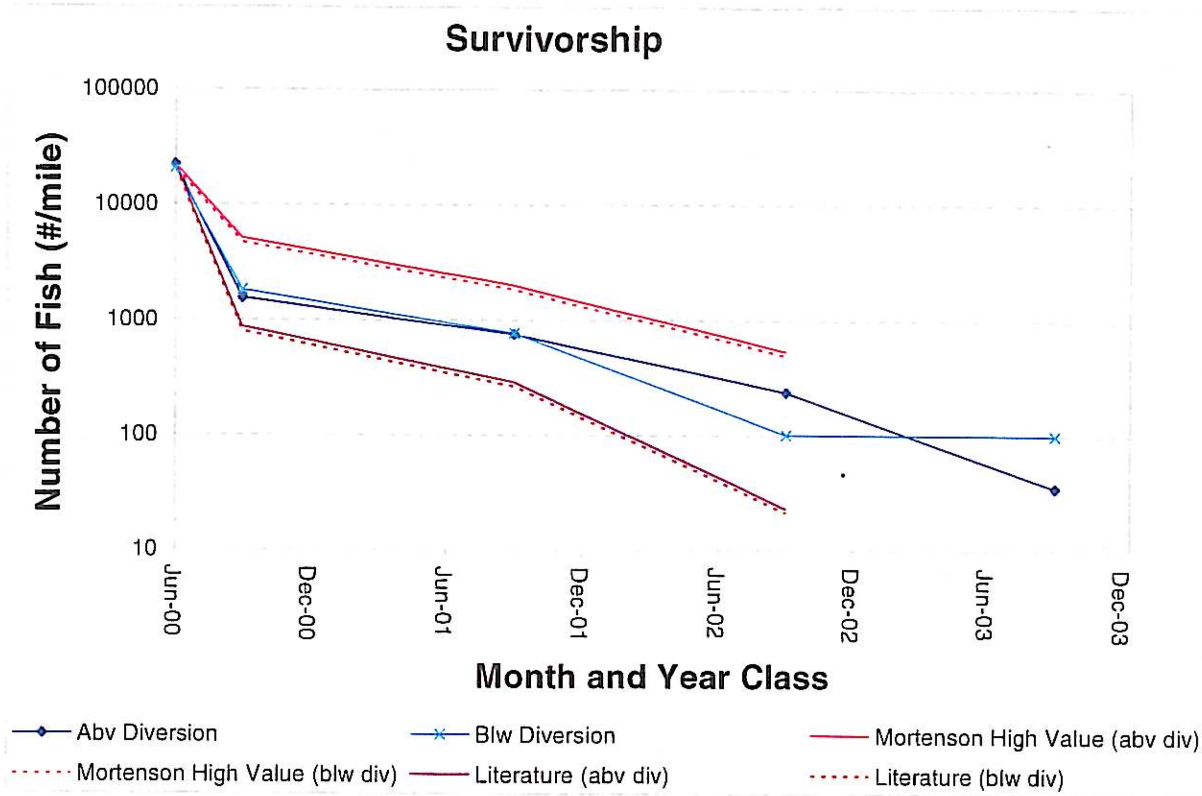


Figure AQ 7-9. Survivorship Curves for Duncan Creek Compared to Literature Survivorship Curves.



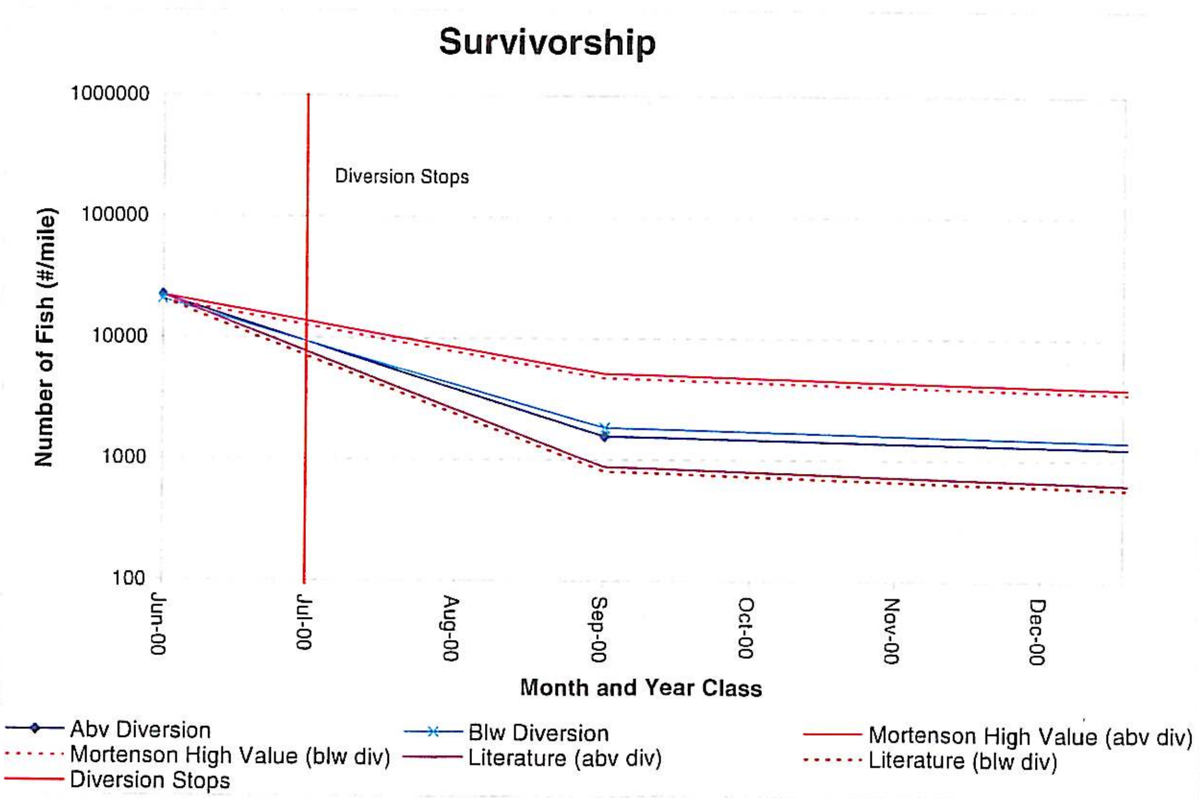
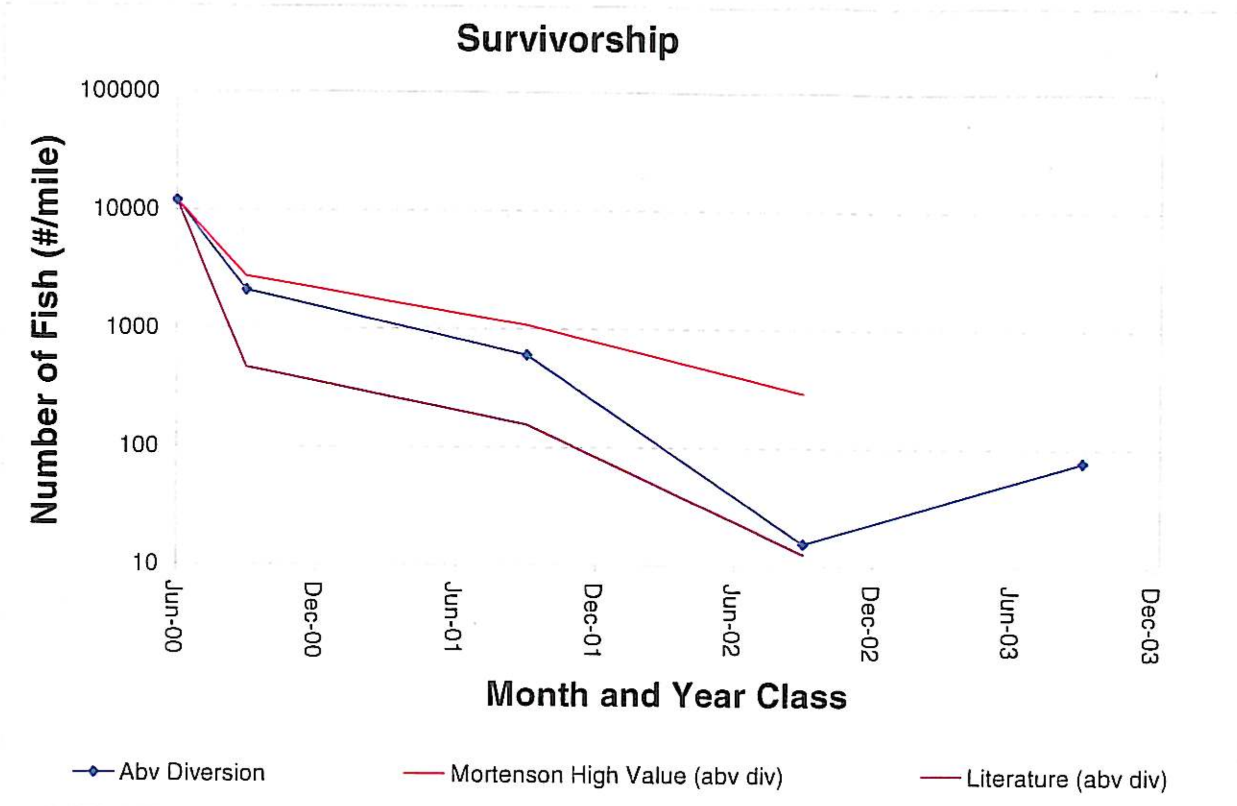


Figure AQ 7-10. Survivorship Curves for Middle Fork American River upstream of Middle Fork Interbay Compared to Literature Survivorshi



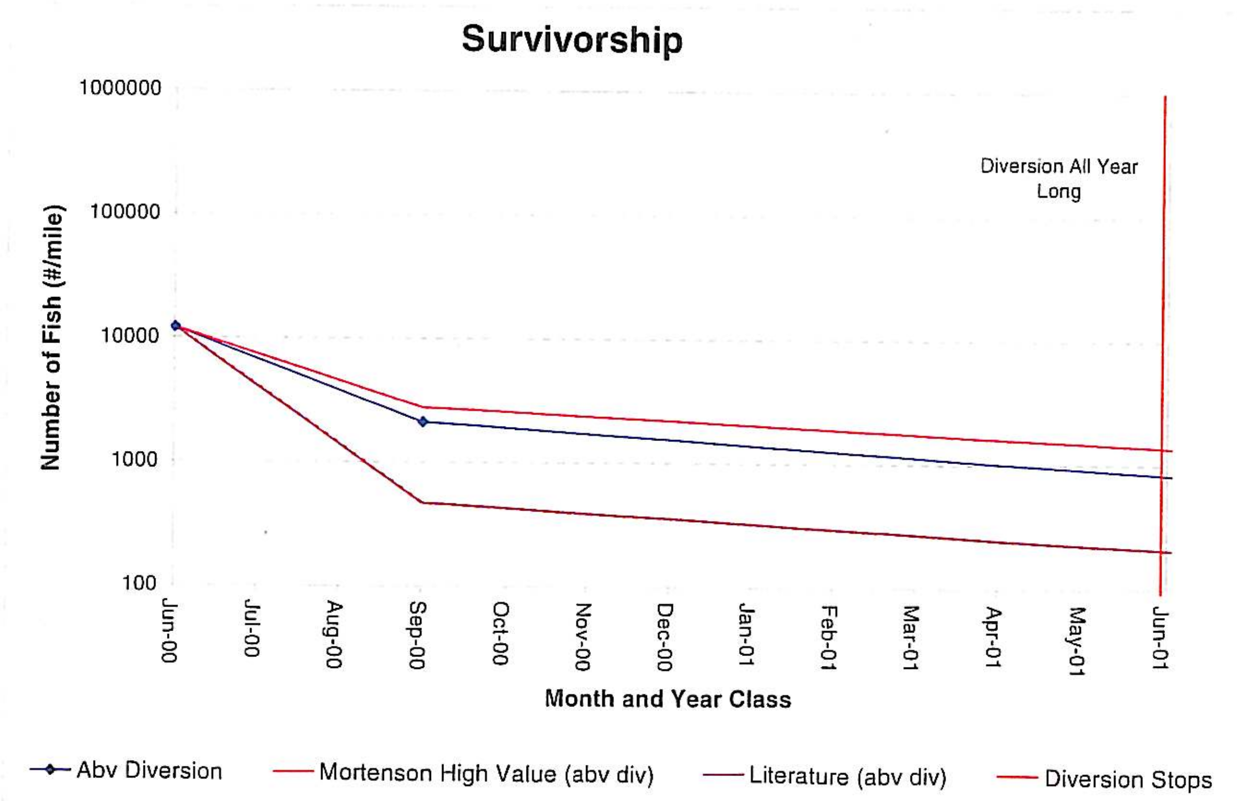
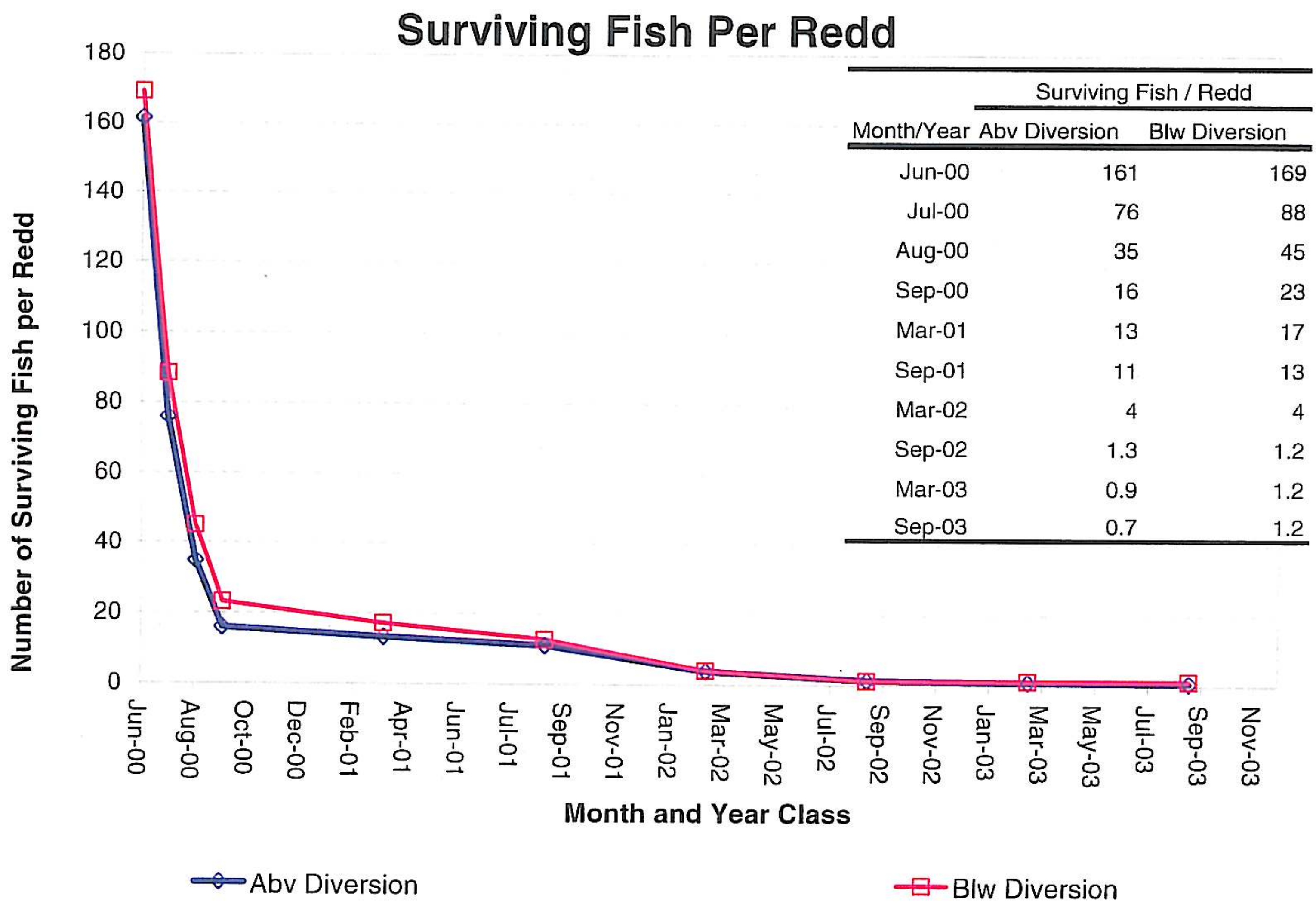
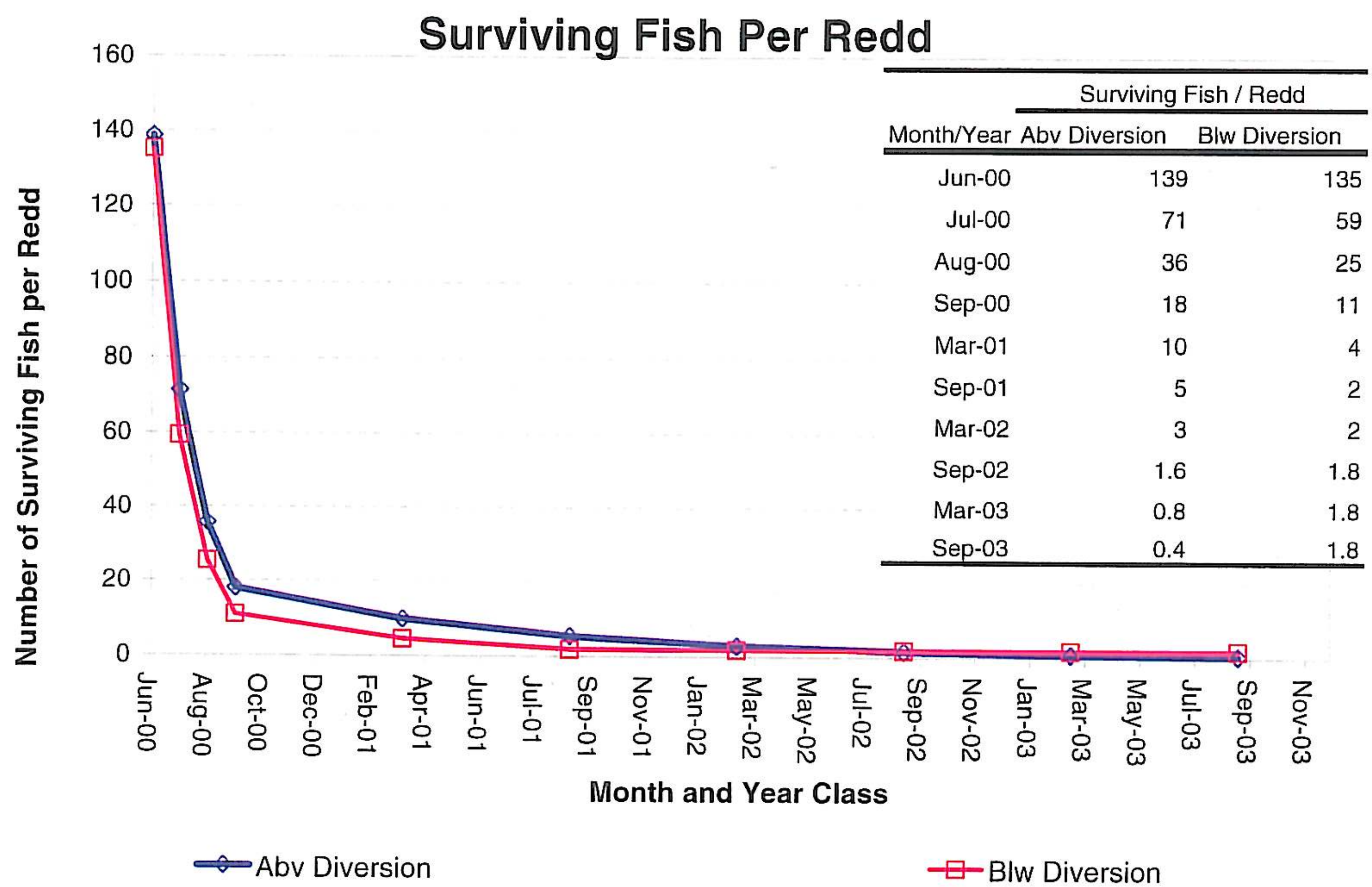


Figure AQ 7-11. Estimated Survivorship per Redd for Fish Populations Above and Below the North Fork Long Canyon Creek Diversion.



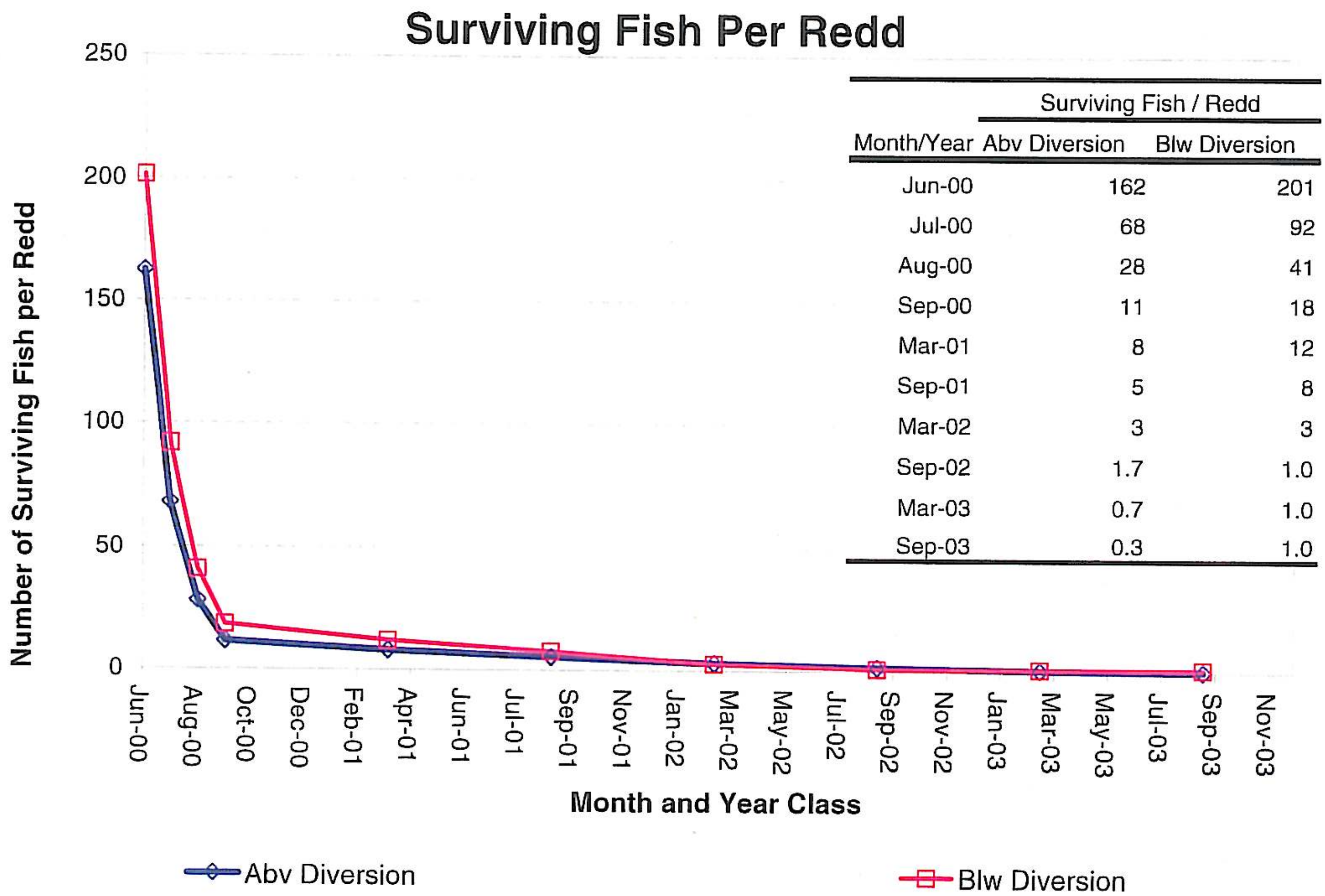
	Surviving Fish / Redd	
Month/Year	Abv Diversion	Blw Diversion
Jun-00	161	169
Jul-00	76	88
Aug-00	35	45
Sep-00	16	23
Mar-01	13	17
Sep-01	11	13
Mar-02	4	4
Sep-02	1.3	1.2
Mar-03	0.9	1.2
Sep-03	0.7	1.2

Figure AQ 7-12. Estimated Survivorship per Redd for Fish Populations Above and Below the South Fork Long Canyon Creek Diversion.



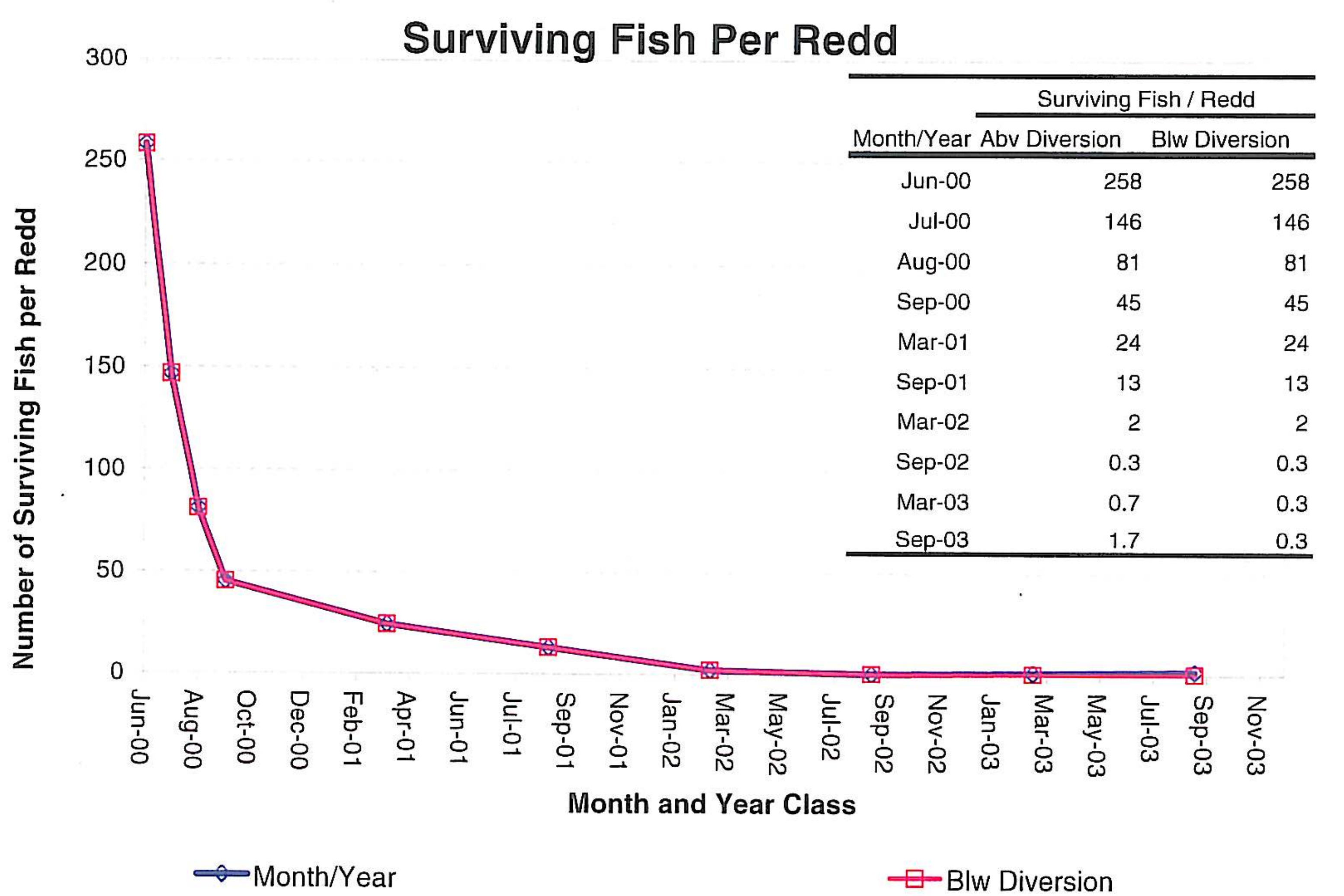
	Surviving Fish / Redd	
Month/Year	Abv Diversion	Blw Diversion
Jun-00	139	135
Jul-00	71	59
Aug-00	36	25
Sep-00	18	11
Mar-01	10	4
Sep-01	5	2
Mar-02	3	2
Sep-02	1.6	1.8
Mar-03	0.8	1.8
Sep-03	0.4	1.8

Figure AQ 7-13. Estimated Survivorship per Redd for Fish Populations Above and Below the Duncan Creek Diversion.



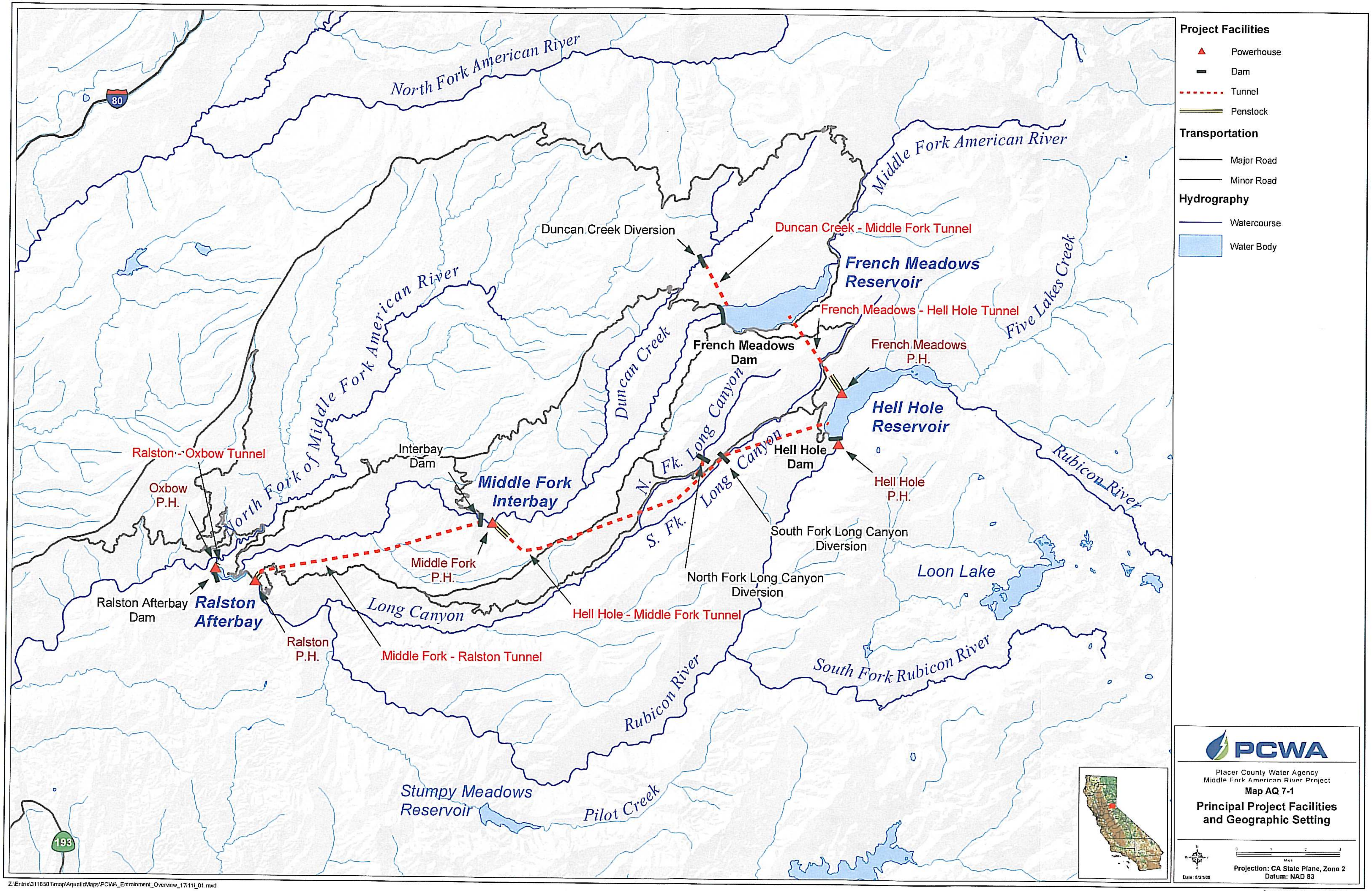
	Surviving Fish / Redd	
Month/Year	Abv Diversion	Blw Diversion
Jun-00	162	201
Jul-00	68	92
Aug-00	28	41
Sep-00	11	18
Mar-01	8	12
Sep-01	5	8
Mar-02	3	3
Sep-02	1.7	1.0
Mar-03	0.7	1.0
Sep-03	0.3	1.0

Figure AQ 7-14. Estimated Survivorship per Redd for Fish Populations Above and Below Middle Fork Interbay.



	Surviving Fish / Redd	
Month/Year	Abv Diversion	Blw Diversion
Jun-00	258	258
Jul-00	146	146
Aug-00	81	81
Sep-00	45	45
Mar-01	24	24
Sep-01	13	13
Mar-02	2	2
Sep-02	0.3	0.3
Mar-03	0.7	0.3
Sep-03	1.7	0.3

MAPS



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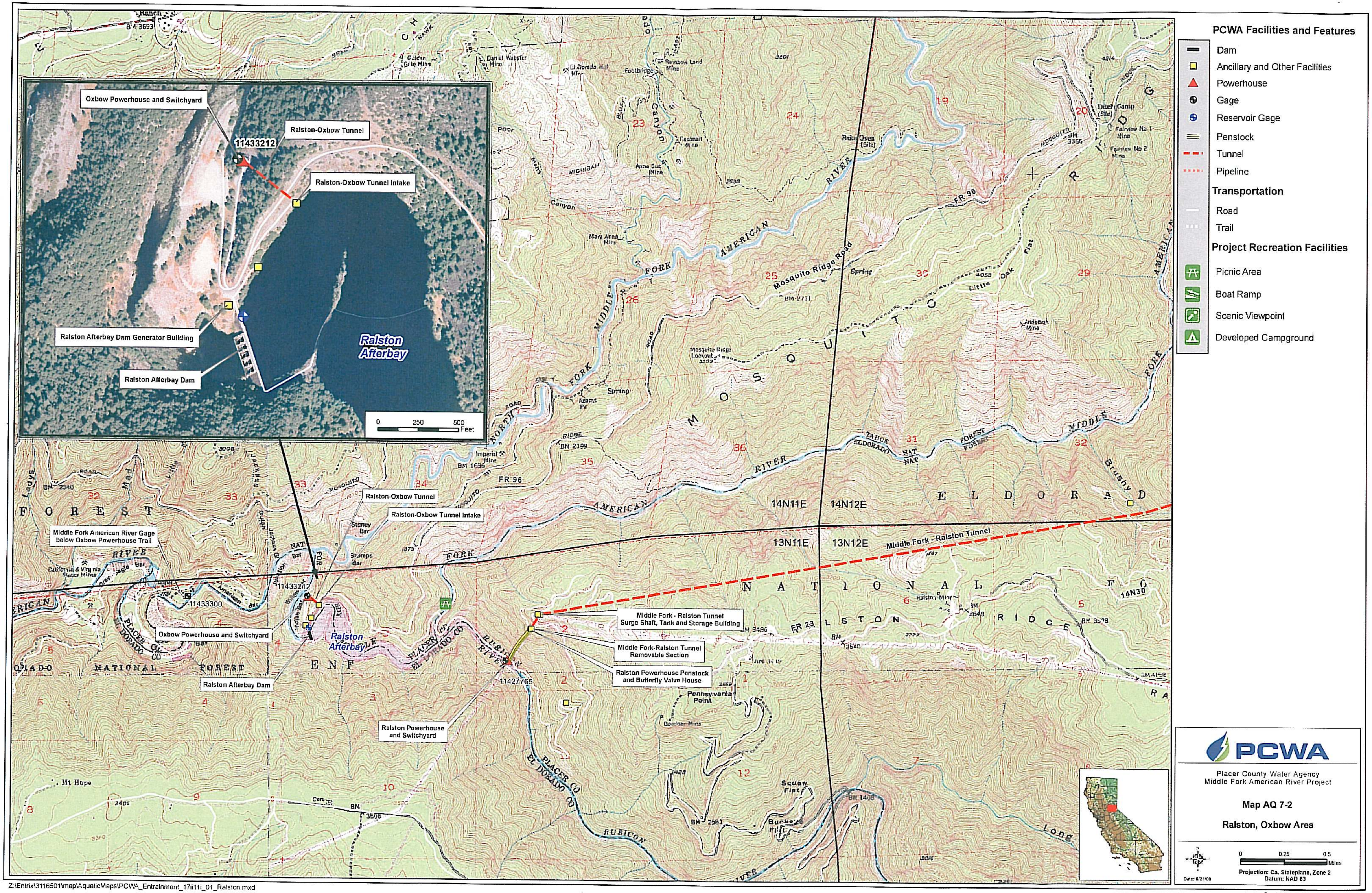

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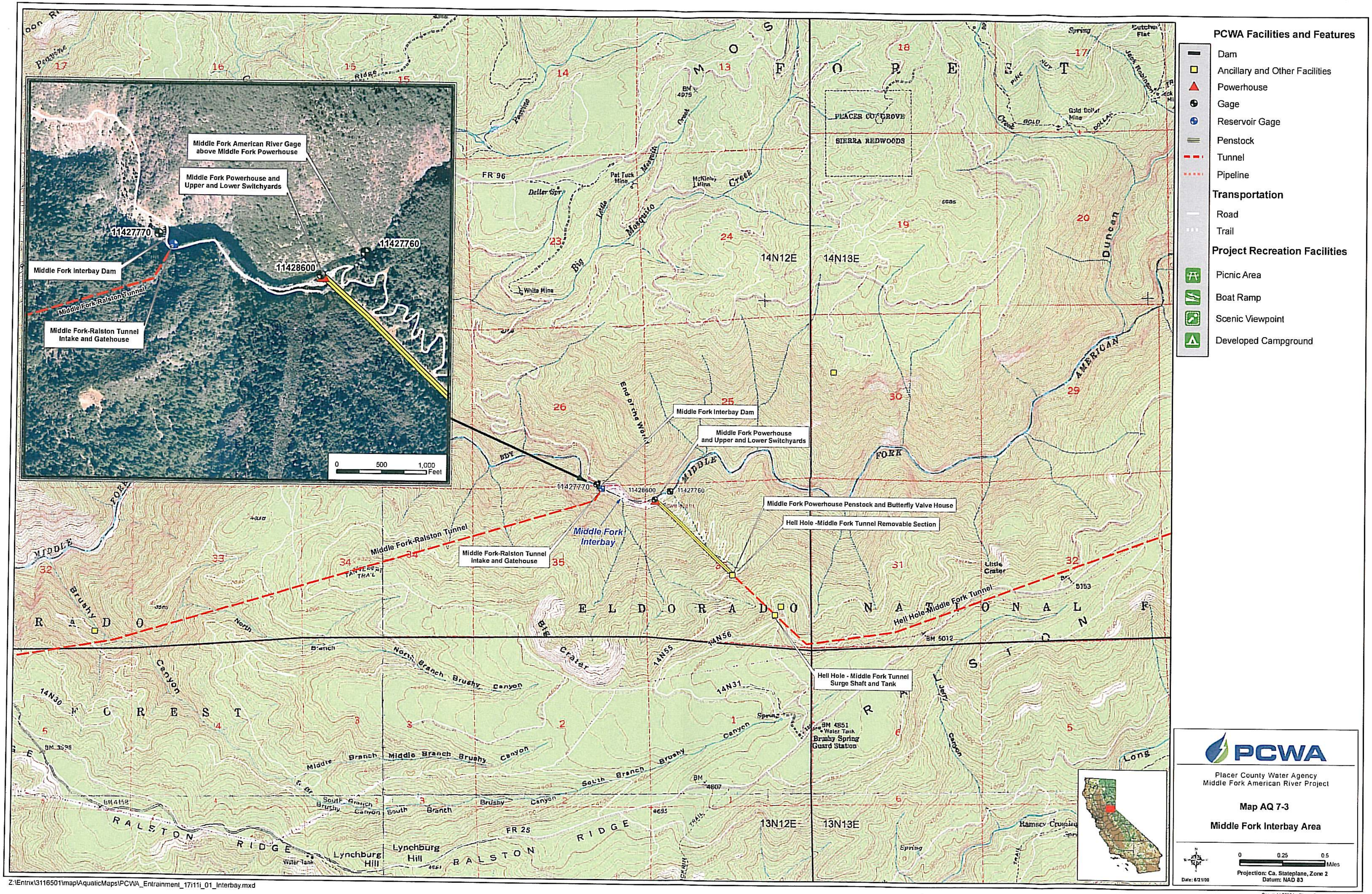

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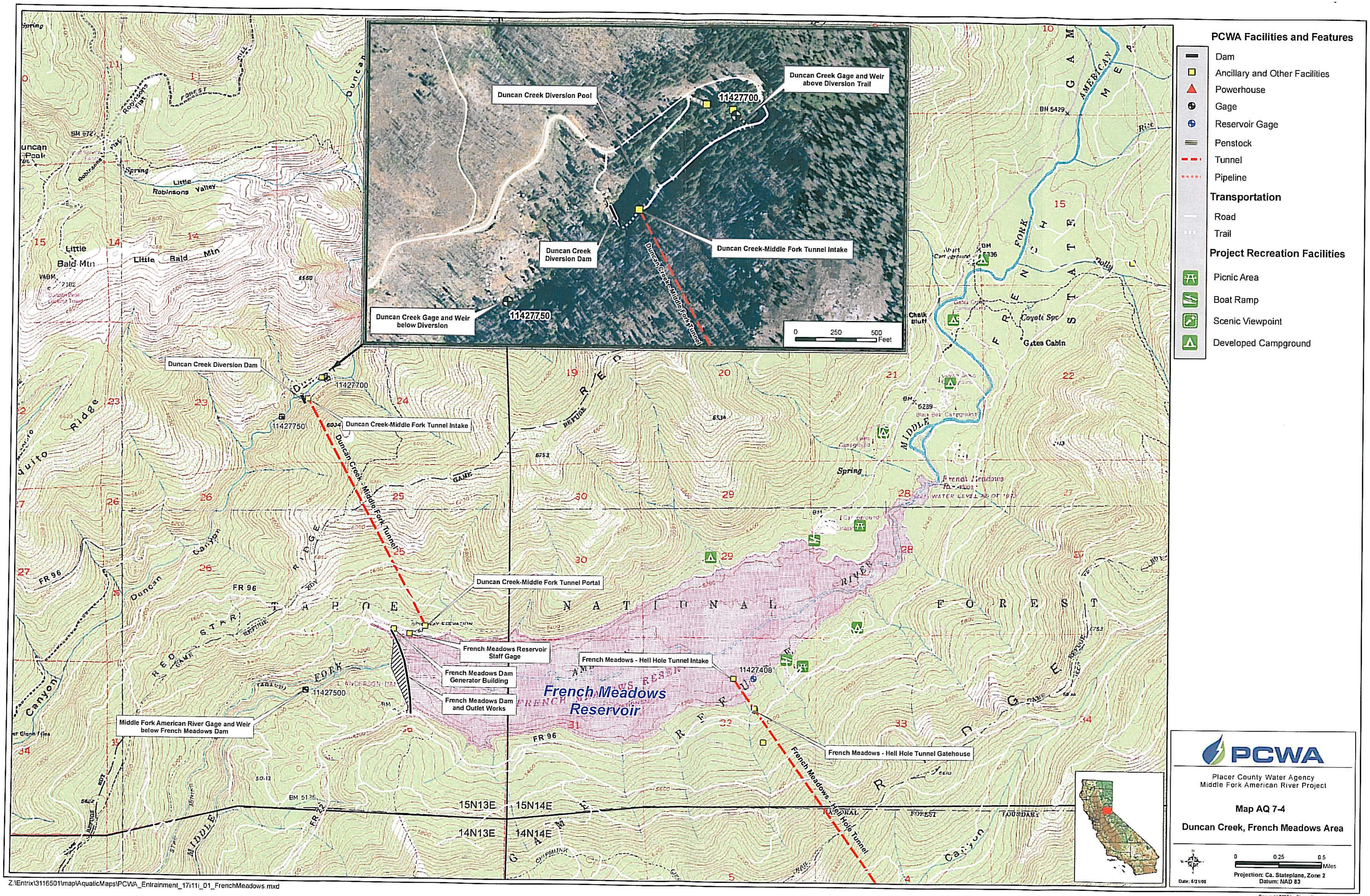

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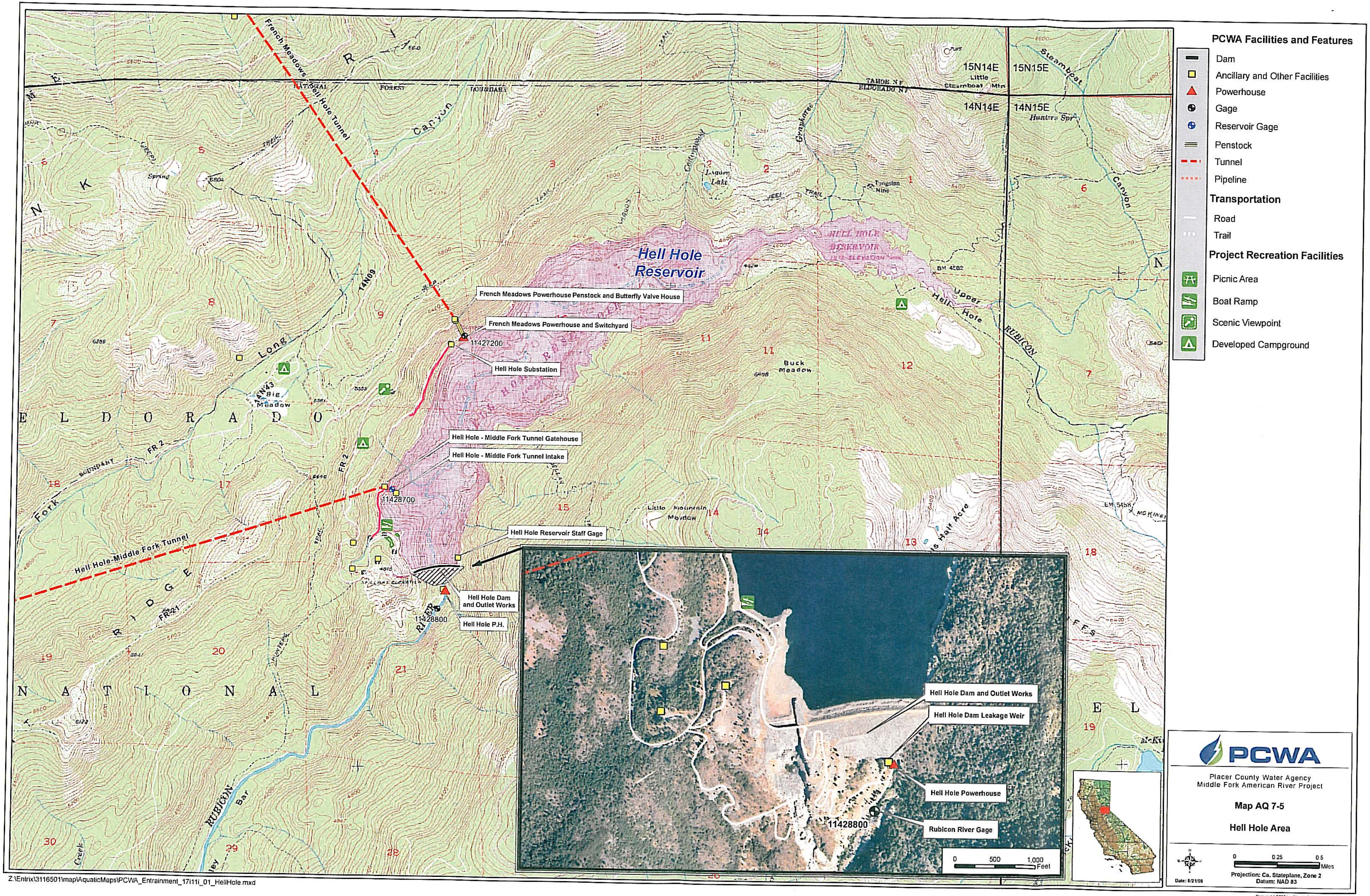

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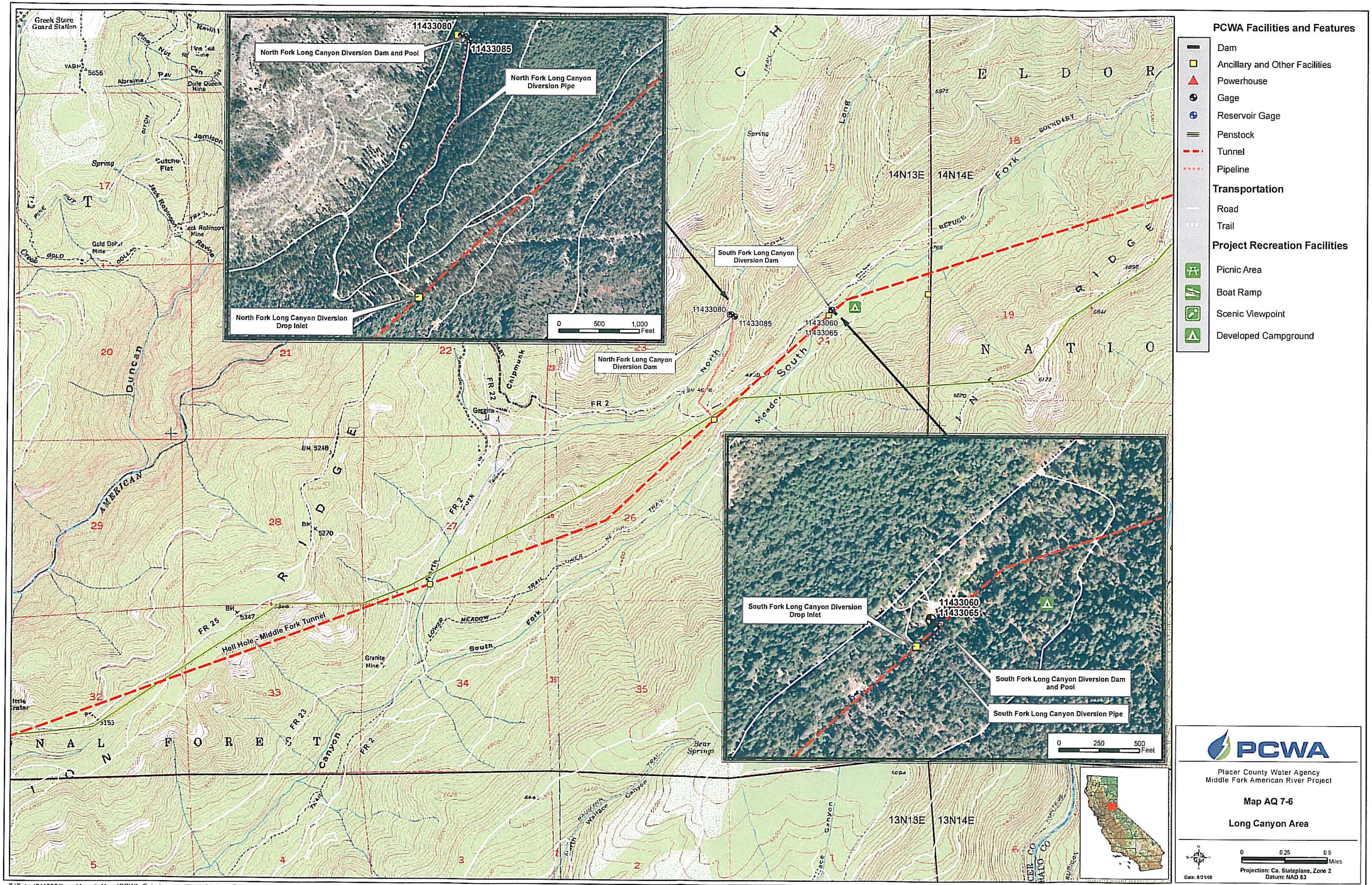

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APPENDIX A

Diversion Photographs

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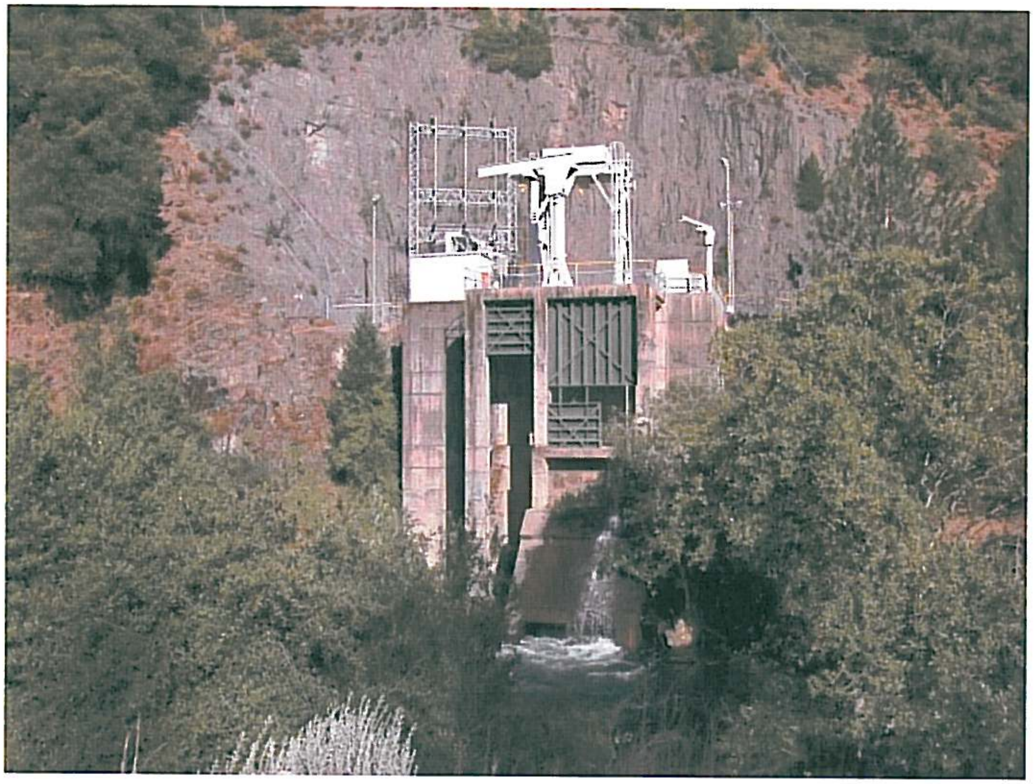
Ralston Afterbay

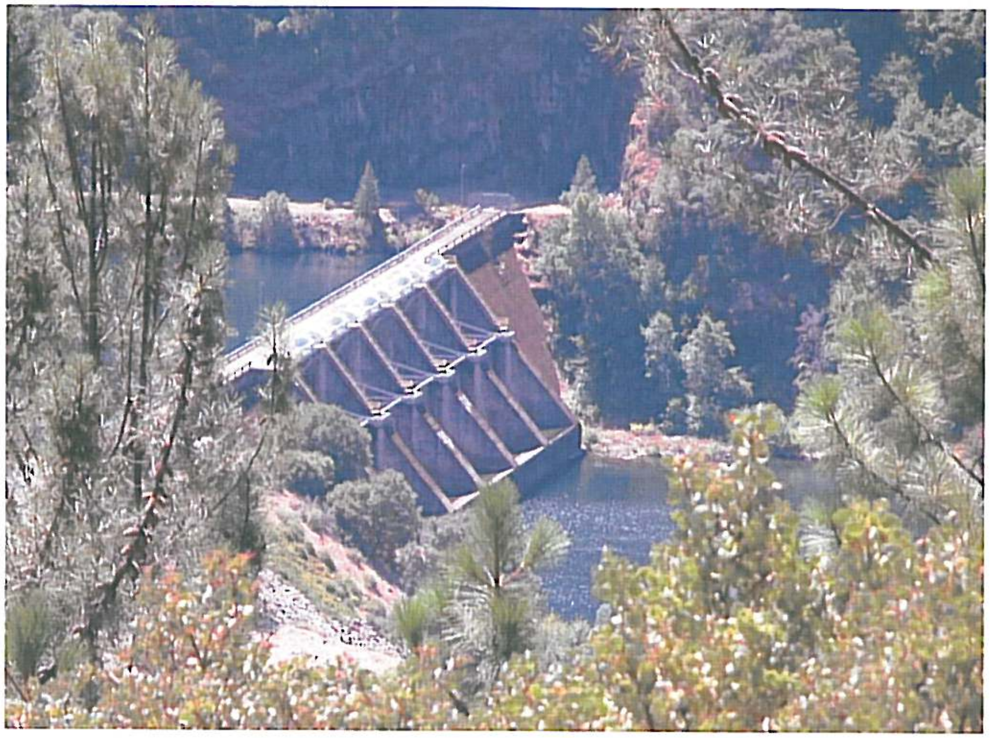
Oxbow Powerhouse Photograph



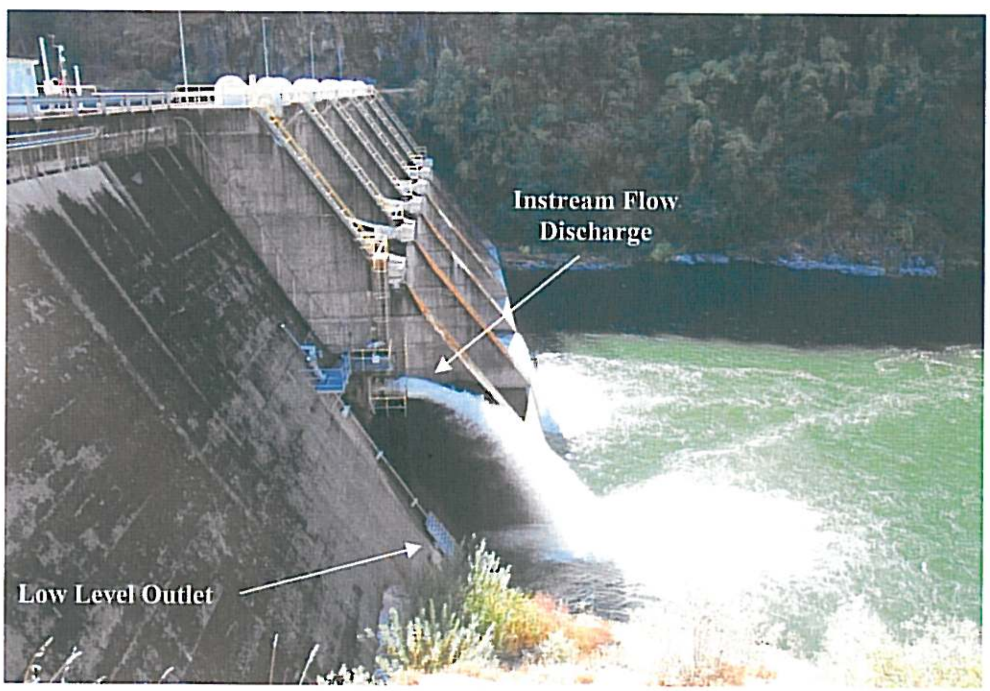
Oxbow Powerhouse

Ralston Afterbay

Ralston Afterbay Dam Photographs



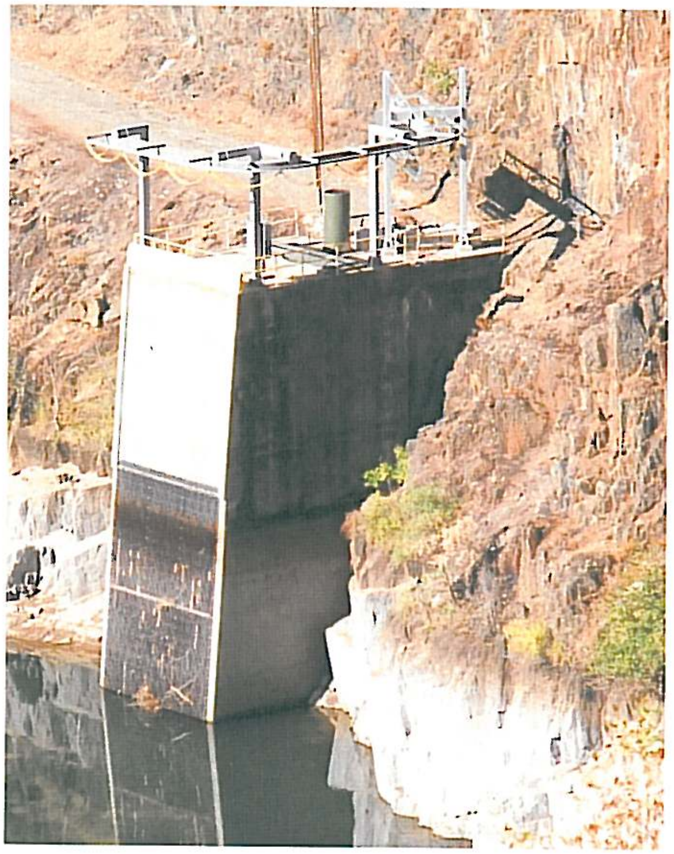
Ralston Afterbay Dam



Ralston Afterbay Dam - Downstream

Ralston Afterbay

Ralston - Oxbow Tunnel Inlet Structure Photograph

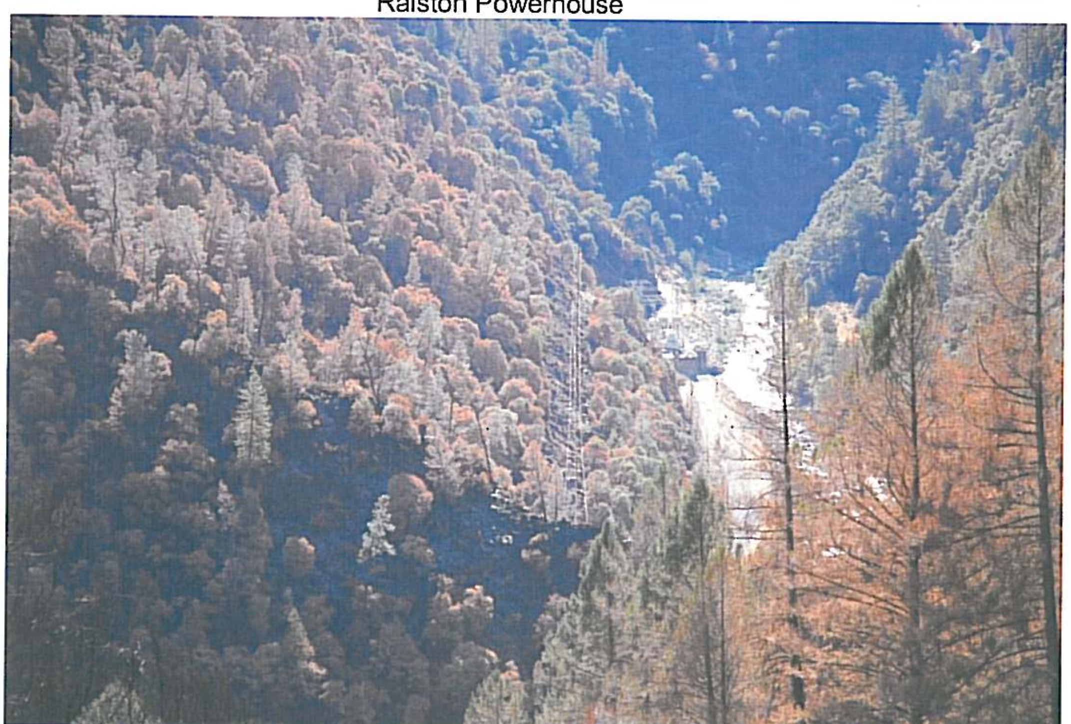


Ralston-Oxbow Tunnel Inlet Structure

Ralston Afterbay

Ralston Powerhouse Photographs

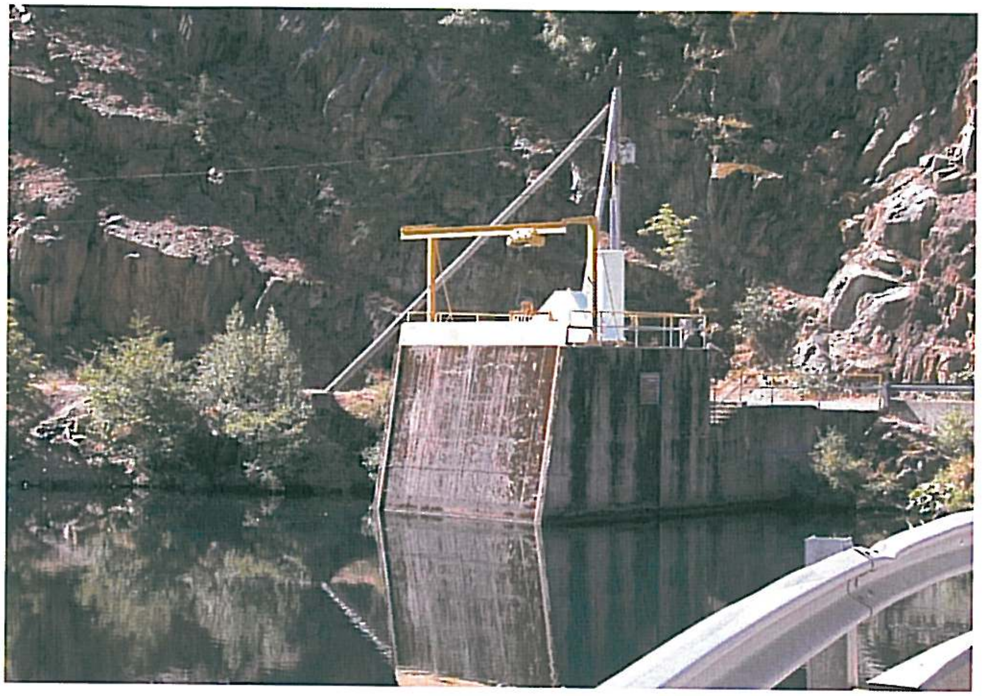
Ralston Powerhouse



Ralston Powerhouse with Low Water Level

Middle Fork Interbay

Middle Fork - Ralston Tunnel Inlet Structure Photograph



Middle Fork - Ralston Tunnel Inlet Structure

Middle Fork Interbay

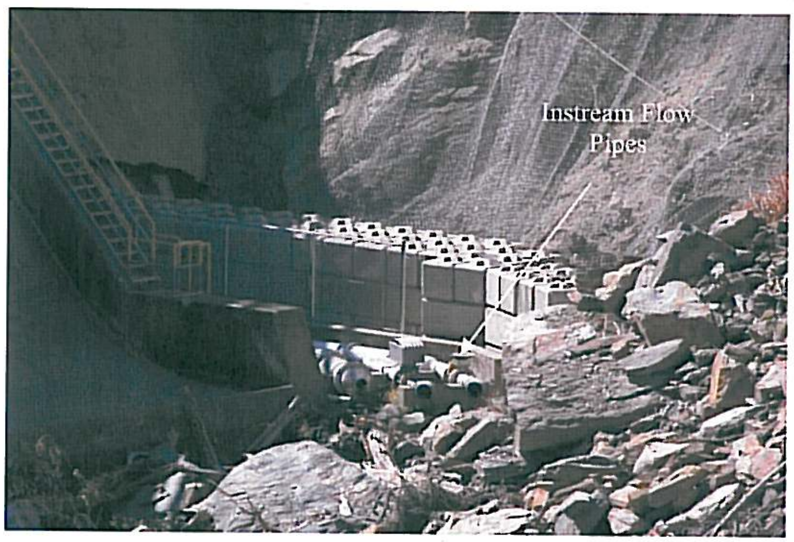
Interbay Low Level Outlet Photograph

Interbay Low Level Outlet

Middle Fork Interbay

Middle Fork Interbay Dam Photographs

Middle Fork Interbay Dam



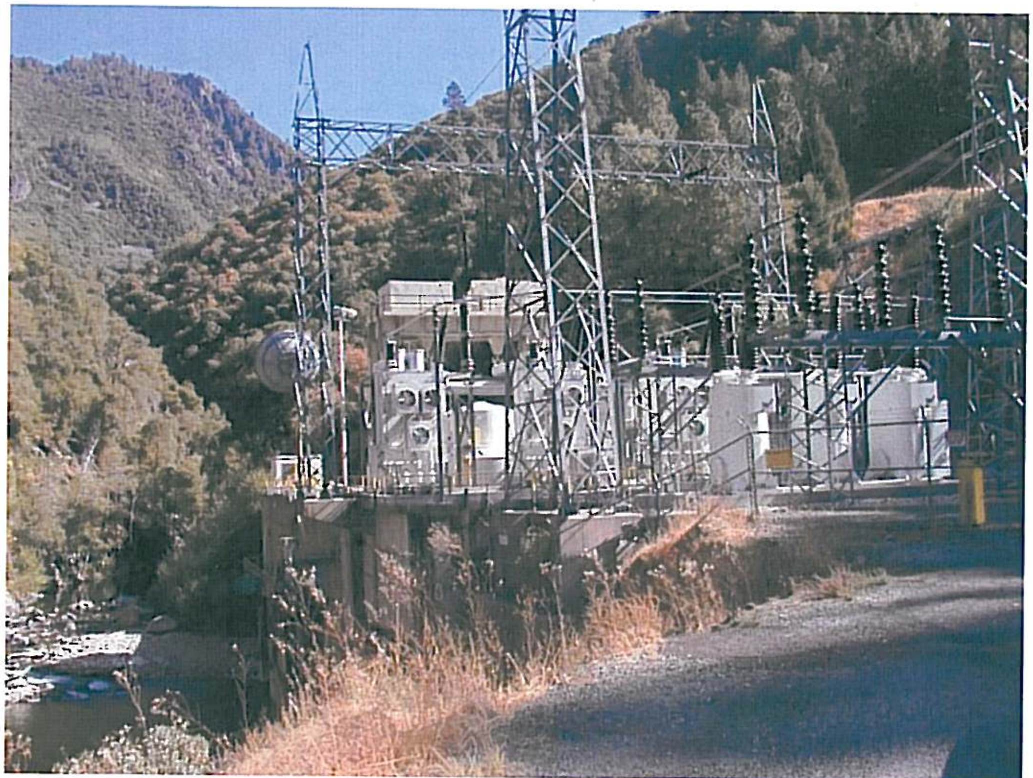
Middle Fork Interbay Dam - Instream Flow Pipes

Interbay Dam Low Level Discharge

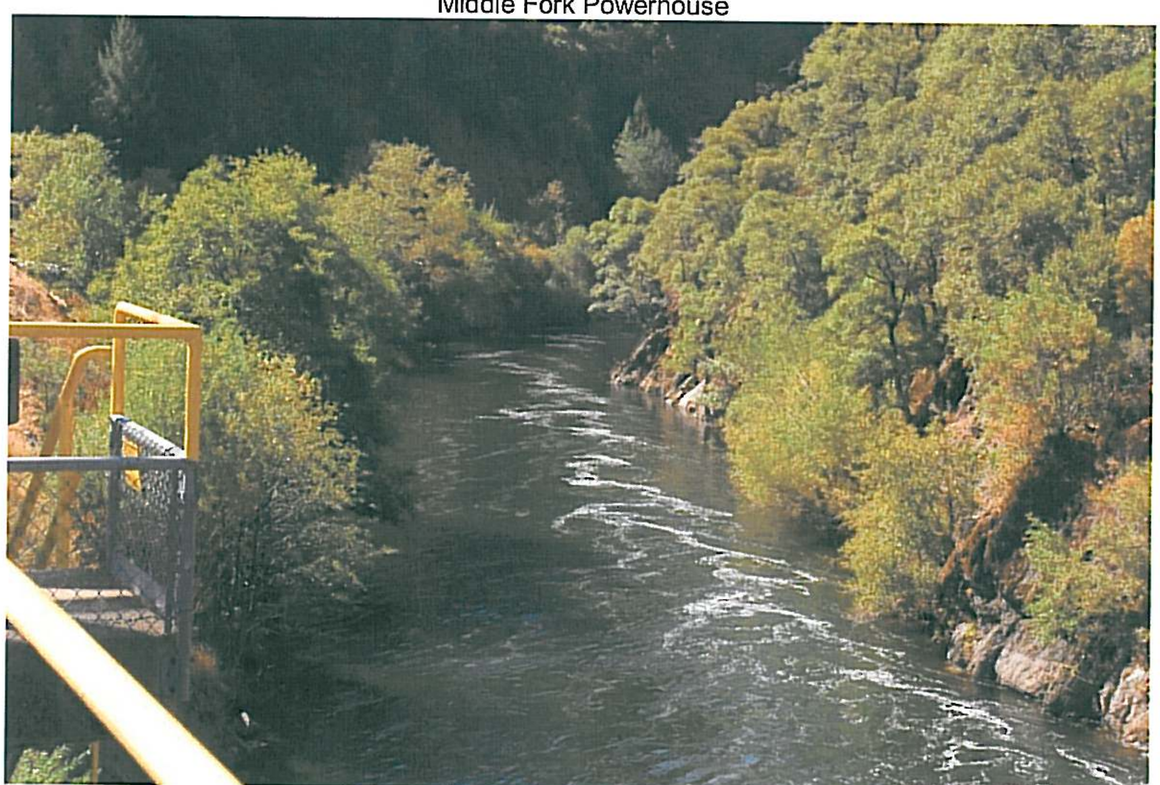
Instream Flow Pipes

Middle Fork Interbay

Middle Fork Powerhouse Photograph



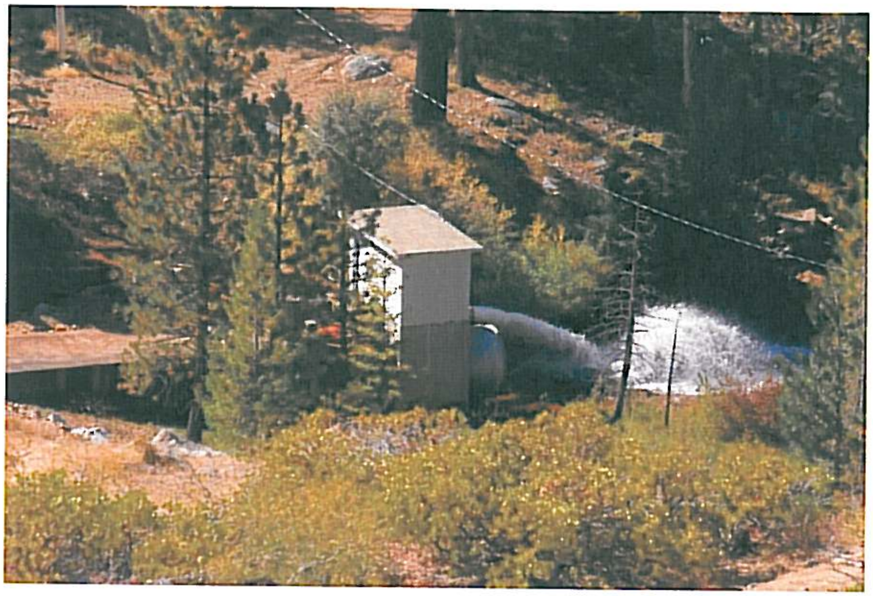
Middle Fork Powerhouse



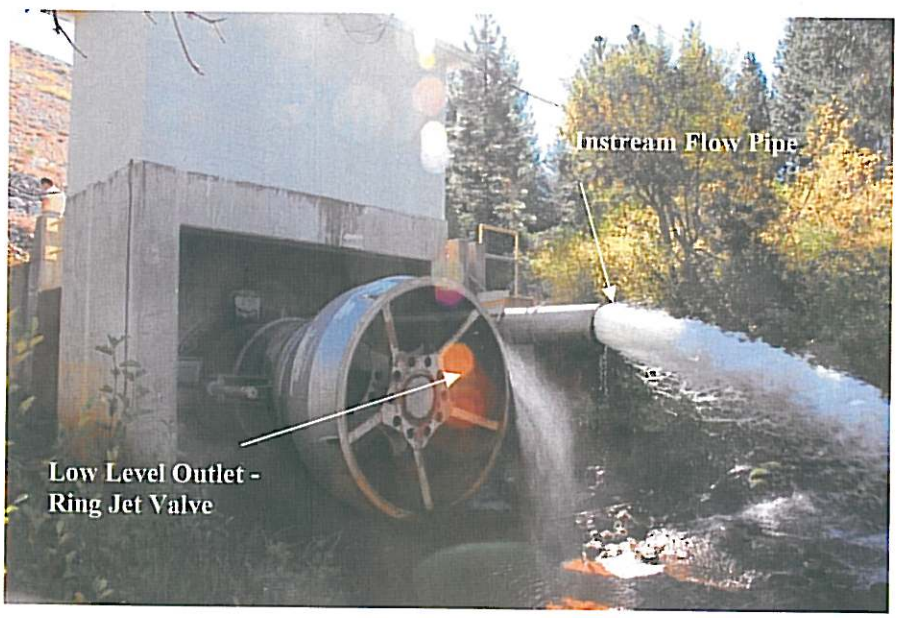
Middle Fork Interbay below Powerhouse

French Meadows Reservoir

French Meadows Dam Outlet Works Photographs



French Meadows Outlet Works



French Meadows Outlet Works - Instream Flow Pipe and Low Level Outlet

French Meadows Reservoir

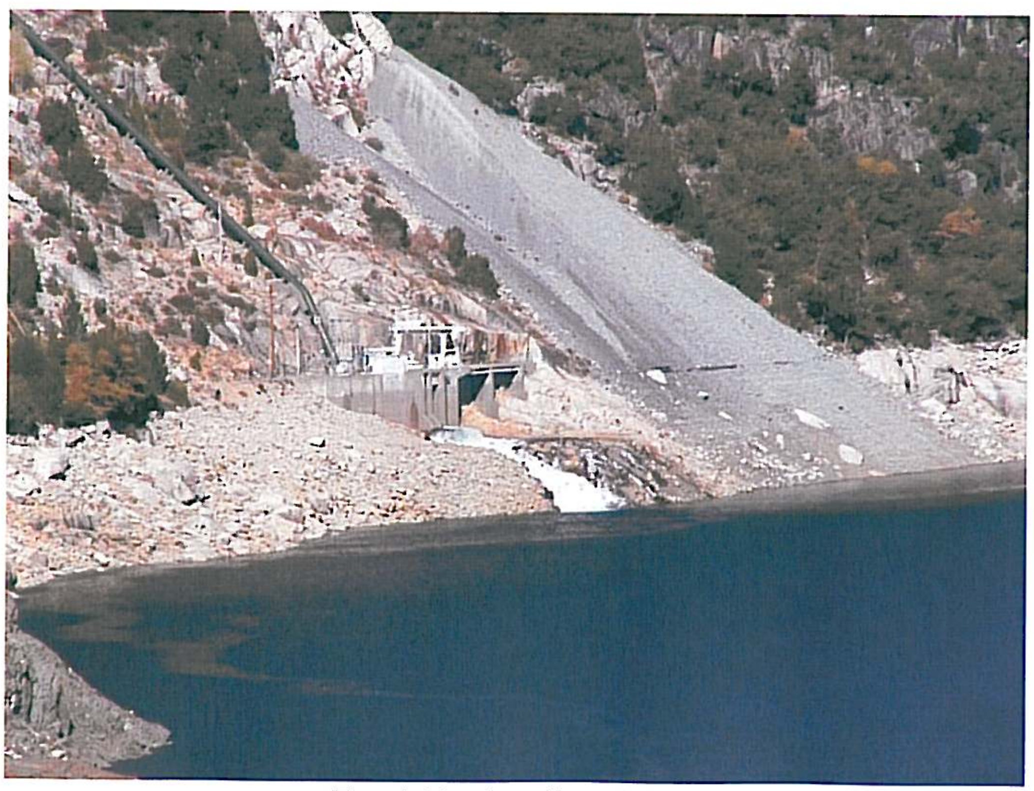
French Meadows - Hell Hole Tunnel Intake Photograph

French Meadows - Hell Hole Tunnel Inlet Gatehouse

Hell Hole Reservoir

French Meadows Powerhouse Photograph

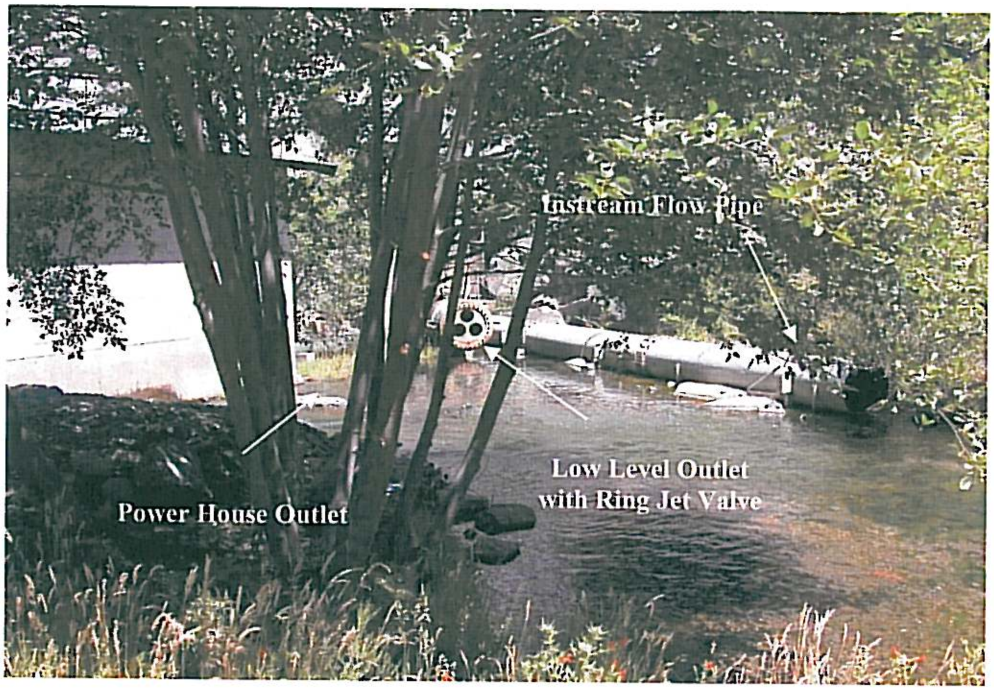
French Meadows Powerhouse



French Meadows Powerhouse

Hell Hole Reservoir

Hell Hole Dam Outlet Works Photographs

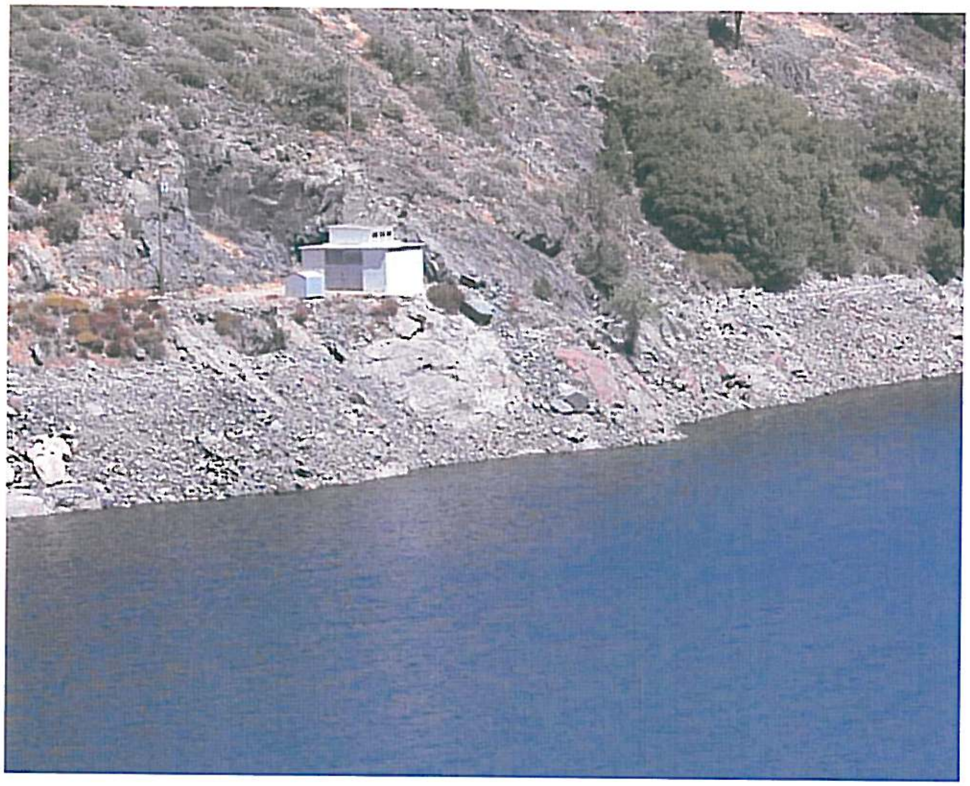


Dam Outlet Works

Dam Low Level Discharge Ring Jet Valve

Hell Hole Reservoir

Hell Hole - Middle Fork Tunnel Intake Photograph



Hell Hole - Middle Fork Tunnel Intake Gatehouse

North Fork Long Canyon

North Fork Long Canyon Diversion Dam Photographs

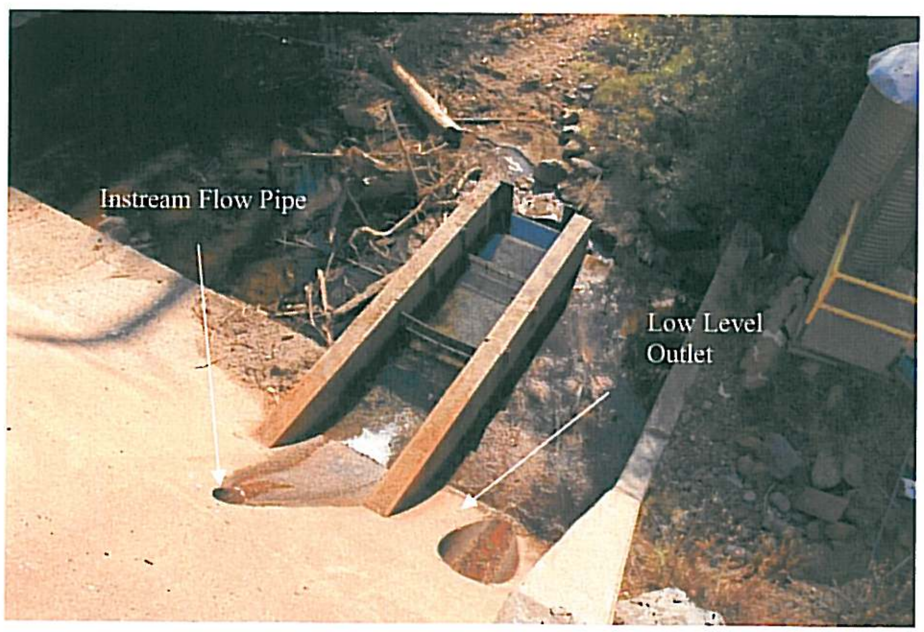
North Fork Long Canyon Diversion - Downstream Side

North Fork Long Canyon Diversion - Instream Flow Pipe

South Fork Long Canyon

South Fork Long Canyon Diversion Dam Photographs

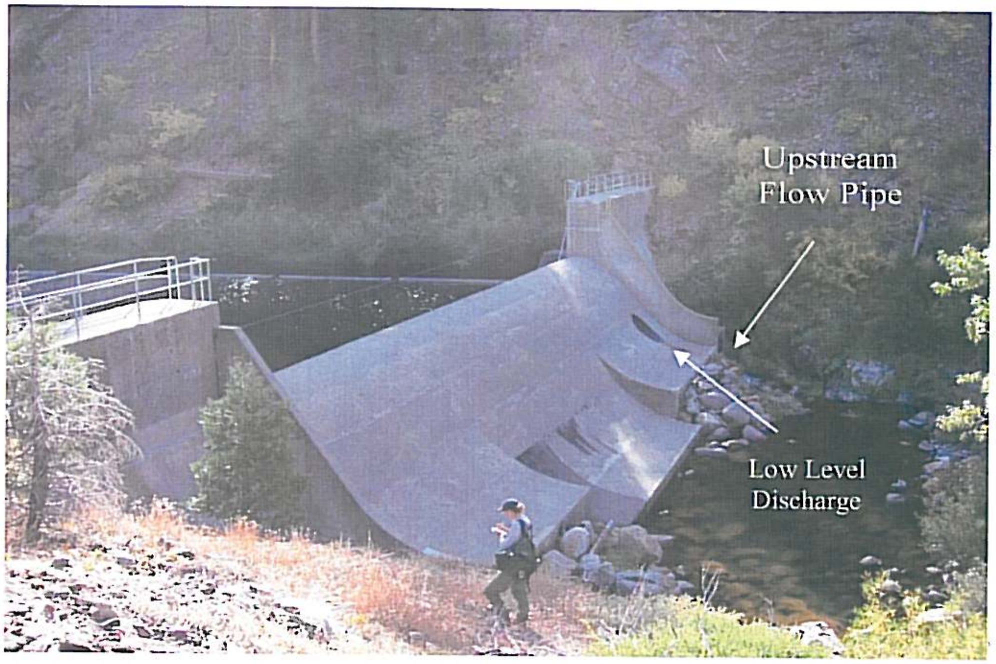
South Fork Long Canyon Diversion Dam



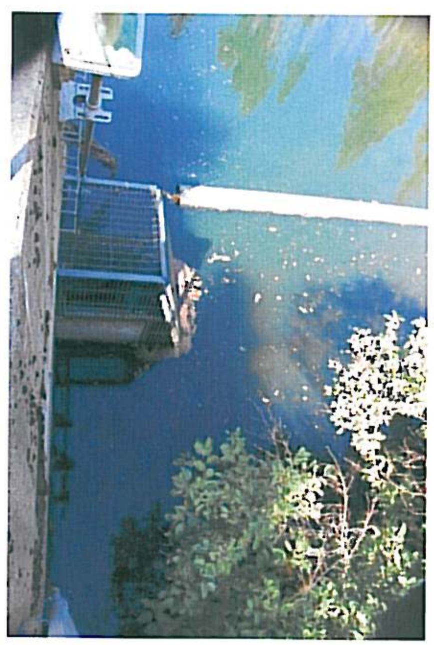
South Fork Long Canyon Diversion Dam - Downstream Side

Duncan Creek

Duncan Creek Diversion Dam Photographs



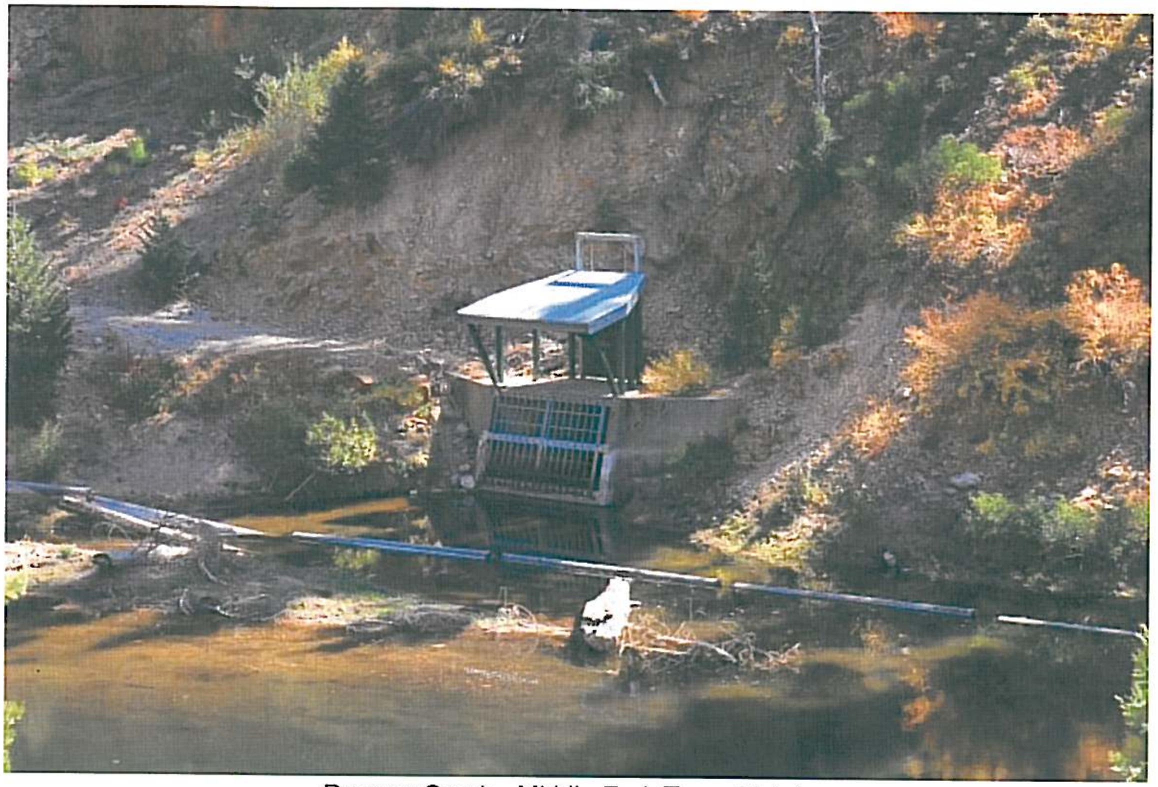
Duncan Creek Diversion Dam - Downstream Side



Inlet to Upstream Flow Pipe

Duncan Creek

Duncan Creek - Middle Fork Intake and Trash Rack Photograph



Duncan Creek - Middle Fork Tunnel Intake

APPENDIX B

Water Diversion Flows and Diagrams

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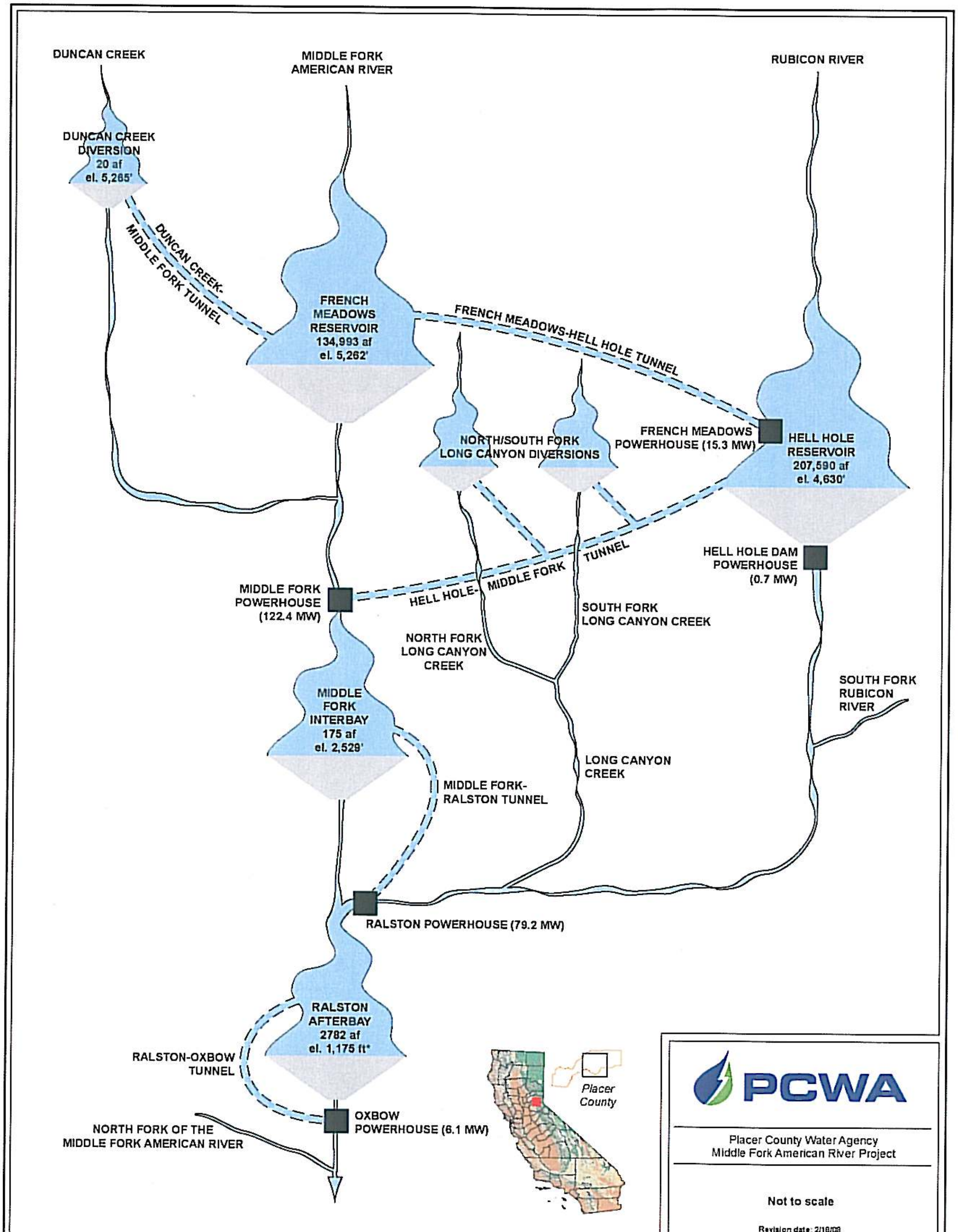
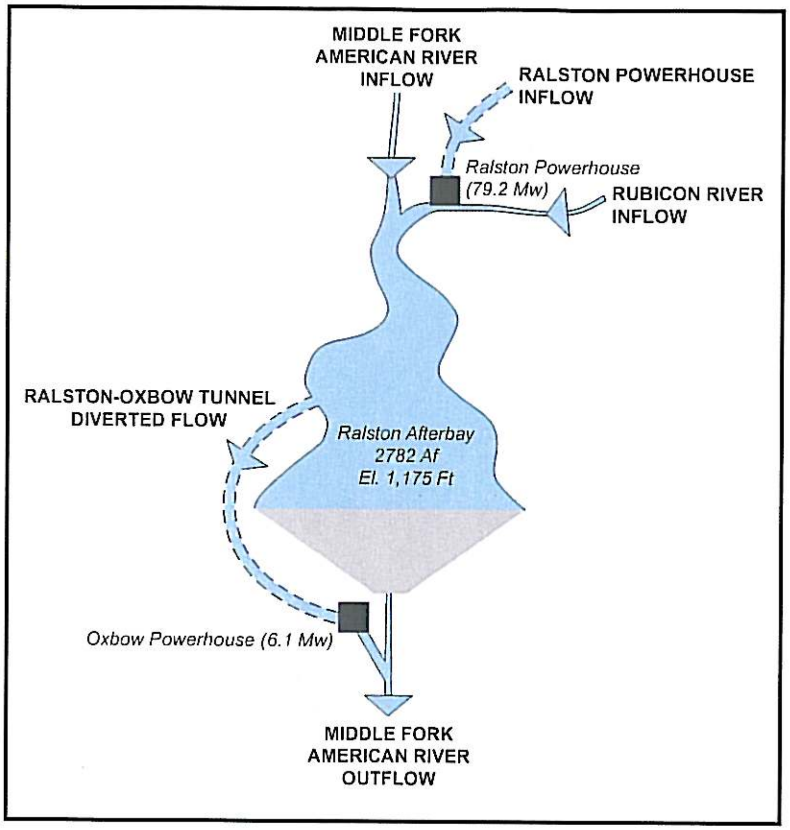
Middle Fork American Project Water Inflow-Outflow Diagram.



Ralston Afterbay



Ralston Afterbay Water Budget.

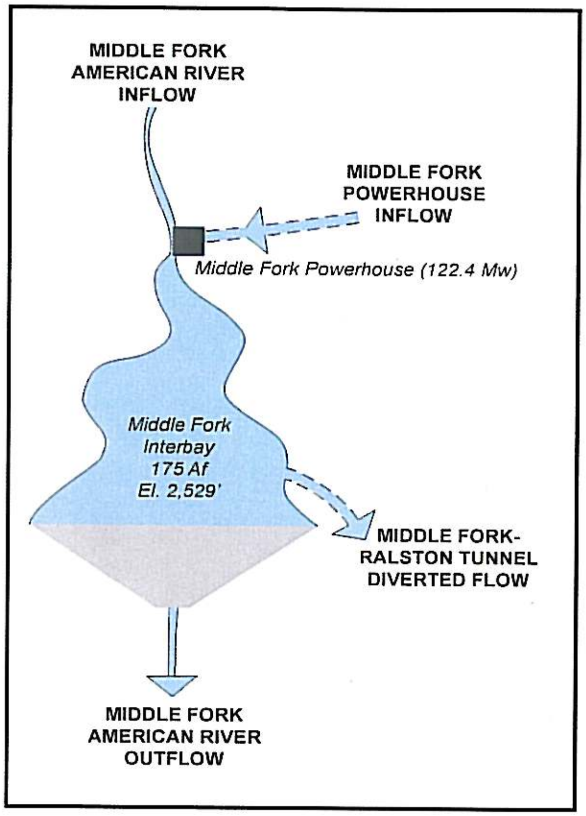
Month	Exceedances				
	10 %	20%	50%	80%	90%
Rubicon River Inflow					
Oct	83	75	64	41	29
Nov	175	100	69	49	44
Dec	481	181	84	56	48
Jan	1102	588	159	65	49
Feb	1287	767	274	107	84
Mar	1358	918	424	185	129
Apr	1051	772	389	150	103
May	1041	630	198	100	82
Jun	600	225	126	63	52
Jul	151	113	76	44	33
Aug	93	78	56	38	26
Sep	83	73	52	37	26
Middle Fork Amercian River Inflow					
Oct	62	47	31	22	19
Nov	101	64	41	30	20
Dec	213	104	46	31	21
Jan	396	202	60	40	27
Feb	578	224	89	46	38
Mar	572	277	115	62	43
Apr	386	242	108	58	46
May	403	159	62	43	33
Jun	304	99	50	36	29
Jul	77	55	38	28	21
Aug	47	38	32	20	17
Sep	45	36	30	20	16

Ralston Afterbay

Ralston Afterbay Water Budget (continued).

Month	Exceedances				
	10 %	20%	50%	80%	90%
Ralston Powerhouse Inflow					
Oct	797	602	88	0	0
Nov	768	602	434	29	0
Dec	908	679	272	18	0
Jan	906	637	261	21	0
Feb	911	891	443	34	9
Mar	914	909	586	57	38
Apr	918	911	452	46	25
May	915	911	586	27	12
Jun	914	909	583	232	18
Jul	908	843	597	331	40
Aug	909	850	615	400	174
Sep	868	703	502	88	0
Middle Fork American River Outflow					
Oct	139	109	74	-1	-33
Nov	178	110	48	-14	-51
Dec	472	170	58	-9	-53
Jan	1184	597	86	19	-28
Feb	1636	860	132	33	-19
Mar	1731	1152	255	55	-32
Apr	1269	843	178	59	3
May	1419	562	139	53	13
Jun	950	253	81	-1	-31
Jul	166	114	34	-18	-40
Aug	93	68	19	-25	-48
Sep	102	87	16	-33	-55
Ralston - Oxbow Tunnel Diverted Flow					
Oct	861	730	0	0	0
Nov	910	758	544	51	0
Dec	958	877	459	77	17
Jan	971	942	570	103	34
Feb	978	968	834	197	85
Mar	981	969	907	309	196
Apr	983	975	841	188	102
May	984	971	843	120	60
Jun	976	961	724	351	76
Jul	950	914	708	428	69
Aug	939	907	730	462	197
Sep	914	808	604	154	0
Percent Diverted					
Oct	107	100	0	0	0
Nov	108	102	85	25	0
Dec	101	93	74	29	6
Jan	96	86	59	32	12
Feb	90	82	55	31	18
Mar	80	71	47	31	23
Apr	63	56	39	24	14
May	55	48	35	21	15
Jun	98	88	62	30	21
Jul	108	102	92	68	26
Aug	109	105	97	90	76
Sep	111	107	99	72	0

Middle Fork Interbay



Middle Fork Interbay Water Budget.

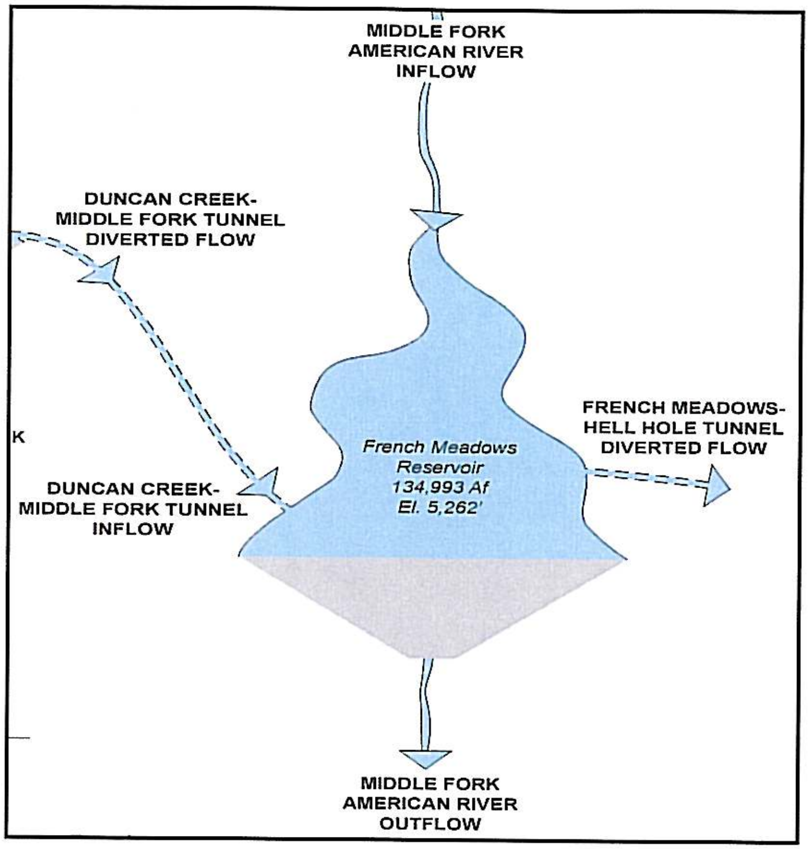
Month	Exceedances				
	10 %	20%	50%	80%	90%
Middle Fork American River Inflow					
Oct	25	21	17	13	10
Nov	62	37	19	16	14
Dec	160	69	31	20	17
Jan	248	158	55	22	19
Feb	278	179	89	37	25
Mar	328	228	123	74	58
Apr	241	196	122	66	50
May	372	224	76	41	32
Jun	222	76	42	22	18
Jul	46	37	25	16	12
Aug	26	23	18	13	10
Sep	21	19	16	12	10
Middle Fork Powerhouse Inflow					
Oct	800	673	133	0	0
Nov	800	719	517	196	12
Dec	920	781	478	223	67
Jan	920	595	114	0	0
Feb	920	769	203	0	0
Mar	936	920	234	0	0
Apr	940	927	333	0	0
May	940	940	541	0	0
Jun	925	920	414	85	35
Jul	920	830	565	218	67
Aug	800	726	565	295	119
Sep	740	628	246	39	0

Middle Fork Interbay

Middle Fork Interbay Water Budget. (continued)

Month	Exceedances				
	10 %	20%	50%	80%	90%
Middle Fork American River Outflow					
Oct	23	23	19	14	11
Nov	23	23	21	16	12
Dec	23	23	23	19	12
Jan	23	23	23	20	12
Feb	23	23	23	23	12
Mar	23	23	23	23	12
Apr	23	23	23	23	12
May	23	23	23	23	12
Jun	23	23	23	22	12
Jul	23	23	23	17	12
Aug	23	23	20	13	11
Sep	23	21	18	13	10
Middle Fork - Ralston Tunnel Diverted Flow					
Oct	800	674	133	0	0
Nov	803	739	532	209	32
Dec	924	814	497	238	75
Jan	924	781	180	10	1
Feb	924	879	286	31	15
Mar	924	924	461	71	47
Apr	924	924	498	55	37
May	924	924	657	24	16
Jun	924	924	443	105	67
Jul	924	841	571	223	69
Aug	800	726	566	295	119
Sep	741	628	247	39	0
Percent Diverted					
Oct	98%	98%	91%	0%	0%
Nov	98%	98%	97%	93%	61%
Dec	99%	98%	96%	90%	72%
Jan	102%	99%	88%	32%	6%
Feb	103%	101%	91%	63%	41%
Mar	105%	101%	91%	78%	72%
Apr	103%	101%	88%	77%	69%
May	98%	95%	81%	57%	46%
Jun	97%	97%	93%	82%	72%
Jul	98%	98%	96%	91%	83%
Aug	98%	98%	97%	95%	90%
Sep	98%	97%	94%	78%	0%

French Meadows Reservoir



French Meadows Water Budget.

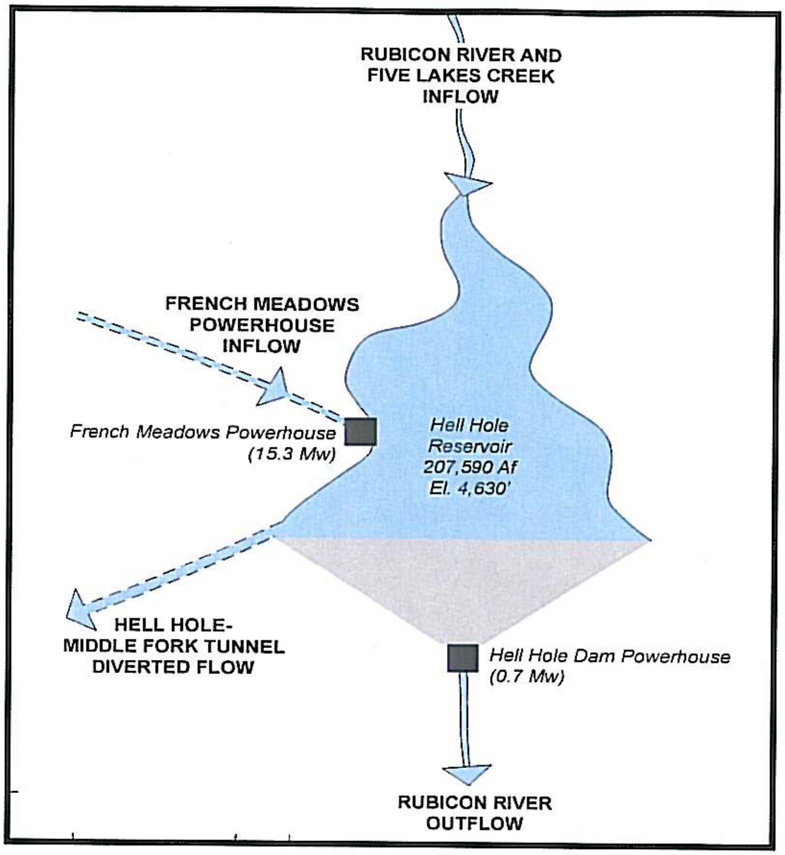
Month	Exceedances				
	10 %	20%	50%	80%	90%
Middle Fork American River Inflow					
Oct	24	14	6	2	1
Nov	119	55	14	5	4
Dec	209	84	28	12	9
Jan	313	170	52	20	14
Feb	323	205	102	30	21
Mar	498	310	169	97	67
Apr	621	486	283	170	122
May	894	719	396	175	104
Jun	774	492	133	42	24
Jul	179	89	33	15	10
Aug	44	27	13	6	3
Sep	23	15	6	3	2
Duncan Creek - French Meadows Tunnel Inflow					
Oct	0	0	0	0	0
Nov	20	4	0	0	0
Dec	40	11	0	0	0
Jan	51	24	2	0	0
Feb	50	31	9	0	0
Mar	86	55	24	8	3
Apr	128	100	52	24	15
May	193	151	80	26	12
Jun	157	90	8	0	0
Jul	12	1	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

French Meadows Reservoir

French Meadows Water Budget (continued).

Month	Exceedances				
	10 %	20%	50%	80%	90%
Middle Fork American River Outflow					
Oct	10	10	9	7	5
Nov	12	10	9	7	6
Dec	14	11	10	7	6
Jan	17	13	10	9	6
Feb	16	13	10	8	6
Mar	18	15	11	9	8
Apr	16	14	11	9	8
May	23	14	10	8	7
Jun	14	11	10	7	5
Jul	11	10	9	7	5
Aug	10	10	9	7	5
Sep	10	10	9	8	5
French Meadows-Hell Hole Tunnel Diverted Flow					
Oct	353	334	237	0	0
Nov	343	327	0	0	0
Dec	352	241	0	0	0
Jan	334	239	0	0	0
Feb	352	335	58	0	0
Mar	362	345	92	0	0
Apr	360	326	0	0	0
May	359	326	0	0	0
Jun	365	325	197	0	0
Jul	342	325	262	146	0
Aug	341	326	269	173	0
Sep	341	322	224	0	0
Percent Diverted					
Oct	6732	4890	1865	0	0
Nov	3903	1611	0	0	0
Dec	707	243	0	0	0
Jan	284	140	0	0	0
Feb	317	208	17	0	0
Mar	225	146	28	0	0
Apr	110	69	0	0	0
May	68	40	0	0	0
Jun	470	245	49	0	0
Jul	2193	1244	535	106	0
Aug	7553	3809	1400	598	0
Sep	9049	6349	2154	0	0

Hell Hole Reservoir



Hell Hole Reservoir Water Budget.

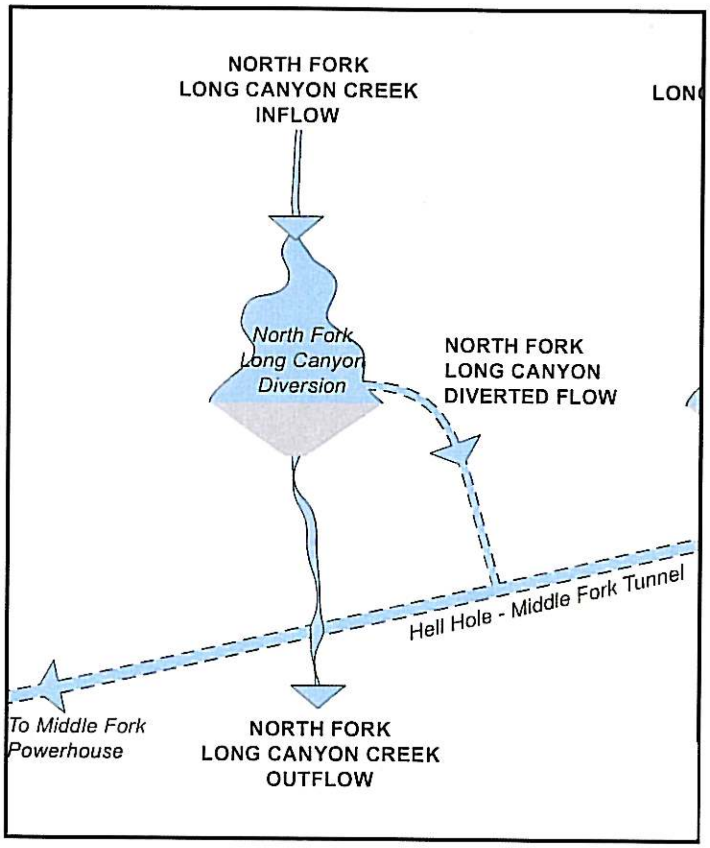
Month	Exceedances				
	10 %	20%	50%	80%	90%
Rubicon River and Five Lakes Creek Inflow					
Oct	21	8	2	1	0
Nov	109	22	8	7	0
Dec	166	60	21	12	0
Jan	293	102	30	18	0
Feb	325	166	56	42	0
Mar	494	265	168	125	0
Apr	769	458	289	202	0
May	1199	697	311	189	0
Jun	856	214	58	32	0
Jul	111	32	9	2	0
Aug	36	16	5	3	0
Sep	20	8	4	2	0
French Meadows Powerhouse Inflow					
Oct	353	334	237	0	0
Nov	343	327	0	0	0
Dec	352	241	0	0	0
Jan	334	239	0	0	0
Feb	352	335	58	0	0
Mar	362	345	92	0	0
Apr	360	326	0	0	0
May	359	326	0	0	0
Jun	365	325	197	0	0
Jul	342	325	262	146	0
Aug	341	326	269	173	0
Sep	341	322	224	0	0

Hell Hole Reservoir

Hell Hole Reservoir Water Budget (continued).

Month	Exceedances				
	10 %	20%	50%	80%	90%
Rubicon River Outflow					
Oct	43	29	22	10	8
Nov	24	23	22	14	8
Dec	23	22	15	12	8
Jan	26	17	13	12	11
Feb	25	20	14	12	11
Mar	24	21	15	12	11
Apr	25	21	15	13	12
May	38	24	21	14	12
Jun	138	24	22	19	12
Jul	23	23	22	17	11
Aug	23	23	21	11	9
Sep	30	23	22	11	9
Hell Hole - Middle Fork Tunnel Diverted Flow					
Oct	806	583	73	0	0
Nov	688	584	384	6	0
Dec	817	629	241	0	0
Jan	776	473	159	0	0
Feb	826	734	313	0	0
Mar	898	796	339	-13	-24
Apr	887	771	219	-17	-34
May	914	852	335	-3	-10
Jun	917	861	555	211	0
Jul	896	845	570	308	26
Aug	911	861	617	368	169
Sep	883	711	487	139	0
Percent Diverted					
Oct	668	253	55	0	0
Nov	3899	1397	173	4	0
Dec	1724	952	132	0	0
Jan	766	309	106	0	0
Feb	269	190	95	0	0
Mar	177	146	62	-6	-9
Apr	134	100	36	-4	-8
May	107	77	35	-1	-3
Jun	337	191	101	34	0
Jul	392	278	183	106	33
Aug	419	312	231	153	113
Sep	4477	438	216	88	0

North Fork Long Canyon



North Fork Long Canyon Diversion Water Budget.

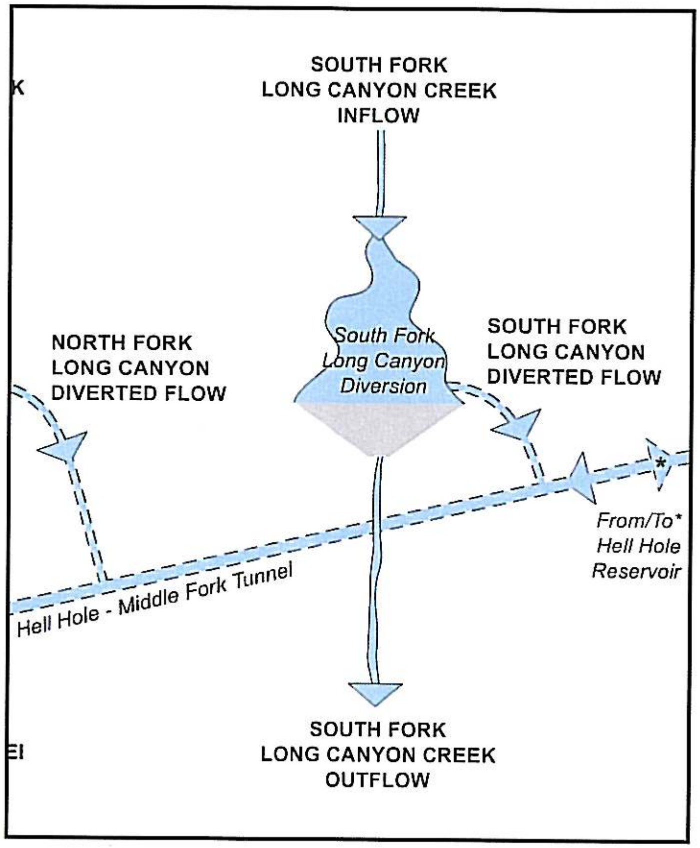
Month	Exceedances				
	10 %	**20%**	**50%**	**80%**	**90%**
North Fork Long Canyon Creek Inflow					
Oct	0.9	0.5	0.3	0.2	0.1
Nov	6.8	4.5	1.0	0.4	0.3
Dec	20.0	8.1	3.0	1.1	0.5
Jan	31.7	18.7	5.2	1.3	0.9
Feb	35.8	21.8	9.7	3.6	2.0
Mar	43.5	30.3	16.5	8.2	5.8
Apr	39.8	31.6	19.5	9.1	5.9
May	44.1	34.1	12.3	4.0	2.7
Jun	14.4	7.7	3.0	1.3	0.9
Jul	2.8	1.7	0.8	0.4	0.3
Aug	0.8	0.5	0.3	0.2	0.1
Sep	0.5	0.4	0.3	0.1	0.1
North Fork Long Canyon Creek Outflow					
Oct	0.9	0.5	0.3	0.2	0.1
Nov	5.9	3.3	1.0	0.4	0.3
Dec	11.1	5.5	2.3	1.1	0.5
Jan	15.2	8.1	2.9	1.3	0.9
Feb	15.9	5.9	3.3	2.0	2.0
Mar	22.9	9.9	3.7	2.6	2.0
Apr	13.8	6.0	3.4	2.0	2.0
May	20.7	5.0	3.3	2.0	2.0
Jun	7.4	4.5	2.5	1.3	0.9
Jul	2.8	1.7	0.8	0.4	0.3
Aug	0.8	0.5	0.3	0.2	0.1
Sep	0.5	0.4	0.3	0.1	0.1

North Fork Long Canyon

North Fork Long Canyon Diversion Water Budget (continued).

Month	Exceedances				
	10 %	20%	50%	80%	90%
North Fork Long Canyon Diverted Flow					
Oct	0.0	0.0	0.0	0.0	0.0
Nov	0.1	0.0	0.0	0.0	0.0
Dec	3.8	0.4	0.0	0.0	0.0
Jan	18.0	9.5	0.0	0.0	0.0
Feb	21.0	13.0	2.5	0.0	0.0
Mar	31.0	22.0	8.5	0.0	0.0
Apr	33.0	26.0	12.0	1.5	0.0
May	33.0	22.0	4.1	0.0	0.0
Jun	5.9	0.7	0.0	0.0	0.0
Jul	0.0	0.0	0.0	0.0	0.0
Aug	0.0	0.0	0.0	0.0	0.0
Sep	0.0	0.0	0.0	0.0	0.0
Percent Diverted					
Oct	0%	0%	0%	0%	0%
Nov	6%	0%	0%	0%	0%
Dec	51%	11%	0%	0%	0%
Jan	84%	71%	0%	0%	0%
Feb	87%	81%	40%	0%	0%
Mar	90%	86%	72%	0%	0%
Apr	92%	89%	77%	21%	0%
May	93%	88%	54%	0%	0%
Jun	68%	14%	0%	0%	0%
Jul	0%	0%	0%	0%	0%
Aug	0%	0%	0%	0%	0%
Sep	0%	0%	0%	0%	0%

South Fork Long Canyon



South Fork Long Canyon Diversion Water Budget.

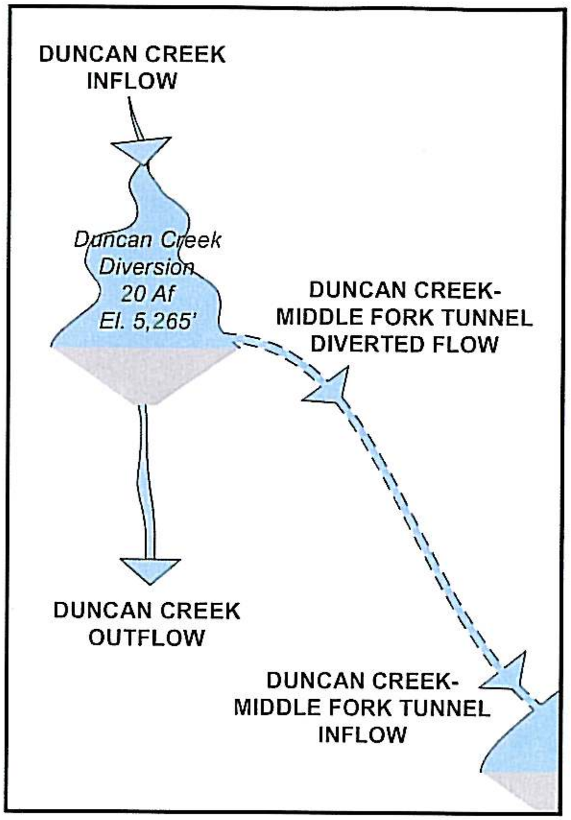
Month	Exceedances				
	10 %	20%	50%	80%	90%
South Fork Long Canyon Creek Inflow					
Oct	1.5	1.0	0.6	0.3	0.3
Nov	15.7	7.8	1.7	0.7	0.6
Dec	37.2	13.7	4.8	1.8	0.9
Jan	56.3	32.2	8.9	2.3	1.6
Feb	66.8	40.6	18.5	6.3	3.5
Mar	79.2	55.6	29.1	14.4	11.1
Apr	72.5	59.0	36.0	17.9	13.7
May	81.0	61.4	31.0	11.2	7.2
Jun	34.0	20.0	6.3	2.5	1.6
Jul	6.0	2.8	1.4	0.8	0.6
Aug	1.4	0.9	0.6	0.3	0.2
Sep	0.8	0.7	0.5	0.2	0.1
South Fork Long Canyon Creek Outflow					
Oct	1.5	1.0	0.6	0.3	0.3
Nov	9.3	5.2	1.7	0.7	0.6
Dec	16.8	8.3	4.2	1.8	0.9
Jan	20.6	7.8	5.0	2.3	1.6
Feb	23.0	7.8	6.0	3.9	2.8
Mar	40.7	14.2	6.3	5.0	4.0
Apr	20.3	6.7	6.0	5.0	3.9
May	34.9	6.5	5.8	5.0	2.9
Jun	8.5	6.1	5.0	2.5	1.6
Jul	5.0	2.8	1.4	0.8	0.6
Aug	1.4	0.9	0.6	0.3	0.2
Sep	0.8	0.7	0.5	0.2	0.1

South Fork Long Canyon

South Fork Long Canyon Diversion Water Budget (continued).

Month	Exceedances				
	10 %	20%	50%	80%	90%
South Fork Long Canyon Diverted Flow					
Oct	0.0	0.0	0.0	0.0	0.0
Nov	0.8	0.0	0.0	0.0	0.0
Dec	9.7	1.6	0.0	0.0	0.0
Jan	34.0	20.0	0.0	0.0	0.0
Feb	38.0	24.0	5.0	0.0	0.0
Mar	61.0	40.0	15.0	0.6	0.0
Apr	63.0	49.0	24.0	5.0	0.0
May	60.0	50.0	15.0	1.6	0.0
Jun	24.0	11.0	0.0	0.0	0.0
Jul	0.0	0.0	0.0	0.0	0.0
Aug	0.0	0.0	0.0	0.0	0.0
Sep	0.0	0.0	0.0	0.0	0.0
Percent Diverted					
Oct	0%	0%	0%	0%	0%
Nov	21%	0%	0%	0%	0%
Dec	58%	27%	0%	0%	0%
Jan	86%	76%	0%	0%	0%
Feb	88%	81%	51%	0%	0%
Mar	91%	86%	67%	10%	0%
Apr	93%	90%	81%	50%	0%
May	92%	89%	74%	22%	0%
Jun	80%	67%	0%	0%	0%
Jul	0%	0%	0%	0%	0%
Aug	0%	0%	0%	0%	0%
Sep	0%	0%	0%	0%	0%

Duncan Creek



Duncan Creek Diversion Water Budget.

Month	Exceedances				
	10 %	20 %	50 %	80 %	90 %
Duncan Creek Inflow					
Oct	3.9	2.3	0.9	0.5	0.5
Nov	29.0	13.0	2.9	1.2	1.0
Dec	54.0	23.0	8.0	3.4	2.1
Jan	82.0	42.0	13.0	4.2	3.0
Feb	73.0	46.0	23.0	6.7	5.0
Mar	112.0	72.0	37.0	21.0	15.0
Apr	147.0	117.0	65.0	38.0	26.0
May	234.0	188.0	93.0	36.0	20.0
Jun	201.0	114.0	18.0	5.3	3.2
Jul	20.0	8.5	2.8	1.2	0.9
Aug	3.2	2.1	1.0	0.5	0.4
Sep	2.1	1.4	0.8	0.4	0.4
Duncan Creek Outflow					
Oct	3.3	2.2	0.9	0.5	0.4
Nov	12.0	7.3	2.5	1.1	1.0
Dec	15.0	13.0	6.5	2.9	1.8
Jan	20.0	15.0	10.0	4.1	2.7
Feb	21.0	15.0	11.0	5.5	4.7
Mar	21.0	17.0	13.0	10.0	9.0
Apr	19.0	16.0	12.0	9.0	7.0
May	42.0	18.0	11.0	8.2	5.4
Jun	16.0	12.0	8.7	4.4	3.1
Jul	9.6	6.8	2.7	1.2	0.8
Aug	2.8	1.9	1.0	0.5	0.4
Sep	2.0	1.3	0.8	0.4	0.3

Duncan Creek

Duncan Creek Diversion Water Budget (continued).

Month	Exceedances				
	10	20	50	80	90
Duncan Creek - Middle Fork Tunnel Diverted Flow					
Oct	0.2	0.0	0.0	0.0	0.0
Nov	19.7	4.0	0.1	0.0	0.0
Dec	40.0	11.0	0.2	0.0	0.0
Jan	51.0	24.1	2.0	0.0	0.0
Feb	50.0	31.0	9.0	0.0	0.0
Mar	86.0	55.0	24.0	8.0	3.1
Apr	128.0	100.0	51.6	24.4	14.5
May	193.0	151.0	80.0	25.7	11.5
Jun	157.0	90.0	8.1	0.0	0.0
Jul	12.0	0.6	0.0	0.0	0.0
Aug	0.2	0.1	0.0	0.0	0.0
Sep	0.1	0.0	0.0	0.0	0.0
Percent Diverted					
Oct	13%	3%	0%	0%	0%
Nov	71%	42%	4%	0%	0%
Dec	73%	55%	7%	0%	0%
Jan	76%	65%	21%	0%	0%
Feb	78%	71%	41%	0%	0%
Mar	84%	78%	62%	37%	22%
Apr	91%	89%	82%	67%	57%
May	94%	92%	85%	65%	49%
Jun	91%	87%	46%	0%	0%
Jul	62%	13%	0%	0%	0%
Aug	17%	8%	0%	0%	0%
Sep	13%	6%	0%	0%	0%

APPENDIX C

Summary of Fish Screening Unit Costs (Dollars/ CFS)

Appendix C. Summary of Fish Screening Unit Costs (Dollars/ CFS)

Project	Date	Maximum Diversion (cfs)	Design Criteria (approach velocity)	Screen Area	Design	Total Project Cost	2008 Cost with 3% Annual Inflation	2008 cost/cfs	
Flow Range 50-100 cfs									
Coyote Canal Diversion	1999	50	0.33		Single flat plate	$470,000	$613,240	$12,260	
Anderson Cottonwood Irrigation District (Bonnyview Pumps)	1992	60			Cylindrical	$330,000	$529,550	$8,830	
Browns Valley ID	1999	65				$298,287	$389,200	$5,990	
Upper Toppenish	1987	72		144	Drum	$264,720	$492,460	$6,840	
Maxwell Irrigation District	1993	80	0.33		Cylindrical	$794,000	$1,237,000	$15,460	
Richland	1985	80		160	Drum	$322,560	$636,600	$7,960	
EBMUD Bixler Slough	1987	90			Cylindrical	$50,000	$93,015	$1,030	
Suisun Resource Conservation District	1997	93				$900,000	$1,245,800	$13,400	
Average 2008 cost/cfs									$8,339
Flow Range 100-500 cfs									
Grizzly Island (CDFG)	1995	100	0.2		Cylindrical	$300,000	$440,560	$4,410	
Maxwell ID	1997	100				$1,545,000	$2,138,600	$21,390	
RD 999	2006	100				$636,000	$674,730	$6,750	
Adams Dam / Rancho Esquon Partners	1998	120	0.33	530	Single flat plate	$558,700	$750,850	$6,260	
Gorrill	1999	121.7	0.33		Single flat plate	$1,515,955	$1,978,000	$16,250	
Parrott-Phelan Irrigation Systems (M&T Ranch)	1997	150	0.33		Cylindrical	$4,500,000	$6,229,100	$41,530	
Dryden	1993	200		500	Single flat plate	$2,394,000	$3,729,800	$18,650	
Banton Carbona	2004	260				$9,800,000	$11,030,000	$42,420	
Reclamation District 104	1999	290				$7,250,000	$9,459,600	$32,620	
Potter Valley	1996	320	0.33	960	Inclined Plane	$14,000,000	$19,961,000	$62,380	
CCWD Rock Slough	1998	350			Single flat plate	$6,600,000	$8,869,800	$25,340	
Contra Costa Canal- Estimated	1992	350		1800	Single flat plate	$3,000,000	$4,814,100	$13,750	
Leaburg (a)	1983	470		675	Chevron	$3,247,400	$6,799,300	$14,470	
Jim Boyd	1987	500		345	Single flat plate	$868,510	$1,615,700	$3,230	
Wapatox	1993	500		1250	Single flat plate	$3,150,000	$4,907,600	$9,820	
Average 2008 cost/cfs									$21,285
Flow Range 500-1000 cfs									
Princeton-Codora Glenn/ Prov ID	1999	605				$10,957,887	$14,298,000	$23,630	
Toppenish-Satus	1986	650		1300	Drum	$1,392,300	$2,667,800	$4,100	
DWR Roaring River	1980	750			Single flat plate	$1,500,000	$3,431,900	$4,580	
RD 108 - Wilkins Slough	1998	800	0.33	2520	Single flat plate	$11,600,000	$15,589,000	$19,490	
Sutter Mutual	2007	960				$21,500,000	$22,145,000	$23,070	
Dalles North FERC	1991	1000		2000	Single flat plate	$4,280,000	$7,074,200	$7,070	
Average 2008 cost/cfs									$11,662
Flow Range 1000 > cfs									
Easton	1988	1170		2340	Drum	$8,256,000	$14,911,000	$12,740	
Sunnyside	1985	1300	0.4	2600	Drum	$5,098,000	$10,061,000	$7,740	
Chandler	1987	1500		3000	Drum	$15,063,000	$28,022,000	$18,680	
Wapato	1986	2000	0	4000		$6,652,000	$12,746,000	$6,370	
Roza	1988	2200		4600	Drum	$19,860,000	$35,869,000	$16,300	
Red Bluff	1990	3000	0.33	6000	Drum	$17,202,000	$29,285,000	$9,760	
Average 2008 cost/cfs									$11,932

Source: NOAA Fisheries

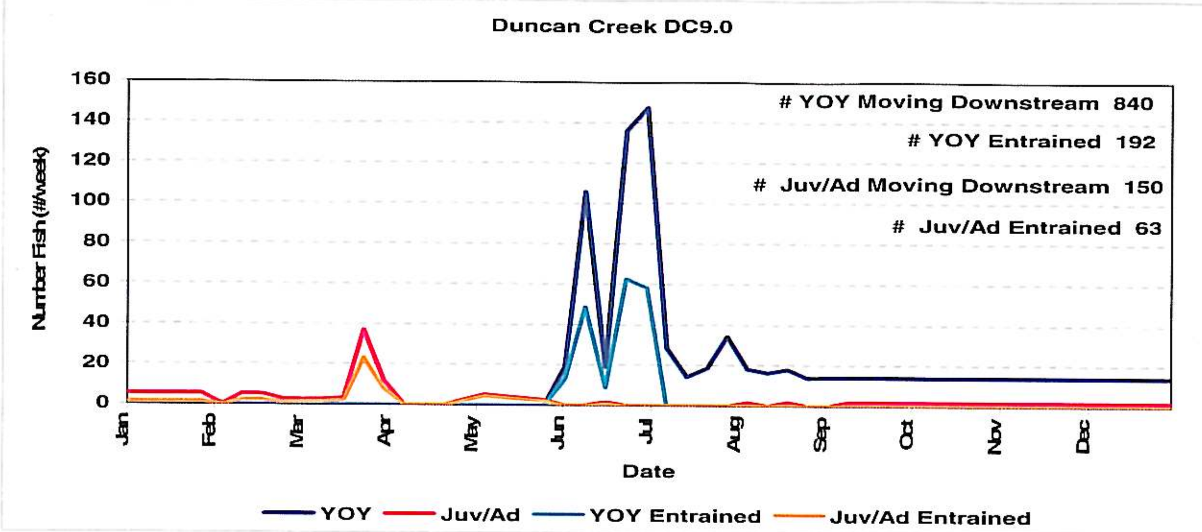
Project	Date	Maximum Diversion (cfs)	Design Criteria (approach velocity)	Screen Area	Design	Total Project Cost	2008 Cost with 3% Annual Inflation	2008 cost/cfs	
Flow Range 50-100 cfs									
Upper WIP	1997	55				$506,715	$701,410	$12,750	
Union Gap	1997	76				$279,984	$387,560	$5,100	
Average 2008 cost/cfs									$8,925
Flow Range 100-500 cfs									
Westside	1988	114				$599,982	$1,083,600	$9,510	
New Cascade	1992	147				$541,401	$868,790	$5,910	
Toppenish Pump	1995	100				$532,400	$781,850	$7,820	
Naches-Selah	1996	137				$695,275	$991,300	$7,240	
Yakima-Tieton	1998	350				$799,750	$1,074,800	$3,070	
Average 2008 cost/cfs									$6,710
Flow Range 1000 > cfs									
Chandler	1987	1500				$3,849,000	$7,160,300	$4,770	
Average 2008 cost/cfs									$4,770

Source: WDFW: Washington State Fish Screening Unit Costs

APPENDIX D

Plots of Monthly Entrainment Calculations

Figure D-1. Duncan Creek



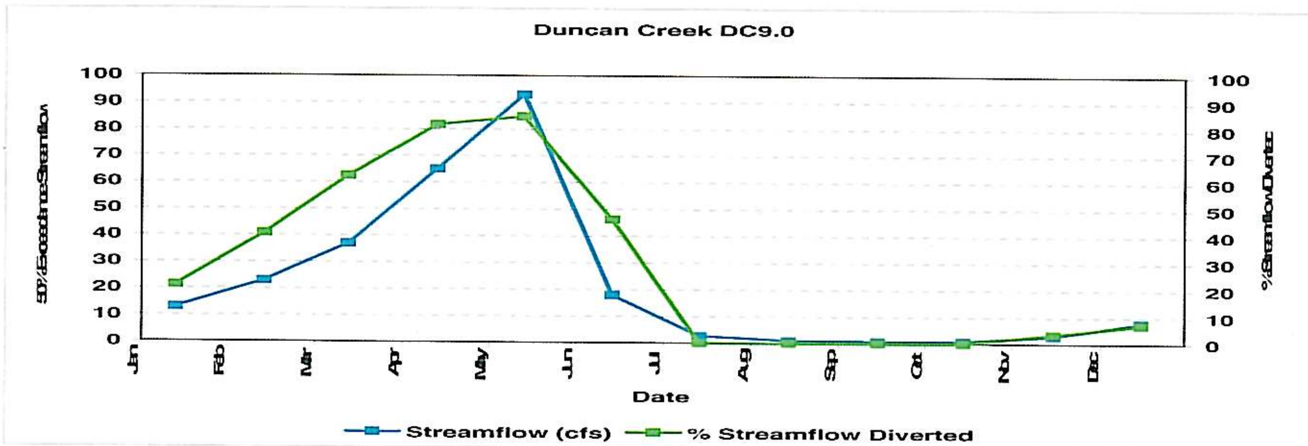
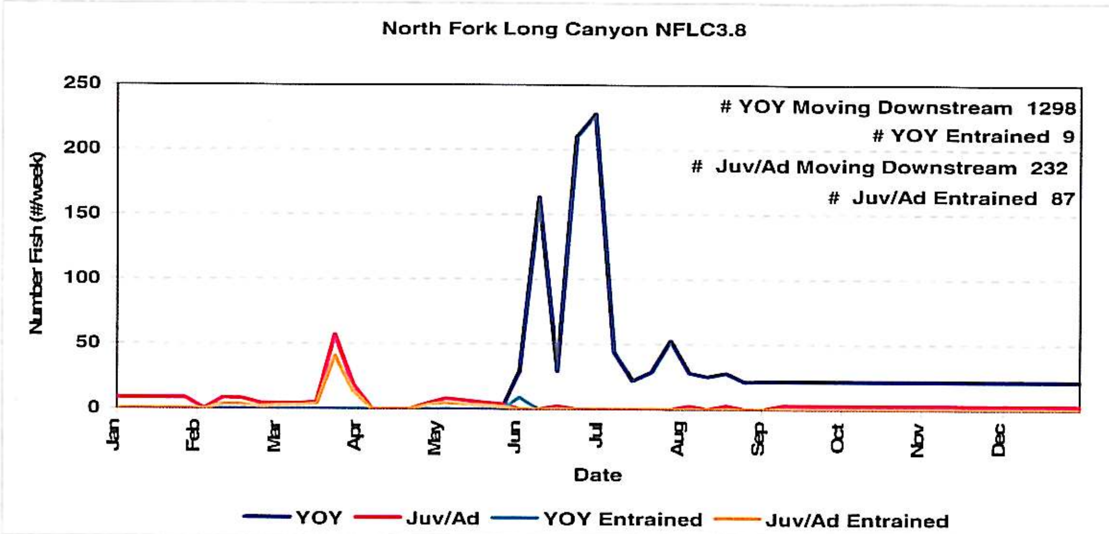


Figure D-2. North Fork Long Canyon Creek



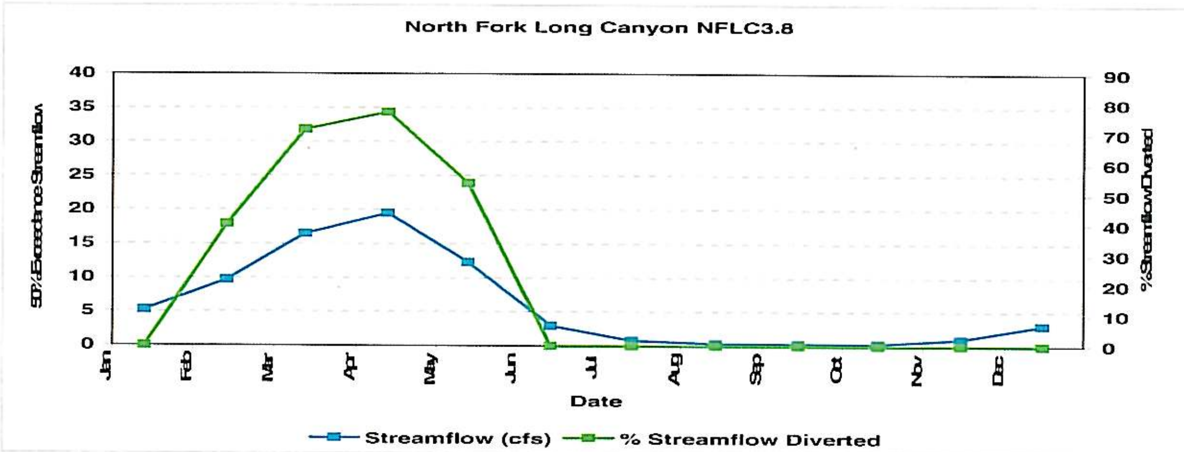
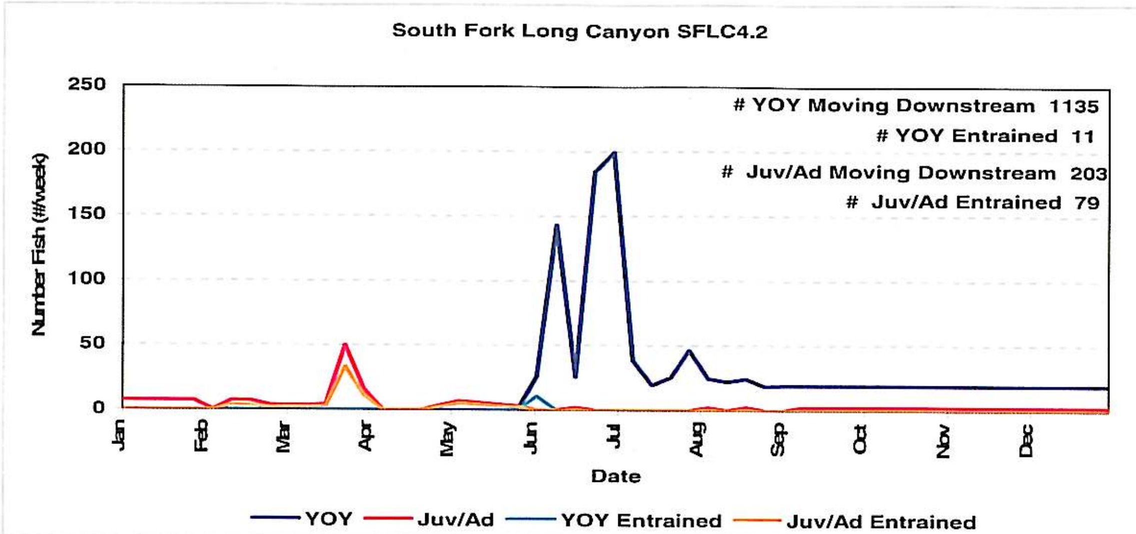


Figure D-3. South Fork Long Canyon Creek



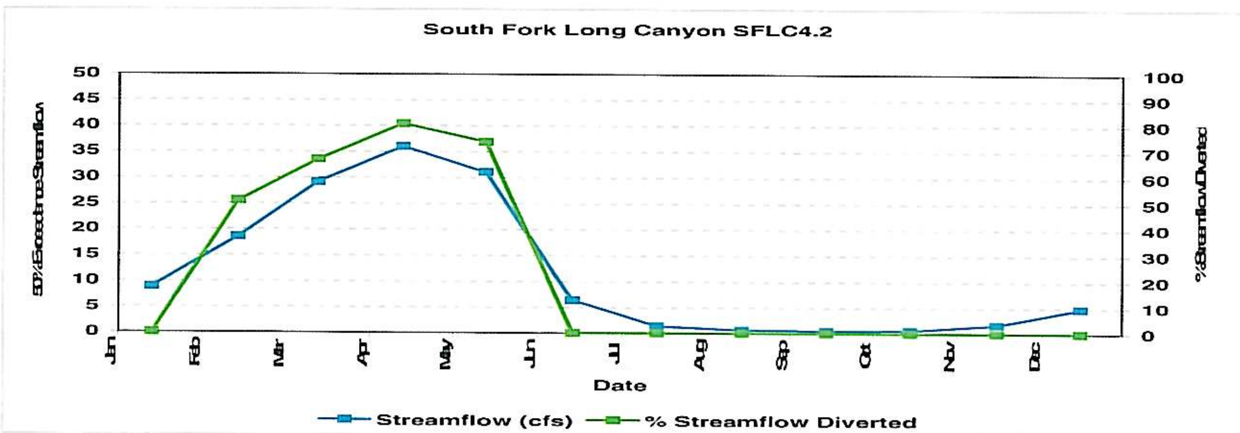


Figure D-4. Middle Fork American River above Interbay